Deliverable 2.2 – Annex 3

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Annex 3

Table of Contents

Annex 3: Focus Groups: Identification of the emerging technologies and markets impacting job profiles and skills

1) Focus Group: Impact of Automotive innovations on microelectronics skills needs

METIS has set up a Focus group dedicated to the identification of job profiles and skills needs in the microelectronics industry in line with the development of automotive electronics and associated emerging technologies and markets. This chapter presents the results of this focus group.

1) Objectives

- To pinpoint the skills that are the most critical and difficult to find in the microelectronics workforce in line with the development of automotive electronics and associated emerging technologies and markets: Advanced Driving Assistance Systems (ADAS), etc.
- To give inputs for the design of training modules.

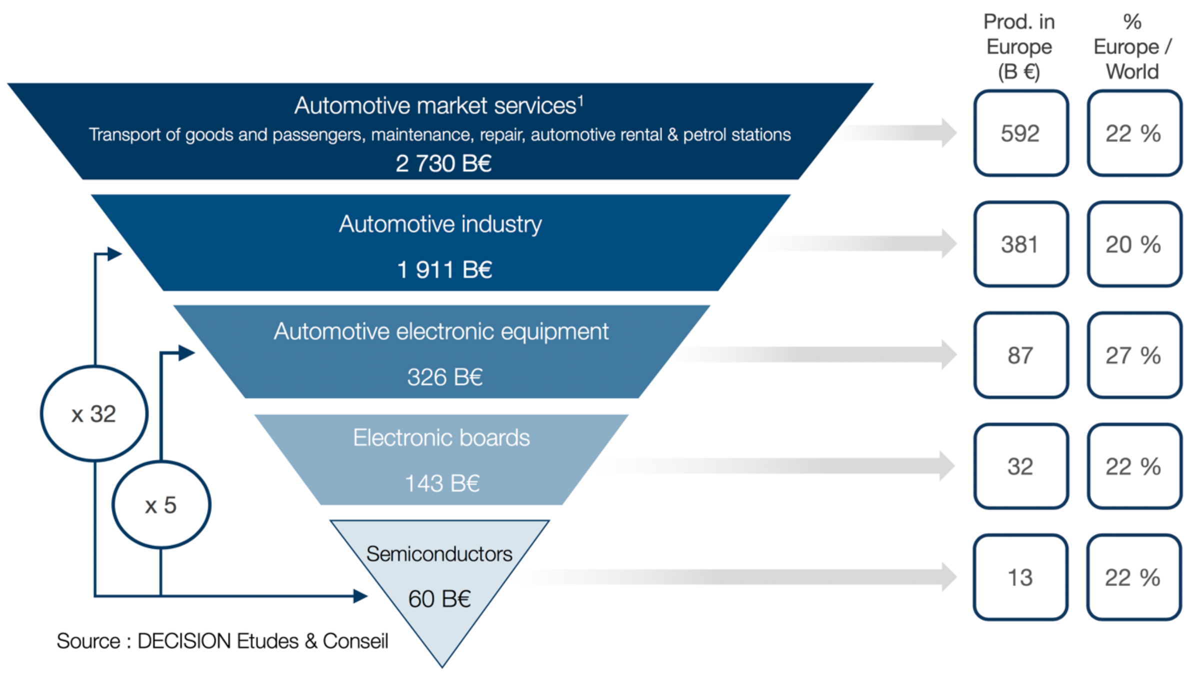
Participants to the Focus group

Organization	Field
Infineon	Large company – Semiconductor & Automotive
Automotive Lighting	Mid-sized company – Automotive electronics supplier
MetaSystem spa	Mid-sized company – Automotive electronics supplier
IAL-FVG	VET
University of Udine Polytechnic Department of Engineering and Architecture	University

Microelectronics, at the heart of automotive innovations

The automotive industry is a high growth industry driven by innovation with a nearly 7% annual growth rate over the past ten years at the global scale in unit (2009-2019), according to the IOMVM. However, **80% of all innovations in the automotive industry today are directly or indirectly enabled by electronics.** For many years now, automotive electronics is becoming an essential part of a vehicle and concentrates most of the innovations.

