WP4 Enhancing Labour Market-Relevant Skills in Advanced Technologies

T4.1 Identifying skill gaps in Advanced Technologies

D4.1 Report on the identified skill gaps in advanced technologies in industry

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INVESTech

Innovation Vocational Excellence

and Sustainability in Tech

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1 Executive Summary

This report identifies skill gaps in advanced technologies in industry (**ATIs**) across **seven key areas:** Artificial Intelligence & Ethics, Big Data, Blockchain, Internet of Things (IoT), ICT for Sustainability, Industry 5.0, and Quantum Computing. It is specifically aimed at vocational education to inform necessary changes in curricula and training approaches. The report highlights how leveraging regional skill ecosystems and international cooperation can enable more flexible, personalized, and standardized educational approaches to better address workforce deficiencies and emerging trends, while also providing actionable solutions to align skill development with market needs.

The methodology of this report is based on a **multi-method approach**, including **desk research** that reviews **EU and national reports** on ATIs, **focus groups** conducted across five countries with industry leaders, educators, and policymakers, and expert **interviews** with professionals in AI, blockchain, IoT, and related fields. **This research provides insights into current skill gaps, existing training structures, national policy approaches, and gaps in current vocational education programs.** Data mapping to the **ESCO** (European Skills, Competences, Qualifications and Occupations) and **eCF** (e-Competence Framework) ensures alignment of identified skill gaps with EU competency standards and provides a structured way to address future workforce needs. Comparative analysis has been conducted across multiple dimensions, including sectoral skill demands, national education policies, and industry readiness. The **aim is to identify current workforce skill gaps, pinpoint critical skills for future occupations, and frame them within the ESCO classification system and skills relationships**. This ensures a standardized approach to competency development across different countries and sectors.

A key finding is that while AI, Big Data, and IoT are relatively mature within the EU, Quantum Computing and Blockchain face significant talent shortages. Industry 5.0 and ICT for Sustainability require interdisciplinary expertise, merging engineering, AI, and cybersecurity skills. Across all sectors, digital literacy, machine learning, and cybersecurity knowledge are essential, yet critical gaps persist in areas such as AI bias detection, regulatory compliance, and data governance.

Comparative analysis framed these skill gaps within the ESCO classification system and skill relationships to ensure standardization across vocational education and industry training. To address these challenges, the report highlights the need for microcredential-based learning pathways that allow learners to stack qualifications in a flexible, modular format. These pathways should be informed by a combination of desk research, industry consultation, and expert insights to ensure their relevance in evolving technological landscapes. Integrating regional skill ecosystems and fostering international collaboration will make vocational education more adaptable to industry needs while maintaining alignment with EU policy frameworks.

The report recommends embedding industry-driven training into curricula, strengthening public-private partnerships, and promoting lifelong learning programs to address skill shortages. Given the rapid pace of technological evolution, continuous updates to training programs are essential to ensure vocational education remains aligned with labour market demands and EU policy priorities. By leveraging regional skill ecosystems and fostering international collaboration, vocational education can be made more adaptable and responsive to the needs of emerging technologies. Through a dynamic vocational education framework that integrates industry-driven learning and supports flexible qualification pathways, the EU can build a resilient technological workforce, enhance industry adaptability, and sustain economic growth in the digital era.

2 Introduction

Skill gap analysis is a key to developing effective learning pathways, e-learning as well as microcredentials. By pinpointing mismatches between labour market needs and existing workforce skills and competencies, especially amid digitalization and green transitions, policymakers can refine Higher Education and vocational education and training (VET) systems to boost employability and growth, up-to-date courses can be designed and offered to experts working in the high dynamic sectors as ICT certainly is.

In essence, **skill gap analysis underpins both broad educational innovation and CoVE success, ensuring that training meets evolving labour market needs and that learners can thrive in a rapidly changing world**.

Addressing skill gaps is essential in Industry 5.0, where human intelligence integrates with advanced technologies like big data, blockchain, IoT, and quantum computing.

As technologies evolve, new skills are required to operate, manage, and innovate effectively. Closing these gaps ensures workforce competitiveness, enabling businesses to adapt quickly and leverage technologies for productivity and innovation. For example, a shortage of data scientists can hinder the use of big data for strategic insights. Skill development also fosters creativity and innovation, empowering employees to explore new ideas in collaborative environments. Additionally, addressing skill gaps supports economic growth by preparing workers for emerging industries and enhancing organizational capabilities. Proactively tackling these gaps equips the workforce with specialized knowledge—such as cryptography for blockchain or algorithms for quantum computing—ensuring readiness for future challenges and opportunities in a rapidly evolving industrial landscape.

In summary, addressing skill gaps is vital for maintaining competitiveness, fostering innovation, supporting economic growth, and preparing for future challenges. Organizations that prioritize skill development will be better positioned to harness the full potential of emerging technologies and thrive in an increasingly complex business environment.

INVESTech project is built upon 4 main pillars:

- Development of labour market relevant skills.
- Green transition of VET organisations.
- Promotion of innovation in VET.
- Promotion of entrepreneurship in VET.

Within the first pillar project INVESTech supports the development of skills, targeting both professionals and students in the ICT sector. More specifically, partners of INVESTech have identified the gaps in skills and competences of professionals at EU and project partner countries levels and pinpoint specific skill requirements, in trending.

Within the **Work package 4 *Enhancing Labour Market-Relevant Skills in Advanced Technologies,* Task 4.1 Identifying skill gaps in Advanced technologies** the report on the identified skill gaps in 7 advanced technologies in industry has been prepared.

Based on this, partners will build microcredentials and online courses (at EQF 4-6 levels), compliant with the European eCompetence Framework (eCF), for professionals.

3 Methodology

The D4.1. Report on the identified skill gaps in the chosen ATIs was prepared within the task T4.1 of the project, and is focused on identification of the gaps in skills and competences of professionals and pinpoint specific skill requirements, in the following fields:

- Artificial Intelligence and Ethics
- Big Data
- Blockchain
- Internet of Things
- ICT for sustainability
- Industry 5.0
- Quantum Computing

3.1 Data collection process

In order to identify the gaps, partners organised desk research, focus groups and interviews with industry representatives and experts in each of 5 project partners' country. National workshops were also organised in each country and involved representatives from companies working in the relevant fields.

- The desk research was carried out at 2 levels: EU level and national levels of 5 project partner countries (Bulgaria, Cyprus, Greece, Lithuania, and Slovakia). All data were gathered and processed in the time period from August 2024 to January 2025. Based on the data gathered via desk research the following reports were prepared
  - Report for each ATI – EU level
  - Reports for all ATIs – national levels of 5 project partner countries
- A focus group, a one-day event with min of 10 participants invited from among industry representatives, experts, employers, educators, government and policy makers, and professionals working in the relevant field was held in each of 5 countries; altogether 5 focus groups to identify skills gaps in agreed ATIs.
- Altogether 5 interviews per country were organized to identify skills gaps in all 7 ATIs. Participants were invited from among industry representatives, experts, employers, educators, and professionals working in the relevant fields.

Based on the data gathered the following reports were prepared:

- Report from desk research on 7 ATIs – EU level
- 5 reports from desk research on 7 ATIs – national level
- 5 reports on focus groups, national level
- 5 reports on interviews, national level

All of the prepared reports are attached as annexes to this Report on skill gaps.

3.2 Limitations of the report

The analysis presented in this report is subject to several limitations that should be considered when interpreting the findings:

- **Uneven Level of Development** and Use of the 7 Analysed ATIs in Partner Countries: The seven analysed Advanced Technology Industries (ATIs) are not equally developed or utilized across the partner countries. This uneven development creates discrepancies in the available data, leading to challenges in comparative analysis and limiting the generalizability of the findings. For example, some countries may have robust ecosystems for AI and Big Data, while others are still in nascent stages of blockchain or quantum computing adoption. This variation directly impacts the identification of skill gaps and complicates the creation of uniform training programs.
- **Data Inconsistency:** Inconsistent data across different sources within individual partner countries can lead to confusion and unreliable analysis. Although the partners responsible for Task 4.1 agreed on mitigation steps and attempted to validate information through triangulation (ensuring findings are consistent across at least three reputable sources), the limited availability of reliable data sources presented significant challenges. In some cases, sector-specific data were missing, and differences in national reporting standards contributed to inconsistencies. These issues may have affected the precision of skill gap identification and forecasting.
- **Terminology Discrepancies**: Significant discrepancies were noted in the terminology used for knowledge, skills, and competences. These variations stem from differences across sectors, countries, and languages used in focus groups (FGs) and interviews (IWs). The lack of standardized definitions made it difficult to align findings across regions. For example, the interpretation of competencies related to AI & ethics or blockchain security varied, which may influence how educational programs and microcredentials are designed.
- **Language Barriers:** Although English language proficiency is high among all project partners' institutions, localised differences in the use of terminology were observed. Subtle distinctions in language can lead to varying interpretations of key concepts, particularly when dealing with technical terms related to emerging technologies.
- **Rapid Technological Advancements:** Given the fast-paced evolution of advanced technologies, the data and insights gathered for this report may become outdated quickly. Skill demands in sectors like quantum computing and AI can shift rapidly, requiring continuous updates to training curricula and microcredentials. The report's findings should thus be revisited periodically to ensure alignment with current market needs.
- **Contextual Variations in Skill Needs:** Skill requirements are often influenced by local economic priorities and industrial strengths. For example, while some partner countries prioritize cybersecurity and blockchain for fintech applications, others focus on sustainability and IoT for smart city development. These contextual differences must be considered when designing regionally relevant educational interventions.

4 EU-Level Analysis of Skill Gaps

4.1 Summary of key EU-level reports

The digital transformation of industries and the expansion of advanced technologies in the European Union have led to a critical demand for highly specialized skills across multiple sectors. This report synthesizes findings from desk research conducted across seven key advanced technology industries (ATIs):

- Artificial Intelligence and Ethics
- Big Data
- Blockchain
- Internet of Things
- ICT for sustainability
- Industry 5.0
- Quantum Computing

The purpose of this synthesis is to identify common and sector-specific skill gaps, examine emerging job roles, and propose actionable recommendations to align workforce capabilities with market needs.

The skill gaps identified across these seven ATIs vary in scope and complexity. Some sectors, such as Big Data and AI & Ethics, have relatively well-developed ecosystems in the EU due to extensive research and implementation in various industries. Others, such as Quantum Computing and Blockchain, are still in the early stages of adoption, facing a severe shortage of trained professionals. The Internet of Things (IoT) and Industry 5.0 are experiencing rapid growth but require interdisciplinary skills that combine engineering, AI, and cybersecurity expertise. ICT for Sustainability is increasingly critical as digitalization intersects with environmental concerns, yet it remains an emerging field requiring a balance of sustainability knowledge and technological proficiency.

While each ATI has unique skill requirements, there are also common skill expectations across multiple sectors. Advanced digital skills such as **AI, machine learning**, and **data analytics** are in high demand across most ATIs. Similarly, **cybersecurity** expertise is crucial for safeguarding interconnected systems in IoT, blockchain, and AI applications. **Regulatory compliance** and **ethics knowledge** is a necessity in AI, blockchain, and sustainability-focused roles. However, some ATIs demand highly specialized competencies—for example, **quantum programming** and **quantum cryptography** in Quantum Computing or smart contract development in Blockchain. This divide between core and specialized skills will influence future talent development strategies.

The extent to which the EU has developed expertise in these fields also varies. Established ATIs like Big Data and AI & Ethics have a strong research presence and industry adoption, whereas fields such as Quantum Computing and Blockchain are still struggling with limited educational pathways and a lack of practical expertise. The challenge for the EU lies in bridging these skill gaps through targeted education, training programs, and policy-driven initiatives.

4.2 Common themes in skill shortages

4.2.1 Common Skill Gaps Across Sectors

Despite targeted investments and a values-driven approach, the EU's position in the advanced technology landscape presents a complex and often contradictory picture.

Tech leadership: The EU holds pockets of global leadership within the advanced technology landscape, particularly where its values and priorities align with technological development. It arguably leads in setting the ethical and regulatory frameworks for AI, exemplified by the pioneering EU AI Act, effectively shaping global standards for responsible AI development and deployment, even if AI development is more potent elsewhere. The EU also leverages its industrial heritage to excel in manufacturing automation, industrial robotics, and embedded systems, positioning it strongly within elements of Industry 5.0. Powered by ambitious climate goals, it is a frontrunner in ICT for Sustainability, fostering innovative solutions in environmental monitoring and smart energy. Furthermore, the EU demonstrates particular expertise in specific Big Data applications, especially those cantered on scientific research and public services, as demonstrated by the Copernicus program.

Tech challenges: The EU faces significant challenges in keeping pace with global competition across several key ATIs. Despite investments, the EU lags behind the US and China in overall AI research, development, and deployment due to disparities in investment and talent concentration. It also faces an uphill battle in Quantum Computing, trailing in both public and private funding, access to hardware, and workforce development. Similarly, while pockets of Blockchain innovation exist, the US and Asia dominate in development and adoption, hindered in the EU by regulatory uncertainty. In the fragmented IoT landscape, the EU struggles against the scale of US and Asian players, possessing strengths primarily in specific industrial applications but lacking a cohesive strategy to contend for broader dominance.

The analysis of the seven ATIs reveals several recurring skill deficiencies that impact multiple industries. One of the most significant gaps is the lack of **advanced digital skills**, particularly in the areas of artificial intelligence (AI), machine learning, quantum computing, blockchain, and big data. Employers struggle to find professionals with deep technical expertise who can develop and implement cutting-edge technologies. This shortage is exacerbated by the **rapid evolution of these technologies**, which outpaces the development of specialized training programs.

Another critical area of concern is **cybersecurity and data protection**. As IoT, blockchain, and AI systems become more integrated into everyday operations, the need for robust security measures has increased. However, there is a shortage of specialists who can ensure compliance with the **General Data Protection Regulation (GDPR)** and other EU regulations. Similarly, knowledge of **regulatory compliance and ethics** remains insufficient across various sectors, particularly concerning AI governance, blockchain security, and sustainable ICT practices.

Furthermore, there is **a notable lack of interdisciplinary knowledge**. Many professionals specialize in either technical disciplines (e.g., AI development, data science, IoT architecture) or sustainability and ethics, but few possess expertise in both areas. This deficiency creates

barriers to implementing sustainable and responsible technological solutions. Moreover, **project management and communication skills are in high demand**, as companies seek professionals who can oversee complex digital transformation projects and translate technical concepts for non-technical stakeholders.

4.3 Sector-Specific Skill Gaps

4.3.1 Internet of Things (IoT)

Employers, including Philips, Bosch, and AWS, are actively seeking IoT specialists across a broad hierarchy, from Junior IoT Engineers to IoT Solutions Architects. In-demand skills span cloud computing, security (especially crucial for preventing intrusions), and programming languages like Python and JavaScript, essential for IoT application development. While courses exist, the labour market demands proficiency in both core competencies and specialized areas like edge computing and IoT communication protocols (MQTT). A critical shortage exists in experts capable of effectively analysing the high volumes of data generated by IoT devices (IoT Data Analysts) and those capable of building user-friendly interfaces (IoT UI Designers). Current learning paths often lack comprehensive coverage, failing to equip professionals with the integration skills needed for roles like IoT Solutions Architect. Therefore, many employers are investing in reskilling their current workers in areas like data analytics and agile project management to meet evolving needs. Besides technical expertise, employers are underscoring the importance of soft skills such as critical thinking and project management, as reflected in skill profiles for IoT Project Managers and Product Managers. Integrated skills profiles like embedded developers, data specialists and front-end developers, are also needed. Thus, there is a critical need for targeted training initiatives that incorporate integrated skills, in-demand programming languages, and security into learning models

- **Key Skill Profiles/Jobs:** IoT Security Engineer, Embedded Systems Developer, IoT Data Analyst.
- **Required Skills:** IoT communication protocols (MQTT, Zigbee), programming in C, C++, Python, IoT security and encryption techniques.
- **Available Skills:** Basic knowledge in embedded systems, but a shortage of security-focused IoT engineers.
- **Comparison of Skill Profiles and Labour Market Demands:** With the increasing use of IoT in smart cities, healthcare, and industrial automation, there is a significant gap in IoT security expertise. Most available professionals focus on development rather than security, creating vulnerabilities in IoT infrastructure.

4.3.2 Industry 5.0

Industry 5.0 is transforming manufacturing, logistics, and healthcare, demanding professionals skilled in Human-Robot Interaction (HRI), Digital Thread applications, and Digital Twin engineering. The automation Engineer and Data Analyst roles are most requested. HRI Specialists require strong interpersonal skills, robotics expertise, and a foundation in psychology to optimize human-machine collaboration. However, existing workers often lack advanced robotics knowledge, AI proficiency, and human-computer interaction experience. Digital Thread Applications Engineers need expertise in PLM systems, data integration, and cybersecurity to ensure end-to-end product lifecycle visibility. The most significant skill gap is not traditional design experience, but advanced usage of product life cycle management (PLM) tools integrated to other company divisions. Digital Twin Engineers, critical for system optimization, need AI/ML, IoT, and cloud computing skills, exceeding the basic proficiency of many current engineers. These are the most requested and the most complex profiles. Soft skills, namely teamwork, communication and adaptability are lacking among technical personnel, too, and companies are in a constant hunt to provide skills and update the knowledge for technical persons to ensure the organization growth in the future. Addressing these gaps requires a shift towards continuous learning and upskilling, with a need for comprehensive training programs that integrate both technical and interpersonal competencies.

- **Key Skill Profiles/Jobs:** Human-Robot Interaction (HRI) Specialist, Digital Twin Engineer, Industry 5.0 Integration Consultant.
- **Required Skills:** AI-driven automation, digital twin simulation, interdisciplinary collaboration.
- **Available Skills:** Engineers with experience in robotics but lacking expertise in AI-human interaction and real-time digital twins.
- **Comparison of Skill Profiles and Labour Market Demands:** While automation engineers are readily available, expertise in human-centric design and digital twins is still lacking, impacting Industry 5.0 adoption in European manufacturing.

Looking ahead, the most acute shortages are expected in roles requiring the ability to integrate diverse technologies and manage complex cyber-physical systems, particularly as Industry 5.0 solutions become more sophisticated and interconnected. A proactive, adaptive workforce is key for successful implementation.

4.3.3 Quantum Computing

The quantum computing sector, attracting talent to tech giants like IBM and Google, academic institutions, and even financial and pharmaceutical firms, demands expertise across quantum algorithms, hardware engineering, and cryptography. Key roles include Quantum Software Engineers, Experimental Physicists, and Cryptography Researchers, requiring a foundation in physics, computer science, or mathematics, and strong collaboration/problem-solving. Available graduates mostly possess traditional skillsets, while the greatest needs lie in highly specialized and interdisciplinary roles connecting theory with practical application (the development, testing and scalability of the hardware, and the security elements). A particular skill shortage exists in developing cryo-stable software solutions to test quantum hardware, due to hardware limitations. Skills gaps arise from the sector's cutting-edge nature, with a deficit in those capable of translating theoretical models into scalable quantum computing solutions that can be deployed in real world contexts. Moreover, a challenge in the sector is a lack of individuals with not only technical background, but soft skills to work in multidisciplinary projects. Addressing these gaps requires promoting specialized master's and PhD programs, as well as prioritizing collaborative research projects to foster interdisciplinary expertise.

- **Key Skill Profiles/Jobs:** Quantum Software Engineer, Quantum Cryptographer, Quantum Hardware Engineer.
- **Required Skills:** Quantum programming (Qiskit, Cirq), cryptographic security, quantum hardware and circuit design.
- **Available Skills:** Limited due to a lack of academic and professional training programs.
- **Comparison of Skill Profiles and Labour Market Demands:** The demand for quantum expertise is growing, but the number of skilled professionals remains low due to limited educational opportunities in Europe.

In the future, the most critical shortages will likely be in professionals bridging the divide between theory and practice, such as Quantum Product Managers and Quantum Consultants, who can translate the business value of quantum computing across varied applications to businesses. Given the lack of Quantum Computing specialized study branches and programs, the EU needs to act fast to provide future generation workforce.

4.3.4 Big Data

Driven by the need for data-driven insights, the Big Data sector's in EU employment spans technology firms, financial institutions, healthcare providers, and emerging AI startups, requiring roles like Data Scientists, Engineers, and CDOs. A combination of analytical capabilities and data science is in high demand in these roles. Core competencies include Python, SQL, and tools like Hadoop, Spark, and Kafka, as well as cloud computing, but proficiency levels vary across experience levels, meeting a range of requirements. There is currently a lack of advanced knowledge and skills like machine learning, cloud computing, big data architecture and those requiring broad understanding of the data landscape among professionals. Foundational skills are relatively common, the labour market demands more advanced skills in machine learning, big data architecture, and cloud computing that the professionals do not have, creating a significant talent gap. Furthermore, GDPR and Data Privacy and Compliance experts are required across all sectors due to regulatory requirements but are rare. It's also a gap the ability to bridge technical and business teams. Reskilling and upskilling initiatives are to be taken to align workforce capabilities with labour market needs as well as soft skills, such as problem solving and communication.

- **Key Skill Profiles/Jobs:** Data Scientist, Big Data Engineer, Cloud Computing Specialist.
- **Required Skills:** Machine learning, Hadoop/Spark, cloud computing (AWS, Azure, Google Cloud), data visualization tools (Tableau, Power BI).
- **Available Skills:** Many professionals have foundational data analysis skills but lack dedicated and advanced in large-scale distributed computing and cloud-based data solutions.
- **Comparison of Skill Profiles and Labour Market Demands:** The EU has a strong research base in data science, but gaps remain in real-world implementation, regulatory compliance, and advanced machine learning techniques. The demand for skilled professionals in data governance, AI-driven analytics, and large-scale data processing is growing faster than the supply of talent.

Looking ahead, the greatest skill shortages will likely be in data governance, regulatory compliance, and translation of complex insights into strategic actions, as well as engineers and scientists with an understanding of the new data landscape.

4.3.5 Blockchain

Blockchain specialists are in demand across finance, supply chain, healthcare, and government sectors in the EU, particularly in hubs like Berlin, London, and Zurich, with key roles spanning from Blockchain Developers and Architects to Security Specialists and Product Managers. The European market is rich with roles across technical and non-technical roles, which brings new insights and job creation. Technical expertise is a major asset in the market, with an exceptional commitment from professionals. Core competencies are based on specialized areas, such as Solidity, Rust, and cloud infrastructure. Despite these, critical shortages exist in Blockchain Security, and in those with interdisciplinary skills bridging technology and business strategy. Skills are a strength in the EU, because blockchain and all the protocols, frameworks and new programming languages it includes require constant update of knowledge. There is a knowledge around what is new in legal requirements, as GDPR rules makes it difficult to navigate compliance. Because of the evolution of technologies, it is increasingly important to have individuals with data and management skills. It comes as a result of data becoming more complex over time and because a large number of projects will demand specific actions and operations.

- **Key Skill Profiles/Jobs:** Smart Contract Developer, Blockchain Security Specialist, Blockchain Compliance Officer.
- **Required Skills:** Solidity, Rust programming, blockchain security, compliance with financial regulations, decentralized application (DApp) development.
- **Available Skills:** Few trained professionals specialize in blockchain compliance and security, leading to high demand in finance, supply chain, and decentralized finance (DeFi) industries.
- **Comparison of Skill Profiles and Labour Market Demands:** Despite blockchain's increasing adoption, there is a critical shortage of experts in regulatory and cybersecurity domains. Organizations seek professionals who can **ensure compliance with financial regulations** while maintaining the security of blockchain-based transactions.

Addressing future shortages will demand specialized education in compliance and security, as well as soft skills. Future job requirements and high demand are in Developers and Architects to build the blockchain networks because of growing interest for blockchain technologies, legal and governance experts because of legal gaps that there are in the regulations to implement the platforms, and in the same way data privacy specialists so that the platforms fulfil all the requirements that come from that area.

4.3.6 ICT for Sustainability

Organizations across tech, energy, government, and consulting sectors need Sustainability Data Analysts, Green IT Specialists, Urban Development Consultants, and Smart City Planners to comply with EU regulations, requiring expertise in data science, environmental engineering, and urban planning. Critical competencies include data analytics, machine learning, cloud computing, and environmental impact assessment. The demand for AI for climate scientists also is increasingly needed. A gap exists: the hybrid profile is rare. The labour market demands competencies in AI, Big Data, and IoT for sustainability, yet existing hybrid profiles (i.e., data scientists and environmental engineers) have very limited availability, and are extremely required. The labour market requires hybrid skills that combine ICT with circular economy concepts, such as green IT and energy efficiency. Professionals need to navigate technical complexities and understand data governance for green infrastructure, making experience expertise key.

- **Key Skill Profiles/Jobs:** Green IT Specialist, Circular Economy IT Consultant, Smart City Planner, Urban Development Consultant.
- **Required Skills:** Energy-efficient computing, IoT for sustainability, environmental data analytics, carbon footprint tracking, renewable energy integration.
- **Available Skills:** Environmental specialists lack ICT expertise, while IT professionals lack sustainability knowledge.
- **Comparison of Skill Profiles and Labour Market Demands:** The demand for ICT sustainability experts is growing, but a lack of cross-disciplinary training programs hinders talent availability. Professionals with expertise in digital solutions for sustainability and energy-efficient computing are highly sought after.

Addressing future gaps requires interdisciplinary training programs, sustainable IT courses, and integrating ICT with sustainable goals in all sectors. The greatest shortages will be in specialists and leaders who can bridge the gap between sustainability knowledge and expertise.

4.3.7 AI & Ethics

EU Institutions, tech firms, and research institutes are key employers seeking AI & Ethics professionals, specifically Data Protection Officers, Ethics Managers, and AI Policy Analysts to ensure responsible AI development and compliance with GDPR. Core competencies encompass AI ethics frameworks, regulatory knowledge, and bias detection, supported by degrees in computer science, law, or ethics. The EU job market lacks essential ethical AI skills, with significant gaps in bias mitigation, algorithm transparency, and GDPR-compliant data management. While technical proficiency in Python and SQL exists, it falls short in in-depth knowledge of ethical considerations and risk management in AI. An essential shortage is in people that combines technical and ethical understanding, and, furthermore, can translate its insights into actionable actions. Employers increasingly prioritize AI model interpretability and compliance and are looking for candidates with in-depth understanding of how the technology can be used, especially with soft skills.

- **Key Skill Profiles/Jobs:** AI Auditor, AI Transparency Specialist, Ethics and Compliance Manager.
- **Required Skills:** Bias mitigation, AI transparency, GDPR compliance, AI risk management, fairness in machine learning models.
- **Available Skills:** Few AI specialists are trained in ethics, governance, and regulatory compliance, creating a significant gap in responsible AI deployment.
- **Comparison of Skill Profiles and Labour Market Demands:** Ethical AI development is a major focus, but the lack of trained compliance officers remains a significant challenge.

Companies are increasingly seeking professionals who can ensure AI systems align with EU ethical standards and data privacy laws.

Moving forward, the most acute shortages will be experienced by companies and governments that are working with people who knows how to lead complex ethical AI projects.

4.4 Cross-sectoral trends

Addressing skill gaps is crucial for the successful implementation and adoption of emerging technologies, positioning organizations for long-term competitiveness. Without skilled personnel, the transformative potential of advancements like AI, blockchain, and quantum computing remains largely untapped. The **Table 1 presents a detailed classification of these gaps across various technological domains**, serving as a valuable resource for strategic workforce planning. It categorizes skills, specifies their sectoral applications, identifies critical roles, and highlights key areas needing attention. This structured overview provides insights into current and future workforce demands, enabling proactive investment in training and talent acquisition.

TABLE 1 Expanded Classification of Skill Gaps by Category

Skill Type	Primary Sectoral Application	Critical Roles Needed	Key Gaps Identified
Technical Skills	AI, IoT, Blockchain, Quantum Computing	AI Engineer, Quantum Software Developer, IoT Specialist, Cybersecurity Analyst, Data Engineer	Advanced programming, cybersecurity, system integration, smart contract development, quantum networking, cloud architecture, embedded systems, robotics design, predictive maintenance, cryptographic security, ethical AI implementation
Analytical Skills	Big Data, AI, ICT for Sustainability, Industry 5.0	Data Scientist, Business Analyst, Sustainability Analyst, Digital Twin Specialist, Process Optimization Engineer	Data governance, statistical modelling, predictive analytics, real-time data processing, anomaly detection, decision automation, environmental impact assessment, computational modelling, supply chain optimization, KPI interpretation, automation efficiency
Soft Skills	Cross-sectoral, Smart Cities, IT, Manufacturing	Project Manager, Team Lead, Human Factors Specialist, Innovation Facilitator, Agile Coach	Communication, leadership, adaptability, time management, cross-disciplinary collaboration, stakeholder engagement, problem framing, creative thinking, negotiation, change management, cross-cultural competency

Skill Type	Primary Sectoral Application	Critical Roles Needed	Key Gaps Identified
Ethical & Legal	AI Ethics, Blockchain, Industry 5.0, Digital Rights Management	Compliance Officer, AI Auditor, Cyber Law Specialist, Policy Advisor, Digital Ethics Consultant	Data privacy regulations, compliance frameworks, ethical governance, AI bias mitigation, intellectual property rights, regulatory impact analysis, algorithm transparency, consumer protection laws, cybersecurity law enforcement, ethical automation strategies
Project Management	IT, AI, IoT, Quantum, Engineering, Supply Chain	Program Manager, Agile Coach, Lean Expert, Operations Manager, Strategic Planner	Risk mitigation, resource allocation, strategic planning, milestone tracking, product lifecycle management, regulatory compliance, cost-benefit analysis, business continuity planning, cross-functional team leadership, execution efficiency
Industry-Specific	Emerging Tech, Smart Factories, Finance, Healthcare, Logistics	Industry Consultant, Technical Advisor, Process Engineer, Automation Specialist, Urban Development Analyst	Regulatory knowledge, sector expertise, technology adoption, industrial AI, precision manufacturing, biomedical informatics, financial fraud detection, logistics optimization, energy management systems, patient-centred healthcare transformation
Digital Literacy	All Sectors, E-Governance, Smart Infrastructure	Digital Transformation Manager, Security Analyst, Cloud Solutions Architect, IT Support Specialist, E-Government Consultant	Cybersecurity awareness, cloud computing, digital platforms proficiency, SaaS integration, hybrid work adaptation, human-computer interaction, virtual collaboration tools, digital identity management, user experience optimization, IT infrastructure resilience

From the classification of skill gaps, we derive key insights into the workforce challenges across different technological domains:

- **Technical Skills**: There is a growing demand for advanced competencies in AI, IoT, blockchain, and quantum computing. However, key gaps remain in system integration, quantum networking, cybersecurity, and smart contract development. Addressing these gaps is critical for the widespread adoption of emerging technologies.
- **Analytical Skills**: The increasing reliance on big data, AI, and digital sustainability underscores the need for data governance, predictive analytics, and computational modelling. Organizations need to strengthen real-time data processing and decision automation capabilities to enhance operational efficiency.
- **Soft Skills**: While technology advances, cross-sectoral skills like communication, leadership, and adaptability remain essential. These skills facilitate collaboration and

innovation in multi-disciplinary environments, particularly in smart cities and manufacturing.

- **Ethical & Legal Skills**: With the expansion of AI and digital systems, expertise in AI ethics, data privacy regulations, and compliance frameworks is vital. Legal and policy professionals must ensure transparency in algorithmic decision-making and safeguard consumer rights in the digital space.
- **Project Management Skills**: The complexity of IT, AI, IoT, and quantum projects highlights the necessity for risk mitigation, strategic planning, and execution efficiency. Effective project management ensures smooth integration of new technologies into business operations.
- **Industry-Specific Knowledge**: Emerging technologies require domain-specific expertise to drive innovation in finance, healthcare, logistics, and smart factories. Bridging regulatory knowledge and sectoral skills will enable a seamless transition to digital and automated solutions.
- **Digital Literacy**: Across all sectors, a fundamental understanding of digital tools, cybersecurity, and hybrid work adaptation is essential. Professionals must develop digital identity management and virtual collaboration skills to keep pace with the digital transformation era.

To effectively address skill gaps across ATIs, several **key questions** must be considered:

- How do skill demands differ across ATIs, and where do they overlap?
- What foundational competencies should be universally integrated into education and training?
- How can interdisciplinary skills facilitate cross-sectoral mobility, and what specialized expertise is required for emerging fields?

Addressing these questions facilitates the creation of a hierarchical model that organizes skills into foundational, interdisciplinary, and highly specialized levels, aligning them with workforce and industry needs. This process involves analysing how skill demands differ across Advanced Technology Industries (ATIs), identifying shared foundational competencies and sector-specific expertise. Understanding these similarities and differences enables targeted educational strategies that integrate digital literacy, technical specialization, ethical considerations, and soft skills. A structured framework ensures that workforce development aligns with technological advancements and industry needs. To structure the necessary skills across various Advanced Technology Industries (ATIs), **we propose a hierarchical pyramid model**. This model organizes skills into three levels: foundational, interdisciplinary, and highly specialized. The framework aids in designing training programs that ensure a progressive learning pathway from general digital literacy to advanced technical expertise.

1. Common General Skills for All ATIs (Foundation Level)

- Digital literacy and computational thinking
- Cybersecurity awareness and data protection compliance
- Basic programming (Python, C++, Java)
- Analytical and problem-solving skills

- Project management and communication skills
- Ethical and regulatory knowledge (GDPR, AI ethics, sustainability compliance)

2. Cross-Sector Skills (Applicable to Two or More ATIs) (Intermediate Level)

- AI & Machine Learning (Big Data, AI & Ethics, Industry 5.0)
- Cloud Computing & Distributed Systems (Big Data, Blockchain, IoT)
- Embedded Systems & IoT Communication Protocols (IoT, Industry 5.0)
- Digital Twin & Simulation Technologies (Industry 5.0, Quantum Computing)
- Blockchain & Smart Contract Development (Blockchain, AI & Ethics, Big Data)
- Energy-Efficient Computing & Green IT (ICT for Sustainability, Industry 5.0, AI & Ethics)
- Cyber-Physical Systems & Robotics (Industry 5.0, IoT, AI & Ethics)

3. Highly Specialized Skills for Specific ATIs (Advanced Level)

- Quantum Programming & Cryptography (Quantum Computing)
- Advanced IoT Security & Edge Computing (IoT)
- Human-Robot Interaction & Digital Twin Engineering (Industry 5.0)
- Decentralized Finance & Compliance (Blockchain)
- Sustainability Analytics & Circular Economy IT (ICT for Sustainability)
- Explainable AI & Algorithm Auditing (AI & Ethics)
- High-Performance Computing & Quantum Simulation (Quantum Computing, Big Data)

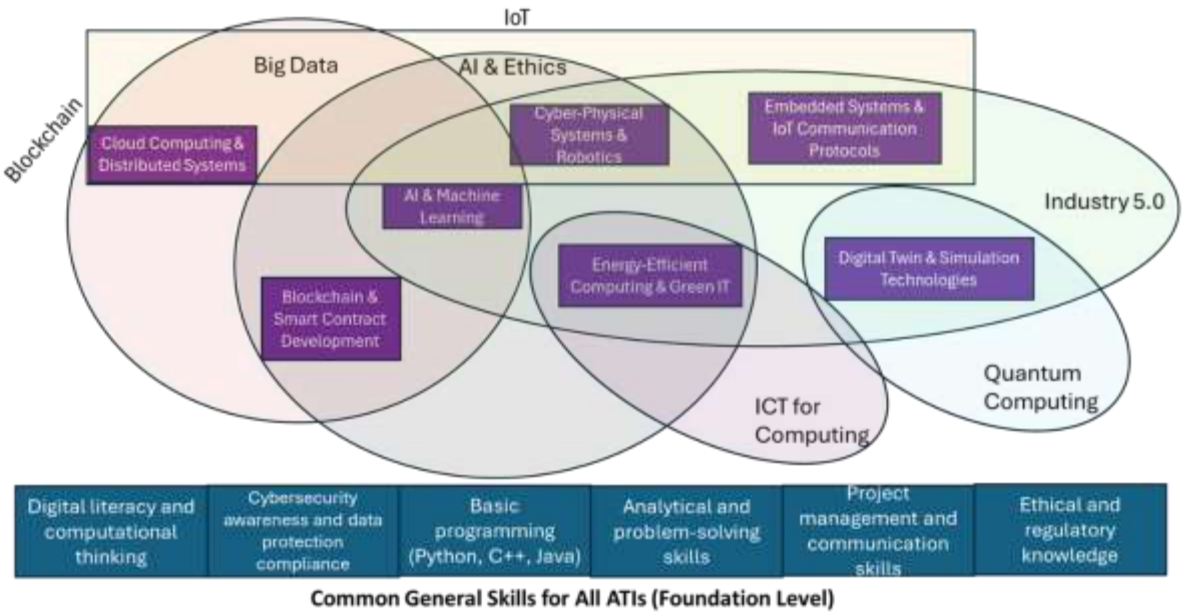

Figure 1: Foundational and cross-sectoral skills in seven ATIs.

Understanding the skill landscape for emerging technologies requires recognizing both the foundational skills common to all domains and the specialized skills that bridge various sectors. While certain fundamental abilities, like digital literacy and analytical thinking, underpin competence across all Advanced Technological Innovations (ATIs), other skills are specifically crucial for navigating the intersections between these rapidly evolving fields. The following Venn diagram visually represents this interplay, illustrating how common skill sets form a base for all ATIs while the overlapping areas highlight cross-sectoral skills that are essential for fostering innovation at the convergence of these technologies. By examining these relationships, we can identify strategic opportunities for workforce development and promote a more integrated approach to training in emerging technological fields.

Beyond foundational skills and cross-sectoral competencies, a complete understanding of the ATI skill landscape also necessitates recognizing highly specialized skills tailored to individual Advanced Technological Innovations, creating a three-tiered framework of proficiency. This structured approach helps categorize skills into foundational, interdisciplinary, and highly specialized levels, making it easier to design training programs and policy interventions that align with workforce demands in the evolving technological landscape.

4.5 Policy and educational initiatives at the EU level

The European Union has implemented a range of policy and educational initiatives to address skill gaps in advanced technologies, ensuring a future-proof workforce that aligns with industry needs. These initiatives focus on vocational training, higher education, and lifelong learning, emphasizing the importance of digital and interdisciplinary competencies.

4.5.1 European Strategies and Funding Programs

The EU has adopted several strategic frameworks and funding mechanisms to support skills development in emerging technologies:

- **The Digital Education Action Plan (2021-2027)**[1]: Aims to enhance digital skills among EU citizens, with a focus on advanced digital competencies in areas such as AI, big data, and quantum computing.
- **Horizon Europe**[2]: Provides research and innovation funding for technology development and skills enhancement, particularly in AI, blockchain, and quantum technologies.
- **The Pact for Skills**[3]: Encourages industry-led upskilling and reskilling initiatives, focusing on digital, green, and industry-relevant competencies.
- **Erasmus+**[4]: Supports mobility and exchange programs for students and professionals in digital and STEM fields.
- **The European Institute of Innovation and Technology (EIT)**[5]: Develops specialized education programs through EIT Digital, EIT Manufacturing, and other Knowledge and Innovation Communities (KICs) that bridge academia and industry.

[1] https://education.ec.europa.eu/focus-topics/digital-education/action-plan
[2] https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe_en
[3] https://pact-for-skills.ec.europa.eu/index_en
[4] https://erasmus-plus.ec.europa.eu/
[5] https://eit.europa.eu/

4.5.2 Vocational Excellence and Industry Partnerships

To strengthen the regional skills ecosystem, the EU promotes **Centers of Vocational Excellence (CoVEs)** that integrate technological training with real-world industry needs. These centres focus on:

- **Industry 5.0 and Digital Twin Technologies**: Facilitating cooperation between universities, vocational training providers, and companies to create specialized curricula.
- **AI and Cybersecurity Training Programs**: Partnering with industry leaders to offer certified courses in AI ethics, cybersecurity, and regulatory compliance.
- **Green and Digital Construction Skills**: Initiatives like the **Green Building CoVE** focus on digitalization and sustainability in the built environment.

4.5.3 Alignment with EU Policies and Future Workforce Needs

The European Commission has outlined skill priorities in alignment with the **European Skills Agenda**[6], including:

- **Strengthening Digital Skills**: Expanding digital skills in all educational levels to ensure future professionals can work in AI, blockchain, and data science.
- **Fostering Interdisciplinary Education**: Encouraging cross-sector training to bridge gaps between sustainability, AI, and emerging tech industries.
- **Regulatory and Ethical Compliance Training**: Ensuring that professionals are equipped to navigate the complexities of GDPR, AI ethics, and cybersecurity regulations.

By integrating these policy initiatives with targeted educational programs, the EU aims to reduce skill shortages, enhance workforce adaptability, and foster innovation across advanced technological industries. The continued collaboration between policymakers, industry leaders, and educational institutions will be crucial in maintaining Europe's competitive edge in the global digital economy.

4.5.4 Future directions

Based on a desktop analysis, several high-demand roles are emerging in the EU labour market, including:

- IoT Security Engineers
- AI Auditors & Algorithm Transparency Specialists
- Human-Robot Interaction Experts
- Quantum Cryptography Researchers
- Big Data Compliance Officers
- Blockchain Governance Specialists

There is a notable **misalignment between educational programs and industry demands**. Universities and training institutions **lack specialized curricula** in advanced technology fields, particularly in quantum computing, blockchain, and AI ethics. Additionally, many **reskilling initiatives focus on generic digital skills** rather than the **deep technical**

[6] https://employment-social-affairs.ec.europa.eu/policies-and-activities/skills-and-qualifications/european-skills-agenda_en

expertise required by employers. To bridge these gaps, the EU should prioritize the following strategic actions:

1. **Expand Advanced Digital Training Programs**: Increase access to training in IoT protocols, quantum computing, blockchain security, and AI auditing.
2. **Strengthen Regulatory and Ethical Education**: Incorporate AI ethics, blockchain compliance, and GDPR-focused courses into technical programs.
3. **Foster Industry Collaboration**: Encourage partnerships between universities and companies to align curricula with labour market needs.
4. **Invest in Reskilling and Upskilling**: Develop EU-funded initiatives to equip professionals with critical digital skills.

By fostering interdisciplinary expertise, expanding educational programs, and strengthening industry collaboration, the EU can build a future-ready workforce capable of driving sustainable, ethical, and technologically advanced innovation. Addressing these skill shortages will ensure Europe remains competitive in emerging digital industries while supporting its broader goals of economic resilience and technological leadership.

5 National-Level Analysis of Skill Gaps

5.1 Skill gap analysis by countries

The rapid development of digital technologies, the transition to a sustainable economy and the emergence of Industry 5.0 are changing workforce requirements across Europe. Addressing critical skills gaps is becoming essential. However, these gaps are not uniform; they reflect the industrial focus, economic priorities and policy frameworks of individual countries. This section examines country-specific trends in skills shortages in Greece, Cyprus, Slovakia, Lithuania and Bulgaria. Understanding these specific gaps is key to developing targeted education programmes, policy interventions and industry-academia partnerships that can bridge these differences. The following country-level analyses highlight where targeted action is needed to create a resilient, future-ready workforce aligned with national development goals.

5.1.1 Greece

- AI & Ethics: Gaps in AI ethics research, bias mitigation, and policy compliance for public sector applications.
- Big Data & Cloud: Lacks expertise in data analytics, Hadoop/Spark frameworks, and AI in cloud solutions.
- Blockchain & Cybersecurity: Shortage in smart contract security, blockchain regulation, and cryptographic security.
- ICT for Sustainability: Needs professionals for Smart City IoT projects and ESG reporting.
- Industry 5.0: Gaps in robotics engineering, human–machine interaction, and cybersecurity.
- IoT & Embedded Systems: Requires skills in IoT security, smart home automation, and embedded AI.
- Quantum Computing: Quantum cryptography and hybrid quantum-classical computing are underdeveloped.

5.1.2 Cyprus

- AI & Ethics: Gaps in ethical AI integration, machine learning deployment, and responsible AI development.
- Big Data & Cloud: Deficits in GDPR compliance, cloud-based AI integration, and big data architecture.
- Blockchain & Cybersecurity: Needs blockchain governance specialists, product managers, and security token experts.
- ICT for Sustainability: Skills gaps in AI for renewable energy, sustainability data science, and circular economy technologies.
- Industry 5.0: Lacks IoT for smart manufacturing, cybersecurity for Industry 5.0, and AI-powered automation.

- IoT & Embedded Systems: Deficiencies in IoT cloud integration, 5G for IoT, and IoT-specific cybersecurity.
- Quantum Computing: Shortages in quantum algorithm design, post-quantum security, and quantum systems engineering.

5.1.3 Slovakia

- AI & Ethics: Shortage of AI ethics specialists, AI software developers, and machine learning engineers.
- Big Data & Cloud: Gaps in cloud DevOps, real-time data streaming, and data privacy & security.
- Blockchain & Cybersecurity: Needs expertise in cryptographic engineering, blockchain–AI integration, and DeFi applications.
- ICT for Sustainability: Lacks Green IT consultants, smart city planners, and energy efficiency technology experts.
- Industry 5.0: Skill shortages in digital twin technologies, AI-driven manufacturing, and project management.
- IoT & Embedded Systems: Industrial IoT, smart city IoT solutions, and edge computing skills are in high demand.
- Quantum Computing: Requires knowledge in quantum error correction, quantum software engineering, and applied quantum AI.

5.1.4 Lithuania

- AI & Ethics: Gaps in AI policy, responsible AI development, and interdisciplinary collaboration.
- Big Data & Cloud: Lacks expertise in AI-powered big data processing, advanced data governance, and data engineering.
- Blockchain & Cybersecurity: Needs professionals in security auditing, digital identity & privacy, and blockchain research.
- ICT for Sustainability: Skills shortages in IoT for smart agriculture, sustainability reporting, and green technologies.
- Industry 5.0: Needs cybersecurity for Industry 5.0, data science for manufacturing, and digital engineering.
- IoT & Embedded Systems: Lacks proficiency in IoT data analytics, IoT security, and embedded system design.
- Quantum Computing: Gaps in quantum hardware research, quantum optics, and quantum machine learning (QML).

5.1.5 Bulgaria

- AI & Ethics: Skill gaps in business intelligence for AI, AI/ML engineering, and data science.

- Big Data & Cloud: Deficiencies in large-scale data infrastructure, cloud security, and business intelligence integration.
- Blockchain & Cybersecurity: Requires blockchain engineers, business integration specialists, and security practice experts.
- ICT for Sustainability: Lacks sustainability data analysts, carbon footprint tracking specialists, and circular economy solution experts.
- Industry 5.0: Shortages in smart factory design, AI-driven process optimization, and sustainable robotics.
- IoT & Embedded Systems: Needs IoT networking protocols experts, secure IoT infrastructure developers, and embedded AI specialists.
- Quantum Computing: Shortfalls in quantum data science, quantum key distribution, and quantum cloud computing.

5.2 Commonalities and differences across the countries

The analysis of skill gaps across Greece, Cyprus, Slovakia, Lithuania, and Bulgaria **reveals both striking commonalities and distinct differences** shaped by each country's industrial priorities. The ubiquity of AI & Ethics gaps, especially in ethical AI implementation, bias mitigation, and regulatory compliance, underscores the growing importance of trustworthy AI aligned with EU regulations. Additionally, Big Data & Cloud Computing expertise—particularly in GDPR compliance, data governance, and cloud-native architectures—represents a cornerstone for digital economy growth. The widespread need for blockchain proficiency (smart contract development and cryptographic security) and IoT integration highlights a collective push toward smart ecosystems and interconnected digital infrastructures. The quantum computing revolution, though still nascent, shows promising potential, with quantum programming, cryptography, and hybrid quantum-classical computing skills emerging as strategic future capabilities. ***However, these skills currently remain concentrated in academic and research settings, suggesting a disconnect between research excellence and industry adoption that must be addressed through targeted innovation policies.***

5.2.1 Common Skill Gaps Across All Countries

- **AI & Ethics:** Universal demand for ethical AI implementation, bias mitigation, and regulatory compliance knowledge.
- **Big Data & Cloud:** GDPR compliance, data governance, and cloud-native solutions are common shortages.
- **Blockchain & Cybersecurity:** Gaps in smart contract development, cryptographic security, and blockchain regulation.
- **ICT for Sustainability:** High need for AI-powered sustainability solutions, IoT for green projects, and ESG reporting.
- **Industry 5.0:** Lack of human–machine interaction skills, IoT integration, and advanced AI and data analytics.

- **IoT & Embedded Systems:** IoT networking protocols, embedded system programming, and IoT cybersecurity are critical gaps.
- **Quantum Computing:** Quantum programming, quantum cryptography, and hybrid quantum-classical computing are widely lacking.

5.2.2 Key Differences in Skill Gaps Across Countries

While each country exhibits unique skill demands aligned with their industrial priorities, **there is broad convergence around: AI ethics, cloud computing, blockchain compliance, IoT integration, sustainable ICT, and quantum computing skills.**

Soft skills such as communication, leadership, and cross-functional collaboration remain universally underdeveloped and are critical enablers for successful digital transformation across all analysed countries.

TABLE 2 Key differences in skill gaps across countries

Country	Unique Skill Focus
Greece	AI ethics research for the public sector, smart home automation, and human–machine interaction design. These priorities reflect Greece's emphasis on public sector digital transformation and human-centric technologies, where ethical AI deployment plays a crucial role.
Cyprus	Sustainability data science, blockchain compliance, and AI-powered automation in energy systems. Cyprus's focus on green energy solutions and its aspiration to become a regional fintech hub is evident through its need for blockchain governance skills and sustainable ICT solutions.
Slovakia	Smart city IoT integration, digital twin technologies for Industry 5.0, and quantum error correction. As a key manufacturing hub, Slovakia is positioning itself at the forefront of Industry 5.0, focusing on advanced manufacturing technologies and quantum computing for industrial optimization.
Lithuania	IoT for smart agriculture, cybersecurity for manufacturing, and quantum optics research. Lithuania's strengths in agritech and cybersecurity are aligned with its strategy to become a leader in digital innovation, especially in sectors critical for sustainable growth.
Bulgaria	Circular economy solutions, sustainable robotics, and quantum cloud computing. Bulgaria's commitment to green transition goals and advanced robotics for industrial sustainability is clear, with a strong focus on leveraging quantum technologies for data-intensive applications.

5.3 The Most Common Jobs/Roles

The table below provides a **mapping** of roles that appear in the national-research reports, and also appear exactly or with a very close equivalent in the **ESCO Classification, Occupation** list. Roles that match **verbatim** are labelled as **Exact**, while roles that match only in essence or title (e.g. "DevOps Engineer" vs. "DevOps Expert Role") are labelled as **Partial**.

TABLE 3 The Most Common Jobs/Roles in 5 countries

Roles from National Reports	Matching ESCO Occupation	Match Type	# of Countries
Data Analyst (e.g. “Data Analyst / Data Manager,” “BI Analyst / Data Analyst,” “Data Analysts”)	data analyst	Exact	5
Data Scientist	data scientist	Exact	4
Chief Data Officer (as part of “Chief Data Officer / Data Privacy Specialist”)	chief data officer	Exact	1
Software Developer (also “Software Developers,” “Software Developer (with sustainability projects),” etc.)	software developer	Exact	5
Project Manager (e.g. Blockchain Project Manager, IoT Project Manager, Quantum PM, or simply PM)	Project Manager Role	Exact	4
DevOps Engineer	DevOps Expert Role	Partial	2
Product Manager (e.g. “Product Manager,” “Product Managers (Blockchain),” “Product Manager (IoT)”)	ICT product manager	Partial	2
Network Engineer	ICT network engineer	Partial	4
Cybersecurity Specialist (sometimes “Cybersecurity Specialist (IoT)” or “Cyber Security Specialists”)	Cyber Security Specialist Role	Partial	4
Green IT Consultant	green ICT consultant	Partial	2
Embedded Software Developer / Engineer (IoT) (“Embedded IoT System Engineer,” “Embedded Software Engineer (IoT)”)	embedded systems software developer	Partial	3
Any “type Developer” roles (e.g. IoT Developer, Smart Contract Developer, Full Stack Developer, Data Lakehouse Developer, Blockchain Developer, Rust Smart Contract Developer, etc.)	Developer Role (generic)	Partial	5
Consultant roles with an ICT flavour (“IoT Consultant,” “Blockchain Consultants,” etc.)	ICT consultant (generic)	Partial	5

Explanation of matching

- **Exact matches** occur when the title in the national reports precisely matches a job title in the ESCO IT jobs (e.g. *“Data Scientist”* is identical in both).
- **Partial matches** indicate close alignment but slightly different wording (e.g. *“DevOps Engineer”* vs. *“DevOps Expert Role”*). For most “Developer” and “Consultant” variants (like “IoT Developer,” “Blockchain Consultant,” etc.), ESCO provides a **generic** *Developer Role* or *ICT consultant* rather than separate specialized titles.
- If a national-research role does not appear in the table above, it means there was **no** sufficiently close or exact match in the ESCO IT jobs list.

For the better understanding and development of microcredentials focused on the critical skill gaps, in the table below we provide the list of **ESCO occupations** from the previous Table **mapped to the EU ICT professional roles**.

TABLE 4 Matching of ESCO occupations and e-CF roles

ESCO Occupation[7]	EU ICT Professional Role[8]
data analyst	Data Specialist Role
data scientist	Data Scientist Role
chief data officer	Digital Transformation Leader Role
software developer	Developer role
Project Manager Role	ICT project manager
DevOps Expert Role	Combination of several roles including: ICT application developer
ICT product manager	Solution Designer Role
ICT network engineer	Network Specialist Role
Cyber Security Specialist Role	ICT security consultant
green ICT consultant	Digital Consultant Role
embedded systems software developer	Developer role

[7] https://esco.ec.europa.eu/en/classification/occupation_main

[8] https://ecfexplorer.itprofessionalism.org/

6 Experts' Insights from Focus Groups

6.1 Basic information on focus groups

Altogether there were 5 focus groups organized; 1 in each project partner country where the experts from various positions participated.

TABLE 5 Focus groups overview

Country	# of participants	Discussed ATIs	feedback obtained from
Bulgaria	12	All 7	6 participants
Cyprus	14, 4 females, 10 males	AI & Ethics, Big data, ICT & Sustainability	10 participants
Greece	22, 9 females, 11 male	All 7	22 participants
Lithuania	11,5 females, 6 male	All 7	5 participants
Slovakia	12, 5 females, 7 males	AI & Ethics, Big data, ICT for sustainability	11 participants

6.2 Key observations from focus groups discussions

The discussions across all five countries revealed a shared struggle with education-industry misalignment, slow curriculum adaptation, and the urgent need for both technical and soft skills. Collaboration between businesses, educators, and policymakers is the foundation for success. While each country has unique challenges, they all face similar obstacles in integrating advanced technologies and preparing the workforce for Industry 5.0.

Across all countries, social and soft skills were identified as equally crucial as technical skills, particularly in the context of Industry 5.0, which emphasizes a human-centric approach to technology and innovation. The growing demand for adaptability, collaboration, emotional intelligence, and interdisciplinary skills was consistently highlighted in the discussions.

All countries agree that a major transformation in education and workforce training is needed. Flexible, industry-responsive training (such as microcredentials, certifications, and internships) is needed, but adoption varies by country.

6.3 Common challenges and trends across all countries

- **Misalignment between education and industry needs**: All countries reported a significant gap between formal education and rapidly evolving industry demands. The slow adaptation of curricula and lack of industry-specific training were recurring concerns. Businesses often need to provide additional training due to the outdated skill sets of graduates.

- **Need for stronger collaboration between stakeholders**: There is a widespread call for improved cooperation between businesses, educational institutions, and policymakers. Industry-driven training for educators (teachers, professors, trainers) is necessary to ensure up-to-date knowledge transfer. More flexible and responsive vocational education and training (VET) systems are needed.
- **Increasing importance of soft skills and adaptability**: Across all countries, soft skills such as adaptability, resilience, and interdisciplinary collaboration were seen as equally important as technical skills. Emotional and social intelligence is becoming crucial, particularly in Industry 5.0 settings. New generations are perceived as lacking adaptability, making it a key training priority.
- **Challenges in implementing advanced technologies**: While advanced technologies (AI, IoT, blockchain, big data) are recognized as crucial, their integration into business and education is inconsistent. Countries struggle with a lack of skilled professionals who can effectively apply and integrate these technologies. Many organizations are hesitant or unable to invest in the necessary training and upskilling efforts.

6.3.1 Bulgaria

It is hard to define strict definitions and separation across the sectors because now all advanced technologies need first the fundamental skills like programming and mainly soft skills. **The industries are developing fast and new positions are open. There is opportunity for very flexible training and in full alignment with the business; the education system is lagging a lot and the market is very underdeveloped**. Still, there are key positions and skills like programming that are fundamental; **Adaptability and resilience are a must** for the new generations lacking at the moment.

Recommendations for future actions: alignment of business and VET, trainings by the business for teachers/professors/trainers is a must. **The change should happen gradually, yet very fast**.

6.3.2 Cyprus

Key findings revealed that while there is recognition of the value of technologies like IoT, AI, and energy-efficient systems, significant obstacles such as funding limitations, generational divides, and a lack of industry-specific training impede their widespread adoption. Furthermore, the existing educational and professional development frameworks do not sufficiently align with the rapidly evolving needs of the ICT and sustainability sectors.

The findings suggest that **without immediate intervention, the country risks falling behind** in capitalizing on advancements in green ICT. However, addressing these challenges strategically could position Cyprus as a leader in sustainable innovation, particularly in areas such as solar energy-powered data centres, IoT-enabled resource management, and e-waste circular economy practices. Moreover, embedding sustainability as a core value within business and educational systems is essential to bridging the existing gaps.

6.3.3 Greece

The discussion highlighted critical skill gaps across digital domains, emphasizing the need for immediate action to align educational programs with industry requirements. **Participants recommended fostering collaboration between stakeholders, prioritizing interdisciplinary skills, and adapting to technological advancements to ensure a competitive and future-ready workforce.** The participants proposed several strategies. **They emphasized the immediate need to focus on advanced machine learning, IoT security, and blockchain business applications. Greater emphasis should be placed on soft skills, including adaptability and interdisciplinary collaboration.** Enhanced collaboration between academia, industry, and policymakers was recommended, alongside the introduction of specialized postgraduate programs and certification courses. Industry internships and co-op programs were suggested to provide hands-on experience. Participants also called for further research, including in-depth analysis of emerging technologies and studies on aligning education with sustainability and digital transformation goals.

The discussion highlighted critical skill gaps across digital domains, emphasizing the need for immediate action to align educational programs with industry requirements. **Participants recommended fostering collaboration between stakeholders, prioritizing interdisciplinary skills, and adapting to technological advancements to ensure a competitive and future-ready workforce**. The participants proposed several strategies. They emphasized **the immediate need to focus on advanced machine learning, IoT security, and blockchain business applications**. **Greater emphasis should be placed on soft skills, including adaptability and interdisciplinary collaboration.** Enhanced collaboration between academia, industry, and policymakers was recommended, alongside the introduction of specialized postgraduate programs and certification courses. Industry internships and co-op programs were suggested to provide hands-on experience. **Participants also called for further research, including in-depth analysis of emerging technologies and studies on aligning education with sustainability and digital transformation goals.**

6.3.4 Lithuania

Key findings revealed significant challenges related to the integration of new technologies into existing operational frameworks. A notable mismatch between innovative ATIs and current systems was identified, along with a **critical need for both technical and soft skills** within the workforce. The discussion also pointed out a concerning lack of basic computer literacy among new employees, which raises questions about organizations' capacity to invest in necessary training and reskilling initiatives since not every organization can spend time on it.

A primary issue identified is the lack of engineers who can come up with ways to implement technologies effectively. Often, products arrive in an immature state and fail to meet expectations. **Having good technology alone is insufficient; it is essential to understand how to integrate it by comprehending not only the technology itself but also the business processes involved**. This understanding is crucial for determining what needs to be done differently to fully leverage the capabilities of the technology.

The participants agreed there is a strong need to strengthen partnerships between industry and educational institutions to ensure that programs are in sync with the evolving technologies and workforce needs, as well as to **develop training programs that include both technical skills such as programming and data analysis and essential soft skills, including communication and business management.**

6.3.5 Slovakia

There are critical skills, currently either missing fully or not sufficiently developed in all 7 analysed ATIs; the lists of these skills are given in the SK report on focus group. These critical skills are of various type: technical, social & emotional, PM, analytical, ethical & legal skills. There are many overlaps in critical skills lists for the analysed ATIs in particular for social & emotional skills. **The cooperation of Quintuple Innovation Helix entities is crucial** and inevitable to meet the needs of experts in ATIs in various training. Non-technical skills should be more in focus as the Industry 5.0 human centricity bring the strong demand for higher emotional & social intelligence of experts.

Key challenges and opportunities identified by participants: **stronger cooperation & communication of all levels of the formal education as well as with the adult educators** are both a challenge and the opportunity as more and more the **soft & social skills are needed in all ATIs**; the request is stronger with the Industry 5.0. Industry trends and their impact on skill requirements: all participants agreed that the influence of Industry 4.0 as well as 5.0 has brought not only requests for new technical skills, but also much stronger need of fast reaction from all types of educators: new courses are needed fast even for the new graduates and of course for the experienced experts. **Microcredentials seem to be one of possible forms to be used across all educational levels**.

6.4 Skill gaps

6.4.1 Technical skill gaps by ATI/country

In the table below we provide the summary of identified **skill gaps for technical skills by country** from all focus groups which, based on the focus groups' participants, require immediate attention.

TABLE 6 Gaps for technical skills by country

ATI	Bulgaria	Cyprus	Greece	Lithuania	Slovakia
Artificial Intelligence (AI)	Machine learning, Regulatory frameworks, Ethical AI development, AI literacy	Machine learning, AI ethics, AI regulation awareness, AI literacy	Machine learning, Regulatory frameworks, Ethics in technology	AI engineering, Deep learning, Data ethics	Coding, Containers (Docker), Machine learning

ATI	Bulgaria	Cyprus	Greece	Lithuania	Slovakia
Big Data	Data governance, Data analytics, AI-driven insights	Data governance, AI-driven insights, Predictive modelling	Cloud computing, Big data frameworks, Business process understanding		Data sourcing, Machine learning, Cybersecurity
Blockchain	Blockchain integration, Smart contracts	Blockchain integration, Smart contracts	Programming expertise, Smart contract development, Cryptographic security	Blockchain for traceability, Digital identity security	Blockchain implementation, Encryption, Compliance
Internet of Things (IoT)	IoT architecture, System integration, Cybersecurity	IoT for sustainability, System integration, Cybersecurity	IoT security knowledge, Data analysis, Specific programming skills	IoT network management, Edge computing	IoT development, Network security, System interoperability
Artificial Intelligence (AI)	Machine learning, Regulatory frameworks, Ethical AI development, AI literacy	Machine learning, AI ethics, AI regulation awareness, AI literacy	Machine learning, Regulatory frameworks, Ethics in technology	AI engineering, Deep learning, Data ethics	Coding, Containers (Docker), Machine learning
ICT for Sustainability	Energy efficiency expertise, AI for resource optimization	Sustainability data analytics, Green ICT systems	Sustainable technology solutions, ESG data analysis	Green ICT policies, AI-driven sustainability models	ICT for sustainability standards, Renewable energy integration
Quantum Computing	Not explicitly mentioned	Not explicitly mentioned	Quantum architectures, IBM tools, Superconducting circuits	Not explicitly mentioned	Quantum encryption, Quantum algorithms

Key Takeaways

- **Machine Learning, Blockchain integration and smart contracts are the only skill gaps explicitly mentioned as critical in all five country reports**. These areas represent the most widespread demand for skills and should be prioritized in training programs and policy initiatives,

6.4.2 Analytical skills

Regardless from the ATI discussed, the **skill gaps identified** in both analytical skills and group of social, or soft skills, were **similar or even identical in all project partner countries**.

The **analytical skills** which require immediate attention for IT experts to be successful and where the significant gaps were identified are as follows:

- ability to analyze complex problems and develop innovative solutions

- critical thinking
- data interpretation and analysis (ability to draw useful conclusions)
- business acumen
- problem-solving abilities
- data-driven decision-making skills
- ethical decision-making
- cybersecurity risk assessment
- regulatory compliance analysis
- process optimization
- AI bias detection

Key observations

- Critical thinking and problem-solving are the most critical analytical skills across all five countries.
- Big Data, AI, and Cybersecurity require specialized analytical skills such as data interpretation, statistical analysis, and risk assessment.
- AI Ethics, Blockchain, and Quantum Computing require deep analytical skills like bias detection and logical analysis.

6.4.3 Social skills

The **social skills** which require immediate attention for IT experts to be successful and where the significant gaps were identified are as follows:

- ability to explain complex digital concepts to non-technical stakeholders.
- client's language, interaction with client
- communication: effective verbal and written communication skills for a variety of audiences
- creativity
- emotional intelligence and adaptability (including flexibility to respond to changing circumstances and adapt to new technologies and changing environments)
- growth mindset
- interdisciplinary collaboration: ability to work well in teams and across departments
- leadership: leading teams, managing projects and making strategic decisions
- teamwork
- time management

6.5 Future trends and emerging skill demands

In some focus groups there were also the future emerging skills discussed. We provide the list below

TABLE 7 Future emerging skills identified in focus groups

Future skill areas	Key future needs
AI Ethics & Governance	Transparent AI models, Bias mitigation, Ethical AI development
Quantum Computing	Quantum algorithms, Quantum encryptions, Superconducting circuits
Cybersecurity & AI	AI-driven threat detection, Zero-trust security models
IoT & Edge Computing	Real-time data processing, Decentralized network security
Blockchain & Digital Identity	Self-sovereign identity, Smart contracts automation
Sustainability & Green ICT	Energy-efficient computing, AI-driven sustainability solutions
Autonomous Systems & Robotics	AI-human collaboration, Advanced robotics integration
Regulatory Compliance in AI & Blockchain	Data privacy frameworks, Legal risk assessment
AI-Powered Automation	Hyper automation, AI process optimization
Big Data & Predictive Analytics	Real-time decision-making, AI-enhanced data analytics

The very interesting point is that there are also **many social and emotional future skills expected**:

- Ethical Leadership, Cross-Disciplinary Communication, and Change Management are key future skills for AI and Industry 5.0.
- Tech Policy & Regulation Awareness will become more important as AI and blockchain adoption grows.
- Cybersecurity resilience and crisis management will be crucial for AI-driven security systems.
- Emotional Intelligence, Negotiation, and Persuasive Communication are essential as AI-human collaboration increases.
- Adaptability remains a core requirement in rapidly evolving tech sectors.

6.6 Industry-specific challenges and recommendations

The table below combines the challenges and recommendations reported.

TABLE 8 Industry-specific challenges and recommendations from focus groups

Industry	Common Challenges Identified	Recommendations
Finance & Banking	Data security, AI bias in decision-making, Compliance issues	Enhance AI transparency, Strengthen cybersecurity, Improve AI regulation
Healthcare & Biotech	Data privacy, AI explainability in diagnostics, AI integration	Develop ethical AI guidelines, Improve interoperability, Strengthen patient data security
Manufacturing & Industry 5.0	Lack of AI-skilled workforce, Cybersecurity risks, High AI costs	Invest in AI upskilling, Strengthen Industry 5.0 security, Promote AI incentives
Retail & E-Commerce	AI-driven personalization fairness, Data security risks, Supply chain automation	Improve AI fairness, Strengthen consumer data protection, Simplify AI supply chain automation
Telecommunications	Cybersecurity risks in 5G, AI-driven network optimization, AI skills shortage	Strengthen 5G security, Train workforce in AI-powered networking, AI-based fraud detection
Public Administration	Regulatory compliance in AI, Data-driven inefficiencies, Low AI adoption	Ensure AI governance transparency, Improve data integration, Increase digital transformation
Energy & Sustainability	AI-driven energy optimization gaps, Cybersecurity in smart grids, Renewable energy integration	Promote AI-driven energy efficiency, Secure energy infrastructure, Develop AI sustainability models
Education & Training	Shortage of AI educators, Resistance to AI-based learning, Lack of AI personalization	Increase AI training programs, Promote adaptive learning, Ensure fair AI-driven education
Transportation & Mobility	Autonomous vehicle cybersecurity, AI-powered traffic optimization, Regulatory gaps	Improve mobility cybersecurity, Optimize AI-driven traffic, Develop AI mobility regulations
Legal & Regulatory	AI ethics challenges, Blockchain legal gaps, AI privacy risks	Develop AI legal frameworks, Strengthen blockchain compliance, Improve AI privacy protection

Key Takeaways

- Finance, Healthcare, and Manufacturing face major AI security, compliance, and adoption challenges.
- Telecom and Energy sectors need cybersecurity enhancements in AI-powered infrastructure.
- Education and Public Administration must improve AI literacy and digital transformation.
- Regulatory and legal frameworks for AI, Blockchain, and IoT are still evolving.

6.7 Summary of Workforce Preparedness Suggestions

TABLE 9 Suggestions for the preparedness of workforce

Area	Key Recommendations
AI & Automation Training	Expand AI-focused education, Offer AI upskilling programs, Introduce AI apprenticeships
Cybersecurity Awareness	Implement mandatory cybersecurity training, Develop AI-driven security awareness modules
Data Literacy & Big Data Skills	Enhance statistical training, Integrate AI-driven data analytics into education
Blockchain & Digital Trust	Introduce blockchain security certifications, Promote decentralized identity training
Quantum Computing Readiness	Develop quantum programming courses, Establish quantum research collaborations
Green ICT & Sustainability	Encourage energy-efficient IT practices, Promote AI-driven sustainability initiatives
Soft Skills & Communication	Strengthen cross-disciplinary teamwork, Improve AI ethics & responsibility training
AI & Regulatory Compliance	Educate on AI laws & regulations, Train professionals in responsible AI governance
Industry 5.0 & Human-Robot Collaboration	Develop skills for human-robot teamwork, Implement AI-enhanced manufacturing training
Lifelong Learning & Digital Adaptability	Promote continuous learning programs, Support reskilling for AI-driven job shifts

Key Takeaways

- AI, Cybersecurity, and Big Data upskilling are essential to workforce readiness.
- Quantum Computing, Blockchain, and Green ICT require emerging skill development.
- Soft skills and AI regulatory awareness are becoming increasingly critical.
- Lifelong learning and adaptability are necessary for workforce sustainability.
- Microcredentials are mentioned in 4 country reports gaining traction as a flexible upskilling approach. They could be an effective solution for bridging skill gaps in AI, Cybersecurity, and Industry 5.0.

7 Experts' Insights from Interviews

7.1 Basic information on interviews

- Number of interviews held: altogether 24 interviews were organized; there were 5 interviews in each partner country, but Bulgaria – there were 4 interviews organized
- ATIs discussed during the interviews by country: based on the discussion among partners responsible for the interviews there was a decision made that not necessarily all ATIs are discussed, rather the focus is put on those ATIs which are important in the relevant country.

7.2 Key observations from interviews in countries

- **Cybersecurity & data protection are universal concerns**: Every ATI faces challenges in data security, encryption, and regulatory compliance.
- **Ethical AI & risk management are needed everywhere**: Across all ATIs, bias mitigation, algorithmic transparency, and responsible automation remain major gaps.
- **Big Data & AI-driven insights must be better leveraged**: Professionals across blockchain, IoT, and Industry 5.0 lack expertise in applying AI-driven analytics for decision-making.
- **Collaboration & communication are key challenges**: Technical experts struggle to communicate ATI insights effectively with business leaders, policymakers, and cross-functional teams.

7.3 Skill gaps

7.3.1 Expert opinions on the most critical skill shortages

- Cybersecurity & Data Privacy are the biggest cross-cutting gaps → AI, Blockchain, IoT, and Quantum Computing all require cybersecurity expertise.
- AI Model Deployment & Bias Detection are essential across ATIs → AI must be explainable, unbiased, and scalable for applications in finance, healthcare, and smart industries.
- Cloud Computing & Edge AI Processing are required in all sectors → Experts stress the need for cloud-driven AI, decentralized Big Data, and edge computing in IoT and Blockchain.
- Regulatory Compliance & Risk Management are becoming urgent → AI ethics, blockchain security laws, IoT governance, and post-quantum cryptography laws are in demand.
- Automation & Robotics will shape Industry 5.0 & IoT → AI-driven process automation, RPA, and cobots (human-AI collaboration) will dominate future industries.

7.3.2 Common skill gaps across ATIs

In the country reports there are **common skill gaps that appear repeatedly, although the specific wording or emphasis may vary by ATI and country**. In the table below we provide a consolidated overview of common skills gaps that that show up—sometimes with different wording or emphasis—in multiple ATIs across the five countries' interview findings. Not every ATI is present in each country, but the underlying skill gap categories recur throughout the reports.

TABLE 10 Overview of common skills gaps from the interview reports

Security / Cybersecurity	Deficits in protecting systems and data from attacks, covering adversarial AI, IoT device security, secure blockchain cryptography, or quantum-safe encryption. Involves threat modelling and safe architectures.
Regulatory Compliance & Data Governance	Insufficient familiarity with laws/regulations (e.g., GDPR, AI Act), plus limited capacity to maintain high-quality data practices. Encompasses privacy-preserving techniques, encryption, secure storage, and formal compliance frameworks.
Practical Implementation & Deployment	Gaps in scaling proofs-of-concept or prototypes to real-world production. Examples include DevOps for AI, real-time streaming solutions for Big Data, or deployment of IoT/Industry 5.0 systems in actual industrial settings.
Ethical / Responsible Usage	Lack of consistent, actionable approaches to bias mitigation, transparency, fairness, and human-centric design. Involves bridging theoretical ethical principles with day-to-day operations and accountability mechanisms.
Data Handling & Analytics Expertise	Challenges in cleaning, analyzing, and interpreting data, from building reliable pipelines (ETL) to advanced ML analytics. Also includes domain-specific data knowledge (e.g., automotive, manufacturing) and real-time data handling.
Cross-Disciplinary Collaboration	Difficulty uniting tech, domain, and business stakeholders. Involves communication, teamwork, and interdisciplinary problem-solving to ensure successful technology adoption (e.g., AI + IoT + sustainability).
Specialized Knowledge or Tool Proficiency	Underdeveloped mastery of specialized frameworks, languages, or platforms (e.g., RPA tools like UiPath, blockchain smart-contract languages, quantum-safe cryptosystems). Also includes staying current with emerging or evolving toolchains.

7.3.3 Technical skill gaps by ATIs in each country

TABLE 11 Technical skill gaps by ATIs in each country

ATI	Bulgaria	Cyprus	Greece	Lithuania	Slovakia
AI & Ethics	Scaling AI from prototypes to production; Adversarial AI security (data poisoning, etc.); Explainable AI; DevOps for AI Compliance	Fairness & bias mitigation; Privacy-preserving AI (e.g. differential privacy); Ethical risk assessment; Regulatory compliance (GDPR, AI Act)	Algorithmic transparency & responsible AI design; Bias mitigation; Ethical AI governance; AI risk/fraud detection; Compliance (GDPR)	Advanced AI usage & bias detection; RPA/automation (UiPath); Cybersecurity awareness for AI; Python/ML proficiency	Advanced ML (GANs, RL); Data quality & compliance; Bias detection & transparency; AI–robotics integration
Big Data	Real-time/streaming data (esp. automotive/edge); Cloud-native data platforms; Data governance & compliance	Advanced data engineering (ETL, large-scale); Real-time streaming; Cloud-based Big Data; Data governance & encryption	Ethical data handling; Real-time data ethics; Privacy-preserving techniques in large datasets	Big data analytics Server engineering; Data pipeline design;	Real-time analytics; Predictive/prescriptive analytics; Data quality & secure pipelines; Business insights
Blockchain	Not discussed	Basic blockchain adoption; Compliance & security considerations	Not discussed	Advanced cryptography; Limited industry usage	Blockchain architecture; Smart contracts (Solidity); Cryptography; Regulatory compliance
Internet of Things	IoT cybersecurity; Real-time device integration	IoT data management; Real-time IoT analytics; Network architecture; Security & compliance	IoT cybersecurity; Ethical data collection; IoT-specific AI governance; Ensuring ethical sensor data use	Not discussed	Not discussed
ICT for Sustainability	Not discussed	Sustainable tech design (energy efficiency), Green software development; Data analytics for resource usage;	Not discussed	Not discussed	Not discussed
Industry 5.0	Not discussed	Human-centric AI design; Cross-disciplinary collaboration; Ethical	Human–AI collaboration; Ethical automation; AI in manufacturing	RPA tools & automation; Bridging Industry 4.0 to 5.0; Robotics synergy	AI & robotics integration in manufacturing; Data integration for advanced production;

ATI	Bulgaria	Cyprus	Greece	Lithuania	Slovakia
		governance			Cross-disciplinary collaboration
Quantum Computing	Not discussed	Post-quantum security; Quantum cryptography	Quantum-safe cryptography; Quantum AI ethics & compliance	Not discussed	Not discussed

Key Insights

- Across five countries, AI and Ethics, along with widespread Big Data use, are key concerns.
- Focus areas include mitigating AI bias, explainable AI, privacy, large-scale data engineering, and real-time analytics.
- Security and compliance are recurring themes across AI, Big Data, Blockchain, and IoT, including adversarial AI, secure data pipelines, blockchain cryptography, and IoT cybersecurity.
- A common challenge is moving prototypes to real-world production (e.g., AI scaling, real-time IoT deployment, cloud-based Big Data).
- All countries emphasize embedding ethical principles (bias detection, data privacy, fairness) in daily operations.

7.3.4 Analytical skills

The **identified analytical skills gaps reveal a pressing need for upskilling in real-time data handling, ML transparency, domain-oriented analytics, and data storytelling—all underpinned by a strong sense of data ethics and regulatory compliance**.

Below is an overview of the analytical skills requiring immediate attention based on the interview findings:

- Real-time & predictive analytics: Professionals need stronger capabilities in low-latency data processing (e.g., Kafka, Spark Streaming), as well as in building and interpreting predictive/prescriptive models for fraud detection, demand forecasting, etc.
- Advanced ML interpretability & ethical analysis: Stakeholders demand explainable AI methods (SHAP, LIME) to ensure fairness and transparency. This includes spotting biases, upholding privacy, and aligning analytics with regulatory requirements (GDPR, AI Act).
- Domain-specific & data pipeline expertise: From manufacturing to healthcare, practitioners lack specialized knowledge for sector-centric analytics (e.g., real-time monitoring, diagnostic AI). Gaps also persist in ETL, data quality, and cross-functional data storytelling to communicate insights effectively.

7.3.5 Social & soft skills

Across five countries, **soft skill gaps in communication, collaboration, ethics in action, adaptability, and leadership** consistently emerge. These deficits undermine the effectiveness of advanced technology initiatives, highlighting the need for targeted training that combines technical upskilling with stronger social/soft competencies.

- Communication & Stakeholder Engagement: ICT experts struggle to explain technical concepts to non-technical colleagues, leading to misunderstandings and slowed decision-making.
- Cross-Disciplinary Collaboration: Lack of common language and frameworks hinders collaboration between domain experts and tech specialists, causing technology initiatives to misalign with industry needs.
- Ethical Mindset & Decision-Making: Practitioners find it challenging to apply ethical principles in practice due to insufficient soft skills like leadership and communication.
- Adaptability & Continuous Learning: Professionals often resist adopting new practices or lack self-directed learning skills needed for rapidly evolving technologies.
- Teamwork & Conflict Resolution: Friction in multi-department projects is exacerbated by a lack of conflict resolution skills, leading to stalled progress.
- Problem-Solving & Critical Thinking: Junior hires struggle with real-world problem-solving despite having theoretical knowledge, lacking resilience and critical thinking.
- Leadership & Ownership: Limited leadership skills hinder projects involving ethical AI or data governance, where cross-functional persuasion is crucial for success.

7.4 Future trends and emerging skill demands

TABLE 12 Emerging skills by ATIs

Future Skill Areas	Key Future Needs	Relevant ATIs
AI & Machine Learning Specialization	Advanced AI ethics, AI governance, bias detection, explainable AI, federated learning	AI & Ethics, Big Data, Industry 5.0
Cybersecurity & Data Privacy	Post-quantum cryptography, AI-driven cybersecurity, Zero Trust security models, blockchain security	AI & Ethics, Blockchain, Big Data, IoT, Quantum Computing
AI & Big Data Integration	Real-time AI-driven decision-making, cloud-based AI models, AI-enhanced predictive analytics	AI & Ethics, Big Data, IoT, Industry 5.0
Automation & Robotics	Robotic Process Automation (RPA), cobots (collaborative robots), AI-driven automation, adaptive robotics	Industry 5.0, AI & Ethics
IoT & Edge Computing	Secure IoT data management, AI-powered IoT solutions, edge computing security	IoT, Industry 5.0, Big Data
Blockchain Development	Smart contract security, AI-integrated blockchain solutions, decentralized finance (DeFi) applications	Blockchain, Big Data, AI & Ethics
Sustainable ICT & Green Tech	Energy-efficient computing, green AI solutions, carbon-aware programming	ICT for Sustainability, AI & Ethics, Big Data
Quantum Computing	Post-quantum encryptions, quantum AI applications, ethical quantum governance	Quantum Computing, AI & Ethics

Key takeaways for future skills development

- Technical depth, security readiness, ethical standards, sustainability, and human-centric design are converging to shape the future skill needs in advanced technologies.
- AI is at the core: Explainable AI and advanced ML techniques factor into multiple ATIs, highlighting AI's expanding influence.
- Security concerns intensify: Quantum-safe cryptography and post-quantum security solutions signal growing urgency in protecting data and systems.
- Ethical governance extends beyond AI: Topics like ethical IoT oversight and AI governance frameworks show that ethics isn't confined to one ATI—it's becoming integral everywhere.
- Sustainability is on the rise: Green software, renewable integration, and carbon-aware coding point to growing environmental priorities across tech domains.
- Industry 5.0 focuses on collaboration: Human–machine synergy (cobots) and human-centric design underscore a shift toward inclusive, people-focused automation.

7.5 Industry-specific challenges and recommendations

TABLE 13 Industry-specific challenges and recommendations for possible solutions

Industry	Common Challenges Identified	Recommendations	Relevant ATIs
Manufacturing	▪ Limited adoption of AI for predictive maintenance ▪ Skill gaps in robotics and human-machine collaboration ▪ Data integration across production systems (OT/IT) ▪ Ensuring safe, ethical automation and minimal downtime	▪ Upskill workforce in AI-driven process optimization, robotics (cobots), and RPA ▪ Invest in cross-disciplinary training (engineering + data science) ▪ Integrate real-time data pipelines and analytics for quality control	AI & Ethics, Big Data, Industry 5.0, IoT
Energy	▪ Complex grid management requiring real-time analytics ▪ Limited expertise in renewable energy integration ▪ Data security and privacy in smart grid systems ▪ Inconsistent adoption of IoT for resource monitoring	▪ Develop advanced predictive analytics skills for load balancing ▪ Focus on secure IoT integration (sensors, edge computing) ▪ Foster sustainability knowledge (carbon reduction, green tech design)	AI & Ethics Big Data, IoT, ICT for Sustainability,
Finance	▪ AI-driven fraud detection & risk assessment lacking sophistication ▪ Regulatory compliance (GDPR, AI Act) and data security ▪ Difficulty explaining AI decisions in lending/credit scoring ▪ Gaps in blockchain-based solutions (crypto, DeFi)	▪ Strengthen ML modelling for credit/fraud analysis ▪ Acquire formal compliance knowledge (GDPR, Basel frameworks) ▪ Advance explainable AI techniques for transparent decisions ▪ Explore smart contract integration for FinTech	AI & Ethics, Big Data, Blockchain
Healthcare	▪ Privacy & data protection (patient records) ▪ Limited AI adoption for diagnostics and predictive analytics ▪ Need for explainable AI in clinical decisions ▪ Integration of IoT wearables with EHR systems	▪ Train professionals in healthcare-specific AI governance ▪ Emphasize privacy-by-design solutions (HIPAA, GDPR compliance) ▪ Adopt real-time analytics for patient monitoring (IoT)	AI & Ethics, Big Data, IoT
Supply Chain	▪ Demand forecasting challenges with large, often siloed datasets ▪ Limited real-time visibility and traceability (logistics, inventory) ▪ Lack of standardized data governance across partners	▪ Implement predictive analytics for inventory optimization ▪ Adopt IoT sensors for real-time shipment tracking ▪ Explore blockchain solutions for secure, transparent data sharing among stakeholders	AI & Ethics Big Data, Blockchain, IoT,

Key takeaways

- AI & Ethics appears in multiple industries (manufacturing, finance, healthcare) to ensure responsible and transparent AI solutions.
- Big Data and IoT are consistently recommended where large-scale analytics and real-time sensor data are necessary (e.g., energy grids, supply chain tracking).
- Industry 5.0 often ties into human–machine collaboration and ethical automation in manufacturing settings.
- Blockchain is especially relevant for secure data sharing and finance innovations, as well as potential supply chain transparency.
- ICT for Sustainability is particularly emphasized in energy (renewables integration) and can apply to manufacturing and supply chain to reduce carbon footprints.

7.6 Summary of workforce preparedness suggestions

TABLE 14 Summary of workforce preparedness suggestions

Area	Key Recommendations
Foundational Digital Skills	▪ Strengthen core digital literacy across all roles (basic coding, data handling) ▪ Introduce early-stage STEM/ICT training in schools
Advanced AI & Data Analytics	▪ Offer specialized courses/certifications in ML, Big Data, cloud deployment ▪ Encourage practical projects to move from theory to real-world
Ethical & Regulatory Compliance	▪ Integrate ethics modules into tech curricula (bias mitigation, data privacy) ▪ Provide ongoing GDPR/AI Act compliance workshops
Cybersecurity & Secure Design	▪ Formalize threat modelling and safe coding practices ▪ Encourage cross-functional teams to address security from the start
Cross-Disciplinary Collaboration	▪ Promote joint programs (e.g., engineering + business) for well-rounded talent ▪ Encourage hackathons, mentorships, and multi-department teams
Continuous Upskilling & Microcredentials	▪ Support professional learning pathways (microcredentials in emerging technologies) ▪ Incentivize certification renewals and skill refreshers
University–Industry Partnerships	▪ Co-develop curricula with employers to reflect market needs ▪ Facilitate internships, apprenticeships, and thesis projects aligned with industry
Sustainable & Green Tech Integration	▪ Include sustainability training (energy efficiency, carbon-aware coding) ▪ Encourage eco-friendly practices (life-cycle assessments, green software)

Key Takeaways

- Bridging the gap between education & industry is crucial for workforce preparedness.
- Emphasizing digital literacy and advanced AI can bridge current skill gaps.
- Ethical frameworks and regulatory awareness foster responsible tech adoption.
- Cross-disciplinary collaboration, continuous upskilling, and strong university–industry ties are essential for a well-prepared workforce.
- Sustainability is increasingly important, encouraging eco-friendly development practices.
- Microcredentials explicitly appear in Slovakia's discussions as a lifelong learning tool, but the underlying idea (short, specialized training programs) surfaces in other countries' reports via bootcamps, certifications, or industry-driven short courses. All point to the same concept: rapid, modular upskilling is necessary to keep pace with evolving technology, and microcredentials are a practical mechanism for achieving this.

8 Cross-Cutting Analysis and Comparative Findings

8.1 Does the EU have different skill gaps in comparison with INVESTech partner countries? Observations from the desk research

In this synthesis, we aim to provide **multiple perspectives in a single comprehensive table**. The table is structured to address key questions:

- What are the **differences between the EU level and the five INVESTech partner countries**?
- Which **skills are specific to the EU and which to the INVESTech partner countries**?
- Which **skill gaps are critical for the future**?
- How are these skills classified according to the seven ATI categories or as cross-cutting skills?
- **Which ESCO occupations or roles are assigned to the identified skills**?

This multi-dimensional approach allows for an interconnected view, showing not only the alignment between skills and occupational demands but also how these competencies fit within broader strategic priorities at both regional and EU levels. This analysis shows that while the EU emphasizes strategic, research-oriented, and long-term skills, the five countries focus more on technical, vocational, and cybersecurity-related skills, reflecting local economic priorities and regional challenges. The five countries may focus on developing practical and technical skills (e.g., cybersecurity, quantum computing) that align with their industrial strengths or economic development plan. EU-level differences arise from overarching policies like the Digital Europe Programme[9], European Green Deal[10], and NextGenerationEU[11], which aim for long-term sustainability, digital sovereignty, and technological leadership. The EU level focuses on broader, strategic competencies that may not be as prominently emphasized in the five countries. These include:

- **Advanced Industry 5.0 Concepts:** Additive Manufacturing and 3D Printing, User Experience (UX) Research, and Explainable AI are EU priorities. These skills reflect the EU's push for high-value manufacturing, user-centric digital products, and transparent AI systems, essential for trust and widespread adoption.
- **Sustainability and Circular Economy:** The EU stresses Circular Economy Strategies and Renewable Energy Integration. At the EU level, policy frameworks such as the European Green Deal drive sustainability and circular economy adoption, influencing skills demand in these areas.

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[9] https://digital-strategy.ec.europa.eu/en/activities/digital-programme

[10] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

[11] https://next-generation-eu.europa.eu/index_en

- **Soft and Interdisciplinary Skills**: Competencies like Behavioural Economics in Decision-Making, Negotiation and Conflict Resolution, and Strategic Foresight and Future Thinking are emphasized. These cross-cutting skills are critical for leadership in a complex, interconnected economy where collaboration and long-term planning are essential.
- **AI and Cognitive Sciences:** Focus on Deep Learning and Neural Networks, Cognitive Neuroscience, and Natural Language Processing (NLP). These skills reflect the EU's investment in cutting-edge AI research and applications, ensuring competitiveness in global AI development.

TABLE 15 Common skill gaps overview based on desk research reports

Common skills gaps EU and 5 countries	observed in ATI
Advanced ML & AI & Machine Learning Algorithms	AI & Ethics, Big Data
Ethical AI & Emotional Intelligence in Leadership	AI & Ethics
Big Data Infrastructure & Smart City Infrastructure	Big Data
Data Analytics (Python, R) & Data Science and Analytics	AI & Ethics, Big Data
Bias Mitigation & Big Data Processing	AI & Ethics, Big Data
Data Visualization & Storytelling & Advanced Materials in Manufacturing	Big Data & Industry 5.0
Cloud Computing & Platform Management & Resilient Supply Chain Management	Big Data, IoT
Data Analytics & Visualization & Geospatial Data Analysis	Big Data, IoT
Data Architecture & ETL Pipelines & Cloud Computing Architecture	Big Data, IoT
Blockchain Platform Knowledge & Blockchain Development and Smart Contracts	Blockchain
Business Integration & Computer Vision	AI & Ethics, Blockchain
Decentralized Applications & Interdisciplinary Team Collaboration	Blockchain & Cross-Cutting
Cross-Chain Solutions & Sustainable Energy Solutions	Blockchain, ICT for Sustainability
Technical Integration & Cross-Cultural Communication	Cross-Cutting Skills
Project Management for Green Initiatives & Change Management in Digital Transformation	ICT for Sustainability
Renewable Energy Integration & Green Building Technologies	ICT for Sustainability
Human-Centric Design & HMI & Human-Robot Interaction	Industry 5.0
Embedded Systems Programming & Embedded Systems Programming	IoT
IoT Networking Protocols & Digital Twin Technologies	IoT
IoT and Smart Systems & Autonomous Systems Engineering	IoT
Cloud Computing & Edge Computing	IoT
Cybersecurity Practices & Cybersecurity Strategies	IoT
Programming Skills & Industrial Robotics Programming	IoT, Industry 5.0
Regulatory & Privacy Skills & Regulatory Compliance in Emerging Technologies	IoT
Regulatory Compliance & 5G Network Technologies	IoT
Cryptographic Security & IoT Systems and Security	IoT, Blockchain

Quantum Error Correction & Fault Tolerance & Quantum Algorithms and Cryptography	Quantum Computing
Quantum Programming & Urban Mobility Planning	Quantum Computing

EU specific	
Deep Learning and Neural Networks	AI
Natural Language Processing (NLP)	AI
Cognitive Neuroscience	AI & Ethics
Explainable AI	AI & Ethics
Behavioural Economics in Decision-Making	Cross-Cutting Skills
Innovation and Entrepreneurship	Cross-Cutting Skills
Negotiation and Conflict Resolution	Cross-Cutting Skills
Risk Assessment and Crisis Management	Cross-Cutting Skills
Strategic Foresight and Future Thinking	Cross-Cutting Skills
Circular Economy Strategies	ICT for Sustainability
Additive Manufacturing and 3D Printing	Industry 5.0
User Experience (UX) Research	Industry 5.0
5 countries specific	
Blockchain Technical Proficiency/ Smart Contract Development	Blockchain
Security Auditing	Blockchain & IoT
Data Governance & Regulatory Knowledge	Cross-Cutting Skills
Interdisciplinary Skills/ Collaboration	Cross-Cutting Skills
Soft Skills	Cross-Cutting Skills
Sustainability-Specific Frameworks	ICT for Sustainability
Specialized Vocational Training	Industry 5.0
Cybersecurity/Data Privacy/Security	IoT & Cybersecurity
Cloud-Based Quantum	Quantum Computing
Hybrid Quantum-Classical Computing	Quantum Computing
Quantum Algorithm Dev & Optimization	Quantum Computing
Quantum Cryptography & Post-Quantum Security	Quantum Computing
Quantum Hardware/Development	Quantum Computing
Quantum Machine Learning (QML)	Quantum Computing

In the table above the following skills can be considered transversal:

- Avoid unconscious bias / Prevent discriminatory bias
- Change management / Digital transformation (often considered a managerial / organizational transversal skill)
- Emotional intelligence / Leadership
- Intercultural communication
- Storytelling (explicitly noted as a transversal skill in the list)
- Teamwork / Collaboration with colleagues

8.2 What we didn't not know from desk research about skill gaps and focus groups & interviews participants told us.

Both **interviews and focus groups clearly showed that experts from various sectors are fully aware of the human centricity as the main feature of Industry 5.0**. The full understanding of the fact that only technical skills are not enough was obvious and clearly expressed. Participants of focus group and interviewees are not only aware of the skill gaps but passed also a very **clear message on their opinion how to close the existing gaps**. The key messages are:

- Strengthen core digital literacy across all roles
- Introduce early-stage STEM/ICT training in schools
- Offer specialized courses/certifications in ML, Big Data, cloud deployment
- Encourage practical projects to move from theory to real-world
- **Integrate ethics modules into tech curricula** (bias mitigation, data privacy)
- Provide ongoing GDPR/AI Act compliance workshops
- **Support professional development, upskill continuously, use microcredentials**

8.2.1 Technical skills

The technical skills identified as critical ones in focus groups and interviews were very similar with many overlaps. However, the terminology used was different in comparison with ESCO or EU ICT. The table below provides the following:

- Critical skill description from focus groups and interviews participants
- Respective ATI
- ESCO skill[12] (exact/partial match) based on the analysis
- Code of group for the assigned ESCO skill
- Recommended level as explained in chapter 4.4., proposed a hierarchical pyramid model, which can be used as possible navigation for EQF[13] levels in the process of microcredentials and e learning development and design.

TABLE 16 Identified critical skills mapped against ESCO skills with recommended level from proposed hierarchical model in Chapter 4.4

ESCO skill		Level recomm.[14]	Skill description from FG & IWs reports	ATI
Data ethics	0223	1	AI ethics, AI & Ethics	AI & Ethics
GDPR	0421	1	Regulatory frameworks, Regulatory Compliance (GDPR, EU AI Act, etc.)	AI & Ethics
Principles of AI	0619	2	Ethical AI development, Responsible	AI & Ethics

12 https://esco.ec.europa.eu/en/classification/skill_main
13 https://europass.europa.eu/en/description-eight-eqf-levels

14 As explained in chapter 4.4., proposed hierarchical pyramid model

ESCO skill		Level recomm.[14]	Skill description from FG & IWs reports	ATI
			AI Design (Fairness & Accountability)	
Data protection	0612	1	Data governance, Data Governance & Compliance	Big Data
Machine learning	0619	3	Machine learning; Advanced Machine Learning Techniques (GANs, RL, large-scale AI)	AI & Ethics
Cloud technologies	0612	1	Cloud computing; Cloud Computing for Big Data (AWS, Azure, GCP)	Big Data
Smart contract	0613	3	Smart contracts; Smart Contract Development (e.g., Solidity)	Blockchain
Blockchain terminology	0612	2	Cryptographic security; Advanced Cryptography for Blockchain	Blockchain
Cyber security	1031	1	IoT security knowledge IoT Cybersecurity & Secure IoT Ecosystems	Internet of Things
Internet of Things	0611	2	IoT architecture; IoT Device Integration & Network Architecture	Internet of Things
Internet of Things		2	Edge computing; Edge Computing in IoT	Internet of Things
Human-robot collaboration	0714	3	AI-human collaboration; Human–AI Collaboration (co-creation, human-centric design)	Industry 5.0
Design smart grids	S1.11.2	2	Renewable energy integration; Renewable Energy Integration (into ICT systems)	ICT for Sustainability
Design smart grids		2	Energy efficiency expertise; Sustainable Technology Design (energy efficiency, carbon reduction)	ICT for Sustainability
Data analytics	0612	1	Sustainability data analytics; Data Analytics for Sustainability (resource optimization)	ICT for Sustainability
Artificial neural networks	0619	3	AI for resource optimization; Data Analytics for Sustainability (resource optimization)	ICT for Sustainability
Quantum computing	0613	3	Quantum encryption; Secure Quantum Cryptography / Post-Quantum Security	Quantum Computing
Digital twin technology	0613	3		

Level recommended as described in the Chapter 4.4

- 1 Common General Skills for All ATIs (Foundation Level)
- 2 Cross-ATI Skills (Applicable to Two or More ATIs) (Intermediate Level)
- 3 Highly Specialized Skills for Specific ATIs (Advanced Level)

8.2.2 Analytical and social skills

Regardless from the ATI discussed, the skill gaps identified in both analytical skills and group of social, or soft skills, were similar or even identical in all project partner countries. The skills which require immediate attention for IT experts to be successful and where the significant gaps were identified are as follows:

- Critical thinking
- Problem solving
- Business acumen
- data interpretation and analysis (ability to draw useful conclusions)
- Communication: effective verbal and written communication skills for a variety of audiences
- client's language, interaction with client
- emotional intelligence and adaptability
- Creativity
- ability to explain complex digital concepts to non-technical stakeholders.
- client's language, interaction with client

9 Conclusions and recommendations

9.1 Inputs for the microcredentials and eLearning development

Finally, **which skill gaps should be addressed by INVESTech courses?**

We searched for the answer to this question by analysing quite a big but heterogeneous data sets (EU and country level desk research in 5 countries, focus groups and interviews). Since we want to answer the question as properly as we can, we had a look at it from the various angles using the following:

- List of common skill gaps identified from the secondary research (Common skills gaps EU and 5 countries part from the Table 15) which was mapped against the ESCO classification, Skills & competences, Dataset v.1.2.0
- List of skill gaps identified from the primary research (focus groups and interviews) which was mapped against the ESCO classification, Skills & competences, Dataset v.1.2.0
- Intersection analysis of both lists mentioned above
- List / a cross-section of ICT – related occupations with skills identified as critical which require immediate attention

In the table below we provide the list of **technical skills** which were identified based on the lists mentioned above as critical/requiring immediate attention and we **recommend to use these as the main input for the microcredentials development.**

TABLE 17 Critical skill gaps requiring immediate attention MAIN INPUT for microcredentials development

#	Identified critical skills	ESCO Match	Closest ESCO Skill	ESCO Code	ATI
1	Machine learning	Exact	ML (computer programming)	0613	AI & Ethics
2	AI with ethical considerations	Partial	Principles of artificial intelligence	0619	AI & Ethics
3	Big data infrastructure	Partial	Big data	0612	AI & Ethics
4	Data analysis	Partial	Data analytics	0612	Big Data
5	Data visualisation	Partial	Deliver visual presentation of data	S1.4.2	Big Data
6	Cloud computing	Exact	Cloud computing	0612	Big Data
7	Data architecture	Partial	Database management systems	0612	Big Data
8	Blockchain technology	Exact	Blockchain	0619	Big Data
9	Blockchain technology (decentralized applications)	Partial	Develop blockchain technology	S5.2.1	Blockchain

#	Identified critical skills	ESCO Match	Closest ESCO Skill	ESCO Code	ATI
10	Blockchain technology (multi-chain focus)	Partial	Blockchain	0619	Blockchain
11	ICT system integration	Exact	ICT system integration	0612	Blockchain
12	Embedded systems programming	Partial	Embedded systems	0714	Industry 5.0
13	Internet of Things / Network protocols	Partial	Internet of Things – network standards	0612	Internet of Things
14	Internet of Things / Smart systems	Partial	Internet of Things	0611	Internet of Things
15	Cybersecurity	Exact	Cyber security	1031	Internet of Things
16	Programming	Partial	Computer programming	0613	Internet of Things
17	Cryptography	Partial	Implement cryptographic constructs	S5.2.1	AI & Ethics
18	Quantum computing (error correction)	Partial	Quantum computing	0613	Blockchain
19	Quantum computing (programming)	Partial	Quantum computing	0613	Quantum Computing
20	Artificial intelligence	Partial	Principles of artificial intelligence	0619	Quantum Computing
21	Smart city infrastructure	Partial	Smart city features	0619	AI & Ethics
22	Big data processing	Exact	Big data processing	S2.7.0	ICT for Sustainability
23	ICT platform management	Partial	Administer ICT system	S5.2.1	Big Data
24	Data integration and ETL	Partial	Data extraction, transformation and loading tools	0612	Industry 5.0
25	Blockchain technology / Smart contracts	Partial	Smart contract	0613	Big Data
26	Computer vision	Exact	Computer vision	0619	Blockchain
27	Human-machine interface	Partial	Design user interface	S1.11.1	AI & Ethics
28	Digital twin	Partial	Digital twin technology	0613	Industry 5.0
29	Autonomous systems	Partial	Digital systems	0688	Industry 5.0
30	Edge computing	Partial	Distributed computing	0612	Industry 5.0
31	Robotics programming	Exact	Robotics	0714	Internet of Things
32	Data privacy	Partial	Data protection	0612	Industry 5.0
33	5G technology	Partial	Network engineering	0714	AI & Ethics
34	Fault tolerance in computing systems	Partial	Fault tolerance	613	Internet of Things
35	Data science	Exact	Data science	0688	Big Data
36	Geographic information systems (GIS)	Exact	Geographic information systems (GIS)	0532	Big Data

#	Identified critical skills	ESCO Match	Closest ESCO Skill	ESCO Code	ATI
37	Cloud computing architecture	Partial	Cloud computing	0612	Big Data
38	Neural networks	Partial	Artificial neural networks	0619	Big Data
39	Blockchain terminology	Partial	Blockchain technology	0612	AI & Ethics
40	Human-robot collaboration	Exact	Human-robot collaboration	0714	Blockchain
41	Principles of artificial intelligence	Exact	Principles of artificial intelligence	0619	Industry 5.0

The **Table 17 should serve as a basis for designing microcredentials and courses using actual ESCO skills as references.** Each entry reflects either an exact ESCO match or the closest existing ESCO concept for the provided skill.

- Exact Match: Skills such as "Machine learning," "Data analysis," "Data visualisation," "Cloud computing," "Programming," "Cybersecurity," "Computer vision," "Data science," and "GIS" are found verbatim (or nearly so) in ESCO.
- Partial Match: For skills that are more specialized (e.g. "Artificial intelligence with ethical considerations," "Big data infrastructure," "Blockchain technology (multi-chain focus)," "Edge computing"), we selected the closest existing ESCO skill. For instance, "5G technology" is mapped to the broader domain of mobile telecommunications, and "Edge computing" is approximated by the concept of distributed computing.
- ESCO Codes: The assigned ESCO codes follow the best-fit approach based on the nature of the skill.
- ATI: Each skill is linked to one Advanced Technology Industry category (e.g. AI & Ethics, Big Data, Blockchain, etc.) to support course design.

Besides the technical skills it was strongly recommended by the experts/participants of focus groups and interviews as well there it is mentioned in the desk research reports many times that there are analytical and social skills which also require immediate attention as a part of professional development of experts working in Industry 5.0 and all analysed ATIs. These are:

- Bias mitigation in algorithms
- Business process integration
- Project management (environmental focus)
- Renewable energy systems
- Human-centred design
- Emotional intelligence and leadership
- Storytelling
- Teamwork and collaboration
- Intercultural communication
- Change management and digital transformation

- Green building
- Urban planning and mobility
- Materials engineering
- Supply chain management

As the additional view we also provide the table below, which includes ICT-related occupations from both **Group 25 (ICT specialists) and Group 35 (ICT technicians**), along with a summary of the relevant skills which were identified as critical. Group 25 occupations typically refer to ICT specialists (e.g., developers, architects, data professionals, security specialists), while Group 35 covers ICT technicians (e.g., system administrators). Some skills (such as teamwork, cloud computing, and programming) are transversal within ICT roles given in table.

The table represents **a cross-section of ICT-related occupations with skills identified as critical which require immediate attention**.

The assigned ESCO occupations play a crucial role in designing relevant courses and microcredentials that directly address identified skill gaps. By aligning educational programs with ESCO roles such as Data Scientist, IoT engineer, and Business intelligence analyst, training initiatives can be tailored to meet the evolving needs of the labour market. For example, microcredentials in AI Ethics and Cognitive Neuroscience support EU-level priorities in ethical AI development and cognitive sciences. Additionally, specialized courses in IoT Security, Smart City Planning, and Sustainability Consulting foster interdisciplinary expertise essential for digital sovereignty and green transformation. This interconnected approach ensures that learners develop competencies linked to emerging occupations, enhancing employability and supporting regional and EU-wide strategic objectives.

TABLE 18 A cross-section of ICT- related occupations with skills identified as critical

ESCO Occupations/ ISCO code	Skills identified as critical
Software developer (2512)	▪ Programming ▪ Artificial intelligence / Ethical AI ▪ Big data & Big data infrastructure ▪ Blockchain technology (decentralized, multi-chain, smart contracts) ▪ Cloud computing & Cloud computing (architecture sub-area) ▪ Computer vision ▪ Cryptography / Cyber security / Data privacy ▪ Data science / Perform data analysis / Data visualisation ▪ Edge computing (emerging) ▪ Embedded systems ▪ Fault-tolerant computing / Fault tolerance ▪ Human-machine interface ▪ Internet of things (IoT): network protocols, cybersecurity, smart systems ▪ Quantum computing (niche areas) ▪ Robotics programming (if relevant) ▪ Teamwork / Collaboration
Data scientist (2511)	▪ Data science / Perform data analysis ▪ Big data & Big data infrastructure ▪ Data visualisation / Information visualisation ▪ Extract, transform, load (ETL) / Data integration ▪ Artificial intelligence / Ethical AI (for modelling and prediction) ▪ Cloud computing ▪ Cyber security / Data privacy ▪ Fault tolerance (for large-scale systems) ▪ Programming (e.g., Python, R) ▪ Storytelling (communicating insights) ▪ Teamwork / Collaboration
Business intelligence analyst (2511)	▪ Big data & Big data infrastructure ▪ Data science / Perform data analysis ▪ Data visualisation / Information visualisation ▪ ETL / Data integration ▪ Cloud computing (BI platforms) ▪ Data privacy / Privacy protection ▪ Programming (SQL, Python, R) ▪ Storytelling (for reporting insights) ▪ Teamwork / Collaboration

ESCO Occupations/ ISCO code	Skills identified as critical
ICT system architect (2512)	▪ ICT system architecture / Data architecture ▪ ICT system integration ▪ Cloud computing & Cloud computing (architecture sub-area) ▪ Cyber security / Data privacy ▪ Edge computing (emerging) ▪ Fault-tolerant computing / Fault tolerance ▪ Programming (for prototyping or proof-of-concepts) ▪ Teamwork / Collaboration
ICT solutions architect (2512)	▪ ICT system architecture / Data architecture ▪ ICT system integration ▪ Cloud computing & Cloud computing (architecture sub-area) ▪ Blockchain technology (decentralized, multi-chain, smart contracts) ▪ Edge computing (emerging) ▪ Cyber security / Data privacy ▪ Internet of things (IoT): network protocols & smart systems ▪ Programming ▪ Teamwork / Collaboration
Systems engineer (2512)	▪ ICT system architecture / Data architecture ▪ ICT system integration ▪ Cloud computing & Cloud computing (architecture sub-area) ▪ Edge computing (emerging) ▪ Cyber security / Data privacy ▪ Fault-tolerant computing / Fault tolerance ▪ Embedded systems (in some contexts) ▪ Programming ▪ Human-machine interface (if applicable) ▪ Teamwork / Collaboration
ICT security specialist (2519)	▪ Cyber security ▪ Data privacy / Privacy protection ▪ Cryptography ▪ Internet of things (IoT) / Cybersecurity ▪ Cloud computing (securing cloud environments) ▪ Blockchain technology (if involved in securing such systems) ▪ Comply with regulations (security standards) ▪ Fault-tolerant computing / Fault tolerance ▪ Programming (scripting, penetration testing) ▪ Teamwork / Collaboration

ESCO Occupations/ ISCO code	Skills identified as critical
Data analyst (2511)	▪ Data science / Perform data analysis ▪ Big data & Big data infrastructure ▪ Data visualisation / Information visualisation ▪ ETL / Data integration ▪ Cloud computing (for data storage and processing) ▪ Data privacy / Privacy protection ▪ Programming (e.g., SQL, Python, R) ▪ Storytelling (to convey insights) ▪ Teamwork / Collaboration
IoT engineer (2512)	▪ Internet of things (IoT): network protocols, smart systems, cybersecurity ▪ 5G technology (for enhanced connectivity) ▪ Embedded systems ▪ Edge computing (emerging) ▪ Autonomous systems (advanced IoT solutions) ▪ Fault-tolerant computing / Fault tolerance ▪ Cloud computing (back-end integration) ▪ ICT system architecture / Data architecture / ICT system integration ▪ Cyber security / Data privacy ▪ Programming ▪ Teamwork / Collaboration
ICT system administrator (3512)	▪ ICT platform management ▪ Cloud computing (and, if applicable, cloud architecture fundamentals) ▪ Cyber security / Data privacy / Privacy protection ▪ Basic ICT system architecture / Data architecture knowledge ▪ ICT system integration (maintenance of various systems) ▪ 5G technology (if managing next-gen network infrastructure) ▪ Programming (for scripting and automation tasks) ▪ Teamwork / Collaboration

10 Glossary

- **Advanced Technologies for Industry:** Advanced Technologies are defined as recent or future technologies that are expected to substantially alter the business
- **Analytical Skills:** Analytical skills involve your ability to solve complex problems, analyze data, and make swift decisions. Skills such as financial analysis, statistical modeling, and data analysis are examples of analytical skills.
- **Centres of Vocational Excellence (CoVEs):** CoVEs are the pillars of excellent vocational education in Europe. Centres of Vocational Excellence (CoVEs) are formed by networks of partners that develop local "skills ecosystems" to provide high quality vocational skills to young people and adults, and contribute to regional development, innovation, industrial clusters, smart specialisation strategies and social inclusion. CoVEs stimulate local business development and innovation, by working closely with companies (in particular SMEs) on applied research projects, creating knowledge and innovation hubs, as well as supporting entrepreneurial initiatives of their learners.
- **Competence:** Demonstrated ability to use knowledge, know-how, experience and – job-related, personal, social or methodological – skills, in work or learning situations and in professional and personal development. Competence is not limited to cognitive elements (involving the use of theory, concepts or tacit knowledge); it also encompasses functional aspects – including technical skills – as well as interpersonal attributes (e.g. social or organisational skills) and ethical values; competence can be individual or collective (company, organisation, region).
- **Competences:** Competences can be defined as broader attributes that refer to an ability to use knowledge, skills social and/or methodological abilities in work or study situations and in professional and personal development. Competence is not limited to the cognitive area; it also encompasses functional/technical areas, interpersonal skills and values.
- **Digital literacy:** Digital literacy lays out five digital competence areas and a total of 21 digital competencies. The digital competence areas include information and data literacy, communication and collaboration, digital content creation, safety, and problem-solving.
- **eCF (e-Competence Framework):** eCF classifies 40 competences for the ICT professionals. It establishes a common language for competences, skills and proficiency levels across Europe. Competences in the e-CF are organised according to five ICT business areas and related to the European Qualifications Framework (EQF). The e-CF is developed by experts and stakeholders and today it is maintained by "CEN/TC-428 ICT Professionalism and Digital Competences". The e-CF is an important source for developing ESCO and in particular has been used by the Sectoral Reference Group ICT service activities.
- **ESCO:** ESCO (European Skills, Competences, Qualifications and Occupations) is the European multilingual classification of skills, competences, qualifications and occupations.
- **European Qualifications Framework (EQF):** EQF provides a common reference framework which assists in comparing the national qualifications systems, frameworks and their levels. It makes qualifications more readable and understandable across different countries and systems in Europe. The EQF is an 8-level, learning outcomes-

based framework for all types of qualifications that serves as a translation tool between different national qualifications frameworks. This framework helps improve transparency, comparability and portability of people's qualifications and makes it possible to compare qualifications from different countries and institutions.

- **Hard skills:** Hard skills referred to as technical skills. They are quantifiable abilities that are relevant to a particular industry or job. In general, they are not natural abilities, they are taught and can be verified through demonstration or assessment. Hard skills are important because they determine whether you will be capable of effectively performing tasks, completing projects, and excelling in your role.
- **Micro-credentials:** Micro-credentials certify the learning outcomes of short-term learning experiences, for example a short course or training. They offer a flexible, targeted way to help people develop the knowledge, skills and competences they need for their personal and professional development.
- **Project Management Skills:** Competencies such as project planning, budgeting, and time management demonstrate your ability to lead teams effectively and handle complex tasks.
- **Reskilling:** Reskilling involves acquiring entirely new skills for a different role or career path. This often requires significant training or education, sometimes in a completely unrelated field
- **Skill gap:** Situation where an individual does not have the type or level of skills required to perform adequately the tasks associated with a job.[1] This term is close to, but not synonymous with: skill shortage, skills mismatch. It can be linked to an insufficient level of qualification; it may also refer to situations where the workforce has the right level of qualification but lacks specific types of skills (such as management skills) or experience required to perform a task or a job adequately.
- **Skill gap analysis:** A process that organizations use to identify the difference between the skills that employees currently possess and the skills they need to meet organizational objectives.
- **Skills:** Skills may be defined as the ability to apply knowledge and use know-how to complete tasks and solve useful problems, typically in the workplace.

10.1 Resources

[1.] https://esco.ec.europa.eu/en/classification/occupation_main

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WP4 Enhancing Labour Market-Relevant Skills in Advanced Technologies

T4.1 Identifying skill gaps in Advanced Technologies

EU level Report from the desk research

Date: September 2024 – January 2025

INVESTech

Innovation Vocational Excellence and Sustainability in Tech

PROJECT REF NO. 101143958. ERASMUS-EDU-2023-PEX-COVE

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1 Report from the desk research on AI & Ethics

Prepared by: Centre for Social Innovation, Cyprus

1.1 Introduction & methodology

Definition of AI in ICT & Key Characteristics

Artificial Intelligence (AI) in the Information and Communication Technology (ICT) sector includes algorithms, data processing, and machine learning, which drive decision-making processes, automation, and efficiency. Ethical AI frameworks in the European Union are designed to ensure transparency, accountability, and fairness (European Commission, 2019; European Union, 2021). Key principles include:

- Transparency: Algorithms should be interpretable and understandable (Floridi et al., 2018).
- Accountability: Developers and users are responsible for AI's impact on society (Jobin, Ienca, & Vayena, 2019).
- Privacy and Data Protection: EU's General Data Protection Regulation (GDPR) outlines privacy and data security requirements (European Union, 2016).

European Union Policy Documents and Regulatory Guidelines:

- The EU General Data Protection Regulation (GDPR) and the proposed EU AI Act were primary references. These documents highlight the EU's regulatory focus on AI ethics, privacy, and transparency, directly impacting job roles that handle sensitive data and AI systems (European Commission, 2018; European Union, 2021).
- The Ethics Guidelines for Trustworthy AI by the European Commission provided a foundation for understanding roles that require knowledge of transparency, fairness, and accountability within AI, as these are mandated in the guidelines for developing and implementing AI in the EU (European Commission, 2019).

Industry Reports and Labor Market Analyses:

- Reports from LinkedIn's Emerging Jobs Report and McKinsey Global Institute's publications on AI and automation were critical in identifying emerging job roles in ICT that emphasize ethical considerations in AI. These reports outlined trends in AI roles, including those where privacy, regulatory compliance, and ethical AI use are prioritized (LinkedIn, 2021; McKinsey Global Institute, 2018).
- PwC's Industry Reports on AI compliance and ethical AI in the European context highlighted the demand for AI ethics and regulatory expertise in roles such as DPOs, product managers, and policy analysts (PwC, 2022).

Academic and Research Literature on AI Ethics:

- Publications from the Journal of Artificial Intelligence Research and other academic sources discussed the technical and ethical challenges AI practitioners face, underscoring the need for specialized roles like AI auditors and transparency specialists to address these challenges (Campolo et al., 2018).

Professional Organizations and EU-Focused Research Institutions:

- Organizations like the European Data Protection Board and institutions such as AI Now Institute provided case studies and industry research detailing ethical AI practices. These resources identified the practical application of AI ethics in job roles that require GDPR compliance and transparency, emphasizing the roles of DPOs, compliance managers, and ethics-focused machine learning engineers (AI Now Institute, 2018).

1.2 Identified roles, jobs, skills & competency profiles

Key employers in the EU include:

- **EU Institutions** (e.g., European Data Protection Supervisor, European Commission) for policy compliance and AI ethics roles.
- **National Data Protection Agencies** (e.g., CNIL, ICO) focused on GDPR enforcement and AI oversight.
- **Tech Firms** (e.g., SAP, Siemens, Microsoft EU) seeking ethics managers and data protection officers for AI product compliance.
- **Research Institutes** (e.g., European Research Council, AI Now Institute) hiring ethics-focused AI researchers.
- **Consulting Firms** (e.g., Deloitte, PwC) for advisory roles in AI compliance and auditing.
- **NGOs** (e.g., Access Now, EDRi) advocating responsible AI use, hiring policy analysts.
- **Financial Institutions** (e.g., ECB, Allianz) requiring DPOs and compliance managers to maintain AI transparency and privacy.
- **Universities** recruiting AI ethics researchers to drive academic contributions in ethical AI.

Roles & Career Opportunities in AI Ethics

- Data Protection Officer (DPO) with AI Focus
  - **Relation to AI and Ethics**: Ensures AI systems comply with GDPR, focusing on data privacy in AI projects.
  - **Core Skills**: GDPR compliance, data privacy assessment, AI ethics knowledge, risk management.
- Ethics and Compliance Manager for AI
  - **Relation to AI and Ethics:** Integrates ethical practices in AI development, ensuring adherence to standards like the EU AI Act and bias prevention.
  - **Core Skills:** AI ethics frameworks, regulatory compliance, auditing, risk assessment.
- AI P1Methodologyolicy Analyst
  - **Relation to AI and Ethics**: Analyzes and develops AI policies with a focus on social impact, regulatory alignment, and ethical standards.

  - **Core Skills**: Public policy, regulatory knowledge, ethical AI principles, data privacy.

- AI and Ethics Research Scientist
  - **Relation to AI and Ethics**: Advances ethical AI through algorithm development, focusing on fairness, transparency, and accountability.
  - **Core Skills**: Machine learning, bias mitigation, model interpretability, statistical analysis.

- AI Product Manager (Ethics and Compliance Focus)
  - **Relation to AI and Ethics**: Manages AI product lifecycle, ensuring ethical design, privacy compliance, and transparency.
  - **Core Skills**: Project management, AI ethics knowledge, privacy regulations, stakeholder communication.

- Machine Learning Engineer with an Ethics Specialization
  - **Relation to AI and Ethics**: Designs AI models that integrate fairness and transparency principles, reducing biases and enhancing interpretability.
  - **Core Skills**: Machine learning, bias mitigation, data privacy, algorithmic fairness.

- AI Auditor
  - **Relation to AI and Ethics**: Audits AI systems for compliance with ethical guidelines and regulatory standards, reviewing for biases and transparency.
  - **Core Skills**: Auditing, machine learning ethics, regulatory compliance, risk management.

- Algorithm Transparency Specialist
  - **Relation to AI and Ethics**: Ensures AI model transparency, making algorithms interpretable for stakeholders, critical for trust and regulatory compliance.
  - **Core Skills**: Model interpretability, documentation, ethical communication, regulatory understanding.

Competency Profiles and Common Degrees:

- Competency Profiles:
  - **Regulatory Compliance**: In-depth knowledge of GDPR, EU AI Act, and other regulatory frameworks guiding AI ethics.
  - **Data Privacy and Security**: Proficiency in data protection, risk assessment, and ethical data handling.
  - **Ethical AI Principles**: Skills in bias detection, algorithmic transparency, accountability, and fairness in AI systems.
  - **Technical AI Skills**: Strong foundation in machine learning, model interpretability, and AI auditing.
  - **Project Management and Communication**: Ability to manage ethical AI projects and effectively communicate ethical guidelines to stakeholders.

- Common Degrees:
  - **Computer Science and Data Science**: Focus on AI, machine learning, and data privacy.
  - **Law and Public Policy**: Specializations in technology policy, GDPR, and ethical governance of AI.
  - **Ethics and Philosophy**: Applied ethics and AI ethics, particularly relevant for roles focusing on policy and compliance.
  - **Information Security**: For roles emphasizing data protection and cybersecurity within AI applications.

1.3 Skill gap Analysis

Critical Skills and Competency Gaps:

The EU job market lacks essential ethical AI skills, particularly in bias detection, algorithm transparency, and GDPR-compliant data management (European Union, 2021; PwC, 2022). Specific deficiencies include:

- Bias Mitigation and Fairness in AI
  - **Gap**: Limited expertise in identifying, measuring, and mitigating biases within AI models, essential for fairness and ethical integrity.
  - **Need**: Training on advanced bias detection tools, fairness algorithms, and best practices for reducing discrimination in AI.
- Algorithm Transparency and Interpretability
  - **Gap**: Lack of skills in making AI models understandable and transparent, especially for non-technical stakeholders.
  - **Need**: Competencies in model documentation, interpretability techniques, and explaining AI decisions to meet EU transparency requirements.
- Data Privacy and Security Compliance
  - **Gap**: Insufficient understanding of GDPR compliance and secure data handling in AI processes.
  - **Need**: Knowledge of data privacy regulations, ethical data usage, and compliance strategies to protect user rights.
- Regulatory Knowledge and Ethical Governance
  - **Gap**: Limited familiarity with the EU AI Act, GDPR, and ethical frameworks, leading to gaps in compliance and risk management.
  - **Need**: Training in regulatory compliance, ethics in AI governance, and proactive risk assessment.
- Ethical Project Management
  - **Gap**: Shortage of skills in managing AI projects with a focus on ethics, stakeholder engagement, and cross-functional collaboration.
  - **Need**: Project management skills tailored to ethical AI development, emphasizing clear communication of ethical standards

Skill Proficiency Analysis:

Research from LinkedIn and McKinsey shows that technical skills (e.g., coding, data processing) are common among ICT professionals, but there is a significant gap in ethical AI skills, such as compliance with privacy regulations and bias mitigation techniques (McKinsey Global Institute, 2018; LinkedIn, 2021).

- **Workforce Proficiency Levels**: While technical skills (e.g., Python, SQL) are abundant, ethical AI skills such as bias mitigation and transparency-focused development remain scarce.
- **Comparing Required and Available Skills**: Job market analysis reveals a gap in roles that require in-depth knowledge of ethical considerations, privacy regulations, and anti-bias techniques in AI.
- **Regulatory Knowledge**: Awareness varies; deeper understanding of EU AI Act and ethical guidelines required.

Skill Profile and Labor Market Demand:

Employers increasingly demand skills aligned with AI ethics (e.g., AI model interpretability, GDPR compliance), particularly for product management, data engineering, and ML engineering roles in the EU. However, the available talent often lacks this ethical emphasis, posing a barrier to compliance and public trust.

1.4 Summary & recommendations

Key Findings

The EU ICT sector faces critical skill gaps in ethical AI areas, including bias mitigation and data privacy, due to a lack of experienced professionals (European Commission, 2020; LinkedIn, 2021).

- **Skill Gaps**: Significant gaps exist in bias mitigation, algorithm transparency, GDPR compliance, regulatory knowledge, and ethical project management within AI roles.
- **Proficiency Levels**: Current skills are often basic in essential areas like bias reduction, transparency, and regulatory frameworks, falling short of EU ethical standards and requirements.
- **Market Demand**: Employers in the EU increasingly require AI professionals skilled in ethical and regulatory practices to ensure compliance with the EU AI Act, GDPR, and other ethical guidelines.

Recommendations

- **Targeted Training Programs**: Develop specialized training in bias mitigation, algorithm transparency, GDPR compliance, and ethical AI principles to address core skill gaps.
- **Enhanced Regulatory Education**: Integrate education on the EU AI Act, GDPR, and AI ethics into AI and data science curriculums and professional development programs.

- **Ethical Project Management Certification**: Establish certification programs focused on ethically-driven AI project management to prepare professionals for managing AI projects with regulatory compliance and ethical oversight.
- **Cross-Disciplinary Collaboration**: Encourage partnerships between technology, ethics, and policy experts to foster a holistic approach to ethical AI development.

Prioritized Skill Gaps and Strategies

- Bias Mitigation and Fairness
  - Priority: High
  - Strategy: Develop intensive training programs focused on fairness algorithms, bias detection, and reduction tools. Encourage the use of standardized fairness assessment frameworks and implement hands-on workshops for practical application.
- Algorithm Transparency and Interpretability
  - Priority: High
  - Strategy: Introduce courses in model interpretability and documentation practices. Promote skills in explainable AI techniques to ensure models are transparent and understandable to both technical and non-technical stakeholders.
- Data Privacy and GDPR Compliance
  - Priority: High
  - Strategy: Offer specialized certification programs on GDPR, privacy-by-design principles, and secure data handling in AI systems. Encourage regular updates on evolving privacy laws to keep skills current.
- Regulatory and Ethical Knowledge
  - **Priority**: Medium-High
  - **Strategy**: Incorporate EU AI Act and ethical AI framework modules into AI curricula. Provide workshops and resources on regulatory compliance and encourage collaboration with legal experts to deepen understanding.
- Ethical Project Management
  - **Priority**: Medium
  - **Strategy**: Develop certification programs for ethically-focused AI project management, with modules on stakeholder communication, ethical oversight, and cross-functional collaboration. Promote best practices for managing AI projects with an ethical lens.

Regulatory Compliance: Develop certification courses on EU ethical AI standards for data engineers, product managers, and developers (McKinsey Global Institute, 2022).

Strategies for Addressing Skill Gaps:

- **AI Ethics Certification Programs**: Certification courses on ethical AI standards in the EU for data engineers, developers, and product managers.

- **Incorporation of Ethics in Tech Curriculums**: Universities and training institutions should embed ethics into AI and ICT curriculums to foster a compliance-oriented workforce.

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2 Report from the desk research on Big Data

Prepared by: Frederick University, Cyprus

2.1 Introduction & Methodology

Description of data sources utilized: Data collection and analysis methods employed

The study of Big Data trends at the EU level relies on multiple data sources, including institutional reports from Eurostat, the European Commission's Directorate-General for Communications Networks, Content and Technology (DG CONNECT), and the European Data Portal. Supplementing these are industry-specific databases, market research reports, and peer-reviewed academic publications, which together offer both quantitative and qualitative insights. Data collection involves systematically extracting information from these sources, which is then processed and analyzed using statistical tools and big data analytics techniques. This methodological approach focuses on identifying patterns, trends, and regulatory impacts within the EU's Big Data landscape, allowing for a comprehensive view of sectoral developments, emerging challenges, and policy implications.

Definition of the respective ATI and its key characteristics

In the EU, Big Data is defined by its "5 Vs": volume, velocity, variety, veracity, and value. **Volume** reflects the massive data generated daily; **velocity** represents the speed at which data is processed; **variety** encompasses the diverse data types—like text, video, and sensor data; **veracity** highlights the importance of data accuracy; and **value** captures the insights gained from analyzing this data. The EU places strong emphasis on responsible data governance, integrating ethical considerations such as data sovereignty and citizen rights into its approach to Big Data, with GDPR at the core to ensure privacy, security, and the ethical use of informati

2.2 Identified roles, jobs, skills & competency profiles

Who is hiring: current & potential employers

The demand for Big Data professionals is growing across various sectors in the EU as organizations recognize the value of data-driven decision-making. Current employers include major technology firms, financial institutions, healthcare providers, and government agencies, all leveraging Big Data to enhance efficiency, innovation, and customer insights. Additionally, sectors like retail, transportation, and energy are increasingly adopting Big Data solutions, driving demand for skilled analysts, data engineers, and data scientists. Potential employers also include emerging tech startups and research institutions focused on AI, machine learning, and data security, as these fields rely heavily on Big Data expertise. As Big Data adoption continues to expand, the employment landscape is likely to broaden, encompassing both traditional industries and new market players aiming to harness data for competitive advantage

List of specific roles = professionals working with the respective ATI Career opportunities / jobs/ working positions

The Big Data field offers a range of specialized roles to meet the growing demand for data-driven expertise. **Data Scientists** and **Data Analysts** interpret complex datasets to support strategic decision-making, while **Data Engineers** and **Big Data Architects** design the infrastructure needed to manage and process these vast volumes of data. **Machine Learning Engineers** and **Quantitative Analysts** apply advanced algorithms for predictive analytics and financial modeling, respectively. At a strategic level, **Chief Data Officers (CDOs)** oversee data governance, while **Data Privacy and Compliance Specialists** ensure that data practices align with regulations like GDPR. Additionally, **Business Intelligence Analysts** and **AI/Data Product Managers** transform data into actionable insights and bridge technical and business teams to develop data-driven products. Together, these roles are essential to leveraging Big Data across sectors, from finance and healthcare to technology and government.

Profile/description/competency profile and skills list for the most common jobs/roles for the respective ATI

Professionals in Big Data commonly need expertise in data analysis, data mining, machine learning, and statistical modelling, with strong proficiency in programming languages like Python, R, SQL, and Scala. Familiarity with Big Data frameworks such as Hadoop, Spark, and Kafka is essential, as these tools are central to processing and managing large datasets. In addition to technical skills, competencies in problem-solving, cloud platforms (AWS, Azure), and knowledge of EU data protection regulations (GDPR) are crucial. Equally important are soft skills such as effective communication to present complex findings to stakeholders, teamwork, project management, and critical thinking. Together, these technical and interpersonal skills equip Big Data professionals to drive insights and innovation across diverse sectors.

Common degrees of professionals in the respective ATI

At the EU level, professionals in Big Data commonly hold degrees in fields such as Computer Science, Data Science, Mathematics, Statistics, or Engineering. Other relevant academic backgrounds include Information Systems, Applied Mathematics, and Artificial Intelligence. To stay competitive in this fast-evolving field, many professionals also pursue advanced degrees or certifications in specialized areas like machine learning, data analytics, or big data management, which deepen their expertise and enhance their practical skills in handling complex data challenges.

2.3 Skill gap Analysis

Identification of critical skills & competency

In the EU, Big Data professionals need a blend of technical, analytical, and soft skills. Key technical competencies include data analytics, machine learning, cloud computing, and database management (SQL, NoSQL), alongside programming skills in Python, R, and Java. Proficiency in data visualization tools, such as Tableau or Power BI, is essential for presenting insights effectively. Knowledge of data governance, particularly GDPR, ensures compliance with legal and ethical standards. Soft skills like problem-solving, critical thinking, and effective communication are equally crucial, enabling professionals to interpret complex data and work collaboratively across interdisciplinary teams.

Analysis of skill proficiency levels in the workforce;

In the EU, Big Data proficiency varies with experience and role demands. Entry-level professionals typically excel in foundational skills like Python, SQL, and basic data visualization (Tableau, Power BI), while advanced expertise in machine learning, cloud computing, and big data architecture is seen at senior levels. Familiarity with GDPR is essential across roles, with deeper regulatory knowledge expected in highly regulated sectors like finance and healthcare. Effective communication and teamwork are vital across all levels, whereas advanced critical thinking and project management are key for senior positions. Continuous upskilling is crucial as Big Data technologies and EU regulations evolve, ensuring the workforce remains adaptable and competitive.

Comparison of required skills and available skills; comparison of skill profiles and labour market demands

There is a growing gap between the skill profiles of Big Data professionals and the rapidly evolving demands of the labor market. Foundational skills in programming, data analysis, and visualization (e.g., Python, SQL, Tableau) are widely available among entry-level professionals, meeting the baseline needs of many organizations. However, there is a high demand for advanced skills in machine learning, big data architecture, and cloud computing (AWS, Azure) that is not fully matched by the current talent pool. Additionally, the market increasingly requires expertise in data governance and GDPR compliance, especially in regulated sectors such as finance and healthcare. Employers are also looking for strong soft skills—such as problem-solving, critical thinking, and effective communication—that allow professionals to translate complex insights into strategic actions and collaborate across teams. Bridging this skills gap will require targeted upskilling and reskilling initiatives to align workforce capabilities with labor market needs in this rapidly advancing field.

2.4 Summary & recommendations

Key findings regarding skill and competency gaps

In the EU Big Data sector, skill and competency gaps are becoming more prominent as demand for expertise accelerates. While foundational skills like data analysis, programming (Python, SQL), and data visualization are relatively common, there is a notable shortage of advanced competencies in machine learning, cloud computing (AWS, Azure), and big data architecture. Additionally, expertise in GDPR compliance and data governance remains limited, especially within highly regulated fields like finance and healthcare. The market also shows a gap in essential soft skills, with a strong need for professionals who can apply critical thinking, problem-solving, and communication skills to translate technical insights into strategic actions. Addressing these gaps requires targeted upskilling and ongoing professional development to keep the EU workforce aligned with the sector's rapid growth

Recommendations for addressing identified gaps

To address the skill gaps in Big Data, a multi-faceted approach involving educational institutions, industry stakeholders, and policymakers is essential. Firstly, universities and training providers should expand programs focused on advanced skills like machine learning, big data architecture, and cloud computing, incorporating hands-on projects to deepen practical expertise. Industry partnerships can play a pivotal role by offering internships, apprenticeships, and specialized training that align with current labor market demands. Policymakers could incentivize continuous learning through grants or tax credits for organizations that invest in employee upskilling, especially in data governance and GDPR compliance. Additionally, fostering soft skills such as communication, critical thinking, and problem-solving can be achieved through cross-disciplinary training and team-based projects, preparing professionals to bridge the gap between technical insights and strategic decision-making. Together, these initiatives can help build a robust and adaptable Big Data workforce across the EU.

Prioritized list of skill gaps requiring immediate attention

1. **Advanced Machine Learning and AI Skills** – Demand is high for expertise in developing and deploying machine learning models, critical for sectors using predictive analytics and automation.
2. **Cloud Computing Proficiency (AWS, Azure, Google Cloud)** – With the rise of data storage and processing in cloud environments, expertise in cloud platforms is crucial for scalable Big Data solutions.
3. **Big Data Architecture and Infrastructure Design** – Skills in designing and managing large-scale data systems (e.g., Hadoop, Spark) are essential for supporting complex data workflows across organizations.
4. **Data Governance and GDPR Compliance** – Knowledge of EU data regulations and best practices in data governance is necessary to ensure ethical and compliant data handling, especially in regulated industries.
5. **Data Visualization and Communication Skills** – The ability to translate data insights into accessible, actionable insights for non-technical stakeholders is increasingly sought after.

6. **Critical Thinking and Problem-Solving** – These soft skills are essential for tackling complex data challenges and adapting insights into strategic solutions

Strategies for addressing identified skill gaps

1. **Educational Partnerships**: Strengthen collaborations between universities, technical institutions, and industry players to develop specialized programs focusing on AI, machine learning, and cloud computing. These programs should be tailored to the practical needs of the current job market.
2. **Government-Funded Training and Upskilling Programs**: Implement EU-wide training initiatives to upskill workers in key areas like data governance, cybersecurity, and advanced data analytics. Such programs can be integrated into the EU's Digital Education Action Plan.
3. **Continuous Learning and Certification Programs**: Encourage businesses to adopt lifelong learning models by offering certifications and advanced training in new technologies, such as machine learning and big data architecture, through Massive Open Online Courses (MOOCs) and corporate training platforms.
4. **AI-Assisted Learning Platforms**: Leverage AI to personalize learning paths for professionals based on their current skill levels and areas of interest, ensuring that they receive targeted training in the most relevant fields.
5. **Public-Private Partnerships**: Foster partnerships between governments, industry leaders, and educational institutions to co-create training programs that align with the evolving needs of the labor market.

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3 Report from the desk research on Blockchain

Prepared by: KCCI, Lithuania

3.1 Introduction & methodology

3.1.1 Introduction

Blockchain is a decentralized, distributed digital ledger that records transactions across multiple computers in a way that ensures the data is secure, transparent, and immutable. Each transaction is grouped into a "block," and these blocks are linked chronologically in a chain, where each new block references the previous one through a cryptographic hash. Once recorded, the data in a block cannot be altered without altering all subsequent blocks and gaining consensus from the network, making blockchain highly secure and resistant to tampering or fraud.

One major advantage of blockchains is the level of security it can provide, and this also means that blockchains can protect and secure sensitive data from online transactions. For anyone looking for speedy and convenient transactions, blockchain technology offers this as well. In fact, it only takes a few minutes, whereas other transaction methods can take several days to complete. There is also no third-party interference from financial institutions or government organizations, which many users look at as an advantage.

Blockchain is distinguished by several key features that contribute to its revolutionary potential across various industries:

- Decentralization. In a blockchain, no single entity or central authority (like a bank or government) controls the entire system. Instead, control is distributed across a network of participants (nodes). Each node maintains a copy of the entire blockchain, making the system resilient to failures or manipulation.
- Immutability. Once a transaction is recorded on the blockchain, it cannot be altered or deleted. Each block is cryptographically linked to the previous block, making it extremely difficult to tamper with past records. This ensures the integrity of data.
- Transparency. Every participant in the network can access the full history of transactions, providing a high level of transparency. Although transactions are visible to all, the identities of participants can be anonymized using cryptographic techniques, ensuring privacy where necessary.
- Security. Blockchain uses cryptography to secure transactions. Each block contains a cryptographic hash, which ensures that data cannot be tampered with. The decentralized and consensus-based nature of the system also protects against hacking and fraud, as altering the blockchain would require control over a majority of the network.
- Consensus Mechanisms. Transactions on a blockchain are validated through a consensus mechanism, such as Proof of Work (PoW) or Proof of Stake (PoS). These mechanisms ensure that all participants agree on the validity of transactions, preventing fraudulent entries or double-spending (in the case of cryptocurrencies).

- Distributed Ledger. The blockchain functions as a distributed ledger, meaning that copies of the data are maintained across multiple nodes in the network. This redundancy ensures that the system remains operational even if some nodes go offline or are compromised.
- Smart Contracts. In some blockchain systems (like Ethereum), smart contracts can be used. These are self-executing contracts with the terms of the agreement directly written into code. They automatically trigger actions when predefined conditions are met, allowing for automation and thrustless transactions.

Blockchain technology holds significant relevance at the EU level due to its potential to enhance digital identity management, transform financial services, improve supply chain transparency, streamline public sector operations, and drive innovation. The EU's commitment to exploring and implementing blockchain solutions underscores its recognition of the technology's ability to address contemporary challenges and unlock new opportunities across various sectors. Through regulatory frameworks, research initiatives, and pilot projects, the EU is positioning itself at the forefront of blockchain adoption, aiming to harness its benefits while ensuring a secure and efficient digital future.

To sum up, blockchain's importance in the EU lies in its potential to enhance security, drive financial and operational efficiency, improve transparency, and foster innovation across various sectors.

3.1.2 Methodology

The research on blockchain skills in Europe was made with a purpose to analyse skills mismatches, workforce readiness, and sectoral adoption of blockchain technologies. The methodology is designed to integrate insights from a range of key reports and studies, ensuring a comprehensive view of blockchain talent gaps and opportunities for improvement across the European Union.

Literature Review

Key reports analysed include:

- Blockchain Skills for Europe (2020): This study highlights the skill mismatches within the blockchain sector, identifying the gaps between demand for blockchain professionals and the available talent pool in the European labour market.
- Artificial Intelligence, Blockchain, and the Future of Europe (2021): This report examines how disruptive technologies like AI and blockchain can drive the green and digital economies, emphasizing the skills required for adopting these technologies.
- European Landscape on the Use of Blockchain Technology by the Public Sector (2022): This report assesses blockchain adoption across public sector entities in Europe and highlights the digital transformation challenges, including skills shortages.
- The literature review will also incorporate industry-specific reports, such as the Advanced Technologies for Industry – Final Report (2021), which tracks trends in blockchain adoption within the industrial sector and its impact on workforce requirements

3.2 Identified roles, jobs, skills & competency profiles

3.2.1 Who is hiring: Current & potential employers

In the European Union, blockchain specialists can find opportunities across various sectors due to the technology's versatility and growing adoption. Here are some key sectors:

Finance and Banking: Blockchain is used for improving security, efficiency, and transparency in financial transactions. Major banks and financial institutions in the EU, like Deutsche Bank, BNP Paribas, and Santander, are exploring blockchain solutions. Blockchain specialists from these sectors are among those driving the adoption and implementation of blockchain technology in the financial sector, working on projects ranging from digital currencies to improved transaction security and efficiency.

Supply Chain and Logistics: Blockchain helps in tracking and verifying goods throughout the supply chain. Companies such as Maersk and DHL are integrating blockchain to enhance their logistics operations. blockchain specialists in the supply chain and logistics sector are focused on leveraging blockchain to improve transparency, traceability, and efficiency throughout the supply chain. They work closely with various teams and stakeholders to implement solutions that address specific challenges within the industry.

Healthcare: Blockchain can manage patient data securely and transparently. Institutions like Siemens Healthineers and various EU health organizations are investigating blockchain applications. The roles like patient identity management specialist who develop and manage blockchain-based solutions for secure and efficient patient identity verification and management, clinical trials specialist who utilize blockchain to enhance the management and transparency of clinical trials reflect the diverse ways blockchain technology can be applied to improve healthcare systems, from enhancing data security and interoperability to increasing transparency and efficiency in clinical trials and supply chains.

Government and Public Sector: Blockchain is being used for secure voting systems, digital identities, and public records. Governments in countries like Estonia are pioneers in blockchain-based services. Blockchain specialists contribute to enhancing transparency, security, and efficiency in public sector services and operations. They often collaborate with various government departments, technology partners, and stakeholders to implement and manage blockchain-based solutions.

Energy: Blockchain enables decentralized energy trading and management systems. Companies like Enel and E.ON are exploring blockchain to optimize energy distribution and trading. Blockchain specialists in the energy sector typically focus on areas such as decentralized energy trading, grid management, renewable energy certification, and energy efficiency. They work with various stakeholders, including energy companies, regulatory bodies, and technology providers, to advance the adoption and integration of blockchain technology in the energy industry.

Retail and E-commerce: Blockchain can enhance transparency in transactions and supply chain management. Retail giants and e-commerce platforms are incorporating blockchain to improve customer trust and traceability. In these positions, blockchain specialists contribute to enhancing transparency, security, and efficiency in retail and e-commerce operations.

Blockchain specialists in this sector help in areas such as supply chain management, fraud prevention, loyalty programs, and improving customer trust and engagement.

Real Estate: Blockchain is used for property transactions, digital land registries, and smart contracts. Real estate firms and developers in the EU are starting to adopt blockchain technology. Specific roles depend on the size of the organization, the complexity of the projects, and the specific needs of the real estate sector. Blockchain specialists in real estate are instrumental in transforming traditional property transactions and management processes by enhancing transparency, efficiency, and security through blockchain technology.

Insurance: Blockchain is being used for streamlining claims processing, fraud prevention, and underwriting. Major insurers in the EU are developing blockchain-based solutions to enhance their services. Blockchain specialists in the insurance sector are involved in a range of activities from technical development and project management to compliance and strategic innovation. Their roles are crucial in leveraging blockchain technology to enhance efficiency, transparency, and security within the insurance industry.

Legal and Compliance: Blockchain helps in contract management, compliance tracking, and legal documentation. Law firms and compliance departments are beginning to utilize blockchain for more efficient operations. In the Legal and Compliance sector within the EU, a blockchain specialist typically holds a position focused on ensuring that blockchain technologies and implementations comply with legal and regulatory standards. Overall, a blockchain specialist in Legal and Compliance plays a crucial role in bridging the gap between technology and regulation, ensuring that blockchain projects are legally sound and compliant with relevant laws and standards.

Technology and Startups: Many startups across the EU are working on innovative blockchain solutions, covering a wide range of applications from decentralized finance (DeFi) to non-fungible tokens (NFTs) and beyond. In startups, roles may be more flexible and encompass multiple responsibilities due to the smaller team sizes and fast-paced environment. Blockchain specialists in this sector often have opportunities to wear multiple hats, work on a variety of projects, and be involved in the strategic direction of innovative technologies.

Overall, the demand for blockchain specialists spans a diverse range of sectors as organizations seek to leverage blockchain's potential for various applications.

3.2.2 List of Specific Roles in blockchain

The European blockchain job market is rich with opportunities across various technical and non-technical roles. The following roles can be named as specific roles for blockchain specialists currently sought in the Europe.

Blockchain Developer. These blockchain specialist specializes in designing and developing blockchain solutions, including smart contracts and decentralized applications (dApps). There is a high demand of these professionals across tech hubs in Europe like Berlin, London, and Zurich. Major players in the market regularly hire for these roles due to ongoing demand for scalable blockchain solutions in finance and Web3.

Smart Contract Developer focuses on coding and deploying self-executing contracts for applications in DeFi, supply chain, and legal tech. In demand within DeFi platforms and blockchain-focused companies, especially in Switzerland and Germany where innovative financial applications are emerging

Blockchain Architect. These specialist designs the infrastructure and architecture of blockchain platforms, ensuring they are secure, scalable, and optimized. There is a high-demand role in sectors like finance, health, and supply chain management, with strong opportunities in London, Amsterdam, and Zurich as companies and institutions prioritize secure blockchain frameworks.

Blockchain Security Specialist protects blockchain networks from security threats by implementing protocols and ensuring data and asset safety. It is a vital role in crypto exchanges and digital asset firms, where the demand for high-level security solutions continues to grow.

Blockchain Analyst monitors and analyses blockchain data, trends, and investment opportunities, providing insights for financial and investment firms. Banks, financial institutions, and blockchain analytics companies in Europe increasingly seek blockchain analysts to understand and leverage blockchain data.

Blockchain Product Manager manages blockchain product development, aligning with business goals and market needs. There is a high demand in blockchain startups and fintech firms, where product managers guide projects from conception to launch.

These roles illustrate the diverse career paths available for blockchain specialists in the EU, driven by the increasing adoption of blockchain across sectors like finance, supply chain, and enterprise technology. These positions often come with high growth potential, competitive salaries, and the opportunity to work at the forefront of technology transformation across Europe.

However, in the European Union, the emergence of specific blockchain specialist roles reflects both the rapid development of blockchain technology and the growing need for secure, regulatory-compliant, and scalable blockchain solutions. Decentralized Finance (DeFi) Specialist can be named as one on the most emerging work position of blockchain specialists as this role focuses on developing and managing decentralized financial products and services, such as lending platforms, decentralized exchanges, and stablecoins.

3.2.3 Profile/Description/Competency Profile and Skills List for the Most Common Jobs/Roles

Blockchain professionals need a range of soft skills to complement their technical expertise, particularly as they work in interdisciplinary teams, navigate regulatory environments, and engage with stakeholders.

Soft skill domain	Description of soft skill	Correlation with blockchain
Problem-Solving and Critical Thinking	The ability to identify, analyze, and resolve complex issues in a logical, efficient manner.	The blockchain field often involves working with novel technologies and concepts. Effective problem-solving ensures that professionals can overcome technical challenges and find innovative solutions to industry-specific problems.
Analytical and Strategic Thinking	The importance of staying current with emerging technologies, changing regulations, and industry trends.	The blockchain sector is dynamic, with constant updates and innovations. Professionals must stay adaptable to remain competitive and to implement cutting-edge technologies that meet new market demands.
Communication and Interpersonal Skills	The ability to clearly and effectively communicate both technical and non-technical information.	Being able to communicate effectively ensures smooth collaboration and stakeholder alignment.
Collaboration and Teamwork	The ability to work well in teams, contribute to group efforts, and foster collaboration across interdisciplinary teams.	Blockchain solutions often require expertise from various fields, such as finance, law, and IT. Collaboration ensures that all perspectives are considered and that the project meets all functional, regulatory, and technical requirements.
Project Management	Covers the skills needed to plan, execute, and manage blockchain projects efficiently.	Blockchain projects can be complex, with multiple teams and stakeholders. Strong project management skills ensure that these projects stay on track, within budget, and meet strategic objectives.
Leadership and Decision-Making	covers leadership abilities, including decision-making, motivation, and the ability to guide teams toward achieving goals.	Leadership is essential for driving blockchain innovation and ensuring that teams stay focused, motivated, and aligned with business objectives.

The technical skills domain for blockchain professionals includes specialized knowledge and technical expertise required to develop, implement, and maintain blockchain solutions.

Technical skill domain	Description of soft skill	Correlation with blockchain
Blockchain Architecture	Covers a deep understanding of how blockchain systems are structured and function, and blockchain protocols.	Understanding blockchain architecture is essential for designing, developing, and deploying blockchain systems that are efficient, secure, and scalable. Professionals need to know how to build and optimize blockchain networks.
Blockchain Security	It includes knowledge of cryptographic security, consensus protocols, and secure coding practices.	Security is paramount in blockchain since once a transaction is validated, it is immutable. Blockchain professionals must ensure that systems are resilient to attacks and data breaches.
Blockchain Standards and Compliance	Includes knowledge of regulatory frameworks, legal standards, and compliance measures related to blockchain technologies.	Professionals must ensure their projects comply with data protection laws, financial regulations, and industry standards to avoid legal issues.
Database Management	Brings an understanding how data is stored and managed in decentralized systems.	Professionals must manage how data is stored, retrieved, and integrated with blockchain systems.

3.2.4 Common Degrees of Professionals in blockchain

Blockchain professionals come from a variety of educational backgrounds, but certain degrees are particularly common due to their relevance to the technical and business aspects of blockchain technology. Here are some of the most common degrees among blockchain professionals:

- Computer Science (Bachelor's Degrees, Master's Degrees, Ph.D.).
  This is the most common degree for blockchain professionals, as it provides a strong foundation in programming, algorithms, data structures, and software development—all crucial for blockchain development.
- Information Technology (IT) (Bachelor's Degrees).
  IT degrees cover a broad range of topics related to computing, network security, and systems administration, all of which are relevant to blockchain technology.
- Software Engineering (Bachelor's Degrees, Master's Degrees, Ph.D.).
  This degree focuses on software development methodologies, coding, and system design, which are directly applicable to creating and managing blockchain applications.

- Mathematics (Bachelor's Degrees, Master's Degrees, Ph.D.).
  Mathematics degrees are valuable for blockchain professionals, especially those involved in developing cryptographic algorithms, data analytics, and optimizing blockchain protocols.
- Finance (Bachelor's Degrees, Master's Degrees).
  For blockchain professionals working in areas like cryptocurrency, smart contracts, and decentralized finance (DeFi), a finance degree provides a strong understanding of financial systems and economic principles.
- Economics (Bachelor's Degrees, Master's Degrees).
  Economics degrees can be useful for blockchain professionals involved in tokenomics, market analysis, and the economic impact of blockchain technology.
- Business Administration (Bachelor's Degrees, Master's Degrees).
  Those degrees are relevant for those focusing on the business and strategic aspects of blockchain technology, such as project management, consulting, and blockchain implementation in various industries.

While these degrees provide a solid foundation, blockchain professionals often supplement their education with specialized courses, certifications, and hands-on experience in blockchain technology. This combination of formal education and practical experience is key to succeeding in

3.3 Skill gap Analysis

3.3.1 Identification of Critical Skills & Competencies

Blockchain technology has grown significantly in the European Union (EU), particularly as its applications expand beyond cryptocurrencies into industries such as finance, healthcare, supply chain management, and governance. As businesses and public sector entities across the EU increasingly adopt blockchain, the demand for skilled professionals to develop, implement, and maintain blockchain systems has risen sharply. However, this rapid growth has exposed significant skills gaps in the EU workforce.

Despite that the blockchain is one of the fastest-growing skills in the EU, particularly in countries like Germany, France, and the Netherlands, the demand for blockchain talent extends across the entire continent, as more industries integrate the technology into their operations. A 2021 report by the European Commission and INATBA (International Association for Trusted Blockchain Applications) found that blockchain job openings across Europe had increased by 40% from 2020, with roles in blockchain development, security, and smart contract design being particularly sought after.

As the blockchain ecosystem evolves, the need for skilled professionals who can build, manage, and innovate using this technology has become critical.

Technical Competence, including technical expertise is one of the major strengths of blockchain professionals in the EU. A 2020 Gartner study on blockchain technology adoption highlights the technical skills of EU developers, noting that Europe is one of the leading regions in terms of contributing to blockchain open-source projects. This technical proficiency is particularly evident in the rapidly growing decentralized finance (DeFi) sector, where blockchain professionals are helping to develop new financial applications and services.

Another strength of blockchain professionals in the EU is their broad understanding of how blockchain can be applied across various industries. A 2021 report from the European Commission emphasized that the EU workforce has demonstrated strong competence in deploying blockchain solutions for industries like supply chain management, healthcare, and energy. Professionals in the region are increasingly skilled at translating blockchain's potential into real-world solutions that meet the specific needs of different sectors, demonstrating an ability to integrate technology with business objectives.

EU blockchain professionals have a strong culture of collaboration and open-source contributions, which is crucial for the growth of the global blockchain ecosystem. A 2021 report from the European Blockchain Observatory and Forum highlights the importance of open-source development in Europe, where developers actively contribute to platforms like Ethereum, Hyperledger, and Polkadot. These contributions are critical to the evolution of blockchain technology and enable rapid innovation and problem-solving.

Despite these strengths, blockchain professionals in the EU also face several challenges. Gaps in education, regulation, and interdisciplinary expertise have been noted across the region, and these deficiencies are becoming increasingly evident as the demand for blockchain skills intensifies.

While EU blockchain professionals are technically competent, there is a shortage of advanced expertise in blockchain security. As blockchain adoption accelerates across industries, concerns about security vulnerabilities are growing. A 2021 report by the European Union Agency for Cybersecurity (ENISA) emphasizes the importance of robust security measures in blockchain systems, particularly in light of recent cyberattacks targeting decentralized finance (DeFi) platforms and smart contracts. Security expertise, particularly in areas such as cryptography, digital signatures, and secure coding practices, remains a key weakness in the blockchain talent pool.

Another area of weakness is the lack of interdisciplinary skills and business acumen among blockchain professionals. While developers and engineers are generally technically proficient, a 2020 study by the European Blockchain Observatory and Forum found that many professionals lack the broader business, economic, and strategic understanding necessary to scale blockchain projects effectively. For instance, blockchain's application in tokenization and decentralized governance models requires a deep understanding of economics, game theory, and incentive structures.

Additionally, the gap between technical skills and business needs is becoming more evident as blockchain moves from experimental projects to large-scale implementations. Professionals with the ability to bridge the gap between technical development and business strategy are in short supply, which is particularly problematic as blockchain technology becomes increasingly integrated with other emerging technologies, such as artificial intelligence (AI) and the Internet of Things (IoT).

Many blockchain developers and project managers in the EU lack sufficient knowledge of regulatory compliance and legal frameworks, making it difficult for them to build systems that meet the stringent requirements of industries like finance and healthcare. As a result, businesses often have to rely on external legal advisors or consultants to navigate this complex environment, slowing down project implementation and raising costs.

Despite the growing demand for blockchain skills, the workforce faces several gaps in both availability and preparedness. A 2021 study by the Enterprise Ethereum Alliance found that over 60% of organizations struggle to find blockchain talent with the necessary experience. This shortage is particularly pronounced for senior-level roles, such as blockchain architects and security experts.

Moreover, blockchain's rapid evolution makes it difficult for professionals to keep up with emerging frameworks, protocols, and programming languages regularly entering the market. A 2020 report by Gartner suggests that the constant flux in blockchain technology is a primary reason behind the talent shortage, as educational institutions and training programs struggle to keep up.

3.3.2 Analysis of Skill Proficiency Levels in the Workforce

The blockchain industry in Europe is experiencing rapid growth, but a notable skills gap is emerging as demand for specialized blockchain skills outpaces the available talent pool. This research compares the specific skills needed for various blockchain roles against the current skill set of employees in the EU, highlighting the most significant mismatches.

For blockchain developers, companies require strong programming skills in languages like Solidity, Rust, and Go, as well as experience with blockchain frameworks like Ethereum and Hyperledger. Smart contract developers also need proficiency in tools like Truffle and Hardhat to build and test applications. Furthermore, blockchain architects are expected to have in-depth knowledge of cloud infrastructure, cryptographic protocols, and distributed ledger technology. There is a shortage of developers with hands-on blockchain experience, especially those with knowledge of specific blockchain languages and protocols while many developers have traditional coding experience (in Python, Java, etc.), only a small percentage have experience with blockchain-specific languages. The demand for blockchain-specific coding languages and protocols is far higher than the supply. This skills gap is particularly acute for smart contract developers and blockchain architects, roles that require specialized technical expertise.

Blockchain product managers must understand the technology's unique lifecycle, including, decentralized governance, and blockchain-specific project management tools. Similarly, blockchain project managers must be adept in agile methodologies tailored to blockchain's iterative and community-driven development processes. This role in blockchain often require knowledge of agile practices and blockchain fundamentals, but research from the European Blockchain Partnership (EBP) reveals that most current product managers come from traditional tech backgrounds and lack specific experience with blockchain. Traditional product management skills do not fully transfer to blockchain environments. This results in a need for reskilling as blockchain products often require unique handling, governance, and lifecycle management.

Blockchain analysts and data scientists are required to interpret on-chain data, track trends, and provide insights for investment and business development. Most data analysts in

Europe have experience in traditional data tools (SQL, Tableau) but lack skills in blockchain-specific data management tools. There is a clear lack of blockchain data management expertise. This gap is particularly impactful for blockchain investment firms and analytics companies that rely on insights from on-chain data.

To address these challenges, the European Commission and various private-sector initiatives are investing in blockchain training programs. Upskilling initiatives focusing on blockchain languages, security protocols, and compliance can help reduce the skills gap and better align the EU workforce with the demands of the blockchain industry.

3.3.3 Comparison of Required Skills and Available Skills

The blockchain sector has experienced rapid growth in recent years, driven by advancements in technology and increasing adoption across various industries. This analysis examines the current landscape of blockchain workers in the European Union (EU), focusing on specific skill sets in demand and comparing them to job openings that require those skills.

According to the European Commission's report on digital skills (2023), the EU is home to a growing number of blockchain professionals, estimated at around 200,000. These individuals possess a variety of skills, including smart contract development, blockchain architecture, cryptography, regulatory compliance, data analysis.

The following table outlines the estimated number of blockchain professionals currently available in the EU compared to the number of job openings for each key skill set.

Skill/Role	Current Workers	Job Openings	Supply-Demand Gap	Trend
Smart Contract Development	5,000	12,000	-7,000	High Demand, Low Supply
Blockchain Architecture	4,500	8,500	-4,000	High Demand, Low Supply
Cryptography	3,000	6,000	-3,000	High Demand, Low Supply
Blockchain Data Analysis	2,500	5,500	-3,000	High Demand, Low Supply
Blockchain Compliance	1,200	4,000	-2,800	High Demand, Low Supply
NFT Management	800	2,500	-1,700	Emerging Demand
Blockchain Project Management	2,000	3,500	-1,500	Moderate Demand, Low Supply

3.3.4 Comparison of Skill Profiles and Labor Market Demands

Because of evolvement of Blockchain technologies, various future roles and skills will become critical to its continued development and application across industries. Different kind of roles indicate the interdisciplinary nature of blockchain's future, blending technical, legal, and strategic skills.

Blockchain Developers and Architects: the need for developers skilled in smart contracts, decentralized apps, and blockchain architecture will expand as the blockchain platforms are growing. These roles will require expertise in cryptography, programming languages like Solidity, and understanding decentralized networks.

Legal and Compliance Experts: Blockchain's disruptive impact on industries like finance and supply chains brings regulatory challenges. Legal experts skilled in digital assets, tokenization, and blockchain law will be in demand to navigate evolving regulations in the EU and globally[1].

Data Privacy and Security Specialists: With the rise of blockchain in sectors like healthcare, finance, and supply chain management, professionals who can ensure data integrity and security will be crucial. These specialists will need to address regulatory requirements and develop secure blockchain infrastructures.

Blockchain Governance and Strategy Consultants: As decentralized platforms mature, blockchain governance and management will become essential. Professionals will help develop governance models for blockchain ecosystems, ensuring collaboration across diverse stakeholders.

Blockchain Integration Specialists: Integrating blockchain with existing technologies will be vital for industries looking to adopt the technology. This role involves blending blockchain with cloud services, IoT, and artificial intelligence, creating a seamless digital environment[2].

3.4 Summary & recommendations

The analysis clearly indicates a substantial skills gap in the blockchain workforce within the EU, with high demand for several key roles far outpacing the current supply of skilled professionals. A critical issue is the mismatch between the fast-evolving demands of the blockchain job market and the skills provided by educational institutions. This skills shortage is exacerbated by the limited awareness of blockchain technology and the inadequate training opportunities available. Moreover, there is an urgent need for a comprehensive skill set that includes not only technical expertise related to blockchain but also essential soft skills, such as problem-solving, teamwork, and a customer-oriented mindset. To bridge this gap, stakeholders—including educational institutions, industry organizations, and governments—must collaborate to develop targeted training programs that equip the workforce with the necessary skills to meet the evolving demands of the blockchain sector.

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Prioritized list of skill gaps requiring immediate attention

- **Technical Skills**
  - **Smart Contract Development** – Solidity, Rust, Go, Truffle, Hardhat.
  - **Blockchain Architecture** – Decentralized networks, cryptographic protocols, cloud infrastructure.
  - **Cryptography & Security** – Digital signatures, secure coding, cryptographic protocols.
  - **Blockchain Data Analysis** – On-chain analytics, blockchain-specific data tools.
  - **Regulatory Compliance & Legal Expertise** – Blockchain law, tokenization, compliance frameworks.
  - **Blockchain Integration** – AI, IoT, cloud computing integration with blockchain.

- Soft Skills
  - **Blockchain Project Management** – Agile methodologies, decentralized governance.
  - **Business Acumen & Strategy** – Understanding blockchain's business applications and scalability.
  - **Problem-Solving & Critical Thinking** – Addressing security, governance, and technical challenges.
  - **Collaboration & Communication** – Working with multidisciplinary teams in open-source and corporate environments.

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4 Report from the desk research on ICT for sustainability

Prepared by: Emphasys Centre, Cyprus

4.1 Introduction & Methodology

Description of data sources utilized

This included publicly available digital resources such as:

The data sources used in this research were primarily collected through online research.

- Academic journals and research papers were accessed via online databases (e.g., Google Scholar, PubMed, JSTOR).
- Government websites for official reports, statistics, and policies.
- Industry reports and white papers from recognized organizations and businesses.

Data collection and analysis methods employed

- Identification of Relevant Sources: A set of keywords related to the research topic was used to search for relevant materials across online databases, academic repositories, and websites.
- Inclusion Criteria: Data sources were selected based on their publication date (to ensure the timeliness of information), the credibility of the source, and relevance to the research objectives.
- Screening and Validation: The gathered information was assessed for accuracy, bias, and reliability. Peer-reviewed journals, government publications, and well-established industry reports were prioritized to ensure high-quality data.

Definition of the respective ATI and its key characteristics

ICT plays a vital role in advancing sustainability efforts within the European Union, supporting its environmental, economic, and social goals. The EU emphasizes the importance of digital technologies in tackling issues such as climate change, resource management, and environmental protection. These technologies are integral to initiatives like the European Green Deal and the Digital Decade strategy.

One area where ICT has a significant impact is **energy efficiency and decarbonisation**. Through the use of smart energy grids and better management of renewable energy resources, digital tools optimize energy use in various sectors, including buildings, transportation, and industry, leading to reduced carbon emissions.

ICT also supports the **circular economy**, where the focus is on minimizing waste, reusing materials, and extending product life. Technologies such as blockchain, artificial intelligence, and big data are essential for tracking resources, improving recycling processes, and maximizing resource efficiency.

The push for a **green digital transition** is another priority for the EU. This includes ensuring that data centres and cloud services operate using renewable energy. Digital innovations assist sectors such as agriculture, manufacturing, and transportation by enhancing automation and introducing new sustainable technologies.

In sustainable urban development, **smart cities** are central to the EU's vision. The use of IoT and AI technologies improves traffic management, reduces air pollution, and fosters sustainable mobility, contributing to lower emissions in cities.

Finally, **climate monitoring** and adaptation are key areas where ICT contributes significantly. The collection and analysis of environmental data through satellites, AI, and big data enable better monitoring and forecasting of climate patterns, facilitating more effective policymaking and disaster response.

4.2 Identified roles, jobs, skills & competency profiles

Who is hiring: current & potential employers

- **Tech Companies and Startups**: These firms focus on innovative digital solutions that promote sustainability, such as smart city technologies or energy-efficient infrastructures. Examples include companies developing cloud computing systems with a low carbon footprint or smart mobility services.
- **Energy and Utility Companies**: Renewable energy organisations, such as those involved in solar or wind energy, require ICT professionals to manage smart grids, enhance energy production, and improve overall efficiency.
- **Public Sector and Government Agencies**: European and national institutions working on environmental policies, climate monitoring, or smart city initiatives need ICT specialists for tasks like analyzing climate data or implementing green policies.
- **Sustainability Consultancies**: Consulting firms that provide advice on sustainability strategies frequently rely on data-driven ICT solutions for environmental assessments and impact analysis.
- **Large Multinational Corporations**: To comply with EU sustainability regulations, major companies are increasingly hiring sustainability managers, green IT experts, and environmental data analysts to help reduce their carbon footprint (i.e Coca-Cola).

List of specific roles = professionals working with the respective ATI Career opportunities / jobs/ working positions

- **Smart Grid Engineer**: Focuses on designing and managing advanced energy grids that enhance energy efficiency and reduce waste.
- **IoT Sustainability Specialist**: Implements IoT technologies to monitor energy consumption, lower emissions, and support eco-friendly operations.
- **Sustainability Software Developer**: Creates software tools designed to track environmental impacts and improve resource management practices.
- **AI for Climate Change Scientist**: Utilizes artificial intelligence and machine learning models to predict environmental trends, improve renewable energy usage, and aid in disaster response planning.
- **Cybersecurity for Sustainable Systems Specialist**: Protects green energy infrastructure, ensuring the security of systems like smart grids from cyber risks.

- **Circular Economy IT Consultant**: Advises organizations on using ICT solutions to minimize waste, optimize resources, and extend the lifespan of products.

Profile/description/competency profile and skills list for the most common jobs/roles for the respective ATI

Sustainability Data Analyst:

- **Skills**: Proficiency in data analytics, big data, machine learning, environmental science, and sustainability metrics.
- **Competencies**: Skilled in analyzing and interpreting large datasets, creating sustainability models, and using tools like Python, R, and Power BI.

Green IT Specialist:

- **Skills**: Expertise in energy-efficient IT systems, data centre management, cloud computing, and carbon footprint analysis.
- **Competencies**: Strong understanding of sustainable IT infrastructure, architecture, and renewable-powered data centres.

Smart City Planner:

- **Skills**: Urban planning, IoT integration, environmental impact assessments, and GIS.
- **Competencies**: Ability to design eco-friendly city infrastructure, proficiency in smart city technologies, and familiarity with regulatory compliance.

Renewable Energy Systems Engineer:

- **Skills**: Engineering, smart grid technologies, renewable energy systems, and data analytics for improving energy efficiency.
- **Competencies**: Expertise in managing energy systems, integrating renewable sources, real-time monitoring, and optimization.

Common degrees of professionals in the respective ATI

- **Computer Science with a Focus on Sustainability**: Concentrates on green IT, energy-efficient technologies, and digital tools designed to tackle environmental issues.
- **Environmental Engineering**: Focuses on solving environmental problems through technology, incorporating ICT for the development of smart systems.
- **Data Science with Environmental Applications**: Specializes in data analytics, AI, and big data for monitoring and mitigating environmental impacts.
- **Urban Planning with Smart City Development**: Merges urban design principles with technology to create sustainable, tech-enabled cities.
- **Renewable Energy Engineering**: Prepares professionals to maximize the efficiency of renewable energy sources using smart technologies.

4.3 Skill gap Analysis

4.3.1 Identification of critical skills & competency

The need for ICT professionals with sustainability knowledge highlights several critical skills for Europe's shift to a **green and digital economy**. These skills can be categorised into technical digital expertise, sustainability knowledge, and interdisciplinary competencies that bridge both areas.

Digital skills are crucial in supporting sustainability initiatives. For instance, in data analytics and AI, experts manage large datasets to track environmental conditions, forecast climate changes, and measure sustainability metrics. IoT and smart technology integration are also essential, as deploying IoT sensors enhances energy management, waste control, and smart city development. Meanwhile, ensuring cybersecurity for green systems is increasingly important, as it safeguards infrastructures like smart grids and renewable energy systems from cyber threats. In software development, professionals focus on creating tools that help track carbon emissions, improve energy efficiency, and optimize resource usage.

Equally important are **sustainability skills**. Conducting environmental impact assessments is essential for ICT professionals, enabling them to assess how technology projects affect the environment and create solutions that minimize these impacts. Understanding the circular economy is valuable, as it facilitates ICT-driven processes that enhance recycling, resource recovery, and waste reduction. Expertise in energy efficiency and green IT—such as managing sustainable data centres, energy-efficient hardware, and low-carbon cloud computing—is also vital for lowering the carbon footprint of digital technologies.

Finally, **interdisciplinary skills** are key to connecting ICT and sustainability. Strong project management abilities are necessary to oversee complex projects that integrate technology with environmental objectives. Professionals also need a solid grasp of regulatory frameworks, especially EU regulations focused on carbon reduction, energy efficiency, and data privacy. Additionally, innovative problem-solving skills are essential for tackling sustainability challenges, such as decarbonizing industries, optimizing smart grids, and improving waste management with advanced ICT solutions.

4.3.2 Analysis of skill proficiency levels in the workforce;

- **Advanced Digital Skills**: Although the EU has made strides in cultivating a digitally proficient workforce, there remains a gap in professionals with advanced expertise, particularly in cutting-edge areas such as artificial intelligence, the Internet of Things, and data analytics. According to the European Commission's DESI report, 57% of companies face challenges in recruiting for ICT-related positions.
- **Sustainability Expertise**: Similarly, there is a shortage of workers with strong knowledge in sustainability, particularly in industries such as renewable energy, smart grids, and the circular economy. Many ICT professionals lack adequate training in environmental science and sustainability practices, limiting the integration of green strategies into digital innovations.
- **Cross-Disciplinary Competence**: A significant challenge lies in merging digital and environmental skills. For instance, while data scientists may excel in analytics, they

often lack familiarity with sustainability metrics. Conversely, engineers working in green energy may not possess the necessary digital skills to implement smart technologies effectively.

4.3.3 Comparison of required skills and available skills; comparison of skill profiles and labour market demands

Comparison of Required Skills and Available Skills

The gap between labour market needs and the skills available is especially evident in the fields of ICT and sustainability. Notable areas of this discrepancy include:

AI and Big Data for Sustainability: There is a significant need for AI experts to engage in environmental initiatives, such as climate modelling and optimizing renewable energy systems. However, the candidates proficient in both AI and sustainability is quite limited.

IoT for Smart Cities and Grids: The EU is making substantial investments in smart cities and grids, yet many municipalities and utility companies struggle to find personnel who possess both IoT integration skills and urban planning knowledge essential for large-scale implementation.

Green IT and Energy-Efficient Systems: As tech companies strive to enhance the energy efficiency of their IT infrastructures, there is a notable shortage of Green IT specialists who are well-versed in both energy management and cloud technologies.

Circular Economy and Digital Tools: There is a high demand for professionals who understand the circular economy and can apply ICT solutions, such as blockchain to enhance supply chain transparency or automation in waste management. However, the lack of hybrid skills that merge ICT with circular economy concepts creates a significant obstacle for businesses looking to adopt sustainable practices.

Comparison of Skill Profiles and Labour Market Demands

To gain a clearer understanding of the skills mismatch, it's important to examine the profiles of current ICT professionals concerning the market demand for sustainability-focused roles:

ICT Workforce: Most ICT professionals have expertise in software development, network engineering, or cloud technologies. However, there is a notable lack of individuals skilled in areas that directly contribute to sustainability, such as smart grids, energy efficiency, and environmental data analytics.

Labour Market Demand: Sectors like renewable energy, transportation, and construction increasingly require ICT specialists who can facilitate carbon reduction efforts through digital transformation. In these industries, professionals need to design systems that not only operate digitally but also support sustainability objectives, such as lowering energy consumption, reducing emissions, and optimizing resource utilization.

4.4 Summary & recommendations

Key findings regarding skill and competency gaps

Mismatch of Skills: There is a significant gap between the skills available in the workforce and the skills needed for emerging roles that integrate ICT and sustainability. Many professionals have strong technical skills but lack expertise in sustainability practices.

Limited Interdisciplinary Knowledge: Professionals often possess either ICT skills or sustainability knowledge but rarely both. This lack of interdisciplinary expertise prevents effective collaboration in sectors crucial for achieving sustainability goals.

Insufficient Advanced Digital Skills: The demand for advanced digital skills in areas such as AI, big data, and IoT is growing, yet the current workforce struggles to meet this demand, especially in relation to sustainability applications.

Underrepresentation in Sustainability Roles: There is a shortage of professionals in sustainability-specific roles that require a combination of ICT skills and environmental knowledge, particularly in fields like renewable energy, smart city planning, and circular economy management.

Recommendations for addressing identified gaps

Curriculum Development: Educational institutions should revise their curricula to incorporate interdisciplinary programs that combine ICT and sustainability training. Degrees that focus on Environmental Data Science or Green IT should be prioritized.

Industry Collaboration: Partnerships between educational institutions and industry stakeholders can facilitate the development of training programs that align with market needs. Internship and co-op opportunities should be expanded to provide real-world experience.

Upskilling and Reskilling Initiatives: Existing professionals should be encouraged to participate in upskilling and reskilling programs focused on sustainability competencies. Governments and organizations should offer incentives for continuous learning.

Awareness Campaigns: Initiatives to raise awareness of the importance of sustainability in ICT careers can motivate students and professionals to pursue relevant education and training.

Prioritized list of skill gaps requiring immediate attention

Data Analytics for Sustainability: Skills related to using big data and analytics tools to address environmental challenges.

IoT and Smart Technologies: Proficiency in integrating IoT solutions in energy and urban planning contexts.

Circular Economy Knowledge: Understanding circular economy principles and how to implement them through ICT.

Green IT Practices: Knowledge of energy-efficient computing practices and sustainable data management.

Cybersecurity for Green Systems: Skills to protect digital infrastructures that support sustainable initiatives from cyber threats.

Strategies for addressing identified skill gaps

Develop Interdisciplinary Programs: Encourage universities to create joint programs that combine ICT and sustainability training, ensuring graduates are equipped with the necessary skills for the green transition.

Implement Continuous Professional Development (CPD): Create CPD programs tailored to existing professionals, focusing on the integration of ICT and sustainability practices in their work.

Enhance Online Learning Platforms: Expand access to online courses that cover emerging skills in sustainability and ICT, allowing flexibility for professionals to learn at their own pace.

Promote Industry Certifications: Develop certifications in key areas like Green IT and sustainable data practices to provide professionals with recognized credentials that demonstrate their expertise (i.e microcredentials).

Foster Collaboration Among Stakeholders: Engage government bodies, educational institutions, and industry leaders in collaborative initiatives aimed at addressing skill shortages and aligning training with market demands. For example, establishing synergies and collaborations amongst organisations through new and established forums such as the CoVE forum.

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5 Report from the desk research on Industry 5.0

Prepared by: SLOVAKIA, Astra

5.1 Introduction & methodology

Description of data sources utilized; Data collection and analysis methods employed

While gathering the inputs for this report we checked on the following:

- Job postings and skills requirements: we analysed job postings in various industries to identify the skills that employers are most frequently seeking; then we compared this data to the skills that are commonly listed on resumes and profiles of job seekers.
- Industry reports and surveys: we reviewed reports and surveys conducted by organizations such as the World Economic Forum, McKinsey & Company, Deloitte, Gartner, and the European Commission. These reports often identify skills gaps in the workforce.
- Educational institutions: we checked the skills being taught in various programs and the skills that employers are seeking in graduates.
- Professional development organizations: Organizations that focus on professional development and skills training often identify skills gaps in the workforce.

Definition of the Industry 5.0 and its key characteristics

European industry is a key driver in the economic and societal transitions. In order to remain the engine of prosperity, industry must lead the digital and green transitions. This approach provides a vison of industry that aims beyond efficiency and productivity as the sole goals, and reinforces the role and the contribution of industry to society.

Industry 5.0 is still constantly developing, so experts and researchers from different perspectives have given different definitions for the discussion of this.

Industry 5.0:

- places the wellbeing of the worker at the centre of the production process and uses new technologies to provide prosperity beyond jobs and growth while respecting the production limits of the planet.
- complements the existing "Industry 4.0" approach by specifically putting research and innovation at the service of the transition to a sustainable, human-centric and resilient European industry.

In the EU words: “Industry 5.0 is characterized by going beyond producing goods and services for profit. It shifts the focus from the shareholder value to stakeholder value and reinforces the role and the contribution of industry to society. It places the well-being of the worker at the centre of the production process and uses new technologies to provide prosperity beyond jobs and growth while respecting the production limits of the planet.”

The vision for Industry 5.0 builds upon the technological and business principles of Industry 4.0 with a focus on three ESG (environmental, social, and governance) tenets: Human Centricity, Resilience, and Sustainability.

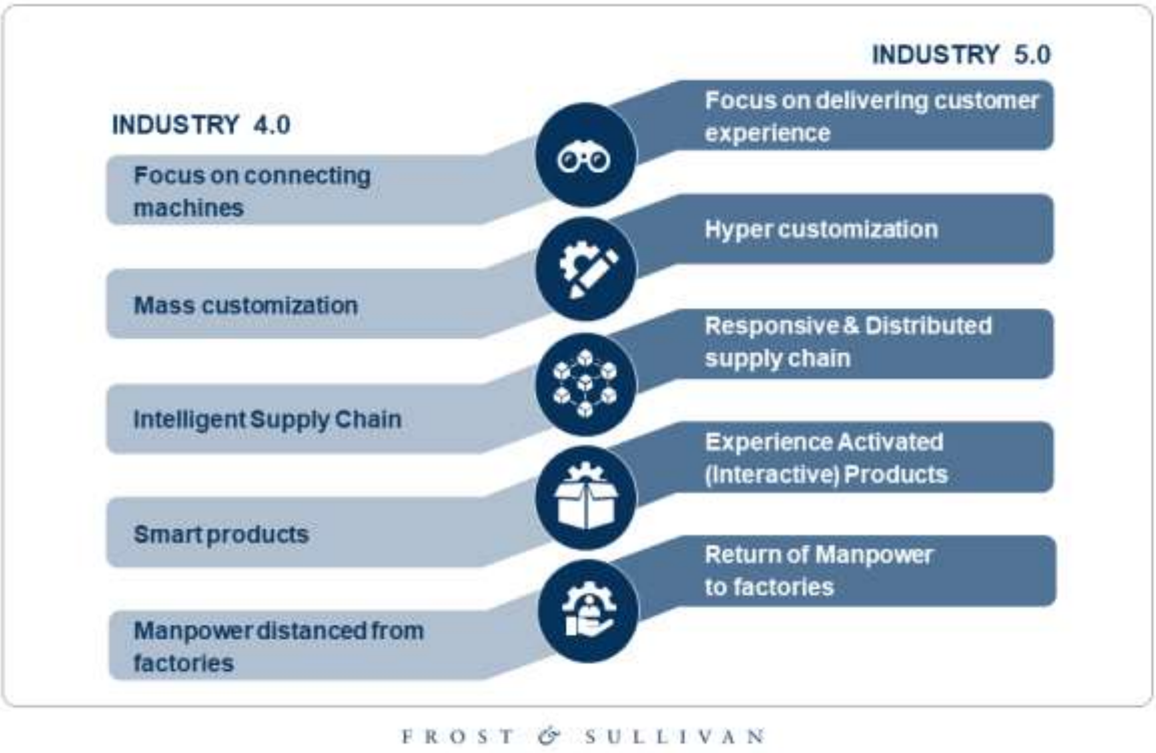
Picture 1 The 3 pillars of Industry 5.0 according to the EC – human-centric, resilient and sustainable

Human-Centric Approach: Industry 5.0 emphasizes designing technology and workflows that prioritize workers' needs and well-being. Rather than viewing employees as replaceable, it values their creativity and problem-solving, fostering meaningful jobs where people feel engaged and purposeful.

Resilience: Industry 5.0 focuses on resilience—industries and workers must adapt and thrive amid challenges like economic shifts or global crises. Resilient industries can maintain growth and job security even in tough times.

Sustainability: Sustainability in Industry 5.0 includes environmental and workforce aspects. It's about creating secure jobs and fostering a positive impact on society and the planet, ensuring long-term growth and sustainability.

Highlights of Industry 5.0 compared to Industry 4.0



Picture 2 Industry 4.0 and Industry 5.0 compared in the view of Frost & Sullivan Source

5.2 Identified roles, jobs, skills & competency profiles

List of specific roles in Industry 5.0

In general, nowadays skills needs are evolving as fast as technologies. European industries are struggling with skills shortages and educational and training institutions are unable to respond to this demand. This applies to both expert level and general digital skills requirements. On the supply side, young people do not feel adequately equipped with the skills needed for the future labour market.

Digital skills are not the only skills that will be pertinent for industry 5.0. The World Manufacturing Forum has identified a top-10 of skills that will be needed in future manufacturing. Surprisingly, only four of them refer to digital skills: "digital literacy, AI and data analytics," "working with new technologies," "cybersecurity", and "data-mindfulness". The remaining skills are more transversal skills linked to creative, entrepreneurial, flexible and open-minded thinking

Picture 3 World Manufacturing Forum's ten skills for the future of manufacturing © World Manufacturing Forum

Based on our desk research we provide some of the Industry 5.0 job roles

- Human-Technology Integration Engineer: Implants human skills, logic, and creativity into advanced technology systems.
- Digital Thread Applications Engineer
- AI Ethics Compliance Specialist: Ensures artificial intelligence (AI) systems in manufacturing settings adhere to increasingly stringent ethical guidelines and government regulations.
- Personalized Product Design Engineer: Specializes in the rapid production of highly personalized products leveraging AI, additive manufacturing, and other advanced manufacturing technology.
- Smart Factory Supply Chain Integration Engineer: Integrates Internet of Things (IoT), AI, blockchain and other emerging technologies to maximize supply chain resilience and efficiency in smart factories.

- Cobotics System Analyst: Analyses and improves the efficiency of collaborative robots working alongside humans in the manufacturing workforce.
- Digital Twin Engineer: Creates and manages virtual replicas of physical entities for process optimization and predictive maintenance.
- Robotics System Integrator: Engineers, deploys and maintains advanced robotic systems to work seamlessly with humans and technology.
- Interactive Technical Documentation Developer: Optimizes technical documentation for accessibility, understanding, and user engagement.
- Knowledge Graph Engineer: Constructs and maintains knowledge graphs from interlinked systems and entities.
- Documentation Quality Control AI Engineer: Engineers AI systems that automatically review tech docs for accuracy, usability, and completeness.
- Digital Twin Validation Engineer: Conducts testing and validation of virtual replicas of physical entities.
- Cyber-Physical Systems Engineer: Optimizes digital manufacturing technology with physical processes.
- Digital Thread Analyst: Ensures end-to-end visibility and traceability of products and processes.
- Augmented Reality Technical Documentation Developer: Leverages augmented reality (AR) in technical documentations and instructional content.

Based on the search results, the table below offers an overview of the ten most requested working positions in the sector of Industry 5.0 within the European Union, along with the current number of job offers for each position.

Table 1 The most requested working positions in the sector of Industry 5.0

Position	Number of Job Offers
1. Automation Engineer	12,500
2. Data Analyst	10,300
3. Project Manager	9,800
4. Human-Robot Interaction Specialist	7,600
5. AI and Machine Learning Engineer	8,200
6. Cybersecurity Specialist	6,900
7. Sustainability Consultant	5,500
8. Digital Transformation Manager	4,800
9. Industrial IoT Specialist	4,200
10. Software Developer (Industry Focused)	3,900

Insights:

- Automation Engineer: This role remains highly sought after due to the increasing automation in manufacturing processes.
- Data Analyst: As data-driven decision-making becomes essential, demand for data analysts continues to grow.
- Project Manager: With numerous projects aimed at integrating new technologies in Industry 5.0, skilled project managers are crucial.
- Human-Robot Interaction Specialist: This emerging role focuses on optimizing collaboration between humans and machines.
- AI and Machine Learning Engineer: The integration of AI technologies into industrial processes drives demand for specialists in this area.

The most common jobs/roles for the Industry 5.0

For the purpose of this report we have chosen, based on the desk research and not to duplicate the roles which are reported under the other chosen ATIs, the 3 roles/jobs that seem to be the most frequent ones in the field of Industry 5.0:

5.2.1 Human-Robot Interaction (HRI) Specialist

This role is critical in fields such as manufacturing, healthcare, and logistics, where human-robot collaboration is essential for efficiency and safety. It is increasingly important as companies look to integrate Industry 5.0 concepts into their operations, with an emphasis on human-centric technology and sustainability.

A Human-Robot Interaction (HRI) Specialist focuses on optimizing the interaction between humans and robotic systems, ensuring that machines can effectively and intuitively assist or collaborate with people. They work in various industries, including manufacturing, healthcare, automotive, and education, developing systems where humans and robots can work together harmoniously. This role emphasizes making robotic systems more responsive to human needs, communication, and behaviour, enhancing productivity and safety.

- Key Responsibilities
  - Design and develop interaction systems: create intuitive interaction methods (gesture, voice, or visual cues) to facilitate seamless communication between humans and robots.
  - Behavioural analysis: understand human behaviour and ergonomics to inform robot design and functionality.
  - Safety and usability: ensure robots function in safe and user-friendly ways within collaborative environments.
  - Testing and optimization: test robotic systems in real-world environments and optimize interaction protocols based on user feedback.
  - Collaborate with multidisciplinary teams: work closely with engineers, designers, and AI specialists to refine robot interaction models.

- Competency Profile & required skills
  - Interpersonal and Communication Skills: Able to understand human psychology and behaviour in a work environment to design better interaction models.
  - Technical Expertise: Strong knowledge of robotics systems, programming, AI, machine learning, and human factors engineering.
  - Problem-Solving: Ability to troubleshoot interaction issues between humans and robots, especially in dynamic and unpredictable environments.
  - User-Centred Design: Expertise in designing robotic systems that prioritize human needs, ease of use, and safety.
  - Teamwork and Collaboration: Ability to work with a team that includes designers, engineers, and safety experts to develop comprehensive interaction systems.
  - Human Factors Engineering: Knowledge of ergonomics and cognitive psychology to create effective human-machine interfaces.
  - Programming Skills: Experience with languages such as Python, C++, and ROS (Robot Operating System).
  - User Interface (UI) and User Experience (UX) Design: Expertise in designing interfaces that humans can easily and intuitively operate.
  - Machine Learning and AI: Ability to apply AI techniques to enhance robot decision-making and responsiveness to human actions.
  - Robotics Knowledge: Proficiency in robotic systems, sensors, actuators, and their integration with human operations.
  - Data Analysis: Skill in analysing data from human-robot interactions to improve functionality and efficiency.
- Additional Skills:
  - Communication and presentation: ability to explain complex robotics systems in simple terms to end-users.
  - Prototyping: experience in creating and testing prototypes of human-robot interaction models.
  - Ethics and safety consideration: awareness of ethical concerns and safety protocols when developing interaction systems.

Human-Robot Interaction (HRI) is a multidisciplinary field that combines elements of computer science, engineering, psychology, and sociology. To become an HRI specialist, specialists would typically need a strong foundation in one of these fields, along with specialized coursework in HRI.

■ Educational Background & Common degrees of professionals

Table 2 Overview on study branches, programs & degrees typical for HRI professional

Computer Science or Engineering	▪ Bachelor's Degree: A bachelor's degree in computer science, computer engineering, electrical engineering, or a related field is a solid foundation for HRI. ▪ Master's Degree: A master's degree in robotics, artificial intelligence, human-computer interaction, or a related field can provide deeper expertise. ▪ Doctoral Degree: A PhD can equip you with advanced research skills and in-depth knowledge of HRI principles.
Psychology or Sociology	▪ Bachelor's Degree: A bachelor's degree in psychology or sociology can provide valuable insights into human behaviour and social interaction. ▪ Master's Degree: A master's degree in human-computer interaction or cognitive science can further enhance your understanding of human-machine interactions.
Interdisciplinary Programs	HRI-Specific Programs: Some universities offer specialized HRI programs that combine elements of computer science, engineering, psychology, and sociology.

■ Who is hiring: current & potential employer, industries

Human-Robot Interaction (HRI) specialists are in high demand across a variety of industries. Here are some common sectors where they find employment:

- Technology Companies: Robotics Companies: Companies specializing in robotics and automation, such as ABB, FANUC, and KUKA.
- AI Companies: Companies developing artificial intelligence and machine learning technologies.
- Tech Giants: Major tech companies like Google, Amazon, and Microsoft often have research teams focused on HRI.
- Research Institutions & universities: Universities with robotics, computer science, or human-computer interaction departments often employ HRI specialists for research and teaching.
- Government Research Labs: Government-funded research institutions may focus on developing HRI applications for various sectors, such as healthcare, defence, or manufacturing.
- Automotive Industry: Automakers are increasingly using robots in manufacturing processes, creating a demand for HRI specialists.

- Electronics Manufacturing: Companies in the electronics industry use robots for assembly, packaging, and other tasks.
- Logistics and Supply Chain: HRI can be applied to improve efficiency and safety in logistics and supply chain operations.
- Healthcare
- Medical Robotics: Companies developing medical robots for surgery, rehabilitation, or patient care.
- Assistive Technology: Organizations developing assistive technologies for people with disabilities.
- Other Sectors
- Entertainment: Companies developing interactive robots for entertainment or education.
- Service Industry: Hotels, restaurants, and retail stores may use HRI to improve customer service.

The specific sectors where HRI specialists find employment will continue to evolve as technology advances and new applications for robots emerge.

5.2.2 Digital Thread Applications Engineer

This is a critical role in ensuring the end-to-end integration and traceability of data throughout the entire product lifecycle, from design to manufacturing and maintenance. This role bridges the gap between physical processes and digital technology, focusing on enhancing product visibility and optimizing manufacturing operations through the use of connected data. These engineers typically work in sectors such as aerospace, automotive, manufacturing, and Industry 4.0/5.0 technologies. This profile requires a combination of strong technical expertise, familiarity with advanced technologies, and the ability to integrate systems across the entire product lifecycle to optimize operations and product performance

Key responsibilities

- Develop and implement digital thread solutions that connect data across various stages of the product lifecycle.
- Ensure seamless communication between design, production, and maintenance systems using connected data architectures.
- Collaborate with cross-functional teams (engineering, IT, operations) to enhance data traceability and product lifecycle management (PLM).
- Analyze and optimize data flows within and across organizations to enhance operational efficiency.
- Ensure compliance with industry standards and integration of emerging technologies like IoT, AI, and machine learning.
- Integrate data/models from multiple disciplines, such as given below, to build real and live digital threads:
  - SysML/UAF/UML modeling tools, including SysML v2
  - Requirements management tools
  - Hardware design and development, such as PLM, CAD/CAE systems

- Software design and development, such as ALM, Software Version Control, and IDE systems
- Analysis and Simulation environments
- Verification and Test management systems
- Real-time Data Streams and Databases
- Data Science and Notebook platforms.

Competency profile & required skills

- Technical skills
  - Ability to build and execute models in engineering tools related to Systems Modelling, PLM, CAD/CAE, Simulation, Verification/Test, Software Development, or Requirements management.
  - Ability to work directly with customers and deliver project work, such as software, engineering models, reports, and whitepapers.
  - Excellent written and oral communication skills.
  - Excellent problem-solving and analytical thinking skills
  - An aptitude and eagerness to learn new technologies and improve skill sets
  - An attitude to genuinely help people, to work patiently with them, and be their superhero.
  - Product Lifecycle Management (PLM): Expertise in PLM systems like Siemens Teamcenter, Dassault Systèmes' ENOVIA, or PTC Windchill; Understanding of digital twins, BOM (Bill of Materials), and data management.
  - Data Integration and Analytics: Proficiency in integrating systems such as ERP (Enterprise Resource Planning) and MES (Manufacturing Execution Systems); Skills in using data analytics platforms and managing large datasets to track product performance.
  - Programming and Scripting: Familiarity with languages such as Python, Java, or C++ to automate processes.
  - CAD and Digital Design: Familiarity with CAD software and the ability to interact with design teams to streamline the digital thread from design to production.
  - Cloud Computing: cloud platforms (e.g., AWS, Azure) to host and manage data solutions; Proficiency in cloud-based digital thread applications that offer real-time data access.
  - Systems Engineering and Architecture: Understanding of IoT, cyber-physical systems, and digital twin architectures; Ability to design and develop comprehensive digital frameworks that integrate across departments.
  - Cybersecurity: Knowledge of cybersecurity practices related to the digital thread to ensure data integrity and security across the product lifecycle.

- Soft Skills:
  - Communication:
  - Ability to explain complex digital concepts to non-technical stakeholders.
  - Strong written and verbal communication skills to collaborate across teams.

- Project Management: Experience managing cross-functional projects and ensuring that digital thread solutions meet organizational goals. Familiarity with Agile or similar project management methodologies.
- Problem-Solving: Analytical skills to identify and address bottlenecks in digital data flows. Ability to troubleshoot integration issues and optimize data visibility across the product lifecycle.

Educational Background & Common degrees of professionals

Bachelor's or master’s degree in mechanical engineering, computer science, electrical engineering, or systems engineering, computer engineering, robotics, manufacturing, or industrial engineering.

5.2.3 Digital Twin Engineer

A Digital Twin Engineer is responsible for creating and managing virtual models of physical systems, processes, or products. These digital replicas (or twins) are used to monitor, simulate, and optimize the performance of the corresponding real-world entities. The role involves using advanced data analytics, machine learning, and simulation techniques to enhance operational efficiency, predict maintenance needs, and drive innovation.

This role often requires experience in simulation engineering, IoT integration, or data analytics, depending on the specific industry focus.

- **Key Responsibilities**:
  - Designing digital twins: develop and integrate virtual models of physical assets using data from IoT sensors and simulations.
  - Data integration: ensure that data from physical systems is effectively integrated into the digital twin, maintaining real-time accuracy.
  - Optimization & simulation: use simulations and predictive modelling to improve system performance, identify potential failures, and optimize processes.
  - Collaboration with engineering teams: work closely with mechanical, electrical, and software engineers to ensure that the digital twin accurately reflects the physical system.
  - Maintenance and updates: continuously update the digital twin as real-world systems evolve and new data is available.
- **Competency profile**
  - Technical Expertise: Strong knowledge of system modelling and simulation tools (e.g., Simulink, ANSYS); Proficiency in IoT technologies for real-time data collection and integration; Familiarity with data analytics, machine learning, and predictive maintenance algorithms.
  - Analytical and Problem-Solving Skills: Ability to analyze large datasets and use insights to optimize system performance; Creative problem-solving to address complex system interactions between digital twins and physical systems.
  - Communication and Collaboration: Excellent collaboration skills with multidisciplinary teams (e.g., engineers, IT specialists, data scientists); Ability to explain technical concepts to non-technical stakeholders and ensure alignment between teams.

- Adaptability: Comfort in adapting to new technologies and methodologies as digital twin technology evolves.
- Project Management: Ability to manage projects that involve the integration of multiple systems and require alignment of cross-functional teams.

Skills required

- Programming and Scripting: Proficiency in programming languages such as Python, C++, and Java, used for integrating and analysing system data; Experience with software frameworks for simulation and modelling (e.g., MATLAB, Simulink).
- Data Analytics and AI: Knowledge of data analysis tools (e.g., R, Python, PowerBI) and machine learning techniques for predictive modelling and optimization; Proficiency in data integration platforms like Kafka, Hadoop, or other big data tools.
- IoT and Real-Time Systems: Experience in working with IoT sensors and devices to capture real-time data from physical systems; Understanding of network protocols and edge computing used in industrial IoT setups.
- Simulation Software: Familiarity with simulation software (e.g., ANSYS, Dymola) and CAD systems for creating virtual replicas.
- Cloud Computing and Cybersecurity: Experience with cloud platforms like AWS, Azure, or Google Cloud for hosting digital twins; Understanding of cybersecurity practices to ensure the security of digital models and data streams.

Emerging Skills

- Digital twin lifecycle management: Understanding the entire lifecycle of a digital twin, from creation to maintenance and updates.
- Ethical considerations: Awareness of the ethical implications of digital twins and ensuring responsible use.
- Interdisciplinary collaboration: Ability to work effectively with teams from various backgrounds, including engineers, data scientists, and domain experts.

Educational Background & Common degrees of professionals

A Digital Twin Engineer typically holds a degree in fields such as:

- Mechanical Engineering
- Electrical Engineering
- Computer Science
- Data Science or a related field

For a Digital Twin Engineer, the educational background typically comes from specific branches and programs that provide both a strong technical foundation and specialized knowledge in system modelling, data analytics, and digital technologies. In the Table below there are some specific study branches and programs relevant to this role.

Table 3 Overview on study branches, programs & degrees typical for Digital Twin Engineers

Mechanical Engineering (with a focus on simulation and modelling)	BSc/MSc in Mechanical Engineering BEng/MEng in Mechatronics MSc in Advanced Engineering Design
Electrical Engineering and Control Systems	BSc/MSc in Electrical Engineering MSc in Control Systems Engineering
Computer Science (with a focus on data analytics, AI, and simulation)	BSc/MSc in Computer Science MSc in Data Science MSc in Artificial Intelligence
Systems and Control Engineering	MSc in Systems and Control MSc in Cyber-Physical Systems
Data Science and Artificial Intelligence	MSc in Data Science MSc in Big Data & Business Analytics MSc in Machine Learning and Artificial Intelligence
Industrial Engineering	MSc in Industrial Engineering and Operations Management MSc in Smart Manufacturing and Digital Industry
Information Technology with IoT Specialization	MSc in Internet of Things (IoT) MSc in Smart Systems
Robotics and Automation	MSc in Robotics Engineering MSc in Autonomous Systems

These programs equip students with the necessary skills in system modelling, data analytics, simulation technologies, and IoT integration, which are all fundamental to the work of a Digital Twin Engineer.

- **Who is hiring: current & potential employer, industries**:
  - Manufacturing: For process optimization and predictive maintenance of machinery.
  - Automotive: To simulate and test vehicle performance in various conditions.
  - Healthcare: For creating digital models of patients or medical devices.
  - Energy: To optimize the operation and maintenance of power plants and renewable energy systems.

5.2.4 Industry 5.0 Integration Consultant EMERGING WORKING POSITION

Industry 5.0 Integration Consultants are professionals who help organizations implement and leverage Industry 5.0 technologies to enhance their operations, productivity, and competitiveness. They bridge the gap between technology and business strategy, ensuring that new technologies are integrated effectively and aligned with organizational goals.

Typical job responsibilities

- Needs assessment: Identifying an organization's specific needs and goals for Industry 5.0 implementation.
- Technology selection: Selecting appropriate technologies and platforms to support Industry 5.0 initiatives.
- Integration planning: Developing a roadmap for integrating new technologies into existing systems.
- Project management: Overseeing the implementation of Industry 5.0 projects, ensuring they are completed on time and within budget.
- Change management: Supporting organizational change and addressing resistance to new technologies.
- Data analysis: Analysing data to identify opportunities for improvement and optimization.
- Training and education: Providing training and support to employees to help them adapt to new technologies.

Core competencies and skills

- Technical skills:
  - Deep understanding of Industry 5.0 principles: A solid grasp of the key concepts and technologies driving Industry 5.0, such as cyber-physical systems, Internet of Things (IoT), artificial intelligence (AI), and big data analytics.
  - Technology expertise: Proficiency in various technologies relevant to Industry 5.0, including cloud computing, automation, robotics, and data science.
  - Systems integration skills: Ability to integrate different technologies and systems into a cohesive solution.
  - Project management: Strong project management skills to plan, execute, and monitor Industry 5.0 integration projects.
  - Change management: Understanding of how to manage organizational change and resistance to new technologies.
- Soft skills
  - Strong communication skills: Ability to effectively communicate with stakeholders at all levels, including technical and non-technical personnel.
  - Problem-solving and analytical skills: Ability to identify challenges, analyze data, and develop solutions.
  - Interpersonal skills: Excellent interpersonal skills to build relationships and collaborate with diverse teams.
  - Adaptability: Ability to adapt to new technologies and changing business environments.

- Business acumen: Understanding of business processes and how technology can improve them.

Educational Background & Common degrees of professionals

While there is no specific degree or certification required for this role, a background in engineering, computer science, information technology, or business administration is often preferred. Additionally, experience in consulting, project management, or a related field can be beneficial.

5.3 Skill gap Analysis

5.3.1 For HRI specialist

Human-Robot Interaction (HRI) Specialists need a broad array of technical competencies to efficiently design, build, and implement human-robot interfaces. Considering present-day advancements and industry needs, the following competencies are deemed essential for success and the gaps were identified there:

- Robotics: A solid understanding of robotics principles, including kinematics, dynamics, and control systems, is essential for designing and programming robots.
- Artificial Intelligence (AI): Proficiency in AI algorithms, machine learning, and natural language processing is crucial for enabling robots to interact with humans in a natural and intuitive way.
- Human-Computer Interaction (HCI): Knowledge of HCI principles, user experience design, and usability testing is necessary to create robots that are easy and enjoyable for humans to interact with.
- Cognitive Science: Understanding human cognition, perception, and decision-making processes is essential for designing robots that can effectively communicate and collaborate with humans.

These skills are interconnected and essential for the successful development and deployment of HRI systems.