World Automotive electronics value chain in 2018 (B €)



[1] The services measured in this diagram only corresponds to the "market services", that is the services produced for sale on the market at a price intended to cover production costs and to provide a profit for the producer. Yet, industrial equipment provide a majority of "non market services" once they are sold.

Electronics and microelectronics systems linked to the automotive sector comprise five macro typologies:

1. **Electronic Control Unit (ECU)**. Embedded systems or sub-systems (including calculators) that controls one or more of the electrical functions of the vehicle. These ECU include printed circuits, semiconductors (microcontrollers/microprocessors, memories, analog inputs), connectors, cabling and other non-electronic components (packaging).
2. **Sensors**: Camera, Lidar, Radar, GNSS (Global Navigation Satellite System), IMU (Inertial Measurement Unit), infrared sensors, ultrasounds sensors…
3. **Screens**: Trip computer screen, head-up display…
4. **Embedded software**: Used by ECUs to control specific commands/applications but is also used to manage ECUs interactions with other ECUs and with external elements.
5. Electronics and Microelectronics systems for the vehicle energy monitoring and management as well as electronic control of the actuators: propulsion systems, auxiliaries, front and rear headlights.

Instead, electric batteries actuators are not considered as automotive electronics.

Over the 2010-2025 period, the four automotive electronics applications that are growing the most and consuming more and more microelectronic components are:

- **Autonomous driving.** ADAS: Advanced Driver Assistance Systems (Levels 1 to 5), including dedicated sensors and software (notably using AI).

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- **Connectivity / Vehicle to everything**: Vehicle to Vehicle, Vehicle to Infrastructure, Vehicle to Network, the connection between the different parts of the vehicle. Such applications are used for instance for shared mobility.
- **Infotainment**: Trip computer, Operating Systems, screens, etc.
- **Electrification of vehicles**. The electrification of powertrains, from petrol/diesel vehicles to hybrid vehicles, Battery Electronic Vehicles (BEV) and Fuel-Cell Electric Vehicles (FCEV), leads to a great increase of the electronic content embedded into cars. According to DECISION Etudes & Conseil, new energy vehicles (Full Hybrid, Plug-In Hybrid, BEV, FCEV), should account for the majority of the world car sales by 2035.

However, the development of such systems (that are mainly at the software/communication level) is and will be enabled by the evolution taking place on the electronics and microelectronics side of the automotive sector which will have a significant impact on future interactions, that is, until 2025.

In return, automotive applications are impacting the microelectronics value chain

As microelectronics is progressively having a key importance in the automotive industry, the automotive industry is impacting the microelectronics value chain at several levels:

1. **IC design**. The microchip card enters the microcontroller. Some time ago the automotive microcontroller was a consumer microcontroller that passed more stringent reliability tests and was therefore transferred to the Automotive sector. Now, however, with the advent of Functional Safety, since Safety must be guaranteed at the electronic architecture level, efforts are being made to bring into the microcontrollers functionalities that allow the development of simpler architectures with a higher level of Safety. The microcontrollers have different peripherals and / or components inside them that allow you to design the electronics following an automotive safety standard. For this reason, the chip has become more complex but contains more features and therefore at the system level less discrete are used. The microcontroller increases in cost, but the number of discretes decreases.

   The chip maker also develops and sells the embedded microcontroller software.
2. **Other semiconductor design (discretes): Reduction of discretes** in favor of the use of microcontrollers and platforms that have multiple safety elements internally.

The impact of automotive applications on microelectronics skills needs

The automotive production is changing with electronics and software playing a major part and representing the significant value of the vehicle, requiring skills that have not, so far, been among the core competences of automotive engineering. Therefore, both car manufacturers (OEM) and Automotive suppliers (Tier 1 and Tier 2) need to increase their microelectronic skills / knowledge needs.

Four main types of knowledge have been identified by the Focus Group as particularly essential to adapt the microelectronics workforce to the requirements of the automotive industry:

1. **Components' reliability.** System design for automotive applications is more and more complex and requires advanced testing systems to assess the reliability of the components as automotive electronic components requires a very high level of fallibility. This implies a greater importance of

test technicians and engineers and their associated skills for microelectronics companies serving the automotive industry.