Table 4 Available and demanded skills: Skill gaps for HRI expert

Skills	Currently Available	Demanded	Skill Gap
Robotics	Basic understanding of robotics principles Familiarity with kinematics and control systems at a foundational level	Solid understanding of robotics principles including kinematics, dynamics, and control systems	Significant gaps in advanced robotics knowledge and application in real-world scenarios
Artificial Intelligence (AI)	Basic knowledge of AI concepts Limited experience with machine learning algorithms	Proficiency in AI algorithms, machine learning, and natural language processing	Insufficient proficiency in advanced AI techniques necessary for effective human-robot interaction
Human-Computer Interaction (HCI)	Basic understanding of HCI principles Limited experience in user experience design	Knowledge of HCI principles, user experience design, and usability testing	Lack of comprehensive knowledge in user-centered design and evaluation techniques
Cognitive Science	Limited understanding of human cognition and perception	In-depth knowledge of cognitive processes relevant to human-robot collaboration	Insufficient understanding of cognitive science principles that inform robot design and interaction
Soft Skills	Basic teamwork and communication skills Limited experience in interdisciplinary collaboration	Strong communication skills Ability to work effectively in interdisciplinary teams	Lack of strong communication and leadership skills necessary for effective teamwork in HRI projects
Social Skills	Awareness of human factors in design Limited understanding of user-centred design principles	In-depth knowledge of social interaction dynamics between humans	Insufficient understanding of advanced social interaction principles critical for effective HRI

5.3.2 Digital Thread Applications Engineer

Table 5 Available and demanded skills for Digital Thread Application Engineer

Skill	Currently available	Demanded
Product Lifecycle Management (PLM) Systems	Many professionals have experience in traditional CAD or manufacturing SW but lack in-depth knowledge of modern PLM systems like Siemens Teamcenter, PTC Windchill, or Dassault Systèmes ENOVIA.	Employers need candidates who can manage end-to-end visibility of product data and integrate it across departments. The gap is often in advanced usage of PLM tools for data synchronization, integration with ERP/MES systems, & maintaining traceability across the product lifecycle
Data Integration and Interoperability	Engineers are skilled in data analysis but lack expertise in interoperability between diverse systems (e.g., ERP, MES). The complexity of integrating different data systems across supply chains is often overlooked in education or training programs	There is high demand for engineers who can connect disparate data sources and ensure smooth data flow across a product's lifecycle. Employers are seeking those proficient in system integration and API knowledge, which is a gap for many in the workforce.
Cybersecurity	Cybersecurity is often not a core competency here, despite its growing importance. Many professionals lack a deep understanding of security protocols and practices relevant to digital manufacturing data	Employers emphasize secure data handling across the digital thread to protect sensitive product information. This is a major gap, as employers need engineers who understand cyber-physical system vulnerabilities & how to implement protective measures.
Systems Engineering & IoT Integration	There is often limited understanding of systems engineering principles, especially when it comes to integrating IoT devices & sensors with digital threads. Many professionals have expertise in traditional automation or robotics but lack exposure to IoT integration.	Employers are looking for expertise in connecting IoT data streams with digital twins and digital threads to optimize manufacturing operations. The gap lies in the practical application of cyber-physical systems in real-world industrial settings.
Programming Skills	While many engineers have basic programming skills, they often lack proficiency in automation scripting and API integration. Many educational programs still emphasize traditional engineering tools over the coding skills needed to automate and integrate systems.	Companies need professionals with programming knowledge, particularly in Python, Java, or C++, to customize PLM and ERP systems, enabling better process automation. There is also a growing need for skills in cloud computing for managing digital thread data.

Skill	Currently available	Demanded
Data Analytics	Many engineers have a general understanding of data analytics but may not have advanced skills in big data processing or real-time analytics. Familiarity with data lakes & cloud-based analytics platforms is often limited.	Employers require experts who can apply predictive analytics & machine learning models to improve product lifecycle performance and maintenance. The gap is in more advanced data analytics and the ability to generate actionable insights from product lifecycle data
Project Management and Cross-functional Collaboration	Technical professionals often have strong individual skills but may lack proficiency in cross-functional collaboration and project management, especially in complex, cross-departmental digital thread projects.	Employers need engineers who can not only work within teams but also lead cross-departmental initiatives, integrating various aspects of the product lifecycle. Skills in Agile methodologies, & collaborative project management are in demand, yet lacking among many technical specialists.

The **significant skill gaps** for Digital Thread Applications Engineers arise from the workforce's limited exposure to advanced PLM systems, data integration, and cybersecurity. Furthermore, there's a shortage of professionals skilled in programming, IoT integration, and advanced analytics. Employers increasingly seek candidates who are not just technical specialists but can also handle complex system integration and cross-departmental collaboration, both of which are areas with noticeable gaps in the current workforce.

The main soft skill gaps for Digital Thread Applications Engineers include effective communication, collaboration, and adaptability, which are essential for working across departments in large, complex organizations. Additionally, there is a need for improved problem-solving, time management, and leadership skills. Developing these areas can significantly enhance the effectiveness of professionals in this role.

5.3.3 For Digital Twin Engineer

Digital Twin Engineers require a diverse range of technical skills to effectively create, manage, and utilize digital twins. However, the following areas currently exhibit significant skill gaps:

- Artificial Intelligence (AI) and Machine Learning: While AI is integral to digital twins, many engineers lack proficiency in AI algorithms, machine learning techniques, and data science.
- Internet of Things (IoT): Understanding IoT protocols, data integration, and security is crucial for connecting physical assets to digital twins. Many engineers may lack expertise in this area.
- Visualization and User Experience: Creating intuitive and informative visualizations of digital twin data is crucial for effective communication and decision-making.

The skill gaps for Digital Twin Engineers arise when comparing the current skillsets in the workforce with the increasingly advanced requirements coming from employers. Here's an overview of the usual skill gaps in this field:

Table 6 Available and demanded skills for Digital Twin Engineer

Skill	Currently available	Demanded
Systems Thinking and Integration Skills	Many engineers have a strong understanding of specific technologies but may lack the broader systems thinking required to integrate digital twins across various platforms and tools.	Employers need engineers who can manage the entire digital twin ecosystem, which includes understanding how different systems, such as IoT, data analytics, and cloud computing, interact. This requires proficiency in systems integration, which is often missing.
Advanced Data Analytics and Machine Learning	Many Digital Twin Engineers are proficient in basic data handling but often lack deeper knowledge of advanced data analytics and machine learning techniques that are now critical for predictive modelling and simulation.	Employers expect expertise in predictive analytics and the use of AI and machine learning for optimizing digital twins. There is a growing demand for professionals who can leverage large datasets to enhance simulations and automate insights.
Cloud Computing and Distributed Systems	Engineers may have experience with traditional on-premise systems but often lack cloud computing expertise. This includes familiarity with cloud-based tools and platforms, such as AWS, Microsoft Azure, or Google Cloud, which are now essential for scaling digital twin solutions.	Digital Twin Engineers need to work with distributed systems and cloud infrastructures, enabling them to manage and deploy digital twins in real-time, often across multiple geographic locations. Skills in this area are often limited within the current workforce
Systems Integration and Interoperability	Many engineers have experience in systems integration, but proficiency in integrating diverse systems and technologies within a digital twin environment may be limited	Employers seek engineers who can seamlessly integrate various components of a digital twin, including physical assets, data sources, and simulation models.
Cybersecurity Awareness	Cybersecurity knowledge among engineers in this field is often lacking, particularly in understanding how to secure digital twin environments from cyber threats.	As digital twins handle sensitive real-world data, cybersecurity is a critical concern. Employers require engineers with skills in network security, data protection, and securing IoT systems integrated into digital twins. This gap is becoming more apparent as digital twin technology scales.

Skill	Currently available	Demanded
Collaboration and Cross-Functional Teamwork	Engineers may have strong technical skills but often lack the ability to work seamlessly with non-technical teams such as marketing, management, or operations.	The role of a Digital Twin Engineer involves collaborating across multiple departments to ensure that the digital twin solutions meet both technical and business goals. Employers are seeking individuals with strong communication and teamwork skills to bridge this gap.

The **critical skill gaps** for Digital Twin Engineers include systems integration, advanced data analytics, machine learning, cloud computing, and cybersecurity. Additionally, the workforce often lacks strong collaborative skills and domain-specific expertise needed to meet employer demands. To bridge these gaps, ongoing professional development in these areas is crucial for Digital Twin Engineers.

5.4 Summary & recommendations

Key findings regarding skill and competency gaps

It is obvious that the Industry 5.0 has brought a strong need for not only technical but also analytical and social skills. The 2019 World Manufacturing Forum Report: Skills for the Future of Manufacturing [4], a whitepaper that explores in detail the skills gap phenomenon, provides the following **list of Skills for future of manufacturing**

- Digital literacy as a holistic skill to interact with, understand, enable, and even develop new digital manufacturing systems, technologies, applications, and tools
- Ability to use and design new AI and data analytics solutions while critically interpreting results
- Creative problem solving in times of abundant data and technological opportunities in smart manufacturing systems
- A strong entrepreneurial mindset including pro-activeness and the ability to think outside the box
- Ability to work physically and psychologically safely and effectively with new technologies
- Inter-cultural and -disciplinary, inclusive, and diversity oriented mindset to address new challenges arising from a more diverse manufacturing workforce
- Cybersecurity, privacy, and data/information mindfulness to reflect the rapidly increasing digital footprint of the manufacturing value chain
- Ability to handle increasing complexity of multiple requirements and simultaneous tasks
- Effective communication skills with humans, IT, and AI systems through different platforms and technologies
- Open-mindedness towards constant change, and transformation skills that constantly question the status quo and initiate knowledge transfer from other domains.

Critical Skills with Significant Skill Gaps in Industry 5.0 which require immediate attention

- Technological Literacy: Understanding and proficiency in advanced technologies such as artificial intelligence (AI), robotics, and the Internet of Things (IoT). Many professionals lack the ability to effectively use and integrate these technologies into existing systems.
- Data Management and Analytics: Skills in managing large datasets, data analysis, and utilizing data visualization tools. There is often a gap in the ability to derive actionable insights from data, which is crucial for decision-making.
- Systems Integration: Knowledge of how to integrate various technological systems within a digital framework. Professionals may struggle with connecting legacy systems to new digital solutions.
- Collaboration and Communication: Effective teamwork and communication skills are essential for cross-functional collaboration. Many workers lack the ability to communicate complex technical concepts to non-technical stakeholders.
- Problem-Solving and Critical Thinking: Advanced analytical skills to tackle complex challenges in production processes. A significant number of professionals may not possess strong critical thinking abilities needed for innovative solutions.
- Sustainability Awareness: Understanding sustainable practices and their importance in modern manufacturing. There is often insufficient knowledge about implementing eco-friendly processes and circular economy principles.
- Adaptability and Flexibility: The ability to adapt to rapidly changing technologies and market demands. Many professionals may resist change or lack the willingness to learn new skills.
- Project Management Skills: Skills in managing projects effectively, including budgeting, resource allocation, and timeline management. Current training often does not adequately prepare individuals for leadership roles in projects.
- Continuous Learning Mindset: Commitment to lifelong learning and professional development to keep up with industry advancements. Many workers do not prioritize ongoing education or skill enhancement opportunities.

These critical skills reflect the evolving demands of Industry 5.0, where human-centric approaches, sustainability, and technological integration are paramount. Addressing these skill gaps through targeted training programs, upskilling initiatives, and fostering a culture of continuous learning will be essential for individuals and organizations aiming to succeed in this transformative industrial landscape.

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6 Report from the desk research on Internet of Things

Prepared by: Bulgaria, Partner: Cluster Sofia knowledge city (CSKC)

6.1 Introduction

Definition of the respective ATI and its key characteristics

The **Internet of Things (IoT)** at the EU level is defined as “interconnected systems and devices, services that communicate and share data with each other over the internet”. The devices have sensors, software, and other technologies to enable decision-making, monitoring, and automation in various domains in real time. According to Oxford dictionary: the interconnection via the internet of computing devices embedded in everyday objects, enabling them to send and receive data.

Some examples of IoT devices include:

- Smart home devices such as thermostats, lighting systems, and security systems.
- Wearables such as fitness trackers and smartwatches.
- Healthcare devices such as patient monitoring systems and wearable medical devices.
- Industrial systems such as predictive maintenance systems and supply chain management systems.
- Transportation systems such as connected cars and autonomous vehicles.

The three main components of the Internet of Things are:

- Devices
- Internet
- Connectivity

Main characteristics of IoT are:

- **Connectivity** - an important requirement of the IoT infrastructure. Things of IoT should be connected to the IoT infrastructure.
- **Scalability** - the number of elements connected to the IoT zone is increasing day by day. IoT setup should handle the great expansion.
- **Interoperability**: IoT devices use standardized protocols and technologies to ensure they can communicate with each other and other systems. Interoperability is one of the key characteristics of the Internet of Things (IoT). It refers to the ability of different IoT devices and systems to communicate and exchange data with each other, regardless of the underlying technology or manufacturer.
- **Data-driven**: IoT devices and systems collect huge amounts of data from sensors and other sources, which is analyzed and used to make data-driven decisions. Data is collected from embedded sensors, actuators, and other sources, such as cloud services, databases, and mobile devices.
- **Dynamic and Self-Adapting (Complexity)**: IoT devices should dynamically adapt themselves to changing contexts and scenarios. For example, a camera meant for

surveillance. It should be adaptable to work in different conditions and different light situations (morning, afternoon, and night).

- **Architecture** – it can't be homogeneous in nature. It should be hybrid, supporting the products by different manufacturers to work in the IoT network. IoT can't be owned by a single engineering field. IoT is in reality a multiple-domain nature.
- **Self Configuring** - one of the most important characteristics of IoT. IoT devices can upgrade their software following requirements with a minimum of user participation. Furthermore, they can set up the network, allowing for the addition of new devices to an already-existing network.
- **Safety and security**: Security is a critical concern for the Internet of Things (IoT), as IoT devices and systems handle sensitive data and are connected to critical infrastructure. The increasing number of connected devices and the amount of data being transmitted over the Internet make IoT systems a prime target for cyberattacks. The EU focuses on safeguarding data integrity and privacy of individuals among other. The General Data Protection Regulation (GDPR) is a key factor to guarantee that IoT systems follow data protection and privacy standards.
- **Ubiquity**: Ubiquity refers to the widespread and pervasive presence of the Internet of Things (IoT) devices and systems in our daily lives. In a ubiquitous IoT environment, devices and systems can be accessed and controlled from anywhere, at any time, using a variety of devices, such as smartphones, laptops, and other connected devices.
- **Human-centric and ethical design**: Ethics is on focus by EU as IoT holds a lot of risks and uncertainties, also allows illegal actions and disturbances. Its development is guided by such principles asinclusivity, accessibility, and ethics, ensuring that IoT serves the needs of individuals and society responsibly.
- **Autonomous operation**: Autonomous operation refers to the ability of IoT devices and systems to operate independently and make decisions without human intervention. Autonomous operation is made possible by advances in artificial intelligence, machine learning, and cloud computing, which enable IoT devices and systems to process and analyze large amounts of data in real time and make decisions based on that data.

6.2 Methodology

Definition of the research

The desk research started with clear definition of the goals, needs and targets for the area of research including trends, challenges, opportunities, SWOT analysis of the main sources and approaches.

Identification of the sources

Part of the desk research is the framework of the research including types of reliable and credible sources: regulatory documents, industry reports, country reports, academic papers and documents like peer-reviewed journals, theses, conference proceedings, news, publications by researchers and institutes, case studies and white papers.

In addition, market research publications and reports are used by leading organisations and companies both at EU and international levels. Annual reports by leading IoT firms are also employed, together with media and news, blogs, technology and innovation platforms, technical standards like ETSI, ISO, or IEEE.

Gathering information

Use of keywords, terminology and findigns: e.g., "characteristics of IoT", IoT in EU policy," "IoT regulations," "IoT market trends") in databases, search engines, and libraries.

Analyzing and summarizing the findings, evaluation and assessment of the information; categorization and preparation of insights for the reports by extracting the most important summary and key points with valuable contribution.

- **Systematic Review**: Organize the data collection process by categorizing sources (policy, technical, market, etc.) and evaluating each systematically.
- **Analyze, synthesize and summarize the findings**: find trends, clusterise the information, prepare summary with the most important insights, compare results, group them, draw conclusions and recommendations, apply the MECE approach (Mutually Exclusive, Collectively Exhaustive) to follow structured and holistic research, ensuring important information is captured and analysis is conducted.

6.3 Identified roles, jobs, skills & competency profiles

6.3.1 Who is hiring: Current & potential employers

The leading companies are from Technology and electronics such as Philips, Bosch and other. Other employers are the software and specialized IoT companies: Amazon Web Services (AWS), Microsoft Azure: offers IoT solutions and regularly hires for IoT-related roles. Samsara: Focuses on IoT solutions for fleet management and industrial processes. Kwant.ai: Develops IoT technology to enhance construction site safety and productivity.

- **Telecommunications** like Cisco systems, O2, AT&T, Telefónica, NTT Docomo, SK Telecom, Vodafone, Deutsche Telekom, and others.
- **Healthcare and medical devices:**
  - Biotronik
  - GE HealthCare
  - Honeywell Life Care Solutions
  - Philips
  - Boston Scientific Corporation
  - Medtronic plc
  - SIEMENS AG
  - Abbott Laboratories
  - Contus
  - OSP Labs

Source: IoT ONE. (2024). IoT ONE 100: Top 100 industrial IoT companies. Retrieved from https://www.iotone.com/iotone100

6.3.2 List of specific roles in IoT - professionals working with the IoT Career opportunities / jobs/ working positions

According to the World Economic Forum the Job taxonomy: The occupational taxonomy was modified and extended from O*NET SOC:

IoT specialists are occupation from Job family *Computer and Mathematical.*

IoT Engineer Job Title Hierarchy:

- IoT Engineer I
- Junior IoT Engineer
- IoT Developer Associate
- IoT Solutions Coordinator
- IoT Engineer II
    - IoT Systems Engineer
    - IoT Hardware Engineer
    - IoT Software Developer
- Senior IoT Engineer
    - Lead IoT Engineer
    - IoT Solutions Architect
    - IoT Integration Specialist

- IoT Engineering Manager
  - IoT Team Lead
  - Principal IoT Engineer
  - IoT Project Manager
- Director of IoT Engineering
  - VP of IoT Technology
  - Head of IoT Development
- Chief IoT Engineer

6.3.3 Profile/description/competency profile and skills list for the most common jobs/roles for IoT

An example of list of skills required for career in IoT is:

- Cloud computing;
- Security and networking;
- Edge computing;
- UI/UX design;
- Programming;
- IoT communication protocols;
- Data analytics.

The following list of job roles is provided:

- IoT Embedded Engineer
  According to literature, embedded engineering is the backbone of IoT. It is undeniably the most popular vacancy in this field. These specialists are responsible for creating and implementing software for embedded systems and gadgets in IoT networks.

- IoT Data analyst
  The main task of an IoT data analyst is receiving relevant data from information assembled via IoT devices. Develops dashboards and visualizations for end-users. In addition, this role analyzes data that is generated by the respective devices to extract and generate insights leading to action.

- IoT Platform Developer
  These specialists create, manage, and monitor IoT devices and systems. They also work with research, data analysis, and technological creation.

- IoT Security Engineer
  One of the promising career directions is an IoT security engineer. As the name implies, such specialists deal with systems and software security, preventing unwanted intrusion and other vulnerabilities.

- IoT UI Designer
  This job role has to create IoT systems that are accessible to users. This profession is ideal for creative people who know how to utilize design tools, think creatively, and strive to create something unusual.

- IoT(Solutions) Architect
  Responsible for designing comprehensive IoT solutions that meet client or organizational needs. IoT Solutions Architects must have a deep understanding of both hardware and software components, as well as the ability to integrate them seamlessly.
- IoT Network Engineer
  Professionals who design and maintain the networks that connect IoT devices. IoT Network Engineers must be knowledgeable about various networking protocols and technologies specific to IoT, such as LPWAN, Zigbee, and Bluetooth LE.
- Director of IoT Engineering
  A leadership role overseeing the IoT engineering department. Directors of IoT Engineering are responsible for strategic planning, resource allocation, and leading cross-functional teams to deliver IoT solutions that align with business objectives.
- VP of IoT
  An executive role with a broad responsibility for the organization's IoT strategy and implementation. VPs of IoT drive innovation, oversee product development, and ensure that IoT initiatives contribute to the overall success of the company.

Each IoT Engineer role is integral to the creation and maintenance of IoT systems, with opportunities for specialization in areas like security, development, and network architecture. As the IoT field grows, these roles evolve, offering a dynamic and exciting career path for tech professionals.

6.3.4 Common degrees of professionals in IoT

Examples of IoT learning paths

In the following tables there are six concrete examples of skills profiles, including the skills they comprise. They also provide an indicative set of courses that can support the development of the skills for each profile. The research showed that these listed courses can be found in the Udemy training ecosystem and the EU-IoT training resources catalogue.

Specifically, each of the contents of the table presents the following information for each one of the six skills profiles:

Individual skills of the profile: This is the list of skills that an IoT professional must possess to qualify for roles associated with the skills:

Table 7 Skills and learning path for the “IoT application developer” skills profile.

IoT skills profile: IoT application developer
Individual skills of the profile: Python, JavaScript, IoT & Cloud Computing, DevOps, Docker, Kubernetes, Sensors, WSN, Arduino, MQTT
Courses of the main learning path: 1. Practical iot concepts-devices, IoT protocols and servers DevOps 2. Introduction to IoT programming with JavaScript 3. Exploring AWS IoT 4. Project - 2022: CI/CD with Jenkins Ansible Kubernetes 5. Arduino for beginners — 2022 complete course
Other relevant courses: 1. Collaboration and emotional intelligence 2.1.T. project management for beginners: a step-by-step guide

Table 8 Skills and learning path for the “IoT data analytics expert” skills profile

IoT skills profile: IoT data analytics expert
Individual skills of the profile: Data science, machine learning, TinyML, sensors, WSN
Courses of the main learning path: 1. Master machine learning and data science with Python 2. Intro to embedded machine learning 3. Sensors/actuators/data visualization with microcontrollers - IoT dashboard with Arduino
Other relevant courses: 1. Statistics for data science and business analysis 2. Collaboration and emotional intelligence

Table 9 Skills and learning path for the “IoT networking engineer” skills profile.

IoT skills profile: IoT network engineer
Individual skills of the profile: Sensors and IoT Devices, LPWAN, 4G/5G/6G, WiFi, Bluetooth, MQTT
Courses of the main learning path: 1. Internet of things (IoT) - demystified using three IoT devices 2. 5G Masterclass: architecture, NR RAN, core, and call flows 3. The ultimate WLAN and WiFi training course 4. The complete bluetooth/IoT design course for iOS
Other relevant courses: 1. Collaboration and emotional intelligence 2. I.T. Project management for beginners: a step-by-step guide

Table 10 Skills and learning path for the “embedded systems engineer” skills profile.

IoT skills profile: embedded systems engineer
Individual skills of the profile: Embedded systems, FPGA, printed circuit board (PCB) design, sensors, actuators, WSN
Courses of the main learning path: 1. Mastering microcontroller and embedded driver development 2. Learn the fundamentals of VHDL and FPGA development 3. Sensors/actuators/data visualization with microcontrollers - IoT dashboard with Arduino 4. Crash course electronics and PCB design
Other relevant courses: 1. Arduino: electronics circuit, PCB Design & IoT programming 2. Collaboration and emotional intelligence

Table 11 Skills and learning path for the “IoT project manager” skills profile.

IoT skills profile: IoT project manager
Individual skills of the profile: Project management, sensors, WSN, DevOps, agile development
Courses of the main learning path: 1. I.T. project management for beginners: a step-by-step guide 2. Agile PM 301 - mastering agile project management 3. Project - 2022: CI/CD with Jenkins Ansible Kubernetes 4. Sensors/actuators/data visualization with microcontrollers - IoT dashboard with Arduino
Other relevant courses: 1. Presentation skills: master confident presentations 2. Management skills - team leadership skills masterclass 2022 3. Collaboration and emotional intelligence

Table 12 Skills and learning path for the “IoT product manager” skills profile.

IoT skills profile: IoT product manager
Individual skills of the profile: Product management, sensors, WSN, cyber-physical systems
Courses of the main learning path: 1. Agile PM 301 - mastering agile project management 2. Great product manager: product management by a big tech's PM 3. Complete guide to build IoT things from scratch to market 4. Sensors/actuators/data visualization with microcontrollers - IoT dashboard with Arduino
Other relevant courses: 1. Presentation skills: master confident presentations 2. Management skills - team leadership skills masterclass 2022 3. Advanced product management: vision, strategy, and metrics

The presented lists are indicative. It is possible to broaden the scope of a skills profile by including additional skills in the list. As already outlined, the development of skills profile could consider the results of our survey toward including both relevant and popular skills in the profile.

Overall, the tables provide a set of representative examples that aim at illustrating the process of specifying learning paths based on available catalogues of training resources. There is however much room for interested stakeholders to fine-tune the learning paths development process by scrutinizing the vast amount of training resources that are available in existing course platforms.

6.4 Skill gap Analysis

Identification of critical skills & competency

Recent studies show that IoT skills are a “catalyst for the accelerated adoption of IoT solutions and the subsequent growth of the IoT market”. This is because the lack of IoT skills is identified as one of the factors challenging IoT deployment. In the past few years, different players like educational organizations, consulting firms, and policymakers have identified skills that enable the development and operation of advanced IoT systems. In various cases, they have set the interoperability of these skills.

However, there is still a lack of a consistent IoT skills framework that considers the latest advancements in the IoT market and technologies.

There is a big impact and need for programming skills (e.g. Python, C, C#, Java Script) and knowledge of IoT protocols (e.g. Message Queuing Telemetry Transport (MQTT)) for the development and deployment of IoT systems. Furthermore, there are resources from research that structure technical skills into integrated IoT profiles such as hardware designers, embedded firmware developers, backend developers, frontend developers, IoT application developers, automation and system integration engineers, and data specialists.

Analysis of skill proficiency levels in the workforce

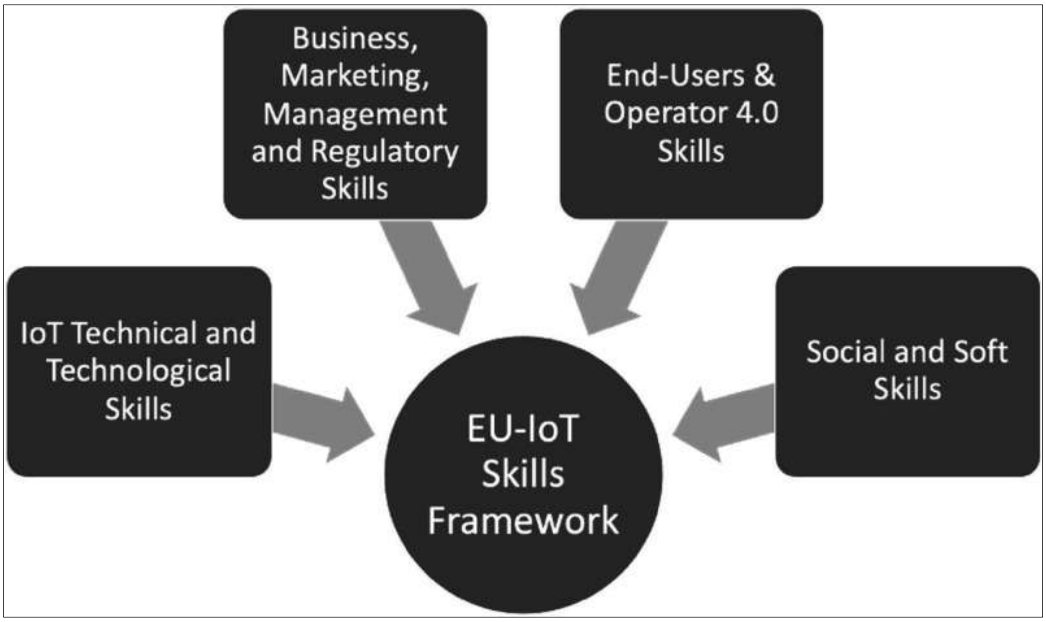
One of the EU IoT frameworks is provided by H2020 EU-IoT project (contract number 956671), which is co-funded by the European Commission (EC) in the scope of its H2020 program.

The framework comprises of four broad categories for IoT-related skills into, as illustrated in the figure below:

- **IoT technical and technological skills**: skills related to IoT technologies, such as to develop, deploy, and operate IoT systems. It provides wide coverage of the various technologies currently associated with IoT systems.
- **Management, marketing, and regulatory skills**: marketing and management skills for the development of IoT products and services. It also includes regulatory-related skills such as general data privacy regulation (GDPR)-related skills and ethics-related skills.

- **IoT end-users and operator 4.0 skills**: This category consists of skills required for using and operating IoT systems in various sectors of the economy with an emphasis on industrial sectors.
- **Social and soft skills**: This comprises soft skills that are important for the development, deployment, operation, and use of IoT systems. It includes popular skills like teamwork, lifelong learning, and collaboration, which have clear relevance to IoT professionals as well.

Each of the above categories includes subsets of IoT skills, structured in subcategories. The structuring of these skills provides a rich foundation for understanding the types of skills necessary for efficient and successful development, deployment, operating, managing, and monetizing IoT systems. These categories provide a structured approach to review and analyse the IoT skills. Nevertheless, the listed skills provide by no means an exhaustive coverage of all available IoT skills. Interested parties can elaborate and enrich the framework with adding more skills that belong to the various main and subcategories.



Source: Factors contributing to the IoT skills shortage, Sofia RC, Soldatos J, editors. Abingdon (UK): River Publishers; 2024 Jan.

The IoT technical and technological skills are further divided into the following subcategories:

- IoT devices skills
- Smart objects skills
- Networks and connectivity
- IoT protocols
- Cloud/edge/mobile computing
- IoT analytics
- IoT security

- IoT software programming skills
- IoT development methodologies
- IoT development and deployment tools

These subcategories provide a useful taxonomy of IoT-related technical and technological skills, which can be added with more skills under the specified skills groups. The specification of these subcategories was partly driven by popular reference architectures that could specify in technical terms the building blocks of contemporary IoT systems.

- Business, marketing, management, and regulatory skills:
  - Business, management, and marketing skills
  - Legal and regulatory skills
- IoT end-user and operator 4.0 skills
  - Industrial automation skills
  - Asset management skills
  - Visualization
- Social, management, and other soft skills
  - Thinking skills, such as critical thinking, analytical thinking, and complex problem-solving.
  - Social skills, such as teamwork, interpersonal skills, and professional ethics.
  - Personal skills, such as lifelong learning, time management, people management, and emotional intelligence.

Thus, one of the conclusions is that soft skills needed for development, deployment, and use of technology systems and applications goes further and beyond the scope of IoT systems and technologies. Their inclusion in the framework ensure that they are not overlooked when developing or seeking for IoT talent.

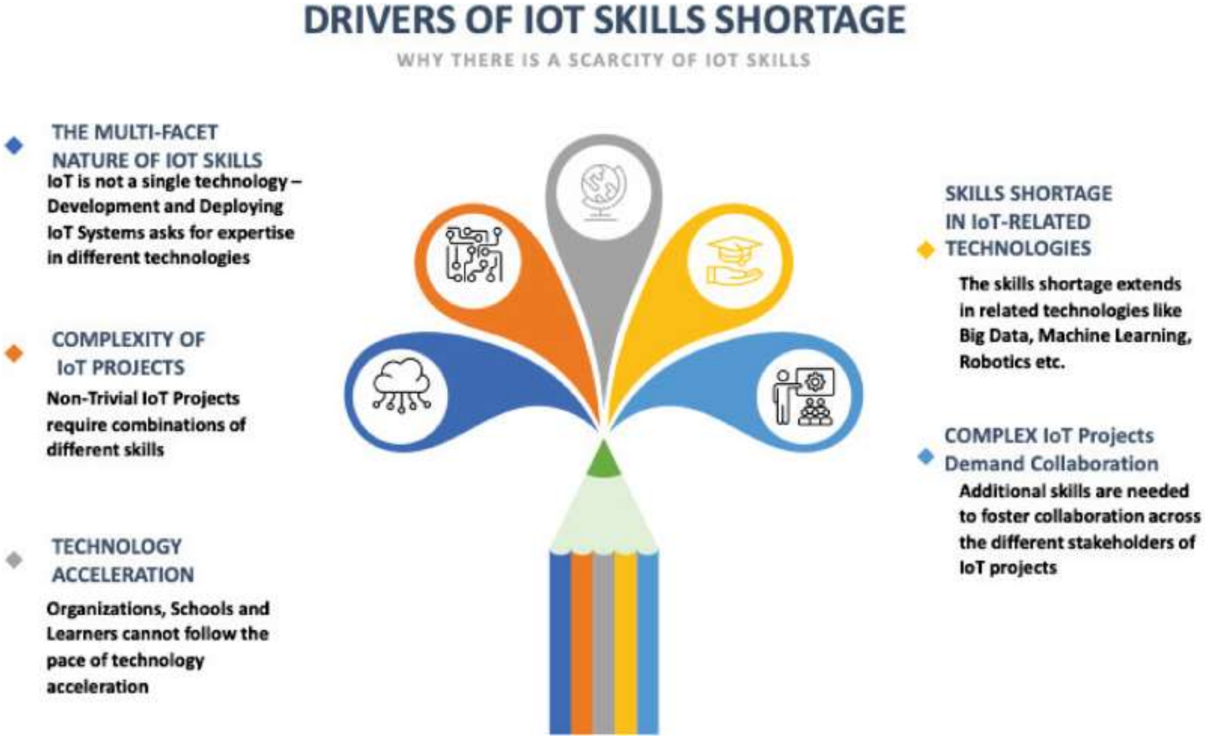
Comparison of required skills and available skills; comparison of skill profiles and labour market demands

In the ever-evolving advanced technologies' landscape most organizations are faced with serious skills gaps, which requires constant reskilling and upskilling of talent.

In a recent survey of the World Economic Forum (WEF) the responding companies pointed out that they expected approximately 40% of their workers to do reskilling every six months. This survey identifies the technical skills that are currently highly demanded by employers, which include IoT. The importance of non-technical skills like active learning and flexibility is highlighted.

Overall, employers point out that there is a need to increase their efforts and investments in developing human skills. At the same time, policy makers are developing policies that enhance digital skills development.

There is a need for skills taxonomies that illustrate how diverse IoT skills are related to each, as well as how they can be bundled into coherent skills profiles.



Source: https://www.ncbi.nlm.nih.gov/books/NBK602363/

6.5 Summary & recommendations

According to the World Economic Forum, by 2025, 50% of all employees will need reskilling due to adopting new technology. “Five years from now, over two-thirds of skills considered important in today’s job requirements will change”.

A third of the crucial skills in 2025 will be technology competencies not yet regarded as essential to today's job requirements.

The Internet of Things (IoT), and Industrial Internet of Things (IIoT) are on the rise.

Nowadays, there is a proclaimed gap in skills for automation and the future of work. Closing this skills gap is very important for adopting and leveraging cutting-edge technologies of the fourth industrial revolution in many economic sectors. IoT skills are among the most important elements of the skills puzzle, as IoT technologies have a broad scope and are widely used in sectors like manufacturing, energy, healthcare, transport, retail, agriculture, and supply chain management. State-of-the-art skills surveys identify some of the skills that are high in demand in the market. Nevertheless, they usually take a broad view that address many different digital technologies rather than focusing on the IoT skills and the IoT market.

Some of the strategies for addressing the gaps are:

- New educational programmes and flexible learning paths as described above
- Collaboration with industry across all IoT sectors and business niches
- Develop soft skills
- Focus on multidisciplinary approach

Prioritized list of skill gaps requiring immediate attention

One of the main areas of expertise is the replication of IT infrastructure (currently many IoT projects belong to this segment) by competitors, where tangible resources are concerned. The standardisation and interoperability are critical for this technology and involves highly critical skillsets. The integration and communication among the diverse IoT devices and systems requires very interrelated skillsets that can leverage on the basic knowledge.

The security measures, especially with connectivity in mind, require more complex skillsets: skills in securing IoT devices, networks, and platforms, including understanding encryption protocols, intrusion detection, and GDPR compliance.

Data analytics and AI for IoT: proficiency in processing and analyzing IoT-generated data using tools like Python, R, TensorFlow, or Spark.

One of the technologies that IoT uses is the Edge computing technology: skills related to deploying and managing IoT solutions with edge computing to reduce latency and optimize performance.

Embedded systems development: knowledge of programming for embedded systems (e.g., C, C++) and IoT hardware like Raspberry Pi and Arduino.

Cloud integration for IoT: understanding cloud services like AWS IoT, Azure IoT Hub, or Google Cloud IoT Core for data storage and analytics.

Protocols and standards: mastery of IoT protocols (e.g., MQTT, CoAP, Zigbee) and standards to ensure device interoperability.

IoT business strategy: skills in IoT product management, market analysis, and innovation strategies.

In conclusion,

It is foreseen that the future of IoT technology is likely to be defined by advancements in edge computing, improved security, standardisation, AI integration, sustainability, ethical considerations, and human-centric design. Thus, it is intriguing to see the developments and trends in the next years and how they will further influence industry and various aspects of our lives.

However, the employers and education and training organisations need to adapt and predict the future to close the gap by individual, customized learning paths and preparation of staff when and where necessary. The demand for specialists in IoT, industrial automation and robotics experts, cybersecurity experts, data scientists and analysts, UX/UI designers for IoT, IoT consultants, and field service technicians has evolved as employers adopt IoT solutions to enhance and improve innovation, optimise operations and customer experiences. Talent with expertise in IoT and its applications in various industries are likely to experience the pressure of acquisition of the right skills for specific IoT positions and occupations.

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7 Report from the desk research on Quantum Computing

Prepared by: GREECE, Partners:NCSR Demokritos

7.1 Introduction & Methodology

Description of data sources utilized

The methodology we followed is structured around four key pillars:

a) **Literature Review:** In this stage, we identified and reviewed academic papers, government reports, industry publications, and white papers that discuss quantum computing within the EU context. We summarized the findings from existing studies on quantum computing skills in the EU, focusing on identifying any mentioned skill gaps or areas requiring further development. Additionally, we analyzed trends in quantum computing education and workforce development, particularly regarding the supply and demand of skills in this field.

Data collection and analysis methods employed

b) **Data Collection:** We gathered data from a variety of sources, including Eurostat, OECD, industry reports, and academic publications. This data encompassed statistics on the current quantum computing workforce, educational programs, and industry needs. We also searched for relevant research papers on platforms such as Google Scholar and IEEE Xplore. Furthermore, we examined reports from leading consulting firms like McKinsey and PwC, as well as think tanks, to analyze the quantum computing landscape in the EU.

c) **Gap Analysis:** After collecting the data, we conducted a gap analysis by comparing the skills demanded by the quantum computing industry with those currently available in the EU workforce. We assessed the availability and adequacy of quantum computing courses, degrees, and certifications across the EU, and examined the specific quantum computing skills required by EU industries.

d) **Synthesize Findings: First we summarized the key findings and then we tried to identify the root causes**. We created a comprehensive summary of the findings, highlighting the most critical skills gaps in quantum computing within the EU. And last we analyzed the root causes of these skills gaps, such as insufficient educational programs, lack of industry-academia collaboration, or underinvestment in quantum research.

Definition of the respective ATI and its key characteristics

Quantum computing is a type of computation that harnesses the principles of quantum mechanics, the fundamental theory in physics that describes the behavior of matter and energy at the smallest scales, such as atoms and subatomic particles. Unlike classical computing, which uses bits as the basic unit of information (where each bit is either a 0 or 1), quantum computing uses quantum bits, or qubits.

Qubits can exist in multiple states simultaneously due to a quantum phenomenon called superposition, meaning they can represent both 0 and 1 at the same time. Additionally, qubits can be entangled, another quantum phenomenon where the state of one qubit is directly related to the state of another, even across large distances. These properties enable quantum computers to perform certain types of calculations much more efficiently than classical computers.

Quantum computing is characterized by several key features: qubits, superposition, entanglement, quantum interference, and quantum error correction. Superposition allows qubits to exist in multiple states simultaneously, enabling quantum computers to explore numerous potential solutions at once. Entanglement links the state of one qubit to another, irrespective of distance, enhancing both quantum communication and computational power. Quantum interference is used in algorithms to amplify correct outcomes and cancel out incorrect ones, increasing computational efficiency. Given the fragile nature of quantum states, error correction is essential for ensuring the practicality and reliability of quantum computing.

In essence, quantum computing has the potential to solve complex problems that are beyond the capabilities of today's classical computers, particularly in areas like cryptography, material science, drug discovery, and optimization. Quantum computing is important because it has the potential to revolutionize various industries by solving complex problems that are currently unsolvable by classical computers. The main advantages of using quantum computing are the following:

1. **Exponential Speedup**: Quantum computers can process and analyze massive amounts of data at unprecedented speeds. This can lead to breakthroughs in fields like cryptography, drug discovery, materials science, and complex system optimization.
2. **Advancements in Cryptography**: Quantum computing can potentially break widely-used encryption algorithms, which poses a threat to current cybersecurity systems. However, it also offers the potential to create unbreakable encryption methods through quantum key distribution.
3. **Scientific Discovery**: Quantum computing can simulate quantum systems, enabling more accurate modeling of molecules and materials. This can accelerate research in chemistry, physics, and biology, leading to innovations in medicine, energy, and materials science.
4. **Optimization Problems**: Quantum computing excels at solving optimization problems that are difficult for classical computers, such as those found in logistics, finance, and artificial intelligence.

Quantum computing is recognized as a strategic technology by the EU due to its potential to provide technological leadership and enhance economic competitiveness on a global scale. To solidify its position in the quantum technology race, the EU has launched the Quantum Flagship, a €1 billion, 10-year research and innovation initiative aimed at advancing quantum computing, communication, sensing, and simulation. Given quantum computing’s potential to disrupt existing encryption methods, the EU is also investing in quantum-resistant cryptography and secure communication networks, such as the EuroQCI (European Quantum Communication Infrastructure) initiative. The EU emphasizes collaboration among member states, academia, and industry to ensure that the benefits of quantum technologies are widely distributed and that the EU remains at the forefront of global quantum research and innovation.

In summary, quantum computing is crucial for revolutionizing various sectors, and it remains a strategic priority for the EU as it seeks to maintain technological leadership, economic competitiveness, and digital sovereignty in a rapidly evolving global landscape."

7.2 Identified roles, jobs, skills & competency profiles

Who is hiring: current & potential employers

Quantum computing experts are sought after by a diverse range of industries, from technology giants and startups to financial institutions, research labs, and government agencies. This broad demand reflects the wide-ranging potential impact of quantum technologies across various sectors, making it a critical area of expertise for the future.

Technology companies are among the primary employers, with big tech firms like IBM, Google, Microsoft, and Intel leading the charge in quantum computing research and development. These companies often seek quantum computing experts to work on building quantum hardware, developing quantum algorithms, and exploring practical applications. Additionally, numerous startups, such as Rigetti Computing, D-Wave Systems, and IonQ, focus on different aspects of quantum computing, from hardware development to quantum software and cloud-based quantum services, making them significant employers in the field.

Research institutions and universities also play a crucial role in hiring quantum computing experts. Academic institutions with strong physics, computer science, or engineering departments often seek these experts for research and teaching roles, contributing to both theoretical advancements and practical applications in quantum computing. These institutions frequently participate in large-scale, collaborative research projects funded by governments or private entities, further driving the demand for expertise in quantum technologies.

Government agencies and **national laboratories** are significant employers as well. In the United States, entities like Los Alamos National Laboratory and the National Institute of Standards and Technology, along with European counterparts such as CERN and national labs within EU countries, hire quantum computing experts to advance national research agendas. Defense and intelligence agencies, like DARPA in the U.S. and similar organizations in Europe, are particularly interested in quantum computing for its potential in cryptography and secure communication.

The **financial sector** is another key area where quantum computing expertise is highly valued. Major financial institutions such as JPMorgan Chase, Goldman Sachs, and Barclays are exploring quantum computing for applications in complex financial modeling, risk analysis, and portfolio optimization. Additionally, venture capital firms and investment funds that focus on technology startups may hire quantum computing experts to evaluate investment opportunities in this emerging field.

Pharmaceutical and chemical companies are exploring quantum computing for its potential to revolutionize drug discovery and material science. Companies like Pfizer, Roche, and Merck see quantum computing as a game-changer for simulating complex molecular interactions, while chemical companies aim to discover new materials with specific properties crucial for industries like energy, electronics, and manufacturing.

Consulting firms also seek quantum computing experts, particularly those specializing in management and technology consulting. Firms like McKinsey & Company, Boston Consulting Group, and Deloitte are building expertise in quantum computing to advise clients on the potential impact of quantum technologies on their businesses. Similarly, technical consulting firms may hire quantum experts to help clients understand and implement quantum solutions.

The **telecommunications sector** is another area of interest, with companies such as AT&T, Deutsche Telekom, and Vodafone exploring quantum cryptography and communication technologies to enhance network security. Finally, the **energy** and **aerospace and automotive industries** are beginning to recognize the potential of quantum computing. Energy companies like ExxonMobil, BP, and Shell are investigating quantum computing for optimizing resource management and improving renewable energy technologies, while aerospace and automotive giants like Airbus, Boeing, and Volkswagen are exploring its use for optimizing design processes, improving materials science, and solving complex logistical challenges.

List of specific roles = professionals working with the respective ATI Career opportunities / jobs/ working positions

- **Quantum Computing & Algorithms**
  - Quantum Software Engineer – Develops algorithms and applications for quantum computers.
  - Quantum Algorithm Researcher – Designs and optimizes quantum algorithms for specific problems.
  - Quantum Information Scientist – Works on theories related to quantum mechanics, cryptography, and information theory.
  - Quantum Machine Learning Engineer – Integrates quantum computing with AI/ML techniques.
- **Quantum Hardware & Experimental Physics**
  - Quantum Hardware Engineer – Designs and builds physical quantum processors and qubits.
  - Quantum Experimental Physicist – Conducts lab experiments to test quantum principles and technologies.
  - Cryogenic Engineer – Develops cooling systems for quantum computers that require ultra-low temperatures.
  - Quantum Optics Scientist – Works with photonic quantum computing and quantum communication.
  - Fabrication Engineer (Nanotechnology) – Builds quantum chips using nano-fabrication techniques.

- **Quantum Communication & Cryptography**
  - Quantum Cryptography Researcher – Develops secure quantum encryption protocols.
  - Quantum Network Engineer – Builds quantum communication infrastructure, such as quantum key distribution (QKD) networks.
  - Quantum Telecommunication Specialist – Works on the integration of quantum technologies with telecom networks.
- **Theoretical & Mathematical Quantum Research**
  - Theoretical Quantum Physicist – Develops mathematical models to describe quantum systems.
  - Quantum Mathematician – Works on the mathematical foundations of quantum theory.
  - Quantum Error Correction Specialist – Focuses on reducing errors in quantum computations.
- **Industry & Business Applications**
  - Quantum Business Strategist – Identifies business use cases for quantum technologies.
  - Quantum Product Manager – Manages the development and deployment of quantum-based products.
  - Quantum Consultant – Advises businesses on integrating quantum solutions into their operations.
- **Education & Outreach**
  - Quantum Educator/Professor – Teaches quantum computing and physics at universities.
  - Quantum Technical Writer – Creates educational and technical documentation for quantum technologies.
  - Science Communicator (Quantum Focus) – Translates complex quantum topics into accessible content for the public.

Profile/description/competency profile and skills list for the most common jobs/roles for the respective ATI

While technical skills are the foundation of quantum computing expertise, soft skills like problem-solving, collaboration, adaptability, and communication are equally important for success in this multidisciplinary and rapidly evolving field. Thus, the below mentioned soft skills help a lot professionals and experts to evolve in their domain.

Soft skill domain	Description of soft skill	Correlation with quantum computing
Problem solving	Analytical thinking	The ability to break down complex problems and devise innovative solutions is critical in quantum computing, where challenges are often novel and require creative approaches
	Critical thinking	Evaluating existing theories and methods critically to push the boundaries of what is possible in quantum computing.
Teamwork	Interdisciplinary Collaboration	Quantum computing projects often require expertise from multiple disciplines (e.g., physics, computer science, and engineering). The ability to work effectively with experts from different fields is essential.
	Communication Skills	Being able to explain complex quantum concepts clearly and concisely to team members with different technical backgrounds is crucial for successful collaboration
Adaptability	Flexibility	Quantum computing is an evolving field with rapid advancements. Professionals need to be adaptable and willing to learn new techniques, tools, and theories as the field progresses
	Resilience	The ability to handle setbacks and persist through challenges, as quantum computing often involves tackling difficult and sometimes unsolved problems.
Self-improvement	Lifelong learning	Staying updated with the latest research, technologies, and methods in quantum computing is vital, given the field's rapid pace of innovation
	Curiosity	A natural curiosity drives deeper exploration and understanding of complex quantum phenomena and encourages innovation.
Project Mgt	Time management	Effectively managing time and resources is important, especially when working on complex, long-term quantum computing projects.
	Organization	Keeping track of multiple aspects of a project, from research to implementation, is key to ensuring that quantum computing initiatives stay on track

Soft skill domain	Description of soft skill	Correlation with quantum computing
Precision	Precision	Quantum computing requires a high level of precision, whether in coding quantum algorithms or working with delicate quantum hardware. Attention to detail is critical in ensuring accuracy and reliability in all aspects of quantum work
Communication and Public Speaking	Technical Writing	The ability to document research findings, write papers, and create detailed project reports is important for sharing knowledge and advancing the field
	Public Speaking	Being able to present complex ideas to both technical and non-technical audiences is valuable, particularly in academic and industry conferences

Common degrees of professionals in the respective ATI

Experts in quantum computing typically possess advanced degrees in fields that provide a strong foundation in both quantum mechanics and computer science. The most common degrees among quantum computing professionals include:

Technological domain	Degree level	Correlation
Physics	Bachelor's, Master's, or Ph.D.	Physics is one of the most common backgrounds for quantum computing experts, as it provides a deep understanding of quantum mechanics, which is fundamental to quantum computing.
Computer science	Bachelor's, Master's, or Ph.D.	A strong background in computer science is crucial for developing quantum algorithms and software. Those with computer science degrees often focus on the computational aspects of quantum computing
Mathematics	Bachelor's, Master's, or Ph.D. in Mathematics	Quantum computing relies heavily on complex mathematical concepts, particularly in areas like linear algebra, probability, and cryptography. A mathematics degree provides the analytical skills necessary to understand and develop quantum algorithms
Electrical Engineering	Bachelor's, Master's, or Ph.D	Electrical engineers contribute to the development of quantum hardware, including the design and construction of quantum processors and other physical components of quantum computers.

Technological domain	Degree level	Correlation
Quantum Information Science	Master's or Ph.D	This is an emerging interdisciplinary field that combines elements of physics, computer science, and mathematics to focus specifically on the study and development of quantum computing and related technologies
Quantum Computing	Master's or Ph.D. in Quantum Computing	Some universities and research institutions now offer specialized degrees in quantum computing, which directly prepare students for careers in this field. These programs often cover quantum algorithms, quantum hardware, and the theoretical underpinnings of quantum mechanics.
Electrical and Computer Engineering	Bachelor's, Master's, or Ph.D	This field is particularly relevant for those working on the hardware aspects of quantum computing, such as the development of qubits, quantum circuits, and control systems
Chemistry	Bachelor's, Master's, or Ph.D	Quantum computing is expected to revolutionize fields like computational chemistry. Chemists with a strong understanding of quantum mechanics are valuable in developing quantum algorithms for simulating molecular structures and reactions.
Materials Science	Bachelor's, Master's, or Ph.D.	This field is relevant for those working on the physical materials used in quantum computing, such as superconductors and other materials critical to the development of qubits.

7.3 Skill gap Analysis

Identification of critical skills & competency

Unfortunately, quantum computing is a technology in developmental stage with significant demand for further growth and expertise. As such, it is quite hard to fully map the skill gaps for a technology which is still growing. Currently, we can provide a skill gap analysis of quantum computing requirements to the level that has been developed so far. Specifically, quantum computing is right now used by academia, defence industries, pharmaceuticals and high tech companies. As mentioned in previous section, the majority of the professionals working in quantum computing have background in physics, computer science, electrical engineering etc.

Thus, the main problems that exist right now in the sector revolve around the quantum algorithm development, quantum hardware engineering, quantum software engineering, mathematics and optimization. Taking into consideration that the pure educational thematics around quantum technology and quantum computing specifically are limited, there is lack of knowledge in the whole thematic even in superficial level which has significant impact to further advancement of the technology. In more details, there is lack of knowledge around quantum physics, cryogenics, quantum mechanics and complex mathematics.

Analysis of skill proficiency levels in the workforce;

The lack of the aforementioned abilities makes hard tasks such as development of algorithms tailored for quantum computers, building and maintaining quantum computers and translation of classical computing algorithms to quantum ones.

Educational programs specifically targeting quantum computing are still emerging. Universities are beginning to offer degrees and certificates in quantum information science, and online platforms (such as Coursera and edX) have also started providing introductory courses.

In the following list, they are presented some introductory courses from coursera[1]:

- Advanced Data Structures, RSA and Quantum Algorithms, University of Colorado Boulder
- Quantum Computing For Everyone - An Introduction, University of Colorado Boulder
- Introduction to High-Performance and Parallel Computing, University of Colorado Boulder
- Dynamic Programming, Greedy Algorithms
- Blockchain Security
- Analysis of Algorithms Princeton University
- DeepLearning.AI, IBM
- Cybersecurity Compliance Framework, Standards & Regulations, Google Cloud
- Site Reliability Engineering: Measuring and Managing Reliability, The University of Sydney
- Blockchain Scalability and its Foundations in Distributed Systems

As it can be seen from the aforementioned indicative list of courses, the majority of the providers are from USA. Indeed, there are very few European Educational organizations that provide MScs and Bachelors in the domain of quantum computing. Specifically, there are only six MSc in EU.

a) **Universiteit van Amsterdam (Netherlands)[2]**: Offers a Master's in **Quantum Computer Science**, which is a research-focused program combining physics, mathematics, and computer science to prepare students for careers in both research and industry. It is closely affiliated with the QuSoft research center.
b) **Barcelona Quantum Master (Spain)[3]**: A one-year Master's program that includes quantum computing and technologies. This interdisciplinary program is conducted by a consortium of universities (University of Barcelona, Autonomous University of Barcelona, and others), providing students with hands-on experience in quantum technologies.
c) **Uppsala University (Sweden)[4]**: Their **Master’s in Quantum Technology** emphasizes quantum phenomena and applications such as quantum optics and quantum information science, preparing students for both academic and industrial careers.

d) **Leiden University & Delft University of Technology (Netherlands)[5]**: The joint **Master's in Quantum Information Science & Technology** covers quantum computing, quantum communication networks, and quantum sensors. It is designed for students with backgrounds in physics, electrical engineering, and computer science.

e) **Collaboration of Demokritio University and National Centre for Scientific Research Demokritos (Greece)**[6]: The joint Master in quantum computing and quantum technologies is designed for professionals in physics, materials and computer science.

Unfortunately, EU Bachelors dedicated in quantum computing are quite rare and the same goes for seminars and courses with the basic principles of quantum computing.

Comparison of required skills and available skills; comparison of skill profiles and labour market demands

So far the need for quantum computing professionals is moderate but it will raise significantly the next few years. According to McKinsey, there were 851 active job postings on December of 2021. However, the number of existing quantum technology Master's level graduates in yearly level do not surpass the number of 290. Thus, there is a significant need currently which is covered by upskilling graduates from related disciplines. It is estimated that are 350.000 graduates in quantum technology relevant fields that could address this need if proper training is provided.

According to McKinsey[7], Quantum computing alone, which represents the largest market potential for the three mains areas of quantum technology (the other two areas being quantum sensing and quantum communications) could account for up to nearly $700 billion in value. Thus, the market potential of industries which focus in these domains is tremendous. The same research paper from McKinsey shows that there is only one qualified quantum candidate available for every three quantum job openings By 2025, it is expected that less than 50 percent of quantum computing jobs will be filled unless significant interventions occur.

Quantum start-ups and established tech companies—especially those in the hardware market, where more than half of today's quantum investments are concentrated —have been the first to wrestle with this talent crunch as they race to solve fundamental questions in the field and deliver fault-tolerant quantum systems, which are necessary to unlock the technology's full potential. It's stil early days, with many unknowns, but the technology is rapidly progressing.

7.4 Summary & recommendations

In summary, the current workforce is relatively small and highly specialized, but with ongoing efforts from academia, industry, and government to close the skills gap, we can expect significant growth in the coming years. However, quantum computing remains highly complex, so building the necessary skills pipeline will take time and sustained investment.

As quantum computing becomes more viable, the demand for talent will surge. Governments and companies are already emphasizing the need for building quantum literacy, but the industry will require a diverse set of skills, ranging from quantum mechanics to systems engineering to AI integration with quantum technologies.

Prioritized list of skill gaps requiring immediate attention

There is lack of knowledge in the whole thematic even in superficial level which has significant impact to further advancement of the technology. In more details, there is lack of knowledge around quantum physics, cryogenics, quantum mechanics and complex mathematics. The lack of the aforementioned abilities makes hard tasks such as development of algorithms tailored for quantum computers, building and maintaining quantum computers and translation of classical computing algorithms to quantum ones.

7.5 References & resources

[1] "Quantum Computation and Quantum Information" by Michael A. Nielsen and Isaac L. Chuang

[2] "Quantum Computing: A Gentle Introduction" by Eleanor Rieffel and Wolfgang Polak

[3] The Theory of Quantum Computation: A Comprehensive Survey":

[4] Quantum Error Correction" by Daniel Gottesman

[5] Quantum Computing courses by Coursera, edX, or MIT OpenCourseWare

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WP4 Enhancing Labour Market-Relevant Skills in Advanced Technologies

T4.1 Identifying skill gaps in Advanced Technologies

National level Reports from the desk research

Date: September 2024 – January 2025

INVESTech

Innovation Vocational Excellence

and Sustainability in Tech

PROJECT REF NO. 101143958. ERASMUS-EDU-2023-PEX-COVE

Co-funded by the European Union

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WP4 Enhancing Labour Market-Relevant Skills in Advanced Technologies

T4.1 Identifying skill gaps in Advanced Technologies

BULGARIA national report from the desk research

Date: September 2024 – January 2025

Prepared by: Joint Innovation Centre of BAS
Cluster Sofia knowledge city

INVESTech
Innovation Vocational Excellence and Sustainability in Tech

PROJECT REF NO. 101143958. ERASMUS-EDU-2023-PEX-COVE

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1 BULGARIA – National report from the desk research

1.1 Artificial Intelligence and Ethics

1.1.1 Introduction & methodology

Description of data sources utilized.

The main sources of data are: Industry reports which are published by leading organizations in the fields of ICT, Blockchain, emerging technologies, and other; Reports by employers' organisations and associations; Academic sources: conference proceedings about IoT, research papers, articles, journals, and analysis of trends and innovations; Business sources – platforms of corporations and start-ups; other sources like: media outlets, social media, market research databases, interviews and videos and other.

Data collection and analysis methods employed.

- Literature review: use of keywords "AI jobs in Bulgaria," "advanced technologies in Bulgaria," "AI trends in Bulgaria, "AI startups in Bulgaria", "key skills and competences in AI", "roles and jobs in AI in Bulgaria".
- Cross referencing of the sources to validate accuracy and precision.
- Collection of targeted data from specific company websites, trends analysis
- Analysis of data on open access and licensed platforms
- Synthesis and generation of insights from data
- Identification of trends and facts
- Comparison
- Categorizing.

As the sector is very dynamic, the main findings are retrieved from sources in the past two years and projections for the next few years.

1.1.2 Identified roles, jobs, skills & competency profiles

According to the Annual AI report 2022:

- There is a clear increase in the number of companies interested in using AI to create innovative solutions that can positively impact Bulgarian society;
- The combined total revenue of Bulgarian AI developers reached a record-high of 25.7 million in 2021, a jump of more than 35% from the amount in 2019;
- Bulgarian entrepreneurs have a strong presence on the local AI scene – 70% of the companies in the area are solely owned by Bulgarian individuals or companies;
- There is an upward trend in the number of employed specialists in the field, a record-high annual growth rate of 25% was reached in 2020;

- In 2021, nearly 40% of those employed in the sector were engaged in research and development, up from 29% in 2020.

Who is hiring

Current & potential employers: Ontotext, myPOS, Acronis, Lenovo, Endurosat, The Coca-Cola Company, Commerzbank Digital Technology Centre Bulgaria, Deloitte, EPAM Systems, Baringa, B EYE Ltd., myPOS, Schwarz Global Services Bulgaria EOOD, PricewaterhouseCoopers Bulgaria Ltd, AXION EDGE OOD, DXC Bulgaria EOOD, Bulwork, Bica services, BLACKDEEP TECHNOLOGIES LTD

List of specific roles = professionals working with the respective ATI Career opportunities / jobs/ working positions:

Fintech, banks, Business intelligence and modeling, data analysis. The main positions retrieved on LinkedIn and Jobs.bg are:

GenAI Engineer with Python

- Responsibilities*:*
  - Developing web and OOP applications using Python.
  - Extracting data from text documents and performing web scraping.
  - Building and maintaining RAG (Retrieval-Augmented Generation) processing pipelines, applying statistical methods and math fundamentals.
- Required skills and experience:
  - Experience in Python and App Development (OOP/web development).
  - Experience with React JS for frontend development.
  - Expertise in data extraction, web scraping, and working with text documents.
  - Experience of RAG processing pipelines and the application of RAG fundamentals (strong math and statistics background).
  - Familiarity with ERP systems.
  - Experience in machine learning methods such as clustering, classification, regression, recommendation systems, and semantic analysis.
  - Proficient in English for business communication.
  - Minimum 2-3 years of experience in Python development.

Senior ML Engineer

- Responsibilities:
  - Lead cross-functional teams including data scientists, data engineers and data analysts, as
  - well as manage expectations of business stakeholders and work to understand business
  - requirements and develop solutions that have an impact on the bottom line.
  - Own the end-to-end development of AI & ML models for real-time and batch-based products,
  - as well as running customer-facing services (APIs) in AWS cloud-based environments.

- Drive and advocate adoption of best practices in cloud-native MLOps (monitoring + alerting).
- Create and be responsible for data pipelines and automation processes that enhance
- efficiency, accuracy and quality in data collection and data preparation.
- Mentor junior ML engineers to support their growth and encourage upskilling.
- Document analytical processes, methodologies, and findings to ensure clarity, reproducibility,
- and knowledge sharing across teams.

- Required skills and experience
  - A Master degree in STEM (Computer Science, ML/AI, Physics, Engineering), along with 5+ years of experience delivering measurable value through data in a commercial setting.
  - Expert in Python 3.12+ and latest versions of frameworks, including Scikit-learn, Numpy and
  - Pandas with practical Data Science experience of Spark SQL and Jupyter notebooks.
  - Experience with MLOps pipelines on AWS and building, training, testing, and deploying ML models at scale on cloud-native infrastructure.
  - Experience with CI/CD tooling and AWS products like EC2, S3, CloudWatch and AWS CDK.
  - Experience with monitoring and alerting solutions such as NewRelic, Datadog or PagerDuty.
  - Strong software testing approach to ensure high test coverage for financial use cases.
  - Strong understanding of the structure and suitability of different ML models and approaches for training trade-offs with experience in testing and accuracy for business performance.
  - Well-versed in version control, with practical experience of Git+Gitflow on Github or Gitlab.
  - Excellent communications skills, able to translate technical finding into business insights.
  - Comfortable managing priorities in a fast-paced and dynamic work environment.
  - A self-starter, detail-oriented who thrives on integrity, initiative, team-playing and results.
  - Desire to stay up-to-date and experiment with the latest Gen AI research.

Junior AI/ML Engineer

- Responsibilities
  - Assist in the research and development of AI/ML algorithms and models under the guidance of senior engineers.
  - Help implement basic Natural Language Processing (NLP) solutions, including sentiment analysis and text classification.
  - Support the team in analyzing Time Series data for forecasting and pattern recognition.
  - Collect, clean, and prepare datasets for analysis and model development.

- Collaborate with the Data team to prioritize new datasets and contribute to model-building processes.
- Assist in testing, optimizing, and fine-tuning AI/ML models.
- Stay up to date with advancements in AI/ML technologies and apply new learnings to ongoing projects.

- Required skills and experience:
  - Bachelor's degree in computer science, Engineering, Mathematics, or a related field.
  - Some experience or academic background in AI/ML or data science projects (internships, coursework, personal projects, etc.).
  - Proficiency in programming languages like Python
  - Familiarity with machine learning concepts and algorithms.
  - Basic understanding of deep learning frameworks such as TensorFlow, PyTorch, or Keras.
  - Willingness to learn and work with cloud platforms like AWS, Azure, or GCP.
  - Good problem-solving skills and eagerness to learn in a fast-paced environment.
  - Strong communication and collaboration skills; ability to work in a team.

AI Researcher

- Responsibilities
  - Participate in externally funded or internal research projects
  - Communicate and collaborate with partners and/or colleagues to identify user needs and transform them to technical requirements
  - Research state-of-the-art algorithms, methods, and tools to propose the most appropriate for the task/project
  - Carry out experiments with the selected methods/algorithms/tools and evaluate results
  - Work together with developers to apply selected methods/algorithms in the implementation of components, services, demonstrators, applications, or products
  - Report project results in deliverables, in scientific papers, in presentations and in blogposts
  - Participate in writing project proposals for national and international funding
  - The position allows for flexible definition of your role and responsibility based on your knowledge, experience and skills.

- Required skills and responsibilities
  - Excellent command of English, both written and verbal
  - Presentations and documentation writing skills
  - Proactive and result-oriented attitude
  - Openness to interdisciplinary tasks and collaboration
  - Teamwork and knowledge transfer skills.
  - AI (ML, NLP, DL)
  - Semantic technologies (ontologies, SPARQL, KGs)
  - Databases (SQL, non-SQL)
  - OOP, Data Structures and Algorithms, graph theory

  - Programming knowledge or experience, ideally in Java and/or Python, and desire to improve it.

- Nice to have:
  - Experience in applied research in AI, Information Systems or Software Engineering
  - Experience with Pytorch and/or Tensorflow
  - (Leading) Work on research projects (national or international funding, internal in the organisation or in cooperation with other organisations)
  - Publications of scientific papers
  - Experience in some of the domains of application (healthcare, pharma, manufacturing, energy, media and publishing, banking and fintech, automotive, buildings and construction)
  - Experience as Senior Researcher or Researcher in computer science
  - Research project reporting, presentations, and documentation, writing of project proposals for funding.

1.1.3 Skill Gap Analysis

Analysis of skill proficiency levels in the workforce:

To become an AI engineer, a diverse set of skills is required, spanning software, algorithms, Python code and data analysis. Here's a comprehensive breakdown of the essential skill sets:

- Programming Skills
  AI engineers must have strong coding skills to develop, implement, and optimize algorithms and models.
  - Languages: Python, Java, R, C++, Julia, Scala.
  - Frameworks and Libraries: TensorFlow, PyTorch, Keras, Scikit-learn, NumPy, Pandas, OpenCV.

- Mathematics and Statistics
  A solid foundation in mathematical concepts is essential for understanding and developing AI models.
  - Linear Algebra: Matrices, vectors, eigenvalues/eigenvectors.
  - Calculus: Partial derivatives, gradients, optimization.
  - Probability and Statistics: Bayes theorem, distributions, hypothesis testing.

- Machine Learning and Deep Learning
  Understanding machine learning algorithms and neural networks is central to AI engineering.
  - ML Algorithms: Linear regression, logistic regression, decision trees, random forests, support vector machines.
  - Deep Learning Concepts: Neural networks, convolutional neural networks (CNNs), recurrent neural networks (RNNs), transformers.
  - Optimization Techniques: Gradient descent, backpropagation.

- Data Skills
  AI engineers work extensively with data, making these skills critical:
  - Data Preprocessing: Cleaning, normalizing, and transforming data.
  - Data Analysis: Using tools like Pandas, Matplotlib, and Seaborn for exploratory data analysis.
  - Big Data Tools: Hadoop, Spark, Apache Kafka.
- Natural Language Processing (NLP)
  For those working with text-based data:
  - Text Processing: Tokenization, stemming, lemmatization.
  - Libraries/Tools: NLTK, SpaCy, Hugging Face Transformers.
- Computer Vision (Optional, but Highly Valuable)
  For AI engineers specializing in image and video data:
  - Concepts: Image classification, object detection, segmentation.
  - Tools/Frameworks: OpenCV, TensorFlow, PyTorch.
- Problem-Solving and Analytical Thinking
  AI engineers must design solutions for real-world problems, which requires:
  - Breaking down complex problems into solvable steps.
  - Evaluating different models and approaches for effectiveness and efficiency.
- Software Engineering Skills
  AI engineers often work as part of a team and need software development expertise:
  - Version Control: Git, GitHub, GitLab.
  - APIs: RESTful services, working with APIs to integrate AI models.
  - Debugging: Identifying and resolving issues in code.
- Cloud Computing and Deployment
  Understanding how to deploy and manage AI models in production:
  - Cloud Platforms: AWS, Google Cloud Platform (GCP), Microsoft Azure.
  - Containerization and Orchestration: Docker, Kubernetes.
  - MLOps: Understanding CI/CD pipelines for ML.
- Domain Knowledge
  Depending on the industry, domain-specific knowledge can be crucial (e.g., healthcare, finance, autonomous systems).
- Communication and Collaboration Skills
  AI engineers often work with multidisciplinary teams:
  - Ability to explain complex technical concepts to non-technical stakeholders.
  - Teamwork to collaborate with data scientists, product managers, and engineers.
- Continuous Learning
  AI is a rapidly evolving field. Staying updated with the latest research, tools, and methodologies is essential:
  - Learning Resources: Research papers, AI conferences (NeurIPS, ICML), online courses.
  - Certifications: Google AI Certification, AWS Machine Learning Specialty.

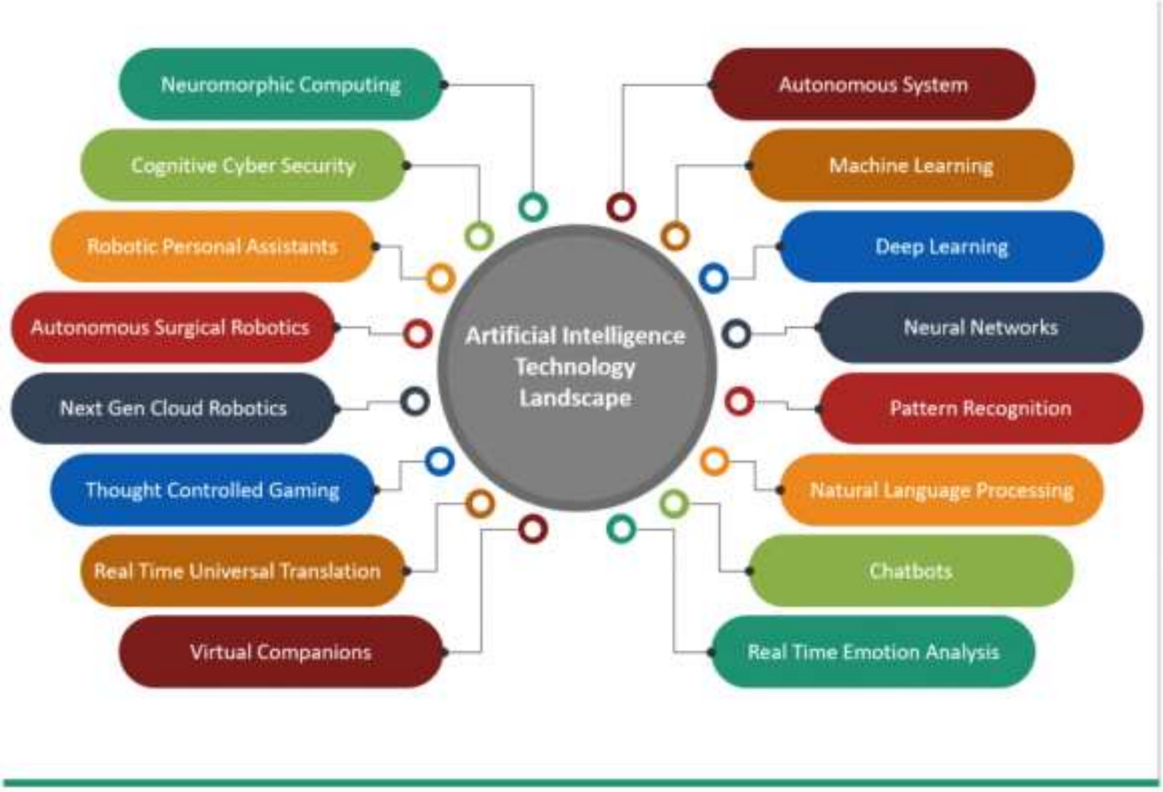

Figure 1 A New Future of Work: The Race to Deploy AI and Raise Skills in Europe and Beyond, July 12, 2024
https://www.consultia.co/a-new-future-of-work-the-race-to-deploy-ai-and-raise-skills-in-europe-and-beyond/

1.1.4 Summary & recommendations

Bulgaria's AI ecosystem is experiencing significant growth, with an increasing number of companies developing innovative solutions that positively impact society. Bulgarian-owned enterprises dominate the sector, making up 70% of the AI ecosystem. Revenue generated by Bulgarian AI developers saw a remarkable growth of over 35% between 2019 and 2021, reaching €25.7 million. This growth is also reflected in employment trends, as the number of professionals in the sector grew by 25% annually in 2020. Furthermore, nearly 40% of employees in 2021 were engaged in research and development, showcasing a shift towards innovation-focused roles. Key players in the Bulgarian AI landscape include Ontotext, Acronis, Lenovo, and various fintech, business intelligence, and data analytics firms, offering roles such as AI/ML engineers and AI researchers.

Despite these advancements, Bulgaria faces several challenges that hinder its full potential in the AI domain. The skillsets of the workforce are not fully aligned with the evolving needs of the industry. High demand exists for professionals skilled in programming languages like Python and Java, machine learning, natural language processing (NLP), and cloud computing. However, there are significant gaps in advanced AI/ML skills, deep learning frameworks, and practical industry experience. Additionally, collaboration between academia, industry, and government remains limited, and there is a need for targeted training programs to bridge these gaps and attract new talent into the field.

To strengthen Bulgaria's position in AI development, several actions are necessary. Upskilling the workforce should be a priority, with the introduction of specialized training programs in AI/ML, certifications in advanced frameworks such as TensorFlow and PyTorch, and enhanced collaboration between universities and industries to ensure curricula align with market needs. Partnerships between academia and the private sector should also extend to joint research initiatives, focusing on emerging technologies like generative AI and ethical AI. These collaborations can foster innovation while providing students and professionals with hands-on opportunities.

Encouraging the growth of AI startups is another crucial step. Providing funding opportunities and creating incubator programs can help nurture innovative ideas. Networking events and platforms can facilitate connections between startups and potential investors or collaborators. At the same time, investment in Bulgaria's digital infrastructure, such as cloud computing and data storage facilities, is essential for supporting the development and deployment of AI projects.

An inclusive approach to building the AI ecosystem will further strengthen Bulgaria's position. Initiatives to engage underrepresented groups, such as women, in AI through scholarships and mentorship programs can broaden participation. Regional inclusivity should also be promoted by extending AI training and employment opportunities to underserved areas, ensuring no community is left behind in the digital transformation.

To provide a robust foundation for these efforts, supportive policies and government incentives should encourage companies to invest in AI and digital transformation. National guidelines for ethical AI development can foster trust and ensure responsible adoption of AI technologies. Additionally, Bulgaria should actively engage in European AI initiatives, leveraging programs like Horizon Europe and Erasmus+ for funding, knowledge exchange, and alignment with EU priorities.

By addressing these areas, Bulgaria can unlock the full potential of its AI ecosystem, creating a dynamic, inclusive, and forward-looking environment for innovation, economic growth, and societal benefit.

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1.2 Big Data

1.2.1 Introduction & methodology

Description of data sources utilized.

The main sources of data are: **Industry reports** which are published by leading organizations in the fields of ICT, Blockchain, emerging technologies, and other; **Reports** by employers' organisations and associations; Academic sources: conference proceedings about IoT, research papers, articles, journals, and analysis of trends and innovations; **Business sources** – platforms of corporations and start-ups; other sources like: media outlets, social media, market research databases, interviews and videos and other.

Data collection and analysis methods employed.

- Literature review: use of keywords "Big Data jobs in Bulgaria, "Big Data trends in Bulgaria, "Big Data startups in Bulgaria", "key skills and competences in Big data", "roles and jobs in Big Data in Bulgaria".
- Cross referencing of the sources to validate accuracy and precision.
- Collection of targeted data from specific company websites, trends analysis
- Analysis of data on open access and licensed platforms
- Synthesis and generation of insights from data
- Identification of trends and facts
- Comparison
- Categorizing.

As the sector is very dynamic, the main findings are retrieved from sources in the past two years and projections for the next few years.

1.2.2 Identified roles, jobs, skills & competency profiles

- Growth Projections:
  - The Bulgarian data center market is expected to grow significantly, with a market volume projected to reach US$201.70 million by 2028.
  - The market is forecasted to grow by 4.94% annually from 2025 to 2029, reaching US$227.50 million by 2029.
- Market Drivers:
  - Increased demand for cloud services and data storage solutions.
  - Expansion of digital infrastructure and investments in new data centers.
- Key Providers:
  - Profiles of major public cloud and data center providers operating in Bulgaria, including their market strategies and offerings.
- Infrastructure Development:
  - Growth in data center space, power capacity, and pricing trends.

- Development of new data center facilities and upgrades to existing ones to meet rising demand.

Who is hiring

Current & potential employers: Sciant (part of Sirma Group), Adastra, Sigma Software Group, N-iX, Intway, VECTOR Labs, CST, B EYE, Sage Data, RS Consult BG, Code Runners, SoCyber, Code Badgers, Zero Down Time Ltd, MENA Software, South Gate Tech Ltd., Indexed, Sirma, Cosmos Thrace Ltd., Ontotext, FTS Group, BRIGHT, Premier research.

List of specific roles = professionals working with the respective ATI Career opportunities / jobs/ working positions:

Business Intelligence and Big Data Solutions, BI & Big Data Consulting & SI, Systems Integration Services, and Data Management Consulting, Building internal dashboards and advising on data architectures, web-based and hybrid mobile application development services. The main positions retrieved on LinkedIn and Dev.bg are:

Data Engineer

- Responsibilities:
  - Design and implement big data infrastructure for analytical and operational purposes.
  - Develop and maintain data pipelines to extract, transform, and load data from various sources into our data solutions.
  - Ensure data pipelines are efficient, scalable, and reliable, integrating data from different sources such as databases, APIs, logs, and external data providers.
  - Perform data transformation and cleansing to ensure data is in a usable format for analysis.
  - Automate routine data engineering tasks using scripting languages such as shell scripts and Python.
  - Collaborate with cross-functional teams to understand data-related requirements and implement solutions that meet business needs.
  - Mentor junior team members and provide technical guidance and expertise.

- Required skills and experience
  - 2+ years experience in database integration, processing and analysis tools, such as Apache Hadoop, SQL, Apache Spark etc.
  - Proficient in programming languages such as Python and/or R.
  - Excellent communication skills to convey complex concepts effectively.
  - Proven experience with statistical concepts and data preprocessing techniques.
  - Proven experience constructing and orchestrating big data ETL pipelines.
  - Proactive with the ability to work independently.
  - Strong analytical skills and a methodical approach to work.
  - Knowledge of insurance business principles is an advantage.
  - Fluency in English

Data Architect

- Responsibilities
  - Data Architecture Leadership:
    - Lead the design and deployment of data architecture solutions tailored to meet business and technical needs.
    - Ensure solutions are scalable, secure, and performance-optimized.
    - Develop comprehensive documentation for processes, standards, and best practices.
  - Data Integration & Consolidation:
    - Strategize and implement integration frameworks connecting diverse data sources and systems.
    - Address challenges related to data quality, consistency, and governance.
    - Create a roadmap for short- and long-term technology stacks and frameworks that align with enterprise goals.
  - Innovation & Collaboration:
    - Stay ahead of emerging technologies, recommending innovative solutions.
    - Partner with cross-functional teams to ensure seamless system integration and alignment with strategic objectives.
- Required skills and experience
  - Bachelor's degree in Computer Science, IT, or a related field (Master's degree preferred).
  - Proven expertise in data architecture, integration, and leadership roles.
  - Proficiency in data modeling, database design, and integration frameworks. Familiarity with cloud platforms (Azure, AWS, Google Cloud) and big data technologies (Hadoop, Spark, Kafka) is highly valued.
  - Strong analytical, project management, and problem-solving abilities. Exceptional communication and stakeholder engagement skills.

Database Architect

- Responsibilities
  - Database Design and Modeling: Design, create and maintain complex databases and define the architecture of these. This involves designing the structure, storage, data flows, and access layers of the database to ensure efficient data storage, retrieval, and processing.
  - Database Optimization: Responsible for optimizing and fine-tuning databases for better performance. This includes optimizing queries, implementing indexing strategies, and ensuring data processing, efficient from performance and stability perspectives.
  - Data Integration and Migration: Managing the integration of new data sources into existing database systems and overseeing data migration projects, ensuring seamless data transfer between different systems or during upgrades.
  - Data Security and Compliance: Ensuring that the databases are secure against unauthorized access or breaches is a critical part of their role. Accountable for ensuring compliance with data protection regulations and standards.

- Capacity Planning: Closely involved in forecasting future database needs, including storage requirements, to ensure scalability and performance.
- Technical Support and Troubleshooting: Providing technical support for database environments and close involvement with problem-solving and troubleshooting issues arising within the database systems.
- Collaboration with IT Teams and Stakeholders: Work closely with different technology teams, such as system administrators, software developers, and data analysts, as well as business stakeholders to understand their data needs and translate these into effective database solutions.
- Documentation and Reporting: Detailed documentation creation for database architectures and updating records of operational procedures and systems changes.
- Staying Updated with Technology Trends: Keep abreast of the latest trends and advancements in database technologies and methodologies to implement the best solutions and practices.
- Training and Mentoring: Ensure the junior staff training needs are addressed and domain related knowledge is properly recorded, stored and shared.

- Required skills and experience:
  - Bachelor's or higher degree in Computer Science, Engineering, or a related field.
  - The role requires a level of seniority (10+ years of industry experience).
  - A strong foundation in database theory, proficiency in relational database languages, such as SQL.
  - Familiarity with database management systems.
  - Hands-on experience with data modeling tools.
  - Additionally, skills in areas such as cloud computing, big data technologies, and data warehousing can be valuable.

Data Analyst

- Responsibilities
  - Ensure the quality, accuracy, and integrity of large-scale datasets
  - Analyze datasets to detect anomalies, enhance data quality, and support data-driven decision-making
  - Develop and enforce quality control standards for data preparation and refinement
  - Monitor and optimize data pipelines to maintain consistency and reliability
  - Design and produce reports and dashboards to visualize data quality metrics
  - Contribute to automation initiatives that streamline and improve data processing

- Required skills and responsibilities
  - Proficient in SQL, Python, and experienced in data warehousing and ETL processes
  - Extensive experience in data analysis and quality assurance, particularly in big data environments
  - Detail-oriented, methodical, and able to maintain high-quality standards
  - Strong analytical and problem-solving skills with the ability to tackle complex challenges
  - Quality-focused with a proactive, solution-oriented approach

- Collaborative team player with strong communication skills for cross-departmental projects
- Experience with tools like AWS Athena, Apache Spark, or Grafana is a plus

Data Manager

- Responsibilities:
  - Assists in preparing clean databases by performing a review of clinical trial data through the CDMS or external data listings to ensure all captured data follows the rules outlined by the protocol and Data Management Plan
  - Provide input to and review of Data Management Plans in support of clinical study deliverables
  - Generates queries to appropriate internal or external personnel (e.g. - investigational sites, vendors, Clinical Research Associates, and client representatives) to resolve problematic data identified during every aspect of the data management process
  - Reviews responses to queries for appropriateness, resolves any discrepancies, and modifies the database accordingly
  - Supports the development of CRFs and edit check specifications per protocol and participates in user acceptance testing of CRFs and associated edit check specifications as required
  - Assists in the user acceptance testing for study-specific data listings ensuring data output adheres with requirements
  - Prepares and maintains documentation related to CRF, edit check, and data listing testing including initial testing and follow-up testing to ensure that the changes have been made, as required
- Required skills and responsibilities:
  - Bachelor degree, or international equivalent from an accredited institution, preferably in a technical, clinical, or health-related field], or equivalent combination of education, training and experience
  - 3 to 5 years of practical experience using commercial clinical data management systems and/or EDC products (eg - Oracle RDC / Inform, Medidata Rave, DataLabs, etc). Alternately, must have proven experience in all primary job functions.
  - Demonstrates excellent English verbal and written communication skills
  - Excellent computer skills in a Microsoft Windows environment including proficiency in the Microsoft Office Suite of tools (eg - Outlook, Work, Excel, etc)
  - Proven ability to drive a successful customer experience through positive customer interactions, provision of quality and timely deliverables, and task ownership
  - Strong analytical and organization skills, able to work independently and manage multiple projects simultaneously in a fast-paced environment with changing priorities

1.2.3 Skill Gap Analysis

To become a Database Architect, which is the highest paid position on the researched market, a diverse set of skills is required such as a blend of technical expertise, analytical abilities, and strategic thinking. Here’s a comprehensive breakdown of the essential skill sets. Becoming a database architect requires a blend of technical expertise, analytical abilities, and strategic thinking. Below are the key skills and knowledge areas essential for this role:

- Database Management and Design
  - Database Systems: Proficiency in relational database management systems (RDBMS) like MySQL, PostgreSQL, Oracle, and SQL Server, as well as NoSQL databases like MongoDB or Cassandra.
  - Data Modelling: Strong understanding of database schema design, normalization, and creating entity-relationship (ER) diagrams.
  - Query Languages: Advanced SQL skills for querying, managing, and optimizing databases.
- System Architecture and Integration
  - System Design: Knowledge of database architecture, including designing for scalability, reliability, and performance.
  - Integration: Expertise in integrating databases with applications and other systems using APIs or middleware.
  - Data Warehousing: Understanding of data warehousing concepts and tools, such as Snowflake or Amazon Redshift.
- Programming Skills
  - Languages: Proficiency in programming languages like Python, Java, C#, or PHP for database interaction and backend development.
  - Scripting: Skills in scripting for automating database tasks.
- Performance Optimization
  - Database Tuning: Ability to optimize database performance through indexing, query optimization, and caching strategies.
  - Monitoring Tools: Familiarity with database monitoring and diagnostic tools like SolarWinds, Nagios, or SQL Profiler.
- Security and Compliance
  - Data Security: Knowledge of data encryption, access controls, and secure database configurations.
  - Regulatory Compliance: Familiarity with data privacy laws and regulations such as GDPR, HIPAA, or CCPA.
- Cloud Computing and Database Services
  - Cloud Platforms: Experience with cloud-based databases and services like Amazon RDS, Google Cloud Spanner, or Microsoft Azure SQL Database.
  - Cloud Architecture: Understanding how to design and manage databases in cloud environments.
- Backup and Recovery
  - Disaster Recovery: Skills in designing and implementing robust backup and recovery solutions.
  - Data Migration: Expertise in migrating data between databases or systems with minimal downtime.

- Analytical and Problem-Solving Skills
  - Ability to troubleshoot database issues and identify solutions.
  - Capacity to analyze complex data requirements and translate them into effective database designs.
- Communication and Collaboration
  - Team Collaboration: Working with stakeholders, software developers, and IT teams to define requirements and design solutions.
  - Documentation: Preparing technical documentation and providing clear explanations of database structures and strategies.

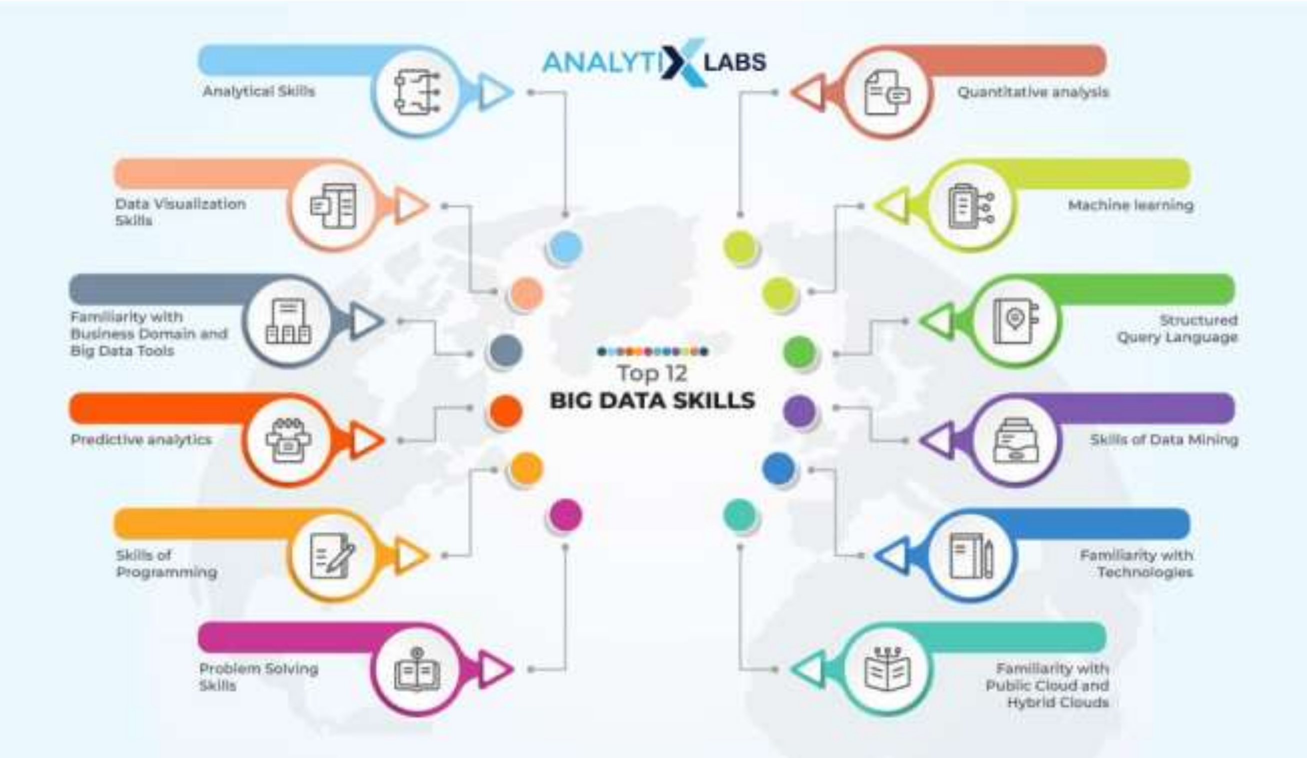

Figure 2 : Top 12 Big Data Skills to Learn, 14 August 2023
https://www.analytixlabs.co.in/blog/big-data-skills/

- Continuous Learning
  - Emerging Technologies: Staying updated on new database technologies, trends, and best practices.
  - Certifications: Earning relevant certifications like:
  - Microsoft Certified: Azure Data Engineer Associate
  - Oracle Certified Professional (OCP) Database Administrator
  - AWS Certified Database Specialty
  - MongoDB Certified DBA Associate

1.2.4 Summary & recommendations

The Bulgarian market for big data services is evolving alongside the growing demand for skilled professionals in the sector. The data center market in Bulgaria is projected to experience significant growth, reaching a volume of $227.5 million by 2029. This expansion is driven by increasing demand for cloud services, data storage solutions, and advancements in digital infrastructure. However, the rapid growth has revealed a pressing need for highly skilled professionals to support developments in big data infrastructure, analytics, and data-driven decision-making.

Leading employers in the Bulgarian big data sector, such as Sciant, Adastra, Sigma Software Group, and Sirma, are actively seeking talent for roles including data engineers, data architects, and data analysts. Despite this demand, a notable gap exists in the availability of qualified professionals with advanced expertise in big data technologies. Many of these roles require proficiency in tools like Apache Hadoop, Apache Spark, and advanced programming languages such as Python and R. Furthermore, there is a misalignment between the current educational offerings and industry requirements, particularly in preparing students and professionals for complex tasks like data architecture, ETL processes, and system integration.

To address these challenges, Bulgaria must enhance its educational services to ensure a high-quality workforce for the big data sector. Collaboration between educational institutions and industry stakeholders is critical to aligning curricula with market demands. Programs must integrate practical training on industry-standard tools and frameworks, while also expanding specialized training and certifications in advanced big data technologies. Strengthening partnerships between academia and industry can create opportunities for internships, co-designed courses, and mentorship programs, bridging the gap between theoretical knowledge and practical applications.

As the big data landscape evolves rapidly, lifelong learning and upskilling initiatives are essential to ensure the workforce remains competitive. Educational providers should focus on offering targeted programs for working professionals, enabling them to stay updated with emerging technologies. Investments in modern digital infrastructure, including access to real-world datasets, virtual labs, and cloud-based tools, are also vital for providing hands-on learning experiences.

In light of increasing data privacy regulations such as GDPR, education programs should emphasize training in data security, compliance, and ethical data handling practices. This focus will prepare professionals to navigate the regulatory landscape effectively and responsibly. Moreover, extending big data education services to underserved regions in Bulgaria is essential to ensure a broader and more inclusive talent pool. Remote training programs and scholarships can help achieve this goal, promoting regional equity in access to quality education.

Bulgaria should also actively leverage European Union-funded initiatives such as Erasmus+ and Horizon Europe, which can provide valuable resources and frameworks for improving digital skills and big data competencies. By implementing these measures, Bulgaria can create a robust pipeline of skilled professionals capable of driving innovation in the big data sector. This, in turn, will support the country's economic growth, technological advancement, and competitiveness in the global digital economy.

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1.3 Blockchain

1.3.1 Introduction & methodology

Description of data sources utilized.

The main sources of data are: **Industry reports** which are published by leading organizations in the fields of ICT, Blockchain, emerging technologies, and other; **Reports** by employers' organisations and associations; Academic sources: conference proceedings about IoT, research papers, articles, journals, and analysis of trends and innovations; **Business sources** – platforms of corporations and start-ups; other sources like: media outlets, social media, market research databases, interviews and videos and other.

Data collection and analysis methods employed.

- Literature review: use of keywords "Blockchain in Bulgaria," "advanced technologies in Bulgaria," "Blockchain trends in Bulgaria, "Blockchain startups in Bulgaria", "key skills and competences in blockchain", "roles and jobs in blockchain in Bulgaria".
- Cross referencing of the sources to validate accuracy and precision.
- Collection of targeted data from specific company websites, trends analysis
- Analysis of data on open access and licensed platforms
- Synthesis and generation of insights from data
- Identification of trends and facts
- Comparison
- Categorizing.

As the sector is very dynamic, the main findings are retrieved from sources in the past two years and projections for the next few years.

1.3.2 Identified roles, jobs, skills & competency profiles

According to Statista.com:

- The Cryptocurrencies market in Bulgaria is predicted to achieve a revenue of US$11.7m in 2025.
- This revenue is projected to experience a steady annual growth rate (CAGR 2025-2025) of NaN%, resulting in a total projected amount of US$11.7m by 2025.
- In 2025, the average revenue per user in the Cryptocurrencies market is estimated to be US$43.4.
- When compared globally, United States is expected to achieve the highest revenue in the Cryptocurrencies market, reaching US$9,423.0m in 2025.
- In Bulgaria, the number of users in the Cryptocurrencies market is expected to reach 269.20k users by 2025.
- The user penetration rate is projected to be 4.10% in 2025 and is anticipated to increase to 4.10% by 2025.
- Bulgaria is emerging as a hotbed for cryptocurrency mining due to its low energy costs and favorable regulatory environment.

Who is hiring:

Current & potential employers: Crypto.com, NTU International A/S, World Bank, LimeChain - Blockchain & Web3 Solutions, ASBIS Bulgaria Ltd., Green Street, Green Street, European Tech Recruit, Redis, Axiom Recruit, OnHires, Dragonfly, Odiin., Enertek Group, Kreativstorm, Hyphen Connect, Foris Europe EOOD, CryptoSphere, Grind Web Studio.

List of specific roles = professionals working with the respective ATI Career opportunities / jobs/ working positions:

High-converting eCommerce, FX, FX Option, Commodities, Equities, Cryptocurrencies, Fintech, Web3 companies, Trading companies. The main positions retrieved on LinkedIn are:

Blockchain Engineer

- Responsibilities:
  - Experience building and managing a protocol with significant TVL
  - Experience in blockchain engineering at a Layer-1, Layer-2, or Infrastructure (Oracle, Bridge, Indexer, RPC Provider, Wallet, or other high-performance app) project
  - Experience researching and developing protocol upgrades
  - Write secure, well-documented, well-tested code, Write code to interface with data stores, including databases (relational and non-relational) and a blockchain
  - Design, implement and document clear and consistent APIs to be consumed by web and mobile clients
  - Guide product decisions
- Required skills and experience
  - Years experience with Golang or C++
  - Years of experience in a backend engineering role
  - Experience with distributed systems
  - Familiarity with a modern web development framework such as Python (Django/Flask), Ruby (Rails), or Javascript (React/Flux)
  - Comfortable operating in dynamic environment

Rust Smart Contract Developer

- Responsibilities
  - Build and optimize smart contracts on Solana, with opportunities to expand into Rust-based ecosystems like ICP
  - Design cross-chain features to make Bitcoin lending and borrowing more accessible, leveraging the strengths of various protocols
  - Pitch in on the backend stack, including Postgres and TypeScript, to ensure smooth integration and functionality
  - Work hand-in-hand with a team of DeFi enthusiasts to develop cutting-edge solutions for Bitcoin-based asset lending and borrowing
  - Contribute to the R&D of prototype applications of cutting-edge blockchain technologies.
  - Actively contribute to the review of technical architecture companywide.
  - Participate in the technical governance of OSS projects

- Required skills and experience
  - Solid experience with Rust, especially in building on Solana or similar ecosystems
  - A curious mindset for diving into other Rust-based platforms like ICP and a passion for tackling cross-chain interoperability
  - Strong skills in backend tech, including Postgres, Prisma, and TypeScript
  - Thrives in a fast-paced environment and communicates clearly in English
  - Contribute to the R&D of prototype applications of cutting-edge blockchain technologies.
  - Actively contribute to the review of technical architecture companywide.
  - Participate in the technical governance of OSS projects

Smart contract engineers

- Responsibilities
  - Design an EVM-based token launchpad system using bonding curves for fair-launch distribution and voting-escrow inspired token locking for rewards incentives
  - Work with our backend engineer to build an event sourcing pipeline using on-chain indexing solutions such as Subgraph or Goldsky
  - Work with our infra engineer to build out on-chain testing environments
  - Perform various contract optimizations using Huff or Yul if needed
  - Ensure contract security by establishing a comprehensive set of unit / fuzz / integration tests using Foundry along with audits using tools like Slither or Echidna
  - Work with external auditors to ensure production readiness prior to launch, designing strategies around module upgrades where appropriate
  - Assist with miscellaneous data tasks such as curating Dune Analytics visualizations
- Required skills and experience:
  - Design an EVM-based token launchpad system using bonding curves for fair-launch distribution and voting-escrow inspired token locking for rewards incentives
  - Work with our backend engineer to build an event sourcing pipeline using on-chain indexing solutions such as Subgraph or Goldsky
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  - Work with external auditors to ensure production readiness prior to launch, designing strategies around module upgrades where appropriate
  - Assist with miscellaneous data tasks such as curating Dune Analytics visualizations

1.3.3 Skill Gap Analysis

To become a Blockchain engineer, a diverse set of skills is required, spanning hardware, software, networking, and data analysis. Here’s a comprehensive breakdown of the essential skill sets:

- Foundational Knowledge
  - Blockchain Basics: Understand blockchain technology, distributed ledger systems, consensus mechanisms (Proof of Work, Proof of Stake), and smart contracts.
  - Cryptography: Gain knowledge of cryptographic principles, including hashing algorithms (SHA-256, Keccak-256) and asymmetric encryption (RSA, ECDSA).
  - Decentralized Systems: Learn how decentralized systems differ from traditional centralized systems.
- Programming Skills
  - Languages:
  - Smart Contracts: Solidity (Ethereum), Vyper.
  - General Programming: Python, JavaScript, Go, C++, Rust.
  - Web Development: Proficiency in front-end (HTML, CSS, JavaScript, React) and back-end (Node.js, Django, Flask) technologies for dApps.
  - Smart Contract Development: Familiarity with Ethereum Virtual Machine (EVM) and tools like Remix and Hardhat.
- Blockchain Frameworks and Tools
  - Platforms: Ethereum, Hyperledger Fabric, Polkadot, Solana, Binance Smart Chain.
  - Development Tools: Truffle Suite, Ganache, MetaMask, Web3.js, ethers.js.
  - Testing and Debugging: Familiarity with test networks (e.g., Ropsten, Kovan) and debugging tools.
- Data Structures and Algorithms
  - Knowledge of linked lists, Merkle trees, and Patricia tries.
  - Understanding blockchain data structures and how transactions are verified and added to the chain.
- Security Knowledge
  - Protect against vulnerabilities like reentrancy attacks, front-running, and integer overflows in smart contracts.
  - Audit smart contracts and secure wallets.
- Understanding Blockchain Architecture
  - Peer-to-peer (P2P) networking.
  - Blockchain nodes: Full nodes, light nodes, and mining nodes.
  - Consensus protocols and their implementations.
- Databases and Storage
  - Knowledge of database systems like SQL and NoSQL.
  - Familiarity with IPFS (InterPlanetary File System) for decentralized storage.
- Mathematical and Analytical Skills
  - Strong grounding in mathematics, especially cryptographic math.
  - Analytical skills to solve complex problems related to blockchain scalability, efficiency, and security.

- Soft Skills
  - Collaboration: Work with diverse teams, including developers, analysts, and product managers.
  - Adaptability: Keep up with rapidly evolving blockchain technologies.
  - Critical Thinking: Analyze and optimize blockchain systems.