2. **Components' functional safety.** Vehicle safety is linked to the improvement of component's reliability and led to the introduction of Functional Safety and the ISO 26262. Today, both technicians (EQF levels 4-5 at entry level) and engineers (EQF levels 6-7 at entry level) need to know and apply the Methodology Functional Safety from design to all production.
3. **Cost management.** Over the last years, a reduction of the vehicle architecture costs, and an increased functionality have been achieved both by a decrease in the number of discretes components in favor of the use of microcontrollers and platforms that have multiple safety elements internally and by the use of standardized microelectronic components and embedded systems and platforms. Engineers must therefore receive training on the design technics to decrease the number of discretes components in systems and on the last standards used in the automotive industry.
4. **Component's security.** In the next few years, the interviewees expect that we will also see a tightening of the security rules applied to the microelectronics for automotive applications, especially because of the increased external connectivity.

In the table below, the interviewees selected 10 professional profiles. For each of these profiles, they have identified **the most important skills to meet the new requirements from the recent automotive trends**. A consensus has been reached in the Focus Group on the fact that the full list of skills required currently in the table below is both essential for the functioning and the competitiveness of the companies and very difficult to find for a single candidate at the entry level on the job market.

Job position	Most critical skills (by order of importance)
Test technician Electrical test technician, environmental and life-time test technician, troubleshooter technician, quality technician	- Setup and operate back-end test equipment and bench-test equipment - Conduct product quality tests, in-circuit-tests, functional tests, burn-in tests - Conduct climatic tests and interpret validation test, perform passive tests
Process or manufacturing technician Process technician, manufacturing support technician	- Learn and install new manufacturing lines, support pilot manufacturing - Gather data from manufacturing and report it to senior staff members; basic knowledge in Word, Excel, Outlook, SAP, QDAS - Operates manufacturing equipment and machines - Map, analyse and develop manufacturing processes - Keep and enforce health and safety regulations of manufacturing environment
Maintenance technician Electrical technician, breakdown technician	- Assure the uninterrupted, safe operation of manufacturing lines and availability of production machines, operating equipment - Inspect and prevent failures of technological procedures; reduce the downtime - Knowledge in health and safety regulations

	- Assist in developing manufacturing equipment, support the install of new manufacturing lines
Design engineer or designer Electrical design engineer, electrical project engineer, electrical product engineer, product development engineer	- Proficient with analogue and digital electronic design, RF design, power supply design; knowledge in analytical tools such as ETAP, schematic, spice simulation; understanding in hardware description languages, e.g., VHDL - Uses computer-aided design (CAD) and computer-assisted engineering (CAE) software to create prototypes, engineering drawings (drafting) & engineering designs - Familiar with design for manufacturing, design for assembly, design for test, design for inspection approaches, optimize complex and advanced designs for manufacturability - Collect and analyse data from tests on prototypes, conduct risk assessments, FMEA/DFMEA and design reviews - Familiar with software tools for design testing, like Matlab, JMP, Datapower, National Instruments LabView, Cadence, ADS
Test engineer Product test engineer, test engineer, Design For Test (DFT) engineer, associate test engineer, senior test engineer	- Programming Automatic Test Equipment (ATE) - using C, C++, Java, Python, LabVIEW or Smalltalk - Competencies in Digital Electronics - Analytic & Problem-Solving Skills - Competencies in Analogue Electronics - Technical Presentation & Report Writing
Process or manufacturing engineer Process engineer, manufacturing support engineer	- Deep knowledge in semiconductor- and electronics assembly technologies, competence in related quality standards (e.g., IPC) - Familiar with design for manufacturing, design for assembly, design for test, design for inspection
Robotic engineer Electrical automation engineer, controls and robotic engineer, control system engineer, PLC programmer engineer	- Excellent understanding in mechanical / electrical and robotic engineering, process control and developing step logic for hardware control systems - Program and code automated and/or embedded systems, e.g., C, C++, C#, Python, Arduino, Raspberry, PLC Ladder Logic, MS.NET, and Object-Oriented Programming - Familiar with industrial safety systems and safety-critical software tools - Proficient with motor Control utilizing variable frequency drives including regulation via PLC (programmable logic control) systems. LAN systems, Profibus communication, and Canbus communication

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Software engineer Controls and software engineer, software developer, solution engineer, computer software engineer	- Develop software code in C, Visual C, C++, C#, .NET, Java, JavaScript, Python, Matlab - Lead design, development and testing of software components
Lead or supervisor Process engineering lead, process engineering superintendent, manufacturing team supervisor	- Lead and develop a team of process engineers, process technologists/technicians, and metallurgists, provide engineering oversight on the team - Analyse business needs and make practical recommendations for continuous process improvement - Collaborate with management to identify, quantify, and develop strategies for mitigating risks, improve risk management - Build and foster networks and relationships with internal/external technical experts and operational staff
Manager or Director Process engineer manager, product manager, engineering and quality manager	- Set the vision, goals and objectives of the manufacturing and processing department - Make decisions concerning selection, training, rating, discipline and remuneration of staff - Develop and manage staff through training, assignments and coaching - Establish high technical standards through processes and culture

Note: The skills listed in this table as the most critical have been indicated as such by at least 3 participants of the focus group out of a total of 6 participants.

2) Focus Group: Industry 4.0

METIS has set up a Focus group dedicated to the identification of job profiles and skills needs in the microelectronics industry in line with the development of Industry 4.0. This chapter presents the results of this focus group.

Industrial electronics is the second largest end-user market of the European microelectronics industry, after automotive. According to DECISION Etudes & Conseil, the European production accounts for 20% of the world market, well over the average of European end user markets (14%), and Europe ranks second in the world for the manufacture of industrial electronics, behind China, but before the USA and Japan. The synergy between end user segment and component supply is particularly efficient in this field. The three large European semiconductor manufacturers (Infineon, STM and NXP) are among the top ten suppliers of analog ICs. Analog ICs correspond to a very large share of the industrial market (~47%), far above their modest share in the total IC market (~15%), according to DECISION Etudes &

Conseil. The same is true for discrete devices. Industry 4.0 is a major trend impacting industrial electronics. A skilled workforce in semiconductor design is therefore crucial of Europe's competitivity.

a. Objectives

- To pinpoint the skills that are the most critical and difficult to find in the microelectronics workforce in line with the development of Industry 4.0.
- To give inputs for the design of training modules.

Participants to the Focus group

Organization	Field
Budapest University of Technology and Economics (BME)	University
Vienna University of Technology	University
Czech Technical University Prague	University
Technical University of Cluj-Napoca	University
Politecnico di Torino	University
Institute of Electron Technology	Research & Development
PwC Innovation Center	Consulting firm

The development of Industry 4.0, an opportunity for Europe

Definition. Industry 4.0 corresponds to the rising connectivity between industrial machines & tools (smart factory) thanks to 5G/6G developments and new IoT communication architectures (LoRa, Sigfox, etc.), associated with the development of software tools to analyse the data generated (digital twins, big data, data mining, neural networks), leading to new applications (predictive maintenance, stock pooling platforms, etc.), as opposed to Industry 3.0 that is the trend of robotization of factories (rising number of robots used in the industry). Over the Internet of Things and cloud computing, the cyber-physical systems communicate and cooperate with each other and with humans in real-time, both internally and across organizational services.

Applications enabled by I4.0:

- **Higher level of automatization**. Virtual visualization of the entire production line (digital twins) and ability to adopt decentralized decisions, etc.
- **Higher production flexibility**. Ability to changeover of manufacturing (set the line to a different product) in ~0 time, enabling the customization and personalization of products to customers. In other words, the increased flexibility and productivity Industry 4.0 produces will make it possible to meet an increasing demand for smaller batch/mixed manufacturing and individualized products at much lower costs and with higher quality. Thus, I4.0 should progressively lead to the use of public tender processes for production/manufacturing services. Factories might become quite similar to service providers (Manufacturing as a Service: MaaS).
- **Predictive maintenance**. Enhanced quality and self-control ability of the production.
- **Quality 4.0**. General increase of quality and reliability of manufactured products.
- **Improvement in supply chain management**. The information gathered from the decentralized model and analytical software used in Industry 4.0 also makes it easier to account for the cost of each item, resulting in better intelligence for business strategy and product pricing. It also enables the use of new supply chain tools such as stock pooling platforms.