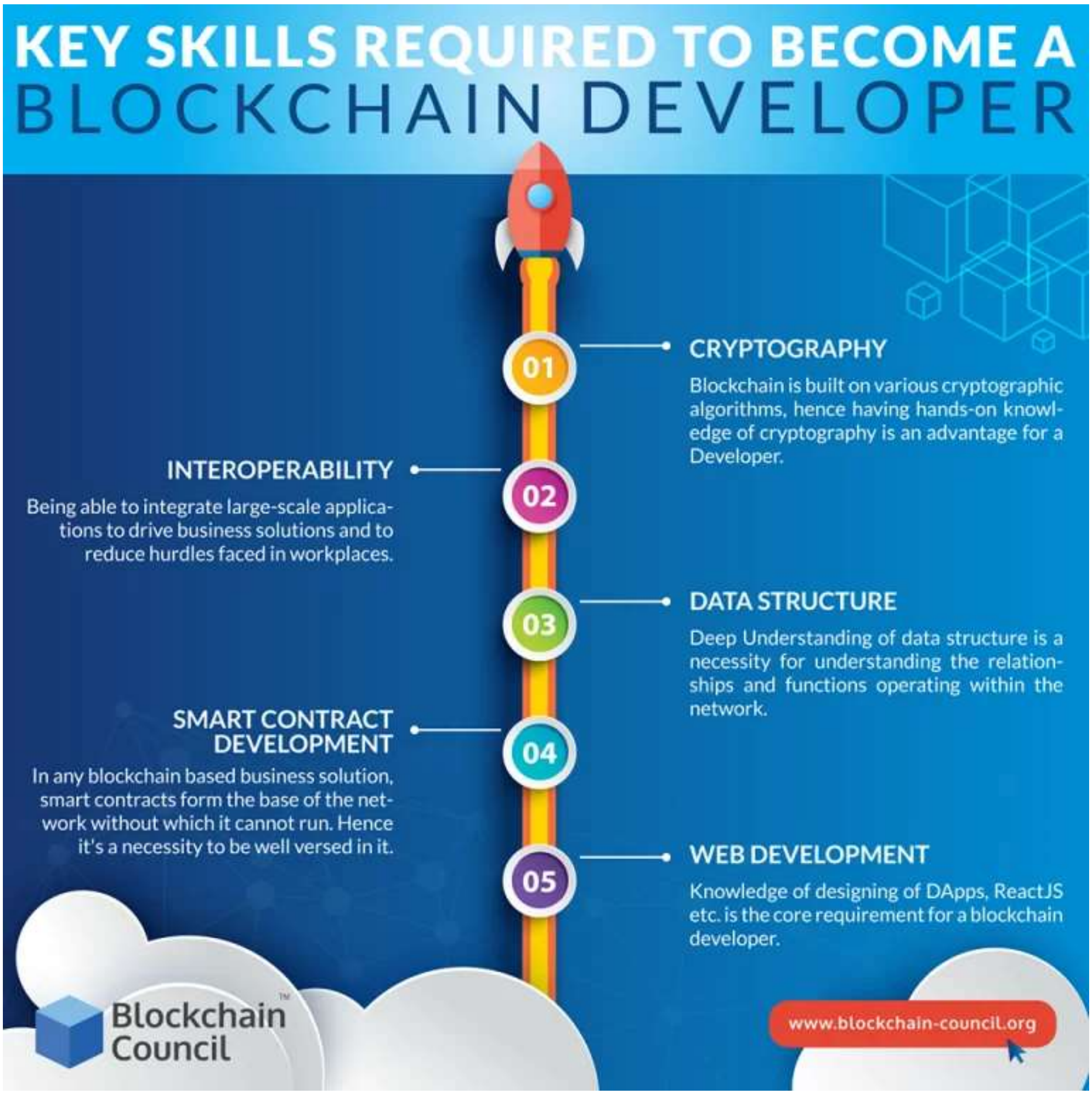

Figure 3 Toshendra Kumar Sharma, January 18, 2023

- Certifications and Learning Resources
  - Pursue blockchain certifications, such as:
  - Certified Blockchain Developer (CBD).
  - Ethereum Developer Certification.
  - Online platforms like Coursera, Udemy, and edX offer blockchain courses.
  - Join open-source blockchain projects to gain practical experience.

- Real-world Experience
  - Contribute to open-source blockchain projects.
  - Build your own dApps or blockchain solutions.
  - Participate in hackathons to showcase your skills.

1.3.4 Summary & recommendations

The report on blockchain competencies and jobs in Bulgaria highlights the country's growing importance in the blockchain and cryptocurrency sectors. With a projected revenue of $11.7 million by 2025 and a user base of 269,200, Bulgaria is becoming a hub for cryptocurrency mining and blockchain innovation, thanks to low energy costs and favorable regulations. Companies like Crypto.com and LimeChain are actively hiring for roles such as Blockchain Engineers, Smart Contract Developers, and Rust Developers. However, there is a notable skills gap in advanced blockchain knowledge, particularly in security, decentralized systems, and cross-chain interoperability. Many professionals lack hands-on experience and certifications to meet industry needs.

To address these challenges and strengthen Bulgaria's position in blockchain innovation, targeted training programs focused on blockchain technologies, cryptography, and security are essential. Collaboration between academia and industry through internships and mentorships can provide practical experience. Promoting certifications and offering financial support for upskilling will enhance workforce readiness. Supporting blockchain startups with grants and resources can foster innovation, while events like hackathons and conferences can create networking opportunities. Establishing a digital resource hub for training, job opportunities, and blockchain-related materials will centralize access to essential tools and knowledge. Clear and supportive regulations will further attract international investment and ensure Bulgaria remains competitive in the blockchain sector.

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1.4 ICT for Sustainability

1.4.1 Introduction & methodology

Description of data sources utilized.

The main sources of data are**: News and reports by the leading research organisations and universities** in Bulgaria: Bulgarian Academy of sciences, University of Plovdiv “Paisii Hilendarski”, Faculty of Mathematics and Informatics, Sofia university “St. Kliment Ohridski” and other; **Industry reports** which are published by leading organizations in the fields of business like association of industry, ICT, Social responsibility, sustainability, and other; **Reports** by employers’ organisations and associations; **Reports** by social and environmental organisations; **Academic sources**: conference proceedings about social esponsibility and technologies, research papers, articles, journals, and analysis of trends and innovations; **Business sources –** platforms of corporations and start-ups; other sources like: media outlets, social media, market research databases, interviews and videos and other; **Interviews by experts and key opinion leaders**.

Data collection and analysis methods employed.

- Literature review: use of keywords "ICT for sustainability in Bulgaria," "advanced technologies in Bulgaria," "ICT for sustainability trends in Bulgaria, “ICT for sustainability skills and competencies in Bulgaria”, “ICT for sustainability positions in Bulgaria”, “roles and jobs in ICT for sustainability in Bulgaria”, circular economy in Bulgaria, green skills lacking and gaps and other.
- Sustainability is quite large field so the main scope was focused on: Harnessing renewable energy for a greener future, Efficient waste management through technological innovations, Building smart cities for a sustainable future
- Analysis of the main roles and profiles in ICT for sustainability at research and business organisations
- Cross referencing of the sources to validate accuracy and precision.
- Collection of targeted data from specific company websites, trends analysis
- Analysis of data on open access and licensed platforms
- Synthesis and generation of insights from data
- Identification of trends and facts
- Comparison and Categorizing.

As the sector is very dynamic, the main findings are retrieved from sources in the past two years and projections for the next few years. Also, sources are used in Bulgarian language and then translated in English.

1.4.2 Identified roles, jobs, skills & competency profiles

Who is hiring

The main fields of sustainable technologies like renewable energy for a greener future, efficient waste management through technological innovations, smart cities. From utilizing clean energy to optimizing resource management and building sustainable urban environments, technology is paving the way for a greener and more sustainable future. The Internet of Things (IoT), machine learning, digital twin technology, artificial intelligence (AI), and similar innovations can play a pivotal role in sustainable development by capturing and interpreting real-time data. AI accelerates the design cycle and enables the rapid prototyping of sustainable products. Furthermore, it can provide manufacturers with insights into the carbon footprint of an item by tracking its entire supply chain and identifying critical hotspots. We are finding solutions to problems that have plagued us for decades, such as understanding how much water a city consumes in real-time. The intelligent cloud provides us with artificial intelligence, advanced analytics, the Internet of Things, mixed reality, and a host of other technologies. Sustainability engineers across the region are combining these capabilities into smart solutions, enabling them to make tangible progress on various issues, from water scarcity to the preservation of wildlife habitats. Big data is central to online marketing, but it also has several applications for enhancing sustainability. By collecting and analyzing large datasets, companies can gain better insights into environmental concerns. Businesses can examine energy consumption and leverage big data to identify areas where efficiency can be improved. These insights also provide companies with a comprehensive understanding of their overall environmental impact and enable them to calculate potential environmental risks. Interactive maps of areas most affected by global warming can help people in more temperate regions understand the severity of climate change. From harvesting vehicles to sensors in irrigation systems, precision farming helps farmers get the most out of their crops. This accuracy can significantly reduce waste and increase yields. Electric vehicles are another field of employers in this aspect.

List of specific roles = professionals working with the respective ATI Career opportunities / jobs/ working positions:

Optimization experts: business analytics systems, with the increasing use of machine learning and artificial intelligence mechanisms. The insights and visualizations provided not only to company management but also to their sales, finance, marketing, and service departments support timely and situation-appropriate decision-making. Whether it's ordering new stock, reducing waste, predicting customer preferences, or optimizing logistics, implemented systems deliver measurable benefits to companies.

Notable is the rapid development of **digital assistants**, both in the banking sector—projects at UBB, BACB, UniCredit Bulbank, and TBI—and in hospitality, where early versions are gaining new functionalities and capabilities. Additionally, digital assistants are entering new fields, including translation and legalization services (AI assistant "Artina"), debt collection, commercial operations, insurance ("Groupama Insurance" project), entertainment services (projects by 7Art and MediaHub), marketing (startup Trackian), and others.

Profile/description/competency profile and skills list for the most common jobs/roles for the respective ATI.

New solutions and services leveraging generative AI will place greater emphasis on both costs and benefits. Significant processes are underway, driven by the fact that if companies do not begin integrating digital solutions into their operations, they risk not only missing growth opportunities but also facing inevitable decline. The wave of consumer expectations demands innovative services that are convenient, always accessible, and available remotely. This is enhanced and complicated even more by the requirements of ESG reporting which requires new digital solutions like apps, software and services. AI experts are also regular profile as they optimize the decrease of resources. The workforce is evolving, with repetitive manual tasks being shifted toward more autonomous processes. The main profiles are: Sustainability and technology experts/managers and other related roles and positions.

Common degrees of professionals in the respective ATI –STEM education and foundational skills in new technologies. Engineering and sustainability - University degree in Environmental Science, Sustainability, Business Administration, or a related field. In terms of green skills most of the universities offering tourism and hospitality programmes emphasise on the sustainability, resource efficiency and environmental management. A very distinctive fact is that universities that specialise in fields like nutrition, food technology, food science and engineering, or agricultural technologies, (e.g. the University of Food Technology, Plovdiv and University of Forestry, Sofia) have a greater tendency to include modules, related to sustainability and green skills.

1.4.3 Skill Gap Analysis

Environmental expert in an automation technology company

- Main responsibilities
  - Creates, updates, and manages the documents of the Environmental Management System (EMS) in accordance with the corporate and legal requirements.
  - Conducts regular inspections of the EMS and monitors the effectiveness of proposed corrective actions.
  - Identifies the main environmental aspects for the company and coordinates the implementation of scheduled improvement projects.
  - Maintains and enhances the integrated environmental management system according to ISO 14001:2015.
  - Builds and maintains an archive and statistics.
  - Controls the implementation of corrective and preventive actions regarding his/her field of responsibility.
  - Monitors changes in the Bulgarian and European legislation and updates the company's legal registry.
  - Develops environmental audit plans (internal and external) and participates in audits, documenting their results.
  - Conducts environmental protection trainings - introductory and regular.
  - Documents and assists in analyzing any incident related to the environmental protection within the company, for prevention purposes.
  - Provides expert environmental assessments for new projects.
  - Participates in the preparation of a list of hazardous waste within the company.
  - Participates in the waste management on the company's premises.
  - Defines potential for improvement in all processes related to his/her field of responsibility.

  - Optimizes document flow processes within the company related to his/her field of responsibility.

- Technical Competencies and Requirements:
  - Higher education – technical field of study.
  - Written and spoken English – at least level B2.
  - Excellent computer literacy - MS Office; experience with SAP will be considered an advantage.

- Professional Competencies and Requirements:
  - Previous experience in the field or on a similar position - at least 3 years.
  - Experience in international teams and multicultural environment.
  - Experience in waste management.
  - Knowledge of the EN ISO 9001:2015 и EN ISO 14001:2015.

- Personal Competencies and Requirements:
  - Capable of making fast decisions and taking the responsibility for the results in dynamic and changing environment.
  - Oriented towards goals achieving and results.
  - Focused on the added value for the internal and/or external clients.
  - Team player, able to work in a multicultural working environment.
  - Thinking outside the box, creativity, and continuous improvement attitude.
  - Flexible, adaptable, and willing to acquire new knowledge and skills.

ESG Manager

- Main Responsibilities:
  - Develop, implement, and oversee ESG strategies and initiatives, ensuring alignment with company goals and regulatory standards,
  - Conduct ESG assessments and reporting, including the preparation of sustainability reports in line with global frameworks,
  - Monitor and analyze ESG-related trends, risks, and opportunities to inform strategic decision-making,
  - Collaborate with cross-functional teams, including engineering, procurement, and operations, to integrate ESG principles into projects and operations,
  - Develop and maintain relationships with key stakeholders, including clients, investors, regulatory authorities, and local communities,
  - Track and report on ESG metrics, setting performance benchmarks and ensuring continuous improvement,
  - Lead initiatives to promote diversity, equity, and inclusion within the organization,
  - Organize training and awareness campaigns to embed ESG values across the company.

- Requirements:
  - Professional experience in ESG management or sustainability – minimum 5 years,
  - Strong knowledge of international ESG standards, frameworks, and reporting requirements,

- University degree in Environmental Science, Sustainability, Business Administration, or a related field,
- Fluent English (written & verbal),
- Result-oriented with a proactive attitude and excellent problem-solving skills,
- Strong project management and organizational skills, with the ability to manage multiple initiatives simultaneously,
- Experience with stakeholder engagement and change management is a strong advantage.

- Personal qualities:
  - Team player;
  - Able to take responsibility;
  - Flexible, proactive and loyal person;
  - Able to work independently and collaboratively with cross-functional teams.

Other less popular positions: Environmental Validation Project Leader, Sustainability specialist, Sustainability leader, Quality control and sustainability managers, Environmental Validation Project Leader, Director Global Sustainability, Energy management specialist/officer/manager, renewable energy experts and roles, smart mobility positions, Hydropower roles, Corporate Social Responsibility Project Manager.

New positions identified also at EU level: Renewable energy experts (quality control, diagnostics, auditing, developer projects engineer, consultants and researchers; coordinators, field engineers (wind energy), geothermal technicians; nuclear engineers; sales and marketing, legal experts; computer specialists), Waste prevention and management of waste (operators industrial recycling), Transport (managing inflows, logistics / ICT coordination of transport systems, carbon audit), Construction sector (organization of companies or approaches to project management (in construction) coordination and testing of the product prior to commissioning, diagnosis, control and performance measurement related to regulatory requirements (energy efficiency, air quality, acoustic measurement) interdisciplinary skills (regulatory impact of lower currents, metrology and software) renewable energy systems (solar, wind, geothermal energy)), Pollution prevention and cleaning environment (environmental engineers, technicians sector training of environmental problems, waste disposal specialists, transportation and experts in recycling materials specialists in hazardous substances), Construction of green buildings (Engineers, carpenters, construction workers, construction and building inspectors, insulation specialists, electricians), Agriculture and landscape (specialists in landscape architecture, hydrologists, geologists, zoologists and biologists, specialists in conservation of forests technicians, specialists in fish and game).

Analysis of skill proficiency levels in the workforce:
In-demand skills:

Specific necessary competences	Lack of environmental management skills	Lack of soft skills
CSR experience and skills	ability to minimize the use and maximize efficiency of energy and water consumption	problem-solving through digital technologies
project management for complex projects	ability to manage waste, sewage, recycling, and composting	proactive and innovative attitude
stakeholders management	conservation of biodiversity	building partnerships
technical proficiency for implementing new technologies	green innovation or eco-innovation	emotional intelligence
software development	industrial recycling	analytical thinking
data analytics	interdisciplinary skills	result-oriented with a proactive attitude
AI, big data and IoT	low-waste technologies and technologies to reduce and control pollution	social skills

1.4.4 Summary & recommendations

Key findings regarding skill and competency gaps

Green skills training is still in infant age in Bulgaria. Many projects and initiatives are trying to raise awareness in the business, private and public institutions about the concepts of sustainability, green development and circular economy. In this regard it is expected in the next few years to increase the demand for relevant education and training in green skills. The data reveal that there is underinvestment in innovative businesses in the experimental phase and that most startups that have been supported are in the scale-up phase with tested and implemented innovative solutions.

Recommendations for addressing identified gaps

Bulgaria has the lowest score of the EU Eco-Innovation Index 2021 which measures the eco-innovation performance of businesses, society and the public administration, as well as its development and support on the level of research, business and government. The difficulties reported for Bulgaria are the weak and almost missing penetration of circular economy practices in production, the unreformed structure of the economy which needs urgent and rapid green transformation, and the low levels of state budget resources allocated for research and development (R&D) activities.

There should be upskilling and reskilling for the new professions like: Renewable energy experts (quality control, diagnostics, auditing, developer projects engineer, consultants and researchers; coordinators, field engineers (wind energy), geothermal technicians; nuclear engineers; sales and marketing, legal experts; computer specialists), Waste prevention and management of waste (operators industrial recycling), Transport (managing inflows, logistics / ICT coordination of transport systems, carbon audit), Construction sector (organization of companies or approaches to project management (in construction) coordination and testing of the product prior to commissioning, diagnosis, control and performance measurement related to regulatory requirements (energy efficiency, air quality, acoustic measurement) interdisciplinary skills (regulatory impact of lower currents, metrology and software) renewable energy systems (solar, wind, geothermal energy)), Pollution prevention and cleaning environment (environmental engineers, technicians sector training of environmental problems, waste disposal specialists, transportation and experts in recycling materials specialists in hazardous substances), Construction of green buildings (Engineers, carpenters, construction workers, construction and building inspectors, insulation specialists, electricians), Agriculture and landscape (specialists in landscape architecture, hydrologists, geologists, zoologists and biologists, specialists in conservation of forests technicians, specialists in fish and game).

Prioritized list of skill gaps requiring immediate attention

- Lack of green skills curricula in formal education, both in secondary and tertiary education
- Lack of awareness of the advantages resulting from the introduction of green innovation among conventional businesses that do not recognize the importance of the uptake of green innovation and its impact on competitiveness or the need for investment in the creation and development of green innovation

Strategies for addressing identified skill gaps

- Introduction of green skills in formal education, both in secondary and tertiary education
- Implementation of awareness campaigns among conventional businesses to clarify the role of green innovation, the opportunities for its uptake by businesses, and its positive impact on the competitiveness of companies
- Better implementation and strategy for green digital innovations and digital solutions in general for sustainability.

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1.5 Industry 5.0

1.5.1 Introduction & methodology

Description of data sources utilized.

The main sources of data are**: News and reports by the leading research organisations and universities** in Bulgaria: Bulgarian Academy of sciences, Sofia university “St. Kliment Ohridski”, INSAIT; **Industry reports** which are published by leading organizations in the fields of business like association of industry, ICT, Industry 5.0, emerging technologies, and other; **Reports** by employers’ organisations and associations; Academic sources: conference proceedings about Industry 5.0, research papers, articles, journals, and analysis of trends and innovations; **Business sources** – platforms of corporations and start-ups; other sources like: media outlets, social media, market research databases, interviews and videos and other; **Interviews by experts and key opinion leaders**.

Data collection and analysis methods employed.

- Literature review: use of keywords "Industry 5.0 in Bulgaria," "advanced technologies in Bulgaria," "Industry 5.0 trends in Bulgaria, “Industry 5.0 skills and competencies in Bulgaria”, “Industry 5.0 positions in Bulgaria”, “roles and jobs in Industry 5.0 in Bulgaria”.
- Analysis of the main roles and profiles in Industry 5.0 at research and business organisations
- Cross referencing of the sources to validate accuracy and precision.
- Collection of targeted data from specific company websites, trends analysis
- Analysis of data on open access and licensed platforms
- Synthesis and generation of insights from data
- Identification of trends and facts
- Comparison and Categorizing.

As the sector is very dynamic, the main findings are retrieved from sources in the past two years and projections for the next few years. Also, sources are used in Bulgarian language and then translated in English.

1.5.2 Identified roles, jobs, skills & competency profiles

Human capital and technology are more dynamically intertwined than ever, leaders must create an environment where people and technology work together synergistically.

Who is hiring:

Industry 5.0 puts people at the center of business processes, with technology now serving not only to automate, but also to support human creativity and innovation. Leaders need to ensure that technological advances not only replace manual labour but also amplify human capabilities. "The main goal of Industry 5.0 is to make technology a partner, not a competitor to humans," says one of the experts in the episode. Approaches that support human-machine collaboration are key to successful human capital management. Leadership in

Industry 5.0 requires agility, innovation, and empathy. Leaders who understand the power of technology and know how to use it to improve human potential will be able to create teams that are motivated and ready for the challenges ahead.

A collaborative robot, or “cobot,” is a robot that works alongside a human as a guide or an assistant. Unlike autonomous robots which – once programmed – work independently, collaborative robots are designed to respond to human instructions and actions. The cobot/human relationship is a synergistic one in which the innate strengths of both humans and machines are brought together to accomplish specific tasks or processes. The automotive sector was an early adopter of cobot technologies, using them as critical components in assembly lines. By automating repetitive and dangerous tasks such as welding, assembly, and painting, humans are freed up to attend to more complex tasks in addition to operating and maintaining the robots. This includes pairing humans and cobots in quality assurance tasks, where “robot vision” can autonomously spot defects or flaws not immediately visible to the human eye. In the automotive sector, there is significant interest and concrete steps being taken toward another trend in Industry 5.0—environmental preservation.

In conclusion, the automotive sector is the most automated in the world and was the first to adopt the technology. The second is the electronics industry, followed by the general machinery industry. In the service sector, banking is following rapidly the trend.

List of specific roles = professionals working with the respective ATI Career opportunities / jobs/ working positions:

- Human-Technology Integration Engineer - key activities: Design new appealing and sustainable solutions for automation integration, Streamlining and enhancing existing programs and functions, Pioneering the development of new applications to meet our customers’ growing integration requirements, Proficiency across the entire technology stack, spanning UI, backend, and database layers
- AI Ethics Compliance Specialist
- Personalized Product Design Engineer
- Smart Factory Supply Chain Integration Engineer
- Cobotics System Analyst
- Digital Twin Architect
- Robotics System Integrator
- Interactive Technical Documentation Developer
- Knowledge Graph Engineer
- Documentation Quality Control AI Engineer
- Digital Twin Validation Engineer
- Cyber-Physical Systems Engineer
- Digital Thread Analyst
- Augmented Reality Technical Documentation Develop

Some of the mentioned requirements and responsibilities include:

- Knowledge and experience in data acquisition board (National Instruments or other);
- Experience with creation of FMEA, control plan, problem solving approach;

- Experience with SQL databases.
- Experience with statistical methods (MSA, Cpk, Cgk, R&R)
- Reverse engineering mindset.
- Analyze client requirements to design customized hardware solutions, with a focus on virtualization, VSAN, and automation.
- Develop detailed architecture plans and technical specifications for server and storage environments.
- Collaborate with engineering teams to integrate virtualization technologies and automation tools into client systems.
- Lead proof-of-concept initiatives to validate solution designs, ensuring they meet client expectations.
- Oversee the rollout of hardware and virtualized environments, automating deployment and management processes.
- Provide post-deployment support, including performance monitoring and ongoing optimization of virtualized systems and VSAN configurations.
- Document all designs, configurations, and procedures, providing clients with comprehensive technical documentation.
- Stay updated on the latest trends in hardware, virtualization, and automation to propose innovative solutions.
- Responsible for development and implementation of continuous improvement initiatives within production areas;
- Prepare and maintain adequate and up-to-date validation plans during development and/or transfer of products;
- Support the development, modification and implementation of manufacturing processes and tests;
- Manage, plan, and organize the ramp up production of new and/or current manufacturing processes based on the LEAN thinking;
- Lead and ensure the transfer of new and/or current production lines. Transfer the knowledge to ensure smooth start of regular manufacturing.
- Experience in CAD programs
- Develops, selects, and applies standard techniques, procedures, and tools in the performance of engineering tasks;
- Identifies variation requests to support contract claims;
- Follows production plans and cost estimates for work in one’s area of responsibility and ensures quality deliverables on time and at targeted cost;
- Assists in communication with customer pertaining to specific project design assignments or meetings;
- Work closely with all functions and reports inefficient process and tools by providing ideas for improvement.
- Completes risk and opportunity assessments in one’s area of responsibility. Reports any contract / quality / program / cost issues to management for resolution;
- Attends project meetings and presents specific aspects of design assignments;

- Collaborates with the supply chain function, reviews vendor documentation, prepares RFQs, provides design related evaluation of proposals for standard materials and equipment.

Profile/description/competency profile and skills list for the most common jobs/roles for the respective ATI

People have access to more advanced technologies in their workplaces. However, there are sectors where technology remains limited, resulting in lower investments in automation, the development of new technologies, and improvements.

A sharper disparity is observed in the food and beverage industry, which requires significant modernization and investment in new technologies. Similar trends can be seen in the wood processing industry. Conversely, other sectors, such as metallurgy and the chemical industry, are receiving substantial investments, with continuously rising standards and requirements.

They work with controllers, automated systems, and control panels. However, there are significant challenges regarding these skills.

Industry 5.0 introduces a new profession—a role like the Chief Robotics Officer (CRO). This is a person specialized in human-machine interaction. A CRO must possess extensive knowledge in fields such as robotics and artificial intelligence. Their role within the company is to make decisions related to these human-machine factors.

Pure automation does not allow for the level of personalization that a human can bring to a process. However, customers demand higher levels of personalization for certain products. Industry 5.0 aims to achieve this by leveraging the potential of new technologies while valuing the human contribution throughout the process. This approach enables workers to eliminate certain repetitive tasks, allowing them to focus on developing more robust strategies or applying their creativity.

Common degrees of professionals in the respective ATI –STEM education and foundational skills in new technologies are crucial for working in the Industry 5.0. Engineering degrees: in Electronics, robotics, smart technologies, mechanical and other.

1.5.3 Skill Gap Analysis

Identification of critical skills & competency: In Industry 5.0 there are nine critical “pillars”:

- Additive manufacturing
- Augmented reality
- Autonomous robots
- Big Data and analytics
- Cloud connectivity
- Cybersecurity
- Horizontal and vertical system integration
- The Internet of Things (IoT)
- Simulation and digital twins.

The adoption of Industry 5.0 as a complement to Industry 4.0 can meaningfully enhance the workforce. In particular, Industry 5.0 brings highly skilled workers and collaborative robots (cobots) to work side-by-side – increasing the value that each brings to production. This evolved generation of machines is equipped with sensors, actuators, and AI-powered controllers that allow them to work next to humans in a safe and nonintrusive fashion. Cobots are versatile, easily programmable, safe, and intuitive to use.

Analysis of skill proficiency levels in the workforce:

According to a research done by one of the leading employers' associations, Bulgarian Industrial Association, only 19–20% of employees meet the standards required for their positions and professions in terms of digital skills. Among the key positions most critical for businesses, only one-third of those holding these roles meet these standards. 90% of jobs have been transformed in terms of the tasks and functions required. Approximately 50% of jobs are involved in entirely new business processes, new business management systems, and technological advancements. Although the pace of digitalization in Bulgaria is relatively slow, it is beginning to put pressure on people, and the requirements are continuously increasing. In practice, digital skills remain at what can be described as a basic level. Another notable result is that around 30% of employers actively invest in the development of digital skills. For the rest, efforts are only partially related to solving and implementing some software. In some places, employees are hardly trained at all. In other words, more attention is being given to technology rather than to people.

Comparison of required skills and available skills; comparison of skill profiles and labour market demands: Every year, it becomes harder for companies to attract and retain the kind of skilled and talented workforce they need to compete. When workers are simply machine operators, they are denied the challenge and creative input that drives human accomplishment. Industry 5.0 principles and technologies provide a more progressive and interesting working environment, which can help lead to increased employee satisfaction and loyalty. The necessary skills are mainly related to: Advanced data management and analysis systems leverage AI and machine learning, Simulation models and digital twins, Collaborative robots and experiential tools like virtual reality (VR) and other.

In-demand skills: Proficiency across the entire technology stack, spanning UI, backend, and database layers; Technological and digital skills: Understanding of automated systems, robotics, artificial intelligence (AI), the Internet of Things (IoT) and data management software.

Specific necessary competences	Critical deficits working with systems	Lack of soft skills
not just knowing how to use certain software	ERP systems for customer relationship management	problem-solving through digital technologies
thinking creatively	enterprise resource management systems	online etiquette—how people communicate
seeking new opportunities for utilizing various software	working with modeling, technical drawing, and design software	new norms in communication have emerged
thinking critically	creating spreadsheets	emotional intelligence
implementing new technologies	cloud-based calculations	analytical thinking
being able to develop briefs for specialists who create software	AI	lateral thinking
digital marketing	data management	adaptability and resilience

Other important soft **skills** that are in high demand in **Industry 5.0** include, leadership, teamwork, creativity and innovation management. Things are changing, and, which often create a negative impression on the other party. This includes skills such as writing—copywriting, creating content in a digital environment, and effectively communicating in a digital space. The ability to work with data is also coming to the forefront, but it requires a different perspective—viewing information as a resource and a prerequisite for doing business.

A significant issue is managing generational differences. In some companies, there is practice of so-called reverse mentoring—mentoring by younger employees toward older ones in the area of digitalization. Overall, there is a need to explore opportunities for collaboration between generations in the workplace, whether through mentoring, coaching, or other methods for building digital competencies among employees. Above all, there needs to be a strong focus on discussing and adopting new technologies.

1.5.4 Summary & recommendations

Key findings regarding skill and competency gaps

What people fail to understand is that there is no such thing as one-time learning. Continuous investment in oneself and skill development is essential to remain employable and relevant in the labor market. Many individuals and their jobs are at risk of becoming obsolete. In the transition to digital workplaces, employers, social partners, and the state must create programs and opportunities for people to retain their jobs and adapt to these changes with resilience and flexibility. Moreover, considering the changes in professions and requirements that will inevitably come, efforts must be made to proactively develop future skills. However, we lack a National Skills Development Strategy.

Recommendations for addressing identified gaps

The human-centric industry 5.0 puts human needs and interests at the center of the production process. Instead of asking what workers can do with new technology, Industry 5.0 asks what the technology can do for workers. While robots are tireless and precise, they're literal and lack the capacity for critical and creative thought of their human partners. Development of Ethical and Legal Standards : As these technologies evolve, ethical and legal standards will need to be developed and enforced for their use, especially when it comes to issues such as security, privacy and liability.

Ultimately, Industry 5.0 in Bulgaria will strive to achieve a balance between human qualities and the capabilities of technology, emphasizing the role of people in the production process and using technology to support human productivity and creativity.

Prioritized list of skill gaps requiring immediate attention

People with more complex skills in this field, including expertise in working with intelligent systems, artificial intelligence, networks, and databases. Many new jobs will emerge in green technologies, such as photovoltaics and other modern energy sources. As a result, the labor market will become even more dynamic, and the gap between supply and demand will widen further.

Increased focus on creativity and innovation: Human intelligence will be used for creative thinking, innovation and problem solving, while routine and dangerous tasks will be left to robots and automated systems.

Increasing importance of training and education: To cope with these changes, workers will need constant training and development of their skills. The changing nature of work will require constant upskilling and adaptability from the workforce.

Strategies for addressing identified skill gaps

Workforce and managers should follow the path towards Lifelong learning and have better adaptability for the dynamic in Industry 5.0, also there should be a National Strategy for reskilling and upskilling in these sectors that are affected. People should continuously invest in themselves and develop the most needed and critical skills to remain employable and adaptable in the labor market.

Human-Robot Collaboration: Instead of replacing humans, robots will work hand-in-hand with them. Human-robot collaboration technologies will evolve, fostering integration and interaction between them.

An essential aspect is increasing public and private investments in developing people's digital skills. This can involve forming associations and creating funds. Another issue is the maturity of the technologies being used. Some businesses lack motivation from employers because they rely on outdated technologies that cannot integrate with modern information and electronic solutions. However, this will inevitably change. Therefore, investment in technology, refinement, and innovation is crucial. We are, after all, living in an economy of knowledge and ideas.

Success comes to those who develop new ideas. Another critical aspect is addressing the barriers within people. This is a key issue. While a technology can be implemented in a short time, changing people's mindset takes much longer and is far more challenging. According to the research done by the Bulgarian Industrial Association people are often not motivated. Many of them perform tasks under pressure to meet requirements rather than out of genuine engagement or willingness.

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1.6 Internet of Things

1.6.1 Introduction & methodology

Description of data sources utilized.

The main sources of data are: **Industry reports** which are published by leading organizations in the fields of ICT, IoT, emerging technologies, and other; **Reports** by employers' organisations and associations; Academic sources: conference proceedings about IoT, research papers, articles, journals, and analysis of trends and innovations; **Business sources** – platforms of corporations and start-ups; other sources like: media outlets, social media, market research databases, interviews and videos and other.

Data collection and analysis methods employed.

- Literature review: use of keywords "IoT in Bulgaria," "advanced technologies in Bulgaria," "IoT trends in Bulgaria, "IoT startups in Bulgaria", "key skills and competences in IoT", "roles and jobs in IoT in Bulgaria".
- Cross referencing of the sources to validate accuracy and precision.
- Collection of targeted data from specific company websites, trends analysis
- Analysis of data on open access and licensed platforms
- Synthesis and generation of insights from data
- Identification of trends and facts
- Comparison
- Categorizing.

As the sector is very dynamic, the main findings are retrieved from sources in the past two years and projections for the next few years.

1.6.2 Identified roles, jobs, skills & competency profiles

According to Statista.com:

- The revenue in the Internet of Things market market in Bulgaria is projected to reach US$764.30m in 2025.
- The automotive IoT sector dominates the market in Bulgaria with a projected market volume of US$206.20m in 2025.
- It is expected that the revenue will show an annual growth rate (CAGR 2025-2029) of 9.05%, resulting in a market volume of US$1,081.00m by 2029.
- In global comparison, United States is expected to generate the most revenue in the IoT market, with US$379.90bn in 2025.
- Bulgaria is emerging as a key player in the Internet of Things market with its growing number of tech startups specializing in IoT solutions.

Who is hiring

Current & potential employers: Scalefocus, Accedia, Dreamix, eLando AD, App Streams Ltd, BVP Software, ITGix, Senstate Technologies SC, Truesight Technologies. Top Internet of Things Companies in Bulgaria according to Clutch.co: BGO Software - The Digital Health

Lab, App Streams Ltd, Quanterall, Aionys, eLando AD, ThingsLog, Senstate Technologies, Dision, Truesight Technologies, MENA Software, IndigoVerge, Wildorb Interactive Design Studio, OBG Ltd., NCB Ltd, Process of Things – PoT, BVP Software. The top listed one is BGO Software - The Digital Health Lab

List of specific roles = professionals working with the respective ATI Career opportunities / jobs/ working positions:

Smart buildings IoT hardware and software solutions providers, e-mobility like electric bikes and cars, smart homes, deployment of IoT open-source solutions (gateways, tools) combined in suites, platforms for cities, government and industry in the processes of net zero transition, transformation of drones into smart instruments for various industrial applications, solutions for respiratory health and diseases and environmental monitoring, IoT security. The main positions retrieved on LinkedIn are:

Network and Systems IoT Engineer

- Key architectural role with the following responsibilities:
  - Ownership of a technical platform. Lead the evolution of the platform, influence the roadmap and make efficient use of right technology
  - Analyse and assess technical solutions and evolution to fulfill business, regulatory, and operational (functional and capacity) requirements considering cost, time to market and quality
  - Ability to understand call-flows and troubleshoot
  - Participate in small to medium-size implementation projects (end-to-end), and collaborate with different stakeholders (product management, operational teams, external suppliers and IT & network colleagues). Activities could be design, implementation, testing, rollout of technical platforms and operational support systems, etc.
  - Write and review functional and technical specifications and RFP (Requests for Proposal) documents
  - Generate methods, procedures and technical documents regarding technical solutions and evolution (mainly architecture and impact analysis) to be used by stakeholders (Marketing, Product Manager, Operational teams, …)
  - Participate in the implementation of technical solutions in collaboration with operational teams

Senior Ubuntu Embedded IoT System Engineer

- Responsibilities
  - Provide software and system engineering services for OEM and ODM customers;
  - Work closely with partners on platform bring up
  - Work with project managers and Field/QA engineers to identify, triage, and fix critical problems;
  - Work with individual upstream projects to find and apply patches for bugs
  - Conduct root cause analysis, collect and organize details to reproduce and explain results

- Facilitate communication between Ubuntu, firmware and hardware engineering teams
- Occasional international travel.

- Required skills and experience
  - English written and verbal communication skills
  - Familiar with C, Python and Bash;
  - Familiar with linux boot up process;
  - Linux kernel, boot and system-level architecture skills;
  - Experience of bootloader development, such as u-boot;
  - Software development on Arm or non-X86 platforms;
  - Linux debugging and resolution abilities
  - Ability to be productive in a globally distributed team
  - Ability to learn fast to work on cutting edge technologies

- Required skills and experience
  - Experience with system firmware, including uboot, UEFI, ACPI, DSDT, boot loaders, device firmware.
  - Experience debugging power management on PCI ASPM, SATA ALPM, low power profiles
  - Experience in board design, bring up, and validation
  - Experience with electrical engineering design tools (e.g. schematic capture, layout)
  - Computer architecture knowledge of x86, ARM, RISC-V
  - Familiarity with Ubuntu development model
  - Shell/Python scripting skills

Software Engineer - Industrial IoT

- Responsibilities
  - Collaborate proactively with a distributed team
  - Develop and maintain open source IoT application packages
  - Debug issues and produce high quality code to fix them
  - Review code produced by upstream and/or other engineers at Canonical
  - Discuss ideas and collaborate on finding good solutions
  - Experiment with Ubuntu Core and showcase industry-grade IoT solutions
  - Work on Matter, the connectivity standard unifying smart homes
  - Contribute to the development of IoT platforms
  - Participate in IoT standardisation working group discussions and planning (Connectivity Standards Alliance, Web of Things, etc)
  - Work from home with global travel 2 to 4 weeks for internal and external events

- Required skills and experience:
  - Proven track record of at least 3 years of professional software development using Go or C++.
  - Experience working with RESTful APIs, MQTT or other messaging protocols
  - Familiar with wireless communication protocols such as WiFi, BLE, Zigbee, Z-Wave, and Thread

- Interest and experience with a few of the following:
- Containers (docker, kubernetes)
- Linux distributions
- Snap, debian, or RPM packaging
- Shell scripting
- CI/CD (Github Actions, Gitlab CI, etc)
- IoT frameworks and protocols
- Real-time applications
- Soft skills, communication and advocacy, and are passionate, enterprising, thoughtful, and self-motivated.

Common degrees of professionals in the respective ATI –
A Bachelor or higher degree in STEM, preferably Computer Science or Electrical Engineering, telecommunications or similar degree.

1.6.3 Skill Gap Analysis

Identification of critical skills & competency:

- the main findings on the job websites and portals are: This fast-paced environment requires excellent time management, insightful debugging, critical thinking, problem-solving skills and deep knowledge of the Linux system;

Analysis of skill proficiency levels in the workforce:
To become an IoT (Internet of Things) engineer, a diverse set of skills is required, spanning hardware, software, networking, and data analysis. Here's a comprehensive breakdown of the essential skill sets:

- Programming Skills
  - Languages: Proficiency in languages such as Python, C, C++, Java, and JavaScript is crucial for developing applications and firmware.
  - Embedded Systems Programming: Understanding how to program microcontrollers and other embedded systems.
- Networking Knowledge
  - Protocols: Familiarity with IoT communication protocols like MQTT, CoAP, HTTP/HTTPS, and WebSocket.
  - Networking Fundamentals: Knowledge of TCP/IP, subnetting, and network configuration.
- Hardware Skills
  - Microcontrollers and Microprocessors: Experience with platforms such as Arduino, Raspberry Pi, or ESP8266/ESP32.
  - Circuit Design: Basic understanding of electronics and circuit design principles.
- Cloud Computing
  - Cloud Services: Experience with cloud platforms like AWS IoT, Google Cloud IoT, or Microsoft Azure IoT for data storage, processing, and analytics.

- Data Management: Understanding of databases (SQL and NoSQL) and data streaming services.

- Data Analytics
  - Data Processing: Skills in data analysis and visualization tools (e.g., Pandas, Matplotlib, Tableau).
  - Machine Learning: Basic understanding of machine learning algorithms can be beneficial for predictive analytics.
- Security Awareness
  - Cybersecurity Principles: Knowledge of IoT security practices including data encryption, secure communication, and device authentication.
- Operating Systems
  - Embedded OS: Familiarity with real-time operating systems (RTOS) such as FreeRTOS or Zephyr.
  - Linux Skills: Proficiency in Linux, as it is commonly used in IoT devices and applications.
- Project Management and Collaboration
  - Agile Methodologies: Understanding of Agile and Scrum methodologies for project management.
  - Collaboration Tools: Experience with tools like JIRA, Trello, or Git for version control.
- Problem-Solving and Critical Thinking
  - Analytical Skills: Ability to troubleshoot and solve complex issues that arise in IoT systems.
- Industry Knowledge
  - Domain-Specific Knowledge: Understanding of the specific industry (e.g., healthcare, manufacturing, smart homes) in which you want to work can be advantageous.

Conclusion

Combining these technical skills with a strong foundation in problem-solving and project management will prepare you for a successful career as an IoT engineer. Continuous learning and staying updated with the latest trends and technologies in IoT will also be crucial for long-term success in this rapidly evolving field.

Comparison of required skills and available skills; comparison of skill profiles and labour market demands:

In-demand skills:

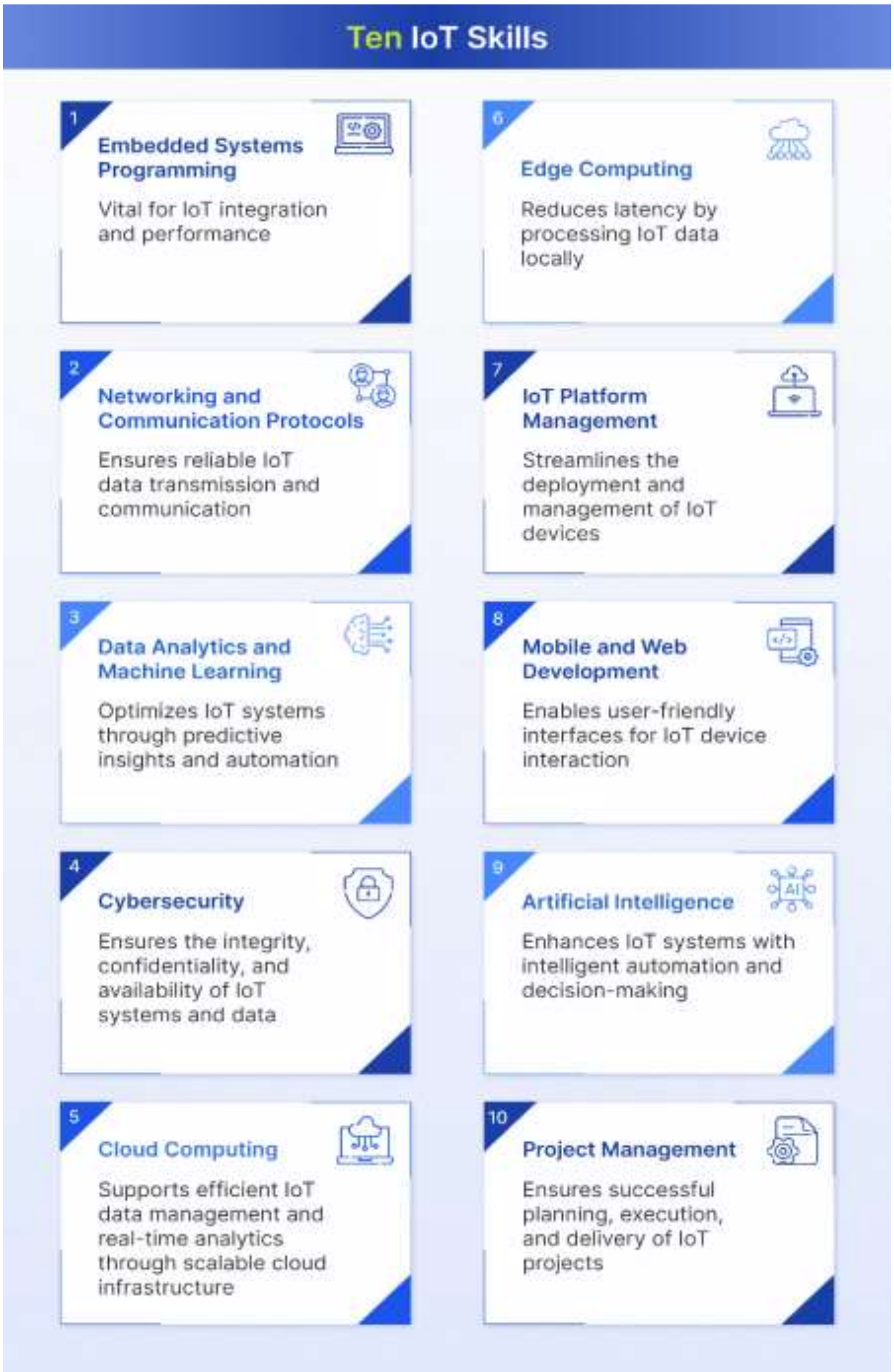

Figure 4 Ten essential IoT skills

1.6.4 Summary & recommendations

According to Statista, the IoT market in Bulgaria is growing fast, with forecast to reach $1,081 million by 2029, with a 9.57% annual growth rate. Large Bulgarian cities such as Sofia, Varna, Burgas, Plovdiv and Vratsa have implemented smart cities initiatives for such services like: intelligent traffic management, smart lighting, IoT sensors for air-quality monitoring, smart grid for energy management, and waste-management systems for better urban efficiency and reduced environmental impact. At the same time there is insufficient and no development in this direction in the smaller cities. The Bulgarian government, with EU backing, has launched initiatives to promote IoT and smart cities. Strategies for addressing identified skill gaps is introducing of micro-credential by the largest employers' organisation Association for Industrial Capital in Bulgaria who introduced micro-credits in VET. The strategy towards closing the gaps includes obtaining knowledge and skills that are industry-specific and focused on those that are more related to programming but the soft skills remain at core.

One of the general takeaways are that the context of business in Bulgaria is still insufficiently supportive of the digital advancements across industries and with focus on smart city solutions including IoT. Partnering with different organisations is now a must: those companies lacking the required of skill sets to select, deploy and utilise IoT projects should work more closely with expert service providers to close the IoT skills gaps.

For the time being trainings are provided by private companies who focus on specific skill sets.

Since October 2024 there is a project "Technical support for the development of a National Skills Strategy for the Republic of Bulgaria" was funded by the European Union via the Technical Support Instrument and implemented by the OECD, in cooperation with the European Commission.

According to it: developing skills among youth and adults is essential and these are the main fields; The proposed objectives, actions and benchmarks are categorized as three main groups: (1) Developing skills, (2) Using skills effectively, and (3) Strengthening the governance of the skills system.

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1.7 Quantum computing

1.7.1 Introduction & methodology

Description of data sources utilized.

The main sources of data are**: News and reports by the leading research organisations and universities** in Bulgaria: Bulgarian Academy of sciences, Sofia university “St. Kliment Ohridski”, **Industry reports** which are published by leading organizations in the fields of ICT, emerging technologies, and other; **Reports** by employers’ organisations and associations; Academic sources: conference proceedings about Quantum computing, research papers, articles, journals, and analysis of trends and innovations; **Business sources** – platforms of corporations and start-ups; other sources like: media outlets, social media, market research databases, interviews and videos and other.

Data collection and analysis methods employed.

- Literature review: use of keywords "quantum computing in Bulgaria," "advanced technologies in Bulgaria," "quantum computing trends in Bulgaria, “quantum computing skills and competencies in Bulgaria”, “quantum computing positions in Bulgaria”, “roles and jobs in quantum computing in Bulgaria”.
- Analysis of the main roles and profiles in Quantum computing at research and business organisations
- Cross referencing of the sources to validate accuracy and precision.
- Collection of targeted data from specific company websites, trends analysis
- Analysis of data on open access and licensed platforms
- Synthesis and generation of insights from data
- Identification of trends and facts
- Comparison and Categorizing.

As the sector is very dynamic, the main findings are retrieved from sources in the past two years and projections for the next few years.

Research was done in both Bulgarian and English languages.

1.7.2 Identified roles, jobs, skills & competency profiles

In February 2023 QUASAR Centre announces the launch of the National Quantum Communication Infrastructure Plan of Bulgaria. It is a positive development towards advanced technologies. This launch is done within European initiative **EuroQCI** – European Platform for Quantum Communication Infrastructure. The initiative is towards a unified quantum-communication network across the European Union, and Brussels aims to ensure cybersecurity and communication sovereignty. Bulgaria also joined the European Declaration on Quantum Technologies in 2024. The Declaration views the Union's efforts to develop quantum technologies through the prism of protecting strategic assets, interests, autonomy and security and as a way to avoid strategic dependence on non-EU sources. It highlights the need for the EU to build its own capacity to research and develop quantum technologies and produce devices and systems based on them, while investing in the whole quantum package - from hardware to software to applications and standards, in the main application areas of quantum technologies: quantum computing and simulation, quantum communications and quantum sensors and metrology.

- Who is hiring: in emerging companies developing quantum technologies or in the software industry; universities, scientific institutes and laboratories, carrying out fundamental research in the field of quantum technologies; development of quantum software, modeling of systems and data analysis.
- List of specific roles = professionals working with the respective ATI Career opportunities / jobs/ working positions: quantum project manager, quantum computing consultant, researcher in quantum technologies, or roles in technology strategy and innovation within various industries.

The main positions retrieved on LinkedIn are 11 in total:

Senior Quantum Engineer

- Requirements:
  - Hands-on experience with quantum hardware systems such as superconducting qubits, trapped ions, or platforms like IBM Q, Rigetti, or Google Quantum.
  - Proficiency in algorithms like Shor's, Grover's, and variational quantum algorithms, and a strong understanding of quantum mechanics, entanglement, superposition, and error correction.
  - Strong command of programming languages like Python, C++, or Julia, with a focus on optimization and computational efficiency.
  - 2-5 years of experience (at least 1+ year in quantum algorithms, quantum cryptography, or quantum computing, with the remainder in related fields like Generative AI or Data Science).
  - Understanding of machine learning and deep learning algorithms, including random forests, neural networks, and when to apply each technique.
  - Familiarity with open-source frameworks like PyTorch, Keras, and TensorFlow.
  - Experience with publishing research on quantum algorithms or quantum computing applications in highly reputed international journals.
- Primary Skills:
  - Deep understanding of linear algebra and advanced quantum computing concepts.
  - Proficiency with gate-based quantum systems, IBM Qiskit, D-Wave’s quantum annealing, and optimization using D-Wave’s Leap/Ocean platform.
  - Hands-on knowledge of D-Wave’s QUBOs for solving optimization problems, quantum cryptography, quantum NLP.
  - Strong proficiency in Python.
- Secondary Skills (Good to Have):
  - Practical knowledge of applying machine learning and deep learning techniques using TensorFlow, Keras, and Scikit-learn with Python.
  - Experience with research publications in top international journals.

Other position covering Quantum Computing are (Product) Researcher, Developer Relations Engineer, Gen AI Architect, Patent engineer and other.

The companies who are hiring are a few and they state their need for innovation, exploring how emerging technologies are applied to real-world business use cases.

Common degrees of professionals in the respective ATI – PhD, Master's and Undergraduate degrees in Computer Science or STEM, bachelor's degree and acquired basic knowledge in the field of **quantum** physics.

1.7.3 Skill Gap Analysis

Identification of critical skills & competency:

There is a master's programme **Quantum Technologies** designed for students with a bachelor's degree and acquired basic knowledge in the field of quantum physics. It aims to train highly qualified specialists in the rapidly developing fields of quantum informatics and quantum technologies – quantum computers, quantum simulations, quantum communications, quantum cryptography, quantum metrology and quantum sensors. The programme prepares specialists in the field and within the Quantum Computing and Quantum Algorithms course, students gain practical hands-on skills in writing quantum software for the IBM Online Quantum Computer.

In addition, there are online courses by private organizations like the Knowledge Academy who provide Quantum Computing Training in 16 modules. There are similar courses which cover the main skills and competencies as follow:

- Introduction to Quantum Computing
  - Overview of quantum computing vs classical computing
  - Key concepts: qubits, superposition, and entanglement
  - Current state of quantum technology
- Quantum Algorithms and Their Business Implications
  - Introduction to quantum algorithms: Grover's and Shor's algorithms
  - Case studies: cryptography, financial modeling, and optimization
  - Quantum algorithms for data analysis
- Potential Applications of Quantum Computing in Business
  - Cryptography and cybersecurity in the quantum era
  - Logistics optimization with quantum solutions
  - Quantum computing in financial risk management
- Understanding Quantum Hardware and Technology Limitations
  - Quantum hardware: types, challenges, and current providers
  - Limitations of today's quantum technology and future expectations
  - Practical challenges in implementing quantum computing
- Quantum Computing and Data Modeling
  - Introduction to quantum-enhanced data analysis
  - Exploring quantum machine learning potential

  - Using quantum algorithms for predictive modeling
- Ethics and Security in Quantum Computing
  - Privacy considerations in quantum computing
  - Ethical implications of quantum-driven data analysis
  - Risk management for quantum-powered solutions
- The Future of Quantum Computing in Business
  - Emerging trends and timelines for commercial quantum computing
  - Preparing for quantum disruption in business practices
  - Identifying industry opportunities for early adoption

Analysis of skill proficiency levels in the workforce:

Computer scientists need to be ready to both harvest the potential of these new types of machines and address the numerous challenges that will arise in cyber security. Quantum computers are currently not widely available to the public and are extremely expensive and difficult to manufacture. In most cases, they are owned or operated by large corporations, research institutions and government bodies, so access to them depends on the access conditions of these commercial enterprises and institutions. This relates to the high needs for advanced skills sets and competences including scientific and research profiles of the talent. Companies can leverage quantum computing resources through cloud services offered by companies such as IBM, Microsoft, Rigetti Computing, D-Wave, and Google. The cost of using these services can vary depending on the time and resources used, but typically ranges from a few dollars to several thousand dollars per hour.

Quantum computing systems like IBM's are sold for tens of millions as part of full services in a few years. By comparison, Microsoft's cloud quantum computing service, Azure, allows early adopters to use $500 in Azure Quantum credits for free at any participating quantum equipment vendor. AWS, another quantum computing provider, offers pricing plans for using the cloud service that start at $29 per month and include AWS support.

Comparison of required skills and available skills; comparison of skill profiles and labour market demands:

In-demand skills:

Quantum computing is an interdisciplinary field that requires a combination of skills from various domains. Here are the key skills needed for a career in quantum computing. It is very difficult to find the right talent so companies make a combination of talents and focus on the major ones to achieve their goals. As for the researchers they need to posses strong competencies and scientific and research background.

By developing a combination of the below skills, set good grounds for careers in quantum computing research, development, and application.

- Mathematics
  - Linear Algebra: Essential for understanding quantum states and operations.
  - Probability and Statistics: Important for quantum algorithms and error correction.
  - Complex Numbers and Functions: Used extensively in quantum mechanics.

- Physics
  - Quantum Mechanics: Fundamental knowledge of quantum theory and principles.
  - Statistical Mechanics: Understanding of systems with many particles, which is relevant for quantum systems.
- Computer Science
  - Algorithms and Data Structures: Knowledge of classical algorithms helps in understanding quantum algorithms.
  - Programming Skills: Proficiency in languages like Python, C++, or specialized languages like Qiskit, Cirq, or Q#.
- Quantum Theory and Quantum Algorithms
  Familiarity with key quantum algorithms (e.g., Shor's algorithm, Grover's algorithm) and concepts like quantum gates and circuits.
- Software Development
  Experience with software engineering principles, version control (e.g., Git), and collaborative coding practices.
- Hardware Knowledge
  Understanding of quantum hardware platforms (e.g., superconducting qubits, trapped ions) and the challenges in building quantum computers.
- Problem-Solving Skills
  Ability to tackle complex and abstract problems, often requiring innovative approaches.
- Interdisciplinary Collaboration
  Skills to work with professionals from diverse fields such as physics, engineering, and computer science.
- Communication Skills
  Ability to explain complex concepts clearly to audiences with varying levels of expertise.
- Research Skills
  Familiarity with scientific research methodologies, including literature review, experimental design, and data analysis.

Additional Considerations

- Continuous Learning: The field is rapidly evolving, so a commitment to ongoing education and staying updated with the latest research is crucial.
- Ethics and Societal Impact Awareness: Understanding the implications of quantum computing on privacy, security, and society.

1.7.4 Summary & recommendations

Bulgaria has advanced well in the development of strategic technologies such as chips and quantum computing. Enterprises' adoption of advanced digital technologies (either cloud, data analytics, or AI) in Bulgaria stands at 29.3%, significantly below the EU average of 54.6% and ranking last among EU Member States. Specifically, 14.2% of enterprises have adopted cloud technologies, remarkably below the EU average of 38.9%, 3.6% of enterprises have adopted AI, below the EU average of 8%, and 21.9% of enterprises are using data analytics, also below the EU average of 33.2%.

The Bulgarian National Quantum Communication Infrastructure (BG QCI) is the national consortium selected to deploy the first ever quantum secure communication links and networks in Bulgaria. The plan utilises long standing knowledge in quantum theory and technologies and communication networks expertise to target the adoption of modern encryption technologies based on Quantum Key Distribution (QKD) for highly secure communication among our public authorities and private organisations.

There are serious efforts to close the skills gap by leading universities and private organisations together with research and development institutes and businesses as this field is in the cross-section between science and ICT.

Quantum computers are still very expensive machines and far from becoming an everyday reality for most SMEs. However, they represent a revolutionary technology that is developing rapidly and that SMEs should be prepared and explore opportunities to deploy them. R&D institutes and research organisations in public-private partnerships are the main employers who currently need the most talent and they require a combinations of profiles and cross-disciplinary talents.

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WP4 Enhancing Labour Market-Relevant Skills in Advanced Technologies

T4.1 Identifying skill gaps in Advanced Technologies

CYPRUS national report from the desk research

Date: September 2024 – January 2025

Prepared by: P12 Emphasys, P13 Cyric, P14 FREDU, P15 CSI

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2 CYPRUS – National report from the desk research

2.1 Introduction & methodology

To conduct comprehensive desk research in the fields of **AI and Ethics**, **Big Data**, **IoT**, **ICT for Sustainability**, **Quantum Computing**, and **Industry 5.0**, a multi-faceted approach was adopted to gather and analyze relevant data from both primary and secondary sources. The methodology employed a combination of qualitative and quantitative research techniques to ensure a robust and thorough assessment of the current state of each of these fields.

Data Collection Sources:

- Primary Sources:
    - **Academic Literature**: Research papers and journal articles were reviewed to understand the latest developments, trends, and challenges in each field. These sources provided in-depth theoretical frameworks and case studies relevant to the research.
    - **Industry Reports**: Reports from leading industry bodies, technology firms, and research organizations were analyzed to understand current market trends, technological innovations, and workforce readiness.
    - **Governmental and Regulatory Documents**: Relevant national and international policy papers and strategic documents were considered to assess governmental priorities, funding initiatives, and regulations affecting each field.
- Secondary Sources:
    - **Government Websites and Portals**: Publicly available documents, national strategies, and policy reports published on government websites were reviewed to understand how government initiatives are shaping the development of these technologies.
    - **Industry Websites and Market Research**: Secondary data from market research firms, technology companies, and specialized publications were sourced to gather insights into ongoing trends and the demand for skills within the various sectors.
    - **Public Databases and Online Resources**: Open-access datasets and publications from international organizations were used to gather data on technological advancements and emerging issues in AI, Big Data, IoT, ICT for Sustainability, Quantum Computing, and Industry 5.0.

Limitations and Addressing Data Gaps:

Due to the rapid pace of technological advancements and the evolving nature of these fields, some areas of research were limited by the availability of formal data, particularly in emerging technologies like quantum computing and Industry 5.0. To address these gaps, data was combined.

2.2 Artificial Intelligence and Ethics

2.2.1 Identified roles, jobs, skills & competency profiles

Who is hiring: current & potential employers

- **Cyprus Research and Innovation Centers:** Engage in AI and ICT projects with a focus on ethical data use and innovation.
- **National Government Agencies:** Implement ethical guidelines for AI in public services, ensuring data privacy and responsible AI practices.
- **ICT-Focused SMEs:** Work on developing AI solutions while integrating ethical frameworks, particularly in data collection and privacy.
- **Educational Institutions (e.g., Frederick University, Cyprus Computer Society):** Promote ethical AI education, research, and training, emphasizing human-centric data collection approaches.

In ICT ethics, a **human-centric approach** to data collection prioritizes user consent, transparency, and privacy, aligning with ethical AI guidelines and GDPR compliance.

List of specific roles = professionals working with the respective ATI Career opportunities / jobs/ working positions

- **Data Engineer**: Focused on building robust data pipelines and preparing datasets for ethically aligned AI models. Skilled in SQL, Python, data warehousing, and ensuring GDPR compliance. Expertise in ethical data sourcing, feature engineering, and bias elimination to deliver high-quality, unbiased data for model training.
- **Product Manager (Tech Focus)**: Oversees the AI product lifecycle with an emphasis on ethical guidelines for design, deployment, and user data management. Skilled in project management, AI ethics, regulatory compliance, and privacy laws. Ensures products adhere to EU ethical standards and mitigates bias in AI model outputs.
- **Software Developer/Engineer**: Develops AI-driven applications, ensuring model transparency, security, and fairness. Skilled in algorithm development, secure coding, explainable AI, and reducing algorithmic biases. Engineers applications that comply with ethical standards, offering transparency and fairness to end-users.
- **DevOps Engineer**: Optimizes software delivery efficiency with a focus on ethical and secure AI automation. Skilled in CI/CD pipeline development, ethical data management, and compliance with security protocols. Integrates ethical considerations into software workflows to enhance reliability and security.
- **Machine Learning Engineer**: Specializes in creating and refining AI models with a focus on fairness, accountability, and interpretability. Skilled in model development (TensorFlow, PyTorch), bias detection and mitigation, and ethical data handling. Designs models that align with EU ethical AI frameworks, promoting accountability and minimizing bias.

Profile/description/competency profile and skills list for the most common jobs/roles for the respective ATI

- **Competencies**: Critical thinking, understanding of GDPR, expertise in algorithmic transparency, data protection, and ethical problem-solving.

Common degrees of professionals in the respective ATI

- **Education**: Software Engineering, Computer Science, Data Science, AI, and Ethical Technology degrees, with emphasis on privacy laws and bias in machine learning, are the most common educational backgrounds for professionals in the AI and tech industry roles mentioned above.

The job market in Cyprus reflects a growing demand for professionals in AI and ethics, with roles increasingly integrating ethical oversight within technical positions to meet industry standards and EU regulations.

2.2.2 Skill Gap Analysis

Identification of critical skills & competency

For the ICT sector in Cyprus, the demand for AI and ethics-related competencies is rapidly increasing due to the country's commitment to digital transformation and ethical technology. Critical skills identified include:

- **Bias Detection and Mitigation**: Essential for ensuring fairness in AI, especially in fields handling sensitive data.
- **Transparency and Explainability**: Important for creating interpretable AI systems that comply with EU regulations.
- **Data Privacy and GDPR Compliance**: A high-priority skill as ethical AI applications need to align with legal frameworks like the GDPR.
- **Algorithmic Accountability**: Knowledge of accountability measures in AI to ensure models operate responsibly and without unintended harm.

Analysis of skill proficiency levels in the workforce;

While the Cyprus workforce demonstrates a basic proficiency in general ICT skills, there is a noticeable gap in specialized ethical AI competencies:

- **Technical Skills:** High competency in programming languages like Python and SQL, but limited experience in bias mitigation tools and explainable AI.
- **Data Privacy:** Basic understanding of GDPR across ICT roles, though in-depth skills in privacy-by-design and data protection in AI-specific contexts are limited.
- **Ethics and Compliance Knowledge:** Generally low levels of proficiency in AI ethics frameworks, such as the EU AI Act, indicating a need for targeted training.

Comparison of required skills and available skills; comparison of skill profiles and labour market demands

The analysis reveals that while foundational ICT skills are available in the workforce, specialized competencies in AI ethics are not sufficiently met:

- **Demand for Transparency and Accountability:** While required for roles like AI Product Manager and Machine Learning Engineer, current skill levels often lack the depth needed for practical application in high-stakes environments.
- **Ethical AI Development and Compliance:** There is a market demand for professionals who can handle AI's ethical dimensions, especially concerning privacy, fairness, and legal compliance, yet training in these areas is limited within Cyprus.

2.2.3 Summary & recommendations

Key findings regarding skill and competency gaps

- **Significant Gaps**: Key skills in bias mitigation, data transparency, and GDPR-compliant AI development are lacking.
- **Emerging Demand**: As Cyprus prioritizes ethical AI, demand is growing for professionals who can integrate ethics into AI workflows, especially in roles related to data engineering, product management, and machine learning.

Recommendations for addressing identified gaps

- **Vocational Training in AI Ethics**: Establish programs focused on bias mitigation, algorithmic transparency, and GDPR compliance for ICT roles.
- **Enhanced Curriculum in Higher Education**: Integrate AI ethics modules into computer science and data science degrees to produce graduates skilled in ethical AI.
- **Certification Programs**: Develop specialized certifications on ethical AI, tailored to Cypriot professionals in roles such as AI Product Managers and Data Protection Officers.

Prioritized List of Skill Gaps Requiring Immediate Attention

- **Bias Mitigation and Fairness**: Immediate training on bias reduction techniques for professionals in data engineering and machine learning.
- **Algorithm Transparency**: Focus on interpretability skills to ensure AI model outputs are understandable and accountable.
- **Data Privacy and GDPR Compliance**: Essential training for roles handling sensitive data to align with regulatory standards.

Strategies for addressing identified skill gaps

- **Industry-Academic Partnerships**: Collaboration between universities and local companies to provide hands-on experience in ethical AI, ensuring that students are well-prepared for the job market.
- **Focused Workshops and Bootcamps**: Intensive sessions on ethical AI, transparency practices, and data privacy compliance tailored to both students and professionals.

- **Government and Industry Support for Ethical AI Training**: Engage national agencies and ICT-focused SMEs in developing a standardized approach to ethical AI training, leveraging Cyprus's 2035 vision and the Quintuple Innovation Helix framework.

These recommendations will help Cyprus strengthen its ICT workforce in ethical AI, promoting sustainable growth and alignment with EU standards in technology.

2.2.4 References & resources

[1.] **Cyprus Information Technology Enterprises Association (CITEA)** (2022) – Provides industry survey data on ICT skills and workforce needs specific to Cyprus, highlighting demand for AI and ethics competencies.

[2.] **Cyprus Employers and Industrialists Federation (OEB)** (2022) – Offers insights into ICT skill gaps, with a focus on ethical AI requirements in the Cyprus job market.

[3.] **European Commission: Ethics Guidelines for Trustworthy AI** (2019) – Outlines ethical principles such as transparency, accountability, and fairness in AI, forming the foundation for AI and ethics training in Cyprus.

[4.] **European Union: GDPR** (2016) – Establishes essential data privacy regulations, crucial for ICT roles handling AI in compliance with EU standards.

[5.] **European Union: AI Act Proposal** (2021) – Aims to standardize ethical AI practices across the EU, emphasizing the need for specific competencies in Cyprus's ICT workforce.

[6.] **National Statistical Service of Cyprus (CYSTAT)** (2022) – Provides employment and education data in ICT, identifying educational gaps in AI ethics and regulatory compliance.

[7.] **Frederick University and University of Cyprus** (2021-2022) – Academic studies analyzing skill shortages in AI ethics and privacy, proposing curriculum updates for vocational training.

[8.] **Cyprus Research and Innovation Center (CyRIC)** (2022) – Research on ethical AI practices and industry demands in Cyprus, with recommendations for responsible data handling.

[9.] **European Commission: Digital Economy and Society Index (DESI)** (2020) – Highlights Cyprus's progress in digital skills, underscoring the need for competencies in AI ethics.

[10.] **Quintuple Helix Innovation Model** (2021) – Discusses the alignment of ethical AI and digital skills with sustainable development goals in Cyprus's 2035 vision.

2.3 Big Data

2.3.1 Identified roles, jobs, skills & competency profiles

Who is hiring: current & potential employers

Big Data talent is in high demand across sectors in Cyprus. Key employers include **technology firms**, **financial institutions** (which leverage data for fraud detection and risk management), **government agencies** (focusing on efficient public service delivery), and **healthcare providers** (using data for patient care and predictive diagnostics). The **finance sector** remains one of the highest spenders on IT services, driven by long-term investment in data infrastructure and analytics. Additionally, sectors like **telecommunications**, **retail**, **energy**, and **education** are expanding their data capabilities, with tech startups in AI and analytics emerging as potential employers. Cyprus's Smart Specialization Strategy further promotes data adoption in sectors such as agrifood and maritime, making Big Data expertise essential for the country's digital and economic transformation.

List of specific roles = professionals working with the respective ATI Career opportunities / jobs/ working positions

In Cyprus, demand for Big Data roles spans various sectors, with key positions like **Data Scientists** and **Data Engineers** managing complex datasets and infrastructure, while **Big Data Architects** and **Machine Learning Engineers** focus on building scalable systems and predictive models. **Business Intelligence Analysts** and **Data Analysts** transform data into actionable insights, often using tools like Tableau and Power BI. Compliance with GDPR is essential, making roles such as **Data Privacy Specialists** and **Chief Data Officers** key for data governance. Additionally, **Data Product Managers** oversee data-driven product development, and **Quantitative Analysts** in finance apply statistical models for risk and forecasting. Together, these roles provide the critical skills needed to support Cyprus's growing Big Data ecosystem.

Profile/description/competency profile and skills list for the most common jobs/roles for the respective ATI

Common Big Data roles in Cyprus require a mix of technical, analytical, and soft skills. **Data Scientists** and **Data Engineers** typically need proficiency in programming languages like Python and SQL, experience with big data frameworks (e.g., Hadoop, Spark), and knowledge of cloud platforms like AWS or Azure. **Machine Learning Engineers** require advanced skills in machine learning algorithms and model deployment, often with expertise in frameworks like TensorFlow and PyTorch. **Big Data Architects** focus on designing and managing scalable data systems, ensuring compliance with data governance standards, particularly GDPR.

Roles such as **Data Analysts** and **Business Intelligence Analysts** emphasize data visualization skills using tools like Tableau and Power BI, combined with strong analytical abilities to transform data into actionable insights. **Data Privacy Specialists** and **Chief Data Officers (CDOs)** are critical for compliance, requiring deep knowledge of GDPR and ethical data handling practices. Across these roles, soft skills—such as problem-solving, critical thinking, and effective communication—are essential to interpret complex data and collaborate across teams. These competencies form the foundation of Cyprus's growing Big Data workforce, equipping professionals to drive digital transformation across sectors.

Common degrees of professionals in the respective ATI

Big data professionals in Cyprus often hold degrees in fields such as Computer Science, Data Science, Statistics, Mathematics, Engineering, and Information Technology. For specialized roles like Business Intelligence (BI) Analysts, degrees in Information Systems or Business Management are also common, as they provide insights into business processes and strategies. Many pursue further specialization through master's programs in Data Analytics, Artificial Intelligence, or Machine Learning.

In addition to formal education, certifications in big data tools, cloud platforms, data management systems, and cybersecurity are highly valued by employers, reflecting the importance of continuous learning and skill enhancement in this evolving field.

2.3.2 Skill Gap Analysis

Identification of critical skills & competency professionals in this field

Critical technical skills include data analytics, programming in languages like Python and R, and proficiency with data visualization tools such as Tableau and Power BI. Additionally, expertise in machine learning frameworks, data governance, data warehousing, and cloud computing is increasingly necessary as more organizations rely on cloud services for data management and processing.

Cyprus, however, faces a significant shortage in advanced digital skills, especially in areas like cybersecurity, artificial intelligence, machine learning, big data, and software engineering. In [9] it is indicated a 21% gap in basic digital skills required to meet EU targets, underscoring the need for foundational digital upskilling across the population. Soft skills, including critical thinking, problem-solving, and communication, are equally essential, enabling professionals to interpret data insights effectively and communicate findings to non-technical stakeholders

Analysis of skill proficiency levels in the workforce;

An analysis of skill proficiency levels in the Cypriot workforce shows notable disparities in big data competencies. Although the number of graduates in IT and data science from local universities is rising, many have only foundational skills and lack the hands-on experience necessary for advanced roles. Employers report that even recent graduates face challenges in applying their knowledge to complex data analytics and machine learning tasks, underscoring a skills gap that limits the effective contribution of new professionals to the expanding big data sector.

In reference [13] it is highlighted this gap, showing that only 50% of Cypriots have basic digital skills, falling below the EU average of 54%. Moreover, only 3.1% of graduates are in ICT-related fields, an insufficient figure given the high demand for digital skills. Gender disparities also exist, with women making up only 21.6% of ICT specialists. This shortfall in digital proficiency and specialization is particularly concerning as digital transformation accelerates across industries in Cyprus.

Comparison of required skills and available skills; comparison of skill profiles and labour market demands

A comparison of required and available skills in the Cypriot labor market reveals a significant gap, particularly in big data and advanced analytics, which limits the effective utilization of these technologies. Employers in finance, healthcare, and tourism report an urgent need for advanced analytics capabilities; however, many job candidates lack proficiency in essential tools and methodologies. Although graduates often have a strong theoretical foundation in data science, they frequently fall short in practical skills, such as predictive modeling and real-time data processing. These skills mismatch not only impacts individual employability but also challenges organizations seeking to leverage big data for strategic decision-making.

Reference [10] presents a similar issue across digital skills, noting a shortage of talent in cybersecurity, AI, and data analytics. Despite high demand and business interest in digital transformation, the gap in specialized digital skills underscores the urgent need for targeted upskilling and reskilling programs to align workforce competencies with industry requirements.

2.3.3 Summary & recommendations

Key findings regarding skill and competency gaps

In Cyprus, significant skill and competency gaps are emerging in the Big Data sector, largely due to the rapid growth in demand across industries such as finance, healthcare, and government. While foundational skills in data analysis, programming (Python, SQL), and visualization tools (Tableau, Power BI) are common, there is a notable shortage of advanced competencies in machine learning, big data architecture, and cloud computing, as highlighted in [9]. The [10] further underscores that demand for technical expertise in scalable data systems and model deployment exceeds current workforce capabilities. Compliance with EU data privacy regulations, especially GDPR, is also limited, with gaps in data governance skills, particularly in heavily regulated fields. The [11] identifies the need for targeted training in compliance and ethics, given the high standards required for data handling. Additionally, Cyprus faces a soft skills gap, as employers increasingly seek professionals with critical thinking, communication, and problem-solving skills, crucial for transforming technical insights into strategic decisions. In [12] it is support this, emphasizing the importance of fostering interdisciplinary skills to drive Big Data innovation across key sectors like agrifood and maritime. These gaps suggest a critical need for targeted upskilling and continuous learning initiatives to align the workforce with Cyprus’s evolving digital landscape.

Recommendations for addressing identified gaps

To close Big Data skill gaps in Cyprus, a multi-level approach is needed, involving educational institutions, industry, and government. Firstly, **expanding specialized training in machine learning, cloud computing, and data governance** through partnerships with universities and technical institutes is essential. Programs should incorporate hands-on learning in key technologies like AWS, Hadoop, and data privacy, reflecting the **Digital Skills National Action Plan**. Collaboration with industry can provide practical experience through internships, apprenticeships, and real-world projects, as highlighted in the [10], ensuring that graduates are job-ready and equipped with relevant skills.

To encourage lifelong learning, **government incentives like grants and tax credits** could support companies investing in workforce upskilling, particularly in high-demand areas such as GDPR compliance and big data architecture, as outlined in the [11]. Enhancing **soft skills development** through cross-disciplinary projects is also critical, fostering communication, problem-solving, and critical thinking capabilities to meet the [12] goal of strengthening Big Data applications across sectors like agrifood and maritime.

Finally, **promoting Big Data career opportunities to underrepresented groups, especially women**, will help create a more diverse and robust talent pipeline. Together, these initiatives will enable Cyprus to build a skilled workforce aligned with its digital transformation objectives and the demands of an evolving EU digital economy,

Prioritized list of skill gaps requiring immediate attention

The most urgent skill gaps in Cyprus's big data landscape that require immediate attention are:

- **Advanced Machine Learning and AI Skills** – Demand for machine learning expertise is high across sectors using predictive analytics and automation, making this a top priority.
- **Cloud Computing Proficiency (AWS, Azure, Google Cloud)** – The need for scalable data solutions has made cloud computing skills critical, especially as more businesses adopt cloud-based Big Data platforms.
- **Big Data Architecture and Infrastructure Design** – Skills in designing and managing large-scale data systems (e.g., Hadoop, Spark) are essential to support Cyprus's growing data landscape.
- **Data Governance and GDPR Compliance** – Compliance with EU data privacy standards is a pressing need, especially in regulated sectors like finance and healthcare, highlighting a gap in data governance expertise.
- **Data Visualization and Communication Skills** – The ability to translate complex data into actionable insights for non-technical stakeholders is increasingly valued.
- **Critical Thinking and Problem-Solving** – As interdisciplinary work grows, critical thinking and problem-solving are essential for adapting data insights to strategic business decisions

Strategies for addressing identified skill gaps

To address Big Data skill gaps in Cyprus, develop specialized educational programs and certifications in high-demand areas like machine learning, cloud computing, and data governance, incorporating practical, hands-on experience with tools such as AWS and Hadoop. Strengthen industry-academia partnerships to provide internships and apprenticeships that bridge theory with real-world application. Government incentives for continuous professional development, especially in compliance and advanced analytics, will encourage upskilling. Additionally, integrate soft skills training into programs, focusing on critical thinking and communication to enable effective cross-functional collaboration. Finally, promote Big Data careers to underrepresented groups, with targeted initiatives and mentorships to build a diverse talent pipeline.

2.3.4 References & resources

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[10.] Cyprus ICT 2022 Analysis and 2023-2025 Forecast (https://ccs.org.cy/el/downloads/get/file/99)

[11.] National Digital Decade Strategic Roadmap (https://digital-skills-jobs.europa.eu/en/actions/national-initiatives/national-strategies/cyprus-national-digital-decade-strategic-roadmap)

[12.] Smart Specialisation Strategy of Cyprus 2030 (https://chiefscientist.gov.cy/wp-content/uploads/stratigiki-eksypnis-ekseidikefsis-2023-20301.pdf)

[13.] Digital Economy and Society Index (DESI) https://digital-strategy.ec.europa.eu/en/policies/desi

2.4 Blockchain

2.4.1 Identified roles, jobs, skills & competency profiles

Who is hiring: current & potential employers

In May 2019, the Cyprus government unveiled its National Blockchain Strategy ("NBS"), with the primary goal of promoting blockchain technology development via innovation and collaboration between the public and commercial sectors. The government worked with numerous institutions, both public and commercial, to assess market demands and committed to implementing the NBS in order to usher in the new era of digitalisation. Furthermore, Cyprus has signed the European Blockchain Partnership and the 'Declaration of the Southern Mediterranean Countries on Distributed Ledger Technologies' to facilitate international collaboration (Syllouris & Georgiades, 2019).

Cyprus is well-known for being headquarters for several international ICT corporations, the island is a hub for software development, digital marketing or service integration companies. Blockchain is mainly popular in projects of the financial services market, including among others, crypto-related projects. Currently, there are nine crypto-asset service providers registered with the Cyprus Securities and Exchange Commission, including crypto-exchange platforms. Further, blockchain technology is being used by entities involved in the finance and regulatory tech space, know-your-client procedures and record-keeping transactions. Some of the top IT Companies in Cyprus specialized in Blockchain are: IF Fintech, Circlegain, Pundi X365, Aria Health, Alterno NFT, NNN Community LTD, Mr. Probot Ltd., Magic Square, infotropic.tech, Naviaddress, etc (F6s, 2025).

According to the market overview in the National Strategy for Cyprus, there are different employers and stakeholders in the field of blockchain:

- Academic institutions such as the University of Nicosia and the Cyprus International Institute of Management (CIIM).
- The non-profit Cyprus Blockchain Technologies Ltd, a collaboration among academic institutions, regulators, financial institutions, banks, and technology companies.
- Financial institutions and banks.
- The Cyprus Securities and Exchange Commission (CySEC), which has an Innovation Hub focusing on FinTech, RegTech, and blockchain technologies.

List of specific roles = professionals working with the respective ATI Career opportunities / jobs/ working positions

(National Strategy of Cyprus, Jobs in Cyprus - Cyprus Jobs & Recruitment | Cyprus Work and University of Nicosia):

- Blockchain Researchers: Conduct studies on blockchain technologies and their integration with other fields like AI and IoT (e.g., initiatives from the University of Nicosia's Institute for the Future).
- Product Manager: Professionals working closely with cross-functional teams to develop, refine, and launch products that align with the mission of simplifying blockchain technology

- Blockchain Strategists and Advisors: Roles involved in shaping blockchain policies and advising stakeholders.
- Blockchain Back-end Developers: focusing on building and maintaining the backend infrastructure for blockchain-based applications.
- Managers in FinTech, RegTech industries or related posts in finance, regulation, and government offices

Profile/description/competency profile and skills list for the most common jobs/roles for the respective ATI

- Technical Skills:
  - Understanding of distributed ledger technologies (DLT) and blockchain frameworks.
  - Familiarity with smart contracts and their enforceability/legal implications.
  - Knowledge of GDPR compliance and privacy issues related to blockchain.
- Soft Skills:
  - Collaboration with regulators, academics, and the private sector.
  - Strategic thinking for applying blockchain to public and private sectors.

Common degrees of professionals in the respective ATI

Common Degrees of Professionals in DLT:

- The University of Nicosia offers a Master's Degree in Digital Currency, the first of its kind globally.
- Other educational institutions in Cyprus, such as CIIM, provide blockchain-related seminars and lectures.
- The National Coalition for Digital Skills and Jobs is a collaborative initiative involving public, private, and civil society organizations aimed at supporting education and training by promoting digital literacy, bridging the digital divide, and enhancing workforce participation in the digital economy.

2.4.2 Skill Gap Analysis

Based on the University of Nicosia, as well as the National Blockchain Strategy (NBS), the critical skills and competencies required for working in the DLT/blockchain sector, as highlighted in the text, include:

- Blockchain technology and DLT knowledge: Understanding of blockchain frameworks, smart contracts, and decentralized systems.
- Cryptography: Proficiency in cryptographic principles essential for secure blockchain applications.
- Regulatory and legal knowledge: Familiarity with regulatory environments, including banking, legal, and financial regulations, particularly those governing blockchain, cryptocurrencies, and data privacy (e.g., GDPR).
- Blockchain development: Skills in programming languages (Solidity for smart contracts), backend systems development (Node.js, TypeScript), and database management (PostgreSQL).

- Innovation and problem-solving: Ability to design and implement blockchain-based solutions and address industry challenges.
- Business and finance: Understanding the intersection of blockchain with business applications, including its potential for financial services and economic transformation.
- Collaboration and communication: Ability to work with multidisciplinary teams, including academic, regulatory, and technical stakeholders, to develop and deploy blockchain solutions.

The NBS suggests that many professionals in various sectors may not yet fully understand DLT/blockchain, and this lack of understanding, combined with its complexity, means that workforce proficiency levels are not yet at the level needed for widespread adoption. For this reason, the current workforce might not have sufficient skills in DLT/blockchain technologies, given the challenges like scalability, regulatory uncertainties, and legal risks that are slowing technical advancement. Many individuals and institutions are still working on understanding how DLT works and how its potential can be unlocked. It is noted that while academic institutions in Cyprus (such as the University of Nicosia) are pioneering blockchain education with programs like a Master's Degree in Digital Currency, a significant gap likely exists in the broader workforce outside academia. The government and academic institutions are working to address these gaps, with initiatives such as the Cyprus Securities and Exchange Commission (CySEC) Innovation Hub and blockchain-focused training programs.

The labor market for DLT/blockchain skills is growing, with increasing demand for blockchain developers, project managers, and regulatory experts as more industries explore its applications. While the academic sector, especially institutions like the University of Nicosia, is producing skilled professionals, the broader workforce still faces a skills gap, particularly in practical experience. Regulatory bodies like CySEC are creating environments to foster blockchain innovation, further fueling demand for specialized personnel. However, the gap between available skills and market needs suggests that more efforts are needed to align education and workforce training with the rapidly evolving demands of the DLT sector.

2.4.3 Summary & recommendations

Key findings regarding skill and competency gaps

Key findings reveal that while Cyprus is making strides in blockchain development, significant skill and competency gaps exist. The demand for blockchain-related skills, such as DLT knowledge, cryptography, regulatory expertise, and blockchain development, is growing rapidly. However, the current workforce lacks practical experience and comprehensive understanding of blockchain's complex applications. Educational initiatives like the University of Nicosia's Master's Degree in Digital Currency are addressing some of these gaps, but broader efforts are needed.

Recommendations for addressing identified gaps

To address these gaps, several recommendations are proposed. First, enhanced educational programs should be implemented, expanding blockchain training at all levels, and integrating practical hands-on experience alongside theoretical knowledge. Second, industry collaboration between academia, government, and the private sector should be strengthened to ensure educational outcomes align with market needs. Third, incentivizing the upskilling of current professionals, particularly in blockchain development, cryptography, and regulatory compliance, should be prioritized. Finally, public awareness campaigns should be launched to raise awareness about blockchain's potential and regulatory landscape, addressing misconceptions and building public trust.

Prioritized list of skill gaps requiring immediate attention

The most urgent skill gaps that need immediate attention include practical blockchain development experience, understanding of regulatory and legal frameworks such as GDPR, and expertise in cryptography.

Strategies for addressing identified skill gaps

By addressing these gaps through strategic investments in education and collaboration, Cyprus can foster a workforce ready to meet the demands of an evolving digital economy.

2.4.4 References & resources

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2.5 ICT for Sustainability

2.5.1 Identified roles, jobs, skills & competency profiles

Who is hiring: current & potential employers

- **Technology Companies**: Both local startups and international tech firms, such as gaming companies (For example Wargaming, which also has Unicorn status) and software development firms, such as Technlink, LaunchOptions and K1CORE are prominent employers.
- **Telecom Providers**: Major players in telecommunications, such as CYTA and Primetel, are continuously looking for skilled IT personnel.
- **Public Sector**: Government offices and public entities, like the Digital Transformation Office, are hiring for positions focused on IT infrastructure and smart city initiatives.
- **Financial Institutions and Fintech**: Both established banks such as The Bank of Cyprus and AlphaBank, and emerging fintech companies such as Investing.com and IronFX are looking to fill roles in cybersecurity, blockchain, and AI technologies.
- **Renewable Energy Companies**: Firms that focus on green energy solutions, such as smart grids or solar technology, are hiring engineers and technicians. Examples of companies hiring are EnergyIntel, EvenEnergy and EFS Cyprus.
- **Consulting Agencies**: Large consulting firms are frequently in need of tech specialists for projects related to digital transformation, AI, and big data analytics. Some companies include IsoTech, NMore Group, 4Sight Group and many more.
- **Research Institutions**: Universities such as the Cyprus University of Technology and research centres such as The Cyprus Institute are actively recruiting people for teaching roles and research projects related to cutting-edge technology.

*The companies mentioned are examples. There are many more companies in Cyprus hiring for these positions.

List of specific roles = professionals working with the respective ATI Career opportunities / jobs/ working positions

- Software Developer
- Data Analyst
- Cybersecurity Expert
- Network Specialist
- AI/Machine Learning Engineer
- Cloud Engineer
- Blockchain Developer
- IoT Engineer
- Renewable Energy Specialist
- IT Project Manager
- UX/UI Designer

Profile/description/competency profile and skills list for the most common jobs/roles for the respective ATI

- **Software Developer**: Requires coding knowledge (such as Java, Python, or C++) and familiarity with software development frameworks.
- **Data Analyst**: Focuses on data analysis and visualisation, often using tools like Python or R, with an understanding of statistics.
- **Cybersecurity Expert**: Involves a strong understanding of security protocols, ethical hacking, and risk management.
- **AI Specialist**: Requires knowledge of machine learning algorithms, programming languages, and AI development frameworks.
- **Blockchain Developer**: Focuses on distributed ledger technologies, cryptography, and the development of smart contracts.
- **IoT Engineer**: Involves working with embedded systems, wireless communications, and sensor technologies.
- **UX/UI Designer**: Requires design expertise and the ability to create user-friendly interfaces based on customer needs.

Common degrees of professionals in the respective ATI

- **Computer Science or Software Engineering**: Essential for those in software development and AI roles.
- **Electrical Engineering**: Relevant for positions in IoT, renewable energy, and network engineering.
- **Data Science or Applied Mathematics**: Beneficial for data scientists and analysts.
- Cybersecurity or Information Systems: Critical for cybersecurity roles.
- **Environmental or Mechanical Engineering**: Useful for renewable energy professionals.

2.5.2 Skill Gap Analysis

Identification of critical skills & competency

In Cyprus, as in many countries, the landscape of the job market is changing rapidly, especially in the advanced technology and innovation sectors. Identifying the most critical skills and competencies is the first step in ensuring that the workforce is equipped to meet the demands of today’s industries. Key sectors such as ICT, fintech, renewable energy, and smart infrastructure heavily rely on professionals with both technical expertise and adaptable problem-solving skills.

In Cyprus, for instance, there’s a rising demand for skills in **software development**, **cybersecurity**, **data science**, and **AI**. Moreover, with the island’s growing focus on **renewable energy** and **sustainable technologies**, professionals with experience in green tech solutions, energy-efficient systems, and smart city technologies are also in high demand. On top of technical proficiency, Cypriot employers are increasingly looking for individuals who are adaptable, can think critically, and work well in team environments, reflecting the shift towards more interdisciplinary roles.

According to the **Digital Economy and Society Index (DESI) 2023** report, Cyprus ranks **21st out of 27 EU countries** in terms of digital readiness. This ranking indicates that while progress has been made, there's still a considerable gap in digital skills, especially when it comes to more advanced areas. Around **55% of Cypriots** have basic digital skills, which is lower than the EU average of **59%**. This suggests that although a good portion of the population can handle basic tech tasks, more advanced digital expertise is lacking.

In terms of **ICT specialists**, only about **3.8% of the workforce** in Cyprus works in ICT-related fields, which is below the EU average of **4.5%**. This statistic highlights that there is a shortage of professionals in critical fields like **cybersecurity**, **AI**, and **software development** compared to what businesses need.

A **2022 report by KPMG** highlighted that the number of fintech companies grew by **57%** between 2017 and 2022. Despite this growth, the local talent pool hasn't kept up. There's a significant shortage of professionals with skills in **blockchain technology**, **digital currencies**, and **online banking systems**. As a result, many fintech companies are either bringing in experts from abroad or upskilling their existing staff to keep pace with industry demands.

The **CYSTAT** (Cyprus Statistical Service) shows that about **11%** of university graduates specialize in **engineering** and **construction**, and another **10%** are trained in **ICT**. However, despite these promising figures, many graduates still lack the hands-on technical skills that are needed for jobs in areas like **AI**, **cybersecurity**, and **data analytics**. This indicates that while the education system is producing graduates in key fields, there's still a gap in practical, job-ready skills.

Cyprus is also heavily investing in **renewable energy** to meet its climate goals for 2030. The **Cyprus Energy Regulatory Authority (CERA)** has set a target for **23% of energy** consumption to come from renewable sources by 2030. As this sector grows, it's clear that the workforce will need to keep pace, with specific demands for skills related to **solar energy**, **smart grids**, and **energy storage solutions**. Unfortunately, there aren't enough trained professionals in these areas right now, and companies are having trouble finding people with the right knowledge and expertise.

The innovation scene in Cyprus is also growing, especially in the tech sector. According to the **Research and Innovation Foundation (RIF)**, initiatives like the **Cyprus Start-up Visa program** have been launched to attract foreign entrepreneurs and boost areas like **blockchain** and **AI**. However, many local businesses report a shortage of skilled workers to fill these highly technical positions. This has forced startups to either recruit talent from other countries or outsource certain projects to teams abroad.

The **Cyprus Human Resources Development Authority (HRDA)** conducted a survey where more than **50% of companies** admitted they're having trouble finding workers with the necessary technical skills in areas like **AI**, **machine learning**, and **data science**. Businesses pointed out that they often need to invest heavily in training their staff to bring them up to speed with the latest industry requirements. This indicates a clear skills gap in the market, particularly in emerging technologies.

Analysis of skill proficiency levels in the workforce;

Cyprus, being a hub for technology companies and startups, requires workers with diverse technical skills. However, the actual levels of expertise can vary significantly.

For example, many professionals in Cyprus may possess a good foundational knowledge of programming languages like Python or Java, but fewer have the advanced skills needed for complex AI algorithms or machine learning models. Similarly, while many workers might have a basic understanding of cybersecurity measures, they may lack the deeper knowledge required to counter more sophisticated cyber threats that have become common in recent years.

Assessing these skill levels can be done through a combination of industry feedback, internal company assessments, and certifications. Companies in Cyprus can work closely with their employees to gauge their current abilities and identify areas where further development is needed. This helps ensure that the workforce is not only meeting the current demands of their roles but is also equipped for future challenges that arise as the technology landscape evolves.

Comparison of required skills and available skills; comparison of skill profiles and labour market demands

One of the most crucial steps in a skill gap analysis is comparing the skills that Cypriot employers need with the skills that are available in the workforce. In Cyprus, there's a noticeable gap in certain areas—particularly in **emerging technologies** like **blockchain**, **AI**, and **IoT**. While the country has a growing base of tech professionals, there is still a shortage of individuals with deep expertise in these fields. This gap can pose challenges for local businesses trying to stay competitive in the global market.

Take the **fintech** sector in Cyprus, for example. As financial services become increasingly digital, companies are searching for professionals skilled in areas like **blockchain development** and **digital currencies**, yet there are limited numbers of experts available with these niche competencies. Similarly, the **renewable energy** industry is booming in Cyprus, but there's a gap in highly specialized knowledge related to **smart grids**, **energy storage systems**, and **sustainable energy technology**.

By comparing the skills that businesses need with the skills that are currently available, it becomes easier to highlight the exact areas where there is a mismatch. This gives local institutions—such as universities, vocational training centres, and technical schools—a clear direction on where to focus their efforts to bridge these gaps. At the same time, it provides employers with the insights needed to decide whether they should invest in upskilling their current workforce or look for new talent from outside the country.

Aligning the skill sets of professionals with the needs of the Cypriot labor market is essential for ensuring the long-term growth and competitiveness of the country's economy. The technology sector, for example, is moving quickly, and what is required today may not be enough to meet tomorrow's needs. In Cyprus, the demand for multi-skilled professionals is growing—especially in roles that combine various disciplines such as **data analysis**, **AI**, and **business strategy**.

For example, **cybersecurity professionals** in Cyprus are no longer just expected to protect networks from attacks; they're increasingly required to integrate security measures into **cloud computing** and **IoT platforms** as these technologies become more widespread. Similarly, **software engineers** are expected to have experience not only with traditional programming languages but also with modern cloud infrastructure tools and **AI integration**.

As the Cypriot economy shifts towards digital transformation and **green technologies**, the labour market requires professionals who are versatile, adaptive, and open to continuous learning. By aligning educational programs, certifications, and on-the-job training with these evolving demands, Cyprus can better prepare its workforce for the future. This proactive approach will help ensure that companies operating in Cyprus remain competitive and innovative, while employees have access to rewarding career opportunities that align with the changing dynamics of their industries.

Overall, understanding these skill gaps and working to address them will be crucial for maintaining Cyprus's growth in key areas like tech, energy, and finance. Without this alignment, companies may struggle to find the talent they need, and professionals may miss out on job opportunities in the sectors where demand is highest.

2.5.3 Summary & recommendations

Key findings regarding skill and competency gaps

Based on a deep dive into the workforce and market demands in Cyprus, it's clear that while certain sectors are growing rapidly, there are significant gaps between the skills businesses need and what the current workforce can provide. The **tech sector**, including **ICT** and **fintech**, is advancing, but the local talent pool is struggling to keep up with the rapid development in fields like **AI**, **blockchain**, and **cybersecurity**.

Moreover, the push towards **renewable energy** and **sustainability** is creating demand for specialized knowledge in **solar energy**, **smart grids**, and other green technologies. Although Cyprus is taking steps to become a leader in these areas, the shortage of trained professionals with specific technical expertise is a hurdle to further progress.

Another significant finding is the gap between the **education system** and **industry needs**. While there are university graduates entering fields like ICT and engineering, there's a disconnect between the theory they learn and the practical skills required for today's job market, especially in fast-evolving areas like **AI** and **data science**.

Recommendations for addressing identified gaps

To close these gaps and ensure Cyprus remains competitive in key industries, several strategies need to be considered:

Upskilling and Continuous Learning Programs: Both government and private sector initiatives should prioritize the creation of upskilling programs, focusing on developing the necessary advanced technical skills, especially in **AI**, **cybersecurity**, and **data analytics**. Offering accessible professional development courses, online certifications, and industry workshops would help bridge the gap for existing professionals and help them transition into high-demand roles.

Revising Education Curricula: Universities and technical schools should collaborate closely with businesses to adjust their curricula to better reflect the realities of the market. Practical, hands-on experience should be integrated into degree programs, ensuring graduates not only understand the theory behind technologies like **blockchain** and **machine learning** but also how to apply them in real-world settings.

Government-Industry Partnerships: A coordinated effort between the Cypriot government, industry leaders, and educational institutions will be critical to designing training programs that match future market demands. Offering incentives to companies that invest in training their staff can also encourage businesses to actively engage in solving the skills gap.

Attracting Foreign Talent: In the short term, Cyprus might need to continue relying on foreign expertise, particularly for advanced roles in **tech** and **fintech**. Initiatives like the Start-up Visa are helpful, but they should be expanded to attract more skilled workers in high-demand areas. At the same time, local professionals can be trained alongside international experts to build in-house expertise over time.

Fostering Lifelong Learning: With the rapid pace of change in fields like **ICT**, **AI**, and **renewable energy**, learning shouldn't stop after university. Companies should foster a culture of lifelong learning, where employees are encouraged to continually develop new skills and stay current with technological advances. This will help address ongoing shifts in the industry.

Prioritized list of skill gaps requiring immediate attention

- Skill gaps that require immediate attention include:
- **Cybersecurity and Data Protection**: With increasing digital threats, the need for skilled cybersecurity professionals is urgent. The current shortage in this field poses significant risks for businesses in Cyprus.
- **Artificial Intelligence and Machine Learning**: AI is rapidly becoming a cornerstone of various industries, from fintech to energy. There is a clear need for professionals who can develop and integrate AI solutions.
- **Blockchain and Fintech Technologies**: As Cyprus's fintech sector grows, so does the need for blockchain expertise, especially with the rising adoption of digital currencies and decentralized finance solutions.
- **Renewable Energy and Sustainable Technologies**: The green energy transition in Cyprus is moving forward, but the workforce lacks sufficient expertise in areas like **solar power**, **energy storage**, and **smart grid technologies**.
- **Advanced Data Analytics**: With the explosion of data in nearly every sector, professionals skilled in **data science** and **big data analytics** are in high demand but in short supply.

Strategies for addressing identified skill gaps

- **Upskilling Programs**: Offering courses and certifications in high-demand areas like AI, cybersecurity, and data analytics to help current professionals gain advanced skills.
- **Education Updates**: Universities are working with businesses to ensure students get practical experience in technologies like AI and renewable energy, not just theory.

- **Government-Industry Collaboration**: The government is partnering with companies to create training programs that meet future market needs, offering incentives for businesses that invest in staff training.
- **Attracting Foreign Talent**: Expanding initiatives like the Start-up Visa to bring in skilled international professionals, while training locals alongside them.
- **Lifelong Learning**: Promoting continuous learning to keep the workforce updated with fast-changing technology.

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2.6 Industry 5.0

2.6.1 Identified roles, jobs, skills & competency profiles

Who is hiring: current & potential employers

Tech Companies and Startups: The tech sector aims to integrate smart technologies and reduce environmental impact, aligning with the global trend towards green technology and Industry 5.0. With a focus on developing digital transformation, Cyprus is creating vacancies in AI, Data and more. Wargaming, Amdocs, Cyric, Apriorit, NetU, Green Energy and etc, are offering multiple positions related to Industry 5.0, IoT, Green Technology and more.

Public Sector and Government Organizations: The Cypriot government and its public sector is working on environmental policies, smart city initiatives and enhancing the skills of individuals while focusing on a more human-centric policy with the purpose to optimize and improve the quality of life of Cypriot citizens. Government and public entities, such as CYTA, the Department of Environment and Cyprus University of Technology are prominent employers.

Universal Organizations: Global Organizations in Cyprus are focused on Industry 5.0, Green Technology and Digital Transformation. This is enabled by following industries outside of Cyprus and transferring their knowledge and systems to the island. Some examples are UNDP and PeopleCert, both companies supporting the development of technological, environmental and economic infrastructure of the island.

List of specific roles = professionals working with the respective ATI Career opportunities / jobs/ working positions

- **Data Scientists/Analysts:** Focuses on analyzing data to improve decision making, optimize processes and generate solutions. In Industry 5.0, data specialists play a crucial role in automating systems and thus, simplifying and enhancing efficiency.
- **IoT Specialists:** Specialists in this department are working with smart devices and date collection systems to monitor machinery, optimize energy use and enhance efficiency.
- **Software Engineers/Developers:** With a focus on automation, these professionals build systems that optimize processes and improve production lines.
- **Vocational Educators**: The main role is to equip individuals with practical and digital skills that are applicable to specific roles. Vocational educators are responsible for addressing skill gaps and ensuring that workers are gaining the necessary knowledge for technical jobs and requirements.
- **Climate Change and Sustainability Services Managers/Consultants:** Professionals are responsible for assisting clients through their Sustainability Transformation and Energy Transition, either in the public or private sector.

Profile/description/competency profile and skills list for the most common jobs/roles for the respective ATI

- **Data Scientists/Analysts:** Proficiency in data analytics, big data, and machine learning algorithms, with a deep understanding of cloud technologies. Ability to analyze and interpret large datasets using tools like Python, R, and SQL. Strong problem-solving abilities for developing predictive models and optimizing processes.
- **IoT Specialists:** Expertise in IoT platforms and communication protocols such as HTTP. A strong understanding of IoT systems, including hardware and software components. Proficient in maintaining, troubleshooting, and analyzing IoT technologies, ensuring effective integration and performance.
- **Software Engineers/Developers:** Proficiency in programming languages such as Java, Python, C++, and JavaScript. Knowledge of web frameworks and experience with both SQL and NoSQL databases. A solid understanding of the software development lifecycle, with strong debugging and performance optimization skills.
- **Vocational Educators:** Expertise in fields like engineering, IT, or Green Technologies, combined with knowledge of pedagogical strategies. Familiarity with e-learning platforms and assessment methods. Understanding of Industry 5.0 technologies and how to integrate them into vocational training, along with an agile mindset, adaptability, and strong communication skills.
- **Climate Change and Sustainability Services Managers/Consultants:** Expertise in energy audits, renewable energy, smart grids, and GHG protocols, along with strong quantitative and data analytical skills. In-depth understanding of current and emerging challenges in sustainability and the energy sector, with a creative approach to problem-solving considering global and national issues.