- Etc.

The last developments associated with Industry 4.0 are aiming to increase the sustainability of Industry 4.0 applications.

- **Edge computing**. In this regard, Industry 4.0 is associated to the topic of edge computing and the necessity to ultra-low power devices able to store and process data at the edge in order to reduce the required bandwidth and energy consumption required to compute the data generated.
- **Industry 5.0.** Industry 5.0 is focusing on human and customers issues and skills: human capabilities to co-work with robots and associated critical thinking.

Proposals for training modules

For METIS training, the target learners are:

- At entry level (no experience in a similar position, except internships and apprenticeships).
- Covering education levels from EQF 4 (High school diplomat), to EQF 5 (College-based higher education), EQF 6 (bachelor's degree), and EQF 7 (Master's degree).

Table: Identified knowledge & skills needed & recommendations for training modules in line with the development of Industry 4.0

Field	Knowledge	Potential training
Industry 4.0	Industry 4.0 needs to be taught as a topic itself rather than as a side topic in courses dedicated to other issues, as it is mostly the case currently given the novelty of the concept. Universities shall teach the I4.0 concept as a whole, not just the individual sub-topics. At the moment, sub-topics of I4.0, like virtual prototyping, big data analyses, machine learning techniques, VR and AR techniques, Quality 4.0, advanced manufacturing machines are taught in separate curricula, even under the management of different faculties in universities. All of the relevant sub-topics could be brought together under one curriculum, or specialisation on EQF level 6-7, preferably on level 7. Staff already on the market also need to be trained and vocational training appears very important for the adaptation of the workforce to Industry 4.0.	- Introduction to Industry 4.0 - Industry 4.0
Teamwork / Multidisciplinary	Employees from many fields should be able to work together, including engineers from mechanical engineering, electrical engineering,	

	and software engineering fields, e.g., to implement I4.0 software related requirements even in the early design phase of the electronics product.	
Soft skills	Education 4.0 should cover soft skills that should be taught at all educational levels (teaching should be started as soon as possible, even in elementary schools)	- **Especially Teamwork** as I4.0 is a complex, multidisciplinary approach - Complex problem solving - Creativity - Management - Adaptability (changing circumstance) - Life-long-learning mind-set - Language skills - Industry 5.0 should be emphasized – human-robot collaboration (collaboration is much more than knowing how the machine works but knowing how humans can learn from machines and machines can learn from humans)
Hardware and software co-design	Software on board, adapting the electronics design optimisation from software point of view. Thinking on full-system level becomes more important. Trainings at EQF levels 6-7 (Engineers)	- Hardware and software co-design
Basic AI and machine learning knowledge	Skills in selecting and using the machine learning toolsets for manufacturing and ERP. Trainings at EQF levels 6-7 (Engineers)	- Basic AI and machine learning knowledge
Basic knowledge in standardisation	Trainings at EQF levels 6-7 (Engineers)	- Knowledge in standardisation in I4.0.

		- Knowledge in standardised data handling - Skills in plug-n-play techniques for engineers - Ability in focusing on standardised process
New skills and knowledge in marketing and operation monitoring	I4.0 and thus production line changes affect the ERP (Enterprise Resource Planning) systems. Skills are needed in this area. Manufacturing-as-a-service will made real change in ERP, if customers typically order small batch sizes, there will be more customers with more specific requests. It requires real changes in purchasing planning, productions planning, etc.	- Flexible marketing - Adaptation of ERP to I4.0 and product customization

Source: Focus Group on Industry 4.0. Participants: Budapest University of Technology and Economics (BME), Vienna University of Technology, Czech Technical University Prague, Technical University of Cluj-Napoca, Politecnico di Torino, Institute of Electron Technology, PwC Innovation Center.