Common degrees of professionals in the respective ATI

- **Environmental Engineering:** Aims to train individuals to operate, supervision and construction of engineering systems in order to give them knowledge of how to ensure the recovery of the environment and prevent pollution. The program emphasizes ergonomics, computer science, statistics, engineering management and green technologies.
- **Artificial Intelligence Engineering:** Equips students with skills to design, develop and implement AI technologies in sectors to create smarter and efficient systems. It combines machine learning, robotics and automation.
- **Computer Science with focus in Environmental Management and Sustainability:** Integrates data science and AI environmental monitoring and resource optimization. It also prepares students for roles in green technologies and sustainable system design.
- **Energy Systems Engineering:** Focuses on energy production, resource management, system optimization and energy efficiency, equipping participants with the skills to use smart technologies, efficiently allocating human-centrism in systems.
- **Education Management**: Aims to educate leaders by producing solutions to the current problems in the education system by being moved and challenged from the current situation.

- **Agricultural Sciences and Biotechnology:** Trains to solve problems of the agricultural sector in line with the modern and current state of things. It promotes respect to the environment and the principles of sustainability while also focusing on the technological aspect of the degree.

2.6.2 Skill Gap Analysis

Identification of critical skills & competency

Industry 5.0 integrates human-centric technologies, focusing on collaboration between humans and advanced technologies (such as AI, IoT, robotics, and automation). The key competencies required for Industry 5.0 in Cyprus include:

Digital literacy and technology skills will be crucial while Cyprus is transitioning to Industry's 5.0 modifications. Professionals must be proficient in Artificial Intelligence (AI) and Machine Learning (ML) to develop, implement, and manage intelligent systems that optimize production processes and improve decision-making. Additionally, robotics and automation will play a key role, requiring expertise in integrating collaborative robots (cobots) into production environments, ensuring seamless human-robot interaction. The Internet of Things (IoT) will further drive this transformation by enabling connected devices and smart systems to enhance operational efficiency. Moreover, as digital systems become more complex, cybersecurity expertise will be critical in safeguarding these systems from potential cyber threats, ensuring that industrial operations remain secure and trustworthy.

As sustainability becomes a core focus of Industry 5.0, professionals will need to integrate **sustainable and ethical practices** into their workflows. This includes applying green technologies, optimizing resource use, and reducing waste in production. Industry 5.0 also requires a strong emphasis on **ethical AI** and **human-centered design**, ensuring that AI systems are developed transparently and ethically, aligning with human values and welfare. Professionals will also need **environmental awareness**, incorporating eco-friendly materials, renewable energy solutions, and energy-efficient practices in their work to meet both sustainability and regulatory requirements. These competencies will be critical in supporting Cyprus' green transition and helping local industries align with the EU's sustainability goals.

With the increasing use of digital technologies and automation, **data and analytical competencies** will also be essential for implementing Industry 5.0 in the workforce. Professionals skilled in **big data analytics** will need to analyze vast amounts of data generated by IoT devices, sensors, and production systems, extracting actionable insights to drive improvements in efficiency, product quality, and customer experience. In addition, expertise in **cloud computing** and **system integration** will be necessary to ensure that different technologies and systems across industries work together seamlessly.

Additionally, in Industry 5.0, **soft skills, leadership and interdisciplinary skills** are also crucial. Effective collaboration and teamwork are necessary as humans and machines work together, requiring clear communication across technical and non-technical teams. Strong leadership is essential to guide organizations through technological changes, ensuring that employees are trained and supported. Additionally, leaders must foster an environment of continuous learning and adaptation. Interdisciplinary skills will also be important, as professionals need to work across different fields, blending technology, creativity, and sustainability to drive innovation and progress.

Finally, Cyprus, with its strong presence in industries such as tourism, shipping, and energy, will require professionals who are not only skilled in general Industry 5.0 competencies but also in **sector-specific technologies**. In tourism and hospitality, AI and IoT will be used to enhance customer experiences through personalization and automation. In shipping and logistics, Industry 5.0 will require professionals who understand smart logistics systems, including automation, predictive analytics, and IoT-enabled tracking, to optimize shipping routes and supply chain management. In Tourism, as Cyprus's economy is mostly based on it, the new industry will need professionals who can use the new technological advancements in the benefit of modernizing and optimizing the quality of life, enabling at the same time environmental protection. Finally, the growing energy sector in Cyprus will need professionals proficient in renewable energy technologies, smart grids, and energy-efficient systems to support the country's green transition and align with EU sustainability objectives. These industry-specific skills will be essential to ensuring that Cyprus remains competitive in these critical sectors.

Analysis of skill proficiency levels in the workforce;

AI and Robotics: While there is growing interest in AI technologies and robotics, only a limited number of professionals are specialized in these fields. Many engineers and IT specialists have basic knowledge, but advanced expertise is often lacking.

Sustainability Skills: As green technologies and sustainable practices are a key focus for the government and businesses, professionals with expertise in this area are emerging. However, the need for deep integration of sustainability with digital systems is still growing.

Human-Machine Collaboration: The concept is gaining attention in industrial sectors, but companies may not yet have fully integrated these systems at scale, leaving a gap in the workforce regarding proficiency in this specific area.

Data Science and Cybersecurity: There is a higher proficiency in general data science and cybersecurity knowledge, but the expertise specific to Industry 5.0-related smart technologies is still in development.

Comparison of required skills and available skills; comparison of skill profiles and labour market demands

- **Required Skills:** Industry 5.0 demands a high level of expertise in advanced robotics, AI applications, and smart energy management systems. Additionally, there is a pressing need for workers who can combine technical knowledge with sustainability principles.
- **Available Skills**: In Cyprus, the workforce possesses basic to intermediate knowledge in areas like AI, data analytics, and sustainability. However, advanced skills in human-machine collaboration, IoT integration for smart cities, and advanced energy systems are not as widespread
- **Labor Market Demand:** Employers in Cyprus, particularly in the tech and manufacturing sectors, are increasingly seeking professionals skilled in data science,

AI, robotics, IoT, smart cities, and energy management. The demand is especially high for cross-disciplinary skills, such as sustainability integration with technology and human-centered AI applications.

- **Skill Profiles:** While there are a growing number of data scientists, software engineers, and environmental engineers in the workforce, there remains a gap when it comes to professionals who combine these skills with human-centric technologies or deep expertise in sustainable energy systems. Many professionals may have basic skills in AI or robotics, but lack the expertise to develop integrated, smart systems or sustainable tech solutions at scale.

2.6.3 Summary & recommendations

Key findings regarding skill and competency gaps

There is also a lack of proficiency in advanced technical fields, such as AI, IoT, and sustainability, particularly in industry 5.0-related sectors. Immediate attention is needed to develop competencies in these fields.

- **Lack of Advanced Digital Skills**: Cyprus faces a shortage of professionals with advanced skills in AI, data analytics, IoT, and robotics, which are essential for the emerging Industry 5.0 technologies, such as human-machine collaboration, smart cities, and sustainable energy systems. A survey conducted by the ICT showed that between the ages 16-74, a 70% of them is familiar with basic or above digital skills with a main focus on young people.
- **Limited Knowledge in Green Technologies**: There is a notable gap in sustainability-related skills, particularly in green manufacturing, renewable energy, and energy efficiency. Industry 5.0's emphasis on sustainability requires the workforce to be skilled in these areas, but many workers are still lacking the necessary competencies.
- **Lack of Specialized Vocational Training**: While there are many academic degrees in technology and engineering, specialized vocational training programs that cater to Industry 5.0-specific skills, such as smart manufacturing technologies and robotics, are still under development.
- **Underrepresentation in Sustainability Roles**: While there is growing interest in sustainability, many sectors in Cyprus are slow to transition towards greener practices. This results in fewer job openings for professionals specializing in sustainability, green and human-centered technologies and environmental management.

Recommendations for addressing identified gaps

Develop and Promote Specialized Training Programs: Cyprus should implement more industry-specific vocational training programs and certifications that focus on Industry 5.0 skills, such as AI, smart technologies, sustainability, and robotics. Focus on hands-on, practical learning experiences through internships, training workshops, and simulation labs to strengthen theoretical knowledge with real-world applications. This will enable students and professionals to help them upskill and reskill.

Upgrade Higher Education Curriculum: Universities should enhance their undergraduate and postgraduate programs to include cross-disciplinary courses that combine AI, robotics, sustainability, and human-centered design. Moreover, the education sector should encourage industry-academia partnerships to ensure that graduates are prepared with relevant skills that align with Industry 5.0 needs.

Support Innovation and Research: Encourage research and innovation in emerging technologies, particularly those aligned with sustainability and human-centered tech. Cyprus can support research grants, innovation hubs, and tech incubators to create a workforce skilled in this area. Fortunately Cyprus has already established Hubs in its society (such as: Cyprus Tech Hub, Cyprus Digital Innovation Hub, Hub Nicosia and more), establishing the ''Cyprus Vision 2035'', but the support of the Government is needed more than ever.

Awareness Campaigns: Initiatives to raise awareness of the importance of sustainability in ICT careers can motivate students and professionals to pursue relevant education and training.

Prioritized list of skill gaps requiring immediate attention

- **Digital Skills (AI, IoT, Data Science):** Although the citizens of Cyprus every year are getting more familiar with digital skills, especially the percentage of young people's knowledge in digital skills is at 70%, on the other hand people are lacking in advanced skills. An immediate focus is needed on training professionals in AI, machine learning, big data analytics, and IoT systems to support Industry 5.0 technologies. With regard to people over 55, basic digital skills are lacking.
- **Sustainability Skills (Green Technologies, Renewable Energy):** Immediate focus on skills in energy management, green technologies, circular economy, and sustainable manufacturing to support Cyprus' transition to eco-friendly practices. Great example is HRDA which is supporting the implementation and identification of green skills in Cyprus by leading studies and generating suggestions for the green, eco-friendly and sustainable transition.
- **Human-Centered Design**: Enhance human-centric design skills, focusing on smart city technologies, robotics, and collaborative human-robot environments that align with Industry 5.0 principles. A great start is Municipality of Paphos which has a goal to implement a Smart Parking Management System using IoT and mobile technologies. This €770,000 project involves the installation of 3,100 sensors for real-time monitoring of parking space availability. It aims to optimize parking, reduce traffic congestion, and promote environmental sustainability by minimizing unnecessary vehicle movement.
- **Vocational Training in Smart Manufacturing and Robotics**: Launch targeted vocational training programs for robotics and smart manufacturing processes to meet the growing demand for advanced industrial skills.

Strategies for addressing identified skill gaps

Curriculum Overhaul: Universities and technical institutions should update their curricula to offer interdisciplinary programs in AI, data science, robotics, and sustainability. These programs should focus on practical, hands-on experiences and industry projects that equip students with skills required by the Industry 5.0 workforce.

Industry Partnerships:

- Foster strong collaborations between Cypriot businesses and educational institutions to create internships, apprenticeships, and co-op programs where students and workers can gain experience working with cutting-edge Industry 5.0 technologies.
- Partner with international companies and EU innovation hubs to bring in best practices and advanced training in sustainable tech and human-machine collaboration.

Subsidized Training and Certification Programs:

- The government should subsidize online and offline training programs in critical areas like AI, IoT, robotics, energy systems, and sustainability to support the development of industry-ready skills. Integrating these practices will help individuals to learn at their own pace and to have access to tools, needer for their career.
- Encourage universities to create joint programs that combine Industry 4.0 and 5.0 and sustainability training, ensuring graduates and professionals are equipped with the necessary skills for the green transition.

Public Awareness Campaigns:Launch public awareness campaigns that highlight the importance of Industry 5.0 skills and green technologies for the Cypriot workforce. This could involve engaging with youth, vocational schools, organizations and companies to raise awareness of opportunities in these growing sectors.

Fostering Research and Development: Establish more innovation labs and R&D programs in collaboration with the private sector to work on real-world Industry 5.0 projects, including smart city initiatives, renewable energy systems, and advanced manufacturing technologies.

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2.7 Internet of Things

2.7.1 Identified roles, jobs, skills & competency profiles

Who is hiring: current & potential employers

Cyprus's IoT landscape is expanding, offering diverse roles that require a blend of technical expertise and analytical skills. Professionals with relevant competencies are well-positioned to capitalize on these emerging opportunities. Several companies in Cyprus are actively involved in IoT development and are potential employers for IoT professionals:

- Cyta, the leading telecom provider, consistently invests in cutting-edge technologies, including the advancement of the innovative NarrowBand-Internet of Things (NB-IoT) network.
- CyRIC IoT: Offers end-to-end IoT solutions for applications such as smart cities, environmental monitoring, and building automation.[1]
- Pundi X 365: Provides blockchain, AI, and IoT solutions and consulting services.[2]
- AVN Innovative Technology Solutions: Specializes in ICT domains, including IoT, offering design flows, tools, and system design services.[3]
- Deep Orbital: Develops hardware IoT sensors and gateways for agriculture and industrial sectors.[4]
- Lumoscribe LTD: Focuses on developing optical fiber sensors and lasers, contributing to IoT hardware components.[5]

List of specific roles = professionals working with the respective ATI Career opportunities / jobs/ working positions and Profile/description/competency profile and skills list for the most common jobs/roles for the respective ATI

The IoT industry encompasses a wide range of specific roles and competency profiles, each requiring a unique set of skills and expertise. **IoT Developers** focus on creating and optimizing software applications, firmware, and cloud-based systems for IoT devices. **IoT Solutions Architects** are responsible for planning and designing the overall IoT infrastructure, integrating hardware, software, and connectivity solutions. On the networking side, **IoT Network Engineers** ensure robust connectivity using protocols like MQTT, CoAP, and LTE-M, while **IoT Security Specialists** focus on safeguarding devices and networks from vulnerabilities. **Data Scientists and Analysts** play a crucial role in processing and interpreting the massive amounts of data generated by IoT systems, often employing machine learning to extract actionable insights. **Product Managers** oversee the development and deployment of IoT solutions, aligning technical capabilities with market needs. Additionally, **IoT Consultants** advise organizations on the adoption and implementation of IoT technologies to optimize operations and enhance efficiency. Together, these roles require interdisciplinary competencies, including knowledge of hardware,

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[1] CyRIC IoT - End-to-End IoT Solutions
[2] Next Generation Technologies | Pundi X 365 | Cyprus
[3] https://www.avntechgroup.com/
[4] Deep Orbital | F6S
[5] Lumoscribe | Sense the Future

software, data analytics, and cybersecurity, making IoT professionals essential to the success of connected systems.

Common degrees of professionals in the respective ATIIoT professionals commonly pursue degrees that equip them with the technical and analytical skills needed to design, develop, and manage IoT systems. These are:

- **Computer Science**: Focus on programming, software development, cloud computing, and cybersecurity.
- **Electrical or Electronics Engineering**: Emphasis on circuit design, embedded systems, and sensor technology.
- **Information Technology (IT)**: Specialization in networking, IT infrastructure, and system integration.
- **Data Science or Data Analytics**: Expertise in big data, machine learning, and data visualization.
- **Cybersecurity**: Skills in securing IoT devices, networks, and data.
- **Mechanical Engineering**: Focus on automation, robotics, and integration with IoT technologies.
- **Telecommunications Engineering**: Specialization in wireless communication, networking protocols, and signal processing.
- **Artificial Intelligence and Machine Learning**: Development of smart, predictive algorithms for IoT systems.
- **Industrial Engineering**: Optimization of manufacturing processes and logistics using IoT solutions.

2.7.2 Skill Gap Analysis

Identification of critical skills & competency

Addressing the skill gap in IoT industry requires a clear understanding of the critical skills and competencies needed to succeed. These skills can be grouped into technical, analytical, and domain-specific categories:

- Technical Skills
  - **Programming and Software Development**: Proficiency in languages like Python, C/C++, JavaScript, and Java for IoT device programming and application development.
  - **Embedded Systems**: Knowledge of microcontrollers, firmware development, and real-time operating systems (RTOS).
  - **Networking and Connectivity**: Expertise in IoT communication protocols (e.g., MQTT, CoAP, Zigbee, LoRaWAN) and wireless technologies (e.g., Wi-Fi, Bluetooth, 5G).
  - **Hardware Design**: Understanding of sensor integration, circuit design, and prototyping IoT hardware.
  - **Cloud Computing**: Familiarity with cloud platforms like AWS IoT Core, Microsoft Azure IoT, and Google Cloud IoT for data storage and processing.

- **Cybersecurity**: Skills in encryption, secure authentication, and risk assessment to safeguard IoT systems.
- **AI and Machine Learning**: Ability to build and deploy intelligent systems for predictive analytics and automation in IoT.

- Analytical Skills
  - **Data Analysis and Visualization**: Competency in processing large datasets using tools like Tableau, Power BI, or Python libraries (e.g., Pandas, Matplotlib).
  - **Big Data Management**: Knowledge of tools like Hadoop, Apache Kafka, or Spark to handle IoT-generated data efficiently.
  - **Problem-Solving**: Critical thinking to troubleshoot and resolve complex IoT system issues.

- Domain-Specific Knowledge
  - **IoT Ecosystem Understanding**: Familiarity with IoT architecture, device lifecycle management, and system interoperability.
  - **Industry Applications**: Knowledge of specific IoT use cases in domains like smart cities, industrial IoT (IIoT), healthcare, agriculture, and transportation.
  - **Standards and Regulations**: Awareness of IoT compliance standards like GDPR, HIPAA, or ISO/IEC 30141.
  - Analysis of skill proficiency levels in the workforce;

The IoT industry is rapidly evolving, but skill levels within the workforce vary widely, creating challenges in keeping pace with technological advancements. Here's a breakdown of the current landscape and areas for improvement:

- Technical Skills
  IoT professionals often have a strong foundation in programming, particularly in languages like Python and Java, which are widely used for software development. However, there's a noticeable gap when it comes to low-level programming for embedded systems, such as C/C++, and familiarity with IoT-specific tools like Node-RED and Arduino IDE is inconsistent. Networking knowledge is generally solid at a basic level, covering essentials like TCP/IP and Wi-Fi, but there's less familiarity with specialized IoT protocols such as MQTT and Zigbee. Emerging technologies like 5G and LPWAN (e.g., LoRaWAN) remain areas where deeper expertise is needed. On the security side, while most professionals understand basic encryption and authentication, advanced cybersecurity skills—like penetration testing and incident response—are less common. Similarly, while cloud computing platforms like AWS IoT and Azure IoT Hub are widely used, designing robust, scalable IoT cloud systems remains a skill gap.

- Analytical Skills
  Data analysis and visualization skills are becoming more common, with professionals using tools like Tableau or Python to process and present data. However, IoT systems generate massive amounts of real-time data, and handling this effectively remains a challenge. Expertise in big data tools such as Hadoop or Apache Spark is limited, particularly in smaller organizations. Machine learning is gaining traction, but practical applications tailored to IoT, such as predictive analytics for sensor data, are still underdeveloped.

- Domain-Specific Knowledge
  Understanding the basic architecture of IoT ecosystems is fairly widespread, but more advanced concepts like edge computing, interoperability, and lifecycle management are less understood. Additionally, industry-specific knowledge can vary significantly. For instance, professionals working on IoT solutions for smart cities or healthcare often lack in-depth knowledge of tailored use cases and compliance requirements, such as GDPR or ISO standards. There's also a clear need for better integration skills, especially when bridging industrial IoT systems with enterprise IT infrastructures.

Comparison of required skills and available skills; comparison of skill profiles and labour market demands

The required skills for the IoT sector emphasize comprehensive capabilities in end-to-end IoT deployment, advanced AI and machine learning applications, and expertise in developing industry-specific use cases such as those in healthcare or smart cities. However, the skills currently available in the workforce are largely limited to basic programming and networking, with a noticeable lack of proficiency in building scalable IoT solutions and implementing robust security systems.

When comparing skill profiles to labor market demands, there is a growing need for professionals adept in AI-driven IoT applications and cybersecurity, reflecting the critical role of these areas in IoT innovation. Unfortunately, much of the existing talent pool possesses only general IT skills and lacks the specialized expertise required to address the complexities of modern IoT projects.

Skill Category	Market Demand	Available Skills	Gap
Programming	Advanced programming for IoT systems	Intermediate	Advanced embedded system programming and low-level coding expertise are lacking.
Networking	IoT-specific protocols and LPWAN technologies	Basic networking skills	Knowledge of IoT protocols (e.g., MQTT, Zigbee) and 5G/LoRaWAN expertise are insufficient.
Cybersecurity	IoT device and network security	General cybersecurity knowledge	Specialized IoT security skills, such as risk assessment and secure firmware updates, are rare.
Data Analytics	Real-time data processing and predictive modeling	Foundational data analytics	Expertise in big data tools and IoT-specific analytics is limited.
Industry Knowledge	Deep expertise in IoT applications by sector	General understanding of IoT applications	In-depth knowledge of specific industries, such as healthcare or smart cities, and regulatory compliance is inadequate.

2.7.3 Summary & recommendations

- Key findings regarding skill and competency gaps
  - programming (C/C++) and real-time operating systems critical for IoT device functionality.
  - **Networking Protocols**: Insufficient knowledge of IoT-specific protocols (e.g., MQTT, Zigbee, CoAP) and LPWAN technologies (e.g., LoRaWAN).
  - **Cybersecurity**: Weak understanding of IoT-specific security practices, such as device encryption, risk assessment, and secure firmware updates.
  - **Data Analytics and AI**: Limited skills in handling large IoT datasets, real-time analytics, and applying machine learning to IoT scenarios.
- Domain-Specific Knowledge:
  - Poor understanding of advanced IoT concepts like edge computing, lifecycle management, and interoperability.
  - Lack of sector-specific knowledge (e.g., healthcare, manufacturing, smart cities) and regulatory compliance expertise (e.g., GDPR, HIPAA).
- Soft Skills:
  - Deficient project management capabilities, particularly in agile methodologies suited to IoT.
  - Limited cross-functional collaboration and adaptability to new IoT technologies.

Recommendations for addressing identified gaps

- Immediate Actions:
  - Launch focused training programs to address critical skill shortages in embedded systems, IoT protocols, and cybersecurity.
  - Partner with industry leaders to provide hands-on experience in IoT-specific tools, frameworks, and platforms.
- Short-to-Medium Term:
  - Develop certifications in IoT data analytics, AI, and machine learning tailored to IoT applications.
  - Establish industry-specific training tracks, focusing on regulatory compliance and real-world IoT use cases.
- Long-Term Strategy:
  - Build a pipeline of IoT talent by integrating IoT-focused curricula in universities and technical schools.
  - Foster continuous learning by encouraging professionals to stay updated with emerging IoT trends like blockchain and edge computing.

Prioritized list of skill gaps requiring immediate attention

  - **Embedded Systems Expertise**: Critical for IoT device functionality and hardware-software integration.
  - **IoT-Specific Networking Protocols**: Essential for seamless connectivity and device communication.

- **Cybersecurity Skills**: Vital for protecting IoT systems against breaches and vulnerabilities.
- **Data Analytics and Machine Learning**: Necessary for processing and deriving insights from IoT-generated data.
- **Regulatory Compliance Knowledge**: Urgent for sectors like healthcare and finance to ensure adherence to legal standards.

Strategies for addressing identified skill gaps

- Industry-Academia Collaboration:
  - Collaborate with universities and technical schools to design IoT-specific programs focusing on embedded systems, networking, and cybersecurity.
  - Include internship opportunities and real-world IoT projects to provide practical experience.
- Targeted Upskilling Initiatives:
  - Launch online and in-person courses, certifications, and bootcamps tailored to critical IoT skills.
  - Use immersive training technologies like AR/VR and IoT labs to enhance learning experiences.
- Corporate Training Programs:
  - Encourage organizations to invest in employee upskilling through customized IoT training.
  - Provide incentives for certifications in IoT platforms (e.g., AWS IoT Core, Azure IoT).
- Sector-Specific Development:
  - Develop targeted programs for industries like smart cities, manufacturing, and healthcare to build domain-specific IoT expertise.
  - Focus on compliance with industry regulations through case studies and workshops.
- Soft Skill Enhancement:
  - Offer leadership development programs to build project management capabilities.
  - Promote cross-functional collaboration through team-based IoT projects and hackathons.
- Continuous Learning Culture:
  - Establish a culture of lifelong learning by offering employees access to IoT knowledge resources, webinars, and industry conferences.
  - Encourage self-paced learning through platforms like Coursera, Udemy, and LinkedIn Learning.

2.7.4 References & resources

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2.8 Quantum Computing

2.8.1 Identified roles, jobs, skills & competency profiles

Who is hiring: current & potential employers

- **Academic Institutions:**
  Major universities like the Cyprus University of Technology (CUT), The Cyprus Institute (CyI), University of Cyprus, and Neapolis University Pafos are the main leaders in quantum computing education and research through dedicated programs and collaborations with international entities [2] [5].

- **Research Centres:**
  Specialized centres such as the Computation-based Science and Technology Research Centre (CaSToRC) at CyI and the Quantum Computing for Science and Technology (QSciTec) Centre of Excellence at the University of Cyprus are pioneering research and innovation in quantum technologies while developing local talent [4] [8].

- **Government Agencies:**
  The Deputy Ministry of Research, Innovation, and Digital Policy plays a crucial role in promoting technology adoption and funding quantum initiatives. Other governmental organizations, including the Digital Security Authority and Cyprus Telecommunications Authority (CYTA), anticipate incorporating quantum technologies into their long-term technological strategies [7].

- **Industry:**
  Although private sector involvement in quantum computing in Cyprus is currently minimal, sectors like finance, healthcare, and materials science are expected to become significant players as practical applications for quantum computing develop.

The above-mentioned sectors will require an increased number of experts in the field of quantum computing in order to provide relative solutions in areas which include pharmaceutical development, risk modelling and advanced materials design to name a few [6].

List of specific roles = professionals working with the respective ATI Career opportunities / jobs/ working positions

- **Quantum Software Developer:** Responsible for creating algorithms and applications for quantum systems using libraries like Qiskit or Cirq [2] [1].
- **Quantum Algorithm Designer:** This position focuses on developing and fine-tuning algorithms for specific quantum computing applications, including optimizations and simulations.
- **Quantum Researcher:** Engages in foundational and applied research in quantum mechanics, quantum hardware, and computational models [4].

- **Quantum Systems Engineer:** Supervising and maintaining hardware involved in quantum computation and devising communication and integration with legacy/traditional computing systems.
- **Quantum Cryptography Specialist:** Designs secure communication protocols to withstand quantum attacks.
- **Quantum Project Manager:** Leading interdisciplinary teams to deliver quantum computing projects aligned with organizational goals.
- **Policy Advisor for Quantum Technologies:** Guiding regulatory frameworks and national strategies related to quantum computing.

Profile/description/competency profile and skills list for the most common jobs/roles for the respective ATI

- **Quantum Software Developers and Algorithm Designers:** Proficiency in Python and quantum development kits (Qiskit, Cirq, or similar), strong foundations in quantum mechanics, and the ability to optimize algorithms for noisy intermediate-scale quantum (NISQ) devices.
- **Quantum Systems Engineers:** Knowledge of quantum hardware, including qubits, error correction, and hardware-software integration.
- **Quantum Researchers:** Expertise in theoretical physics, linear algebra and experimental procedures for quantum systems.
- **Quantum Cryptography Specialists:** Expertise in cryptographic protocols, cybersecurity principles, and post-quantum cryptography techniques.

Across these roles, soft skills such as interdisciplinary collaboration, critical thinking, and effective communication are essential for driving progress and translating quantum research into practical applications.

Common degrees of professionals in the respective ATI

Professionals entering the quantum computing field in Cyprus typically hold degrees in Physics, Mathematics, Computer Science, or Electrical Engineering. Advanced roles often require postgraduate qualifications, such as a master's or PhD in Quantum Information Science, Quantum Engineering, or a related field.

There is also increased need for training and certifications in various frameworks and tools used in quantum science such as Qiskit Developer Certification, in order to underline the importance of lifelong learning for existing scientists and professionals in this emerging field.

2.8.2 Skill Gap Analysis

Identification of critical skills & competency

There are significant gaps concerning specific skills and competences in the sector of quantum computing. These competencies include Python coding proficiency specifically with AI and quantum computing libraries, as well as specific frameworks such as Qiskit, Cirq and TensorFlow Quantum [6] [5]. Additional competencies include quantum algorithm design, qubit fabrication, and hardware control systems, as well as knowledge of quantum cryptography and quantum machine learning techniques. As the field evolves, skills in managing and implementing interdisciplinary research projects, as well as knowledge of classical computing concepts, are equally important.

Nevertheless, there is considerable shortage of professionals and academics with knowledge in advanced quantum computing in Cyprus, specifically skilled workforce needing in designing, building and managing hardware specifically for quantum computing, designing quantum algorithms and applying them to areas such as cryptography and machine learning. Moreover, soft skills such as problem-solving, scientific communication, and collaboration are essential to complement technical expertise and drive the practical application of quantum computing innovations.

Analysis of skill proficiency levels in the workforce;

The analysis of the situation of the current workforce of Cyprus showcases a gap between the skills needed for quantum computing and the ones which are available.

While academic institutions produce graduates with strong theoretical knowledge in physics, computer science, and engineering, these individuals often lack hands-on experience in quantum-specific tools and technologies.

For example, a significant amount of new university graduates has almost zero experience with quantum programming and quantum hardware development [2] [4] [7].

This gap is compounded by the nascent state of quantum computing research and development in Cyprus, where resources and opportunities for specialized training remain limited. Employers and research institutions report challenges in recruiting individuals with a comprehensive understanding of quantum technologies and their applications, further emphasizing the need for targeted training programs to bridge this gap [5] [8].

Comparison of required skills and available skills; comparison of skill profiles and labour market demands

The mismatch between the required and available skills in Cyprus is evident, particularly in roles demanding advanced quantum computing expertise.

For example, open positions for Quantum Research Scientists and Quantum Hardware Engineers require a proficiency in the sector where knowledge of specific programming tools and skills are required, they are not yet available through the local workforce. Similarly, roles like Quantum Software Developer and Data Scientist require a combination of quantum and classical computing expertise, which many candidates lack [6] [7].

While academic programs at institutions such as the Cyprus University of Technology (CUT) and the University of Cyprus lay a strong foundation, they often fall short in providing applied training or direct industry exposure. Employers in academia, government, and emerging private sectors struggle to find professionals capable of addressing practical challenges, such as implementing quantum algorithms or managing quantum research projects [2] [5] [8].

This skills gap is further highlighted by the limited number of graduates in quantum-related fields. Despite growing interest in quantum technologies, Cyprus currently lacks sufficient educational pathways to equip professionals with the advanced competencies required to meet industry needs. Addressing this gap will require the development of specialized training programs, greater collaboration between academia and industry, and targeted investment in quantum education and research infrastructure.

2.8.3 Summary & recommendations

Key findings regarding skill and competency gaps

Analysing the field of quantum computing in Cyprus highlights several key gaps:

Limited Talent Pool: Professionals with specialized expertise in the field is limited reflecting the infancy of quantum computing in Cyprus [2] [5] [8].

Lack of Practical Experience Opportunities: Limited adoption of quantum technologies by industry means fewer opportunities for hands-on experience in real-world applications [4] [6].

Weak Industry-Academia Collaboration: Insufficient collaboration between academic institutions, research centres, and industry hampers the development of relevant skills and knowledge transfer [7] [8].

These results enhance the need for initiatives which target partnerships with the world of entrepreneurs and academia to develop a workforce in Cyprus which is quantum-ready.

Recommendations for addressing identified gaps

To address these gaps, a comprehensive, multi-disciplinary approach is required:

- Expand Education and Training Programs:
  - Introduce quantum computing courses at undergraduate and postgraduate levels and develop professional development programs to upskill the current workforce in quantum technologies [2] [5].
  - Strengthen Industry-Academia Partnerships:
  - Foster collaborations between universities, research centres, and industry to create internship and research opportunities [4] [6] as well as establish joint projects to provide students and professionals with real-world experience in quantum applications [7].
- Attract International Expertise:
  Offer competitive incentives and research funding to attract global quantum computing experts to Cyprus [8].
- Promote Awareness and Career Pathways:
  Launch educational programs to raise awareness and interest in secondary education students and the public, showcasing quantum computing career opportunities [2] [6] and to develop mentorship programs to guide young talent into the field [5].
- Develop a National Quantum Strategy:
  Create a comprehensive strategy to guide investment in quantum research, education, and industry applications, ensuring alignment with global trends [7].
  - prioritized list of skill gaps requiring immediate attention
  - Quantum Programming and Algorithm Development
  - Expertise in quantum algorithms, frameworks like Qiskit, and programming in Python [2] [5].

- Quantum Hardware Engineering
- Skills in qubit fabrication, control systems, and quantum hardware testing [4] [8].
- Quantum Machine Learning and Data Analysis
- Proficiency in applying quantum techniques to analyse large datasets and build predictive models [6] [7].
- strategies for addressing identified skill gaps

- Develop a National Quantum Computing Curriculum Framework:
  Design a standardized curriculum to provide a cohesive educational pathway, from foundational knowledge to advanced specialization in quantum computing [2] [5] [8].
- Establish a Quantum Computing Skills Development Fund:
  Promote funding by the industry to academics for scholarships, fellowships through grants which will support them in research in the field [7].
- Create a Quantum Computing Innovation Hub:
  Establish a central platform to facilitate collaboration between academia, research centres, and industry, fostering joint projects, knowledge exchange, and workforce training [4] [6].
- Promote Lifelong Learning Opportunities:
  Offer certifications and short-term training programs in quantum computing tools and techniques to ensure continuous professional development [8].
- Encourage Diversity in Quantum Computing:
  Launch initiatives to attract underrepresented groups to the field, building a diverse and inclusive talent pipeline [5] [7].

By implementing these strategies, Cyprus can overcome its skill gaps and develop a robust quantum computing ecosystem, giving the opportunity for the country to play a meaningful role in global quantum advancements.

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WP4 Enhancing Labour Market-Relevant Skills in Advanced Technologies

T4.1 Identifying skill gaps in Advanced Technologies

GREECE national report from the desk research

Date: September 2024 – January 2025

Prepared by: NCSR Demokritos

INVESTech

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and Sustainability in Tech

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3 GREECE – National report from the desk research

3.1 Introduction & methodology

In order to identify the skill gaps between industry demands and the existing competencies of professionals in Greece across emerging fields such as AI and Ethics, Blockchain, Big Data, ICT for Sustainability, Quantum Technology, IoT, and Industry 5.0, a structured methodology combining quantitative and qualitative research was employed. This approach provides a comprehensive assessment, capturing insights from industry stakeholders and professionals to highlight specific skill deficiencies. The methodology comprises four primary stages: literature review and preliminary analysis, data collection, data analysis, and validation and reporting. Each stage incorporates specific techniques to ensure reliable data and actionable insights.

The **first stage**—literature review and preliminary analysis—aims to establish a foundational understanding of each domain and the essential skills required. This involves reviewing academic journals, industry reports, government publications, and international studies on necessary competencies in AI, Blockchain, Big Data, and other key fields. This review defines core competencies, from technical skills like programming and machine learning to regulatory knowledge in data privacy and environmental standards. The outcome is a comprehensive skills framework for each domain, guiding the design of surveys, interviews, and focus group questions. However, as noted in Section 2.5, literature references specific to these skill gaps are limited for the Greek Ecosystem

Given the scarcity of literature-based data, feedback from industry representatives and professionals was crucial for this report, primarily collected during the **data collection and analysis stage**. The analysis examined average proficiency levels across technical, regulatory, and soft skills, facilitating comparison with industry-rated importance. Additionally, a comparative analysis of academic program offerings versus industry requirements was conducted to identify gaps where academic training may not meet real-world needs.

The **validation and reporting stage** ensures that findings accurately reflect both industry requirements and educational shortcomings. At this stage, the report is structured to provide clear insights into skill gaps for each domain, with sections summarizing findings for AI and Ethics, Blockchain, Big Data, ICT for Sustainability, Quantum Technology, IoT, and Industry 5.0. Actionable recommendations are included to bridge these skill gaps, including educational reforms, stronger industry-academic partnerships, and continuous professional development initiatives.

3.2 Artificial Intelligence and Ethics

3.2.1 Identified roles, jobs, skills & competency profiles

Who is hiring: current & potential employers

The main employers in Greece's AI and Ethics ecosystem primarily include research organizations, academic institutions, government bodies, and large technology and consulting firms. Below are the key players in this field:

- **NCSR Demokritos**: As a leading research center in Greece, "Demokritos" hosts an AI lab focused on machine learning, natural language processing, and ethical AI. The lab's projects emphasize responsible AI development and the ethical implications of AI systems.
- **National Observatory of Athens**: Within the Institute of Informatics and Telecommunications, researchers conduct extensive studies on AI, particularly concerning privacy, data ethics, and big data. They often collaborate with international and European organizations on policy development.

Additionally, several Greek universities, such as the **National and Kapodistrian University of Athens** and the **Aristotle University of Thessaloniki**, have departments dedicated to AI and ethics. Faculty members frequently collaborate with EU institutions, contributing to ethical AI research, regulatory frameworks, and exploring AI's social impact.

Global consultancies, including **Accenture** and **Deloitte**, also have a strong presence in Greece, focusing on ethical AI consulting. They support Greek businesses in integrating AI responsibly, with an emphasis on data privacy, security, and fair AI deployment.

Government bodies and nonprofits, such as the **Hellenic Data Protection Authority**, play an instrumental role in shaping the ethical landscape of AI. They develop guidelines and policies aligned with GDPR and AI regulations, often working closely with European agencies.

List of specific roles = professionals working with the respective ATI Career opportunities / jobs/ working positions and Profile/description/competency profile and skills list for the most common jobs/roles for the respective ATI

The majority of the professionals working in this field are typically interdisciplinary, combining technical expertise in AI with a strong understanding of ethical, philosophical, and legal principles. Their roles might include AI ethics researchers, data scientists, AI policy advisors, and compliance officers focused on AI ethics. In more details, the majority of the professionals are **proficient** in machine learning, data analysis, and programming (Python, R), with strong analytical skills to assess ethical considerations. Additionally, they have a strong knowledge of data privacy laws, human rights implications, and EU regulatory requirements is critical. As far as the soft skills, the professionals have strong communication and critical thinking. These professionals often work at the intersection of technology and ethics, translating complex technical information into ethical considerations and vice versa.

Common degrees of professionals in the respective ATI

As far as their educational background, the professionals hold the following degrees:

- Computer Science & Engineering: Most AI professionals in Greece hold degrees in computer science, data science, or engineering, with further specialization in machine learning, AI, or data analytics.
- Philosophy, Ethics, and Law: Given the ethical considerations, professionals often have backgrounds in philosophy or ethics, with some trained in law (especially EU data protection law) to handle regulatory and legal aspects.
- Interdisciplinary Programs: Some universities now offer specialized degrees or certifications in AI and ethics, combining courses in computer science, philosophy, and data privacy, equipping professionals with a well-rounded perspective on responsible AI.
- Postgraduate Degrees: Advanced degrees such as a Master's or PhD in AI, data science, or applied ethics are common, especially for roles in research or policymaking.

3.2.2 Skill Gap Analysis

Identification of critical skills & competency

Professionals in AI and Ethics need a unique combination of technical and ethical/regulatory skills, as well as essential soft skills. Technical skills include machine learning (ML) and artificial intelligence (AI), where professionals must be proficient in designing, training, and deploying AI models with ethical applications in mind. Data science and analytics skills are also essential, as they enable the collection, analysis, and interpretation of data crucial for understanding and mitigating biases in AI systems. Programming skills, particularly in languages such as Python, R, and Java, along with experience in AI frameworks like TensorFlow and PyTorch, are fundamental for professionals in this domain. An understanding of data privacy and security, especially regarding GDPR compliance and data anonymization, is also critical.

In addition to technical skills, professionals need ethical and regulatory knowledge, particularly in ethical AI principles, fairness, accountability, and transparency. A strong grounding in ethical philosophy, especially in frameworks relevant to AI's societal impact, enables them to evaluate AI applications critically. Familiarity with EU regulations, notably GDPR and the evolving EU AI Act, is increasingly necessary to ensure compliance in AI development. Soft skills, such as critical thinking, analytical abilities, and effective communication, are essential, allowing professionals to translate complex technical concepts into ethical considerations and communicate effectively with interdisciplinary teams.

Analysis of skill proficiency levels in the workforce;

The Greek workforce shows varying levels of proficiency in these skills, with a relatively high technical proficiency but limited expertise in ethical and regulatory aspects. For example, data science, programming, and basic AI/ML frameworks are well-covered, especially among computer science graduates and data scientists, thanks to the emphasis Greek universities place on these areas. However, proficiency in advanced AI specializations like natural language processing (NLP) and computer vision is moderate, with rising demand creating an urgent need for further development in these areas.

Conversely, ethical and regulatory proficiency levels are generally moderate to low. Many professionals possess technical knowledge but lack formal training in ethical AI and regulatory compliance. While awareness of AI ethics is growing, driven by industry collaborations and some university programs, the current skill levels remain insufficient to meet all labor market demands, especially in the areas of EU data compliance and ethical philosophy.

Comparison of required skills and available skills; comparison of skill profiles and labour market demands

Comparison of Required vs. Available Skills Greece has a strong foundation in technical AI skills, though a skills gap remains in specialized AI areas, such as computer vision and NLP, and in integrating AI with ethical principles. Professionals often need upskilling in areas like responsible AI development and bias mitigation. Ethical and regulatory expertise is another area with a pronounced shortage. The need for interdisciplinary training is pressing, as skill levels in data compliance, ethical philosophy, and responsible AI are not yet aligned with the industry's needs. Soft skills, such as communication and interdisciplinary collaboration, are somewhat limited. Professionals often lack experience in communicating technical information to non-technical audiences, an essential skill for bridging technology and ethics

3.2.3 Summary & recommendations

Prioritized list of skill gaps requiring immediate attention

To bridge the skills gap in AI and Ethics, implementing interdisciplinary programs that integrate AI, ethics, law, and regulatory training within AI and computer science degrees is essential.

Other recommendations

Such programs would foster a workforce aligned with industry needs and prepared to meet regulatory requirements. Examples from other countries demonstrate the effectiveness of this approach: the University of Oxford, for example, offers an MSc in Social Science of the Internet with a focus on ethical AI, data privacy, and the societal impact of technology, emphasizing interdisciplinary study. In Germany, the Fraunhofer Institute collaborates with universities to provide AI ethics courses within technical degree programs, equipping students with both technical and ethical perspectives on AI.

Upskilling opportunities through short courses and certifications in AI ethics, GDPR compliance, and responsible AI practices can help professionals transition into specialized roles. For instance, the Singapore Government's AI Ethics and Governance Body of Knowledge provides courses on AI ethics principles, risk management, and privacy considerations, enabling professionals to adapt to AI ethics challenges across sectors. Enhanced collaboration between industry and academia in Greece on research projects can also provide practical experience. For instance, the collaboration between MIT and Harvard University, offering the AI Ethics and Governance Certification, could serve as a model for similar partnerships in Greece. Continuous training in ethical AI for current professionals is crucial to ensure that Greece's AI workforce meets the standards set by EU regulations. By developing a balanced skill set that encompasses both technical and ethical dimensions, Greece can lead in creating responsible and compliant AI solutions. According to Binns (2018)[6], this balanced approach is critical for preventing algorithmic biases and ensuring public trust in AI systems.

3.2.4 References & resources

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3.3 Big Data

3.3.1 Identified roles, jobs, skills & competency profiles

Who is hiring: current & potential employers

The Greek Big Data ecosystem is expanding, driven by sectors like finance, telecommunications, e-commerce, and research. With the rise of data-driven decision-making, many organizations in Greece are investing in big data capabilities, either through in-house teams or collaborations with specialized firms. The main employers in this domain include:

- **Telecommunications Companies (e.g., COSMOTE, Vodafone Greece)** Major telecom companies like COSMOTE and Vodafone handle vast amounts of data daily and employ data teams to analyze user behaviors, optimize network operations, and improve customer experiences through predictive analytics.
- **Banks and Financial Institutions (e.g., National Bank of Greece, Alpha Bank)** Banks in Greece are increasingly adopting big data solutions to enhance their risk assessment, customer segmentation, fraud detection, and personalized financial services, working within strict compliance frameworks.
- **E-commerce & Retail (e.g., Skroutz, Public)** Large e-commerce platforms like Skroutz and retail chains such as Public use big data to optimize supply chains, improve customer targeting, and personalize recommendations. Data-driven insights in these companies are crucial for improving competitiveness.
- **Research Centers (e.g., National Centre for Scientific Research "Demokritos")** Research institutions like "Demokritos" are heavily invested in big data for scientific research, particularly in healthcare, environmental studies, and AI. They work on both theoretical and applied aspects of big data analysis, often in collaboration with the private sector.
- **Consulting Firms (e.g., PwC Greece, Accenture)** Global consulting firms with offices in Greece provide big data and analytics consulting to help organizations leverage their data assets. They focus on data strategy, governance, and implementing data solutions aligned with organizational goals.
- **Technology and Software Development Companies (e.g., Intrasoft, Uni Systems)**
  Greek technology firms provide custom big data solutions to clients across sectors, offering data infrastructure management, software development, and analytics. They often work with data engineers and analysts to support digital transformation efforts.

List of specific roles = professionals working with the respective ATI Career opportunities / jobs/ working positions

Professionals in big data often work in roles like data scientists, data engineers, business intelligence (BI) analysts, and data architects.

Profile/description/competency profile and skills list for the most common jobs/roles for the respective ATI

They typically have a strong foundation in quantitative and technical skills, as well as knowledge in data management and analytics. They are proficient in programming languages like Python, R, and SQL, experience with big data frameworks (e.g., Hadoop, Spark), and familiarity with cloud platforms (e.g., AWS, Google Cloud, Azure). Additionally, they have very high skills in statistical analysis, data visualization, and machine learning are essential. Their soft skills entail problem-solving, communication, and teamwork are crucial, as big data professionals often work in cross-functional teams, translating data insights into actionable business strategies.

Common degrees of professionals in the respective ATI

The educational background of the professionals active in this domain hold one or more degrees in the following domains:

- **Computer Science & Data Science** Most professionals hold degrees in computer science, data science, or software engineering, providing a technical foundation for data management and algorithmic processing.
- **Statistics and Applied Mathematics** Many have backgrounds in statistics, mathematics, or similar quantitative fields, essential for data analysis and modeling. This background is especially prevalent among data scientists and analysts.
- **Engineering and Physics** Engineering and physics graduates are common in the field, as these programs emphasize analytical thinking and technical skills, which can be adapted for big data analysis and engineering.
- **Postgraduate Degrees** Advanced degrees such as a Master's or PhD in data science, artificial intelligence, or analytics are common for roles involving complex data modeling or machine learning.

3.3.2 Skill Gap Analysis

Identification of critical skills & competency

Professionals in the Greek Big Data field need a combination of technical, data governance, and soft skills to meet the demands of the industry effectively. Key technical skills include data management and engineering, where professionals are expected to have strong competencies in data architecture, ETL processes, and data warehousing. Familiarity with big data platforms like Hadoop and Spark, along with cloud solutions such as AWS, Azure, and Google Cloud, is crucial. Data analytics and statistical modeling skills are also in high demand, requiring proficiency in Python, R, SQL, and data visualization tools like Tableau and Power BI. Machine learning and predictive analytics play an increasingly important role, as organizations seek to derive predictive insights. Knowledge of machine learning techniques, including supervised and unsupervised learning, deep learning, and model deployment, is essential for professionals aiming to excel in this field.

Beyond technical skills, expertise in data governance and regulatory knowledge is critical for managing large data sets, especially in light of GDPR requirements. Professionals must understand data privacy and security principles, with emphasis on data governance and quality assurance practices that ensure data accuracy, consistency, and security. Soft skills, such as analytical thinking and communication, are equally essential. Big Data professionals must not only interpret complex data but also communicate insights effectively to both technical and non-technical stakeholders, often requiring cross-functional collaboration within organizations.

Analysis of skill proficiency levels in the workforce;

In Greece, workforce proficiency levels vary across big data skills. Core competencies, such as basic data management, SQL, and statistical analysis, are well-represented, with many professionals holding backgrounds in computer science, engineering, or mathematics. Data analysts and data scientists generally have strong proficiency in data manipulation and statistical modeling, which is reflected in the relatively high levels of skill in these areas. However, proficiency is more moderate in machine learning, data engineering, and cloud-based big data platforms. While interest in these specialized skills is growing, more training and practical experience are needed, especially as organizations begin to implement large-scale data solutions.

In terms of data governance and regulatory knowledge, professionals in sectors like finance and telecommunications show moderate proficiency due to the high regulatory standards in these industries. Awareness of data privacy requirements under GDPR is widespread, but deeper expertise in complex regulatory compliance and data quality frameworks is still limited. On the soft skills front, many professionals possess strong analytical and problem-solving capabilities, which are emphasized in Greek STEM education. However, experience in cross-functional communication and collaboration remains a challenge for some, especially when it comes to translating data insights into actionable strategies for non-technical teams.

While Greece has a solid foundation in foundational big data skills, there is a clear gap in more specialized competencies needed for advanced data engineering and analytics roles. Core skills in data analysis, SQL, and basic programming for data manipulation are well-covered, but there is a shortage of highly skilled data engineers with experience in large-scale data frameworks (such as Hadoop and Spark) and cloud-native solutions. Machine learning expertise is also lacking, with few professionals experienced in deploying ML models or building predictive analytics solutions at scale.

Demand for data governance expertise is growing, especially in highly regulated industries like finance and healthcare, but there are few professionals with comprehensive knowledge of data quality management and regulatory compliance. While analytical skills are generally strong, many professionals lack experience in effectively communicating data insights to non-technical audiences, a crucial skill in data-driven decision-making.

Comparison of required skills and available skills; comparison of skill profiles and labour market demands

Comparison of Skill Profiles and Labor Market Demands Industry demand in Greece is increasingly outpacing academic output in specialized big data skills. Although Greek universities are producing graduates with solid data science fundamentals, few programs offer advanced, hands-on training in data engineering or cloud-based big data solutions, leading to a skills gap in roles like data engineering, data architecture, and machine learning engineering. The shortage is particularly pronounced in data governance positions that require knowledge of GDPR compliance, data quality assurance, and risk management. This gap has become more apparent as organizations prioritize structured data management and regulatory compliance.

3.3.3 Summary & recommendations

Prioritized list of skill gaps requiring immediate attention

To address the skills, gap in Big Data, it is essential to promote advanced big data training in universities and technical institutes, focusing on data engineering, machine learning, and cloud computing. For instance, Ireland's "Skills for Big Data" program has successfully implemented training in data engineering, machine learning, and analytics through partnerships with industry leaders, producing job-ready graduates. Greece could adopt similar industry-university programs, with local companies providing students hands-on data projects to align their skills with market demands. Upskilling through certifications in big data platforms like Hadoop, Spark, and cloud services (AWS, Azure, Google Cloud) would support professionals transitioning into specialized roles. In the United States, the University of California, Berkeley, offers a certification in Data Science that includes big data platforms and cloud infrastructure, a model that could inspire Greek institutions. Continuous professional development in data governance and compliance is particularly crucial in fields like finance and healthcare. In Sweden, the Data Governance Institute provides regular training for data professionals in regulatory compliance and GDPR, an approach that could address Greece's needs for data governance expertise.

Other recommendations

Developing a workforce skilled in both fundamental data science and advanced big data competencies will allow Greece's Big Data ecosystem to meet the demand for data-driven insights, promoting growth across multiple sectors. A literature review by Gandomi and Haider (2015)[7] supports the importance of comprehensive training in big data analytics and data governance to maximize organizational performance and data security.

3.3.4 References & resources

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outlines the skills needed for blockchain applications and highlights challenges in training, which is relevant for understanding Greece's blockchain ecosystem.

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3.4 Blockchain

3.4.1 Identified roles, jobs, skills & competency profiles

The Greek blockchain ecosystem is strongly related with sectors such as finance, logistics, and energy, as well as with startups focusing on blockchain innovation. Organizations are exploring blockchain's potential for enhancing security, transparency, and efficiency in transactions and data management. The main employers in Greek Blockchain ecosystem entail:

- **Financial Institutions (e.g., National Bank of Greece, Alpha Bank)** Major Greek banks are exploring blockchain for secure transactions, digital identity verification, and cross-border payments. They are also investing in research to understand blockchain's role in decentralized finance (DeFi).
- **Blockchain Startups (e.g., Cryptense, Orvium)** Greece is home to several innovative blockchain startups, such as Cryptense, which focuses on blockchain solutions for financial markets, and Orvium, which leverages blockchain in scientific publishing and data sharing. These startups are at the forefront of applying blockchain in unique and disruptive ways.
- **Consulting and Technology Firms (e.g., Deloitte Greece, PwC Greece, Accenture)**
  Global consulting firms with Greek offices provide blockchain advisory services to local businesses, focusing on implementing blockchain in supply chain management, traceability, and data security. These firms often help clients navigate blockchain's regulatory aspects.
- **Research Institutions and Universities** (e.g., National Centre for Scientific Research "Demokritos," National Technical University of Athens) Research institutions and universities are engaged in blockchain research, focusing on its application in cybersecurity, data integrity, and IoT. They also contribute to policy discussions and regulatory frameworks in collaboration with European Union bodies.
- **Energy Sector Companies (e.g., Public Power Corporation - PPC)** Companies in the energy sector, like PPC, are investigating blockchain applications in energy trading, smart contracts, and renewable energy certificates, aiming for transparency and efficiency in energy distribution.

Professionals in blockchain typically have a multidisciplinary skill set that combines software development, cryptography, and knowledge of blockchain platforms. Common roles include blockchain developers, smart contract developers, blockchain analysts, and blockchain consultants. They are proficient in programming languages like Solidity, JavaScript, Python, and understanding of blockchain platforms such as Ethereum, Hyperledger, and Corda. They have also knowledge of cryptographic protocols, distributed ledger technology (DLT), and decentralized applications (dApps) is also crucial. The majority of professionals hold one or more degrees in the following areas:

- Computer Science & Software Engineering
  Most blockchain professionals hold degrees in computer science, software engineering, or information technology. This provides a strong foundation in programming, algorithms, and cryptography essential for blockchain development.
- Mathematics and Cryptography
  Backgrounds in mathematics, especially cryptography, are common among professionals working on the security and cryptographic aspects of blockchain. This expertise is vital for developing secure and efficient blockchain protocols.
- Business and Finance
  Since blockchain is widely used in finance, some professionals have degrees in business, finance, or economics, particularly those working as blockchain analysts, consultants, or advisors. They often possess specialized knowledge in decentralized finance (DeFi) and blockchain's role in financial systems.
- Postgraduate Degrees and Certifications
  Advanced degrees such as a Master's in computer science or blockchain technology, as well as specialized certifications in blockchain development, are common, especially for those in blockchain-specific roles. Certifications from platforms like Ethereum, Hyperledger, or Corda are also valued for technical roles.

3.4.2 Skill Gap Analysis

Identification of critical skills & competency

Professionals in the Greek blockchain ecosystem require a mix of technical, regulatory, and soft skills to effectively implement and manage blockchain solutions. Core technical skills include proficiency in blockchain platforms such as Ethereum, Hyperledger, and Corda, along with programming languages commonly used in blockchain development, such as Solidity, JavaScript, and Python. Knowledge of cryptography is essential, as it forms the backbone of blockchain security. This includes an understanding of cryptographic protocols, encryption techniques, and public and private key management. Additionally, expertise in smart contracts—self-executing agreements on the blockchain—is increasingly critical as blockchain applications extend beyond finance into sectors like supply chain and real estate.

Another essential area of expertise is data privacy and regulatory knowledge, particularly with respect to GDPR and data protection standards. As Greece operates within the EU regulatory environment, professionals must be knowledgeable about data privacy requirements and how blockchain can meet or adapt to these regulations. Familiarity with distributed ledger technology (DLT) and decentralized applications (dApps) is also valuable as they support the implementation of blockchain across diverse industries. Complementary to technical skills are soft skills like problem-solving, communication, and adaptability, as blockchain professionals often work in fast-evolving environments and must explain complex technologies to non-technical stakeholders.

Analysis of skill proficiency levels in the workforce;

In Greece, blockchain-related proficiency levels vary, with a solid foundation in software development and basic blockchain principles but limited expertise in advanced areas. Core technical skills, such as programming (Python, JavaScript) and software development, are generally strong among professionals with backgrounds in computer science and software engineering. However, more specialized blockchain skills, including proficiency in smart contract development and cryptographic protocols, are still emerging as blockchain remains a niche field in Greece. Most blockchain developers have moderate proficiency with Ethereum and Solidity, though fewer are experienced with enterprise-grade platforms like Hyperledger, which are essential for applications in regulated industries.

Knowledge of data privacy and regulatory compliance is moderate, as professionals in the finance and telecom sectors tend to have a solid understanding of GDPR and other data protection laws. Yet, many lack detailed knowledge of how these regulations intersect with blockchain's decentralized nature, which can present challenges in regulatory compliance. Soft skills, such as problem-solving and adaptability, are generally strong, as many blockchain professionals come from engineering or technical backgrounds. However, communication skills, especially the ability to convey blockchain's value and complexity to non-technical stakeholders, could benefit from further development.

While the Greek workforce is well-prepared in foundational programming and software development, there is a clear gap in specialized blockchain skills needed for more complex applications. Core programming skills and familiarity with blockchain basics are widely available; however, a shortage of advanced expertise in smart contract development, cryptography, and blockchain architecture remains. As industries like finance and energy increasingly seek blockchain applications, the need for professionals with a deep understanding of distributed ledger technology (DLT) and cryptographic security protocols becomes more urgent.

There is also a significant gap in data privacy and regulatory knowledge specific to blockchain. Although GDPR awareness is common, few professionals have the expertise required to navigate the unique compliance challenges posed by blockchain's immutable and decentralized nature. Consequently, regulatory and compliance roles are challenging to fill, especially for projects that require adherence to strict data protection laws. Soft skills such as communication and collaboration, though generally present, could be further strengthened to bridge the gap between technical teams and business stakeholders.

Comparison of required skills and available skills; comparison of skill profiles and labour market demands

Comparison of Skill Profiles and Labor Market Demands The demand for blockchain talent in Greece is outpacing the supply of skilled professionals, particularly in specialized roles. While Greek universities and training programs produce graduates with strong software development skills, few provide focused blockchain education that covers smart contract programming, DLT, and cryptography in depth. As a result, positions for blockchain developers, architects, and consultants with expertise in these advanced areas are often challenging to fill. Additionally, the need for blockchain-focused compliance officers and data privacy experts is growing, driven by the regulatory complexities of blockchain in industries like finance and logistics. The shortage of professionals experienced in both blockchain technology and regulatory compliance creates a notable gap in the Greek labor market, especially as more organizations look to integrate blockchain solutions within a framework that complies with EU regulations. Industry-specific roles, such as blockchain consultants in finance or logistics, are also in high demand, as companies seek guidance on how blockchain can enhance transparency and efficiency while maintaining compliance. However, few professionals in Greece currently possess the interdisciplinary skills required for these roles, leading to a reliance on upskilling and specialized training to bridge this gap.

3.4.3 Summary & recommendations

Prioritized list of skill gaps requiring immediate attention

To bridge the skills gap in blockchain, universities and training institutions in Greece could introduce comprehensive blockchain curricula, covering advanced platforms, cryptography, and regulatory compliance. For instance, the University of Nicosia in Cyprus offers a Master's in Digital Currency and Blockchain Technology, which could serve as a model, as it combines technical, financial, and regulatory training. Singapore has also established blockchain academies that provide in-depth training on smart contract development and blockchain security, which Greece could adapt. Short courses and certifications in smart contracts and blockchain security, like those offered by the Blockchain Training Alliance in the US, can enable Greek professionals to advance or transition into this field.

Other recommendations

Regular training in data privacy, GDPR compliance, and blockchain-specific regulations will help professionals meet EU standards. In Switzerland, the Crypto Valley Association offers continuous blockchain regulatory training, which strengthens regulatory compliance within the industry. By fostering a workforce with a blend of technical and regulatory skills, Greece's blockchain ecosystem can better meet labor demands, supporting growth across multiple sectors as outlined by Tapscott and Tapscott (2016)[8] in *Blockchain Revolution*.

3.4.4 References & resources

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3.5 ICT for Sustainability

3.5.1 Identified roles, jobs, skills & competency profiles

Who is hiring: current & potential employers

The Information and Communication Technology (ICT) for sustainability ecosystem in Greece is a dynamic field where technology is leveraged to address environmental challenges and promote sustainable practices across industries. The focus spans energy efficiency, waste management, smart city solutions, and sustainable agriculture. Greek organizations, often supported by EU-funded initiatives, are increasingly adopting ICT solutions to promote sustainable development, reduce carbon emissions, and optimize resource management. The main employers in this domain include:

- **Public Power Corporation (PPC)** PPC, Greece's largest power utility, is a major player in ICT for sustainability. The company uses ICT to modernize energy distribution, improve grid efficiency, and integrate renewable energy sources. They also invest in smart grid and smart metering technologies to support energy conservation.
- **Telecommunications Companies (e.g., COSMOTE, Vodafone Greece).** These companies incorporate sustainability into their operations, focusing on reducing energy consumption through IoT and ICT solutions. They offer smart city services, including traffic management and air quality monitoring, aimed at reducing urban environmental impact.
- **Research Institutions** (e.g., National Centre for Scientific Research "Demokritos," Centre for Renewable Energy Sources and Saving – CRES. Research institutions play a crucial role in R&D for ICT solutions in energy efficiency, environmental monitoring, and renewable energy. CRES, for instance, focuses on sustainable energy and energy conservation, often collaborating with universities and companies on EU-funded projects.
- **Technology and Software Development Firms (e.g., Intrasoft International, Uni Systems).** Greek technology firms provide ICT solutions tailored for sustainability across sectors like energy, logistics, and agriculture. They focus on developing software for resource optimization, data analytics, and environmental monitoring, helping organizations meet sustainability goals.
- **Municipalities and Local Government.** Many municipalities, such as Athens and Thessaloniki, are investing in ICT for sustainable urban development. These projects include smart city initiatives like smart lighting, waste management, and public transportation systems, aimed at reducing energy consumption and pollution in urban areas.
- **Agriculture and Agritech Startups (e.g., Augmenta, Centaur Analytics).** In agritech, startups like Augmenta and Centaur Analytics use ICT for precision farming, leveraging sensors, IoT, and data analytics to reduce water usage, pesticide application, and overall resource consumption in farming.

List of specific roles = professionals working with the respective ATI Career opportunities / jobs/ working positions

Professionals in ICT for sustainability often come from multidisciplinary backgrounds, combining technical expertise with knowledge of environmental issues and sustainable practices. Common roles include sustainability analysts, IoT engineers, data scientists, environmental consultants, and software developers focused on sustainability solutions.

Profile/description/competency profile and skills list for the most common jobs/roles for the respective ATI

They are usually proficient in programming (Python, R, SQL), data analysis, and experience with IoT and cloud platforms (AWS, Azure). Knowledge of environmental policies, energy management, and climate change science is valuable, as is familiarity with data visualization tools for sustainability reporting.

Common degrees of professionals in the respective ATI

The professionals usually hold one or more degrees in the following domains:

- **Environmental Science & Engineering** Many professionals have backgrounds in environmental science or engineering, which provides a solid understanding of ecological systems, sustainability practices, and the environmental impact of technology.
- **Computer Science & Data Science** A background in computer science or data science is common, especially for those developing software, data analytics, or IoT solutions to support sustainability goals. This expertise is crucial for handling large datasets and creating software to monitor and optimize resource usage.
- **Electrical and Mechanical Engineering** Electrical and mechanical engineers play a significant role in the design and implementation of sustainable technology, focusing on areas like energy efficiency, smart grid technology, and IoT-enabled environmental sensors.
- **Sustainability Management and Environmental Policy** For professionals focused on the strategic aspects of sustainability, degrees in sustainability management, environmental policy, or renewable energy are common. These fields offer a blend of policy, management, and technical knowledge to drive sustainable initiatives.
- **Postgraduate Degrees and Certifications.** Advanced degrees such as a Master's in sustainable development, environmental engineering, or data analytics are common for those in strategic or technical roles.

Certifications in green building, energy management, and sustainability are also valued in the field.

3.5.2 Skill Gap Analysis

Identification of critical skills & competency

The ICT for sustainability sector requires a combination of technical, analytical, and regulatory skills, as well as essential soft skills to manage interdisciplinary projects. Core technical skills include **data analytics and environmental monitoring**, where professionals need proficiency in data collection, analysis, and interpretation. Knowledge of tools such as

GIS (Geographic Information Systems) and data visualization platforms (e.g., Tableau, Power BI) is crucial for mapping and analyzing environmental data. Familiarity with **IoT and sensor technologies** is also essential, as these tools are widely used for real-time monitoring of energy use, air quality, and resource consumption in smart city and industrial settings.

Data management and regulatory knowledge are equally important. Professionals must have a strong understanding of **data privacy regulations** such as GDPR, as sustainability projects often involve extensive data collection, especially in public spaces. Knowledge of **environmental policies and sustainability frameworks** is also critical, particularly in areas like energy management, carbon reduction, and compliance with EU environmental standards. Additionally, professionals must be proficient in **project management** and **cross-functional collaboration**, as sustainability initiatives require input from diverse stakeholders, including engineers, policymakers, environmental scientists, and local authorities.

Analysis of skill proficiency levels in the workforce;

In Greece, workforce proficiency in ICT for sustainability is developing, with strengths in some foundational technical skills but limited expertise in more specialized sustainability knowledge. Many Greek professionals in computer science and engineering possess strong **data analysis and programming skills**, particularly in languages like Python, SQL, and R. Proficiency in data visualization tools and GIS technology is moderate to high among professionals working in energy, environmental science, and urban development sectors. However, expertise in emerging technologies like IoT for environmental monitoring is limited, as few professionals have experience with large-scale IoT deployments or real-time data processing for sustainability applications.

Knowledge of environmental policies and sustainability frameworks varies. Professionals in the energy and environmental science sectors tend to have a good understanding of EU environmental regulations and sustainability practices. However, fewer professionals in the tech and data sectors are familiar with these policies, which can create challenges in integrating ICT solutions within sustainability frameworks. In terms of soft skills, Greek professionals generally have strong analytical and problem-solving abilities, though interdisciplinary communication and project management skills could benefit from further development, given the collaborative nature of sustainability projects.

While Greece has a solid foundation in data analytics and technical programming skills, there is a skills gap in the specialized competencies required for ICT-driven sustainability initiatives. Core skills in data analysis, visualization, and basic GIS applications are widely available, yet expertise in advanced IoT technologies for environmental monitoring and sustainable resource management is less common. The demand for professionals skilled in IoT deployment, real-time data processing, and predictive analytics for energy and environmental management is growing, but the availability of professionals with hands-on experience in these areas is limited.

There is also a noticeable gap in sustainability-specific regulatory knowledge among ICT professionals. While many are aware of general data protection regulations like GDPR, few have comprehensive expertise in environmental policies, energy management standards, or carbon reduction frameworks. Consequently, roles that require both ICT and environmental policy expertise, such as sustainability analysts or green technology consultants, are more difficult to fill. Soft skills like project management and communication are also in demand, as these skills are critical for coordinating sustainability projects that involve multiple departments and stakeholders.

Comparison of required skills and available skills; comparison of skill profiles and labour market demands

Comparison of Skill Profiles and Labor Market Demands Industry demand for ICT for sustainability talent in Greece is beginning to outpace the current supply of specialized professionals, particularly in sectors like energy, agriculture, and urban development, where sustainable practices are increasingly prioritized. Greek universities and technical institutes offer programs in data science, engineering, and environmental studies, but few provide interdisciplinary training that combines ICT skills with environmental science and policy. As a result, roles for sustainability-focused data scientists, IoT engineers, and sustainability project managers are increasingly challenging to fill, especially for projects in smart cities and energy-efficient urban infrastructure. The shortage of professionals experienced in both ICT and sustainability-specific regulatory compliance also presents challenges, as more organizations strive to meet EU standards for environmental protection and carbon reduction. Demand is particularly high for roles that require knowledge of both ICT and environmental sustainability, such as environmental data analysts and green technology consultants, but few professionals in Greece currently have the interdisciplinary skills required for these positions. This gap has led to a reliance on upskilling and specialized training to meet industry needs.

3.5.3 Summary & recommendations

Prioritized list of skill gaps requiring immediate attention

To address the skills gap in ICT for sustainability, Greek universities could offer interdisciplinary programs combining ICT, environmental science, and sustainability policy. Sweden’s KTH Royal Institute of Technology offers a Master’s in Sustainable Technology that integrates ICT with environmental science and policy, which Greece could adopt as a model. In addition, short courses on green technology, smart city solutions, and carbon accounting could support upskilling. The Netherlands, through the Amsterdam Smart City initiative, provides practical training on sustainable urban planning and green technology, promoting continuous professional development in sustainability.

Other recommendations

Collaborating with industry would also enhance Greece’s ICT for sustainability talent pool, providing exposure to real-world projects. In Australia, the Green Skills Hub links students and professionals to environmental sustainability projects, giving them practical experience that reflects market needs. By cultivating a workforce equipped with technical and regulatory skills, Greece’s ICT for sustainability sector can support organizations aiming to reduce environmental impact, as argued by Holdren et al. (2010)[9] in the importance of ICT for environmental efficiency.

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3.6 Industry 5.0

3.6.1 Identified roles, jobs, skills & competency profiles

Who is hiring: current & potential employers

In Greece, Industry 5.0 is an emerging area of focus, where technology integrates with human-centric, sustainable, and resilient practices to enhance the manufacturing and industrial sectors. Industry 5.0 in Greece emphasizes human-machine collaboration, sustainability, and innovative use of data and automation. This ecosystem is primarily supported by large manufacturing companies, technology firms, and research institutions working to modernize and future-proof industrial processes. The main employers in this domain include:

- **Manufacturing Companies (e.g., Titan Cement, Hellenic Petroleum, ElvalHalcor)** Major Greek manufacturers in industries like cement (Titan), energy (Hellenic Petroleum), and metal processing (ElvalHalcor) are exploring Industry 5.0 technologies to improve production efficiency and sustainability. These companies employ automation, robotics, and IoT to enhance operational efficiency and reduce environmental impact.
- **Telecommunications and Technology Firms (e.g., COSMOTE, Vodafone Greece, Intracom Telecom)** Telecom providers play a key role by supplying the 5G infrastructure required for real-time data sharing and machine-to-machine communication in Industry 5.0. Intracom Telecom, for example, provides solutions for industrial IoT and data analytics, helping industrial sectors implement automation and enhance productivity.
- **Research Institutions (e.g., National Centre for Scientific Research "Demokritos," National Technical University of Athens)** Research institutions are crucial for advancing Industry 5.0 R&D in Greece, focusing on robotics, artificial intelligence, and machine learning applications for the industrial sector. Collaborating with European research networks, these institutions often develop pilot projects and work with manufacturers to integrate cutting-edge technologies.
- **Industrial Automation and Robotics Firms (e.g., DeltaTech)** Companies like DeltaTech specialize in robotics and automation solutions for industrial settings. They help manufacturers integrate human-centric robotics and automation into their production lines, emphasizing Industry 5.0 principles of collaboration between humans and machines.
- **Government and Public-Private Initiatives** Several public-private initiatives in Greece aim to support Industry 5.0 through funding and policy support. These programs, often in collaboration with the European Union, fund research and development in smart manufacturing, digital transformation, and sustainable practices.

List of specific roles = professionals working with the respective ATI Career opportunities / jobs/ working positions

Industry 5.0 professionals work in roles like robotics engineers, IoT specialists, data scientists, human-machine interaction designers, and industrial engineers

Profile/description/competency profile and skills list for the most common jobs/roles for the respective ATI

They have expertise in advanced technology and focus on integrating human-centric approaches to improve productivity and sustainability. They are usually proficient in robotics, machine learning, and IoT, alongside programming languages (Python, C++, Java). Expertise in industrial automation platforms, human-machine interfaces (HMI), and digital twins is also essential. Familiarity with augmented reality (AR), virtual reality (VR), and 5G technology is beneficial for roles that require advanced human-machine collaboration.

Common degrees of professionals in the respective ATI

The professionals usually hold one or more degrees in the following domains:

- **Electrical and Mechanical Engineering** A background in electrical or mechanical engineering is common among professionals in Industry 5.0. These fields cover essential topics like automation, robotics, and control systems, which are key to developing smart factories and automated processes.
- **Computer Science & Artificial Intelligence** Computer science and AI expertise are valuable for roles involving data analytics, machine learning, and robotics. Professionals with this background often develop algorithms for predictive maintenance, quality control, and optimization of production processes.
- **Industrial Engineering and Automation** Industrial engineers bring expertise in optimizing production processes, enhancing workflow efficiency, and managing resources. With additional training in robotics or IoT, these professionals are essential in designing systems that meet Industry 5.0's goals of efficiency and human-centered design.
- **Human-Computer Interaction (HCI) and Cognitive Science** As Industry 5.0 emphasizes collaboration between humans and machines, some professionals have backgrounds in HCI or cognitive science, focusing on designing intuitive interfaces and enhancing human-machine interaction for better productivity and safety.
- **Postgraduate Degrees and Certifications** Advanced degrees in robotics, AI, or industrial engineering are common for leadership roles or specialized positions. Certifications in IoT, cybersecurity, and machine learning are also valued, especially as Industry 5.0 integrates these technologies to create secure and efficient industrial environments.

3.6.2 Skill Gap Analysis

Identification of critical skills & competency

Industry 5.0 demands a unique blend of **technical, human-centric, and regulatory skills**. Core technical competencies include **automation, robotics, and AI**, where professionals are expected to have experience with robotics integration, control systems, and machine learning models to enhance production efficiency and safety. Proficiency in **programming languages** like Python, C++, and Java, as well as familiarity with automation tools and industrial software (e.g., SCADA, PLC programming), is essential for developing and maintaining smart manufacturing systems. Knowledge of **IoT and cyber-physical systems** is also critical, as these technologies enable real-time data exchange and machine-to-machine communication, foundational to Industry 5.0's interconnected and adaptive environment.

Human-centric skills, such as **human-machine interaction (HMI)** and **ergonomic design**, are increasingly important, as Industry 5.0 emphasizes collaboration between humans and machines. Professionals need expertise in designing interfaces that make it easier for human workers to interact with machines and access insights generated by AI and IoT. Regulatory knowledge, particularly in areas like **data privacy, safety standards, and environmental regulations**, is crucial for ensuring that Industry 5.0 practices comply with EU standards, especially as industries adopt more digital and automated systems. Additionally, **project management** and **cross-functional collaboration** skills are vital, as Industry 5.0 projects often involve interdisciplinary teams working to align technology, sustainability, and operational goals.

Analysis of skill proficiency levels in the workforce;

In Greece, workforce proficiency in Industry 5.0-related skills is developing, with strong foundational technical skills but limited experience in advanced and human-centric competencies. Many Greek professionals, especially those with backgrounds in electrical, mechanical, or computer engineering, have solid programming and automation skills. Proficiency in robotics and basic AI applications is moderate, with a growing number of engineers and technicians familiar with automation tools, PLC programming, and robotics control systems. However, specialized skills in areas like AI for predictive maintenance or IoT for real-time monitoring are less widespread, reflecting the early stages of Industry 5.0 adoption in Greece.

Human-centric design and HMI expertise are less common, as few programs in Greece currently emphasize the collaborative aspects of Industry 5.0. This skill gap limits the workforce's ability to design systems that facilitate seamless human-machine interaction, an essential component of Industry 5.0. Regulatory and compliance knowledge is moderate, especially within regulated sectors like manufacturing and energy, where awareness of safety standards and environmental compliance is more prevalent. However, fewer professionals possess detailed knowledge of data privacy standards related to interconnected industrial systems, which is increasingly important in digitally transformed industrial environments. Soft skills, such as project management and interdisciplinary collaboration, are generally strong but could be further developed to meet the collaborative requirements of Industry 5.0.

While Greece has a solid foundation in programming, automation, and basic robotics skills, there is a significant gap in advanced competencies required for fully realizing Industry 5.0. Foundational technical skills like PLC programming, basic robotics, and data analysis are well-represented in the workforce. However, there is a shortage of professionals with expertise in advanced AI applications, IoT integration, and real-time data processing, which are crucial for implementing adaptive, data-driven systems. Similarly, there is limited availability of human-centric design skills and expertise in human-machine interaction, which are essential for creating ergonomic and efficient Industry 5.0 workplaces.

The demand for regulatory knowledge is also growing, particularly in data privacy and safety compliance, but relatively few professionals have in-depth expertise in these areas as they relate to advanced manufacturing systems. This skills gap is most noticeable in roles that require a combination of technical and regulatory knowledge, such as Industry 5.0 compliance officers and industrial data protection specialists. Soft skills in project management and cross-functional collaboration are essential for Industry 5.0 but are not always sufficiently developed, especially for professionals transitioning from more traditional industrial roles.

Comparison of required skills and available skills; comparison of skill profiles and labour market demands

Comparison of Skill Profiles and Labor Market Demands Industry demand for Industry 5.0 skills in Greece is rapidly increasing, particularly in sectors like manufacturing, logistics, and energy, where companies are seeking to modernize processes and adopt sustainable practices. However, there is a clear gap between the demand for interdisciplinary Industry 5.0 skills and the supply of qualified professionals. While Greek universities and technical institutes produce graduates with strong engineering and data science backgrounds, few programs offer training in specialized areas such as IoT for industrial applications, AI for predictive maintenance, or human-machine interaction design. As a result, roles like industrial data scientists, IoT engineers, and Industry 5.0 project managers are difficult to fill, particularly as more organizations strive to align with EU sustainability and digital transformation goals. The shortage of professionals with both technical and regulatory expertise in Industry 5.0 is particularly challenging for companies aiming to implement automated systems within a framework that complies with EU safety and privacy regulations. Demand is especially high for interdisciplinary roles, such as smart manufacturing consultants and sustainability analysts for Industry 5.0, where a combination of engineering, data analysis, and regulatory knowledge is required. However, few professionals in Greece currently possess this mix of skills, leading to a reliance on upskilling and additional

3.6.3 Summary & recommendations

Prioritized list of skill gaps requiring immediate attention

To build skills in Industry 5.0, Greek universities could introduce programs on IoT, AI for industrial automation, and human-machine interaction. For example, Denmark's University of Southern Denmark offers an Industry 4.0 program with hands-on training in smart manufacturing. The curriculum could be adapted to Industry 5.0, adding a human-centric design component, similar to Japan's Smart Society 5.0 initiative, which integrates robotics and IoT with a focus on human interaction and safety.

Other recommendations

Short courses in predictive maintenance, regulatory compliance, and sustainable industrial practices are also beneficial for continuous upskilling. France's Industry of the Future

Alliance promotes similar training, preparing professionals for digitized manufacturing roles. Collaboration between Greek industries and academia, like Germany's Fraunhofer-Gesellschaft's applied research model, would also strengthen the talent pool. A skilled workforce in both technical and human-centric Industry 5.0 elements would enhance competitiveness in Greek manufacturing, aligning with findings by Rüßmann et al. (2015)[10] on Industry 4.0's transformative potential.

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3.7 Internet of Things

3.7.1 Identified roles, jobs, skills & competency profiles

Who is hiring: current & potential employers

The Internet of Things (IoT) ecosystem in Greece is steadily expanding, driven by sectors such as telecommunications, energy, agriculture, and urban development. Greek organizations are increasingly adopting IoT solutions for smart city projects, industrial automation, and energy efficiency, supported by partnerships with global tech firms and research institutions. The main employers in Greek IoT ecosystem entail the following groups of companies

- **Telecommunications Companies (e.g., COSMOTE, Vodafone Greece)**
  Telecom giants like COSMOTE and Vodafone Greece are significant players in the IoT domain, focusing on network infrastructure and IoT platforms. They provide connectivity solutions for IoT applications in areas like smart cities, agriculture, and logistics, leveraging 5G technology for higher data transfer speeds.
- **Energy and Utility Companies (e.g., Public Power Corporation - PPC, Hellenic Petroleum)**
  Energy companies are integrating IoT into their operations for energy management, smart metering, and grid optimization. PPC, for instance, employs IoT solutions to monitor and improve energy distribution, reduce waste, and support renewable energy initiatives.
- **Technology and Software Development Firms (e.g., Intrasoft International, Uni Systems)**
  Greek technology firms provide custom IoT solutions for both local and international clients, focusing on system integration, software development, and data analytics for IoT applications. They work across industries, including manufacturing, transportation, and healthcare.
- **Research Institutions and Universities (e.g., National Centre for Scientific Research “Demokritos,” National Technical University of Athens)**
  Research institutions and universities in Greece are actively involved in IoT R&D, working on projects related to smart cities, connected devices, and industrial IoT (IIoT). They collaborate with the public and private sectors, often funded by the EU, to advance IoT technology and explore innovative applications.
- **Agriculture and Agritech Startups (e.g., Augmenta, Centaur Analytics)**
  IoT is crucial in the agritech sector in Greece, with startups like Augmenta and Centaur Analytics leading in precision agriculture and crop monitoring. These companies leverage IoT sensors and analytics to optimize crop yields, reduce waste, and enable sustainable farming practices.

List of specific roles = professionals working with the respective ATI Career opportunities / jobs/ working positions

Professionals in IoT often come from engineering, computer science, or data analytics backgrounds, with expertise in areas such as embedded systems, IoT platforms, and data Professionals in IoT often come from engineering, computer science, or data analytics backgrounds, with expertise in areas such as embedded systems, IoT platforms, and data analysis. Common roles include IoT engineers, data scientists, embedded systems developers, IoT architects, and IoT project managers

Profile/description/competency profile and skills list for the most common jobs/roles for the respective ATI

They are proficient in programming languages like Python, C/C++, and Java, and experience with IoT platforms such as AWS IoT, Azure IoT, and Google Cloud IoT. Knowledge of networking, embedded systems, sensor technologies, and data analysis is also critical.

Common degrees of professionals in the respective ATI

The majority of professionals hold one or more degrees in the following areas:

- **Electrical and Computer Engineering**
  Many IoT professionals hold degrees in electrical and computer engineering, as these fields cover essential topics such as embedded systems, wireless communication, and circuit design.

- **Computer Science & Software Engineering**
  A computer science or software engineering background is also common, especially among IoT software developers and data analysts. This background provides the programming and data processing skills needed for IoT software and platform development.

- **Mechanical Engineering**
  Mechanical engineers play a key role in IoT for industrial applications, focusing on areas like automation, robotics, and sensor integration, especially in fields like manufacturing and industrial IoT (IIoT).

- **Physics and Data Science**
  Some professionals have backgrounds in physics or data science, especially those focusing on IoT data analytics and sensor technology. These fields offer the analytical and problem-solving skills needed to interpret and manage IoT data.

- **Postgraduate Degrees and Certifications**
  Advanced degrees such as a Master’s in IoT, embedded systems, or automation are valuable for professionals in technical or research-oriented roles. Certifications in IoT platforms and protocols are also valued for roles involving IoT architecture or systems integration.

3.7.2 Skill Gap Analysis

Identification of critical skills & competency

The IoT domain requires a combination of technical, data management, and regulatory skills, along with soft skills essential for cross-functional teamwork. Core technical skills include **embedded systems and IoT platform management**, where professionals need experience in designing, deploying, and maintaining IoT devices and systems. Proficiency in **programming languages** such as Python, C/C++, and Java is crucial, along with familiarity with popular IoT platforms like AWS IoT, Azure IoT, and Google Cloud IoT. Knowledge of **networking protocols** (e.g., MQTT, CoAP, Zigbee) and wireless communication (e.g., 5G, LoRaWAN) is also essential for IoT connectivity and device management.

Data analytics and management competencies are highly sought after, as IoT generates vast amounts of data that need to be processed, analyzed, and interpreted. This includes skills in **data analysis, machine learning, and data visualization**, often using tools like Power BI, Tableau, and machine learning libraries in Python or R. Knowledge of **data governance and security** is also critical, as IoT devices often collect sensitive data. With GDPR and other data privacy regulations in effect, professionals must understand data protection requirements and how to secure IoT systems against cyber threats.

Soft skills, such as **problem-solving, adaptability, and communication**, are equally vital in IoT, as projects often require collaboration across hardware and software teams. Professionals need to translate complex technical concepts for cross-functional teams, especially as IoT deployments involve stakeholders from various parts of an organization.

Analysis of skill proficiency levels in the workforce;

In Greece, the workforce shows a moderate to high proficiency level in basic technical skills but faces limitations in more specialized IoT knowledge. Many Greek professionals with backgrounds in electrical engineering, computer science, and data science possess solid programming skills, especially in Python and Java, which are widely applicable in IoT. Proficiency in basic networking and embedded systems is also relatively strong among engineers, given the technical focus of Greek universities and technical institutes. However, more advanced IoT-specific skills—such as familiarity with IoT platforms, advanced networking protocols, and device connectivity—are less widespread, limiting the ability to deploy large-scale or highly specialized IoT solutions.

Data analytics skills are generally strong, especially in terms of basic data analysis, visualization, and handling structured datasets. Yet, expertise in real-time data processing and machine learning for IoT-generated data is less common. Professionals are typically proficient in handling batch data, but fewer have experience with continuous data streams or large-scale, unstructured IoT data.

In terms of regulatory and data governance skills, many professionals are familiar with GDPR due to the EU regulatory environment. However, specific knowledge of how GDPR applies to IoT and secure data management in IoT environments is limited. Soft skills, particularly in cross-functional collaboration, tend to be moderately strong, though the ability to communicate technical concepts to non-technical stakeholders could benefit from improvement, given the interdisciplinary nature of IoT projects.

While the Greek workforce has a solid foundation in fundamental IoT skills, there are clear gaps in specialized competencies needed to support complex IoT implementations. For example, while programming and basic networking skills are widely available, fewer professionals have hands-on experience with IoT platforms like AWS IoT or Azure IoT. Similarly, proficiency in advanced networking protocols specific to IoT, such as LoRaWAN or NB-IoT, is limited, creating a shortage of professionals capable of deploying IoT systems in industrial or rural settings.

Data analytics skills are strong at a foundational level, but there is a noticeable gap in real-time data processing, machine learning, and analytics specific to IoT applications. As IoT-generated data often requires instant analysis for applications like predictive maintenance and anomaly detection, the demand for these skills is high, yet the availability of experienced professionals is limited. Knowledge of data security and governance is increasingly important, but many professionals lack detailed expertise in securing IoT devices and ensuring compliance with privacy regulations.

Comparison of required skills and available skills; comparison of skill profiles and labour market demands

Comparison of Skill Profiles and Labor Market Demands Industry demand for IoT talent in Greece is beginning to exceed the current supply of specialized professionals, particularly as IoT applications expand across various sectors. Greek universities and technical institutions produce graduates with strong backgrounds in software development and data science, but few offer dedicated IoT programs that cover the full range of skills, from embedded systems to IoT data management. As a result, roles for IoT engineers, embedded systems developers, and IoT data analysts are increasingly challenging to fill, especially in sectors like agriculture and energy, where IoT deployment is rising. The shortage of professionals experienced in both IoT technology and regulatory compliance poses challenges for companies aiming to maintain GDPR compliance while managing IoT devices and data. Demand is particularly high for IoT architects and engineers capable of integrating IoT platforms with legacy systems, as well as data governance specialists who understand the nuances of IoT data privacy and security. Additionally, there is a growing need for professionals with expertise in industrial IoT (IIoT), as companies look to automate and optimize production processes in manufacturing and energy.

3.7.3 Summary & recommendations

Prioritized list of skill gaps requiring immediate attention

To bridge the IoT skills gap, universities and training institutes in Greece should consider IoT-specific curricula that cover embedded systems, IoT platforms, and data security for IoT applications. For instance, Germany's RWTH Aachen University offers a Master's in Embedded Systems, preparing students for real-world IoT applications. Israel has also launched national IoT programs that integrate industry collaborations, enabling students to gain hands-on experience in IoT platforms, data processing, and industrial automation.

Other recommendations

Short courses in IoT platform management, advanced networking, and IoT security, similar to those offered by India's National Institute of Electronics and Information Technology, can facilitate continuous upskilling. Collaboration between industry and academia is essential, as seen in Finland's IoT Alliance, where companies partner with universities to create programs reflecting market needs. By developing both foundational and advanced IoT skills, Greece can support IoT-driven growth in smart cities, industrial automation, and resource management. As described by Vermesan et al. (2011)[11], IoT solutions can significantly benefit from a workforce that combines technical and regulatory expertise to meet diverse market needs.

3.7.4 References & resources

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3.8 Quantum Computing

3.8.1 Identified roles, jobs, skills & competency profiles

Who is hiring: current & potential employers

The quantum technology ecosystem in Greece is an emerging field, primarily driven by research institutions and universities, with a focus on quantum computing, cryptography, and quantum communication. While quantum technology is still in its nascent stages in Greece, it has strong support from European Union funding and collaborations with international research networks. The main employers in this domain include:

- **National Centre for Scientific Research "Demokritos"** "Demokritos" is a leading research center in Greece actively engaged in quantum research, focusing on quantum computing, quantum cryptography, and quantum communication. They collaborate with European and international institutions to conduct advanced quantum experiments and develop theoretical frameworks.
- **Universities (e.g., National and Kapodistrian University of Athens, Aristotle University of Thessaloniki)** Major Greek universities, including the National and Kapodistrian University of Athens and the Aristotle University of Thessaloniki, have research departments focusing on quantum mechanics, quantum information, and quantum computing. These universities provide research programs and host conferences to promote the development of quantum technology.
- **Institute of Nuclear and Particle Physics (INPP)** Part of the National Centre for Scientific Research "Demokritos," INPP specializes in theoretical and experimental physics, including studies in quantum mechanics and quantum field theory. Researchers at INPP work on quantum simulations and computational applications.
- **European Union and Public-Private Partnerships** The EU is a significant funder of quantum research in Greece, supporting projects in quantum technology through initiatives like the Quantum Flagship program. These funds support public-private collaborations, R&D, and international partnerships focused on advancing Greece's quantum research capabilities.
- **Telecommunications and Technology Firms (e.g., COSMOTE, Vodafone Greece)**
  While telecom companies in Greece are not direct players in quantum research, they collaborate on projects related to quantum cryptography and secure communications. These companies often work with universities and research centers to explore future applications in quantum communication networks.

List of specific roles = professionals working with the respective ATI Career opportunities / jobs/ working positions

Professionals in quantum technology are primarily researchers, quantum physicists, cryptographers, and computational scientists.

Profile/description/competency profile and skills list for the most common jobs/roles for the respective ATI

They are typically specialized in the theoretical and experimental aspects of quantum mechanics and work on developing quantum algorithms, cryptographic protocols, and quantum communication methods. They have strong background in quantum mechanics, linear algebra, and advanced mathematics. Proficiency in programming languages such as Python, MATLAB, and Qiskit (IBM's quantum programming platform) is essential for developing quantum algorithms and conducting simulations. Additionally, they are familiar with high-performance computing, machine learning, and cryptographic protocols is beneficial, especially for those working on quantum cryptography.

Common degrees of professionals in the respective ATI

The professionals usually hold one or more degrees in the following domains:

- **Physics and Quantum Mechanics**
  Most quantum professionals in Greece hold advanced degrees in physics, particularly quantum mechanics or theoretical physics. This background provides the essential mathematical and conceptual foundation needed to work in quantum technology.
- **Computer Science and Computational Physics**
  Some professionals come from computer science or computational physics backgrounds, especially those involved in quantum algorithm development or quantum cryptography. This expertise is essential for implementing quantum simulations and programming on quantum platforms.
- **Mathematics and Applied Mathematics**
  A strong foundation in mathematics, particularly in linear algebra, probability theory, and complex numbers, is valuable in quantum technology. Professionals in quantum cryptography often have backgrounds in applied mathematics, focusing on cryptographic methods and security.
- **Electrical Engineering and Information Theory**
  Those working on quantum communication and cryptographic protocols may come from electrical engineering or information theory backgrounds, which provide knowledge of signal processing, secure communication, and network security.
- **Postgraduate Degrees and Certifications**
  Professionals in the quantum field typically hold a Master's or PhD in physics, computer science, or mathematics, with specializations in quantum mechanics, quantum computing, or cryptography. Many also attend international conferences and courses on quantum technology to stay current with advancements in this rapidly evolving field.

3.8.2 Skill Gap Analysis

Identification of critical skills & competency

Quantum computing requires a unique blend of **theoretical knowledge, computational skills, and cryptographic expertise**. Core competencies include a strong foundation in **quantum mechanics and quantum theory**, essential for understanding qubit behavior, quantum entanglement, and superposition principles. Professionals must also have experience in **mathematics, particularly linear algebra, probability theory, and complex numbers**, which underpin quantum algorithms and computations. Quantum software development is a growing area of expertise, with proficiency in quantum programming languages such as Qiskit (IBM), Cirq (Google), and Q# (Microsoft) necessary for building and testing quantum algorithms.

Advanced **cryptography and cybersecurity** knowledge is another critical skill, especially given the impact quantum computing may have on data security through quantum cryptography and encryption-breaking potential. Additionally, experience in **high-performance computing (HPC)** and parallel processing is beneficial, as quantum computing often intersects with traditional supercomputing for complex simulations. **Problem-solving, research skills, and interdisciplinary collaboration** are essential soft skills, as quantum computing requires close collaboration between physicists, mathematicians, and computer scientists to translate theoretical models into practical applications.

Analysis of skill proficiency levels in the workforce;

In Greece, the workforce shows relatively high proficiency in foundational skills like mathematics, physics, and basic computational science, as these subjects are strongly emphasized in Greek universities. Many professionals in academia and research institutions possess a deep understanding of **quantum mechanics and theoretical physics**, which is fundamental for quantum computing. Greek universities produce skilled graduates in physics, mathematics, and engineering, providing a solid base in linear algebra, complex numbers, and other core mathematical areas necessary for quantum computing. However, practical experience in **quantum programming and algorithm development** is limited, as few Greek institutions offer hands-on training with quantum programming languages or simulators.

Cryptography expertise in Greece is moderate, with several professionals in cybersecurity and cryptography aware of quantum threats to encryption. However, the skill level in **quantum cryptography** specifically is limited, as this is a niche area requiring specialized knowledge in quantum protocols and quantum key distribution (QKD). Proficiency in high-performance computing and parallel processing exists but is largely concentrated in research institutions like the National Centre for Scientific Research “Demokritos” and universities, where researchers use HPC resources for scientific simulations. Soft skills such as problem-solving and interdisciplinary collaboration are generally strong, especially among researchers accustomed to working in collaborative, cross-functional projects.

While Greece has a solid foundation in theoretical physics and mathematics, there is a clear gap in specialized skills necessary for practical quantum computing applications.

Foundational knowledge in quantum mechanics and mathematical principles is widely available; however, there is a shortage of professionals with hands-on experience in **quantum programming, quantum algorithm design, and quantum simulations**. The need for quantum software developers and researchers familiar with platforms like Qiskit or Cirq is growing, yet very few professionals in Greece have practical experience with these tools due to limited exposure and training opportunities. In terms of cryptography, Greece has professionals skilled in classical cryptography, but few have the expertise needed to develop and manage quantum-resistant encryption protocols. This is particularly crucial as demand for quantum cryptography solutions grows, driven by the potential for quantum computers to disrupt current encryption standards. Additionally, there is a scarcity of professionals with knowledge of **quantum error correction and fault tolerance**, both essential for maintaining the reliability of quantum computations, especially in sectors requiring high accuracy and security.

Comparison of required skills and available skills; comparison of skill profiles and labour market demands

Comparison of Skill Profiles and Labor Market Demands Industry demand for quantum computing talent in Greece is beginning to increase, especially in research, cybersecurity, and sectors interested in leveraging quantum computing's computational advantages for complex problem-solving. However, there is a considerable gap between the demand for specialized quantum skills and the current supply of qualified professionals. Greek universities and research institutions produce graduates with strong backgrounds in theoretical physics and mathematics, but few programs offer hands-on training in quantum software development, quantum algorithms, or quantum-specific cryptography. Roles such as quantum software developers, quantum algorithm researchers, and quantum cryptographers are increasingly challenging to fill, particularly as Greek organizations aim to participate in EU-led quantum research projects or contribute to the development of quantum-resistant cryptographic standards. Demand is especially high for interdisciplinary roles that require a blend of physics, cryptography, and computer science expertise, yet the current workforce lacks professionals with this combination of skills, creating a reliance on upskilling and specialized training.

3.8.3 Summary & recommendations

Prioritized list of skill gaps requiring immediate attention

To bridge the skills gap in quantum computing, Greek universities and research institutions could introduce dedicated programs on quantum programming, algorithm design, and quantum cryptography. Canada's University of Waterloo offers a specialized quantum computing program and collaborates with industry partners like IBM to provide hands-on quantum computing experience. Greece could replicate such partnerships with global quantum technology firms, enabling access to simulators and cloud-based processors.

Other recommendations

Short courses in quantum programming, quantum cryptography, and high-performance computing would support continuous professional development, especially for those transitioning from fields like physics and cryptography. Singapore's Centre for Quantum Technologies offers professional courses in quantum cryptography and high-performance computing that Greece could use as a model. By building a workforce skilled in both theoretical and practical aspects of quantum computing, Greece can contribute to the EU's quantum research landscape, as outlined by Montanaro (2016)[12], supporting secure, high-performance solutions across sectors.

These recommendations provide a structured pathway for Greece to enhance its talent pool across diverse technology sectors, strengthening the country's ability to innovate and align with global standards in emerging technologies.

3.8.4 References & resources

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WP4 Enhancing Labour Market-Relevant Skills in Advanced Technologies

T4.1 Identifying skill gaps in Advanced Technologies

LITHUANIA national report from the desk research

Date: September 2024 – January 2025

Prepared by: Lithuania, KCCI

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4 LITHUANIA National report from the desk research

4.1 Introduction & methodology

Literature Review. A comprehensive review of existing literature, including academic articles, industry reports, and government publications, was conducted to gather insights on the current state of ATI's in Lithuania. This included exploring the latest trends, challenges, and opportunities facing the workforce in this domain. Key sources included reports from organizations like the Lithuanian Government, research institutes, and relevant EU publications.

Data Collection. Data on the number of professionals currently working in ATI's roles were gathered from various industry reports and job market analyses.

Job Market Analysis. An analysis included keywords related ATI's compliance, and interdisciplinary expertise, helping to quantify the gap between available talent and market needs.

4.2 Artificial Intelligence and Ethics

4.2.1 Identified roles, jobs, skills & competency profiles

Who is hiring: Current & potential employers in Lithuania

The AI sector in Lithuania is poised for growth, supported by a collaborative environment among private companies, government bodies, and academic institutions. This multi-faceted approach not only emphasizes technological advancement but also prioritizes ethical considerations in AI deployment. As companies navigate these emerging technologies, the importance of ethical frameworks will be crucial in shaping a responsible AI ecosystem in Lithuania.

The landscape for employment in Artificial Intelligence (AI) and Ethics in Lithuania is rapidly evolving, with various sectors embracing AI technologies while emphasizing ethical considerations.

- **Information and Communication Technology (ICT) sector.** The ICT sector in Lithuania is robust, with a strong emphasis on artificial intelligence and big data. Companies like Vinted and Civitta are notable employers in this sector, focusing on data-driven solutions and digital services that integrate ethical considerations into their AI applications.
- **Healthcare.** The healthcare sector is leveraging AI for various applications, including diagnostics and patient management. Ethical considerations are paramount here, especially concerning data privacy and bias in AI algorithms used in medical settings.

- **Public Sector.** The Lithuanian government is actively developing ethical guidelines for AI through initiatives like the creation of an AI ethics committee. This indicates a significant demand for ethical AI specialists within governmental bodies to ensure transparency and fairness in public services and policies.
- **Finance and Fintech**. The financial services sector is rapidly adopting AI technologies for risk assessment, fraud detection, and customer service. Ethical AI is critical in this field to avoid discrimination and ensure compliance with regulations.
- **Education and Research Institutions.** Universities and research institutions in Lithuania are focusing on developing AI curricula and conducting ethical research in AI. This sector presents opportunities for ethical AI specialists to contribute to educational programs and guide research initiatives.
- **Manufacturing and Industry**. The manufacturing sector is increasingly integrating AI for automation and efficiency improvements. Ethical considerations around labour displacement and automation ethics are areas where specialists can play a role.

List of Specific Roles in AI & Ethics in Lithuania

According to the analyses made, AI and ethics professionals in Lithuania play crucial roles in ensuring that artificial intelligence technologies are developed and applied in a responsible and ethical manner. Their specific functions align with national strategies and EU guidelines, addressing the need for transparency, accountability, and fairness in AI deployment.

AI professionals in Lithuania primarily include data scientists, machine learning engineers, and data engineers. These roles are crucial for developing AI systems that enhance productivity and innovation. They analyse data to inform AI models and ensure that the data used is free from bias and adheres to ethical standards. As industries increasingly adopt AI, the demand for these specialists has risen significantly.

AI Ethics Officers are tasked with ensuring that AI systems are developed and implemented in accordance with ethical guidelines. These professionals focus on ensuring that AI systems are designed and implemented responsibly. Their role involves developing ethical guidelines, conducting impact assessments, and advocating for transparency and fairness in AI processes. They assess AI technologies for biases, privacy issues and compliance with regulations such as the General Data Protection Regulation (GDPR).

AI researchers investigate the ethical implications of AI technologies and contribute to academic discussions about responsible AI practices. They also develop new methodologies to assess ethical risks in AI systems, conduct research on the ethical implications of AI technologies, contributing to the creation of best practices and innovative solutions that prioritize ethical considerations.