The impact of Industry 4.0 on microelectronics skills needs

Value chain level	Educational level (EQF)	How is Industry 4.0 impacting the skills/knowledge required from employees?
Microelectronics in general	Technicians (EQF levels 4-5)	Using AR and VR tools, adapting to limited machine-to-human interaction and increased machine-to-machine interaction.
	Engineers (EQF levels 6-7)	Skills and knowledge in adapting to and using the smart factory concept in general.
Electronics assembly & manufacturing	Technicians (EQF levels 4-5)	Ability to learn how to maintain new machines and production systems, basic media skills, flexibility.
	Engineers (EQF levels 6-7)	Ability and willingness to learn new concepts in the frame of I4.0, advanced media skills, understanding and basic knowledge in data gathering & big data analyses, knowledge and understanding in advanced sensor systems; heterogeneous integration assembly.

Electronics **system** design	Engineers (EQF levels 6-7)	Skills in High Frequency design for IIOT, advanced Wi-Fi, 5G technologies, product design utilising smart sensor systems, sensor clusters.
IC and semiconductor design	Engineers (EQF levels 6-7)	Skills in custom chip design for IIOT, smart metering, machine-to-machine interaction, MEMS and NEMS sensor design; knowledge in integrated phase-arrays and radiating elements.
Semiconductor assembly & manufacturing	Technicians (EQF levels 4-5)	Ability to learn how to maintain new machines and production systems, basic media skills, flexibility.
	Engineers (EQF levels 6-7)	Ability to learn new concepts in the frame of I4.0; advanced media skills, understand and basic knowledge in data gathering & big data analyses, knowledge and understanding in advanced sensor systems; understanding in MES4.0 (manufacturing execution system) and smart factory; semiconductor heterogeneous manufacturing.
Semiconductor equipment manufacturing	Technicians (EQF levels 4-5)	Understand of new safety standards introduced by cyber-security production systems (secure operational procedures, e.g., segregation of duties, use of least privilege and logging), especially when operating wafer assembly machines (die-attach, die-bonders, wire-bonders, and inspection machines), which are connected to the I4.0 infrastructure media skills for understanding virtual prototyping.
	Engineers (EQF levels 6-7)	Ability to establish digital model of manufacturing equipment especially at the wafer assembly level, like digital-twins of wire-bonder machines, skills in advanced programming tools like "Beckhoff TwinCAT", e.g., for advanced PLC and motion control programming of wafer transport systems, proficient with advanced sensor systems, understanding in data gathering and cloud computing.
Materials for semiconductors and electronics	Technicians (EQF levels 4-5)	Ability to handle with care new materials, like shape-memory materials, composites, materials for additive manufacturing.
	Engineers (EQF levels 6-7)	Ability to inspect, analyse, test and characterize new materials like, like shape-memory materials, composites, materials for additive manufacturing, both in micro- and nano range; knowledge in typical application of new materials and ability in applying them in those applications; basic knowledge in chemistry (missing in many curricula).

Source: Focus Group on Industry 4.0. Participants: Budapest University of Technology and Economics (BME), Vienna University of Technology, Czech Technical University Prague, Technical University of Cluj-Napoca, Politecnico di Torino, Institute of Electron Technology, PwC Innovation Center.

Table - How is Industry 4.0 impacting the skills/knowledge required for the main job profiles of the microelectronics industry?

According to the Focus Group, Software engineer is by far the job profile the most impacted by I4.0 and the most critical to integrate I4.0 functions in production processes.

Job position	Name and describe the skills
Software engineer: Controls and software engineer, software developer, solution engineer, computer software engineer	• Data Science Management: design and implementation of Big Data architectures and software platforms (e.g., Hadoop or Data Lake) • IT-OT Integration Management: implementation of IT architectures, platforms, components and operations technologies of industrial automation (OT) oriented towards Industry 4.0. • Security by design: skills used for cyber-physical (production) systems like diagram a network for security, advanced intrusion detection and prevention, advanced skills in forensics and reverse engineering.