Policy Advisors and Regulators advise government bodies on the ethical implications of AI deployment, helping to formulate regulations that govern AI technology. This includes establishing ethical committees that assess the impact of AI on fundamental rights and societal norms.

Profile/Description/Competency Profile and Skills List for the Most Common Jobs/Roles

In Lithuania, the roles and skills required for AI and ethics professionals are evolving alongside the country's commitment to developing responsible AI systems. Both technical and soft skills are essential for these specialists, who play a critical role in shaping ethical AI practices within various sectors.

Technical skill domain	Description of technical skill	Correlation with AI & Ethics
Data Science and Machine Learning	Allows to understand algorithms, statistical analysis, and data management.	Enable to evaluate AI systems critically and ensure their function as intended.
Programming Languages	The capacity to implement and test AI solutions.	Understanding software development processes helps in assessing the ethical implications of AI technologies.
Ethics in Technology	The ability to understand ethical theories and applying them to real-world AI applications, ensuring systems are designed and used responsibly.	Ensures that technological advancements in AI are aligned with ethical standards, promoting trust and accountability in the technology's application.
Knowledge of Regulatory Frameworks	The ability to navigate legal and ethical standards that govern AI deployment	Allows to navigate legal complexities, advocate for ethical practices, and influence policy development, ultimately fostering a responsible and trustworthy AI ecosystem.

Soft skill domain	Description of soft skill	Correlation with AI & Ethics
Interdisciplinary Collaboration	The ability to work effectively across various fields, collaborating with engineers, legal experts, and policymakers.	Allows to navigate the complexities of AI technologies effectively by informing about policy, mitigates risks, and fosters innovation.
Critical thinking and problem solving	The capacity to analyze complex scenarios, anticipate potential ethical dilemmas, and devise practical solutions.	This skill allows professionals to navigate the intricacies of AI applications.
Communication skills	The ability to convey technical information and ethical considerations to non-experts.	Empower AI and ethics specialists to effectively bridge the gap between technical complexity and ethical discourse.

Soft skill domain	Description of soft skill	Correlation with AI & Ethics
Adaptability and continuous learning	Staying informed about new developments, frameworks, and ethical discussions.	Empower AI and ethics specialists to remain relevant and effective in their roles by address the complex and evolving ethical challenges posed by AI technologies.

Common Degrees of Professionals in AI & Ethics in Lithuania

After the analyses made it can be assumed that in Lithuania, the educational pathways for professionals specializing in Artificial Intelligence (AI) and ethics encompass various degrees, including bachelor's, master's, and PhDs. These programs are increasingly relevant due to the growing demand for skilled workers in technology and ethical oversight as AI continues to develop rapidly.

Educational program	Degree	Correlation with AI & Ethics
Science in Artificial Intelligence Systems	Bachelor's degrees	Foundation in machine learning, data analysis, and system development. The curriculum covers essential skills for addressing challenges in image recognition and natural language processing.
Computer Science, Data Science, AI	Bachelor's degrees	Emphasizes practical applications and theoretical knowledge essential for creating AI solutions
Data Science and Artificial Intelligence	Master's degrees	These programs are designed to cultivate a generation of AI specialists who understand the social implications of technology, promoting a responsible approach to AI development.
Artificial Intelligence Systems	Master's degrees	Delves into AI systems, including embedded systems and real-time decision-making technologies. Graduates can pursue careers in project management, electronic systems analysis, and further academic research.

For those pursuing academic or high-level research careers, PhD programs in AI often combine technical training with a focus on ethics. These programs enable candidates to explore the societal impacts of AI technologies and contribute to academic discourse around ethical AI development.

4.2.2 Skill Gap Analysis

Identification of Critical Skills & Competencies

Lithuanian professionals in AI generally possess strong technical skills, particularly in programming, data analysis, and machine learning. Universities like Vilnius University and Kaunas University of Technology have robust programs that prepare students in these areas, making them competitive in the job market.

Lithuania is noted for its dynamic tech start-up ecosystem, which fosters innovation in AI applications. The Lithuanian Artificial Intelligence Association highlights the active involvement of various stakeholders in developing AI solutions that address local and international challenges

Lithuania is noted for its dynamic tech start-up ecosystem, which fosters innovation in AI applications. The Lithuanian Artificial Intelligence Association highlights the active involvement of various stakeholders in developing AI solutions that address local and international challenges.

However, a notable weakness lies in the insufficient emphasis on ethics within the technical training programs. Many professionals have strong technical backgrounds but lack comprehensive training in AI ethics, which is crucial for responsible AI deployment.

There is also a significant deficiency in soft skills such as communication, teamwork, and problem-solving. These skills are essential for effectively collaborating across disciplines and for conveying complex ethical issues related to AI.

Because of the lack of continuous learning and upskilling skills many professionals are keeping pace with the latest developments in both AI technology and ethical frameworks, leading to potential gaps in knowledge and application.

In summary, the strengths of AI and ethics professionals in Lithuania lie in the area of technical skills, but there is still an obvious lack of soft skills. This requires greater attention in both academic programs and professional development to ensure the comprehensive training of professionals that meets the changing demands of the labor market.

Analysis of Skill Proficiency Levels in the Workforce.

In Lithuania, the demand for professionals skilled in Artificial Intelligence (AI) and ethics is growing, but there are notable gaps between the skills required for jobs in these fields and those currently possessed by the workforce.

After the analyses it can be summed up that the there is a need for both technical and soft skills of AI & Ethics specialists in the market. From the point of technical skills, the highest market demand is related with the need of data science and machine learning, programming skills. Also, skills related with ethics in AI, digital skills and jobs platform skills. A lack of regulatory knowledge skills, which a crucial for understanding both national and EU regulations related to data protection and AI deployment is also felt.

The demand for soft skills is related with the critical thinking and the ability to evaluate complex problems and derive sound solutions, particularly in ethical dilemmas. Also, the communication skills which allows effectively articulate technical and ethical considerations to diverse audiences, including policymakers and the public. Interdisciplinary collaboration also appears on the list of required skills as the companies are often engaged with professionals from various fields by ensuring comprehensive approaches to AI ethics.

It can be pointed out that the skills which employees in Lithuania in the field of AI & Ethics currently have been mostly related with such technical skills as digital literacy. Lithuania ranks high in digital skills, placing 2nd among 63 countries in the IMD World Competitiveness Yearbook 2022[13]. The workforce is generally proficient in using digital tools, which is foundational for AI roles. Programming skills are also mentioned as the most common skills as employees frequently have proficiency in programming languages such as Python and R, essential for developing AI solutions. However, deeper expertise in algorithm optimization and software engineering is often lacking.

Many AI positions require specialized knowledge in advanced algorithms and machine learning, which is often not covered in traditional curricula. This creates a gap where graduates may have basic programming skills but lack advanced capabilities in AI applications. Also, there is a critical understanding about the need for professionals who can navigate ethical frameworks associated with AI. The current workforce often lacks training in ethical analysis specific to AI, which is essential as companies and institutions strive to implement responsible AI solutions. Soft skills deficiency is obvious when technical skills are emphasized in educational programs, soft skills such as critical thinking and communication are often underdeveloped. This deficiency makes it challenging for specialists to effectively engage with interdisciplinary teams and communicate ethical implications.

In summary, while Lithuania has a promising foundation of technical skills in its workforce, significant gaps remain in advanced AI capabilities and ethical training. Addressing these mismatches through enhanced educational programs and professional development initiatives will be essential for equipping AI & Ethics specialists to meet the growing demands of the field.

Comparison of Required Skills and Available Skills

According to the data provided in the sources, currently Lithuania faces a significant gap between the demand for AI & Ethics professionals and the supply of those with the necessary skills. This mismatch is most apparent in technical expertise, advanced AI ethics specialization, and cross-disciplinary roles that blend ethical, legal, and technical skills.

Regarding the availability of AI & ethics professionals, Lithuania has approximately 300-500 active professionals working in AI-related fields, but only a small subset of them specializes in AI ethics. Data scientists and machine learning engineers make up the bulk of AI professionals, yet these fields still have a skills gap, particularly in more advanced areas like AI explainability, fairness, and bias mitigation.

In terms of job openings, the demand for AI professionals, particularly those with ethical knowledge, is outpacing supply. There has been a sharp increase in job postings for roles like AI Ethics Officer, AI Risk Management Specialist, and AI Compliance Manager. According to several reports, demand for AI talent has risen by 40-50% year-on-year in

[13] https://www.imd.org/uupload/IMD.Wcc/PDFSource/LT.pdf

Lithuania, with particular emphasis on ethical AI implementation in sectors like finance, healthcare, and public administration. While AI engineers and data scientists are relatively more available, there is a 40-50% skills gap in roles requiring expertise in AI ethics, governance, and interdisciplinary AI advisory. Skills like critical thinking, cross-disciplinary communication, and regulatory knowledge remain weak across the board, contributing to a shortage of talent in AI ethics roles.

In summary, while Lithuania has a growing base of AI professionals, the need for more specialized AI ethics experts is not being met. The largest gap is in roles requiring the integration of technical AI skills with ethical and legal frameworks, which are crucial for implementing responsible AI systems.

Comparison of Skill Profiles and Labor Market Demands

Analyses has shown that in Lithuania, the demand for professionals with skills in AI and ethics is growing as the country aims to bolster its AI ecosystem and meet both technical and ethical challenges associated with the technology. As AI evolves, new roles and skills will be critical to ensure both the responsible development and deployment of AI systems.

The future roles.

AI ethics officers will be crucial in ensuring the development of AI systems that align with ethical standards. As Lithuania works on creating a legal and ethical framework for AI, roles related to overseeing ethical AI practices, including fairness, transparency, and bias mitigation, are expected to grow in importance. With the growing integration of AI into business and government processes, AI strategists who understand both technical aspects and how AI can be aligned with business goals will be essential. This role also involves understanding the social and ethical implications of AI in decision-making. AI Advisors for Policymakers will also take an important position as AI impacts various sectors, advisors who can help policymakers navigate AI-related regulations and ethical considerations will become increasingly important. These advisors will need a blend of AI technical skills and an understanding of law and public policy.

In summary, as AI technology continues to evolve in Lithuania, professionals will need to develop a broader skill set that combines technical expertise with strong ethical frameworks. Currently, many AI professionals in Lithuania possess strong technical skills in data science and programming. However, there is a notable gap in ethical training and interdisciplinary knowledge, which is critical for roles that combine AI expertise with ethical considerations. As the field evolves, upskilling in AI ethics and acquiring soft skills like critical thinking and communication will be vital.

Prioritized list of skill gaps requiring immediate attention

- Technical skills
  - **AI Ethics & Laws knowledge.** Very crucial and lacking especially knowledge in regulations and cybersecurity.
  - **Advanced AI & Machine Learning Skills.** Many professionals know basic AI but lack deep expertise in complex AI models. Need better skills in improving AI efficiency and explaining how AI makes decisions.

- Soft Skills
  - **Communication.** Many AI experts struggle to explain technical ideas to non-technical people.
  - Poor problem-solving and teamwork skills make it hard to work with different professionals.
  - **Ongoing Learning & Improvement.** Professionals are not keeping up with the fast-changing AI industry.

4.2.3 Summary & recommendations

In summary, Lithuania's workforce in Artificial Intelligence and Ethics is at a pivotal point. The country has a solid foundation in technical skills, particularly in data science and software development. However, there is a critical gap in specialized roles focused on ethical AI practices, which is increasingly important as AI technologies evolve. Current professionals are primarily trained in technical areas, with a noticeable shortage of skills related to ethical reasoning, interdisciplinary collaboration, and AI policy advisory roles. The demand for AI and Ethics specialists is growing rapidly, driven by the need for organizations to navigate complex ethical landscapes and ensure compliance with emerging regulations. Universities and vocational institutions should develop and offer specialized programs focusing on AI ethics, including courses that combine technical skills with ethical and legal training. Collaborative initiatives with tech companies can help ensure that curricula meet industry needs. Organizations should invest in upskilling current employees by providing training in ethical AI practices, critical thinking, and cross-disciplinary knowledge.

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4.3 Big Data

4.3.1 Identified roles, jobs, skills & competency profiles

Who is hiring: Current & potential employers in Lithuania

In Lithuania, various sectors are emerging as potential employers for big data specialists, reflecting the increasing importance of data-driven decision-making across industries.

Information and Communication Technology (ICT) sector remains the largest employer for big data specialists, driven by the growth of tech companies and startups focusing on AI, data analytics, and machine learning.

Finance and Insurance institutions leverage big data for risk assessment, fraud detection, and personalized services, leading to a significant demand for data analysts and data scientists.

Healthcare sector is increasingly using big data for patient management, predictive analytics, and operational efficiencies. This sector is witnessing a growing need for specialists who can analyse complex datasets to improve healthcare outcomes.

Retail and E-commerce companies utilize big data to enhance customer experience, optimize supply chains, and tailor marketing strategies. The demand for data analysts in this sector is robust as businesses strive to understand consumer behaviour.

Public Administration related with government agencies are adopting data analytics for policy-making and improving public services, resulting in a growing need for data professionals.

Manufacturing and Logistics companies in these sectors employ big data professionals to streamline operations, improve production efficiency, and manage supply chains effectively.

Education and Research sector and it’s academic institutions and research organizations are increasingly employing data analysis for educational assessments and research projects, creating opportunities for data scientists[14].

The landscape for big data employers in Lithuania is diverse, spanning various sectors from IT and finance to healthcare and public services. As the demand for data professionals continues to grow, these sectors are likely to expand their capabilities in data analytics and seek skilled employees who can turn data into actionable insights.

List of Specific Roles in Big Data in Lithuania

According to the analyses made, Lithuania’s growing tech sector and its focus on becoming a digital economy leader have spurred a significant demand for big data specialists. Major investments in Lithuania's digital infrastructure and its startup-friendly ecosystem are creating varied roles in big data across sectors. There can be emphasised the main key roles for big data specialists currently in demand in Lithuania.

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[14] https://www.oecdskillsforjobsdatabase.org/data/country_notes/Lithuania%20country%20note.pdf

Data engineers and their main focus on designing, building, and maintaining data pipelines and storage solutions. They ensure that data is accessible, scalable, and secure for use by data analysts and scientists. Lithuania's booming tech infrastructure has increased the need for skilled data engineers. They are highly sought by companies, which rely on robust data infrastructure to deliver digital services.

Data scientists, as a role, are tasked with collecting, analysing, and interpreting large datasets to help companies make data-driven decisions. Their work often involves building predictive models, optimizing processes, and contributing to business strategies. Data scientists are in high demand in Lithuania, especially within finance, e-commerce, and technology firms. Large banks and fintech companies are increasingly seeking data scientists to enhance decision-making processes and create personalized customer solutions.

Big data architects – they are responsible for designing and implementing scalable big data systems. They work on setting up data lakes, choosing appropriate big data technologies, and ensuring data systems meet both current and future business needs. Big data architects are in demand among large enterprises and startups focused on digital transformation. Companies in finance, telecommunications, and logistics are among those that hire data architects to manage growing data volumes.

Data privacy officer, as a role is essential in ensuring companies comply with data privacy regulations. They manage data protection policies, conduct audits, and train staff on data privacy best practices. With stringent EU regulations, demand for DPOs has grown significantly in Lithuania, particularly in finance and health sectors. Organizations handling sensitive information actively seek DPOs to manage compliance.

Despite the rising demand, Lithuania faces challenges in meeting the skills required for big data roles. According to the European Commission's Digital Economy and Society Index (DESI), Lithuania scores well in digital skills but still lacks enough advanced data specialists, particularly in roles demanding machine learning, cloud, and big data framework expertise.

Profile/Description/Competency Profile and Skills List for the Most Common Jobs/Roles

Lithuania's growing digital economy and the increasing adoption of big data analytics in finance, technology, and healthcare sectors have created high demand for skilled big data professionals. Companies are particularly interested in candidates with strong technical competencies, including data processing, analysis, and cloud computing skills, as well as essential soft skills to collaborate effectively across teams. This research reviews the most important technical and soft skills for big data roles in Lithuania, drawing insights from recent studies, industry reports, and employment trends.

Technical skill domain	Description of the skill	Correlation with Big Data
Cloud Computing	Enable to manage cloud-based data storage and processing skills in cloud platforms such as AWS, Microsoft Azure, and Google Cloud Platform	Important for data engineers and big data architects who need to design and manage data infrastructure.
Big Data Framework	Enable efficient processing of large datasets, making them indispensable in industries with high data volumes like telecommunications and finance.	Allows the distributed processing, storage, and analysis of massive datasets across clusters of computers.
Big Data and AI Proficiency	Refers to a combination of skills that enable professionals to manage and extract insights from massive datasets, using advanced analytics and machine learning techniques.	The ability to develop AI-driven solutions, particularly with a focus on automation and predictive analytics.

Soft skill domain	Description of soft skill	Correlation with Big Data
Problem-Solving and Critical Thinking	The ability to solve unexpected challenges, optimize processes, and implement efficient solutions.	Essential for building accurate models and algorithms.
Analytical Thinking	The capacity for identifying trends, deriving insights, and solving business problems.	Ability to interpret, process, and derive insights from complex datasets.
Communication and Data Storytelling	Translating complex data findings into actionable insights and engaging narratives for stakeholders, especially those without technical expertise.	Empower specialist to translate complex data findings into clear, actionable insights that non-technical stakeholders can understand.

These technical and soft skills are interdependent, with technical capabilities enabling efficient data handling and soft skills ensuring that insights are communicated effectively. For Lithuanian data professionals, blending these skills will enhance their ability to drive value from big data projects across sectors like finance, telecommunications, and public administration.

Common Degrees of Professionals in Bid Data in Lithuania

After the analyses made it can be assumed that in Lithuania, the educational pathways for professionals specializing Big Data and its analysis encompass various degrees, including bachelor's, master's, and PhDs. These programs are increasingly relevant due to the growing demand for skilled workers in data sectors.

Educational program	Degree	Correlation with Big Data
Computer Science; Statistics; Data Analysis	Bachelor's degrees	Covers data science fundamentals, programming, and database management, preparing students for entry-level roles in the data sector.
Data Science	Bachelor's degrees	Emphasizes data manipulation, statistical methods, and programming languages critical for data analysis.
Data Science	Master's degrees	Analytical roles across various industries through the Big Data Analysis and Natural Language Processing.
Data Science and Artificial Intelligence	Master's degrees	Crucial for roles such as data scientist or machine learning engineer, where technical proficiency and innovative thinking are paramount.
Mathematics; Informatics	Ph.D.	Allows to conduct advanced research on data-related topics. This path is important by aiming academic or high-level research positions in Big Data analytics or AI development, which contributes to the field through innovation and theoretical advancements[15].

It can be assumed that the educational landscape in Lithuania is well-structured to support the growth of big data professionals. The study program emphasizes the intersection of business big data and the enhancement of skills in mathematics and computer science. It focuses on creating mathematical models that assist in making informed business development decisions. Bachelor's programs provide essential skills for entry-level roles, while master's degrees deepen knowledge and prepare graduates for specialized roles in data science and AI. Ph.D. programs facilitate high-level research, driving innovation in big data applications. These degree programs not only provide technical knowledge but also integrate business acumen essential for analysing data effectively in organizational contexts. Understanding data-driven decision-making and the economic implications of data usage is crucial for professionals looking to leverage Big Data in business strategies.

4.3.2 Skill Gap Analysis

Identification of Critical Skills & Competencies

Strengths in Big Data Skills

According to the analyzed sources, the Information Technology sector is thriving, with a significant focus on data analytics and cloud operations. Many companies are expanding their IT capabilities, and about 37% of business service centers are looking to enhance their IT functions. This indicates a robust demand for technical skills related to Big Data analytics, including proficiency in programming languages such as Python and R, data visualization tools, and cloud computing platforms. With a notable percentage of Lithuanian businesses engaging in e-sales (39%), there is a growing need for skills related to data analytics to optimize customer interactions and improve sales strategies. The demand for data science roles mostly is seen in the IT and financial sectors. Lithuanian workforce also displays strong

[15] https://www.vu.lt/en/studies/master-studies/data-science

technical skills in programming and data analysis field. Many professionals are proficient in languages such as Python and R, which are essential for data manipulation and analysis[16].

However, the analyses have shown the skill gaps between the Big Data specialists. Although there is a push for education in data science and analytics, the demand for advanced skills in machine learning and artificial intelligence is outpacing the current supply of trained professionals. As companies seek to leverage these technologies, the need for highly skilled workers in these areas is becoming critical. What is more, despite strengths in technical skills, there is a notable gap in interdisciplinary skills that combine technical expertise with business and communication acumen. Professionals often lack the ability to effectively translate data insights into actionable business strategies, which is essential for driving organizational growth.

It can be pointed out that Lithuania's Big Data specialists have robust technical skills and are well-positioned to meet growing industry demands. However, again, the soft skills can be named as skill gaps, which should be start of being solved by the educational system.

Analysis of Skill Proficiency Levels in the Workforce.

Despite that particularly educational institutions are producing graduates in fields like Data Science and Computer Science by providing the knowledge of technical skills, the analysed sources have shown that there is a need for both technical and soft skills Big Data professionals in the market.

- Technical skills.

  According to the data, one of the most technical skills needed for the Big Data position is the programming. Programming skills enable professionals to efficiently handle and process data, automate repetitive tasks, and develop algorithms for predictive analysis, which are crucial in sectors such as finance, e-commerce, and telecommunications where Big Data applications are prominent.

  Data Visualization skills also can be named as a demanded technical skill as it provides the ability to design, implement, and maintain databases that can efficiently store and process large volumes of data. The employees need the professionals skilled in Data Visualisation because they present data insights clearly, supporting quicker and better-informed business decisions, also can communicate with non-technical team simplify complex data and making it easier for departments like marketing, sales, and management to understand data-driven recommendations.

  Database management skills are also required in the Big Data positions in Lithuania due to the role databases play in data-intensive tasks and decision-making processes. Skills in database management allow Big Data professionals to optimize systems for performance and scalability, ensuring databases can handle large datasets and support complex analytics tasks. This is crucial in Lithuania's rapidly growing tech and IT sectors, where scalability is a key demand as organizations expand their data capabilities. What is more, database management ensures handling massive volumes of structured and unstructured data which is also crucial for organizations and rises a need of these skills.

- Soft skills.
  Despite that technical skills in most of courses are indicated as needed skills, some of the soft skills also can be named as a needed skills in Big Data position.

  Critical thinking skill is needed because it enables professionals to analyse complex data, identify patterns, and make data-driven decisions, which are crucial skills in Lithuania's increasingly data-dependent industries. Lithuania's Big Data sector, like those globally, requires specialists to solve complex analytical problems, often under time constraints. Critical thinking allows these professionals to approach data-related challenges methodically, identify the root cause of issues, and develop innovative solutions, which is highly valued in areas such as financial risk analysis, e-commerce, and tech innovation.

  Business acumen is a critical soft skill for Big Data professionals in Lithuania because it allows them to align their technical expertise with strategic business goals, making their analyses more actionable and valuable. Strong business acumen can identify the specific data insights that are most relevant to business objectives, whether in sectors like finance, logistics, tourism, or e-commerce, which are increasingly data-reliant in Lithuania.

  It can be indicated that many entry-level and even mid-level employees have strong technical skills, but often lack of soft skills, which are more and more often indicated as desired in Lithuania.

Comparison of Required Skills and Available Skills

As the demand for Big Data specialists grows rapidly in Lithuania, the need for digital transformation and solution-based specialists in all industries is also growing analogously. However, despite the need, there is still a gap between the skills required in the market and the skills available in the workforce.

It can be indicated that there is a very specific need for Big Data special skills in the labor market. This is associated with specific data systems such as Python, JavaScript and Java, data tools such as React, Node.js and React Native. skills in systems architecture, DevOps, and big data engineering are expected to become critical due to their application in AI and advanced analytics across industries.

In terms of specific roles, companies in Lithuania are seeking data scientists, data analysts, and data engineers. It is mostly related with the need to be able to analyze and contextualize data, develop machine learning models, and create scalable data solutions. Furthermore, professionals skilled in data architecture, data visualization, and business intelligence are also in high demand. It is because these roles are essential for transforming raw data into actionable insights for business decision-making.

Currently, Lithuanian market faces a shortage of approximately 7,600 ICT specialists, including big data experts. The difference like this clearly shows the mismatch between available and required skills. Many Lithuanian companies indicate challenges in finding qualified professionals for roles such as systems architects and data scientists, as these roles are essential for handling large datasets and complex data infrastructures. Because of the mismatch there are recommendations such as incentives for skilled immigration and increased support for adult learning in ICT fields provided.

Comparison of Skill Profiles and Labor Market Demands

Following through the information related to the difference between the difference of the needed Big Data skills and the available in the market, it is difficult to provide an exact number of the following difference. The provided information mostly relies on the increasing demand of Big Data specialist and the current lack of the active specialist in the market.

However, despite of the lacking information, the tendency of the Big Data professionals is obvious. It can be mainly explained by the increasing number of FINTECH companies in Lithuania, which are directly related to the Big Data specific. According to the provided data, the potential of Big Data specialist in Lithuania is a long term, with a perspective of the increased demand of the specialist. However, the big market demand can be valued as a threat of making a disbalance in the labor market which is highly related with an insufficient number of properly prepared Big Data specialist. Such situation causes a pressure for the educational system in Lithuania, which should be not only fast in preparing Big Data specialist, bus also do it in a very professional way.

Many companies in Lithuania feel the need to hire not only local, but also foreign talent, since big data analytics requires a wide range of skills - from programming to statistical analysis and understanding of business processes. The current shortage of specialists means that companies can search for qualified employees for a long time, and in some cases consider attracting specialists from other countries

To sum up, although the number of potential Big Data specialists in Lithuania is limited, this field is attractive due to high salaries and career opportunities. The need for this specialty will only grow in the near future, and those who want to enter this field are advised to invest in the necessary programming, data analytics, and business analytics skills.

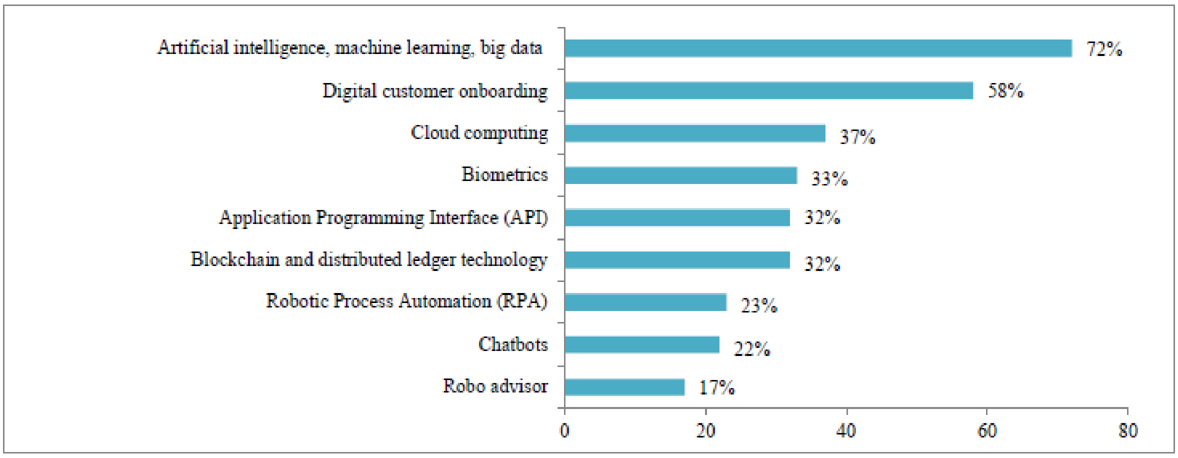

Figure 5 FINTECH companies' leading technologies in 2022-2025[17]

[17] https://finmin.lrv.lt/uploads/finmin/documents/files/2023-2028%20FINTECH%20strategy%20of%20Lithuania.pdf

Prioritized list of skill gaps requiring immediate attention

- Technical skills
  - **Advanced Data & AI Skills**. Shortage of experts in machine learning, data engineering, and AI-driven analytics.
  - **Programming**. Need for better expertise in Python, JavaScript, and Java for data science roles. Skills in React, Node.js, and big data platforms are in high demand but hard to find.
- Soft skills
  - Business and Communication Skills
  - Data Visualization & Decision making

4.3.3 Summary & recommendations

In Lithuania, the skills and competence gaps of big data specialists are driven by both technical and advanced analytical capabilities, especially because the demand exceeds the supply of skilled talent. It is emphasized by the unfilled labour market demand. It can be indicated that Lithuania is lacking highly specialized Big Data professionals, particularly in data engineering, systems architecture, and machine learning. These gaps are the consequence of the rapidly evolving technical requirements and the complexity of advanced data roles. To address the skill gaps for big data specialists in Lithuania, a multi-pronged approach targeting education, industry collaboration, and talent attraction is recommended. It should involve the partnership between the higher education and the industry by integrating advanced data-specific courses, including machine learning, data engineering, and systems architecture in the curriculum with the intention to prepare students for complex roles in big data. Also the current gap situation should be solved by ICT companies collaborating with the government by providing training programs for employees in Big Data roles.

4.3.4 References & resources

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4.4 Blockchain

4.4.1 Identified roles, jobs, skills & competency profiles

According to the analysed sources, blockchain specialist in Lithuania can find employment opportunities across several sectors, with the country positioning itself as a blockchain and fintech hub. Key sectors where blockchain expertise is in demand include:

- **Fintech and Financial Services**. Lithuania has a robust fintech ecosystem, driven by its favorable regulatory environment and the presence of several digital banking and cryptocurrency companies. The Blockchain Centre Vilnius serves as a hub for blockchain startups, connecting professionals with opportunities in blockchain-based payments, cryptocurrency exchanges, and smart contract development.
- **Global Banking / Finance**. Companies in the electronic money and payments space like Revolut and Paysera often seek blockchain expertise to strengthen their offerings
- **Technology and ICT**. The demand for blockchain specialists is growing within Lithuania's expanding ICT sector. Companies working on AI, big data, and digital infrastructure projects are seeking blockchain professionals. Invest Lithuania highlights that the sector is actively looking for back-end developers, data scientists, and systems engineers skilled in blockchain technology.
- **Public Sector and Government Initiatives**. Lithuania has shown a proactive stance in using blockchain for public services. The Centre of Registers and various government initiatives explore the use of blockchain for transparency, regulatory compliance, and identity verification systems. Blockchain professionals may engage in these projects, contributing to national efforts in digital governance.
- **Startups and Innovation Hubs**. Lithuania's startup ecosystem is vibrant, with blockchain startups receiving considerable support. Organizations like Startup Lithuania and Invest Lithuania foster innovation by providing resources and networking opportunities for blockchain-driven startups. This presents opportunities for blockchain developers, entrepreneurs, and consultants to work in innovative environments.
- **E-Commerce and Retail**. During the processing the payment companies facilitating cryptocurrency payments, such as CoinGate, are hiring specialists to help integrate blockchain technology into e-commerce platforms and retail solutions.
- **Research and Education**. Academic Institutions like Vilnius University are hiring blockchain researchers and educators to develop curricula and conduct research in blockchain applications and technology.
- **Logistics and Supply Chain**. Blockchain is being used in logistics for tracking goods, ensuring transparency, and improving efficiency in supply chains. Blockchain professionals can work on developing decentralized solutions for international trade and logistics management.

The demand for blockchain specialists in Lithuania is multi-faceted, with opportunities spanning financial services, technology, e-commerce, academia, and government. As the blockchain ecosystem matures and more organizations seek to leverage its capabilities, the hiring landscape is likely to expand further, creating diverse roles and opportunities for skilled professionals.

List of Specific Roles in blockchain in Lithuania

The analyses has emphasized that in Lithuania, blockchain professionals can find numerous career opportunities across different roles.

- **Blockchain Developer**. By designing and developing blockchain applications, smart contracts, and decentralized apps this role can be adapted not only in one specific sector. But as a multifunctional role it brings an opportunity of employment in different sectors, such as financial sector or various blockchain startups.
- **Blockchain Architect**. Develop blockchain architecture, including consensus protocols, node management, and the underlying infrastructure for blockchain solutions. The science, Innovation and Technology Agency can be named as a potential sector or employer. Here such skills as distributed systems, peer-to-peer networking, cryptography are the most demanded.
- **Blockchain Consultant.** In such role is required to provide consulting services to businesses and government organizations on blockchain strategy, implementation, and regulatory compliance. Consulting firms focusing on fintech or supply chain blockchain solutions are the main target of this position.
- **Cryptocurrency Compliance Officer**. Ensure that companies dealing with cryptocurrencies comply with anti-money laundering (AML) and know-your-customer (KYC) regulations. This position requires skills related with regulatory compliance, risk management, blockchain analysis tools.
- **Blockchain Data Analyst**. This role requires to analyse blockchain data to monitor network activity, transaction trends, and detect fraudulent behaviour.
- **Blockchain Project Manager**. In this position Manage blockchain-related projects from conception to execution, working with developers, stakeholders, and regulatory bodies. This position involves knowledge about other roles of blockchain, such as understanding of blockchain architecture, leadership, and communication.
- **Blockchain Security Engineer**. This role is important by focusing on securing blockchain applications and networks, conducting security audits, and developing security protocols. Here are the essential skills of Cybersecurity, penetration testing, cryptography.
- **Blockchain Researcher**. Here the main responsibility of the role is conduct research on new blockchain technologies, consensus algorithms, and use cases to inform product development or public sector innovations. This position requires such skills as research methodology, cryptography, programming, blockchain protocols.

These roles cater to professionals with different expertise levels, ranging from technical development to consulting and compliance.

Profile/Description/Competency Profile and Skills List for the Most Common Jobs/Roles

The most common roles in blockchain in Lithuania requires strong technical skills related with programming languages, as programming proficiency is the cornerstone of most blockchain roles, particularly for developers and architects, also smart contract development skills, such as writing efficient, secure smart contracts, which automate processes on blockchain platforms. Designing **cross-chain** interoperability solutions (important as more sectors require systems that connect different blockchain platforms) is an essential skill of blockchain architects. With the increasing regulation of cryptocurrencies and blockchain in the EU, as well as in Lithuania, roles like compliance officers and legal experts require in-depth knowledge of blockchain regulations, ensuring compliance with international standards for privacy and anti-fraud measures.

The most common roles in blockchain in Lithuania also requires soft skills related with problem-solving and analytical thinking skills, as blockchain roles, especially for developers and architects, require the ability to solve complex problems, such as optimizing transaction speeds or ensuring system scalability. Blockchain projects, especially those integrating into existing business systems, require careful project management skills to meet deadlines, budgets, and regulatory requirements.

Common Degrees of Professionals in blockchain in Lithuania

Blockchain professionals in Lithuania commonly hold degrees in fields that are integral to both the technical and business dimensions of blockchain technology. This is due to the interdisciplinary nature of blockchain, which spans areas like cryptography, distributed systems, and financial markets. Degrees in computer science, engineering, data science, finance, and business management are particularly prevalent, given their relevance to the practical applications of blockchain and its integration into existing systems. However, after the analysis made it can be indicated that there is still lack of the specific educational programmes for the preparation of highly skilled blockchain specialists. According to it blockchain specialist are a part of different IT related educational programmes:

Educational program	Degree	Correlation with blockchain
▪ Computer science; ▪ Software engineering, ▪ Information technology	Bachelor's degrees	These fields provide a foundational understanding of programming, databases, and cryptography—core aspects of blockchain technology. Courses includes specific modules or projects on blockchain technology.
▪ Economics; ▪ Business; ▪ Administration; ▪ Finance	Bachelor's degrees	These programs enable students to understand how blockchain can revolutionize traditional financial systems, facilitate decentralized finance (DeFi), and optimize business operations.
▪ Data science; ▪ Cryptography; ▪ Cybersecurity	Master's degrees	A master's degree allows for more specialized study, such as advanced cryptographic techniques, smart contract development, or blockchain scalability challenges, making professionals highly valuable in both public and private sectors.

Educational program	Degree	Correlation with blockchain
▪ Business Administration; ▪ Financial technology (FinTech)	Master's degrees	These programs equip individuals with the skills to manage blockchain projects, navigate legal and regulatory issues, and implement blockchain solutions within various industries, such as banking, logistics, and supply chains.

At the highest level, PhD degrees are pursued by individuals interested in academic research, innovation, or leading technical development in blockchain. PhD candidates in Lithuania often work in interdisciplinary fields, combining blockchain with other advanced technologies like quantum computing or artificial intelligence (AI). For example, the Blockchain and Quantum Technologies Group at Vilnius University includes PhD students researching cutting-edge blockchain applications alongside quantum computing and AI. These doctoral programs are crucial for pushing the boundaries of blockchain technology, particularly in areas like blockchain optimization, security protocols, and distributed ledger technologies.

PhD holders often lead research and development (R&D) efforts, consult for major blockchain firms, or contribute to academia through teaching and publication. Their advanced understanding of blockchain's technical infrastructure enables them to design innovative solutions, improve blockchain efficiency, and contribute to policy and regulatory frameworks that govern blockchain applications.

4.4.2 Skill Gap Analysis

Identification of Critical Skills & Competencies

In Lithuania, the state of skills of blockchain specialists is versatile with strong knowledge but meets technical challenges in business and regulatory areas.

Most blockchain specialists in Lithuania have a strong academic base, having obtained education in the fields of informatics, software engineering or cryptography. Lithuanian universities such as Vilnius University and Kaunas University of Technology offer courses and research programs focused on blockchain technologies, distributed systems and data security. This technical expertise gives professionals the ability to design and implement decentralized systems.

Due to the importance of security in blockchain-based systems, many professionals are well-trained in cryptography and security. This is one of the most important skills, because blockchain technologies rely on the safe and reliable management of data exchange in decentralized networks.

However, while technical skills are strong, many blockchain professionals lack business and regulatory experience. Applying blockchain technology in finance or other industries requires a deep understanding of business strategies, regulatory challenges and commercial applications, which is often lacking for those who specialize in technical areas only.

Despite efforts to increase the number of blockchain professionals, there is still a significant skills and talent shortage. There is a growing demand for professionals who are able to combine technical and business knowledge. Such specialists could better deal with issues of project management, strategic planning and the integration of blockchain technology into traditional systems.

Analysis of Skill Proficiency Levels in the Workforce.

According to the analysed data and comparing the skills required for working in blockchain positions with what employees currently have in Lithuania reveals certain areas and existing discrepancies. Blockchain technology requires a broad palette of regulatory technical skills that include technical, business and communication skills.

Technical skills. Blockchain positions require strong programming skills in languages such as Solidity, Python, JavaScript, and an understanding of cryptography, smart contracts, and distributed systems. Employers are also looking for specialists who can work with decentralized applications (DApps) and ensure system security. It can be assumed that blockchain specialists in Lithuania are especially strong in the fields of informatics and software engineering. However, while the technical foundations are solid, there is a growing need for deeper knowledge of the latest blockchain technologies, such as decentralized finance (DeFi) and Layer 2 solutions, which are not yet widely taught in academia.

Business and strategic skills. Blockchain professionals in Lithuania need an understanding of blockchain applications in business, project management, FinTech and business model development. Accordingly, employers value the ability to understand the application of technology in industry, product development and implementation strategies. Although technical skills are strong, most blockchain specialists in Lithuania have little business experience. Specialists often do not have in-depth knowledge of project management, blockchain commercialization and broader strategic application in a business environment. The biggest mismatch occurs between the integration of technology and business strategy. Many professionals can develop technologies, but lack the ability to implement them in practice and commercialize them in various industries.

Regulatory and compliance skills. The same as in EU, in Lithuania regulation of blockchain technology and cryptocurrencies is evolving rapidly, requiring professionals to understand regulations, data protection, anti-money laundering (AML) regulations, and other compliance areas related to blockchain. Despite the fact that the Lithuanian government supports blockchain innovations, employees in this field often do not have a comprehensive legal and regulatory knowledge base. Many professionals have strong technical skills, but they often lag behind in the legal field. In Lithuania, blockchain specialists lack specific knowledge about the legal and regulatory system, especially related to cryptocurrencies and cross-border transactions. This limits the adoption of blockchain technology in industries where strict regulation is required.

Soft skills. Blockchain professionals must also be able to work in teams, communicate clearly and solve problems. The ability to collaborate with different teams, including technical and business areas, is becoming increasingly important. In Lithuania, technology specialists are usually good problem solvers and can clearly communicate technical solutions, but blockchain projects often require interdisciplinary cooperation and strategic thinking, which is not always strongly developed. Smaller discrepancies are seen in soft skills, where professionals sometimes lack the ability to collaborate with business and legal professionals, as well as strategic thinking in larger projects.

Comparison of Required Skills and Available Skills

There were no exact numbers provided in the analyzed sources regarding the comparison the number of workers with specific skills to the number of job openings needing those skills in Lithuania. However, there still the tendency can be identified.

In Lithuania, the supply of blockchain workers and the demand for jobs with specific skills often do not match, and there is a significant shortage of specialists in certain fields. Developers with programming and technical skills who can work with blockchain technologies such as Solidity, Python, and JavaScript for creating decentralized applications (DApps) and developing smart contracts are in particular demand in the market. This specialized knowledge is needed in many fintech and technology startups that use blockchain technology. The IT sector in Lithuania is quite strong, but there is a lack of specialists with experience in specific blockchain programming languages. Solidity programmers and smart contract developers are especially rare, which means demand far outstrips supply. It can be concluded that the demand is far greater than supply. Accordingly, the vacancies often appear in this field.

In connection with blockchain architecture and distributed systems, companies need specialists who can develop and maintain distributed ledger technologies (DLT), design network architecture, and ensure data security and efficiency in decentralized networks. The number of IT infrastructure specialists in Lithuania is large, but the experience of developing distributed systems and blockchain infrastructure is not yet widespread. Most specialists have more experience in traditional IT systems management, and knowledge of blockchain architecture is not as widely available.

In Lithuania blockchain technology relies on cryptography and security solutions to protect data and transactions. This means that there is a high demand for professionals who can ensure the security of networks and data, especially in the fintech sector. Lithuania has a strong cybersecurity base, so the supply in this sector is relatively good, but cryptography specialists with blockchain-specific experience are rarer.

With the rapid growth in the use of blockchain technology in finance and other regulated areas in Lithuania, there is a need for professionals with knowledge of regulatory requirements such as AML (anti-money laundering) and GDPR. This is important in the fintech sector, where the integration of technology and law is essential. There are few specialists in Lithuania who have experience in combining blockchain technologies with legal and regulatory aspects. There is a shortage of specialists in this field.

Companies in Lithuania need specialists who can combine technical knowledge with business strategy to create blockchain solutions that can be applied in existing markets. This includes project management, business development and blockchain integration into corporate operations. Lithuania lacks blockchain specialists with deep business and strategic knowledge. Most of the professionals available are focused on technical aspects but lack business understanding.

To sum up, the higher demand than supply is related with programmers (especially Solidity, smart contract developers), blockchain Architects, regulatory and legal professionals, strategic professionals (with blockchain and business knowledge). A close balance of supply and demand is related with cybersecurity professionals, especially with general cryptography experience, although blockchain-specific knowledge is lacking.

As more industries recognize the potential benefits of blockchain, demand for specialists in implementation and maintenance continues to grow. The evolving regulatory landscape requires organizations to ensure compliance, driving demand for specialists with legal and regulatory knowledge related to blockchain. The gap between the demand for blockchain skills and the available workforce is pushing companies to seek specialized talent to fill these roles.

Comparison of Skill Profiles and Labor Market Demands

As blockchain technology continues to evolve globally, its applications and the associated workforce demands are expanding significantly. Lithuania, as an emerging hub in the blockchain and fintech sectors, is experiencing a growing demand for skilled professionals in blockchain technology. This desk research examines the future roles and skills that will be critical in Lithuania's blockchain ecosystem and compares these to the current state of the labor market.

As the blockchain ecosystem diversifies, the ability to facilitate **interoperability** between different blockchain networks will be critical. Specialists in **cross-chain** solutions will be needed to build bridges between public, private, and hybrid blockchain networks. This skill set is currently lacking in Lithuania, with most professionals focused on single blockchain platforms. The skills gap in **cross-chain interoperability** is significant, and this area will need targeted training and educational programs.

Blockchain technology becomes more embedded into traditional businesses, skills in integrating blockchain into existing business models will be in high demand. These specialists will need to understand both the technical and business aspects of blockchain solutions. Currently, many blockchain professionals in Lithuania focus on the technical aspects of the technology. Few have the interdisciplinary expertise needed to integrate blockchain into a company's broader business strategy. This interdisciplinary gap, particularly combining business strategy with technical expertise, will likely grow unless more professionals gain experience in blockchain use-case development.

Because of increasing use of decentralized finance (DeFi) applications, smart contract auditing will require more advanced formal verification techniques to ensure that smart contracts are secure and free of errors. Lithuania has some cybersecurity experts, but smart contract auditing and formal verification are still niche areas within the country. There is a critical need to develop expertise in formal verification as it will be crucial to ensuring the security of complex blockchain systems in the future.

By addressing these gaps through targeted education, industry partnerships, and upskilling, Lithuania can maintain its competitive edge in the blockchain sector and meet the demands of a rapidly evolving technological landscape.

Prioritized list of skill gaps requiring immediate attention

- Technical skills
  - Blockchain specific programming skills. High demand for Solidity (smart contract development), Python, and JavaScript for DApps.
  - Smart contract development knowledge.
  - Blockchain Architecture & Distributed Systems knowledge.
  - Regulatory & Compliance Knowledge. Growing need for expertise in AML (Anti-Money Laundering), GDPR, and financial regulations for blockchain.
- Soft skills
  - Business management knowledge

4.4.3 Summary & recommendations

In summary, Lithuania's blockchain workforce is growing rapidly, driven by the country's thriving fintech and tech sectors. Despite to it, while the demand for blockchain specialists is increasing, the current workforce lacks the specific skills required for advanced blockchain roles. Many blockchain professionals in Lithuania are highly skilled technically but lack the ability to integrate blockchain solutions into broader business models. This is particularly important as more traditional businesses seek to adopt blockchain technologies. Lithuanian universities and tech programs are starting to offer blockchain-focused courses, and partnerships between industry and academia are beginning to address the skills gap. However, more focused programs on blockchain security, cross-chain development, and formal smart contract verification are still needed.

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4.5 ICT for Sustainability

4.5.1 Identified roles, jobs, skills & competency profiles

Who is hiring: current & potential employers

- **Energy Sector:**
  Companies focusing on renewable energy sources are looking for ICT specialists to integrate smart grids and energy management systems that enhance efficiency and reduce waste.

- **Manufacturing:**
  Manufacturers are adopting ICT solutions to streamline processes and reduce emissions through smart manufacturing technologies.

- **Transportation and Logistics:**
  The logistics sector is integrating ICT to optimize routes, reduce fuel consumption, and improve supply chain sustainability.

- **Agriculture:**
  The agricultural industry is increasingly using ICT for precision farming techniques that minimize resource use while maximizing yield.

- **Healthcare:**
  Healthcare providers are using ICT for better resource management and patient care systems that reduce environmental impact.

- **Government and Public Sector:**
  Public agencies are implementing digital solutions for better governance, data management, and public service delivery focused on sustainability goals.

- **Corporate Sector:**
  Businesses across various industries are hiring sustainability experts to help integrate ICT into their operations in alignment with corporate social responsibility objectives.

List of specific roles = professionals working with ICT for sustainability

- **Data Analysts**
  Data analysts in the sustainability sector are responsible for evaluating environmental impacts by analysing data related to resource usage, emissions, and ecological footprints. Lithuanian companies and organizations, such as the Baltic Environmental Forum, rely on data analysts to support projects aimed at biodiversity conservation and sustainable farming practices. Their analyses help in optimizing resource management and reducing environmental degradation.

- **Sustainability Reporters**
  Sustainability reporters focus on documenting and communicating sustainability efforts within organizations. These professionals play a crucial role in promoting transparency and accountability in sustainability initiatives.

- **Technical Specialists**
  Technical specialists possess proficiency in emerging technologies that support sustainable practices. This includes expertise in areas such as renewable energy systems, smart technologies for resource management, and eco-design principles. They are responsible for implementing innovative solutions that enhance efficiency and reduce waste within organizations. The growing ICT sector in Lithuania has seen an increase in demand for technical specialists who can integrate sustainable technologies into business operations. Educational programs at institutions like Kaunas University of Technology (KTU) prepare graduates to tackle real-world environmental challenges through engineering and management skills focused on sustainability.

Profile/description/competency profile and skills list for the most common jobs/roles for the ICT in sustainability

- Sustainability Analyst
  - Knowledge of sustainability metrics
  - Proficiency in data visualization tools
  - Data analysis (Excel, R, Python)
- ESG Manager
  - Experience with sustainability reporting frameworks (Global Reporting Initiative, SASB Standards)
  - Strong leadership and team management skills
  - Ability to conduct stakeholder assessments
- Green IT Specialist
  - Knowledge of energy-efficient technologies
  - Experience with cloud computing solutions
  - Project management skills

Common degrees of professionals in the ICT for sustainability in Lithuania

Degree Program	University	Focus Area
Master's in Sustainable Management and Production	Kaunas University of Technology (KTU)	Environmental engineering, manufacturing engineering, business.
Bachelor's in Information and Communication Technologies	Kaunas University of Technology (KTU)	ICT systems design and management with a focus on sustainability.
Bachelor‘s in Sustainable Technologies	Vilnius Gediminas Technical University (VILNIUS TECH)	Innovative technologies promoting sustainability in industries.

4.5.2 Skill Gap Analysis

Identification of critical skills & competency

As more and more companies in ICT sector specify the need of not only essential technical knowledge, but soft-skills relevance as well, identification of critical skills can be divided into two tables as follows:

Table 1 Technical Skills needed in the ICT for Sustainability sector

Technical Skill	Description
Software Development	Proficiency in programming languages such as Python and Java for developing sustainable solutions.
Data Analytics	Skills in analyzing data to drive decision-making for sustainability initiatives.
Cybersecurity	Knowledge of securing digital infrastructures that support sustainable practices.
Cloud Computing	Understanding cloud technologies to enhance data storage and processing capabilities sustainably.
Machine Learning/AI	Applying AI techniques to optimize processes and improve sustainability outcomes.
IoT (Internet of Things)	Expertise in IoT technologies for monitoring and managing environmental resources efficiently.

Table 2 Soft skills needed in the ICT for Sustainability sector

Soft Skill	Description
Communication	Ability to convey complex technical information clearly to diverse audiences.
Teamwork	Collaborating effectively with cross-functional teams to achieve sustainability goals.
Problem-Solving	Critical thinking to identify and resolve challenges in sustainability projects.
Creativity	Innovating new solutions for sustainability challenges using technology.

Analysis of skill proficiency levels in the workforce.

The Lithuanian technology sector is facing a shortage of over 7,600 ICT professionals, particularly in areas such as software development, cybersecurity, and data analysis. This gap highlights the urgent need for upskilling and attracting talent to sustain growth in the ICT sector.[18]

[18] https://vilniustechfusion.com/en/news/lithuanian-tech-sector-lacks-over-7600-talents-top-10-professions-in-the-greatest-demand-key-competencies-and-the-highest-paid-positions/

According to data of 2023, approximately 20,000 individuals were employed in the Lithuanian ICT sector, with about 46% classified as ICT professionals. Research shows that while technical skills are present among employees, their effective application in workplace settings varies.

Technical skills: There is a strong demand for specific technical competencies such as software development (especially back-end development), data analytics, and cybersecurity. However, many professionals lack advanced proficiency in these areas, which is critical for driving sustainability initiatives.

Soft Skills: The ability to collaborate effectively and communicate complex ideas is increasingly important. Many workers possess basic soft skills but may struggle with higher-level competencies necessary for interdisciplinary teamwork required in sustainability projects.

Future Skill Development Needs

As regards the potential of the ICT sector in terms of human resources, the situation shows positive trends but also presents development challenges. However, despite the positive trends, Lithuania is lagging behind other countries in the Baltic and Scandinavian region.

As per report made by Innovation Agency of Lithuania, main three restrictive barriers, doing the impact on Lithuanian ITC sector human resources can be seen in the table below:

Enabling factors	Restrictive barriers
High quality training for basic skills ICT professionals	Shortage of IT professionals, brain drain and long-term decline in the working age population
Opportunities and practices for cooperation in improving competences of ICT staff	Lack of soft/horizontal skills - entrepreneurship, product management and marketing
Successful Digital Explorers programme can be viewed as a successful pilot project to develop similar initiatives	Lack of cross-curricular approach at academic level; lack of entrepreneurial/decision empowerment skills

Prioritized list of skill gaps requiring immediate attention

- Technical Skill Gaps
  - **Software Development** in **Python & Java**. Crucial for developing sustainable digital solutions.
  - **Data Analytics**. Limited expertise in analyzing data for decision making in sustainability initiatives.
  - Cybersecurity knowledge.
  - **AI & Machine Learning**. Deficiency in AI-driven optimization for sustainability processes.
- Soft Skill Gaps
  - Communication skills.
  - Problem solving skills.

4.5.3 Summary & recommendations

Continuous education and training programs are essential to bridge the skill gap. Companies are encouraged to invest in upskilling their workforce to meet the demands of emerging technologies and sustainability practices.

Collaboration with Educational Institutions: Strengthening partnerships between industry and academia can ensure that educational programs align with market needs, particularly focusing on sustainable ICT applications.

The analysis indicates that while Lithuania's ICT sector has a solid foundation with a growing talent pool, significant challenges remain regarding skill proficiency levels. Addressing these gaps through targeted upskilling initiatives, attracting global talent, and enhancing collaboration with educational institutions will be crucial for developing a workforce capable of driving sustainability efforts effectively within the ICT for sustainability sector.

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4.6 Industry 5.0

4.6.1 Identified roles, jobs, skills & competency profiles

Who is hiring: current & potential employers of Industry 5.0 in Lithuania

- **Manufacturing:**
  Manufacturing sector remains foundation of the Lithuanian economy, with a significant demand for skilled personnel such as engineers, technicians, and operators. The focus is on advanced manufacturing processes that incorporate digital technologies and automation.

- **Information and Communication Technology (ICT):**
  There is a growing need for IT professionals, including software developers, data analysts, and IT service managers. Digitalization is driving this demand as industries seek to integrate more advanced technological solutions into their operations.

- **Healthcare:**
  The healthcare sector is increasingly adopting digital solutions and requires professionals who can develop and implement innovative technologies to improve patient care and operational efficiency.

- **Transportation and Logistics:**
  With advancements in smart logistics and supply chain management, this sector is looking for professionals who can leverage technology to enhance operational efficiency.

- **Finance and Insurance:**
  The financial sector is experiencing growth in roles related to data analysis, risk management, and compliance, driven by the need for digital transformation in financial services.

- **Education:**
  As the demand for new skills increases, educational institutions are hiring professionals who can develop training programs focused on Industry 5.0 competencies19.

List of specific roles in Industry 5.0 in Lithuania

In Lithuania, several specific roles are emerging in the context of Industry 5.0, reflecting on the integration of advanced technologies and a focus on human-centric practices.

- **Software developers** which are responsible for designing, coding, and testing software applications that support automation and data analysis are crucial to this industry.
- **Data scientists** who have a deep knowledge to analyze complex data and inform business decisions how to improve operational efficiency are of need. Lithuania has a

[19] https://lpk.lt/en/bridges-5-0-2/

huge demand for experienced or fast learning data analysts who would be available to understand big data and make the conclusions depending on a industry sector they are working in.

- **Robotics technicians** who would have the capacity for works on the installation, maintenance, and repair of robotic systems used in manufacturing and other industries and on high demand. Manufacturing companies, start-ups and other sectors who are willing to install new robotic systems are looking for high skilled technicians.
- **Sustainability Consultants**. As businesses evolve and are more open to sustainability practises together with Industry 5.0 transition, sustainability specialists are on demand. Experienced or driven employees who would follow newest regulations with responsibility to help companies to reduce its environmental impact are on high demand, since there are only a small percentage of high profile sustainability experts in Lithuania.
- **Human-Machine Interaction Specialist** is a crucial role while helping companies and employees with Industry 5.0 transition. These specialists focuses on optimizing the interaction between humans and machines to improve productivity and safety and smooth transition and adaptation.
- **Healthcare Technology Specialists** who work at the intersection of healthcare and technology to improve patient care through innovative solutions can be foreseen to be of high demand in Lithuania health sector and its start-ups.
- **Training and Development Specialists** play an essential role in facilitating a smooth transition for companies into Industry 5.0. There is a growing need for new training programs that equip employees with the skills necessary to adapt to new technologies in their fields or students who are planing to work in specific sectors. This demand is expected to continue as Lithuania aims to sustain its position towards Industry 5.0.

Profile/description/competency profile and skills list for the most common jobs/roles

Technical skill domain	Description of technical skill	Correlation with Industry 5.0
Programming Proficiency	Allows to create algorithms that enhance operational efficiency.	The ability to write and understand code in languages like Python, Java, or C++ is essential for developing software applications and automating processes in Industry 5.0.
Data Analysis	The capacity to process huge amounts of data and making conclusions related to business sector.	Skill involves collecting, processing, and interpreting large datasets using statistical methods and tools like SQL to derive actionable insights for informed decision-making in Industry 5.0

Technical skill domain	Description of technical skill	Correlation with Industry 5.0
Cybersecurity knowledge	The ability to protect systems from cyber threats	Understanding how to protect digital systems from cyber threats is crucial, as it ensures the security of sensitive information and the integrity of interconnected industrial operations.
Machine Learning	The ability to understand how new technology can be installed into day-to-day operations.	Machine learning is essential for optimizing production processes and enabling data-driven decision-making. This skill is crucial for improved efficiency, product quality, and adaptability to changing market demands.

Soft skill domain	Description of soft skill	Correlation with Industry 5.0
Adaptability	The ability to be flexible and open to ideas and internal changes	As technologies evolve rapidly in Industry 5.0, professionals must adjust to new tools and processes
Emotional Intelligence	The ability to understand and manage individuals' emotions while empathizing with others.	In a collaborative environment like Industry 5.0, strong emotional intelligence fosters teamwork and helps navigate interpersonal dynamics effectively, enhancing overall workplace harmony.
Communication skills	The ability to clearly convey ideas and collaborate with diverse teams.	In Industry 5.0, where human-machine collaboration is emphasized, effective communication ensures that all stakeholders understand technological processes and can work together efficiently.

Common degrees of professionals

After the analyses made it can be assumed that in Lithuania, the educational pathways for professionals specializing in Industry 5.0 encompass degrees including bachelor's and master's. These programs are increasingly relevant due to the growing demand for skilled workers in this industry and its projects. Universities like Kaunas University of Technology, Vilnius Tech University and Vilnius University are strong in these programs and offer higher education specified to industry needs. Although it can be concluded that technical side of these studies is stronger than the one including soft skills, since educational programs are directed more towards technical aspect of knowledge.

Educational program	Degree	Correlation with Industry 5.0.
Industrial Engineering and Innovation Management	Master’s degree	Prepares students to integrate engineering and management for innovation.
Data Science	Master’s degree	Develops data analysis skills essential for decision-making in Industry 5.0.
Data Science and Statistics	Master’s degree	Focuses on statistical modeling and data analysis crucial for smart manufacturing.
Mechatronics Systems	Bachelor/Master of Engineering	Combines mechanical and electronic systems, vital for smart manufacturing.
Management of Artificial Intelligence Solutions	Master’s degree	Prepares professionals to leverage AI in optimizing industrial processes.

4.6.2 Skill Gap Analysis

The concept of Industry 5.0 emphasizes the integration of knowledge from various sectors, highlighting the importance for specialists in this field to not only understand advanced technology and data analytics or machine learning, but also to grasp the specific business context, whether in manufacturing or service-oriented organizations. In Lithuania, there is a notable shortage of such specialists as the country prepares to further develop Industry 5.0, making their training crucial.

As the advanced technology and industry 5.0. sector continues to grow in Lithuania, employers face challenges in finding skilled workers at all levels. However, there is optimism as more young people are choosing to study technology-related fields. In 2023, there was an over 20% increase in the number of students enrolling in engineering and technology programs, with notable growth also observed in computer science (13%) and mathematics (21%) disciplines. Dr. Milena Seržantė, Director of the Strategic Partnership Center at Vilnius Gediminas Technical University (VILNIUS TECH), reported that enrolment in engineering and technology sciences rose by 22% in 2023.[20]

Graduates from these programs acquire essential skills for working in technology and Industry 5.0 fields; however, a deeper analysis reveals gaps in knowledge regarding work psychology, client interaction, and effective communication. To address the shortage of technology specialists with required knowledge, employers are taking proactive measures. Many tech companies in Lithuania are launching internship programs and establishing specialized academies for beginners and individuals seeking to reskill. Given the current

[20] https://sc.bns.lt/view/item/468553

shortage of employees, companies are prioritizing not only technical skills but also cultural fit and alignment with organizational values.

Analysis of skill proficiency levels in the workforce;

Research indicates a clear shortage of specialists in the labor market, influenced by several key factors: the emergence of artificial intelligence, big data, cloud computing, and other innovations significantly impacts job market dynamics. There is an increasing demand for technology professionals, prompting businesses to collaborate more actively with academic institutions since higher education is primarily responsible for training these specialists.

Comparison of required skills and available skills; comparison of skill profiles and labour market demands

Required Skills for Industry 5.0

- **Digital Skills:**
  Proficiency in programming, data analysis, and digital marketing is increasingly essential due to the rise of digitalization across sectors. The Information Technology (IT) sector remains a leader in job creation, with high demand for software developers, cybersecurity experts, and data scientists.
- **Sustainable Practices:**
  There is a growing emphasis on sustainability-related skills, particularly in renewable energy and environmental science. Occupations focused on sustainable design and practices are becoming critical as Lithuania commits to green initiatives.
- **Soft Skills:**
  Multidisciplinary skills that combine technical expertise with soft skills such as communication, problem-solving, and teamwork are highly sought after.

Available Skills in the Labor Market

Despite the rising demand for specific skills, there exists a notable mismatch between the skills available in the workforce and those required by employers:

- **Skills Mismatch:**
  Lithuania faces one of the highest skill mismatches in Europe, particularly a relative shortage of high-skilled workers. Many job vacancies remain unfilled due to this mismatch. As country leans towards Industry 5.0 more and more experienced technicians with relevant business and sustainability practice understanding are sought.
- **Educational Alignment:**
  Efforts are underway to align educational programs with industry needs to mitigate these mismatches. Collaboration between educational institutions and employers is crucial to ensure that graduates possess relevant skills.
- **Workforce Adaptability:**
  The labor market is adapting through increased self-employment and entrepreneurship as individuals seek to fill gaps left by traditional employment structures.

In conclusion, Lithuania's labor market in 2024 reflects a complex landscape shaped by the demands of Industry 5.0. While there is a huge demand for skilled professionals across various sectors—especially in IT and sustainable practices—significant skill mismatches remains a problem. Addressing these gaps through education reform and targeted training programs will be essential for aligning workforce capabilities with industry needs and ensuring sustained economic growth in the future.

Top skill gaps that need immediate attention

- Technical Skills
  - **Software Development**. Particularly in **Python & Java**, still crucial for developing sustainable digital solutions.
  - **Data Analytics**. Limited expertise in analyzing data for decision making in sustainability initiatives.
  - **Cybersecurity knowledge.** Very crucial and lacking still.
  - **Cloud Computing & IoT.** Few experts capable of integrating IoT and cloud for efficient environmental resource management.
  - **AI & Machine Learning.** Deficiency in AI-driven optimization for sustainability processes.
- Soft Skills
  - Communication skills
  - Problem-Solving skills

4.6.3 Summary & recommendations

Desk Research indicates that the knowledge required for Industry 5.0 comes primarily through experience. Educational institutions are preparing students with the necessary technological foundations in programming, analytics, and engineering. However, there is often a lack of general knowledge about business and the manufacturing sector in the market or sustainability practices. Additionally, a noticeable deficiency in soft skills is evident.

There is a clear need for educational reform and collaboration with companies to create new educational models that incorporate practical experiences within existing businesses as they transition towards Industry 5.0. It is also crucial to integrate subjects such as work psychology and communication into study programs, teaching students not only about technology but also how to present it to individuals who may not have any background in these areas.

Industry 5.0 demands comprehensive knowledge in both technology and psychology. The ability to clearly present facts and teach others how to work with artificial intelligence, as well as to embrace innovations, will be vital in future projects.

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4.7 Internet of Things

4.7.1 Identified roles, jobs, skills & competency profiles

Who is hiring: current & potential employers

- **Information and Communication Technology (ICT)**
  The ICT sector is at the forefront of IoT development in Lithuania. Numerous companies focus on creating IoT solutions, software development, and system integration. With a growing number of startups and established firms specializing in IoT, there is a high demand for software engineers, data scientists, and IoT developers.

- **Healthcare**
  The healthcare sector increasingly relies on IoT for remote patient monitoring and health management systems. Professionals with expertise in healthcare technology, data analysis, and software development are sought after to implement and maintain these systems.

- **Agriculture**
  IoT applications in agriculture, such as precision farming and smart irrigation systems, are gaining attention. Specialists in agricultural technology, data analytics, and sensor technology are needed to develop and manage these solutions.

- **Manufacturing**
  The manufacturing industry is adopting Industrial IoT to enhance operational efficiency through automation and predictive maintenance. Engineers, data analysts, and IoT specialists are required to design and implement IoT systems that monitor equipment performance and optimize production processes.

- **Transportation and Logistics**
  IoT plays a crucial role in fleet management and supply chain optimization. Companies in this sector are looking for experts in logistics technology, data analytics, and software development to improve tracking systems and operational efficiency.

- **Smart Cities**
  As Lithuania invests in smart city initiatives, there is a demand for professionals who can work on urban infrastructure projects involving IoT technologies. This includes roles related to traffic management systems, energy management, and public safety solutions. For example, Kaunas Smart City Initiatives: The city of Kaunas is actively integrating IoT and LoRaWAN technology to enhance its urban services. This initiative is aimed at improving traffic management, energy management, and public safety solutions, indicating a growing need for skilled professionals in these areas.21

[21] https://tektelic.com/projects/lithuanian-city-utilizing-iot-lora-to-join-the-smart-city-movement/

- **Retail**
  The retail sector is utilizing IoT for inventory management and enhancing customer experiences through smart technologies. Specialists in retail technology, data analytics, and customer relationship management systems are of demand.

List of specific roles = professionals working with IoT, opportunities / jobs/ working positions

As Lithuania is paying more and more attention to IOT technologies, from private businesses, manufacturing companies, the health sector to smart cities, more and more specialists will be sought to work with this advanced technology. The main specialists sought in Lithuania are:

- IoT Developer: Responsible for designing and developing IoT applications and systems, often requiring skills in programming languages like Python, Java, and C++.
- Embedded Software Engineer: Focuses on creating software that runs on IoT devices, requiring knowledge of hardware-software integration.
- Data Scientist/Analyst: Analyses data collected from IoT devices to derive insights and inform decision-making processes.
- Network Engineer: Manages the connectivity and communication between IoT devices, ensuring reliable data transmission.
- Cybersecurity Specialist: Protects IoT systems from cyber threats, focusing on securing device communications and data integrity.
- Automation Engineer: Tests IoT applications to ensure they function correctly and meet quality standards.
- Telematics Engineer: Works specifically with vehicle tracking and fleet management solutions, a significant area within IoT.
- Technical Support Specialist: Helps customers using IoT products, solves troubleshoot issues and improves user experience.

Key Companies Hiring Iot specialists in Lithuania:

- Teltonika: https://teltonika-iot-group.com/lt
- Vinted: https://careers.vinted.com/
- Kilohealth: https://kilo.health/careers/
- Nord Security: https://nordsecurity.com/careers

Profile/description/competency profile and skills list for the most common jobs/roles for the IoT sector

Analysing required skills for specialists working in IoT sector in Lithuania can be divided into two groups. As more and more companies highlight the importance of not only technical but also soft skills, it is important to pay attention to specialist emotional intelligence, business understanding as well as technical background.

Technical skill	Skill description
Programming Languages	Proficiency in languages such as Python, Java, C, and C++ is essencial for developing IoT applications.
Data analysis	Understanding data analytics and management is vital for processing the large volumes of data generated by IoT devices.
IoT Security	Skills in securing IoT systems are critical to protect devices and data from cyber attacks.

Soft skill	Skill description
Problem solving skills	The ability to identify issues and develop effective solutions is essential in the dynamic IoT landscape.
Collaboration skills	Working effectively with cross-functional teams, including engineers, designers, and business stakeholders is required in IoT sectors.
Adaptability	The IoT field is rapidly evolving; being adaptable to new technologies and methodologies is crucial.
Communication skills	Strong verbal and written communication skills are necessary for explaining technical concepts to non-technical stakeholders.

Common degrees of professionals in the IoT

Degreed for professionals can be gained in Lithuanian Universities like Vilnius Tech University and Vilnius University. Other higher education institutions also offer similar programmes, but these specific entities can be described as best in the country for specialists in IoT.

University	Degree Programme	Specialization
Vilnius Tech University	Bachelor of Informatics Sciences	Internet of Things; Technologies of Data Communications Networks
Vilnius Tech University	Bachelor of Engineering Sciences in Informatics Engineering	Artificial Intelligence Electronic Systems
Vilnius University	Master of Computing Sciences	Informatics, Software Development, Research

While analysing the available educational programs related to the training of specialists in the IoT sector, we can distinguish not only University programs, but also corporate initiatives. One of the main initiatives is the Academy established by company Teltonika, which allows students to get in touch with IoT technologies, the development of the sector, and choose the most attractive field while still in their studies. Teltonika collaborates with VILNIUS TECH to provide internships through their IoT and B2B academies. Teltonika aims to hire a significant number of specialists in the coming years, indicating a robust job market for graduates.[22]

4.7.2 Skill Gap Analysis

While analysing skill gaps, assessment made by Innovation gave valuable insight. Agency analysed the state of innovation deployment and development in the ICT sector including IoT and assessing the potential for digital breakthroughs and deep technologies. The assessment presented in the table below is based on 4 cross sections: innovation ecosystem, **human resources**, infrastructure and business environment.

Even though Lithuania produces specialists to work in IoT sector, as in all other advanced technology sectors in Lithuania there not only can be seen some skill gaps in experience or soft skill but also human resource insufficiency.

It can be concluded that supply and quality of human resources in IoT sector is stated as medium, which is lowest of other criteria in the table. Analysis can be concluded as a red flag for IoT sector and should be considered by not only educational institutions but also government, new initiatives must be presented to not only prepare high skilled specialists but also to keep talents in IoT sector in Lithuania.

2023 survey by Unicorns Lithuania[23] indicated that the ITC sector including IoT lacks over 7,600 talents, with a high demand for roles such as software developers, DevOps engineers, data analysts, and digital marketing specialists. The demand for digital skills—especially in programming languages like Python, JavaScript, and Java—is outpacing supply. As this survey shows, companies in the ICT sector are including IoT also are looking for business development talents with analytical and digital marketing skills.

Looking ahead to 2025, it is projected that companies will need to recruit approximately 750 additional ICT including IoT management professionals, alongside significant increases in data analytics roles. The sectors anticipated to grow include finance, insurance, information technology, and professional services, with a forecasted employment growth rate of 9.5% in information and communication technologies by 2030.

Prioritized list of skill gaps requiring immediate attention

- Technical skills:
  - Programming languages like Python, JavaScript, and Java
  - Digital Marketing skills

[22] https://teltonika-high-tech-hill.com/lt/iot-akademija

[23] https://unicorns.lt/storage/app/media/Modeliniai%20dokumentai/Talentu%20tyrimo%20ataskaita_final.pdf

Criteria		AI & Big Data	Fintech & Blockchain	Audiovisual Media Tech & Social Innovation	IoT	Cybersecurity	Smart Transport Systems
ENABLERS	Innovation support	Very high	Very high	Medium / Low	Medium	Medium	Medium
	Maturity of ecosystem	High	Very high	High / Low	Low	Medium	Low
	Supply and quality of human resources	High	High	High / Medium	Medium	High	High
	Importance and accessibility of infrastructure	High	High	Medium / High	High	Medium	Medium
	Regulatory and business environment	High	High	Medium / Low	Medium	High	Medium
BREAKTHROUGH POTENTIAL	Potential of technological innovations and science	Medium	High	Medium / Low	Low	Medium	High
	Potential of applied solutions	Very high	High	High / Medium	High	High	Medium
	Market scale and dynamics	Very high 38 % 350	High 26 % 240	High / Low 2-24 % 211	High 19 % 188	Medium 14 % 117	Medium 14 % 35
GENERAL ASSESSMENT OF POTENTIAL		Very high	High	High / Low	Medium	Medium	Medium

4.7.3 Summary & recommendations

To address lack of skilled supply of specialist universities with industry experts need to ensure that graduates possess the required skills. Developing programs aimed at enhancing existing employees' skills to meet evolving technological demands is also crucial if Lithuania wants to succeed in development of IoT sector.

More programs involving existing companies, inviting students to join internships and gain in-depth knowledge, tapping into IoT technologies would also be beneficial. Encouraging university cooperation with industry representatives is necessary to solve the talent problem and avoid an even greater shortage in the future.

It is essential to prioritize these skill gaps:

- Digital skill gaps in specific programming languages used in IoT sector.
- Soft skills gap as communication, adaptability, as well as business management and understanding.
- Engineering skills for IoT systems in various manufacturing sectors.

4.7.4 References & resources

[1] LITHUANIA'S ICT SECTOR ROADMAP EXECUTIVE SUMMARY report (2023) https://inovacijuagentura.lt/site/binaries/content/assets/analitika/analytical-products-en/ict-roadmap-lithuania-2023---executive-summary.pdf

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[3] Invest Lithuania, ICT specialists employed in Lithuania (2023) https://investlithuania.com/technology/

[4] Lithuanian City Utilizing Iot & Lora To Join The Smart City Movement https://tektelic.com/projects/lithuanian-city-utilizing-iot-lora-to-join-the-smart-city-movement/

[5] The need for ICT specialists and work market forecast in Lithuania report (2023) https://unicorns.lt/storage/app/media/Modeliniai%20dokumentai/Talentu%20tyrimo%20ataskaita_final.pdf

4.8 Quantum Computing

4.8.1 Identified roles, jobs, skills & competency profiles

Who is hiring: current & potential employers

Analyzing the current Lithuanian job market and employers seeking employees with expertise in quantum computing presents challenges, as this field is still developing in very early stages. However, it is possible to identify potential future employers and sectors that will likely require specialists in the coming years:

- **Information Technology and Computing**
  Quantum computing significantly enhances processing power, requiring specialists to develop quantum algorithms and integrate quantum solutions with classical computing systems.

- **Telecommunications and Quantum Communications**
  There is an increasing focus on creating secure communication systems based on quantum principles, such as quantum key distribution. This sector will need experts to design and implement quantum communication protocols and devices.

- **Cybersecurity**
  Quantum technologies are set to transform cybersecurity through advanced encryption methods. Specialists will be required to develop and maintain new security frameworks that protect sensitive data against threats posed by quantum computers.

- **Biotechnology and Health Sciences**
  The intersection of quantum computing with biotechnology offers opportunities for breakthroughs in drug discovery and genetic research. Specialists will be needed to apply quantum algorithms for analysing biological data and modelling complex biological systems.

- **Research and Development (R&D)**
  Academic institutions and research organizations will require specialists to conduct fundamental research in quantum mechanics, materials science, and related fields.

- **Defense and National Security**
  Given the strategic importance of quantum technologies, defense sectors are likely to invest in these technologies for secure communications and advanced sensing capabilities. Specialists will be essential for developing applications that enhance national security through technological innovation.

Although Lithuania most likely does not have sufficient resources for the development of core technologies and cannot compete with major ICT technology centres in the US or Western European countries it can be stated that Lithuania is in an excellent position to quickly adopt breakthrough technologies emerging abroad and to develop innovative applied products and business models, more efficient processes or products.[24]

Profile/description/competency profile and skills list for Quantum Computing sector

When analysing what skills, a specialist who would be a potential employee in the Lithuanian quantum computing sector must have, it is possible to distinguish the main technical skills and soft skills:

Technical skill category	Description of skill
Quantum Programming	Proficiency in languages like Q#, Qiskit, Python, C++, and Java.
Quantum Algorithms	Understanding and developing algorithms that leverage quantum mechanics.
Quantum Hardware Knowledge	Familiarity with quantum computer architectures and hardware components.
Mathematical Skills	Strong foundation in linear algebra, probability theory, and statistics.
Strong foundation in linear algebra, probability theory, and statistics	Experience with tools like IBM Quantum Experience, Cirq, and Quantum Development Kit (QDK).
Machine Learning	Knowledge of quantum machine learning techniques.
Quantum Error Correction	Understanding techniques for fault tolerance in quantum systems.
Lab Skills	Practical experience with superconducting circuits and quantum optics.

Soft skill category	Description of skill
Communication Skills	Ability to convey complex concepts clearly to diverse audiences.
Problem-Solving Skills	Creative thinking to tackle complex challenges in quantum technology.
Critical Thinking	Evaluating new technologies and their implications critically.
Adaptability and Continuous Learning	Commitment to staying updated with rapid advancements in the field.

Common degrees of professionals in Quantum Computing

While there are no specific educational programmes focused on solely quantum computing, Vilnius University is currently developing educational programme focused on quantum computing and technologies in Lithuania. Vilnius University plans to introduce a new

[24] https://inovacijuagentura.lt/site/binaries/content/assets/analitika/analytical-products-en/ict-roadmap-lithuania-2023---executive-summary.pdf

programme called „Introduction to Quantum Computing", with additional study programs dedicated to quantum technologies. This initiative is part of a broader effort to position Lithuania as a competitive player in the rapidly evolving field of quantum technologies.[25] In May 2023, VU signed an agreement with the Poznań Supercomputing and Networking Centre, which will enhance access to quantum computing resources and educational materials for students and researchers at Vilnius University. This partnership aims to establish Vilnius University as a centre of excellence in quantum computing, promoting both academic research and practical applications in various fields.

Additionally, mentioned Lithuanian Quantum Technologies Association was established to foster collaboration among scientific institutions and businesses in the quantum technology sector. This association includes contributions from Vilnius University and aims to build a robust ecosystem for quantum technology development in Lithuania.

4.8.2 Skill Gap Analysis

It is not possible to do the skill gap analysis in Lithuania due to quantum computing sector development early stage. Countries like the USA and China are leading in both investment and development, which sets a high standard for Lithuania for the foreseeable future.

- Required Skills:
  - Advanced knowledge of quantum mechanics
  - Expertise in programming languages specific to quantum computing
  - Experience with high-performance computing systems
- Available Skills:
  - Some higher/basic understanding of quantum principles among researchers, scientists.
  - Growing interest from professionals and Universities, creation of programmes.

Comparison of Skill Profiles and Labour Market Demands

The labour market for quantum technologies is evolving, with increasing recognition of its importance for economic competitiveness and national security. The establishment of the Lithuanian Quantum Technology Association signifies a collective effort to build a robust ecosystem that can support the growth of this sector.

- Current Skill Profile:
  - A small pool of researchers with theoretical knowledge
  - Limited practical experience in quantum computing applications
- Market Demand:
  - High demand for skilled professionals capable of bridging the gap between theoretical research and practical applications.
  - Need for collaboration between academia and industry to foster innovation and commercialization of quantum technologies.

[25] https://www.vu.lt/en/news-events/news/vu-scientists-on-quantum-technologies-it-is-high-time-to-acquire-knowledge-now-to-be-able-to-utilise-the-enormous-potential-in-the-future

It is not possible to determine top skills that need immediate attention due to this sector not being developed in Lithuania.

4.8.3 Summary & recommendations

After conducting desk research with very limited available information, it can be stated that quantum computing in Lithuania is still in its introductory phase. Based on examples of initiatives and funding in foreign countries in this sector, Lithuania is on the right path by establishing Lithuanian Quantum Technology Association and signing the European Declaration on Quantum Technologies. Lithuania possesses strong companies operating in the laser sector which may be closely related to quantum computing in the future as well as sectors like national security, medicine, biotechnologies, telecommunications etc. which have huge potential to become future sectors involved with quantum computing.

Although there has not yet been a comprehensive assessment of the current job market situation due to the developing stage of this sector, it can be foreseen that specialists in this field will be particularly needed in the future. Therefore, educational institutions should start considering learning programs and joint projects with foreign countries and their educational institutions that have access to quantum computers or their components.

4.8.4 References & resources

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WP4 Enhancing Labour Market-Relevant Skills in Advanced Technologies

T4.1 Identifying skill gaps in Advanced Technologies

SLOVAKIA national report from the desk research

Date: September 2024 – January 2025

Prepared by: Astra, Slovakia

INVESTech

Innovation Vocational Excellence

and Sustainability in Tech

[10] PROJECT REF NO. 101143958. ERASMUS-EDU-2023-PEX-COVE

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Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

5 SLOVAKIA National report from the desk research

5.1 Introduction & methodology

Methodology: Description of data sources utilized; Data collection and analysis methods employed

- We focused on the personal agencies, recruiters as well as the main employers' web sites and searched for the relevant jobs there.
- We gathered data, compare and analysed them
- Then we built the profile of the chosen jobs.

5.2 Artificial Intelligence and Ethics

5.2.1 Identified roles, jobs, skills & competency profiles

List of specific roles = professionals working with the in Artificial Intelligence in Slovakia

- AI Researcher: Conducts research on AI algorithms, machine learning models, and their applications across various domains.
- AI Software Developer: Develops software solutions that incorporate AI technologies such as machine learning, natural language processing, and computer vision.
- Data Scientist: Analyzes complex data sets to extract insights and develop predictive models using AI techniques.
- AI Ethics Specialist: Focuses on the ethical implications of AI technologies, ensuring compliance with ethical standards and regulations.
- Machine Learning Engineer: Designs and implements machine learning algorithms and systems to solve specific problems.

Profile/description/competency profile and skills list for the most common jobs/roles for the respective AI & ethics

In the AI and ethics field in Slovakia, three of the most requested and difficult-to-hire positions are as follows.

Generative AI Expert

- Profile/Description:
  A Generative AI Expert focuses on developing and implementing AI solutions that leverage generative models for various applications, including natural language processing, image generation, and data analytics. This role requires strong technical expertise and the ability to engage with clients to deliver tailored solutions.

- Competency Profile:
  - Technical Proficiency: Deep understanding of generative models such as Generative Adversarial Networks (GANs) and Variational Autoencoders (VAEs).
  - Project Management Skills: Ability to lead projects from inception to completion, ensuring timely delivery of high-quality solutions.
  - Client Engagement: Strong interpersonal skills to effectively communicate with clients and understand their unique needs.
- Skills required:
  - Programming Languages: Advanced proficiency in Python; familiarity with other languages like R or Java is a plus.
  - AI Frameworks: Experience with frameworks such as TensorFlow, PyTorch, or Keras for developing generative models.
  - Data Management: Skills in data collection, preprocessing, and validation to ensure high-quality inputs for AI models.
  - Analytical Skills: Strong analytical mindset with the ability to interpret complex data sets and derive actionable insights.
  - Problem-Solving Abilities: Creative approach to addressing challenges in AI model development and deployment.
  - Communication Skills: Excellent verbal and written communication skills to present findings and solutions clearly to stakeholders.
  - Ethical Awareness: Understanding of ethical considerations in AI, including bias mitigation and responsible AI use

AI Ethics Specialist

- Profile/Description:
  An AI Ethics Specialist is responsible for ensuring that AI technologies are developed and implemented ethically. This role involves assessing the ethical implications of AI systems, developing guidelines for ethical AI use, and collaborating with technical teams to integrate ethical considerations into projects.
- Competency Profile:
  - Ethical Knowledge: In-depth understanding of ethical frameworks related to artificial intelligence, including data privacy laws (e.g., GDPR).
  - Risk Assessment Skills: Ability to evaluate risks associated with AI technologies and propose mitigation strategies.
  - Interdisciplinary Collaboration: Capacity to work effectively with technical teams, legal experts, and business stakeholders.
- Skills required:
  - Regulatory Knowledge: Familiarity with international regulations concerning AI ethics and data protection.
  - Analytical Skills: Strong analytical abilities to assess the social impact of AI technologies on various stakeholders.
  - Communication Skills: Excellent skills in articulating ethical concerns clearly to diverse audiences, including non-technical stakeholders.

- Research Skills: Ability to conduct literature reviews and research on emerging ethical issues in AI.
- Facilitation Skills: Experience in leading discussions and workshops on ethical considerations in technology development.
- Policy Development: Skills in developing internal policies for responsible AI use within organizations.

Machine Learning Engineer

- Profile/Description:
  A Machine Learning Engineer designs, builds, and deploys machine learning models that can learn from data and make predictions or decisions. This role requires a blend of software engineering skills and expertise in machine learning algorithms.

- Competency Profile:
  - Technical Expertise: Proficiency in machine learning algorithms, data structures, and software engineering principles.
  - Deployment Knowledge: Understanding of how to deploy machine learning models into production environments effectively.
  - Collaboration Skills: Ability to work collaboratively within cross-functional teams that include data scientists, software developers, and product managers.

- Skills required
  - Programming Languages: Proficient in Python or R; experience with Java or C++ is beneficial.
  - Machine Learning Frameworks: Familiarity with libraries such as Scikit-learn, TensorFlow, or Keras for building ML models.
  - Data Handling Skills: Experience with data pre-processing techniques, feature engineering, and exploratory data analysis (EDA).
  - Model Evaluation Techniques: Knowledge of model validation methods (e.g., cross-validation) and performance metrics (e.g., accuracy, precision).
  - Cloud Platforms Knowledge: Experience deploying ML models using cloud services like AWS SageMaker or Google Cloud ML Engine.
  - Version Control Systems: Proficiency in using Git for version control in collaborative projects.
  - Communication Skills: Ability to explain complex technical concepts clearly to non-technical stakeholders.

The roles of Generative AI Expert, AI Ethics Specialist, and Machine Learning Engineer are critical in the evolving landscape of artificial intelligence in Slovakia. Each position requires a unique blend of technical expertise, project management capabilities, and soft skills. Addressing the hiring challenges associated with these roles will be essential for fostering innovation and ensuring the ethical development of AI technologies in the region.

Who is hiring: current & potential employers

Company/Organization	Position Types	Description
AIslovakIA	AI Researcher, AI Software Developer	A national platform for AI development that connects experts with businesses and government institutions.
Profinit	AI Software Developer, Data Scientist	A leading company specializing in custom software development and data science solutions.
Intellica	AI Software Developer, Machine Learning Engineer	Provides innovative software development focusing on data science and AI projects.
Slovak National Center for Artificial Intelligence	AI Researcher, AI Ethics Specialist	Engages in research and development in the field of artificial intelligence and its ethical implications.
T-Systems Slovakia	Data Scientist, Machine Learning Engineer	Focuses on IT services and solutions, incorporating AI technologies into their offerings.
Accenture Slovakia	AI Consultant, Data Scientist	Provides consulting services that leverage AI to improve business processes across various industries

Common degrees of professionals in the Quantum Computing

- Bachelor's Degree in Computer Science; field of study Computer Science / IT.
- Master's Degree in Data Science or Artificial Intelligence; field of study Data Science / AI.
- Bachelor's or Master's Degree in Mathematics or Statistics Mathematics / Statistics.
- PhD in Artificial Intelligence or Related Fields Research / Academia

5.2.2 Skill Gap Analysis

In the Table below we provide an overview of the skill gaps for key positions in Slovakia, focusing on the discrepancy between what the current workforce possesses and what employers require, based on different sectors and types of employers:

Table 3 Overview of the skill gaps for key positions in AI & ethics in Slovakia

AI Research Scientist	
Current Skills: Basic AI knowledge, programming skills	
Required Skills: Advanced machine learning, ethics in AI	
Sector: Academia/ Research	**Type of Employer**: Universities, Research Institutes
Skill Gap Description: Lack of advanced research skills and understanding of ethical implications in AI.	

AI Ethics Specialist	
Current Skills: General knowledge of AI ethics	
Required Skills: In-depth knowledge of regulations, frameworks	
Sector: Legal/ Consulting	**Type of Employer**: Law Firms, Consulting Firms
Skill Gap Description: Limited expertise in specific regulatory frameworks governing AI use.	
Machine Learning Engineer	
Current Skills: Basic ML algorithms	
Required Skills: Deep learning, model interpretability	
Sector: Technology	**Type of Employer**: Tech Companies
Skill Gap Description: Shortage of skills in advanced machine learning techniques and model transparency	
Generative AI Expert	
Current Skills: Basic understanding of generative models	
Required Skills: Advanced generative techniques, ethical considerations in AI outputs	
Sector: Technology	**Type of Employer**: Tech Companies, Startups
Skill Gap Description: Lack of specialized knowledge in generative models and their ethical implications.	

5.2.3 Summary & recommendations

The analysis of the current workforce in Slovakia reveals significant skill gaps in the field of AI and ethics, particularly for key positions such as AI Research Scientist, Machine Learning Engineer, and Generative AI Expert. The discrepancies between the skills possessed by the workforce and those required by employers highlight the urgent need for targeted interventions.

Key Findings

- Lack of advanced technical skills: Many professionals lack advanced knowledge in machine learning, deep learning, and generative AI techniques, which are essential for roles like Machine Learning Engineer and Generative AI Expert.
- Insufficient understanding of ethical implications: There is a notable gap in understanding the ethical considerations surrounding AI technologies. This is critical for roles such as AI Ethics Specialist and Policy Maker.
- Limited regulatory knowledge: Professionals in legal and consulting sectors need more in-depth knowledge of regulations governing AI to effectively advise clients and shape policies.
- Need for practical experience: Many positions require hands-on experience with AI tools and technologies, which is often lacking among candidates.

Recommendations to Close Skill Gaps

- Targeted training programs: develop specialized training programs focusing on advanced machine learning, ethical AI practices, and regulatory frameworks. Collaborate with universities and technical institutes to create curricula that address these gaps.
- Upskilling initiatives for current workforce: implement upskilling initiatives within organizations to enhance existing employees' skills in AI technologies and ethical considerations through workshops and online courses.
- Partnerships with industry leaders: foster partnerships between educational institutions and industry leaders to ensure curriculum relevance and provide students with practical experience through internships or co-op programs.
- Promote awareness of ethical implications: conduct awareness campaigns focused on the ethical implications of AI technologies among professionals in all sectors to cultivate a culture of responsibility in AI development and deployment.
- Regulatory training for legal professionals: provide training sessions for legal professionals on current regulations related to AI, emphasizing compliance and ethical standards to better equip them for advisory roles.
- Encourage research and development: support research initiatives that explore the intersection of AI technology and ethics, fostering innovation while addressing potential societal impacts.

5.2.4 References & resources

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5.3 Big Data

5.3.1 Identified roles, jobs, skills & competency profiles

List of specific roles = professionals working with the big data

In Slovakia, the most requested and difficult-to-hire positions include:

- Software Engineer: High demand across industries, especially in IT, finance, and telecommunications. Difficulty arises in finding candidates with specific expertise, such as cloud technologies or security solutions.
- Data Scientist and Data Analyst: Significant demand due to the growing importance of data-driven decision-making in sectors such as banking, telecoms, and IT services. However, there's a lack of experienced professionals with in-depth knowledge of machine learning, data mining, and business intelligence.
- Full Stack Developer and Front-End Developer: These roles are also highly sought after, particularly by tech companies. While there are available candidates, those with expertise in cutting-edge frameworks and full proficiency in both front-end and back-end technologies are scarce.
- DevOps Engineer: In high demand due to the shift toward continuous integration and delivery. The position requires a deep understanding of both software development and IT operations, making it challenging to find qualified candidates with this dual skill set.
- Senior Software Engineer: Senior-level positions are especially hard to fill, as they require a mix of experience, leadership, and advanced technical knowledge. These roles often remain open longer than mid-level or junior roles due to the high level of specialization required.

In Slovakia, the combination of demand for advanced technical skills and a relatively small pool of experienced professionals makes hiring for these roles particularly difficult. <u>Positions like software engineers, data analysts, and front-end developers are among the most requested but also difficult to hire</u>. Key challenges include a shortage of specialists with both the technical and soft skills needed for these roles, particularly in advanced areas like AI, big data, and software development.

Profile/description/competency profile and skills list for the most common jobs/roles for the respective ATI

Data analyst

- Key responsibilities
  - Data collection and extraction: Accessing Data: Extract data from various databases (SQL, NoSQL, or cloud-based systems) as per business requirements; Data Wrangling: Clean, transform, and integrate data from multiple sources to ensure consistency and quality.
  - Data Analysis and Interpretation: Statistical Analysis: Apply statistical techniques (e.g., regression, time series analysis) to analyze data and identify patterns, trends, and relationships; Exploratory Data Analysis (EDA): Conduct EDA to understand data

structure and highlight important variables; Predictive Analytics: Use predictive models to forecast trends and behaviours based on historical data (relevant for financial and cybersecurity sectors).

- Reporting and visualization: Data Visualization: Design dashboards and reports using Tableau, Power BI, or other visualization tools to present data insights clearly and visually. Business Reporting: Translate technical data findings into business-oriented reports for key stakeholders, enabling data-driven decision-making.
- Collaboration with stakeholders: Work closely with teams such as marketing, finance, cybersecurity, and product development to gather requirements and deliver actionable insights; Present insights to business leaders and external clients, explaining data findings in simple, understandable terms.
- Quality Assurance & Documentation: Data Quality Checks: Ensure the accuracy, completeness, and reliability of the data used in reports and analyses; Documentation: Maintain proper documentation for data models, analytical processes, and data sources to ensure transparency and ease of future modifications.

- Core Competencies
  - Data Collection and Preparation
  - Proficiency in SQL: Strong ability to extract data from relational databases.
  - Data Cleansing and Wrangling: Handling messy, incomplete data using tools like Python or R.
  - ETL (Extract, Transform, Load): Experience in data pipelines and integrating multiple sources of data.
  - Statistical Analysis & Interpretation
  - Quantitative Skills: Knowledge of statistical techniques (regression, hypothesis testing).
  - Tools: Experience with software like R, Python (pandas, numpy), and statistical software (SAS, SPSS).
  - Data Visualization
  - Proficiency in Tools: Ability to create dashboards and reports using tools like Tableau, Power BI, or Qlik.
  - Communicating Insights: Translating complex data into actionable insights for non-technical stakeholders.
  - Machine Learning (ML) Basics
  - Familiarity with Algorithms: Knowledge of predictive analytics and ML concepts like classification, clustering, and regression.
  - Tools: Basic understanding of machine learning libraries (e.g., Scikit-learn, TensorFlow).
  - Business Acumen
  - Sector Knowledge
  - Problem-Solving: Using data to address specific business challenges such as customer behaviour, operational efficiency, and fraud detection.

- Soft Skills
  - Communication: Ability to explain data insights to both technical and non-technical audiences.
  - Collaboration: Working closely with cross-functional teams such as IT, finance, and marketing.
  - Attention to Detail: Ensuring data accuracy and integrity.

Senior software engineer

- Key Responsibilities
  - Deliver high-quality modern user experiences built in modern Front-End and Back-End (React Native, Node.js, TypeScript, JavaScript, Java/.NET) frameworks and libraries.
  - Utilize APIs, connectors, and middleware tools to achieve system interoperability.
  - Leverage best practices, Object Oriented JavaScript programming and TypeScript frameworks.
  - Build interfaces for modern internet applications using the latest front-end and back-end technologies.
  - Implement reusable libraries across applications.
  - Ensure responsive design works across computing platforms.
  - Develop application code and unit tests in selected framework and/or library.
  - Ensure high performance for global users through performance tests and tuning.
  - Partner with the design team around usability and UI/UX concerns.
  - Mentor a development team in building custom applications, workflows, and integrations.
  - Participate in setting coding standards, conduct code reviews, and ensure adherence to best practices. Offer expertise and support in troubleshooting and resolving technical issues.
  - Mentor the team through work estimation based on user stories and functional requirements or wireframes.
  - Write unit and integration tests for all application code.
  - Collaborate with business stakeholders to understand business requirements and design technical solutions. Create architectural diagrams, define system integrations, and establish best practices for development.
  - Collaborate with cross-functional technical teams, including business analysts, project managers, and technical engineers in other global locations, to understand requirements, provide technical insights, and ensure successful project delivery. Communicate effectively to convey technical concepts to non-technical stakeholders.
- Core competencies & skills
  - hands-on experience as a full-stack engineer focused on mobile with following tech stack: React Native, React, Node.js or similar.
  - Hands-on experience and/or willingness to learn new technologies (including Low-Code platforms like Mendix and/or similar.) and adapt to changing business needs.
  - Familiarity with Agile methodologies and project management tools.

- Experience in prototyping, as well as operating at scale, with focus on writing clean, encapsulated and well documented code.
- Extensive experience in designing and implementing integrations between systems using middleware tools. Familiarity with various integration patterns, protocols, and technologies (such as REST, SOAP, JSON, XML).
- Adept at analyzing complex technical issues, identifying root causes, and implementing effective solutions. Proficient in debugging, performance optimization, and troubleshooting mobile/web applications.

- Soft Skills
  - Guiding and mentoring development teams. Ability to provide technical guidance, set coding standards, conduct code reviews, and ensure adherence to best practices.
  - Strong communication and collaboration skills to work effectively with cross-functional teams and stakeholders
  - Strong oral and written communication skills, business acumen, and enterprise knowledge

Data Lakehouse Developer

- Key Responsibilities
  - Design and implementation of lake house solutions within the Microsoft Azure cloud environment.
  - Development and maintenance of data integration processes to ensure the accuracy and completeness of data in the data warehouse.
  - Collaboration with the team, which operates in a Scrum, to understand their data requirements and develop data solutions to meet those requirements.
  - Monitor data lake performance and identify opportunities for improvement.
  - Develop and maintain data dictionaries, metadata, and other documentation.
  - Troubleshoot issues and perform root cause analysis to identify and resolve problems.
  - Develop and maintain automated processes to ensure data quality, consistency, and completeness

- Competency Profile & required skills
  - Strong knowledge of SQL and experience with data warehousing and ETL tools.
  - Knowledge of Microsoft Azure Cloud technology and its related services, such as Azure Data Factory and Azure Databricks.
  - Ability to analyze and interpret complex data and translate business requirements into technical solutions.
  - Strong verbal and written communication skills.
  - Experience working in a Scrum environment.
  - Ability to identify and resolve technical issues and propose and implement effective solutions.
  - Desire to stay current with new technologies, methodologies, and best practices in data warehousing.
  - Ability to work well in a team environment and collaborate effectively with colleagues and stakeholders.

- Knowledge and experience with lake house methodologies optional.

Who is hiring: current & potential employers

- Companies like Eset, Deutsche Telekom IT Solutions, Slovak Telecom, IT services, IBM Slovakia, and AT& T and Accenture are among the main recruiters.
- Banks: Tatra Banka, VÚB Banka, Slovenska sporitelna
- Tech companies: like Innovatrics and DXC Technology
- DXC Technology, GlobalLogic
- Volkswagen Slovakia, Kia Motors Slovakia

Common degrees of professionals in the Big Data

In Slovakia, professionals in Big Data typically hold a mix of Bachelor's (Bc.) and Master's (Magister or Ing.) degrees from the universities, depending on their level of expertise and the specific job requirements.

- Bachelor's Degree (Bc.), Duration: Typically, 3 years. Common fields include Computer Science, Informatics, and Mathematics. Students gain foundational knowledge in programming, data structures, algorithms, and basic data analysis.
- Master's Degree (Magister or Ing.): Duration: Usually 2 additional years after completing the bachelor's. Master's programs, especially in Data Science, Artificial Intelligence, and Big Data, focus on advanced analytics, machine learning, and complex data management.

Many Big Data professionals pursue master's degrees for roles requiring deep technical skills, though bachelor’s degrees are still common in entry-level data analysis or programming roles.

5.3.2 Skill Gap Analysis

Across all roles, there is a general shortage of advanced technical skills, especially in areas like cloud computing, big data, AI, and automation. Additionally, soft skills such as communication, leadership, and project management are often missing, particularly for senior-level roles. Employers are also increasingly looking for individuals with a cross-disciplinary skillset—not only technical abilities but also an understanding of business processes and sector-specific challenges, which the current workforce in Slovakia struggles to meet.

In the list below we provide an overview of the skill gaps for key positions in Slovakia, focusing on the discrepancy between what the current workforce possesses and what employers require, based on different sectors and types of employers:

Data Analyst

- **Sector**: Banking, Telecommunications, IT services
- **Type of Employer**: Tatra Banka, Slovak Telekom, Eset, Innovatrics
- Skill Gaps:
  - Advanced Data Analytics: There's a lack of candidates proficient in predictive analytics and machine learning models. Employers are looking for analysts with expertise in data science tools like R, Python, and advanced SQL, but most applicants have only intermediate-level knowledge.
  - Business Intelligence: Insufficient experience with business intelligence tools such as Power BI, Tableau, or QlikView.
  - Soft Skills: Communication and storytelling with data are frequently lacking, with many candidates struggling to effectively translate data insights into actionable business strategies.

Front-End Developer

- **Sector**: IT, eCommerce, Telecommunications
- **Type of Employer**: Accenture, DXC Technology, & Amazon's development centres.
- Skill Gaps:
  - Advanced Frameworks: basic front-end skills (HTML, CSS, JavaScript) are common, many developers lack proficiency in modern frameworks like React, Angular, or Vue.js, which are in high demand.
  - Cross-Platform Development: Candidates often lack experience in building responsive designs that work seamlessly across mobile, desktop, and tablet platforms.
  - UX/UI Design: Many front-end developers have weak knowledge of user experience (UX) and user interface (UI) design principles.

Data Scientist

- **Sector**: IT, Financial Services, Manufacturing
- **Type of Employer**: Banks (VÚB Banka, Tatra Banka), Tech companies, and large manufacturers.
- Skill Gaps:
  - Deep Learning and AI: Many applicants lack hands-on experience with deep learning frameworks (e.g., TensorFlow, PyTorch). Employers need professionals who can develop and deploy complex AI models.
  - Big Data Management: a gap in experience with big data ecosystems such as Hadoop, Spark, & NoSQL databases.
  - Domain Knowledge: Employers seek data scientists who understand business-specific problems and industry contexts (e.g., financial risk in banking), which many candidates lack.

Software Engineer

- **Sector**: IT, Telecommunications, Automotive
- **Type of Employer**: Siemens, AT&T, Accenture, and Deutsche Telekom IT Solutions
- Skill Gaps:
  - Cloud Computing: often lack experience with cloud platforms such as AWS, Azure, and Google Cloud,
  - DevOps Integration: lack of understanding or experience with DevOps principles and tools like Jenkins, Docker, or Kubernetes, which employers increasingly expect.
  - Agile Methodologies: Experience with Agile development & Scrum project management is often missing

Full Stack Developer

- **Sector**: IT services, eCommerce
- **Type of Employer**: Innovatrics, DXC Technology, and tech startups
- Skill Gaps:
  - Back-End Knowledge: lack experience with back-end technologies such as Node.js, Django, or Ruby on Rails.
  - Database Management: Insufficient knowledge of database design & management (both SQL & NoSQL databases).
  - API Development: Full-stack developers are expected to be proficient in API design and development, yet many lack this crucial skill.

Development Operations Engineer (DevOps Engineer)

- **Sector**: IT, Telecommunications, eCommerce
- **Type of Employer**: Eset, Accenture, and Deutsche Telekom IT Solutions
- Skill Gaps:
  - Continuous Integration/Continuous Deployment (CI/CD): Lack of experience with tools like Jenkins, CircleCI, or GitLab CI/CD, which are crucial for modern DevOps practices.
  - Automation and Scripting: Many candidates are not proficient in scripting languages such as Python or Bash, which are needed to automate tasks in DevOps.
  - Containerization: There’s a significant gap in understanding and managing container technologies (Docker, Kubernetes).

Senior Software Engineer

- **Sector**: IT, Automotive, Financial Services
- **Type of Employer**: Siemens, AT&T, and Eset
- Skill Gaps:
  - Leadership and Mentorship: many lack the leadership & mentoring.
  - Architectural Design: Experience with large-scale software system design and architecture is often insufficient.
  - Project Management: Many candidates lack experience with managing complex projects, including time and resource management.

Data Lakehouse Developer

- **Sector**: finance, telecommunications, IT consulting, technology, manufacturing
- **Type of Employer**: Slovenská sporiteľňa and Tatra banka, VÚB, Slovak Telekom, Orange Slovakia, Accenture Slovakia, IBM Slovakia, and AT&T, DXC Technology, GlobalLogic, Volkswagen Slovakia, Kia Motors Slovakia
- Skill Gaps:
  - Advanced Data Lakehouse Expertise: There is a shortage of developers proficient in Delta Lake or Databricks—technologies crucial for modern data lakehouse architecture.
  - Cloud-Native Data Solutions: there is a gap in deep knowledge of cloud-native data platforms like Snowflake or AWS Redshift.
  - Real-Time Data Processing: Professionals lack sufficient experience with real-time data streaming tools like Kafka or Spark Streaming, which are highly sought after by employers.
  - Data Governance: Knowledge of how to ensure compliance with GDPR and other data regulations, especially in the context of massive data lakes, is limited.
  - Automation & Orchestration: There is a gap in the ability to implement and manage sophisticated automation pipelines with tools like Apache Airflow.
  - AI/ML Integration: While some developers have basic AI skills, integrating these into data lakehouse environments is a gap that many employers are struggling to fill.

This mismatch between supply and demand for key skills is a significant challenge, making recruitment difficult and slowing down the adoption of new technologies in various industries.

5.3.3 Summary & recommendations

For Big Data professionals in Slovakia, we can see several critical skill gaps which need immediate attention to meet employers' demands. These gaps are common in the following areas such as:

- Advanced Data Analytics: Expertise in applying machine learning and deep learning techniques to large datasets to drive decision-making and business intelligence.
- Cloud Data Infrastructure Management: Knowledge of cloud-based big data solutions, such as Apache Spark, Hadoop, Kafka, and Databricks, is underrepresented.
- Data Governance and Security: low proficiency in data privacy, security protocols, and compliance frameworks for big data is urgently needed.
- Real-Time Data Processing: Skills gap in real-time data processing technologies like Kafka, Flink, and real-time analytics tools are in high demand.
- Data Visualization and Communication: low skills in data visualization tools use like Tableau, Power BI, and the ability to communicate insights effectively to non-technical stakeholders.
- Soft skills: communication, project management incl. agile methods

Addressing these skill gaps is critical for Slovakia's big data workforce to align with industry needs and stay competitive in sectors like finance, manufacturing, telecommunications, and IT services.

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5.4 Blokchain

5.4.1 Identified roles, jobs, skills & competency profiles

The blockchain sector in Slovakia is growing rapidly, and there is a significant demand for skilled professionals. The roles of Blockchain Developer, Blockchain Consultant, and Smart Contract Developer are particularly prominent. However, there are notable skill gaps and critical skills that are difficult to find in the labour market, highlighting opportunities for training and development in these areas.

List of specific roles, professionals working with the block chain in Slovakia

Role	Description
Blockchain Developer	Responsible for designing, implementing, and maintaining blockchain applications and smart contracts.
Blockchain Consultant	Provides expertise to organizations on how to implement blockchain technology effectively.
Blockchain Researcher/Academic	Engages in research related to blockchain technology, its applications, and its implications in various fields.
Smart Contract Developer	Specializes in creating and auditing smart contracts on blockchain platforms.
Cryptocurrency Analyst	Analyzes market trends and provides insights related to cryptocurrencies and blockchain projects.
Product Manager for Blockchain Solutions	Oversees the development and launch of blockchain-based products and services.
Regulatory Compliance Specialist	Ensures that blockchain projects comply with legal and regulatory requirements.
UI/UX Designer for Blockchain Apps	Designs user interfaces and experiences for blockchain applications to enhance usability.

Profile/description/competency profile and skills list for the most common jobs/roles for the Block chain

Blockchain Developer

Key Responsibilities	Core Competencies	Soft Skills
Design and develop blockchain based applications and systems	Proficiency in programming languages (e.g., Solidity, Java, C++)	Strong problem solving skills

Key Responsibilities	Core Competencies	Soft Skills
Implement and maintain smart contracts	Understanding of blockchain architecture and protocols	Excellent communication skills
Integrate blockchain solutions with existing systems	Knowledge of cryptography and security best practices	Ability to work collaboratively in teams
Conduct code reviews and optimize blockchain applications for performance	Familiarity with decentralized applications (DApps)	Adaptability to changing technologies
Stay updated on the latest blockchain technologies and trends	Experience with version control systems (e.g., Git)	Attention to detail

Blockchain Consultant

Key Responsibilities	Core Competencies	Soft Skills
Provide strategic advice on blockchain implementation	Deep understanding of blockchain technology	Strong analytical thinking
Assess client needs and develop tailored blockchain solutions	Knowledge of regulatory frameworks related to blockchain	Excellent interpersonal skills
Conduct workshops and training sessions for clients	Business analysis and project management skills	Effective communication
Collaborate with technical teams to ensure successful project delivery	Familiarity with various blockchain platforms	Problem solving abilities
Monitor industry trends and provide insights to clients	Ability to evaluate technology solutions	Flexibility in adapting to client needs

Smart Contract Developer

Key Responsibilities	Core Competencies	Soft Skills
Develop, test, and deploy smart contracts	Proficiency in smart contract programming (e.g., Solidity)	Strong attention to detail
Conduct security audits on smart contracts	Understanding of blockchain security principles	Critical thinking
Collaborate with other developers to integrate smart contracts into applications	Knowledge of decentralized application development	Good communication skills
Optimize smart contracts for efficiency and cost effectiveness	Familiarity with testing frameworks for smart contracts	Ability to work under pressure
Stay informed about advancements in smart contract technology	Experience with development tools (e.g., Truffle, Hardhat)	Teamwork and collaboration

Who is hiring: current & potential employers

The demand for blockchain professionals in Slovakia is growing, with various companies across different sectors actively hiring for roles such as Blockchain Developer, Blockchain Consultant, and Smart Contract Developer. These employers range from startups to established corporations and cover a variety of industries including finance, gaming, cybersecurity, and consulting. This reflects the increasing integration of blockchain technology into various business processes and the need for skilled professionals in this area.

- BTCS Slovakia s.r.o., A subsidiary of Bitcoin Suisse, focusing on crypto asset investing and blockchain technology, hiring Blockchain Developer, Blockchain Consultant
- Localhost.company, a software engineering company based in Košice, specializing in agile development and blockchain solutions, Blockchain Developer
- Intellica, an IT solutions provider that focuses on innovative software development and blockchain projects. hiring Blockchain Consultant
- ESET, a well-known cybersecurity company exploring blockchain applications for security solutions` hiring Blockchain Developer
- Slovenská sporiteľňa, the largest bank in Slovakia, looking into blockchain for financial services and innovations; hiring Blockchain Consultant
- Innovatrics, a technology company specializing in biometric solutions, also exploring blockchain technologies; hiring Smart Contract Developer
- Blockchain Slovakia, an organization that connects researchers, developers, and businesses to promote blockchain technology; hiring various roles including Consultants.
- Pixel Federation, a gaming company interested in integrating blockchain technology into gaming solutions; hiring Blockchain Developer
- Sli.do, a company focused on event management tools, exploring blockchain for enhancing user experience; hiring Blockchain Consultant.

Common degrees of professionals in the Big Data

Professionals in the blockchain field in Slovakia commonly hold degrees in Computer Science, Fintech, Economics, Information Systems, and advanced research degrees (PhDs) related to blockchain technology. These educational backgrounds provide the necessary technical expertise and understanding of the economic implications of blockchain applications, preparing graduates for various roles within the industry.

5.4.2 Skill Gap Analysis

In the Table below we provide an overview of the skill gaps for key positions in Slovakia, focusing on the discrepancy between what the current workforce possesses and what employers require, based on different sectors and types of employers:

Blockchain Developer

Skill Gap	Current Workforce
▪ Proficiency in specific blockchain platforms (e.g., Ethereum, Hyperledger) ▪ Smart contract development skills ▪ Cryptography and security best practices	▪ Limited experience with advanced platforms ▪ Basic understanding of smart contracts ▪ General IT security knowledge
Employer Requirements	**Sector**
▪ Strong knowledge of multiple blockchain frameworks ▪ Advanced skills in writing and auditing smart contracts ▪ In-depth knowledge of cryptographic algorithms and security protocols	▪ Technology, Finance ▪ Technology, Startups ▪ Technology, Cybersecurity

Blockchain Consultant

Skill Gap	Current Workforce
▪ Understanding of regulatory frameworks ▪ Business analysis skills ▪ Strategic thinking	▪ Basic knowledge of regulations ▪ Limited business analysis experience ▪ Some strategic planning experience
Employer Requirements	**Sector**
▪ Comprehensive understanding of blockchain regulations and compliance issues ▪ Strong analytical skills to assess client needs and develop solutions ▪ Ability to develop long-term strategies for blockchain implementation	▪ Consulting, Finance ▪ Consulting, Corporations ▪ Consulting, Technology

Smart Contract Developer

Skill Gap	Current Workforce
▪ Security auditing skills ▪ Advanced programming (e.g., Solidity) ▪ Decentralized application (dApp) development knowledge	▪ Basic coding skills ▪ Familiarity with basic programming ▪ Limited experience with dApps
Employer Requirements	**Sector**
▪ Expertise in security audits for smart contracts to prevent vulnerabilities ▪ Proficiency in Solidity and other relevant languages for smart contract development ▪ Strong understanding of building and integrating ▪ dApps with blockchain solutions	▪ Technology, Finance ▪ Technology, Startups ▪ Technology, Startups

This table provides a clear overview of the skill gaps for Blockchain Developers, Blockchain Consultants, and Smart Contract Developers in Slovakia. It identifies the current capabilities of the workforce compared to employer expectations across various sectors. Addressing these gaps through targeted training and educational initiatives will be essential for meeting the growing demand for skilled professionals in the blockchain field.

5.4.3 Summary & recommendations

The skill gaps identified for Blockchain Developers, Blockchain Consultants, and Smart Contract Developers in Slovakia highlight significant discrepancies between the current workforce's capabilities and employer expectations. Key areas of concern include:

- Technical Proficiency: There is a noticeable lack of advanced technical skills related to specific blockchain platforms, smart contract development, and cryptographic knowledge.
- Regulatory Understanding: Many professionals lack comprehensive knowledge of the regulatory landscape surrounding blockchain technology.
- Business Acumen: Skills related to strategic thinking and business analysis are often underdeveloped among candidates.

These gaps present opportunities for targeted training programs and educational initiatives to better align workforce skills with industry requirements. Addressing these skill shortages will be crucial for enhancing the competitiveness of Slovakia's blockchain sector.

Based on the identified critical skill gaps in the blockchain field in Slovakia, here are proposed solutions to address these gaps, focusing on the discrepancies between current workforce capabilities and employer requirements.

Addressing the critical skill gaps in the blockchain sector in Slovakia requires a multifaceted approach involving targeted training, collaboration between educational institutions and industry, and the establishment of mentorship programs. By focusing on these areas, Slovakia can enhance its workforce's capabilities in blockchain technology, ultimately supporting economic growth and innovation in this rapidly evolving field.

Critical Skill Gap	Proposed Solutions
Proficiency in Specific Blockchain Platforms	▪ **Targeted Training Programs**: Develop specialized training programs focused on popular blockchain platforms (e.g., Ethereum, Hyperledger) through partnerships with educational institutions and industry experts. ▪ **Online Learning Platforms**: Utilize online platforms offering courses specifically on blockchain technologies to increase accessibility for working professionals.
Smart Contract Development Skills	▪ **Workshops and Bootcamps**: Organize intensive workshops and bootcamps that focus on smart contract development, including hands-on coding sessions. ▪ **Mentorship Programs**: Establish mentorship programs pairing experienced developers with novices to enhance practical skills and knowledge transfer.

Critical Skill Gap	Proposed Solutions
Cryptography and Security Best Practices	▪ **Certification Programs**: Create certification programs in blockchain security and cryptography to ensure a standardized level of expertise among professionals. ▪ **Collaboration with Cybersecurity Firms**: Partner with cybersecurity firms to provide training on best practices for securing blockchain applications.
Understanding of Regulatory Frameworks	▪ **Educational Seminars**: Host seminars and webinars focused on the legal and regulatory aspects of blockchain technology, targeting both current professionals and students. ▪ **Collaboration with Regulatory Bodies**: Work with government agencies to ensure that training reflects current regulations and compliance requirements.
Business Analysis Skills	▪ **Cross-Disciplinary Courses**: Offer courses that combine business analysis with technical blockchain knowledge, emphasizing real-world applications. ▪ **Internships and Practicums**: Facilitate internships or practicums within companies that utilize blockchain technology, allowing participants to gain hands-on experience in business analysis roles.
Security Auditing Skills for Smart Contracts	▪ **Advanced Workshops**: Provide advanced workshops focused on security auditing of smart contracts, including case studies of past vulnerabilities. ▪ **Collaboration with Academic Institutions**: Partner with universities to integrate security auditing into their computer science or IT curricula, ensuring future graduates are well-prepared.

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5.5 ICT for Sustainability

5.5.1 Identified roles, jobs, skills & competency profiles

List of specific roles = professionals working with the in ICT for sustainability in Slovakia

The table below provides an overview of various roles in the ICT for sustainability field in Slovakia along with the companies that are actively hiring for these positions. The demand for these roles reflects the growing emphasis on integrating sustainability into technological solutions across different sectors.

Role	Description	Companies hiring
Sustainability Data Analyst	Analyzes data related to environmental impact and sustainability metrics, using ICT tools to track and report on sustainability performance within organizations.	Axians, T-Systems
ESG Reporting Specialist	Focuses on Environmental, Social, and Governance (ESG) reporting, ensuring compliance with regulations and helping companies communicate their sustainability efforts.	Accace, various consulting firms
Green IT Consultant	Advises organizations on how to implement sustainable IT practices, including energy-efficient data centres and responsible e-waste management.	T-Systems, Greenway
ICT Sustainability Manager	Oversees the integration of sustainable practices within the ICT department, focusing on reducing carbon footprints and promoting eco-friendly technologies.	Sensoneo, Axians
Smart City Planner	Works on projects that utilize ICT to enhance urban sustainability, focusing on smart infrastructure, energy efficiency, and improved public services through technology.	Municipalities, various tech firms
Renewable Energy Systems Engineer	Designs and implements ICT solutions for renewable energy systems, ensuring efficient energy use and integration with existing infrastructure.	Greenway
Sustainable Software Developer	Develops software solutions that prioritize sustainability, such as applications for energy management or tools that support sustainable business practices.	Various tech startups
AI for Sustainability Researcher	Conducts research on using artificial intelligence to solve sustainability challenges, such as optimizing resource use or predicting environmental impacts.	Universities, R&D institutions
Digital Transformation Specialist	Facilitates the digital transformation of businesses with a focus on sustainable practices, helping organizations adopt technologies that reduce environmental impact.	Axians, T-Systems
Circular Economy Consultant	Advises companies on implementing circular economy principles through ICT solutions, promoting recycling, reuse, and sustainable product design.	Various consulting firms

Profile/description/competency profile and skills list for the most common jobs/roles for the ICT for sustainability in Slovakia

Based on the search results and the current trends in the ICT for sustainability field in Slovakia, here are three of the most demanded roles along with their competency profiles and skills lists:

Sustainability Data Analyst

Competency Profile	Skills
Data Analysis	Proficient in data analysis tools (e.g., Excel, R, Python)
Sustainability Metrics	Knowledge of sustainability metrics and reporting frameworks (e.g., GRI, ESG)
Statistical Analysis	Strong background in statistical analysis and modelling
Communication Skills	Ability to communicate complex data insights to non-technical stakeholders
Problem-Solving	Strong analytical and problem-solving skills
Technical Proficiency	Familiarity with databases, data visualization tools (e.g., Tableau, Power BI)

Green IT Consultant

Competency Profile	Skills
Sustainable Practices	In-depth knowledge of sustainable IT practices and green technologies
Project Management	Experience in managing projects related to IT sustainability
Technical Expertise	Understanding of energy-efficient systems and e-waste management
Regulatory Knowledge	Familiarity with environmental regulations and standards
Client Engagement	Strong interpersonal skills for client consultations and relationship management
Training & Development	Ability to train staff on sustainable IT practices

AI for Sustainability Researcher

Competency Profile	Skills
Research Skills	Strong research skills with a focus on AI applications in sustainability
Machine Learning Knowledge	Proficiency in machine learning algorithms and techniques
Data Management	Experience in managing large datasets related to environmental impact
Ethical Considerations	Understanding of ethical implications of AI technologies
Collaboration Skills	Ability to work collaboratively with interdisciplinary teams
Publication & Communication	Skills in writing research papers and presenting findings to various audiences

Three roles described above are among the most demanded positions in the ICT for sustainability sector in Slovakia. Each role requires a unique set of competencies and skills that align with the growing emphasis on sustainability within the ICT field.

Common degrees of professionals in the sector of ICT for sustainability

The degrees given below, reflect the educational pathways that professionals in the ICT for sustainability sector typically pursue in Slovakia. The combination of technical skills from computer science and ICT programs with environmental knowledge from sustainability-focused degrees equips graduates to address the challenges of integrating technology with sustainable practices.

- Bachelor's in Computer Science: Focuses on programming, software development, and system design. Graduates are equipped with the skills needed for various roles in the ICT sector, including those related to sustainability.
- Master's in Environmental Management: Covers ecological principles, sustainability practices, and environmental policies. Prepares graduates to integrate ICT solutions into environmental management and sustainability efforts.
- Bachelor's in Environmental Studies: Provides interdisciplinary knowledge about environmental science, ecology, and sustainable development. Graduates understand the impact of technology on the environment and can work on sustainability projects.
- Master's in Information and Communication Technologies (ICT): Emphasizes advanced ICT skills, including data management and software engineering. Graduates can apply these skills to develop sustainable technology solutions.
- Bachelor's in Renewable Energy Engineering: Focuses on technologies related to renewable energy sources and their integration with ICT systems. Graduates are prepared for roles that combine energy management with technology.

5.5.2 Skill Gap Analysis

The table below highlights the required skills for each position, the current skills possessed by the workforce, identified skill gaps, and potential sectors or employers that are hiring for these roles. The analysis indicates a need for targeted training and development programs to bridge these skill gaps and enhance the capabilities of professionals in the ICT for sustainability sector in Slovakia.

Sustainability Data Analyst

Required Skills	Current Workforce Skill
▪ Advanced data analysis (R, Python) ▪ Knowledge of sustainability metrics ▪ Data visualization tools (Tableau, Power BI) ▪ Statistical modelling	▪ Basic data analysis skills ▪ Limited experience with advanced tools ▪ Basic understanding of sustainability metrics
Skill Gap	**Sectors/Employers**
▪ Insufficient proficiency in advanced data analysis tools and techniques ▪ Lack of experience in sustainability-specific metrics and reporting frameworks	▪ Environmental consulting firms, Tech companies (e.g., T-Systems, Axians)

Green IT Consultant

Required Skills	Current Workforce Skill
▪ Knowledge of sustainable IT practices ▪ Project management skills ▪ Understanding of energy-efficient systems ▪ Regulatory compliance knowledge	▪ Basic IT skills ▪ Some project management experience ▪ Limited knowledge of green technologies
Skill Gap	**Sectors/Employers**
▪ Gaps in expertise regarding sustainable IT practices and energy efficiency standards ▪ Need for stronger project management skills specific to sustainability initiatives	▪ IT consulting firms, Energy companies (e.g., Greenway)

AI for Sustainability Researcher

Required Skills	Current Workforce Skill
▪ Machine learning algorithms ▪ Research methodologies ▪ Understanding of ethical AI implications ▪ Data management skills	▪ Basic understanding of AI concepts ▪ Limited research experience ▪ Some knowledge of data management
Skill Gap	**Sectors/Employers**
▪ Lack of advanced machine learning skills and research methodologies ▪ Insufficient understanding of ethical considerations related to AI applications in sustainability	▪ Academic institutions, Research organizations

5.5.3 Summary & recommendations for addressing skill gaps in the field of ICT for sustainability in Slovakia

The ICT for sustainability sector in Slovakia faces significant skill gaps that hinder its growth and ability to meet sustainability goals. The rapid technological advancements and the increasing demand for sustainable practices require a workforce equipped with specialized skills. Key findings indicate that professionals in roles such as Sustainability Data Analyst, Green IT Consultant, and AI for Sustainability Researcher often lack advanced technical skills, knowledge of sustainability metrics, and understanding of ethical implications related to technology.

The most important findings:

- Insufficient technical skills: many professionals do not possess the advanced data analysis, machine learning, or project management skills needed to effectively contribute to sustainability initiatives.
- Limited understanding of sustainability metrics: there is a gap in knowledge regarding specific sustainability metrics and reporting frameworks, which are crucial for roles focused on environmental impact.
- Lack of ethical awareness: professionals, particularly in AI roles, often lack a comprehensive understanding of the ethical implications of their work, which is essential for responsible technology deployment.

Recommendations for addressing existing skill gaps

- Develop targeted training programs create specialized training programs focusing on advanced data analysis, sustainable it practices, and ethical considerations in AI. Collaborate with educational institutions to design relevant curricula.
- Implement continuous professional development (CPD): encourage ongoing training and upskilling for current professionals through workshops, online courses, and certifications focused on sustainability-related ICT skills.
- Promote awareness of sustainability metrics: conduct workshops and seminars to educate professionals about key sustainability metrics and reporting frameworks relevant to their roles.
- Strengthen regulatory knowledge: provide training sessions on environmental regulations and compliance requirements to enhance professionals' understanding of their responsibilities in sustainability initiatives.
- Leverage government support programs:utilize government funding and support programs aimed at education and workforce development to finance training initiatives focused on sustainability skills.

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5.6 Industry 5.0

5.6.1 Identified roles, jobs, skills & competency profiles

List of specific roles = professionals working the in the sector Industry 5.0 in Slovakia

- Project manager: Essential for overseeing projects that integrate new technologies and methodologies associated with Industry 5.0.
- Automation engineer: This role is crucial in implementing and maintaining automated systems, which are central to Industry 5.0.
- Data Analyst for Industry 5.0: Acknowledged as a vital position due to the increasing reliance on data for decision-making and process optimization. Analyzes data generated from smart manufacturing systems to optimize production and improve decision-making
- Human-Robot Interaction Specialist: Focuses on designing and implementing effective interactions between humans and robots.
- Smart Manufacturing Engineer: Works on integrating smart technologies into manufacturing processes to enhance efficiency and flexibility.
- Sustainability Consultant: Advises companies on incorporating sustainable practices into their operations using advanced technologies.
- Cybersecurity Specialist: Ensures the security of interconnected systems and data in smart factories.

Profile/description/competency profile and skills list for the most common jobs/roles for the ICT for sustainability in Slovakia

Here are the competency profiles for three of the most common positions in the **Industry 5.0** sector in Slovakia: **Automation Engineer**, **Data Analyst**, and **Project Manager**. Each profile outlines the key competencies, skills, and knowledge areas required for success in these roles.

Automation Engineer

Competency Area	Details
Technical Skills	▪ Proficiency in programming languages (e.g., Python, C++) ▪ Knowledge of PLC and SCADA systems ▪ Familiarity with robotics and automation technologies ▪ Understanding of IoT and smart manufacturing systems ▪ Skills in data analysis and troubleshooting automation processes
Analytical Skills	▪ Ability to analyze complex systems and processes ▪ Strong problem-solving skills to identify and resolve technical issues
Social Skills	▪ Effective communication skills for collaboration with cross-functional teams ▪ Ability to work in diverse teams and environments

Competency Area	Details
Soft Skills	▪ Critical thinking for optimizing automation solutions ▪ Adaptability to rapidly changing technologies ▪ Continuous learning mindset to stay updated with industry advancements

Data Analyst for Industry 5.0

Competency Area	Details
Technical Skills	▪ Proficiency in data analysis tools (e.g., SQL, Python, R) ▪ Knowledge of data visualization software (e.g., Tableau, Power BI) ▪ Understanding of statistical methods and machine learning techniques ▪ Ability to manage large datasets and perform data cleaning
Analytical Skills	▪ Strong analytical thinking to interpret complex data sets ▪ Ability to derive actionable insights from data analysis
Social Skills	▪ Excellent communication skills for presenting findings to stakeholders ▪ Team collaboration skills for working on interdisciplinary projects
Soft Skills	▪ Creativity for developing innovative data solutions ▪ Attention to detail to ensure data accuracy ▪ Time management skills to prioritize tasks effectively

Project Manager

Competency Area	Details
Technical Skills	▪ Knowledge of project management methodologies (e.g., Agile, Scrum) ▪ Familiarity with digital tools for project tracking (e.g., JIRA, Trello) ▪ Understanding of budgeting and resource allocation
Analytical Skills	▪ Strong analytical skills for assessing project risks and outcomes ▪ Ability to evaluate project performance metrics
Social Skills	▪ Leadership skills to guide teams towards project goals ▪ Strong negotiation skills for stakeholder management
Soft Skills	▪ Excellent communication skills for conveying project objectives and updates ▪ Problem-solving abilities to address challenges during project execution ▪ Flexibility and adaptability in managing changing project requirements

These competency profiles highlight the diverse skill sets required for professionals in Industry 5.0 roles in Slovakia, emphasizing the integration of technical expertise with analytical and interpersonal abilities essential for navigating this advanced industrial landscape.

Common degrees of professionals in the sector of Industry 5.0 for sustainability

The evolution towards Industry 5.0 in Slovakia reflects a broader trend where educational institutions are adapting their curricula to meet the demands of this new industrial landscape, ensuring graduates are well-equipped for future challenges. The educational landscape for Industry 5.0 professionals in Slovakia is diverse, with a strong emphasis on engineering, technology, and sustainability. Graduates from institutions like the Slovak University of Technology and Technical University in Košice are well-prepared to meet the industry's evolving demands. Common Degrees in Industry 5.0:

- Engineering Degrees: Mechanical Engineering: Focuses on the design, analysis, and manufacturing of mechanical systems. Graduates are prepared for roles such as engineering technologists and production managers.
- Electrical Engineering: Covers the study of electrical systems and technologies, essential for automation and robotics in Industry 5.0
- Industrial Engineering: Emphasizes optimizing complex processes and systems, crucial for improving efficiency in production environments.
- Technology and Production Management:
- Production Technologies: This program combines engineering principles with management strategies to prepare graduates for roles in production planning and quality control.
- Additive Manufacturing: As a key component of Industry 5.0, professionals may specialize in 3D printing technologies, focusing on innovative manufacturing processes.
- Computer Science and Data Analytics: Degrees in Computer Science or Data Science are increasingly important due to the reliance on data analysis for decision-making and process optimization in smart factories4.
- Sustainability and Ethics: New roles such as Chief Sustainability Officer (CSO) or Chief Ethics Officer (EO) reflect the growing importance of sustainable practices and ethical considerations in industrial operation

5.6.2 Skill Gap Analysis

The table below highlights the required skills for each position, the current skills possessed by the workforce, identified skill gaps, and potential sectors or employers that are hiring for these roles. The analysis indicates a need for targeted training and development programs to bridge these skill gaps and enhance the capabilities of professionals in the Industry 5.0 sector in Slovakia.:

Project Manager

Competency Area	Details
Required Skills	▪ Project management methodologies (Agile, Waterfall) ▪ Strong leadership & team management skills ▪ Risk management & mitigation strategies ▪ Effective communication & stakeholder engagement

Competency Area	Details
Current Workforce Skills	▪ Basic project management skills ▪ Some leadership experience ▪ Basic risk assessment capabilities ▪ Good communication skills
Skill Gap	▪ Advanced knowledge of Agile methodologies & tools ▪ Enhanced leadership skills to manage cross-functional teams effectively ▪ Comprehensive risk management skills to proactively address potential project challenges ▪ Advanced stakeholder management & negotiation skills

Automation Engineer

Competency Area	Details
Required Skills	▪ Proficiency in automation technologies (e.g., PLC programming) ▪ Data analysis & troubleshooting skills ▪ Systems integration & IoT knowledge ▪ Understanding of cybersecurity measures for automated systems
Current Workforce Skills	▪ Basic knowledge of automation systems ▪ Some data analysis experience ▪ Limited experience with IoT integration ▪ Basic cybersecurity awareness
Skill Gap	▪ In-depth understanding of advanced automation technologies & programming ▪ Advanced data analytics skills to optimize automation processes ▪ Strong systems integration capabilities, especially with IoT devices ▪ Comprehensive knowledge of cybersecurity practices in industrial settings

Data Analyst for Industry 5.0

Competency Area	Details
Required Skills	▪ Proficiency in data analytics tools (e.g., SQL, Python) ▪ Data visualization & reporting skills ▪ Statistical analysis & machine learning techniques ▪ Ability to communicate insights effectively to stakeholders
Current Workforce Skills	▪ Basic data analysis skills ▪ Limited experience with visualization tools ▪ Basic understanding of statistics ▪ Good communication skills

Competency Area	Details
Skill Gap	▪ Advanced proficiency in data analytics tools & techniques ▪ Strong data visualization skills using tools like Tableau or Power BI ▪ In-depth knowledge of statistical methods & machine learning applications ▪ Enhanced ability to present complex data insights clearly to non-technical audiences

5.6.3 Summary & recommendations for addressing skill gaps in the field of Industry 5.0 in Slovakia

The most important findings:

As of January, 2025, the workforce in Slovakia faces significant skill gaps in key positions related to Industry 5.0, particularly for Project Managers, Automation Engineers, and Data Analysts. These gaps hinder the ability of organizations to effectively implement advanced technologies and human-centric approaches essential for Industry 5.0.

- Project Managers
  - Skill Gaps: Project managers often lack advanced knowledge in Agile methodologies, complex problem-solving, data-driven decision-making, and effective collaboration across interdisciplinary teams.
  - Impact: This limits their ability to manage projects that require flexibility and innovation in rapidly changing environments.
- Automation Engineers
  - Skill Gaps: Many automation engineers have insufficient proficiency in advanced automation technologies, data analytics, systems integration, and cybersecurity measures.
  - Impact: This affects their capability to design and implement efficient automated systems that align with Industry 5.0 principles.
- Data Analysts
  - Skill Gaps: Data analysts frequently lack advanced skills in data visualization tools, statistical analysis, machine learning techniques, and effective communication of insights.
  - Impact: This results in missed opportunities for data-driven decision-making that could enhance operational efficiency.

Recommendations for addressing existing skill gaps

- Targeted training programs: Develop specialized training programs focused on the critical skills identified for each position, including workshops on Agile project management, advanced data analytics, and automation technologies. Collaborate with educational institutions to create curricula that align with industry needs, ensuring that graduates are equipped with relevant skills.

- Continuous professional development: Encourage organizations to invest in ongoing professional development opportunities for current employees, including certifications in project management (e.g., PMP, Agile), data analytics (e.g., Tableau, SQL), and automation technologies. Promote a culture of lifelong learning within companies to keep pace with technological advancements.
- Interdisciplinary collaboration initiatives: Foster collaboration between different departments (e.g., IT, engineering, operations) to enhance communication skills and teamwork among professionals. Implement cross-functional project teams to provide practical experience in working collaboratively on complex projects.
- Mentorship programs: Establish mentorship programs where experienced professionals guide less experienced employees in navigating the challenges of Industry 5.0. Encourage knowledge sharing and best practices within organizations through structured mentorship initiatives.
- Focus on soft skills development: Integrate soft skills training into existing professional development programs to enhance communication, leadership, problem-solving, and adaptability. Conduct workshops that emphasize the importance of soft skills in achieving successful outcomes in interdisciplinary projects.
- Engagement with industry stakeholders: Collaborate with industry stakeholders to identify emerging trends and skill requirements specific to Industry 5.0. Create partnerships between businesses and educational institutions to ensure alignment between workforce needs and training programs.

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5.7 Internet of Things

5.7.1 Identified roles, jobs, skills & competency profiles

List of specific roles = professionals working with the in Artificial Intelligence in Slovakia

- IoT Solutions Architect
- Data Scientist
- IoT Software Developer
- Network Engineer
- IoT Security Specialist
- Systems Integrator

Profile/description/competency profile and skills list for the most common jobs/roles for the respective AI & ethics

In the IoT field in Slovakia, three of the most requested and difficult-to-hire positions are as follows.

IoT Solutions Architect

- Competency Profile:
  - System Design: Ability to design scalable and robust IoT architectures that integrate hardware, software, and network components.
  - Technical Leadership: Serve as the primary technical authority in projects, guiding teams on best practices and architectural standards.
  - Stakeholder Communication: Engage with stakeholders to gather requirements and translate them into technical specifications.
- Technical skills required:
  - Cloud Computing: Proficiency in cloud platforms (e.g., AWS, Azure) for deploying IoT solutions.
  - IoT Protocols: Deep understanding of communication protocols such as MQTT, CoAP, and HTTP.
  - Data Management: Skills in managing large datasets, including data collection, storage solutions, and analytics.
  - Security Practices: Knowledge of security frameworks and best practices for protecting IoT systems.
  - Programming Languages: Familiarity with languages like Python, Java, or C# for developing IoT applications.
- Soft skills required
  - Problem-Solving: Ability to identify issues and develop effective solutions, especially in complex IoT environments.
  - Communication: Strong verbal and written skills to explain technical concepts to non-technical stakeholders and collaborate with cross-functional teams.

- Adaptability: Willingness to learn and adapt to new technologies and methodologies as the field of IoT evolves.
- Leadership: Capacity to lead projects and mentor junior team members, ensuring alignment with organizational goals.
- Business Acumen: Understanding of business needs and the ability to align IoT solutions with strategic objectives.

Data Scientist

A Data Scientist in the IoT sector is responsible for extracting, analyzing, and interpreting complex data generated by IoT devices. This role requires a blend of technical expertise, analytical skills, and domain knowledge to transform raw data into actionable insights that support business decision-making.

- Competency Profile
  - Data Analysis & interpretation: Expertise in analyzing complex datasets to extract meaningful insights and drive decision-making. Proficient in statistical analysis and data mining techniques to identify patterns and trends Ability to interpret complex datasets and translate findings into strategic recommendations.
  - Algorithm Development: Ability to create predictive models and algorithms that enhance IoT functionalities.
  - Cross-Disciplinary Collaboration: Work with engineers and product managers to integrate data insights into IoT solutions.
  - Machine Learning and Predictive Modelling: Expertise in developing and implementing machine learning algorithms tailored for IoT data. Knowledge of supervised, unsupervised, and reinforcement learning techniques to build predictive models. Experience with libraries and frameworks like TensorFlow, Scikit-learn, or PyTorch for machine learning applications.
  - Data Visualization: Skills in using visualization tools (e.g., Tableau, Power BI) to create intuitive dashboards that communicate insights effectively. Ability to present complex data findings in a clear and engaging manner to stakeholders.
  - Domain Knowledge: Insight into specific industries (e.g., manufacturing, healthcare) to tailor data solutions that address unique challenges. Ability to align data science initiatives with business objectives and industry standards.
  - Model Deployment and MLOps: Experience in deploying machine learning models into production environments using tools like Docker and Kubernetes. Knowledge of MLOps practices to automate workflows and maintain model performance over time.
  - Data Governance and Ethics: Understanding of data privacy regulations (e.g., GDPR) and ethical considerations in data handling. Ability to implement best practices for data governance to ensure compliance and security.
- Technical skills required
  - Statistical Analysis: Strong foundation in statistics and experience with tools like R or Python libraries (Pandas, NumPy).
  - Machine Learning: Knowledge of machine learning algorithms and frameworks (e.g., TensorFlow, Scikit-learn).

- Big Data Technologies: Experience with big data platforms such as Hadoop or Spark for processing large volumes of data.
- Data Visualization: Proficiency in visualization tools (e.g., Tableau, Power BI) to present data findings effectively.
- Database Management: Skills in SQL and NoSQL databases for data storage and retrieval.

- Soft skills required
  - Analytical Thinking: Strong ability to analyze data trends and derive actionable insights from complex datasets.
  - Collaboration: Ability to work effectively in teams, often bridging the gap between technical and non-technical personnel.
  - Communication: Proficiency in presenting data findings clearly and concisely to stakeholders, ensuring comprehension of technical details.
  - Creativity: Innovative thinking to develop new models or approaches for data analysis and problem-solving.
  - Attention to Detail: Meticulousness in data handling and analysis, ensuring accuracy in results.

IoT Software Developer

An IoT Software Developer is responsible for designing, developing, and maintaining software applications that enable the functionality of IoT devices and systems. This role requires a strong foundation in programming, an understanding of hardware interactions, and the ability to integrate various components into cohesive solutions.

- Competency & skill profile:
  - Programming Proficiency
  - Languages: Expertise in programming languages such as C, C++, Python, and Java is essential for developing embedded software and applications for IoT devices.
    - Scripting: Familiarity with scripting languages like JavaScript or Ruby can be beneficial for developing web interfaces or automating tasks.
    - Embedded Systems Development: Understanding of embedded programming concepts to create efficient code that runs on resource-constrained devices. Experience with real-time operating systems (RTOS) to manage tasks and processes in embedded environments.
  - IoT Protocols and Communication: Proficiency in various communication protocols such as MQTT, CoAP, HTTP, and WebSockets to facilitate data exchange between devices and servers.Knowledge of networking concepts, including TCP/IP, to ensure reliable connectivity.
  - Cloud Computing and IoT Platforms: Familiarity with cloud platforms (e.g., AWS, Azure, Google Cloud) for deploying and managing IoT applications at scale. Experience with IoT platforms like ThingSpeak or Google Cloud IoT for device management and data analytics.
  - Data Management and Analytics: Skills in handling data generated by IoT devices, including storage solutions (SQL/NoSQL databases) and data processing

frameworks (e.g., Apache Kafka). Ability to implement data analytics tools to derive insights from collected data.
    - Security Practices: Understanding of cybersecurity principles specific to IoT, including encryption methods, secure coding practices, and vulnerability assessment. Ability to implement security measures to protect devices and data from unauthorized access.
    - User Interface/User Experience (UI/UX) Design: Basic knowledge of UI/UX principles to create intuitive interfaces for users interacting with IoT applications. Experience with front-end technologies (HTML/CSS/JavaScript) for developing web-based applications.
    - Testing and Debugging Skills: Proficiency in using testing frameworks and debugging tools to ensure software quality and reliability. Ability to conduct unit tests, integration tests, and system tests on IoT applications.
    - Systems Integration: Skills in integrating software with hardware components such as sensors, actuators, and communication modules. Experience in using APIs for interoperability between different systems and services

- Soft skills required
    - Problem-Solving: Strong analytical skills to troubleshoot issues related to software performance or device connectivity.
    - Collaboration: Ability to work effectively within cross-functional teams that include hardware engineers, data scientists, and product managers.
    - Adaptability: Openness to learning new technologies and methodologies as the field of IoT evolves rapidly.
    - Communication: Effective communication skills to convey technical concepts clearly to non-technical stakeholders.
    - Time Management: Ability to prioritize tasks effectively in a fast-paced development environment

Who is hiring: current & potential employers

Company	Position Types	Description
Siemens	Global engineering company focusing on digitalization	IoT Solutions Architect, Data Scientist
IBM	Multinational technology company specializing in AI	Data Scientist, IoT Software Developer
T-Mobile Slovakia	Telecommunications provider offering IoT solutions	Network Engineer, IoT Software Developer
ESET	Cybersecurity company with a focus on smart technologies	IoT Security Specialist
Accenture	Consulting firm providing technology services	Systems Integrator, IoT Solutions Architect

The IoT job market in Slovakia shows promise due to projected growth and a skilled workforce; however, it faces challenges related to lower employment rates among ICT specialists, skill gaps, and salary competitiveness. Compared to more advanced economies in Western Europe, Slovakia must enhance its digital skills training and investment strategies to fully capitalize on its potential within the IoT sector.

Common degrees of professionals in the Quantum Computing

- Bachelor's or Master's Degree in Computer Science
- Bachelor's or Master's Degree in Information Technology
- Bachelor's or Master's Degree in Electrical Engineering
- Bachelor's or Master's Degree in Data Science or Analytics
- Bachelor's or Master's Degree in Telecommunications

5.7.2 Skill Gap Analysis

In the Table below we provide an overview of the skill gaps for key positions in Slovakia, focusing on the discrepancy between what the current workforce possesses and what employers require, based on different sectors and types of employers:

IoT Solutions Architect

Skill Gap	Current Workforce
▪ Advanced cloud computing, IoT protocols, data management, security practices	▪ Basic understanding of cloud services and IoT protocols
Employer Requirements	**Sector**
▪ Lack of advanced skills in cloud architecture and security measures	▪ Technology firms, telecommunications

Data Scientist

Skill Gap	Current Workforce
▪ Machine learning, big data analytics, data visualization, domain knowledge	▪ Basic statistical analysis and data manipulation skills
Employer Requirements	**Sector**
▪ Insufficient expertise in machine learning algorithms and big data technologies	▪ Finance, healthcare, manufacturing

IoT Software Developer

Skill Gap	Current Workforce
▪ Embedded systems programming, API development, testing/debugging	▪ General programming skills (C/C++, Python)
Employer Requirements	**Sector**
▪ Need for specialized knowledge in embedded systems and IoT-specific APIs	▪ Automotive, consumer electronics

Key Insights

- General Shortage of Advanced Skills: Across all positions, there is a notable lack of advanced skills required for effective IoT implementation. While basic digital skills are present among the workforce, advanced competencies such as machine learning for data scientists or embedded programming for software developers are lacking.
- Sector-Specific Needs: Different sectors have unique requirements that highlight specific skill gaps. For instance, technology firms require architects with strong cloud computing skills, while cybersecurity firms need specialists with deep knowledge of IoT security.
- Educational and Training Gaps: The Slovak education system has not sufficiently adapted to meet the demands of the digital economy. There is a need for more targeted training programs that focus on emerging technologies and specific industry needs.
- Collaboration Opportunities: Employers are encouraged to collaborate with educational institutions to develop tailored training programs that can address these skill gaps effectively.
- This overview illustrates the pressing need for upskilling within the Slovak workforce to meet the demands of the evolving IoT landscape. Addressing these gaps will be crucial for enhancing Slovakia's competitiveness in the global market

5.7.3 Summary & recommendations for Addressing Skill Gaps in the IoT Field in Slovakia

The IoT job market in Slovakia presents significant opportunities for growth, driven by increasing demand for skilled professionals across various sectors. However, there are notable skill gaps between what employers require and what the current workforce possesses. Key positions such as IoT Solutions Architect, Data Scientist, IoT Software Developer, IoT Security Specialist, and Network Engineer face challenges related to advanced technical skills, specialized knowledge, and practical experience.

The analysis reveals that while basic digital skills are present among the workforce, advanced competencies—particularly in areas such as machine learning, embedded systems programming, and IoT security—are lacking. This discrepancy hinders the ability of Slovak companies to fully leverage IoT technologies and compete effectively on a global scale.

Recommendations

- Enhance Educational Programs
  - Curriculum Development: Collaborate with universities and technical schools to update curricula that reflect current industry needs. Focus on integrating practical IoT applications, machine learning, cybersecurity, and embedded systems into existing programs.
  - Industry Partnerships: Establish partnerships between educational institutions and companies to provide internships, co-op programs, and hands-on workshops. This will help students gain real-world experience and better prepare them for the workforce.

- Upskilling and Reskilling Initiatives
    - Professional Development Programs: Encourage companies to invest in continuous learning opportunities for their employees through workshops, online courses, and certification programs focused on advanced IoT skills.
    - Bootcamps and Short Courses: Launch intensive training bootcamps that target specific skill gaps in areas like data science, IoT security, and software development. These can be delivered by industry experts or through collaboration with educational institutions.
- Promote Awareness and Interest in IoT Careers
    - Outreach Programs: Implement outreach initiatives aimed at high school students to raise awareness about career opportunities in the IoT sector. Highlight the importance of STEM (science, technology, engineering, mathematics) education.
    - Mentorship Programs: Develop mentorship initiatives where experienced professionals guide newcomers or students interested in pursuing careers in IoT.
- Foster a Collaborative Ecosystem
    - Networking Events: Organize industry conferences, meetups, and hackathons that bring together professionals from various sectors to share knowledge and collaborate on IoT projects.
    - Innovation Hubs: Support the creation of innovation hubs or incubators that focus on IoT technologies. These spaces can facilitate collaboration between startups, established companies, and research institutions.
- Government Support and Policy Initiatives
    - Incentives for Training Programs: Encourage government policies that provide financial incentives for companies investing in employee training programs focused on digital skills.
    - Funding for Research and Development: Increase funding for research initiatives related to IoT technologies within universities and research institutions to drive innovation and skill development.
- Focus on Soft Skills Development
    - Soft Skills Training: Incorporate soft skills training into technical education programs to ensure that graduates possess essential skills such as communication, teamwork, problem-solving, and adaptability.
    - Cross-Disciplinary Learning: Promote interdisciplinary learning opportunities that combine technical knowledge with business acumen and project management skills.

Addressing the identified skill gaps in the Slovak IoT workforce is crucial for enhancing competitiveness in an increasingly digital economy. By implementing these recommendations—focused on education reform, professional development, awareness-raising initiatives, collaboration, government support, and soft skills training—Slovakia can build a robust talent pipeline capable of meeting the demands of the evolving IoT landscape. This proactive approach will not only benefit individual professionals but also contribute to the overall growth of the Slovak economy in the digital age.

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5.8 Quantum Computing

5.8.1 Identified roles, jobs, skills & competency profiles

List of specific roles = professionals working with the QUANTUM COMPUTING

Role	Description
Quantum Researcher	Conducts research in quantum information, quantum algorithms, and quantum technologies.
Quantum Software Developer	Develops software solutions for quantum computers and simulates quantum algorithms.
Quantum Hardware Engineer	Designs and builds quantum computing hardware, including qubits and quantum circuits.
Quantum Algorithm Specialist	Focuses on creating and optimizing algorithms specifically for quantum computing applications.
Quantum Communication Specialist	Works on developing secure communication protocols using quantum technologies.
Postdoctoral Researcher in Quantum Physics	Engages in advanced research projects, often requiring a PhD in a related field.
Quantum Systems Engineer	Integrates various components of quantum systems to ensure functionality and performance.
Quantum Education and Training Specialist	Develops educational programs and training materials for students and professionals in quantum technologies.

Three Most Requested and Difficult-to-Hire Positions in Slovakia

- Quantum Software Developer
  - Demand: High demand due to the need for specialized skills in programming for quantum computers (e.g., Qiskit, Cirq).
  - Difficulty: The niche nature of the skills required makes it challenging to find qualified candidates.
- Quantum Hardware Engineer
  - Demand: Increasing as companies look to build practical quantum computing systems.
  - Difficulty: Requires a deep understanding of both physics and engineering principles, making it hard to find professionals with the right background.
- Quantum Algorithm Specialist
  - Demand: Growing interest in developing algorithms that can leverage the advantages of quantum computing.
  - Difficulty: Candidates need a strong foundation in both theoretical computer science and quantum mechanics, which is rare.

The field of quantum computing in Slovakia is expanding, with various roles emerging as critical to advancing research and technology. The positions of Quantum Software

Developer, Quantum Hardware Engineer, and Quantum Algorithm Specialist are particularly sought after but difficult to fill due to the specialized skills required. Addressing these hiring challenges may involve enhancing educational programs and fostering collaboration between academic institutions and industry players to develop a skilled workforce in quantum technologies.

Profile/description/competency profile and skills list for the most common jobs/roles for the respective ATI

The roles of Quantum Software Developer, Quantum Hardware Engineer, and Quantum Algorithm Specialist are critical in advancing the field of quantum computing in Slovakia. Each position requires a unique set of competencies and skills that reflect the interdisciplinary nature of this emerging field. Addressing the challenges associated with hiring for these positions will be essential for fostering innovation and development within the quantum technology landscape.

Quantum Software Developer

- Profile/Description:
  A Quantum Software Developer is responsible for designing and implementing software solutions for quantum computers. This role involves collaborating with researchers to translate quantum algorithms into functional software and optimizing these solutions for performance on quantum hardware.
- Competency Profile:
  - Strong programming skills, particularly in languages relevant to quantum computing (e.g., Python, Qiskit).
  - Understanding of quantum algorithms and their applications.
  - Ability to work in a collaborative research environment.
- Skills List:
  - Proficiency in Python and quantum programming frameworks (e.g., Qiskit, Cirq).
  - Experience with software development practices (e.g., version control, testing).
  - Knowledge of quantum computing principles and algorithms.
  - Problem-solving skills and analytical thinking.
  - Familiarity with cloud computing platforms for quantum applications.

Quantum Hardware Engineer

- Profile/Description:
  A Quantum Hardware Engineer focuses on the design, development, and testing of hardware components used in quantum computing systems. This role requires a deep understanding of both physics and engineering principles to create functional qubits and other essential components.
- Competency Profile:
  - Expertise in electronic engineering or physics with a focus on quantum technologies.
  - Experience in prototyping and testing hardware systems.
  - Strong analytical skills to troubleshoot complex systems.

- Skills List:
  - Knowledge of quantum mechanics and solid-state physics.
  - Experience with CAD software for circuit design.
  - Proficiency in measurement techniques and instrumentation.
  - Understanding of cryogenics and materials science as they relate to quantum devices.
  - Ability to work collaboratively with interdisciplinary teams.

Quantum Algorithm Specialist

- Profile/Description:
  A Quantum Algorithm Specialist develops new algorithms designed specifically for quantum computers. This role involves researching existing algorithms, optimizing them for performance on quantum hardware, and applying them to solve real-world problems.
- Competency Profile:
  - Strong foundation in theoretical computer science and quantum mechanics.
  - Ability to conduct independent research and collaborate with other scientists.
  - Excellent mathematical skills to analyze algorithm performance.
- Skills List:
  - Proficiency in algorithm design and analysis techniques.
  - Familiarity with programming languages used for algorithm implementation (e.g., Python).
  - Understanding of complexity theory as it pertains to quantum computing.
  - Experience with simulation tools for testing algorithms on classical computers before deployment on quantum systems.
  - Strong communication skills to present research findings effectively.

Who is hiring: current & potential employers

The landscape for quantum computing professionals in Slovakia is supported by various institutions and companies engaged in research, development, and application of quantum technologies. Key employers include academic institutions such as the Institute of Physics SAS and Comenius University, as well as industry leaders like Honeywell Quantum Solutions and Multiverse Computing. These organizations are actively seeking skilled professionals for roles such as Quantum Software Developers, Quantum Hardware Engineers, and Quantum Algorithm Specialists to drive innovation in this emerging field.

Company/Organization	Position Types	Description
Institute of Physics SAS (FÚ SAV)	Quantum Researcher, Quantum Software Developer	Engages in research related to quantum technologies and is involved in projects like the Slovak Quantum Communication Infrastructure (skQCI).
Slovak National Center for Quantum Technologies (QUTE.sk)	Quantum Software Developer, Quantum Hardware Engineer, Quantum Algorithm Specialist	Central coordination for quantum technology research and education, supporting development and implementation projects.
Comenius University in Bratislava	Quantum Researcher, Postdoctoral Researcher	Conducts advanced research in quantum physics and technology, contributing to national and international projects.
Honeywell Quantum Solutions	Quantum Software Developer, Quantum Hardware Engineer	Global leader in quantum computing technology, focusing on the development of quantum hardware and software solutions.
Multiverse Computing	Quantum Software Developer, Quantum Algorithm Specialist	A prominent company in the EU specializing in quantum algorithms and applications across various industries.
Institute of Electrical Engineering SAS	Quantum Hardware Engineer	Involved in research and development of electrical engineering applications related to quantum technologies.
International Laser Center (CVTI SR)	Quantum Researcher, Quantum Hardware Engineer	Focuses on laser technologies that are integral to quantum computing advancements.

Common degrees of professionals in the Quantum Computing

Professionals working in the quantum computing sector in Slovakia typically hold degrees in Physics, Computer Science, Mathematics, and Engineering. Advanced degrees such as Master's and PhDs are common among researchers and specialists, reflecting the interdisciplinary nature of this emerging field. These educational backgrounds provide the necessary theoretical knowledge and practical skills required to advance research and development in quantum technologies.

5.8.2 Skill Gap Analysis

In the Table below we provide an overview of the skill gaps for key positions in Slovakia, focusing on the discrepancy between what the current workforce possesses and what employers require, based on different sectors and types of employers:

TABLE 4 Overview of the skill gaps for key positions in Quantum computing in Slovakia

Position	Skill Gap	Employer Requirements	Sector
Quantum Software Developer	▪ Proficiency in quantum programming languages (e.g., Qiskit, Cirq) ▪ Understanding of quantum algorithms ▪ Experience with cloud-based quantum platforms	▪ Strong knowledge of multiple quantum programming frameworks ▪ In-depth knowledge of algorithm optimization for quantum systems ▪ Familiarity with platforms like IBM Quantum Experience or Google Quantum AI	▪ Technology, Research ▪ Technology, Academia ▪ Technology, Startups
Quantum Hardware Engineer	▪ Expertise in quantum hardware design ▪ Understanding of cryogenics ▪ Skills in measurement and instrumentation	▪ Advanced knowledge of qubit design and fabrication techniques ▪ Proficiency in working with cryogenic technologies for qubit stabilization ▪ Advanced skills in precision measurement techniques specific to quantum systems	▪ Research, Industry ▪ Research, Academia ▪ Industry, Research
Quantum Algorithm Specialist	▪ Advanced knowledge of quantum complexity theory ▪ Proficiency in simulation tools ▪ Ability to translate classical algorithms to quantum equivalents	▪ Deep understanding of quantum complexity classes and their implications for algorithm design ▪ Expertise in using simulation tools to model and test quantum algorithms (e.g., QuTiP) ▪ Strong capability to adapt existing algorithms for quantum efficiency	▪ Academia, Research ▪ Technology, Research ▪ Academia, Industry

5.8.3 Summary & recommendations

The skill gaps identified for Quantum Software Developers, Quantum Hardware Engineers, and Quantum Algorithm Specialists highlight significant discrepancies between the current capabilities of the workforce and employer expectations. Key areas of concern include in the group of technical skills are as follows:

- Technical proficiency: There is a noticeable lack of advanced technical skills related to specific programming languages for quantum computing, hardware design expertise, and understanding of complex theoretical concepts.
- Practical experience: Many professionals lack hands-on experience with cloud-based platforms and cryogenic systems essential for developing practical quantum solutions.

- Algorithmic knowledge: The ability to innovate and adapt existing algorithms for quantum applications is often underdeveloped among candidates.

In the context of quantum computing specialists in Slovakia, project management skills and various soft skills are indeed critical for success, too. Below we provide the analysis of their importance and current availability among professionals in the field:

- Critical project management skills
  - Coordination of Complex Projects: Quantum computing projects often involve interdisciplinary teams and complex technical requirements. Effective project management skills are essential for coordinating these efforts, ensuring that projects are completed on time and within budget.
  - Resource Allocation: Project managers need to optimize resource allocation, manage timelines, and handle stakeholder communication effectively, especially in large projects like the Slovak Quantum Communication Infrastructure (skQCI).
  - Risk Management: The ability to identify potential risks and develop mitigation strategies is crucial in a rapidly evolving field like quantum computing.

  There is a need for training programs that combine technical expertise with project management skills to prepare specialists for leadership roles.

- Critical soft skills
  - Communication Skills: Effective communication is vital for explaining complex concepts to non-technical stakeholders and collaborating within multidisciplinary teams.
  - Teamwork and Collaboration: Quantum computing projects often require collaboration across various fields (e.g., physics, engineering, computer science), making teamwork skills essential.
  - Adaptability: Given the fast-paced nature of technological advancements in quantum computing, professionals must be adaptable to new information and changing project requirements.

Project management skills and soft skills are critical yet often lacking among quantum computing specialists in Slovakia. Addressing these gaps through targeted training initiatives, mentorship programs, and interdisciplinary collaboration can enhance the effectiveness of professionals in this emerging field. By fostering both technical expertise and essential soft skills, Slovakia can strengthen its position in the global quantum technology landscape

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WP4 Enhancing Labour Market-Relevant Skills in Advanced Technologies

T4.1 Identifying skill gaps in Advanced Technologies

Findings & conclusions from the focus group

Date: September 2024 – January 2025

INVESTech
Innovation Vocational Excellence and Sustainability in Tech

PROJECT REF NO. 101143958. ERASMUS-EDU-2023-PEX-COVE

Co-funded by the European Union

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1 Findings & conclusions from the focus group BULGARIA

Held in: Bulgaria, Sofia
Held on: 23.10.2024, from 10 to 17

1.1 Focus group methodology

Short description of the focus group incl. information on moderation and note taking:

The FG was moderated by Milena Koleva from CSKC (P9), note taking was done by Theodora Sotirova from JIC-BAS (P10). The presentation was one main and supported by various handouts, materials online and videos shown during the sessions. All project managers from the three BG organisation took active participtation. In the beginning the participants introduced themselves giving details on the field of their own and their area of expertise as well as details on the ATIs applied currently.

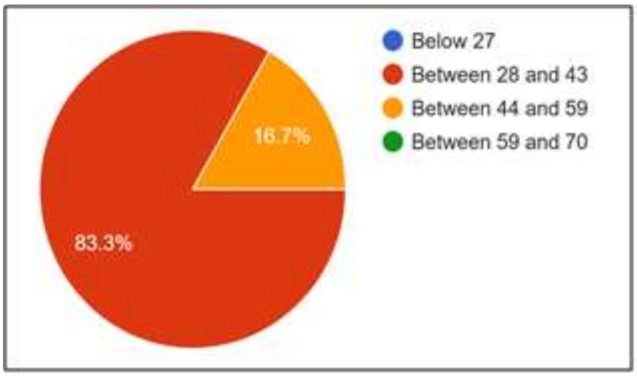
Participants

Recruitment & selection: the participants were invited based on the previous cooperation with the BG project partners and mainly the area of ATI; all partners gathered to discuss potential overlapping and miscommunication to invite valuable experts with insights.

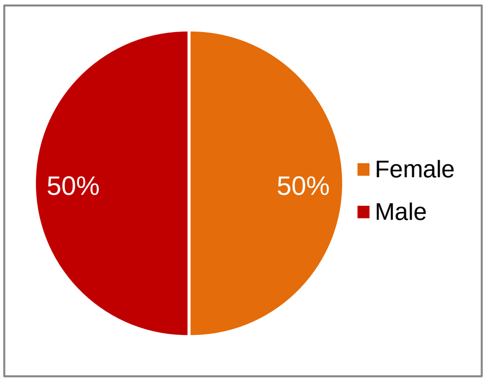
- Number of participants: there were 12 external participants form partners outside of the project and associated partners and 6 persons from the project partner institutions.
- Demographics, based on the data gathered using the feedback questionnaire
  - Age: in the groups 28 to 43 and 60 to 70 years of age there were 4 participants in each, while in the age group of 44 to 55 years of age, there were 3 participants
- Participants
  - recruitment & selection, number of participants: we aimed for fair selection and inclusion of men/women/ages as well as representatives from the quantiple helix as agreed: Intellectual property manager, IT experts, Chief Business Officer, CEOs, web developers, DevOps engineers.
  - Industries: Science and technology, IT/Software, ICT, Education, IT, Software Engineering.
- Demographics used:
  - Age
  - Gender
  - Education level
  - Working position
  - Years of experience
  - Company size and industry
  - Geographic location
  - Technology Focus

■ Results:

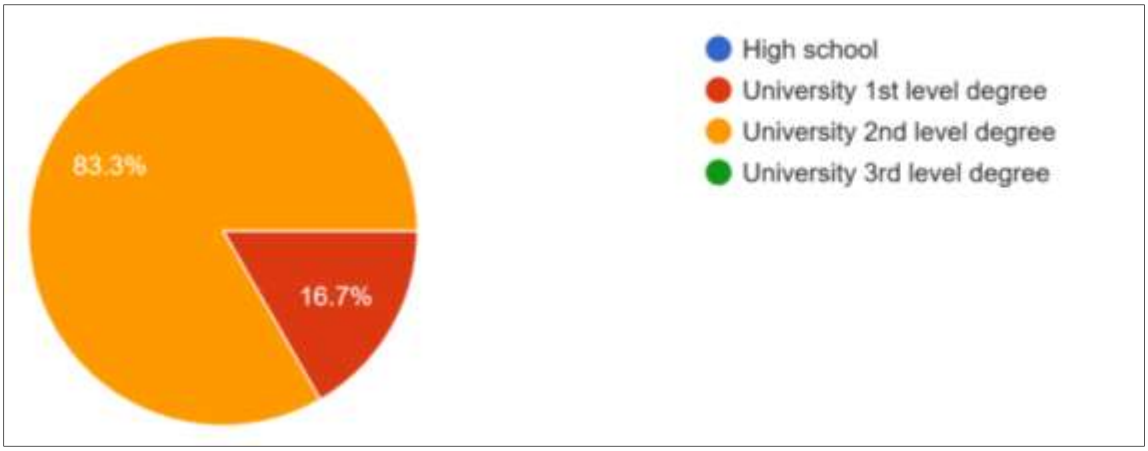
Age:



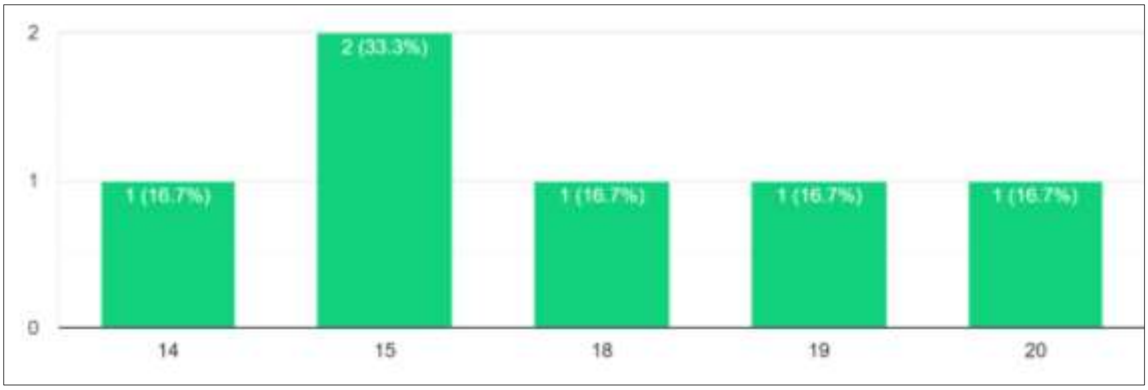
Gender:



Education level:



Years of experience:



Type of organisations:

1.2 Focus group findings & outputs

- Understanding the current landscape
  - Participants' perception of the current state of 7 ATIs in the country & their sectors:
    - It is hard to define strict definitions and separation across the sectors because now all advanced technologies need first the fundamental skills like programming and mainly soft skills
  - Key challenges and opportunities identified by participants
    - New knowledge is required
    - The main sectors affected by the advanced technologies skills:
      - Scientific research
      - Software/Hardware/Websites
      - We are developing customized digital platforms
      - Digital Advocacy and Campaigning
      - Website and Eshop development
      - Automotive software development.
  - Industry trends and their impact on skill requirements

- Skill gaps and competencies
  - Core technical skills identified as deficient
  - Soft skills and competencies required for success: leadership and project management is lacking in general.
  - Other skills identified as deficient or/and required for success:
    - Functional literacy
    - Lack of connection between HR, recruiters, technical team
    - Outsourcing requires concrete technical skills which does not allow for development
    - Productivity
    - Teamwork and soft skills
    - Adaptability
    - Flexibility
    - People skills
    - Try new things

- AI makes thinking optional, Critical thinking
    - Technical fundamental gaps
    - Gaps in HEIs programs which provides opportunities and niche for the business trainings
    - Alignment of current educational programs with industry needs is essential
    - There are few major academies started by big corporations and acceleration programs for start-ups and entrepreneurs
  - Emerging skill requirements due to technological advancements:
    - Engineering and prompt engineering
    - AIand machine learning: proficiency in developing and training ai models for assistive devices.
    - data analytics: ability to analyze user data to improve assistive technologies.
    - programming: knowledge of programming languages (e.g., python, c++, javascript) to build software solutions.
    - IoT integration: skills to connect devices in smart ecosystems, enhancing accessibility.
    - Robotics: knowledge of robotics for physical assistive devices like exoskeletons.
    - Virtual/Augmented Reality: designing immersive environments for rehabilitation and learning tools.

- Industry perspectives and challenges
  - Industry-specific challenges and opportunities related to advanced technologies: mostly Big Data and AI, AR, VR
  - Collaboration between academia, other education institutions, and industry in addressing skill gaps – this is cruvial and very much lacking in Bulgaria
  - Impact of technological advancements on business models and operations – new start-ups, outsourcing is decreasing, new centres are not opened so often.

- Recommendations
  - Prioritized list of skill gaps requiring immediate attention
  - Suggested strategies for addressing identified skill gaps
  - Recommendations for further research and data collection

The summary of all recommendations are listed below:

Table 1 Advanced Technologies for Industry (ATI) by sectors
the missing areas are in bright, less required in lighter

1. Artificial Intelligence and Ethics	
Healthcare	AI for diagnostics, drug discovery, medical image analysis, treatment plans, and personalized medicine.
Finance	Fraud detection, algorithmic trading, CRM and risk management.
Manufacturing	Predictive maintenance, quality control, and process optimization.
Retail	Customer analytics, inventory management, and personalized marketing.
Automotive	Autonomous vehicles, supply chain optimization, predictive maintenance, and customer support.
Public Sector	Policy making, public safety, and administrative automation.
Entertainment	Content recommendation, virtual assistants, video game development

2. Big Data	
Finance	Market analysis, fraud detection, and customer insights.
Healthcare	Patient data analysis, personalized medicine, and medical research.
Retail	Consumer behavior analysis, demand forecasting, and supply chain management.
Telecommunications	Network optimization, customer analytics, and predictive maintenance.
Energy	Smart grid management, resource optimization, and predictive analytics.
Transportation	Route optimization, logistics, and fleet management.
Public government	Public policy analysis, urban planning, citizen services

3. Blockchain	
Finance	Cryptocurrencies, smart contracts, and secure transactions.
Supply Chain	Traceability, transparency, and fraud prevention.
Healthcare	Secure patient records, drug traceability, and clinical trials.
Real Estate	Property transactions, smart contracts, and title management.
Public Sector	Voting systems, identity verification, and public records.
Entertainment	Digital rights management, content distribution, and anti-piracy.

4. Internet of Things (IoT)	
Manufacturing	Smart factories, predictive maintenance, and inventory management.
Healthcare	Remote monitoring, medical devices, and patient management.
Agriculture	Precision farming, livestock monitoring, and resource management.
Transportation	Fleet management, connected vehicles, and smart logistics.
Energy	Smart grids, energy management, and resource optimization.
Home Automation	Smart homes, security systems, and energy efficiency.
Smart Cities	Infrastructure management, public safety, environmental monitoring

5. ICT for Sustainability This are is still under development and will become crucial soon as per the new directives by EU	
Energy	Renewable energy systems, smart grids, and energy efficiency.
Construction	Green building technologies, smart cities, and sustainable materials.
Transportation	Electric vehicles, public transportation systems, and logistics optimization.
Agriculture	Sustainable farming practices, resource management, and environmental monitoring.
Waste Management	Recycling technologies, waste reduction, and resource recovery.
Public Sector	Environmental policy, smart city initiatives, and sustainability planning.

6. Industry 5.0	
Manufacturing	Human-robot collaboration, personalized production, and smart factories.
Healthcare	Personalized medical devices, surgical robots, and patient-centered care.
Automotive	Custom vehicle manufacturing, human-machine interfaces, and advanced safety systems.
Retail	Customized products, seamless human-machine interactions, and smart logistics.
Aerospace	Advanced manufacturing, human-centered design, and safety systems.
Education	Personalized learning environments, human-technology interaction, and educational robots.

7. Quantum Computing Underdeveloped in Bulgaria as a whole	
Finance	Risk analysis, portfolio optimization, and fraud detection.
Pharmaceuticals	Drug discovery, molecular modeling, and genomics.
Energy	Optimization of energy resources, material science, and cryptographic security.
Transportation	Route optimization, traffic management, and logistics.
Cybersecurity	Quantum encryption, secure communications, and data protection.
Research and Academia	Fundamental research, simulations, and educational programs.
Cybersecurity	Quantum encryption, secure communications, and data protection.
Research and Academia	Fundamental research, simulations, and educational programs.

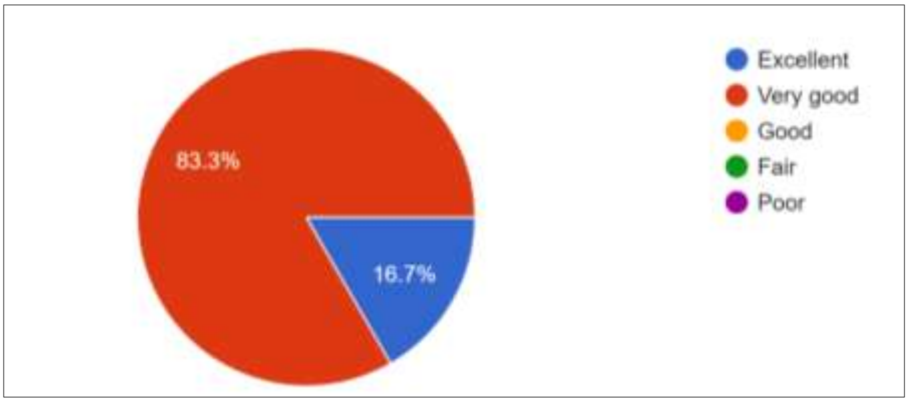
- Conclusion
  - Summary of key findings and implications: the industries are developing fast and new positions are open. There is opportunity for very flexible training and in full alignment with the business; the education system is lagging a lot and the market is very

underdeveloped. Still, there are key positions and skills like programming that are fundamental; Adaptability and resilience are a must for the new generations lacking at the moment.

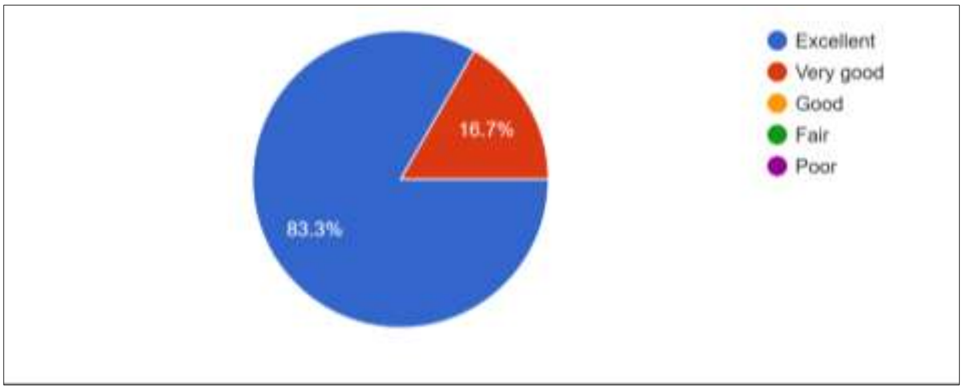
- Recommendations for future actions: alignment of business and VET, trainings by the business for teachers/professors/trainers is a muct. The change should happen gradually, yet very fast.

Very high level of satisfaction:

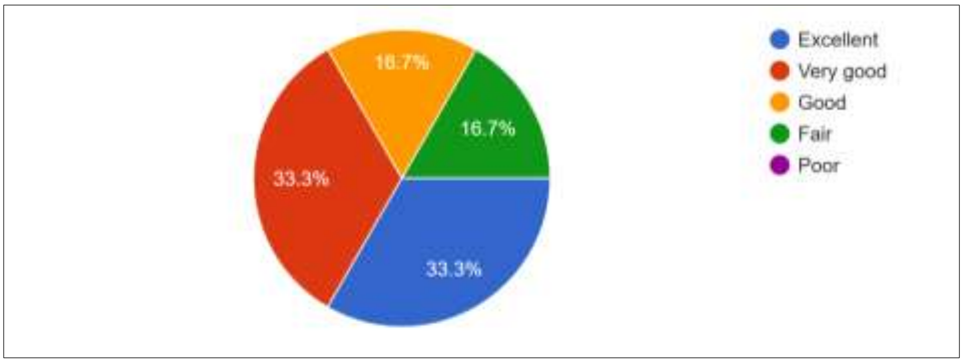
What is your opinion on the overall organisation of the event?



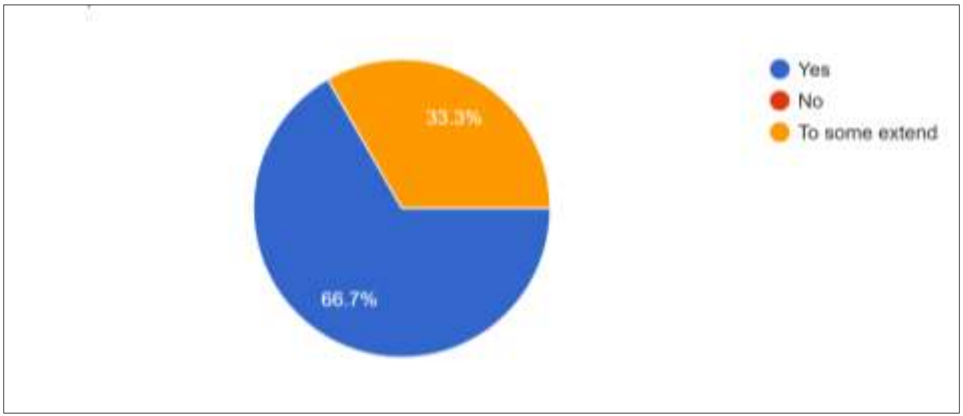
What is your opinion on the speakers and their presentations?



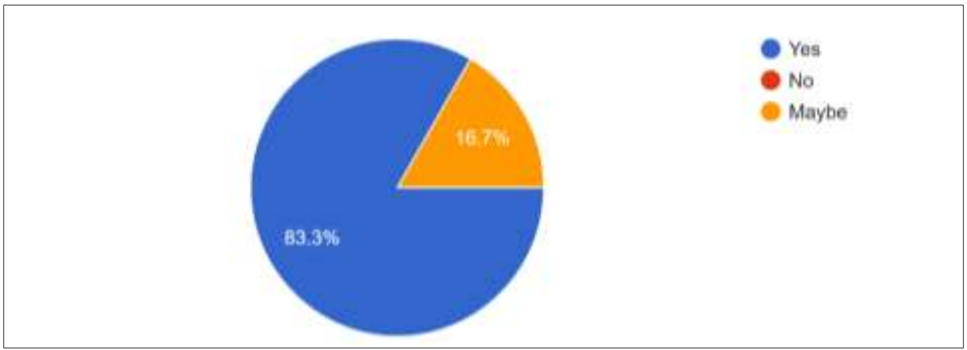
What is your opinion on the venue that hosted the event?



Do you think today's event was innovative and taught you new things?



Do you feel motivated to use the project outputs that were presented to you?



2 Findings & conclusions from the focus group CYPRUS

2.1 AI and Ethics

Held in: Nicosia, Cyprus, University of Frederick
Held on: 16.11.2024, from 15:00 - 16:15 (1.5 hours)

2.1.1 Focus group methodology

Short description of the focus group incl. information on moderation and note taking.

The focus group began with a short introduction of the four participants as well as the facilitator and note keeper. After that there was an introduction of the topic the five pillars the discussion will focus as well as some indicative guidelines for a smooth discussion. Each participant was free to talk when they felt it is necessary and answer or complete the comments of someone else. Everyone contributed to the discussion, as they come from different backgrounds and have different expertise. The focus group concluded by handing out the evaluation questionnaires and thanking the participants for their time and valuable contributions. Coffee and snacks were provided at the end of the focus group to let participants meet and reflect with the participants from the other focus groups implemented in Nicosia, Cyprus.

Participants

- recruitment & selection, number of participants
  Professionals representing academia, industry, and non-governmental organizations were selected and invited by email and telephone conversation. Four of them participated to the focus group representing different sectors.
- Demographics, based on the data gathered using the feedback questionnaire
  - Age
  - Gender
  - Education level
  - Working position
  - Years of experience
  - Company size and industry
  - Geographic location
  - Technology Focus

In the following link you can see the demographic and the evaluation of the focus group from the participants.

2.1.2 Focus group findings & outputs

Understanding the current landscape

The current situation of AI and Ethics in Europe is primarily driven by the EU regulatory framework AI Regulation implemented in August 2024, which has increased organizational awareness about ethical considerations in AI. In the past, more effort and resources were given to AI development, with only a narrow focus on governance. Nowadays, this trend is shifting due to compliance requirements and more emphasis is given on ethical considerations and governance. Sectors such as banking, already have AI policies and governance frameworks in place to address the dual focus on ethics and regulation.

Some skills are essential for the ethical compliance of both developers of AI and their end users, especially the former. Regarding the latter, AI is being democratized, i.e. it is getting more and more normalized for the broader community to integrate AI into different aspects of their life without prior technical knowledge. This can be observed, for example, in tools such as Microsoft's AI Copilot, which integrate AI features into commonly used software, making advanced AI capabilities available to the general public and accessible across industries. This makes it essential for end users to have well-developed critical thinking skills and AI Literacy to gain the ability to discern fact from hallucination, especially when relying on generative AI tools, as well as training in ethical prompt usage, data governance, and bias awareness. Developers and organizations navigating the requirements of new AI regulations need to be able to follow this regulation and must be trained in AI governance and lifecycle management. Additionally, to ensure unbiased and ethical outcomes, AI developers must be trained on human-centered approaches and inclusive language, to incorporate in the AI models they are developing.

Integration of ethical AI in applications contains some challenges that need to be addressed, as well as some opportunities:

The challenges identified are:

- Trust and reliability of AI systems
  There is a trend for users to express over-reliance on tools like OpenAI, despite their potential to hallucinate or provide false information, often without cross checking the output against other sources. Additionally, there are liability concerns when AI systems provide false information.

- Biases in AI output
  Historical data influencing AI often perpetuates discrimination. For instance, tools for CV screening have been shown to favour white, male candidates due to unaddressed biases in training datasets. Such biases can erode organizational credibility and trust.

- Human oversight gaps
  There's a growing challenge of balancing AI efficiency with human oversight, as many organizations fail to ensure critical review of AI-generated outputs. This gap raises copyright issues in higher education as it affects the referencing methodologies as users of OpenAI do not reference it properly.

- Ethical dual-use risks
  Technologies like drones with dual-use capabilities—helpful for firefighting but also adaptable for harmful military applications—highlight the need for robust ethical safeguards.

The opportunities that can be observed from the increased awareness of Ethics in AI are:

- There is a heightened awareness as the new regulations have pushed organisations for better governance, compliance, and responsible use of AI.
- The ethical implications of AI are to strengthen multi-disciplinary collaboration between developers, policymakers, and social scientists.
- An increased focus on training developers in governance, AI literacy, and ethical application design can be observed.

Skill gaps and competencies

Several skills have been identified that address developers, organisisations, and end users.

Some of the **technical skills** and abilities discussed are:

- AI governance and compliance: Limited expertise in adhering to AI regulatory frameworks and designing and implementing AI governance framework, as well as gaps in understanding the lifecycle management of AI systems, from design to decommissioning.
- Data handling and analytics: Lack of proficiency in data pre-processing, data governance, and bias mitigation and AI practices in data collection and processing.
- Algorithmic transparency: Deficiencies in explaining and auditing complex AI models, particularly those relying on neural networks and other black-box techniques.
- AI for content creation and trust management: Lack of a clear understanding of how to responsibly use AI in content creation and lack of frameworks to assess AI's impact on information accuracy, trustworthiness, and the potential risks of misinformation.

Soft skills that are required for success are:

- Ethical judgment and decision-making: The ability to make ethical decisions about data use, AI application, and algorithm design.
- Critical thinking: The ability to critically evaluate AI-generated outputs and detect biases and hallucinations.
- Problem-solving and risk assessment: The ability to provide solutions to fake information to minimize risk.
- Human-centered skills: The ability to understand human values, cultural diversity and ethical consideration
- Collaboration across disciplines: teamwork and communication amongst technical, legal, humanitarian experts and/or policy makers, with a strong emphasis on the importance of incorporating humanities studies—such as ethics, philosophy, and social sciences—into the AI framework to ensure a well-rounded, ethical approach to innovation.
- Adaptability: continues to learn and adapt to emerging tools, standards, practices and regulations.

Other important skills are:

- AI Literacy for end users: Non-technical staff need a foundational understanding of how AI tools work, their limitations, and responsible usage protocols. As OpenAI enters our community without prior knowledge or training for many users, some were unprepared to effectively adopt these tools.
- Prompt engineering: Skills in crafting precise and effective prompts for generative AI tools, ensuring outputs align with organizational objectives and ethical standards.
- Human oversight in AI processes: Training to ensure proper supervision and quality assurance of AI systems to mitigate errors or unintended consequences.
- AI Academic Referencing: The ability to reference and utilize AI tools for academic purposes.

Participants noted a **significant misalignment between academic curricula** and the practical needs of industries adopting AI:

- Universities and training institutes focus heavily on programming and model development, with minimal attention to governance, ethics, and compliance.
- Few programs emphasize applied AI literacy or integrate multidisciplinary approaches combining ethics, law, and social impact.
- Few programs emphasise AI literacy and critical thinking to identify hallucinations from the perspective of the end-user.
- Industry-specific use cases of AI (e.g., in healthcare, finance) are often underexplored in educational settings.

In conclusion, due to this rapid technological advancement that will continue to overrun our society, some skills are essential for the successful and safe integration of Ethics in the AI systems. These skills are AI auditing and explainability, ethical prompt design, regulatory compliance and risk management, inclusive design and accessibility, as well as AI system maintenance and lifespan management.

Industry perspectives and challenges

The industry faces challenges and opportunities related to advanced technologies. The main challenge includes the organisational lack of necessary skills to operate and manage advanced technologies as well as the resistance to change among workers. Additionally, the integration of advanced technologies and AI solutions in the business requires high costs and resources. The industry also faces a lack of clear guidelines on the ethical and legal implications of integrating and using these technologies. Multinational organisations face extra difficulties as global regulations and ethical standards vary. On the other hand, these technologies come with many opportunities, as business can create innovative business models. The automation and AI tools present opportunities for improving productivity and reducing operational. Advanced analytics and AI enable businesses to make data-driven decisions, improving customer engagement and market positioning.

Regarding the collaboration between academia, educational institutions, and industry, participants emphasized the critical need to empower it in order to address existing skill gaps. A key insight was the necessity for academic programs, particularly in IT studies, to focus on emerging areas such as AI Governance, AI Lifecycle Management, and Human-

Centered approached in AI systems. These areas were identified as vital for equipping students with the technical expertise required to meet industry demands for ethics in AI. Furthermore, participants noted that AI literacy should be integrated into academic curricula, not only for technical specialists but also for end users of AI systems. This would ensure that a broader range of professionals understand the capabilities and limitations of AI, enabling them to use these technologies effectively and responsibly in their work. There was also a call for more structured, ongoing collaborations between academia and industry to ensure that educational programs continuously evolve in response to technological advancements.

Recommendations

- Prioritized list of skill gaps requiring immediate attention
  Based on the focus group results, as high priority skills, the following can be considered: AI Literacy & Critical Thinking, Ethical AI Development & Governance Knowledge as the increased integration of AI in various sectors requires developers to understand the ethical implications of their work and create systems that are fair, non-discriminatory, and align with ethical standards. A medium priority is AI Regulation awareness as this framework is rapidly evolving and companies must ensure their compliance with it. Human-centered AI design and inclusive language are also a medium priority as AI systems can significantly affect marginalized and vulnerable groups. Another skill gap is the AI for content creation and trust management as the lack of critical skills to evaluate AI outputs provokes risks of spreading false or misleading information, affecting organizational credibility.
- Suggested strategies for addressing identified skill gaps
  Some suggested strategies for addressing those skills gaps include:
  - Develop AI Literacy programs that implement comprehensive training on AI literacy across all levels (for both developers and end-users), including critical thinking, fact-checking, and identifying hallucinations in AI-generated content.
  - Integrate AI Ethics into curriculum and certification by encouraging universities, training providers, and industry bodies to offer specialized courses and certifications in AI ethics, including governance, lifecycle management, and human-centered approaches.
  - Strengthen collaboration between developers and ethicists to incorporate ethical decision-making into the design and development process.
  - Raise awareness about AI's social implications by conducting campaigns and seminars.
- Further research will be beneficial on the following topics:
  - Exploring the role of AI in vulnerable populations
  - Case Studies on AI Governance failures
  - Cross-Cultural studies on Ethical AI
  - Tracking the evolution of AI Ethics policies in companies

Conclusion

- Summary of Key Findings and Implications

  This report highlights the growing importance of AI ethics, driven by new regulations like the EU AI Regulation. Key challenges include:

  - Trust and reliability: Over-reliance on AI tools can lead to inaccurate outputs and liability concerns.
  - Biases in AI: AI models often perpetuate biases, particularly in hiring and decision-making.
  - Human oversight gaps: Insufficient human review of AI outputs raises concerns, especially in academic and legal contexts.
  - Ethical dual-use risks: Technologies like drones have both positive and harmful potential, demanding stronger ethical controls.

  Opportunities include heightened awareness of ethical implications, multi-disciplinary collaboration, and a focus on training developers in AI governance and ethical practices.

- The recommendations for future actions include:
  - AI Literacy programs: Implement comprehensive training for both developers and end-users, focusing on critical thinking, ethical prompt design, and evaluating AI outputs.
  - Ethics in education: Integrate AI ethics, governance, and lifecycle management into curricula to prepare students for the challenges of responsible AI development.
  - Industry-Academia collaboration: Strengthen partnerships to ensure educational programs evolve with industry needs, especially in AI regulation and content creation.
  - Ongoing professional development: Encourage continuous training in AI governance, ethical decision-making, and risk management.
  - Further research: Focus on AI's impact on vulnerable populations, AI governance case studies, cross-cultural ethics, and tracking the evolution of AI ethics policies in companies.

In conclusion, it is crucial that there is a multi-disciplinary and coordinated effort to address the aforementioned gaps mainly through education, skills development, research and collaboration to ensure responsible AI tool development (for developers) and AI use (for end-users), achieving minimal risk and maximising societal benefits for the wider population.

2.2 Big Data

Held in: **Cyprus, Nicosia, Frederick University**

Held on: 16.11.2024 date, from 15:30 - 17:00 (about 1½ hours)

2.2.1 Focus group methodology

Short description of the focus group incl. information on moderation and note taking.

Based on Task 4.1, the main objective is to identify the gaps in skills and competences of professionals and pinpoint specific requirements in Advanced Technologies for Industry. The INVESTech CY consortium was responsible for identifying the roles, skills, skill gaps for AI & Ethics, Big Data, and ICT & Sustainability. In order to identify the gaps, during the INVESTech 1st National Workshop, a set of focus groups (FG) were conducted with industry representatives and experts.

As part of the organisation of the INVESTech 1st National Workshop, the participants invited were provided with a choice to attend one of the three FG that were conducted during the Workshop. Each FG session was recorded (partially) so that the participants, as well as the organisers, could have a record of the ideas and suggestions exchanged during the FG. In addition, the recordings could be made available to participants that were present in one FG session, but they were also interested in obtaining information about any of the other FG sessions. In each of the FG sessions, one person was appointed to notes and minutes another person was appointed for taking photographs.

Each session began with a short introduction to the topic and some suggestive questions were made in order to initiate the discussions about each topic. Specifically, an overview of the Big Data landscape was presented during the FG. The short presentation covered a range of topics including the Attributes and Drivers, Sources and Forms of Big Data, Big Data Landscape in terms of platforms, database systems, integration, tools, frameworks, and reporting systems. During the FG discussion each participant had the opportunity to present and express their own views, experience, and contributions towards the discussions, as they had different backgrounds and expertise. Each session concluded with handing out of the questionnaires and thanking the participants for their time and valuable contributions.

- Participants
  - The participants of the INVESTech 1st National Workshop, had the opportunity to express interest in participating in the Big Data FG. Based on the Quantuple helix, stakeholders were targeted from the Academia, the Industry, the Government, the Civil Society, and the general Environment. Email invitations were sent out to stakeholders, and based on the responses received, the participants of the FG on Big Data were selected.
  - **14 participants in total - 4 participants participated in the Big Data FG**
- Demographics, based on the data gathered using the feedback questionnaire
  - **Age**: Most participants fall in the age group 44 to 59, with one participant in the group 59 to 70.

- **Gender**: Three participants are Male, and one is Female
- **Education Level**: Three participants have a "University 3rd level degree.", One participant has a "University 2nd level degree."
- **Working Position**: Network Design Supervisor, Research, Project Manager, and Academia
- **Years of Experience**: Three participants have more than 15 years of experience, one participant has 6-10 years of experience.
- **Company Size and Industry**: Participants' organisations and company sizes varied
- 250 or more employees: Semi-state organization and educational institutions.
  - 50 to 249 employees: Banking Segment.
  - 1 to 49 employees: Civil society.
- **Geographic Location**: Nicosia or Pancyprian.
- **Technology Focus**: ICT focus was noted by another participant IoT and Big Data was specifically mentioned by one participant, and Two participants did not specify any particular technology focus

2.2.2 Focus group findings & outputs

Understanding the current landscape

- **Participants' perception of the current state of Big Data in their country & their sectors**: The participants demonstrated a comprehensive understanding of the current state of Big Data, emphasizing its transformative impact across industries through scalable platforms and cloud services such as AWS and Azure. They recognized the importance of Big Data in today's everchanging environment.
- **Key challenges and opportunities identified by participants**: Participants identified a significant lack of expertise in advanced technologies such as compliance, cloud computing, and AI, despite their growing importance in the industry. In addition, practical application and hands-on experience with Big Data platforms, tools, and frameworks, as well as the use and applications of NoSQL databases were noted as missing elements. There was a consensus on the misalignment between theoretical academic curricula and real-world industry requirements, particularly in processing Big Data, Big Data integration, processing, data analytics and visualisation, as well as the use of machine learning.
- **Industry trends and their impact on skill requirements**: Increasing reliance on cloud platforms for scalable and cost-effective data management was highlighted as a dominant trend. With the growth of unstructured and semi-structured data, the use of Relational and NoSQL databases is becoming critical for data storage and retrieval. The growing emphasis on predictive analytics, AI, and machine learning is transforming how industries leverage data for decision-making. As decision-making becomes increasingly data-driven, tools like Tableau and Power BI are widely adopted to simplify data interpretation for non-technical stakeholders. This trend underscores the need for skills in creating compelling dashboards and actionable insights.

Skill gaps and competencies

- **Core technical skills identified as deficient**: Participants identified several critical technical skill gaps that are hindering the ability of professionals to fully leverage Big Data technologies. Chief among these deficiencies is expertise in cloud computing and architecture, particularly in designing and managing scalable solutions on platforms. Proficiency in Relational and NoSQL databases (e.g., MongoDB, Cassandra) was also noted as lacking, especially the ability to handle unstructured data and implement polyglot persistence strategies. Other significant gaps include a limited understanding of data integration tools, which are essential for real-time data streaming and processing. Similarly, participants highlighted a deficiency in machine learning frameworks, reflecting a need for advanced skills in developing and deploying AI models. Furthermore, there is a lack of expertise in data visualization and reporting tools, which are increasingly essential for translating complex data into actionable insights.
- **Soft skills and competencies required for success**: Participants noted a rising demand for professionals who can combine technical skills with domain-specific expertise, such as business analytics or academic research. Soft skills, such as communication and teamwork, are critical for cross-disciplinary collaboration.
- **Other skills identified as deficient or/and required for success**: Participants highlighted a deficiency in critical thinking and the ability to approach Big Data challenges creatively. Professionals must be able to analyse complex datasets and derive insights that drive innovative solutions. Given the fast-paced evolution of Big Data technologies, the ability to adapt quickly to new tools, frameworks, and methodologies is essential. Lifelong learning and a growth mindset were noted as critical for staying relevant in the field. Participants indicated a need for training in project and time management and organizational skills to meet tight deadlines without compromising quality. With increasing emphasis on data privacy and regulatory compliance, such as GDPR, participants identified a need for better understanding and application of ethical data practices. Skills in data governance, security, and traceability are vital to ensure compliance.
- **Alignment of current educational programs with industry needs**: Participants in the focus group highlighted a significant misalignment between current educational programs and the evolving needs of the Big Data industry. While many academic institutions provide a solid foundation in theoretical concepts, there is a noticeable gap in the practical application of these skills. Participants noted that educational programs often lack hands-on training with industry-standard tools and technologies. Theoretical courses in programming languages like Python and R are widely offered, but these often fail to include the advanced use cases required in roles like Data Engineer, Machine Learning Engineer, or Data Analyst. Similarly, essential competencies in machine learning frameworks and data visualization tools are underrepresented in many curricula. Participants also emphasized that soft skills, including communication, project management, and data ethics, are often overlooked, despite their importance for cross-functional collaboration and regulatory compliance.

- **Emerging skill requirements due to technological advancements**: Emerging technological advancements in Big Data have driven the need for a diverse set of new skills across technical and interdisciplinary domains, based on the view of the participants. Proficiency in cloud computing platforms, as well as expertise in distributed systems, is increasingly critical for building scalable and efficient data pipelines. Similarly, the adoption of machine learning (ML) and artificial intelligence (AI) requires advanced skills in platforms, tools, and frameworks such as TensorFlow and PyTorch, alongside competencies in model deployment and optimization. Additionally, the growing reliance on real-time data integration tools like has highlighted the need for expertise in handling live data streams.
- Other emerging requirements include knowledge of Relational and NoSQL databases (e.g., MongoDB) for unstructured data management, and the ability to create compelling data visualizations using tools like Tableau and Power BI to communicate insights effectively. The rise of IoT and edge computing has further expanded skill requirements, emphasizing data processing closer to the source.

- Industry perspectives and challenges
  - **Industry-specific challenges and opportunities related to advanced technologies**: Industries face several challenges related to adopting advanced technologies in Big Data, including limited access to cutting-edge tools in smaller organizations, skill shortages in areas like cloud computing, AI, and real-time integration, and difficulties integrating legacy systems with modern platforms, according to the participants views. Compliance with regulations like GDPR and ensuring data security add further complexity, particularly in finance, education, and civil society sectors. Resource inequality between smaller and larger organizations exacerbates these issues, hindering widespread adoption of advanced technologies.
  - Despite these challenges, significant opportunities exist, based on the discussion conducted among participants. The adoption of IoT and edge computing can enhance real-time data processing, while cloud platforms like AWS and Azure offer scalability and cost efficiency. AI and machine learning open avenues for predictive analytics and automation, driving innovation across industries.
  - **Collaboration between academia, other education institutions, and industry in addressing skill gaps**: Participants emphasized the critical need for collaboration between academia, other educational institutions, and industry to address the growing skill gaps in Big Data. One of the primary challenges identified was the disconnect between theoretical education and the practical skills required in the industry. Academic programs often lack training in cutting-edge Big Data Analytics tools, and cloud platforms, which are essential for roles in data engineering, analytics, and machine learning.
  - Collaboration was seen as a pathway to bridge this gap by co-developing curricula that incorporate industry-relevant tools and techniques. Industry partners can provide insights into emerging technologies and their practical applications, while academia can offer a structured foundation of knowledge. Internships, apprenticeships, and joint research projects were highlighted as effective mechanisms for enabling students to gain hands-on experience and exposure to real-world challenges.

- **Impact of technological advancements on business models and operations**: Technological advancements in Big Data are profoundly transforming business models and operations across industries, according to the participants. The shift to data-driven decision-making, enabled by tools like data analytics and visualisation, and machine learning frameworks, has enhanced strategic planning and responsiveness. Real-time data integration tools, allow businesses to move from reactive to proactive approaches, while cloud platforms provide scalability and cost efficiency. These technologies also enable new business models, such as data monetization and subscription-based services, particularly in industries like telecom and finance. Additionally, advancements in AI and automation are optimizing workflows and reducing operational costs, driving innovation in customer engagement and supply chain management.
- However, participants have indicated that these opportunities come with challenges, including the complexity of data management, compliance with regulations like GDPR, and the need for advanced cybersecurity measures. Organizations must also invest in upskilling their workforce to handle emerging tools and technologies. By leveraging these advancements effectively, businesses can enhance customer personalization, operational flexibility, and overall productivity, paving the way for innovative and scalable growth strategies.

- Recommendations
  - **Prioritized list of skill gaps requiring immediate attention**: According to the discussion conducted among participants the list of skills gaps requiring immediate attention are the following:
    - **Cloud Computing and Architecture**: Proficiency in cloud platforms for building and managing scalable, secure, and cost-effective data solutions is urgently needed. This includes skills in data pipelines, infrastructure management, and cloud-native services.
    - **Identifying, Accessing, and Using Big Data Sources**: Skills in locating, acquiring, and effectively utilizing diverse Big Data sources, including structured, unstructured, and real-time data streams. This includes understanding data accessibility, integration across platforms, and ensuring data quality.
    - **Data Integration**: Expertise in integrating data from multiple sources into centralized warehouses or data lakes, ensuring accessibility and consistency. This includes knowledge of ETL processes, data processing tools. Expertise in tools for integrating and processing live data streams is increasingly important, particularly for organizations transitioning to real-time operations.
    - **Data Governance and Compliance**: Knowledge of data privacy, governance, and regulatory compliance, including GDPR, is vital. This includes skills in managing ethical data practices, ensuring traceability, and implementing robust security measures.
    - **Data Visualization and Business Intelligence**: Competence in tools like Tableau, and Power BI to create interactive dashboards and translate complex datasets into actionable insights is a key requirement. These skills are crucial for enabling data-driven decision-making across teams and stakeholders.

- Suggested strategies for addressing identified skill gaps: Based on the suggestions from the participants, the following multi-pronged strategy is proposed to bridge the divide between current capabilities and industry requirements:
    - **Industry-Academia Collaboration**: Establish partnerships between academia and industry to co-develop curricula that incorporate practical, hands-on training in advanced technologies such as cloud platforms, machine learning frameworks, and data integration tools. Facilitate industry-sponsored internships and apprenticeships to provide real-world experience with Big Data tools and processes. Organize joint research projects to address specific challenges in data governance, integration, and analytics.
    - **Development of Microcredential Programs**: Create targeted microcredentials to upskill and reskill students and professionals in high-demand areas. Establish training labs equipped with cutting-edge Big Data technologies, allowing students and professionals to practice with Big Data platforms, tools, and frameworks. Introduce project-based learning with a hands-on approach in microcredentials programs to enable students/participants to solve real-world Big Data problems using industry-standard tools and methodologies.
    - **Soft Skills Enhancement**: Integrate soft skills training into technical programs, emphasizing communication for effectively presenting data insights. Collaboration and teamwork across interdisciplinary teams. Critical thinking for innovative problem-solving in Big Data scenarios.
    - **Focused Workforce Development**: Provide sector-specific training tailored to the needs of industries like finance, education, civil society, and semi-state organizations. Develop customized training modules addressing regulatory compliance (e.g., GDPR), ethical data practices, and advanced analytics for specific domains.
    - **Lifelong Learning Initiatives**: Promote lifelong learning programs through professional training institutes and educational platforms. Encourage Workshops and bootcamps focused on advanced Big Data tools and concepts. Access to online learning platforms offering certification in emerging technologies. Encourage businesses to sponsor continuous learning programs for their employees to maintain a competitive edge.
    - **Regular Skill Gap Analysis**: Conduct regular market research and skill gap analyses to identify emerging technologies and competencies required by the industry. Use this feedback to update training programs and curricula dynamically.
- **Recommendations for further research and data collection**: Based on the feedback and insights provided by the participants during the focus group, the following areas of further research and data collection are recommended to address gaps and enhance the understanding of skill requirements in Big Data:
    - **Market Research on Skill Demand**: Conduct comprehensive research to map the current and emerging skill demands across industries, including high-demand tools and technologies for roles like Data Analyst, Data Scientist, and Machine Learning Engineer. Sector-specific skill requirements, such as IoT and real-time

data processing for labour markets, and GDPR compliance for civil society organizations.
    - **Industry-Specific Challenges**: Conduct research on the unique challenges faced by industries (e.g., finance, education, and civil society) in adopting advanced Big Data technologies. Explore barriers to adopting tools like cloud platforms, NoSQL databases, and machine learning frameworks in smaller organizations and resource-constrained sectors.
    - **Big Data Adoption Trends**: Investigate how different industries are adopting advanced Big Data technologies, such as real-time data processing tools, cloud computing platforms and their impact on scalability and cost efficiency. IoT integration and its effect on operational models. Collect case studies to document successful adoption strategies and lessons learned.
    - **Collaboration Opportunities**: Research opportunities for collaboration between academia, industry, and government to address skill gaps. Explore models for public-private partnerships in developing Big Data training infrastructure and resources.
    - **Impact of Emerging Technologies**: Research the potential impact of emerging technologies like AI, edge computing, and blockchain on skill requirements in Big Data. Investigate how these technologies can be integrated into existing business models and what training is needed to support this integration.