Job position	Name and describe the skills
Test technician: Electrical test technician, environmental and life-time test technician, trouble-shooter technician, quality technician	• Media skills: ability to use all VR and AR devices, become familiar easily with new, advanced user interfaces and HMIs ***.** • Ultra-High Frequency testing: understand the basics of HF testing over 5GHz; ability to perform tests in correct manner of ultra-HF devices.
Process or manufacturing technician: Process technician, manufacturing support technician	• Media skills: ability to use all VR and AR devices, become familiar easily with new, advanced user interfaces and HMIs • MaaS: understand the concept of MaaS (manufacturing-as-a-service), adapt to shared use of a networked manufacturing infrastructure. • Smart production: adapt to the increase in machine-to-machine interaction.
Maintenance technician: Electrical technician, breakdown technician	• Media skills: ability to use all VR and AR devices, become familiar easily with new, advanced user interfaces and HMIs. • Enhanced maintenance: ability to repair smart manufacturing equipment, basic understanding in sensor and actuator systems.

Operator inspector: Machine operator, inspector, repair operator	• Media skills: ability to use all VR and AR devices, become familiar easily with new, advanced user interfaces and HMIs. • Smart manufacturing: using IoT devices at all aspects in her/his work, like digital instructions for inspections, repairs, reworks etc..
Design engineer or designer: Electrical design engineer, electrical project engineer, electrical product engineer, product development engineer	• Smart design: joint design of product and service, integration with the enterprise IT systems • Advanced design: design of smart products (integration of sensors, antennas, chips and other components); knowledge of new components for I4.0 systems.
Test engineer: Product test engineer, test engineer, Design for Test (DFT) engineer, associate test engineer, senior test engineer	• Smart testing: utilizing cloud computing in data gathering, remote testing. • Ultra-High Frequency testing: proficient with HF testing over 5GHz; ability to developed and manage tests of ultra-HF devices. • Quality4.0: understanding and knowledge in Quality4.0 – advance quality management.
Process or manufacturing engineer: Process engineer, manufacturing support engineer	• Smart data analyses: understanding in Big Data analytics (e.g., machine learning, Bayesian classifiers, deep learning); analysis, modelling and simulation of production based on big data from sensors and devices. • Advanced manufacturing: analysis and use of innovative production materials (e.g., shape-memory materials, composites) and/or production processes (e.g., additive manufacturing), either utilizing IoT tools. • Quality4.0: understanding and knowledge in Quality4.0 – advance quality management.
Robotic engineer: Electrical automation engineer, controls and robotic engineer, control system engineer, PLC programmer engineer	• Advanced robotics: designing and programming of collaborative/autonomous/mobile robots; use of modelling tools to generate digital twins of manufacturing systems and simulate" what if scenarios". • IoT: understanding and knowledge in concept of internet of things, required for autonomous robots, open connectivity and facility interaction.
Software engineer: Controls and software engineer, software developer, solution engineer, computer software engineer (this will be a critical role to the opinion of FG)	• Data Science Management: design and implementation of Big Data architectures and software platforms (e.g., Hadoop or Data Lake) • IT-OT Integration Management: implementation of IT architectures, platforms, components and operations technologies of industrial automation (OT) oriented towards Industry 4.0. • Security by design: skills used for cyber-physical (production) systems like diagram a network for security, advanced intrusion detection and prevention, advanced skills in forensics and reverse engineering.

Quality and reliability engineer	• <u>Quality assessments:</u> ability the use of Quality 4.0 tools. • <u>Reliability analyses:</u> knowledge in system level analyses; multidisciplinary knowledge in failure analyses; physics of failure. • <u>Soft skills:</u> teamwork with engineers from other fields: chemical, physical, mechanical etc.
Material engineer	• Required skills are similar to that included at "Materials for semiconductors and electronics". The focus group thought that Material engineers, who have a focused knowledge on semiconductor and electronics materials, are missing even now from the industry. The knowledge required today for materials engineers is much broader, and focuses also on steels, polymers, ceramics etc. The field of semiconductor/electronics materials requires knowledge not just from traditional material engineering, but additionally from chemical and physical sciences (e.g., nanostructures).
Expert in security, privacies and safety	• Similar to the security skills of software engineer, but with a deeper knowledge level.