Conclusions

- The discussion highlighted significant gaps in education and practical skill application, particularly in emerging areas like GDPR compliance, cloud computing, and AI, underscoring the need for enhanced academic-industry collaboration and targeted upskilling through Microcredentials
- Addressing these gaps through microcredentials and targeted training programs was identified as a key strategy to ensure professionals are equipped to meet the demands of the evolving Big Data landscape.
- To better align with industry needs, participants recommended greater integration of interdisciplinary projects, industry-led workshops, and internships into educational programs. Microcredentials were also identified as a promising solution to bridge specific skill gaps, particularly in emerging technologies. This alignment effort requires closer collaboration between academia and industry to ensure curricula remain relevant and responsive to the rapid advancements in Big Data.
- Professionals must also develop capabilities in ethical data practices, including data governance, privacy, and compliance with regulations like GDPR. To stay relevant, professionals must continually adapt to new tools and frameworks, making lifelong learning and microcredentialing essential for addressing these rapidly evolving technological advancements.
- Cross-sector collaboration and investment in upskilling through microcredentials can address skill gaps, democratize access to Big Data insights, and empower organizations to leverage advanced technologies effectively. These opportunities highlight the potential for industries to overcome barriers and achieve greater efficiency and innovation.

- The development of microcredentials tailored to industry needs was also emphasized, with participants recommending that academia work closely with industry to create certification programs in areas like cloud computing, machine learning, and data governance. These certifications would allow professionals and students to upskill or reskill quickly and efficiently. Such partnerships would not only enhance employability but also ensure a steady pipeline of skilled talent to meet the evolving demands of the Big Data industry.
- Technological advancements in Big Data are driving transformative changes in business models and operations, offering opportunities for innovation, efficiency, and scalability while introducing new complexities in data management and compliance. These changes necessitate ongoing investment in technology adoption and workforce upskilling to fully capitalize on the potential of Big Data.
- The prioritized list of skill gaps requiring immediate attention reflects the critical importance of data integration and warehousing as a foundational component for leveraging Big Data effectively. It underscores the need for comprehensive skill-building in these areas to enable scalable and efficient data operations.
- Based on the feedback and insights provided by the participants regarding the recommendations for further research and data collection by addressing these research areas, stakeholders can gain a deeper understanding of the challenges and opportunities in Big Data skill development and create targeted strategies to meet industry needs effectively.

2.3 ICT & Sustainability

Held in: Cyprus, Nicosia, Frederick University
Held on: 16.11.2024 date, from 15:30 - 17:00 (about 2 hours)

2.3.1 Focus group methodology

Short description of the focus group incl. information on moderation and note-taking.

Cyprus had 3 topics to discuss during the Focus Groups - AI & Ethics, Big Data and ICT & Sustainability.

The participants were asked beforehand to declare which topic they wished to contribute further. Each session was recorded (partially) so that the participants could hear any of the sessions if they wanted to know more about the other topics and also for moderation purposes. In addition, each session had one assigned person per session, to take notes and minutes another person for photographs.

Each session began with a short introduction to the topic and some suggestive questions were made in order to initiate the discussions about each topic. Each participant had their own take and their own contributions towards the discussions, as they had different backgrounds and expertise. Each session concluded with handing out of the questionnaires and thanking the participants for their time and valuable contributions.

Each session began with a short introduction to the topic and a number

- Participants
  - recruitment & selection,
    - Emails were sent out to stakeholders and to participants who had shown an interest in participating in the Online workshops. The participants fall under the umbrella of Quantuple helix
  - number of participants
    - 14 participants in total - 6 participants participated in the ICT & Sustainability focus Group
- Demographics, based on the data gathered using the feedback questionnaire
  - Age
  - Gender
  - Education level
  - Working position
  - Years of experience
  - Company size and industry
  - Geographic location
  - Technology Focus

2.3.2 Focus group findings & outputs

Key Challenges Identified by Participants

- **Cultural Barriers**: A lack of prioritisation for sustainability in organisational cultures, with minimal awareness and commitment at the leadership level.
- **Skills Gap**: A shortage of professionals with expertise in ICT and sustainability, particularly in combining technical and strategic roles.
- **Generational Divide**: Older employees often lack familiarity with advanced technologies, while younger employees may lack experience in applying these tools strategically for sustainability.
- **Funding Limitations**: Insufficient investment in energy-efficient products, renewable energy, and green ICT systems.
- **Policy and Regulation**: Complex or unclear regulatory frameworks discourage organizations from fully integrating sustainability measures.

Key Opportunities Identified by Participants

- **Solar Energy Utilization**: Cyprus's abundant solar resources offer a unique opportunity for powering ICT operations sustainably, such as solar-powered data centers.
- **EU Support**: Leveraging European funding and collaborative projects can enable research, training, and implementation of sustainable ICT practices.
- **Smart Applications**: Introducing IoT systems to monitor and manage resource consumption, particularly in homes and businesses, could drive efficiency.

- **Green Branding**: Sustainability-focused organizations can differentiate themselves in the market, particularly in tourism, where eco-friendly practices align with customer expectations.
- **Technology Innovation**: Cyprus's growing tech startup ecosystem provides opportunities to develop innovative solutions for e-waste management, energy monitoring, and resource efficiency.

Industry Trends and Their Impact on Skill Requirements

- **Green Data Centers**: As the demand for energy-efficient data storage rises, professionals skilled in AI-driven energy optimization, renewable integration, and data center management will be needed.
- **IoT and Smart Systems**: The rise of IoT for resource management (e.g., water, energy) will require skills in IoT development, network optimization, and data analysis.
- **AI and Predictive Analytics**: Skills in machine learning and predictive maintenance will be critical as these technologies become more prevalent across sectors like aviation and manufacturing.
- **E-Waste Management**: Knowledge of circular economy principles, modular design, and recycling processes will become increasingly valuable.
- **Energy Efficiency Tools**: Familiarity with programming energy-saving systems (e.g., smart appliances, automated shutdown systems) will become a baseline competency in ICT roles.

2.3.3 Skill Gaps and Competencies

- Core Technical Skills Identified as Deficient
  - **Energy Efficiency Expertise**: Lack of knowledge in optimizing ICT systems for energy consumption, including green computing and energy audits.
  - **IoT and Smart Systems**: Limited skills in developing, managing, and maintaining IoT-based sustainability applications.
  - **Data Analysis and AI Integration**: Deficiency in applying AI and big data analytics for predictive maintenance, resource optimization, and carbon footprint reduction.
  - **E-Waste Management**: Few professionals are trained in circular economy practices, such as recycling and designing modular, repairable devices.
  - **Renewable Energy Integration**: Insufficient expertise in integrating solar or other renewable energy systems into ICT infrastructure.

- Soft Skills and Competencies Required for Success
  - **Critical Thinking and Problem-Solving**: The ability to identify sustainability challenges and create innovative ICT-based solutions.
  - **Strategic Awareness**: Understanding how sustainability aligns with business goals and regulatory requirements.
  - **Change Management**: Capacity to foster a sustainability-focused organizational culture and manage resistance to change.

- **Collaboration and Communication**: Skills to effectively collaborate across departments and communicate the benefits of green ICT practices to stakeholders.

- Other Skills Identified as Deficient or Required
  - **Sustainability Reporting**: Competency in documenting and reporting sustainability metrics, aligned with EU and international standards.
  - **Regulatory Knowledge**: Understanding of local and EU sustainability regulations, and how they impact ICT operations.
  - **Digital Literacy Among Older Generations**: Bridging the generational gap in adopting and using advanced ICT tools effectively.

- Alignment of Current Educational Programs with Industry Needs
  - **Gaps in Curriculum**: Existing programs in Cyprus (e.g., KEPA & ANAD courses) focus on general sustainability but lack emphasis on ICT-specific sustainability practices, such as green data management or energy-efficient system design.
  - **Practical Training Deficiencies**: Limited opportunities for hands-on training in implementing and managing green ICT solutions.
  - **Lack of Certification Programs**: Few recognised certifications in ICT sustainability are offered, making it challenging for professionals to validate their skills.

- Emerging Skill Requirements Due to Technological Advancements
  - **AI and Machine Learning for Sustainability**: Skills to develop AI-driven solutions for resource optimisation, predictive maintenance, and energy management.
  - **Cloud and Edge Computing**: Proficiency in leveraging cloud and edge computing to reduce energy consumption and improve efficiency in data handling.
  - **IoT Development and Management**: Expertise in creating and deploying smart systems for urban planning, building management, and resource optimisation.
  - **Cybersecurity in Green ICT**: Ensuring data security while deploying energy-efficient systems and IoT devices.
  - **E-Waste Circular Economy**: Skills in managing electronic waste through innovative recycling, upcycling, and modular design practices.

Industry perspectives and challenges

- Challenges:
  - **High Initial Costs**: Adopting advanced technologies like IoT, AI, and renewable energy systems requires significant capital investment, posing a challenge for SMEs in Cyprus.
  - **Infrastructure Limitations**: Limited renewable energy infrastructure and slow IoT adoption hinder the implementation of green ICT solutions.
  - **Regulatory Complexity**: Uncertainty around EU and local regulations creates hesitancy in committing to large-scale sustainability projects.
  - **Awareness and Expertise Gaps**: Many industries lack awareness of how to leverage advanced technologies for sustainability and face a shortage of skilled professionals.

- Opportunities:
  - **Solar Energy Integration**: Cyprus's abundant sunlight presents a significant opportunity for industries to power ICT systems sustainably.
  - **Smart Systems Implementation**: IoT and AI solutions can optimize energy use, reduce operational waste, and enhance efficiency across sectors like tourism, manufacturing, and urban planning.
  - **Eco-Tourism Growth**: Sustainable ICT practices in the tourism sector can attract eco-conscious travelers, boosting competitiveness.
  - **EU Funding**: Access to European grants can support research and adoption of advanced technologies in industries focused on sustainability.

Collaboration Between Academia, Other Education Institutions, and Industry

- **Industry-Driven Curricula**: Academic institutions should co-develop programs with industries to ensure graduates are equipped with relevant skills, such as green ICT and renewable energy integration.
- **Internships and Apprenticeships**: Partnerships between universities and industries can provide hands-on experience in real-world sustainability projects.
- **Knowledge-Sharing Platforms**: Regular forums and conferences involving academia and industry can help exchange ideas, best practices, and the latest research.
- **Public-Private Partnerships**: Collaborative projects leveraging public funds and private expertise can drive innovation and address skill gaps in emerging technologies.
- **Cross-Border Collaboration**: Collaborating with international institutions can expose local talent to global best practices and advanced training opportunities.

Impact of Technological Advancements on Business Models and Operations

- **Shift Toward Digital Operations**: Technologies like IoT and AI are enabling data-driven decision-making, increasing operational efficiency, and reducing resource waste.
- **New Revenue Streams**: Businesses leveraging advanced ICT (e.g., smart applications for energy management) can explore subscription-based or service-oriented revenue models.
- **Decentralised Operations**: Edge computing and renewable energy systems are enabling businesses to operate more independently from centralised power and data infrastructures.
- **Sustainability as a Differentiator**: Companies incorporating green ICT into their operations are gaining a competitive edge by appealing to environmentally conscious consumers and partners.
- **Job Role Evolution**: Technological advancements are creating demand for hybrid roles, combining ICT expertise with sustainability strategy, such as "Green ICT Managers" or "Sustainability Analysts."
- **Regulatory Adaptation**: Businesses must integrate sustainability into their models to meet EU directives, avoiding penalties and accessing incentives.

Recommendations

- Prioritised List of Skill Gaps Requiring Immediate Attention
  - **Energy Efficiency in ICT**: Knowledge of designing and implementing energy-optimized systems, such as green computing and solar-powered data centres.
  - **IoT and Smart Systems Development**: Skills to create, deploy, and manage IoT solutions for sustainability, such as smart energy grids and resource monitoring.
  - **Data Analytics and AI**: Proficiency in using data and AI to optimise resource use, predict maintenance, and monitor carbon footprints.
  - **E-Waste Management**: Understanding circular economy principles and practical e-waste management techniques, including modular design and recycling processes.
  - **Regulatory Knowledge**: Familiarity with EU and local sustainability policies, including compliance standards and funding opportunities.

- Suggested Strategies for Addressing Identified Skill Gaps
  - Develop Targeted Training Programs:
    - Partner with organisations like KEPA and ANAD to introduce ICT-focused sustainability courses.
    - Create certification programs emphasising energy-efficient design, IoT for sustainability, and e-waste management.
  - Incorporate Practical Learning:
    - Provide hands-on workshops, internships, and apprenticeships within industries to build real-world expertise.
    - Promote "learning by doing" through pilot projects, such as implementing IoT solutions in local businesses or municipalities.
  - Leverage Industry-Academia Collaboration:
    - Establish advisory boards with industry leaders to guide the development of academic curricula aligned with market needs.
    - Facilitate joint research initiatives to explore advanced ICT applications for sustainability.
  - Raise Awareness Through Knowledge Sharing:
    - Organise conferences, webinars, and public campaigns to emphasise the importance of ICT in sustainability and showcase success stories.
    - Use "shock facts" to highlight issues like e-waste and energy consumption, motivating stakeholders to take action.
  - Provide Incentives for Skill Development:
    - Offer subsidies or grants to organisations that invest in employee upskilling for green ICT.
    - Recognise businesses excelling in sustainability through awards or certifications, encouraging others to follow suit.
  - Encourage Lifelong Learning:
    - Establish flexible learning paths to upskill mid-career professionals, especially those from older generations less familiar with ICT.
    - Promote online courses and micro-credentials to accommodate busy professionals.

- Recommendations for Further Research and Data Collection
  - **Workforce Needs Assessment**: Conduct sector-specific studies to identify detailed skill requirements and gaps in ICT for sustainability.
  - **Impact Studies**: Analyze the ROI of existing green ICT implementations in Cyprus to highlight economic and environmental benefits.
  - **Industry Demand Trends**: Gather data on emerging technologies and their adoption rates across Cypriot industries, identifying future workforce needs.
  - **Regional Benchmarking**: Compare Cyprus's progress with similar markets in the EU to identify best practices and areas for improvement.
  - **Behavioural Research**: Investigate attitudes toward sustainability in ICT among Cypriot businesses and employees to tailor training and awareness campaigns effectively.

Conclusion

- Summary of key findings and implications

  This Focus Group highlighted the current challenges, opportunities, and skill gaps at the intersection of ICT and sustainability within the Cypriot context. The findings highlighted the need for concerted efforts to address pressing issues such as cultural barriers, regulatory complexities, and the lack of expertise in integrating advanced technologies for sustainable practices. Participants consistently emphasized the potential of Cyprus's abundant solar resources, the growing tech startup ecosystem, and access to EU funding as unique opportunities for fostering sustainable ICT innovation.

  Key findings revealed that while there is recognition of the value of technologies like IoT, AI, and energy-efficient systems, significant obstacles such as funding limitations, generational divides, and a lack of industry-specific training impede their widespread adoption. Furthermore, the existing educational and professional development frameworks do not sufficiently align with the rapidly evolving needs of the ICT and sustainability sectors.

  The findings suggest that without immediate intervention, the country risks falling behind in capitalizing on advancements in green ICT. However, addressing these challenges strategically could position Cyprus as a leader in sustainable innovation, particularly in areas such as solar energy-powered data centers, IoT-enabled resource management, and e-waste circular economy practices. Moreover, embedding sustainability as a core value within business and educational systems is essential to bridging the existing gaps.

- Recommendations for future actions
  - Targeted Skill Development:
    - Develop and implement ICT-specific sustainability training programs.
    - Prioritise certifications and hands-on learning opportunities to build competencies in areas like green computing, IoT for sustainability, and AI-driven energy management.
  - Enhancing Collaboration:
    - Strengthen partnerships between academia, industry, and policymakers to co-create curricula, internships, and research initiatives.

- Establish knowledge-sharing platforms to facilitate continuous learning and innovation in green ICT practices.

- Leveraging Local Advantages:
  - Invest in solar energy integration for ICT systems, utilising Cyprus's abundant sunlight to create cost-efficient and sustainable solutions.
  - Support local startups to innovate in green technologies and incentivise industries to adopt their solutions.
- Policy and Awareness Campaigns:
  - Simplify regulatory frameworks and provide clear guidance to encourage businesses to adopt sustainable practices.
  - Raise awareness about the importance of ICT in achieving sustainability goals through targeted outreach and success stories.
- Continuous Monitoring and Research:
  - Conduct ongoing assessments of workforce needs and skill gaps to align training programs with industry trends.
  - Benchmark against EU peers to identify best practices and opportunities for collaborative improvement.

3 Findings & conclusions from the focus group GREECE

Held in: Greece, Athens digitally meeting
Held on: 5th of December 11 00 to 15 00

3.1 Focus group methodology

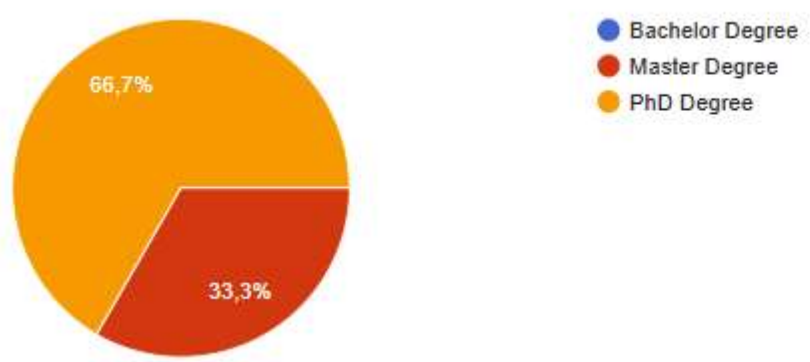
The Focus Group was moderated by Dr. Katerina Tzortzatou from NCSR Demokritos, with note-taking facilitated by Mrs. Varvara Vasilaki, also from NCSR Demokritos. Dr. Tzortzatou additionally delivered the presentation.

The session began with a roundtable introduction, during which each participant briefly shared their educational background, area of expertise, role within their organization, and their organization's primary focus. Following the introductions, Dr. Tzortzatou presented an overview of the project, supplemented by detailed information on each ATI and the specific feedback sought from the participants.

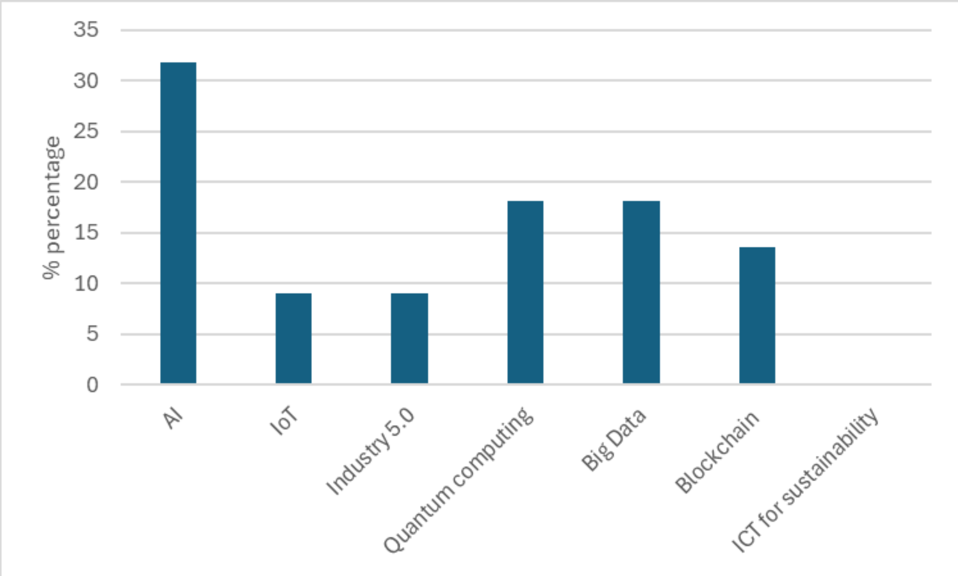
The Focus Group included 22 participants, all invited based on prior collaborations with NCSR Demokritos. No selection process was necessary, as only experts with a demonstrated interest in ATI were approached.

Participants' ages ranged from 28 to 55, with 6 individuals in the 44–55 age group and the remaining participants in the 28–43 age group. Of the 22 participants, 9 were women, and 13 were men. All participants live and work in Athens.

The graph below illustrates the educational backgrounds of the participants.



The technological background of the participants is illustrated in the following graph. While none of the participants had expertise specifically in the domain of ICT for Sustainability, the discussion provided valuable insights. It became evident that this area represents a significant gap within organizations and companies, highlighting an opportunity for further development and focus.



3.2 Focus group findings & outputs

Understanding the Current Landscape

Participants highlighted several key perceptions and challenges related to the current state of digital domains and their sectors. In the field of AI and Ethics, despite the presence of professionals with a strong data science and analytics background, there is a growing demand for advanced machine learning skills and ethical considerations in AI technologies. The need for interdisciplinary collaboration between technical and philosophical domains was emphasized. For Big Data, while there is a large pool of professionals in data science, advanced skills in machine learning and big data frameworks are increasingly required to meet market demands. Participants noted a lack of alignment between current industry needs and the educational programs offered. In the Blockchain domain, there is a significant gap in professionals who can bridge technical expertise and business strategy. While many individuals have strong technical skills, there is insufficient knowledge of regulatory frameworks and commercial applications. The Internet of Things (IoT) domain has a substantial pool of experts; however, the rapid evolution of IoT technologies has outpaced the knowledge imparted in university programs. There is also a noted gap in sector-specific expertise, such as in retail, logistics, and agriculture. Industry 5.0 faces skill shortages at all levels, with identified gaps in work psychology, client interaction, and effective communication, alongside a need for knowledge of advanced technologies like cybersecurity and machine learning. Quantum Computing suffers from limited practical expertise and a small pool of researchers, with market demand emphasizing the need for bridging theoretical understanding with practical applications. ICT for Sustainability is seeing a rising awareness within the ICT sector in Greece, with opportunities in roles such as Sustainability Consultant and ESG Advisor, focusing on integrating ICT solutions with sustainability objectives.

Skill Gaps and Competencies

Several core technical and soft skills deficiencies were identified across domains. For AI and Ethics, skills such as machine learning, regulatory frameworks, and ethics in technology were found to be lacking. Big Data requires competencies in cloud computing, big data frameworks, and business process understanding. In Blockchain, there is a need for programming expertise, smart contract development, and cryptography. IoT professionals require IoT security knowledge, data analysis, and specific programming skills. Industry 5.0 demands machine learning, cybersecurity, and programming skills, while Quantum Computing emphasizes quantum architectures, IBM tools, and superconducting circuits. ICT for Sustainability professionals require skills in sustainable technology solutions and ESG data analysis.

Soft skills were also identified as critical. AI and Ethics professionals need critical thinking, interdisciplinary collaboration, and adaptability. Big Data roles demand communication, analytical thinking, and data storytelling. Blockchain professionals must excel in problem-solving and understanding regulatory frameworks, while IoT roles require adaptability and sector-specific collaboration. Industry 5.0 highlights the importance of emotional intelligence and client interaction, and Quantum Computing roles require strong communication and problem-solving skills. Bridging theoretical and practical knowledge is essential across all domains.

Participants also discussed the alignment of educational programs with industry needs, noting significant gaps in areas such as IoT and Blockchain. They suggested integrating industry-oriented courses and practical training into academic programs. Emerging skill requirements were also highlighted, including sustainability-focused ICT roles, advanced expertise in quantum computing frameworks, and cross-disciplinary skills in AI and Ethics.

Industry Perspectives and Challenges

Participants identified several industry-specific challenges and opportunities. Collaboration between academia and industry was noted as insufficient in addressing skill gaps. There is a need for dynamic educational programs that adapt to evolving technologies. The rapid pace of technological advancements is altering business models, necessitating adaptable and forward-looking skill sets. Industries are also required to embrace self-employment and entrepreneurial approaches to meet workforce demands.

Recommendations

To address the identified skill gaps, participants proposed several strategies. They emphasized the immediate need to focus on advanced machine learning, IoT security, and blockchain business applications. Greater emphasis should be placed on soft skills, including adaptability and interdisciplinary collaboration. Enhanced collaboration between academia, industry, and policymakers was recommended, alongside the introduction of specialized postgraduate programs and certification courses. Industry internships and co-op programs were suggested to provide hands-on experience. Participants also called for further research, including in-depth analysis of emerging technologies and studies on aligning education with sustainability and digital transformation goals.

Conclusion

The discussion highlighted critical skill gaps across digital domains, emphasizing the need for immediate action to align educational programs with industry requirements. Participants recommended fostering collaboration between stakeholders, prioritizing interdisciplinary skills, and adapting to technological advancements to ensure a competitive and future-ready workforce.

4 Findings & conclusions from the focus group LITHUANIA

Held in: Lithuania, Klaipeda, Chamber of Commerce, industry and Craft premises.
Held on: 2024 11 20

4.1 Focus group methodology

Short description of the focus group incl. information on moderation and note taking.

The focus group organized by the Klaipeda Chamber of Commerce, Industry, and Crafts took place on 2024- 11-20. Moderation was conducted by project manager Vitalija Brazauskienė, and notes were taken by Daniela Diržininkaitė, a chamber employee involved in various chamber event organizing.

- 11 participants from different IT, Education, private business sectors, and the Directorate of Klaipeda Port attended the event.
- After the focus group, a questionnaire was sent to the participants. Five responses were received, with the following demographics:
  - Age: One participant aged 28–43; four participants aged 44–59. Gender: Three men, two women.
  - Education level: One participant with a doctoral degree; two participants with master’s degrees; two participants with bachelor’s degrees.
  - Working position: Two IT managers, one project manager, and two company directors. Years of experience: 24 years, 23 years, 1 year, 4 years of experience.
  - Company size and industry:
    - Manufacturing company, 3,000 employees.
    - Education institution, middle-sized company.
    - IT services, small-sized company.
    - Public sector, small-sized company.
    - Logistics company, around 230 employees.
  - Geographic location: Klaipeda, Kaunas, Vilnius region.
  - Technology focus: Companies aim to be at the forefront of technological solutions, constantly introducing innovations that help customers and business partners achieve their goals more efficiently. They use technologies that optimize processes, save resources, and create value. Additionally, they strategically invest in new technologies or are open to starting investments.

4.2 Focus group findings & outputs

During the focus group the participants clearly expressed their opinion about the existing and growing need of ATIs in the country. It was explained that the industry must cooperate and use the ATIs as a must condition for survival. If the industry refuses to keep connected with ATIs, according to the participants, the industry is more likely to be scattered. However, the same situation was prognosed to happen if the industry is late to do it. Especially it is relevant to the production sector, where ATIs brings an especial value for the final product.

The main challenges are strongly related to the integration of technologies into industrial processes. One of the main challenges was emphasized the mismatch between the new ATIs which tend to be integrated and the current working systems. However, the intention to find the solution to this challenge is strongly related to an understanding about the economic grow which industry can face by involving the newest technologies.

The discussion revealed the strong trend of automation and robotization based on the increasing of automated production lines, using robots and artificial intelligence. Also, digital solutions were identified as a industry trend by expanding the investments on the such ATIs as Internet of Things or Big Data analytics.

Skills identified as most relevant in ATI'S development and integration into company:

Skill	Description
Machine learning	High programming skills, mathematics knowledge, and expertise in various algorithms to develop and evaluate predictive models.
Data analysis	Systematic examination and interpretation of data to extract meaningful insights and support decision- making.
Communication	Ability to express information clearly and effectively to various business sectors and employees, ensuring that messages are understood and adaptable easier.
Business psychology	Ability to work on strategies to identify areas for improvement, ultimately fostering a healthier and more effective work environment. Especially pointed out as a critical skill by IT sector attendees.
Business Management	Ability to understand business that specialist works in, its principles, being able to blend technical skills with market knowledge and analysis to make better decisions, pointed out as a crucial lacking skill by all attendees.

Machine learning was identified as one of the most important technical skills required because of its adaptability too. Data analysis and management were also highlighted as significant skills due to their role in supporting decision-making, driving operational improvements, and fostering innovation. Soft skills were also mentioned throughout the focus group, and its big importance and lack in the industry, IT sector signified the need for soft skills training by education organizations. Besides very strong technical base knowledge, deeper skills, more practical experience is needed to be included into educational programs.

While discussing strategies for addressing identified skill gaps it was offered for educational institutions attending focus group to focus not only on technical skills but to also include skills like communication or understanding of business management or even psychology in business.

It was pointed out that a significant number of employees lack basic computer literacy, with many entering the workforce without proficiency in Excel, even after completing university. This raises the critical question of whether organizations have the time and resources to invest in training and reskilling their workforce. The willingness and openness of individuals to adapt and learn new skills are crucial factors in this process. Organizations must consider the adaptability of their employees when implementing new technologies.

The cooperation with the educational institutions was indicated as an opportunity for the industry to optimize the empowerment of the ATIS.

During the focus group, a lot of attention was dedicated to ATIS and the willingness of already employed specialists to adapt and learn how to work with new technology. It was noted that employees with longer experience in the company are usually apprehensive about the technology, while new specialists trained in machine learning lack soft skills, such as how to communicate and encourage employees with no knowledge of the technology to use it.

A primary issue identified is the lack of engineers who can come up with ways to implement technologies effectively. Often, products arrive in an immature state and fail to meet expectations. Having good technology alone is insufficient; it is essential to understand how to integrate it by comprehending not only the technology itself but also the business processes involved. This understanding is crucial for determining what needs to be done differently to fully leverage the capabilities of the technology.

Moreover, there is uncertainty about the specific skills and types of personnel that will be needed in the future. While efforts are being made to prepare existing staff, there is a consensus that hiring untrained specialists may not be a viable solution.

In addition to technical skills such as programming, there is a growing recognition of the importance of psychological insights in fostering a helpful environment for learning and adaptation.

It was stated by one of the University's perspectives that employees are changing, and there are shifts occurring. Some are resisting in implementis ATI'S into the work but once they do work becomes easier. Talking about future prognosis it gradually becomes clear that fewer data analysts will be needed, especially in junior roles.

When it comes to data protection, there was concern when the GDPR was introduced, but people have relaxed since. At present, there's hope that the cyber security law will tighten up, with stricter penalties, and that it will be taken more seriously.

After the focus group discussion, it was stated that it is important to continue these dialogues and further research between educational and business sectors, where all can share their experiences and success stories between each other.

Conclusion

The focus group highlighted the important need for ATIs across various industries, particularly in the production sector, where their adoption is essential for maintaining competitiveness and ensuring survival. Participants emphasized that collaboration with ATIs is not merely beneficial but vital, warning that industries that fail to engage with these technologies risk stagnation and might not even survive in the future.

Key findings revealed significant challenges related to the integration of new technologies into existing operational frameworks. A notable mismatch between innovative ATIs and current systems was identified, along with a critical need for both technical and soft skills within the workforce. The discussion also pointed out a concerning lack of basic computer literacy among new employees, which raises questions about organizations' capacity to invest in necessary training and reskilling initiatives since not every organization can spend time on it.

Recommendations from focus group:

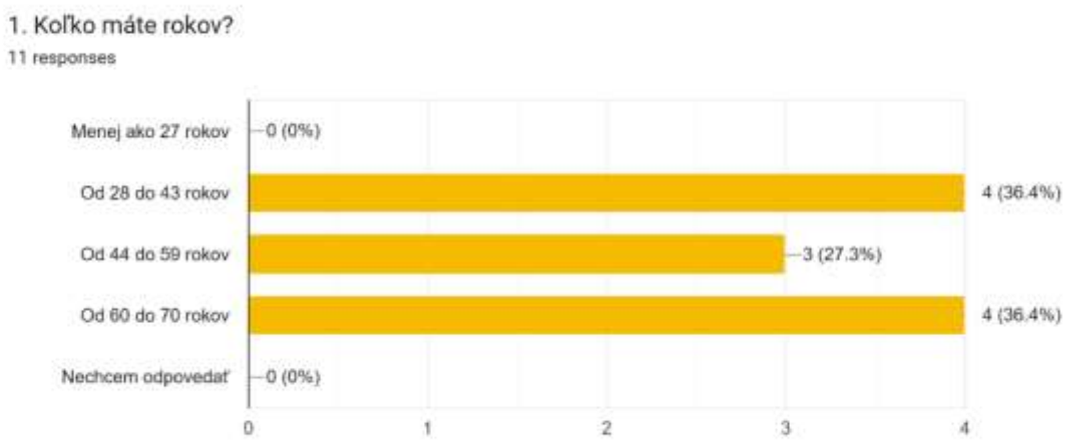
- Strengthen partnerships between industry and educational institutions to ensure that programs are in sync with the evolving technologies and workforce needs.
- Develop training programs that include both technical skills such as programming and data analysis and essential soft skills, including communication and business management.
- Dedicate resources toward upskilling current employees, particularly in areas like machine learning, data management, and effective technology integration.
- Foster a culture of openness and adaptability within organizations to ensure smoother transitions when integrating new technologies and to encourage continuous learning.
- Establish ongoing discussions between education sectors and industry leaders to share insights, experiences, and best practices for bridging skill gaps and preparing for future technological advancements.
- Security must be an integral part of IT system management, ensuring that systems are not only functional but also secure.
- Participants expressed their desire to continue discussion between sectors in the future with similar events like focus group.

5 Findings & conclusions from the focus group SLOVAKIA

Held in: Slovakia, Kosice, on 16 October, 2024, from 9.00 am until 3.00 pm

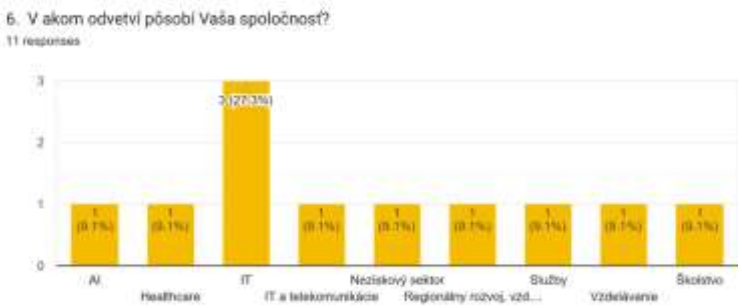
5.1 Focus group methodology

- Short description of the focus group incl. information on moderation and note taking.
  - The FG was moderated by Iveta Orbanova from Astra, note taking was done by Zuzana Fedakova from IT Valley. The presentations were given by Oto Hudec, from TUKE & Iveta Orbanova. Based on the FG agenda, the participants introduced themselves giving details on the field of their own & their companies expertise as well as details on the ATIs applied currently.
- Participants
  - Recruitment & selection: the participants were invited based on the previous cooperation with the SK project partners; there was no selection as we consulted the participation prior to the invitation sending, and invited only those experts which were interested and the planned FG time was suitable for them.
  - number of participants: there were 12 external participants and 6 persons from project partner institutions
- Demographics, based on the data gathered using the feedback questionnaire
  - Age: in the groups 28 to 43 & 60 to 70 years of age there were 4 participants in each, while in the age group of 44 to 55 years of age, there were 3 participants



  - Gender: 5 women, 6 men out of 11 external participants which filled in the questionnaire
  - Education level: 5 participants with first level university degree, 5 with the second level uni degree, one graduate of secondary school

- Working positions: 2 IT managers, 1 Executive Director, 2 heads of NGOs, 3 managers, 1 Strategy & Technology Officer, 1 CEO, 1 project manager
- Company size and industry:
  - the following sectors were represented: healthcare, IT, AI, services, education, public administration/ regional development, NGO
  - size of the represented companies: 2 micro companies (less than 9 employees), 4 SMEs, 5 large companies



- Geographic location: 10 out of 11 participants' have their company in Kosice
- Technology Focus
  - IoT, ML, AI, application development
  - On all key :)
  - Gen AI, Orchestration, NLP,
  - Education, Data Science
  - ICT, Big Data, IoT, Industry 5.0, Artificial Intelligence, ...
  - AI, robotics, IoT, software, big data
  - AI
  - Cloud, SAP, BI
  - Technology Quality 5.0; connecting automated systems with human creativity and intelligence

5.2 Focus group findings & outputs

- Understanding the current landscape
  - All participants were familiar with all ATIs analysed within the Investech project. However, not all ATIs are applied in all represented institutions. Participants'

perception of the current state of 7 ATIs in the country & their sectors was very similar regardless from the sector or institution they came from. All of them agreed that the formal education is not in the shape to provide the necessary skills & knowledge to their graduates because of the high dynamics in the ICT and analysed ATIs as well as the emerging Industry 5.0.

- Key challenges and opportunities identified by participants: stronger cooperation & communication of all levels of the formal education as well as with the adult educators are both a challenge and the opportunity as more and more the soft & social skills are needed in all ATIs; the request is stronger with the Industry 5.0
- Industry trends and their impact on skill requirements: all participants agreed that the influence of Industry 4.0 as well as 5.0 has brought not only requests for new technical skills, but also much stronger need of fast reaction from all types of educators: new courses are needed fast even for the new graduates and of course for the experienced experts.

- **Skill gaps and competencies**: within the SK FG the participants worked in 3 groups; each group focused on 2 ATIs.
    - The 1st group has focused on AI & Big data. They had a look at the single phases of the ATIs application as well as from the working positions view; the skills then were divided into 3 groups: CRITICAL (must have), RECOMMENDED (should have), and NICE TO HAVE (could have). **status, how much we lack in** The outputs of the 1st group work are given in the Table 1 below

Table 2 Output of the 1st group

ATI: AI & Big data - SKILLS						
PHASE problem understanding						
Working position	**MUST CRITICAL**	**%**	**should recommended**	**%**	**could nice to have**	**%**
data analyst	design thinking	50	AI application areas	75	regulations	100
data scientist	requirement analysis	50	system integration	20	cyber security standards	80
solution architect	client's language	90	innovation/ experimenting	80	model …/select what	60
PM	domain/sector knowledge	100	vision	80	agile development	
	data sourcing	50				
	problem solving	50				
	critical thinking	50				
	business thinking	100				
	communication	100				

PHASE design/use case						
working position	**MUST CRITICAL**	**%**	**should recommended**	**%**	**could nice to have**	**%**
data engineer	design thinking	75	model engineering/ design		vision	
AI/data architect	systems engineering	50	ML		NLP, ANN	
integration tester	cloud/virtualization		AI/HCI		edge computing	
conversational designer	critical thinking		business thinking			
	system integration		communication			
	cyber security standards		team work			
	problem solving		Multi disciplinarity			
			agile development			
			innovation/ experimenting			

PHASE development testing/quality assurance						
working position	**MUST CRITICAL**	**%**	**should recommended**	**%**	**could nice to have**	**%**
ML engineers	coding/programming					
ML/BI developers	SW engineering	50				
analysts	containers(docker…)	40				
QA/test designers	ML	50				
	critical thinking	90				

PHASE use/apply						
working position	**MUST CRITICAL**	**%**	**should recommended**	**%**	**could nice to have**	**%**
implementation engineer	critical thinking	75	business thinking		agile	
integration engineer	integration	90	cloud/virtualization		machine learning	
product owner/manager			communication			

- The 2nd group worked on Industry 5.0 & ICT for sustainability. The outputs of the 2nd group work are given in the Table below

Table 3 Output of the 2nd group

ATI: ICT for sustainability & Industry 5.0	CURRENT situation: skills missing or unsatisfactory currently
Technical skills	CAD
	CAM, CAE
	Digital simulations
	Digital twins
	Extended reality
	Virtual reality
	Generative AI & prompt engineering
	Data analysis
Analytical skills	Critical thinking
	Data interpretation
	Business acumen/thinking
Soft & social skills	Flexibility
	Client's language
	Ethics
FUTURE expected needs	Domain/sector knowledge
	Hyperautomation
	cooperation human/robots
Overlaps/skills needed for all ATIs	Data as a value
	Resilience
	Risk management
	Creativity

- The 3rd group worked on IoT & Big data.

Table 4 Output of the 3rd group

IoT & Big data	Currently OK	Currently missing	Future, expected
Technical skills			
Programming and coding: knowledge of languages such as Python, Java, C++ and ROS.	x		
Data analysis: skills in processing, analysing and interpreting large data sets		x	x
Systems integration: ability to integrate different systems and technologies.		x	x
Network security: knowledge of cybersecurity principles and practices.		x	x
Cloud computing: knowledge of cloud platforms such as AWS, Azure and Google cloud.		x	x
Machine learning and AI: understanding of algorithms, data models and artificial intelligence frameworks.		x	x
IoT development: skills in sensor technology, IoT architecture and connectivity protocols.		x	x
Mobile application development	x		
Software testing	x		
Network management	x		
CAD software	x		
Project management tools	x		
Graphic Design Software	x		
Analytical skills			
Problem solving: ability to identify problems and propose effective solutions.		x	x
Critical thinking: logical and systematic evaluation of information and arguments. Ability to analyse complex problems and develop innovative solutions.		x	x
Data interpretation: ability to make sense of complex data and draw useful conclusions.		x	x
Innovation: developing new ideas and approaches to improve processes and products.		x	x
Business acumen: understanding business processes and how technology can improve them.		x	x

Soft & social skills	Currently OK	Currently missing	Future, expected
Communication: effective verbal and written communication skills for a variety of audiences.		x	x
Collaboration: ability to work well in teams and across departments.		x	x
Adaptability: flexibility to adapt to new technologies and changing environments.		x	x
Leadership: leading teams, managing projects and making strategic decisions.		x	x
Time management: prioritising tasks and managing time effectively.		x	x
Interpersonal and communication skills: Ability to understand human psychology and behaviour in the work environment in order to design better interaction patterns.		x	x
Teamwork and collaboration: Ability to work collaboratively in a multicultural and multigenerational team that includes designers, engineers and safety experts to develop complex interaction systems		x	x
Ability to explain complex digital concepts to non-technical stakeholders.		x	x
Project management skills			
Planning and organisation: ability to plan, implement and supervise projects.		x	x
Resource management: efficient use of resources including time, budget and staff.		x	x
Risk management: identification and mitigation of potential risks.		x	x
Ethics & legal competences			
Ethics in technology: understanding the ethical implications and responsible use of technology.	x		x
Data protection: knowledge of data protection regulations and practices.	x		x
Compliance: ensuring compliance with industry standards and regulations.	x		x

- Interesting observation: many of currently lacking skills are non-technical as well as considered to be the ones expected in the future.
- Recommendations: based on the inputs given in the tables above, FG Minutes as well as the discussions which followed the working in groups, we can conclude that FG participants recommended the following skills & competencies as critical ones

List of skill gaps requiring immediate attention

- Technical skills
  - CAD
  - CAM, CAE
  - Cloud computing
  - cloud/virtualization
  - Coding /programming
  - Containers (docker…)
  - Data analysis
  - Data sourcing
  - Digital simulations
  - Digital twins
  - Extended reality
  - Generative AI & prompt engineering
  - IoT development
  - Machine learning
  - Network security
  - requirement analysis
  - SW engineering
  - Systems engineering
  - Systems integration
  - Virtual reality
- Analytical skills for all analysed ATIs
  - Critical thinking
  - Data interpretation
  - Business acumen/thinking
  - problem solving
  - Innovation
- Soft & social skills
  - Flexibility
  - Client's language
  - Ethics
  - Interpersonal skills & communication
  - Collaboration
  - Adaptability
  - Leadership
  - Time management
  - Teamwork & collaboration
  - Ability to explain complex digital concepts to non-technical stakeholders.

- Other
  - Project management:
    - Planning and organisation: ability to plan, implement and supervise projects.
    - Resource management: efficient use of resources including time, budget and staff.
    - Risk management: identification and mitigation of potential risks.
  - Cyber security standards

Suggested strategies for addressing identified skill gaps were also discussed, but not in details. Certainly, the cooperation among all education & training organisations, regardless from the type & level is strongly needed - in particular, for the social & soft skills. The form of the training & education should be carefully considered to possibly embrace the different levels & reach the flexibility and fast reaction to the very dynamic sector and rapidly changing requests.

Conclusion

- Summary of key findings and implications
  - There are critical skills, currently either missing fully or not sufficiently developed in all 7 analysed ATIs; the lists of these skills are given in the tables 1-3 above
  - These critical skills are of various type: technical, social & emotional, PM, analytical, ethical & legal skills.
  - There are many overlaps in critical skills lists for the analysed ATIs in particular for social & emotional skills
  - The cooperation of Quintuple Innovation Helix entities is crucial and inevitable to meet the needs of experts in ATIs in various training
  - Microcredentials seem to be one of possible forms to be used across all educational levels
  - Non-technical skills should be more in focus as the Industry 5.0 human centricity bring the strong demand for higher emotional & social intelligence of experts

WP4 Enhancing Labour Market-Relevant Skills in Advanced Technologies

T4.1 Identifying skill gaps in Advanced Technologies

Findings & conclusions from the interviews held

Date: September 2024 – January 2025

INVESTech

Innovation Vocational Excellence and Sustainability in Tech

PROJECT REF NO. 101143958. ERASMUS-EDU-2023-PEX-COVE

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1 Findings & conclusions from the interviews held in BULGARIA

1.1 Executive Summary

- Number of interviews held: 4
- Held from - to /duration: December 2024 - January 2025
- Information on participants:
  - Male/female – 3 male, 1 female
  - Positions - Human Resources expert, Lead AI Engineer, DevOps Engineer, Founder and director
  - Sectors: Automotive, Outsourcing, Software engineering
- Which ATIs did you discuss within the interviews held in your country:

  ☑ Artificial Intelligence and Ethics
  ☑ Big Data
  ☐ Blockchain
  ☑ Internet of Things
  ☐ ICT for sustainability
  ☐ Industry 5.0
  ☐ Quantum Computing

1.2 Interview Methodology

- Interview Format: Describe whether the interviews were structured, semi-structured, or open-ended.
  All interviews were semi-structured using the provided guidelines and key points for the discussion aiming to drive the main content of the template for findings and conclusions. This method allowed in-depth exploration of topics and encouraged participants to share personal insights.
- Interview Questions: List the core questions used to guide the conversation:
  - Can you describe the role of advanced technologies (e.g., AI, automation, IoT, robotics) in your industry?
  - What specific technologies have had the most significant impact on your sector in recent years?
  - In your experience, what are the most critical skill gaps in your industry due to technological advancements?
  - How have job roles and required skills evolved with the adoption of advanced technologies?
  - Are there any particular areas (e.g., AI programming, cybersecurity, data analytics) where talent shortages are most noticeable?

- How do employees generally respond to automation and AI-driven processes—are they resistant or adaptive?
- What are the biggest challenges your organization (or industry) faces in integrating new technologies?
- Have you seen any effective upskilling or reskilling programs in your industry? If so, what made them successful?
- Do you think collaboration between industry and educational institutions can help close the skills gap? How?
- How do you see the role of advanced technologies evolving in your industry over the next decade?
- What advice would you give to individuals entering the workforce who want to stay competitive in a tech-driven industry?

- Additional Notes: Mention any additional materials (e.g., pre-interview surveys or follow-up questions) used to prepare or support the interview.
  - Handout with main information about the project
  - Overview of the company and the industry of the interviewee
  - Main facts about the companies and background of the people

- Key Findings: Summarize the main points covered, highlighting critical skills gaps, challenges, and any recommended solutions.
  - Bulgaria has a well-established tech sector with strong outsourcing and startup ecosystems. However, significant skill shortages hinder its ability to sustain and expand its role as a leading European IT hub. The most pressing gaps include:
  - Cybersecurity & Digital Resilience – As cyber threats grow, Bulgaria faces a shortage of experts in cybersecurity governance, ethical hacking, and digital forensics. The demand for professionals trained in Zero Trust security models and cloud-native security is particularly high.
  - AI, Data Science & Machine Learning – While AI adoption accelerates globally, Bulgaria needs more skilled professionals in AI development, NLP, data analytics, and business intelligence to drive innovation in finance, healthcare, and automation.
  - Cloud Computing, DevOps & Automation – The shift to cloud-native technologies requires expertise in AWS, Azure, Kubernetes, containerization, and CI/CD pipelines to enhance software development efficiency and scalability.
  - Software Engineering & Low-Code Development – Companies seek developers proficient in Python, JavaScript (React, Angular), Rust, and Go, as well as low-code/no-code platforms that accelerate digital transformation.
  - Blockchain, Web3 & FinTech Innovation – With Bulgaria being a European blockchain leader, the demand for smart contract developers, DeFi experts, and crypto regulation specialists is rising.
  - IoT & Smart Manufacturing – The increasing digitalization of manufacturing calls for embedded systems engineers, industrial IoT experts, and automation specialists to support Industry 4.0 adoption.

- Recommendations:
  - Stronger University-Industry Collaboration – Expand internship programs, industry-sponsored hackathons, and collaborative research projects.
  - Microcredential & Continuous Learning Incentives – Support professionals with certifications in AI, cybersecurity, and cloud computing.
  - Government-Backed Upskilling Initiatives – Provide funding for reskilling mid-career professionals into emerging tech fields such as blockchain, IoT, and AI.
  - Tech Incubators & Innovation Hubs – Strengthen public-private partnerships to support local tech startups with funding, mentorship, and networking.
  - Workforce Preparedness: Bridging the Digital Skills Gap.
  - Enhancing STEM Education – Introduce mandatory coding courses and AI-driven learning platforms in schools. Encouraging Certification-Based Learning – Promote online certifications from Coursera, Udacity, AWS, and Google Cloud to enhance professional skills. Building Soft Skills & Entrepreneurship Mindset – Foster creativity, adaptability, and critical thinking to support startup culture and tech leadership.

1.3 Experts' Insights

1.3.1 Artificial Intelligence and Ethics

- Current State of skills:
  - While Bulgaria is recognized for its strong talent pool in IT and outsourcing, the HR expert notes a significant gap in aligning technical skillsets with rapidly evolving client demands. Professionals often excel in foundational skills but lag behind in advanced areas such as cloud architecture, hybrid environments, and modern cybersecurity practices.
  - Bulgaria has established itself as a hub for AI talent, but there are critical gaps in scaling AI projects from prototypes to production. Many professionals are skilled in research and development but lack experience in deploying robust, real-world AI systems. Skills in managing big data pipelines and implementing responsible AI practices are still underdeveloped.
  - While AI adoption accelerates globally, Bulgaria needs more skilled professionals in AI development, NLP, data analytics, and business intelligence to drive innovation in finance, healthcare, and automation.
  - Cloud Computing, DevOps & Automation – The shift to cloud-native technologies requires expertise in AWS, Azure, Kubernetes, containerization, and CI/CD pipelines to enhance software development efficiency and scalability.
- Core Skills Gaps Identified:
  - Limited knowledge of managing multi-cloud infrastructures and tools like Terraform, Azure Arc, and Google Anthos.
  - Insufficient expertise in advanced cybersecurity frameworks, including Zero Trust architecture and threat intelligence platforms.

- Weakness in customizing CRM tools and integrating workplace technologies to improve efficiency and customer experience.
- Technical Skills:
  - Limited hands-on experience with deploying AI/ML models using tools like TensorFlow Serving, Kubernetes, or AWS SageMaker.
  - Lack of proficiency in data engineering skills, including building ETL pipelines and handling unstructured datasets.
  - Weak understanding of AI-specific security challenges, such as adversarial attacks and data poisoning.
- Analytical Skills:
  - Insufficient expertise in translating business challenges into AI-driven solutions.
  - Difficulty in evaluating and ensuring the explainability of AI models, particularly in regulated industries like finance and healthcare.
- Soft Skills:
  - Communication gaps between AI teams and business stakeholders.
  - Limited collaboration skills to bridge the gap between data scientists, software engineers, and domain experts.

- Emerging Needs and Future Skills:
  - AI & Autonomous Systems – AI-powered automation in industries like logistics, retail, and healthcare will require AI engineers, robotic process automation (RPA) specialists, and AI ethics experts.
  - Cybersecurity Awareness and Practices: Training employees at all levels to recognize and mitigate security threats.
  - Cloud-Native Technologies: Specializing in container orchestration, serverless computing, and automation for cloud deployments.
  - Client-Centric Skills: Improving empathy, adaptability, and problem-solving abilities to enhance customer relationships in CRM and workplace services.
  - AI in Automation: Understanding how to integrate AI with robotic process automation (RPA) and intelligent workflows.
  - Edge AI: Skills in optimizing AI models for deployment on edge devices to reduce latency and improve real-time decision-making.
  - Ethical AI and Governance: Knowledge of ensuring fairness, transparency, and compliance with global AI regulations such as GDPR and AI Act.
  - AI Integration in DevOps: Leveraging AI for autonomous vehicle software testing and predictive analytics.
  - Hybrid Cloud and Edge Computing: Balancing on-premise and cloud solutions to enable real-time processing for autonomous systems.
  - Extended Reality (XR) & the Metaverse – Demand for VR/AR developers, 3D designers, and spatial computing specialists will increase, especially in gaming, education, and real estate.

- Industry-Specific Competency Requirements
  - Sector-Specific Skills:
    - The outsourcing industry requires a combination of technical expertise and adaptability to meet diverse client needs. Key competencies include:

- Cybersecurity: Mastery of compliance standards like GDPR, ISO 27001, and NIST frameworks, along with proactive threat detection and response.
- Skills in building AI models for diagnostics, imaging, and patient management while ensuring compliance with HIPAA and GDPR.
- Brain Drain & Talent Retention – Many skilled IT professionals relocate to Western Europe or work remotely for foreign companies, limiting local tech sector growth.
- Education-Industry Mismatch – Universities struggle to keep up with the fast-paced tech industry, resulting in graduates with outdated skill sets.
- AI, Automation & Data Science – Establishing AI-driven business solutions, focusing on predictive analytics, NLP, and AI-powered automation.

- Certification and Compliance Knowledge:
  - Certifications such as AWS Certified Solutions Architect, Certified Information Systems Security Professional (CISSP), and Microsoft Certified: Dynamics 365 Fundamentals are highly valued. Knowledge of compliance regulations such as GDPR and ISO 27001 is critical, especially for managing sensitive client data.
  - Certifications like TensorFlow Developer, AWS Certified Machine Learning – Specialty, and Microsoft AI Engineer are valuable. Knowledge of global and regional regulations, such as the EU AI Act and GDPR, is becoming increasingly essential, especially for AI applications in sensitive domains like healthcare and finance.

1.3.2 Big Data

- Current State of skills:
  - The automotive industry is transitioning towards software-defined vehicles and autonomous systems, placing immense pressure on IT professionals to acquire specialized skills. In Bulgaria, while there's a growing DevOps talent pool, there's limited expertise in automotive-specific technologies such as real-time system deployment, vehicle-to-everything (V2X) communication protocols, and functional safety standards (ISO 26262).
  - Cloud Computing, DevOps & Automation – The shift to cloud-native technologies requires expertise in AWS, Azure, Kubernetes, containerization, and CI/CD pipelines to enhance software development efficiency and scalability.
  - Software Engineering & Low-Code Development – Companies seek developers proficient in Python, JavaScript (React, Angular), Rust, and Go, as well as low-code/no-code platforms that accelerate digital transformation.

- Core Skills Gaps Identified:
  - Technical Skills:
    - Limited experience with DevOps for embedded systems and real-time operating systems (RTOS).
    - Gaps in managing edge computing platforms and deploying applications close to vehicles.

- Analytical Skills:
  - Insufficient understanding of predictive maintenance analytics for connected vehicles.
  - Lack of data processing skills for real-time decision-making in autonomous systems.
- Soft Skills:
  - Difficulty in fostering collaboration between DevOps teams and hardware/software engineers in automotive R&D.
  - Limited experience in agile project management frameworks tailored for automotive development cycles.

- Emerging Needs and Future Skills:
  - Cybersecurity Awareness and Practices: Training employees at all levels to recognize and mitigate security threats.
  - Cloud-Native Technologies: Specializing in container orchestration, serverless computing, and automation for cloud deployments.
  - Client-Centric Skills: Improving empathy, adaptability, and problem-solving abilities to enhance customer relationships in CRM and workplace services.
  - DevSecOps in Automotive: Ensuring secure deployment of software updates over-the-air (OTA) while meeting cybersecurity standards such as ISO/SAE 21434.
  - Hybrid Cloud and Edge Computing: Balancing on-premise and cloud solutions to enable real-time processing for autonomous systems.
  - Sustainable & Green IT Solutions – As ESG (Environmental, Social, and Governance) requirements rise, professionals with skills in energy-efficient computing, carbon-aware programming, and green cloud architectures will be highly sought after.
  - Extended Reality (XR) & the Metaverse – Demand for VR/AR developers, 3D designers, and spatial computing specialists will increase, especially in gaming, education, and real estate.
  - Limited Practical Training & R&D – A shortage of university-business collaboration means graduates lack hands-on experience, while R&D funding remains low.
  - Regulatory Barriers & Investment Gaps – Startup and scale-up ecosystems require better tax incentives, regulatory clarity, and venture capital investment to drive growth.

- Industry-Specific Competency Requirements
  - Sector-Specific Skills:
    - IT Services: Proficiency in ITIL frameworks, service management platforms, and automation tools for IT support.
    - CRM & Workplace Services: Expertise in customizing and integrating CRM systems like Salesforce and Microsoft Dynamics.
    - Cloud & Managed Services: Understanding the intricacies of hybrid cloud setups, disaster recovery solutions, and performance monitoring.
    - Cloud Computing, DevOps & Automation – The shift to cloud-native technologies requires expertise in AWS, Azure, Kubernetes, containerization, and CI/CD pipelines to enhance software development efficiency and scalability.

    - Software Engineering & Low-Code Development – Companies seek developers proficient in Python, JavaScript (React, Angular), Rust, and Go, as well as low-code/no-code platforms that accelerate digital transformation.
    - Blockchain & FinTech Innovation – Strengthening Bulgaria's reputation in blockchain by advancing expertise in DeFi, crypto regulation, and smart contracts.
  - Certification and Compliance Knowledge:
    - Microcredential & Continuous Learning Incentives – Support professionals with certifications in AI, cybersecurity, and cloud computing. Expanding Vocational & Bootcamp Training – Develop bootcamps in AI, cloud security, and software engineering.
    - Enhancing STEM Education – Introduce mandatory coding courses and AI-driven learning platforms in schools. Encouraging Certification-Based Learning – Promote online certifications from Coursera, Udacity, AWS, and Google Cloud to enhance professional skills. Building Soft Skills & Entrepreneurship Mindset – Foster creativity, adaptability, and critical thinking to support startup culture and tech leadership.
    - **Microcredentials: A Key Solution for Closing Skill Gaps.**

1.3.3 Internet of Things

- Current State of skills:
  - IoT & Smart Manufacturing – The increasing digitalization of manufacturing calls for embedded systems engineers, industrial IoT experts, and automation specialists to support Industry 4.0 adoption.
- Core Skills Gaps Identified:
  - Technical Skills:
    - Weak integration of cloud technologies (e.g., AWS IoT Core, Azure IoT Hub) with automotive systems.
  - Analytical Skills:
    - 5G, Edge Computing & Network Innovation – With the rollout of 5G networks, Bulgaria will need network engineers, IoT security specialists, and edge computing developers.
  - Soft Skills:
    - Limited experience in agile project management frameworks tailored for automotive development cycles.
- Emerging Needs and Future Skills:
  - IoT, Smart Manufacturing & Green Tech – Enhancing Industry 4.0 initiatives, focusing on energy-efficient smart factories, IoT security, and sustainability tech.
  - Cybersecurity & Digital Resilience – Becoming a regional cybersecurity hub with expertise in ethical hacking, cyber threat intelligence, and zero-trust security frameworks.
  - Positioning Bulgaria as a cloud transformation leader, specializing in hybrid cloud, Kubernetes, and serverless computing.

- Industry-Specific Competency Requirements
  - Sector-Specific Skills:
    - Functional Safety: Ensuring compliance with ISO 26262 for safety-critical software development.
    - V2X Communication Protocols: Skills in managing vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) connectivity.
    - Smart Manufacturing: Understanding DevOps in Industry 4.0 settings, including continuous deployment for robotic process automation (RPA) and digital twins.
    - Strengthening Bulgaria's reputation in blockchain by advancing expertise in DeFi, crypto regulation, and smart contracts.
  - Certification and Compliance Knowledge:
    - Certifications like AWS Certified DevOps Engineer and Kubernetes Administrator (CKA) remain relevant, but additional knowledge of automotive standards, such as ISO/SAE 21434 for cybersecurity and ISO 26262 for functional safety, is essential. Professionals should also be familiar with compliance in connected and autonomous vehicle ecosystems.
    - Government-Backed Upskilling Initiatives – Provide funding for reskilling mid-career professionals into emerging tech fields such as blockchain, IoT, and AI.
    - Industry-Driven Learning – Courses designed by Google, Microsoft, IBM, and AWS ensure direct relevance to employer needs.
    - European & Global Recognition – Certifications can be integrated into higher education and professional development.

2 Findings & conclusions from the interviews held in CYPRUS

2.1 Executive Summary

- Number of interviews held: 5
- Held from - to /duration: **January 2025 - February 2025**
- Information on participants:
  - 3 Male & 2 Female
  - Positions:
    - Andreas Victoras Pallikaras (male) works in an ESG expert (Environmental, social, and governance) at KMPG - Group 4 and is also a board member of the NGO Friends of the Earth. He has a background in environmental studies and is in constant trainings in order to keep up with the technological advancements in the Environmental sector.
    - Dr Josephina Antoniou (female), Associate Professor in Computing, Deputy Head of the School of Sciences, Deputy Course Leader of MSc Computing / MSc Cybersecurity / MSc Cybersecurity Distance Learning at Uclan University. She is also a senior Member of the ACM (Association for Computing Machinery) and a Professional Member of ACM-W (ACM Women).
    - Dr. Elisavet Kiourti (female), Academic Advisor at Open University of Cyprus in the Faculty of Humanities and Social Sciences with education in Language, Literacy and Education and Computational Linguistics. Founder of Humane Technology,
    - Konstantinos Erotokritou (male) is currently the Acting Presales Manager at NewCytech Business Solutions. With a background in Enterprise System Architecture, he has extensive expertise in cloud-based platforms, including AWS, Azure, and Google Cloud. His work focuses on Big Data adoption and implementation, particularly in areas such as customer analytics, predictive maintenance, and operational efficiency.
    - Kyriakos Fragkeskos (male) is a Data Scientist and Data Lead at Bank of Cyprus, with extensive expertise in Generative AI, Large Language Models (LLMs), and Data Science. His professional focus is on developing and deploying AI-driven solutions, leveraging Python, microservices architecture, and FastAPI to build scalable, event-driven systems. He specializes in knowledge graph analysis and applying graph-based techniques to extract insights for solving complex problems.

- Which ATIs did you discuss during the interviews held in your country

☑ Artificial Intelligence and Ethics
☑ Big Data
☐ Blockchain
☐ Internet of Things

☐ ICT for sustainability
☐ Industry 5.0
☐ Quantum Computing

2.2 Interview Methodology

- Interview Format: Semi-structured
- Interview Questions:

  <u>*General Information*</u>

  1. *Can you share your name, role, and expertise in ATI (or related fields)?*
  2. *Which organization are you associated with, and what is its role in the ATI field?*

  <u>*Purpose & Insights*</u>

  0. *What is the current state of skills and knowledge in ATI among professionals in your field?*
  0. *What are the biggest gaps in ATI skills today? Could you categorise these as technical, analytical, or soft skills?*
  0. *Can you share examples of technical skills that professionals need but often lack?*
  0. *What about analytical skills—what are the key areas where improvement is needed?*
  0. *Are there any soft skills that are crucial but underdeveloped in this sector?*

  <u>*Emerging Trends & Future Needs*</u>

  0. *What skills do you think will become more important in the near future due to emerging trends in ATI?*
  0. *How do you see the role of certification and compliance knowledge evolving in this field?*

  <u>*Industry-Specific Insights*</u>

  0. *Are there unique skills required for specific industries (e.g., finance, healthcare, or government) that use ATI?*
  0. *How important is an understanding of regulations and certifications in the industries you work with?*

  <u>*Recommendations*</u>

  0. *What strategies or solutions would you recommend to bridge the current skills gaps?*
  0. *Are there specific training programs, certifications, or resources you think professionals should pursue?*

  <u>*Interview Reflection*</u>

  0. *Is there anything else you'd like to add about ATI skills, challenges, or opportunities?*

- Additional Notes: Mention any additional materials (e.g., pre-interview surveys or follow-up questions) used to prepare or support the interview.
- Key Findings:
  - Skills Gaps:
    - **Technical Expertise:** A lack of professionals proficient in sustainable technology design, data analytics for energy efficiency, and green software development.
    - **Cross-disciplinary Skills**: A gap in individuals with both ICT and environmental sustainability knowledge, necessary for creating eco-friendly digital solutions.
  - Challenges:
    - **Rapid Technological Change:** ICT innovations evolve faster than sustainability standards, making it difficult to ensure compliance with eco-friendly regulations.

- **High Energy Consumption:** ICT infrastructure, especially data centers and cloud computing, consumes significant energy, presenting a major sustainability challenge.
- **Integration of Sustainable Practices:** Many ICT companies struggle to integrate sustainable practices throughout their operations, from production to disposal.
- **Cost Barriers:** Transitioning to more sustainable ICT systems can be expensive, creating barriers for businesses and public sectors to adopt eco-friendly solutions.

- Recommended Solutions:
  - **Upskilling and Training Programs:** Offer specialised training and education that blends ICT with sustainability, helping professionals develop the necessary expertise.
  - **Collaborative Innovation:** Encourage partnerships between ICT and environmental sectors to drive innovation in green technologies and processes.
  - **Energy-efficient Technologies:** Invest in low-power hardware, renewable energy for data centres, and the development of green software to reduce energy consumption.
  - **Policy and Regulation Support:** Governments should implement incentives and regulations to encourage sustainable ICT practices, including financial support for adopting green technologies.

2.3 Experts’ Insights

2.3.1 Artificial Intelligence and Ethics 1

- Current State of skills:

  Experts in the field of ICT and sustainability emphasize that the current skill levels among professionals in Advanced Technology Integration (ATI) are insufficient to meet the growing demands of the sector. While there is a basic understanding of ICT technologies, there are significant competency gaps in areas critical to sustainable development.

  Specific Competencies Lacking:

  - Sustainable Technology Design: Many professionals lack the expertise to design and implement technologies that prioritize energy efficiency and environmental impact reduction.
  - Data Analytics for Sustainability: There is a shortage of skills in analysing large datasets for optimizing energy usage and minimizing carbon footprints in ICT systems.
  - Green Software Development: Few professionals are equipped to develop software that follows sustainability principles, focusing on low power consumption and efficient resource use.

- Core Skills Gaps Identified:
  - Technical Skills Gaps:
    - Sustainable Technology Design: Lack of proficiency in designing energy-efficient and eco-friendly ICT systems.
    - Green Software Development: Shortage of skills in creating software that minimizes energy consumption and environmental impact.
    - Renewable Energy Integration: Insufficient knowledge in incorporating renewable energy sources into ICT infrastructure like data centres and cloud systems.
  - Analytical Skills Gaps:
    - Data Analytics for Sustainability: Professionals lack the ability to use data analysis techniques to optimize resource efficiency, energy consumption, and carbon emissions in ICT operations.
    - Life Cycle Assessment (LCA): Insufficient understanding of assessing the environmental impact of ICT products and services across their entire lifecycle, from design to disposal.
  - Soft Skills Gaps:
    - Cross-disciplinary Collaboration: A lack of collaboration skills between ICT and sustainability professionals to drive joint innovations.
    - Change Management for Sustainability: Limited capacity to lead and manage the transition toward greener, more sustainable ICT practices within organizations.
    - Communication of Sustainable ICT Solutions: Difficulty in effectively communicating the benefits and strategies of sustainable ICT solutions to stakeholders, including business leaders and policy-makers.

- Emerging Needs and Future Skills:
  - Technical Skills:
    - Drone Technology: Expertise in operating drones and analysing aerial data to help farmers monitor crops and improve yields.
    - AI and Machine Learning: Skills to interpret data from drones and sensors, optimizing farming and sustainability practices.
    - IoT Integration: Ability to connect smart farming systems and other sustainable infrastructure for real-time data collection and management.
  - Analytical Skills:
    - Big Data Analysis: Proficiency in analysing environmental data from drones and IoT to improve agricultural and sustainability outcomes.
    - Predictive Analytics: Skills to optimize resource use in agriculture through data-driven decision-making.

- Industry-Specific Competency Requirements

  Sector-Specific Skills: The interviewee emphasized the importance of AI across industries, highlighting its potential to enhance efficiency and sustainability. For example, AI can help a hotel accurately calculate food waste, allowing for better planning and reducing waste, which presents a significant environmental benefit. In the energy sector, AI can assist electricity providers by predicting energy consumption, optimizing generator use, and increasing reliance on renewable energy. It can even incorporate weather forecasting to improve energy management and reduce unnecessary emissions.

Certification and Compliance Knowledge: The interviewee stressed the importance of accurate and compliant data collection across industries. For example, if two companies are measuring waste, but one uses a methodology that doesn't comply with legal regulations, even though they are measuring the same thing, the non-compliant data will not be accepted. Ensuring that data collection methods align with regulations is essential for it to be valid and useful. It is also important to have an understanding for the laws and regulations and that all is in compliance.

2.3.2 Artificial Intelligence and Ethics 2

Key Gaps Identified Skills Gaps

Both Dr. Elisavet Kiourti and Dr. Josephina Antoniou emphasized critical gaps in AI and Ethics competencies, spanning technical, analytical, and soft skills.

- Technical Skills Gaps:
  - Limited expertise in AI system design that incorporates fairness, transparency, and accountability.
  - Insufficient knowledge of bias mitigation and privacy-preserving techniques, such as differential privacy.
  - Lack of interdisciplinary AI training that integrates humanities, linguistics, and ethics.
  - Gaps in prompt engineering and ethical AI development.
- Analytical Skills Gaps:
  - Limited ability to assess the societal impact of AI systems, particularly concerning marginalized communities.
  - Inadequate skills in ethical risk assessment, bias evaluation, and regulatory compliance.
  - Deficiencies in critical multimodal literacy (analyzing text, images, and audio for ethical implications).
- Soft Skills Gaps:
  - Lack of ethical leadership and communication skills to effectively advocate for responsible AI.
  - Limited interdisciplinary collaboration and shared terminology between technical and non-technical teams.
  - Insufficient stakeholder engagement to incorporate diverse perspectives in AI decision-making.

Emerging Needs and Future Skills

As AI and Ethics evolve, the demand for interdisciplinary expertise will increase. Both experts identified several emerging skill needs:

- Future Technical Competencies:
  - Enhanced regulatory compliance knowledge, including GDPR and the EU AI Act.
  - Advanced AI governance and ethical AI auditing techniques.
  - Stronger hands-on training in AI fairness and accountability frameworks.

- Soft and Analytical Skill Priorities:
  - Increased cultural sensitivity and ethical problem-solving skills.
  - Training in interdisciplinary teamwork and shared ethical frameworks.
  - Ethical leadership to drive AI governance and regulatory adaptation.
- Recommended Solutions:
  - **Personalized Workshops:** Focused on interdisciplinary collaboration and ethical literacy.
  - **Continuous Education:** Lifelong learning programs to keep pace with rapid AI developments.
  - **Certifications:** AI ethics, governance, and compliance training to standardize ethical practices across industries.

Industry-Specific Competency Requirements

Different sectors require tailored AI ethics knowledge to navigate regulatory and operational challenges.

- Healthcare:
  - Strong focus on data privacy and patient confidentiality.
  - Ethical integration of AI into diagnostics and treatment.
  - Compliance with healthcare-specific AI regulations.
- Finance:
  - Expertise in AI-driven decision-making transparency, particularly in lending and risk assessment.
  - Adherence to financial regulatory frameworks governing AI applications.
- Government:
  - AI systems that prioritize public trust and ethical decision-making.
  - Understanding of public sector regulations and AI governance for fair implementation.
- Certification and Compliance Knowledge:
  - Professionals must acquire knowledge of global regulatory trends.
  - Certifications in AI governance and compliance are crucial for industry-wide standardization.

Conclusion: Both experts underscored the importance of integrating ethical considerations into AI training and development. Addressing competency gaps through targeted education, regulatory awareness, and industry-specific skill development will be crucial for responsible AI adoption.

2.3.3 Big Data

- **Key Findings:** Experts describe Big Data adoption as partial, with room for improvement. While organizations recognize its potential, implementation remains inconsistent due to skill shortages and infrastructure challenges.

- **Key Challenges & Skills Gaps**
  - Technical Skills Gaps
    - Cloud Platform Expertise: Many professionals lack proficiency in cloud-based Big Data solutions (AWS, Azure, Google Cloud).
    - Data Governance & Security: Ensuring high-quality data and compliance with industry standards is a major challenge.
    - Machine Learning & AI Integration: Professionals need expertise in advanced AI applications, including Machine Learning.
    - Big Data Architecture & Microservices: Understanding how to build and scale Big Data infrastructures using modern frameworks (FastAPI, event-driven systems) is a growing requirement.
  - Analytical & Business Skills
    - Graph Analysis & Knowledge Graphs: Expertise in extracting insights from complex datasets is in high demand.
    - AI-Driven Product Management: Companies need professionals who can bridge the gap between data science and business objectives.
  - Soft Skills Deficiency
    - Problem-Solving & Critical Thinking: Handling Big Data requires an analytical mindset to interpret and apply data-driven insights.
    - Cross-Team Collaboration: Effective integration of AI and Big Data tools into business workflows necessitates improved communication between data scientists, engineers, and product managers.
  - Examples of Challenges
    - Delays in project delivery due to skill shortages, particularly in cloud technologies and advanced AI applications.
    - Data security concerns due to inconsistent governance practices and a lack of compliance expertise.
  - Recommended Solutions
    - Educational & Certification Pathways:
      - Cloud Certifications (AWS, Azure, GCP) are crucial for workforce upskilling.
      - Advanced training in AI & Machine Learning, with a focus on AI-driven analytics.
      - Degrees in Data Science & Analytics should integrate hands-on Big Data architecture training.
    - Organizational Training & Continuous Learning
      - Encouraging access to online learning platforms for self-paced skill development.
      - Providing structured mentorship programs to foster knowledge transfer between experienced and junior professionals.

- Strategic Investments in Emerging Technologies
    - Adoption of Machine Learning platforms and cloud-based analytics solutions should be prioritized.
    - Businesses should enhance data governance frameworks to ensure secure and high-quality data management.

- **Current State of skills:** The core skills gaps in Big Data identified by experts in Cyprus span technical, analytical, and soft skills. On the technical side, professionals lack expertise in cloud computing platforms (AWS, Azure, Google Cloud), Big Data architecture, and AI/ML integration. There are also deficiencies in data governance, security, and compliance, making it challenging to ensure high-quality, secure, and regulatory-compliant data practices. Analytically, advanced data processing, predictive analytics, and knowledge graph analysis remain underdeveloped, limiting the ability to extract meaningful insights from large datasets. Additionally, professionals often struggle with cross-team collaboration, problem-solving, and effectively communicating data-driven insights in a business context. Addressing these gaps through targeted training, certifications, and stronger academic-industry collaboration is crucial to advancing Cyprus's Big Data capabilities.

- **Core Skills Gaps Identified**: Based on expert insights, the following specific skills and competencies are identified as lacking, categorized into technical, analytical, and soft skills:
    - Technical Skills Gaps:
        - Big Data Infrastructure & Cloud Computing – Limited expertise in managing cloud-based data storage and processing platforms like AWS, Azure, and Google Cloud.
        - Data Engineering & ETL Pipelines – Shortage of skills in designing and maintaining efficient data pipelines for transforming and integrating large datasets.
        - Advanced Machine Learning & AI for Big Data – Lack of proficiency in applying AI/ML techniques for large-scale data analysis and automation.
        - Real-time Data Processing & Streaming Technologies – Gaps in working with tools like Apache Hadoop, Spark Streaming, and Flink.
        - Data Security & Privacy Regulations – Insufficient knowledge in GDPR compliance, data encryption, and privacy-preserving computation techniques.
    - Analytical Skills Gap:
        - Advanced Data Interpretation & Insights Extraction – Deficiency in processing large datasets, applying statistical models, and interpreting complex data relationships.
        - Big Data-Driven Decision Making – Lack of understanding of how to translate data insights into actionable business strategies.
        - Predictive & Prescriptive Analytics – Professionals struggle with forecasting trends, AI-powered decision-making, and prescriptive analytics for business impact.
        - Data Quality & Management – Gaps in ensuring high-quality data, data cleaning, transformation, and preparation for analysis.

- Soft Skills & Cross-Disciplinary Competencies:
    - Data Storytelling & Visualization – Difficulty in communicating complex insights to non-technical stakeholders.
    - Interdisciplinary Collaboration – Difficulty working effectively across data science, engineering, and business teams, leading to misalignment between data insights and business strategy.
    - Problem-Solving & Critical Thinking – Professionals often lack the ability to apply data-driven insights to real-world challenges and develop innovative solutions.
    - Communication & Business Perception – Need for better translation of technical findings into actionable business strategies for decision-makers.

Experts identified the following skills as becoming more important in the future due to emerging trends:

- Technical Skills:
    - AI and Machine Learning Integration – Understanding how to integrate AI/ML with Big Data for predictive analytics and automation.
    - Advanced Data Engineering – Skills in managing large-scale data architectures, data lakes, and cloud-based solutions.
    - Cybersecurity and Data Privacy – Ensuring data protection, compliance with regulations, and handling cybersecurity threats.

- Analytical Skills:
    - Real-time Data Processing – Expertise in handling and analyzing streaming data for instant decision-making.
    - Interdisciplinary Data Analysis – Ability to extract insights by combining data from different sectors (e.g., finance, healthcare).
    - Ethical AI and Bias Mitigation – Understanding ethical considerations in AI-driven decision-making.

- Soft Skills:
    - Data Storytelling and Visualization – Communicating complex data insights in an understandable manner.
    - Collaboration Across Domains – Working in cross-functional teams with expertise in business, tech, and policy.
    - Adaptability and Continuous Learning – Staying updated with evolving technologies and methodologies.

Experts highlighted that data governance, AI ethics, and domain-specific knowledge (such as regulatory compliance in different industries) will also become crucial as Big Data continues to evolve.

Sector-Specific Skills: Based on the information from the experts from various industries identified critical skill gaps in applying Big Data effectively to sector-specific challenges. In banking and finance, professionals lack expertise in fraud detection, regulatory compliance, and secure transactions, limiting their ability to leverage data for risk assessment and financial transparency.

The public sector faces challenges in data-driven policymaking, smart city analytics, and cybersecurity, which hinder the efficient use of Big Data for governance and infrastructure planning. In retail and e-commerce, professionals struggle with personalized marketing analytics, omnichannel data integration, and AI-driven pricing models, limiting customer engagement and competitive advantage. Meanwhile, the energy sector lacks expertise in smart grid data analytics and predictive maintenance, essential for optimizing energy distribution and preventing infrastructure failures. Across all industries, experts emphasize that the biggest challenge is not just technical skills but the ability to apply Big Data insights effectively within industry-specific contexts.

Certification and Compliance Knowledge: Experts emphasize that Big Data professionals must strengthen their certification and compliance knowledge to navigate the increasingly complex regulatory landscape. There is a growing need for formal certifications, industry-specific training, and practical compliance knowledge to ensure that Big Data applications remain ethical, secure, and legally compliant. However, current gaps in awareness, training, and implementation pose challenges that need to be addressed through better education and industry-wide initiatives.

3 Findings & conclusions from the interviews held in GREECE

3.1 Executive Summary

- Number of interviews held: 5
- Held from - to /duration: K. Tzortzatou with duration 30 minutes
- Information on participants:
  - Male/female: 3/2
  - Positions: senior researchers and directors
  - Sector: IT
- Which ATIs did you discuss within the interviews held in your country

  ☑ Artificial Intelligence and Ethics
  ☑ Big Data
  ☐ Blockchain
  ☑ Internet of Things
  ☐ ICT for sustainability
  ☑ Industry 5.0
  ☑ Quantum Computing

3.2 Interview Methodology

The interviews were structured containing the following questions

- Current state of ATI in industry
  - How would you describe the current state of ATI development and its ethical considerations in your industry?
  - What are the major ethical challenges you face in your work with ATI?
- Skills and competency gaps
  - What specific skills do you believe are essential for professionals working in ATI?
  - Where do you see the biggest gaps in skills and competencies among current professionals?
  - Can you provide examples of situations where these gaps have impacted your work or the industry?
- Education and training
  - What types of educational backgrounds do the professionals in your team typically have?
  - Are there any particular degrees or certifications that you find most valuable for ATI?
  - What additional training or education do you think is necessary to fill the current skills gaps?

- Role of ethics in ATI development
  - How integrated are ethical considerations in the ATI development process at your company?
  - Do you believe that the current workforce is adequately prepared to handle the ethical implications of AI? Why or why not?
- Future needs
  - What do you think the future holds for ATI in industry?
  - What new skills or competencies do you foresee becoming essential in the next 5-10 years

The findings from the national desk research and EU study were mentioned to the persons we interviewed.

3.3 Experts' Insights

3.3.1 Artificial Intelligence and Ethics

Experts indicate that professionals possess a foundational grasp of AI but struggle with **ethical AI principles, bias mitigation, and explainability**. Key skill gaps include **technical** challenges in algorithmic transparency and responsible AI design, **analytical** weaknesses in assessing AI bias and fairness, and **soft skill deficiencies** in ethical decision-making and AI governance. Future trends emphasize **federated learning, ethical AI auditing, and regulatory adaptation** as critical competencies. In **finance**, AI risk assessment and fraud detection require enhancement, while **healthcare** demands AI-driven diagnostics with strict ethical oversight. **Supply chains** need robust AI-driven optimization, and **government sectors** require AI policy and compliance knowledge. Certifications in **AI ethics, bias mitigation, and regulatory frameworks (e.g., GDPR, ISO AI standards)** are becoming essential.

3.3.2 Big Data

While professionals exhibit strong technical expertise in **data analytics and machine learning**, gaps exist in **ethical data handling, privacy-preserving techniques, and bias detection in large datasets**. **Technical deficits** include a lack of expertise in differential privacy and secure multi-party computation, **analytical gaps** involve weaknesses in ethical data governance and anomaly detection, and **soft skills** are lacking in regulatory adherence and interdisciplinary collaboration. Future skills demand **proficiency in explainable AI, real-time data ethics, and responsible data monetization**. Industry-wise, **finance** requires stronger AI-driven risk analytics, **healthcare** demands compliance with **HIPAA and GDPR** in big data applications, and **supply chains** must enhance AI-powered predictive analytics. Certification in **data ethics, compliance, and privacy-preserving AI** is increasingly important.

3.3.3 Internet of Things

Experts highlight that professionals have a solid grasp of **IoT deployment and network architecture** but lack critical knowledge in **cybersecurity, ethical data collection, and IoT-specific AI governance**. **Technical gaps** exist in securing IoT ecosystems and ensuring ethical sensor data use, **analytical deficiencies** are found in responsible AI applications in IoT, and **soft skills** need strengthening in **ethical risk assessment and compliance knowledge**. The future of IoT demands skills in **blockchain-based IoT security, privacy-enhancing AI techniques, and regulatory-compliant IoT system design**. **Sector-specific skills** include **cyber-physical security in manufacturing, privacy-aware smart healthcare solutions, and AI-powered IoT applications in government infrastructure**. Knowledge of **compliance frameworks like NIST IoT guidelines and ISO security standards** is increasingly necessary.

3.3.4 Industry 5.0

The transition from Industry 4.0 to **Industry 5.0** places greater emphasis on human-AI collaboration, ethical AI governance, and sustainability-driven innovations. Professionals struggle with **aligning AI with human-centric principles, ensuring ethical automation, and integrating sustainability in AI-driven decision-making**. **Technical gaps** include ethical AI co-creation with human workers, **analytical weaknesses** involve impact assessments of AI in manufacturing, and **soft skill deficiencies** arise in cross-disciplinary collaboration. Future competencies require expertise in **adaptive AI systems, ethical robotic-human interaction, and circular economy-driven AI solutions**. **Sectoral applications** span **human-in-the-loop AI for manufacturing, ethical AI automation in logistics, and AI-driven sustainable supply chain models**. Certifications in **Industry 5.0 ethics, sustainable AI, and human-AI collaborative design** are emerging as critical industry requirements.

3.3.5 Quantum Computing

Quantum computing professionals show competency in **theoretical principles** but lack hands-on expertise in **quantum AI ethics, secure quantum cryptography, and responsible quantum-enhanced machine learning**. **Technical skill gaps** include **quantum-safe cryptographic protocols and quantum explainability**, **analytical deficiencies** involve bias detection in quantum AI, and **soft skills** are underdeveloped in ethical quantum governance and regulatory alignment. Future trends emphasize **post-quantum cryptography, ethical quantum AI applications, and the integration of quantum computing in real-world AI systems**. Industry-specific needs include **quantum-secured financial transactions, healthcare quantum simulations for drug discovery, and quantum optimization in logistics**. Certification in **quantum AI ethics, quantum-safe cybersecurity, and quantum policy compliance** is becoming essential for industry professionals.

4 Findings & conclusions from the interviews held in LITHUANIA

4.1 Executive Summary

- Number of interviews held: 5
- Held from 17th December to 8th of January
- Information on participants: 5 male participants
- Which ATIs did you discuss within the interviews held in your country
  ☑ Artificial Intelligence and Ethics
  ☑ Big Data
  ☑ Blockchain
  ☐ Internet of Things
  ☐ ICT for sustainability
  ☑ Industry 5.0
  ☐ Quantum Computing

4.2 Interview Methodology

- Open-ended.
- Interview Questions: List the core questions used to guide the conversation.
  - Current Industry Situation
    How would you describe the current state of advanced technology development and related skills in ATI’s?
  - Skills Gaps
    What are the main skill and competency gaps you observe among current professionals while interviewing, following today’s trends, situation in Lithuania?
  - Essential Skills
    What specific technical and non-technical skills are essential for professionals working with advanced technologies?
  - Education and Training
    Which educational programs or certifications do you consider most valuable for specialists in this field?
  - University/College Programs
    Do university/college programs sufficiently prepare specialists for this field?
  - Future Needs
    What new skills or competencies do you consider essential over the next 5–10 years, considering technology trends?

- Industry Trends
  Which industry trends or changes, in your opinion, will most impact the skills needed by professionals in the future?
- Recruitment Challenges
  What are the main difficulties in finding qualified professionals capable of working with advanced technologies?

- Key Findings:
  - Experts highlighted significant gaps in AI, programming, Industry 5.0, and digitalization skills among both recent graduates and experienced professionals.
  - University programs provide broad but shallow knowledge, leaving graduates unprepared for specialized roles, requiring up to a year of additional training in companies.
  - Key technical deficiencies include programming depth, AI application, big data analytics, cybersecurity, robotic process automation (RPA), and server engineering.
  - Soft skills such as time management, communication, and independent problem-solving were also identified as lacking among new specialists.
  - Cybersecurity is becoming increasingly critical, especially in AI, blockchain, IoT, and big data sectors, due to rising security threats.
  - Industry 5.0 skills, particularly in automation and human-machine collaboration, are underdeveloped, with a lack of knowledge in RPA and tools like UiPath.
  - Blockchain was deemed underdeveloped in Lithuania, with limited companies working in the field, making the creation of specialized educational programs inefficient.
  - Experts emphasized the need for education reform, advocating for specialized training programs to better align with industry needs.
  - While future skills remain unpredictable, addressing current competency gaps in AI, automation, and cybersecurity is essential for sustainable progress.
  - Motivation and adaptability were seen as key hiring criteria, as technical skills can be trained, but the ability to learn and apply knowledge efficiently is crucial.

4.3 Experts' Insights

4.3.1 Artificial Intelligence and Ethics

- Current State of Skills
  Experts across different industries emphasize that AI-related skills, particularly in practical application, remain underdeveloped among professionals. University graduates often lack a deep understanding of AI, as their education provides broad but shallow knowledge. Additionally, ethics in AI, including cybersecurity, bias mitigation, and responsible AI usage, is not a major focus in current training programs. As a result, companies must invest significant time, often up to a year, training employees before they can work independently in AIdriven environments.

- Core Skills Gaps Identified
  - Technical Skills
    - **AI Tools Proficiency**: A general lack of understanding of how to integrate AI into business operations.
    - **Robotic Process Automation (RPA)**: Limited knowledge of automation tools like UiPath.
    - **Big Data Analytics**: Weak data analysis skills necessary for AI-driven decision-making.
    - **Programming Expertise**: Knowledge is too generalized, with little depth in languages like Python, which is crucial for AI development.
    - **Cybersecurity Awareness**: Growing risks in AI applications make security a critical but underdeveloped competency.
    - **AI Decision-Making and Ethics**: A lack of understanding of how AI models make decisions, their limitations, and their potential biases.
  - Soft Skills
    - **Critical Thinking in AI Implementation**: Inability to ask the right questions to optimize AI outputs.
    - **Problem-Solving Using AI**: A gap in applying AI for real-world business efficiency improvements.
    - **Independent Work**: Professionals struggle with self-guided learning and problem-solving, leading to excessive reliance on employers for training.
    - **Communication**: Weak ability to explain AI-related concepts to non-technical stakeholders.
    - **Project Management in AI Contexts**: Limited skills in overseeing AI-driven projects, leading to inefficiencies in business adoption.

- Emerging Needs and Future Skills

  Experts agree that the key priority should be addressing existing AI skill gaps rather than speculating on future trends. However, certain skills will become increasingly critical:
  - **Deep AI Understanding**: Moving beyond basic AI knowledge to include AI ethics, cybersecurity, and responsible AI use.
  - **AI Ethics and Compliance**: Professionals will need to be well-versed in data privacy laws, algorithmic bias, and responsible AI governance.
  - **Sector-Specific AI Expertise**: As AI adoption grows, industry-specific applications will demand more specialized knowledge.

- Industry-Specific Competency Requirements
  - Sector-Specific Skills
    - **Supply Chain & Automation**: AI-driven logistics optimization and predictive analytics are crucial but currently lacking.
    - **Finance**: Stronger AI-driven fraud detection and risk assessment expertise are needed.
    - **Healthcare**: Ethical considerations in AI-driven diagnostics and patient data security require more attention.

- Certification and Compliance Knowledge
    - Most companies do not currently prioritize AI ethics certifications due to more pressing technical skill gaps.
    - However, cybersecurity and AI compliance regulations will become increasingly important, especially in sectors handling sensitive data.

4.3.2 Big Data

- Current State of Big Data Skills

  The topic of Big Data skills was briefly addressed in the interviews, primarily by Giedrius Delininkaitis. He noted that there is no strong emphasis on Big Data Analytics in current educational programs, meaning students graduate with only basic knowledge of the field. Other experts did not explicitly discuss Big Data skills.

- Core Skills Gaps Identified
    - Technical Skills Gap:
        - **Big Data Analytics**: Giedrius highlighted that universities provide only surface-level knowledge of Big Data, leaving a shortage of specialists who can properly analyze large datasets.
        - **Server Engineering**: Giedrius also noted that server engineering is not adequately covered in IT programs, which could impact the ability to manage large-scale data systems.
    - **Soft Skills Gap**: Experts did not specifically discuss soft skills related to Big Data, but Giedrius emphasized a broader lack of independent problem-solving skills and critical thinking, which are crucial for data analysis roles.

- Emerging Needs and Future Skills

  Giedrius emphasized that the most important step is to address current deficiencies before speculating about future trends.

4.3.3 Blockchain

- Current State of Blockchain Skills
    - Giedrius Delininkaitis mentioned the importance of **cybersecurity** knowledge in blockchain, along with AI, IoT, and Big Data, due to high risks associated with sensitive information and hacking threats.
    - Dinas emphasized that, in his expert opinion, discussing and developing a blockchain program is not appropriate since this field is not yet developed in Lithuania. There are only a few companies working with blockchain, making the creation of such a program inefficient.

4.3.4 Industry 5.0

- Current State of Skills

  Experts expressed concern that professionals entering the workforce, including recent graduates and even experienced specialists, are not adequately prepared to work with

Industry 5.0 technologies. The transition from Industry 4.0 to 5.0 requires a deeper understanding of digitalization, automation, and human-machine collaboration, but current education programs do not sufficiently cover these aspects. Companies often need to invest significant time sometimes up to a year to train new employees in these areas.

- Core Skills Gaps Identified
  - Technical Skills:
    - **Robotic Process Automation (RPA):** A key component of Industry 5.0, but there is a noticeable lack of specialists with RPA expertise.
    - **UiPath:** Many professionals are unfamiliar with this workflow automation platform, which is widely used for automating repetitive tasks.
    - **AI Tools and Integration:** Understanding how to implement AI into automation and robotics is still underdeveloped among specialists.
  - Soft Skills:
    - Experts did not emphasize soft skills as a critical gap but highlighted the importance of motivation and adaptability when working with Industry 5.0 technologies.

- Emerging Needs and Future Skills

  Experts believe that, rather than predicting future skills, the priority should be to address the existing gaps in Industry 5.0-related competencies. Ensuring specialists have a strong foundation in automation, digitalization, and AI implementation will be essential for long-term success.

- Certification and Compliance Knowledge

  Experts did not emphasize certifications or compliance knowledge as a major requirement. The current focus is on developing strong technical expertise rather than regulatory aspects.

5 Report on findings & conclusions from the interviews held in SLOVAKIA

5.1 Executive Summary

- Number of interviews held: 5
- Held from - to /duration: November 2024 to January 2025, each interview app 2-3 hours
- Information on participants:
  - Male/female: 3 males, 2 female
  - Positions: 1 senior project manager, 4 CEOs
  - Sectors: IT
- Which ATIs did you discuss within the interviews held in your country
  ☑ Artificial Intelligence and Ethics
  ☑ Big Data
  ☑ Blockchain
  ☐ Internet of Things
  ☐ ICT for sustainability
  ☐ Industry 5.0
  ☐ Quantum Computing

5.2 Interview Methodology

- Interview Format: all IWs were either semi-structured, or open-ended.
- Interview Questions: we used the discussion prompts originally developed for the focus groups, but since the interviewees are senior experts in their fields, all discussions were very productive.
- Additional Notes: We also used some other materials originally developed for FG, and shared the IW report with each interviewee, giving them a chance to add more info or comment/adjust the reports.

Key Findings

In general, all experts said that it is very difficult to detach Industry 5.0 from all other ATIs as there are natural interconnections. They also, although using the different examples, spoke about the common trends which are being described as future or emerging ones, but to some extent are already being observed nowadays. These are:

- **AI Literacy Across All Functions**: The ability to understand and leverage AI tools will become a fundamental skill across industries, similar to how digital literacy evolved in the last decade. Over time, we may stop thinking of AI as something we need to understand and focus instead on how we can differentiate and adapt to what it brings.

- **Adaptability and Lifelong Learning**: Given the rapid pace of technological change, professionals must continuously upskill and adapt to new tools and frameworks. AI gives an amazing opportunity to learn things at a much faster pace as well as memorize more critical things on a larger scale. 3 out of 5 interviewees mentioned microcredentials as the possible and suitable tool for lifelong learning.
- **Sustainability and ESG**: Particularly in Europe, where the EU is driving ESG regulations, skills in measuring and reporting sustainability metrics will be crucial and helpful.
- **Interdisciplinary Knowledge**: Future experts will need to bridge technical knowledge with business and ethical considerations to foster holistic understanding, critical thinking, real-world application, collaboration, and innovation. This requires both deep specialization and broad, cross-functional understanding.

In the field of AI & Ethics, many professionals struggle with moving from theory to practice, particularly in applying AI models to real-world problems. Understanding of AI ethics often remains surface-level. Professionals need deeper insights into managing biases and ensuring transparency as well as improvement of communication and stakeholder management.

More general yet very important topics mentioned are about the cooperation of the various sectors from the quintuple helix.

- Significant gaps in graduates' technical skills related to advanced AI algorithms applicable in industry, weak transfer of needs and knowledge between the private (e.g. industrial) and academic sectors.
- Lack of cooperation between the academic and industrial sectors in conducting theses (lack of support from businesses in conducting theses - economic motivation, as is the case, for example, in France).
- Lack of a system platform for the mobility of teachers and experts from practice between academic institutions and the private sector, which would contribute to improving study programs and thus increasing the qualifications of graduates.
- Legislative complexity of the process of changing study programs. The dynamics of education is significantly slower than the dynamics of the development of ICT and AI technologies.

5.3 Experts’ Insights

5.3.1 Artificial Intelligence and Ethics & Big Data

- Current State of Skills

  Experts indicated that professionals in Artificial Intelligence (AI) and Ethics possess a solid technical foundation, particularly in data analysis and programming. However, there is a notable gap in practical application, with many struggling to translate theoretical knowledge into real-world solutions. While awareness of ethical concerns is increasing—

especially in sectors like finance and healthcare—the understanding of AI ethics often remains superficial. Professionals require deeper insights into bias management and transparency to effectively navigate ethical challenges in AI deployment.

- Core Skills Gaps Identified
  Interviewees have identified several core skills gaps categorized into technical, analytical, and soft skills:
  - Technical Skills:
    - Advanced machine learning techniques (e.g., reinforcement learning, generative adversarial networks).
    - Data quality management, including understanding and handling biased datasets to ensure high-quality and unbiased data for training models
    - Proficiency in programming for AI and machine learning (e.g., Python, TensorFlow, PyTorch),
    - Integration of AI systems with IoT for predictive maintenance and operational optimization,
    - Expertise in data engineering and managing big data pipelines in real-time,
    - Ensuring compliance with privacy regulations (e.g., GDPR), and implementing transparent algorithms,
    - Knowledge of robotics systems and their application in human-robot collaboration.
    - Expertise in high-quality and unbiased data for AI training models
  - Analytical Skills
    - Proficiency in AI bias detection and mitigation,
    - Competence in ethical AI evaluation frameworks.
    - Critical Thinking: The ability to assess the reliability and validity of data sources.
    - Data Interpretation: Skills in interpreting AI-driven insights in a way that is meaningful and actionable for businesses.
  - Soft Skills
    - Effective communication skills to explain complex data-driven insights to non-technical stakeholders.
    - Ability to explain complex data-driven insights to non-technical stakeholders.
    - Collaboration and project management abilities, particularly in cross-disciplinary teams.

- Emerging Needs and Future Skills
  Looking ahead, experts emphasize the need for skills that align with emerging trends:
  - Advanced Machine Learning Techniques: With a focus on scalability and deployment.
  - Bias Detection and Mitigation: As awareness of ethical implications grows.
  - Ethics and Responsible AI: A critical area as organizations strive for transparency and accountability in AI systems.
  - Scalability and Deployment
  - Advanced AI: Deep learning for predictive maintenance, quality control, and explainable AI for transparency.

- Human-Centric Robotics: Designing collaborative robots (cobots) for adaptive and safe production systems.
- Big Data: Real-time analytics, cloud/edge computing, and secure data management.
- Digital Leadership: Driving innovation and managing digital transformation.
- Collaboration: Facilitating teamwork between technical and business experts.
- Ethical Awareness: Promoting fairness, inclusion, and sustainable practices.

- Industry-Specific Competency Requirements/ Sector-Specific Skills
  Almost all interviewed experts emphasized that it is all about the data quality. The uniqueness, sector specific “skills” is in the sector specific data. AI experts must collaborate closely with the sector experts to make sure the accurateness and usability of the data in order to create AI applications that are optimized for different environments, sectors and which can address sector specific challenges. Yet, insights revealed that certain industries require unique competencies:
  - Finance: Skills in predictive analytics and risk management are crucial due to the reliance on AI for assessing risks. Understanding algorithmic bias is paramount to ensure transparency in financial decisions.
  - Healthcare: Professionals must navigate ethical concerns related to patient data privacy while implementing AI solutions.
  - Supply Chain: Knowledge of data quality specific to logistics and operations is essential for optimizing AI applications.

  Experts stressed that collaboration between AI experts and sector specialists is vital for ensuring data accuracy and relevance.

- Certification and Compliance Knowledge
  There is a growing emphasis on the importance of knowledge regarding regulations, compliance frameworks, and industry certifications related to AI ethics. Experts highlight that proficiency in data privacy regulations (e.g., GDPR) is increasingly essential as organizations seek to address ethical considerations effectively.Overall, the landscape of skills required for effective AI implementation is evolving rapidly, necessitating ongoing education and collaboration across disciplines to bridge existing gaps.

5.3.2 Blockchain

Experts have identified several specific technical skills lacking in the field of blockchain. These gaps can be categorized as follows:

- Technical Skills Gaps
  - Understanding of Blockchain Architecture: Many professionals lack a deep understanding of the underlying architecture of blockchain systems, including consensus mechanisms and network protocols.
  - Cryptography: There is a deficiency in knowledge about cryptographic principles that secure blockchain transactions, which is crucial for ensuring data integrity and security.

- Smart Contract Development: Skills in developing and deploying smart contracts are insufficient, particularly in languages like Solidity, which is essential for Ethereum-based applications.
- Distributed Ledger Technology (DLT): A comprehensive grasp of different types of distributed ledger technologies beyond blockchain, such as Directed Acyclic Graphs (DAGs), is often missing.
- Data Analysis Specific to Blockchain: Professionals frequently lack the ability to analyze blockchain data effectively, which is essential for deriving insights and ensuring compliance with regulations.
- Regulatory Compliance Understanding: There is a notable gap in knowledge regarding the regulatory landscape surrounding blockchain technology, which is critical for legal and ethical implementation.
- Security Assessment Skills: Skills related to assessing the security of blockchain applications and understanding potential vulnerabilities are underdeveloped.

These technical gaps highlight **the need for targeted training and education** to equip professionals with the necessary competencies to thrive in the evolving blockchain landscape investech

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WP4 Enhancing Labour Market-Relevant Skills in Advanced Technologies

T4.1 Identifying skill gaps in Advanced Technologies

D4.1 Report on the identified skill gaps in advanced technologies in industry

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