***General comment for technician role:**

⇨ **Finding technicians, who are able to learn and use VR will be a real challenge. These skills should be taught even prior to EQF4-5, maybe in early secondary schools.**

⇨ **Besides, technician roles might shift to BSc level within the next 10 years.**

**** There were different opinions about multidisciplinary knowledge (whether or not it is required at engineering level). Conclusion: fine balance should be found in interdisciplinarity (systems are highly interconnected, but not losing the specialised knowledge).**

Source: Focus Group on Industry 4.0. Participants: Budapest University of Technology and Economics (BME), Vienna University of Technology, Czech Technical University Prague, Technical University of Cluj-Napoca, Politecnico di Torino, Institute of Electron Technology, PwC Innovation Center.

3) Focus Group: Edge AI

METIS has set up a Focus group dedicated to the identification of job profiles and skills needs in the microelectronics industry in line with the development of edge Artificial Intelligence (AI). This chapter presents the results of this focus group.

1) Objectives

- To pinpoint the skills that are the most critical and difficult to find in the microelectronics workforce in line with the development of edge Artificial Intelligence.
- To give inputs for the design of training modules.

Participants to the Focus group

Organization	Field

IMEC	Research & Development
Fraunhofer	Research & Development
Zhejiang University	University
Center for Data Innovation	Think thank
Sainsbury	End-user services
SEMI	Industry Association

The development of Edge AI, an opportunity for Europe

Definition of Edge AI (Artificial Intelligence).

AI chips are chips specifically designed to run/accelerate artificial intelligence applications, especially artificial neural networks and machine-learning. AI chips can be Cloud-based or Edge-based.

A consensus is emerging that the main risk assorted to AI algorithms is power constraints that will be very high and could be a barrier to AI adoption, generating a need for the adoption of a solution which substantially reduce the power draw of high-consuming AI chips and the required bandwidth of communication networks.

A solution is AI at the edge. Edge AI corresponds to edge-based machine-learning chipsets (as opposed to cloud- based AI chipsets, that is to say AI chipsets designed to run cloud-based machine-learning algorithms). Edge AI consist in System-on-a-chip (SoC) accelerators, application-specific integrated circuits (ASICs), Graphic Processing Units (GPUs), Central Processing Units (CPUs), FPGAs, etc.

Regarding edge AI dedicated to IoT applications, it is possible to run inference models on microcontrollers and relatively low-end chips, but most machine-learning and decision functions need to interface with additional (Edge) devices that segregate the data and manage huge data flows with cloud infrastructure for training and model adjustment purposes. Such interface device can be based on dedicated MPU, GPUs, FPGAs, ASICs, SoC or dedicated Neural Networks Units (or any combination of the above) configurations, as well as combinations of GPUs. AI inference also often requires the help of hardware accelerators, designed to help resource-constrained x86-based devices to process large volumes of image or audio data.

The development of edge AI.

Within the AI chips market, edge AI should represent more than 75% of the sales in value by 2023. Indeed, as more IoT devices are deployed, the need for AI-enabled solutions supported by edge computing grows exponentially. It will no longer be feasible to rely on the cloud to process and analyze data to drive real-time decision- making, neither to ensure the proper level of security. The capabilities of edge computing to handle AI algorithms and machine learning locally without the inherent latency of cloud computing will provide more efficient insights to drive operations and increase productivity, security and privacy and lowering the global energy consumption.

The major Cloud AI platforms are today operated by American or Chinese leading vendors (GAFAM, BATX), as well as the Cloud AI chips (Nvidia, Intel, etc.). Yet, in the edge domain, and in addition to its high-Scientific level in AI algorithms, software and mathematics, the EU has some very strong industrial competencies in Embedded Systems and Microcontrollers (STMicroelectronics, Kalray, etc.), which should help to promote European domestic AI solutions for emerging high-value IoT applications (Industrial electronics, Connected or Autonomous cars, Defense and Security, Health, Smart-City). There is therefore a great opportunity for the EU to invest in edge AI chips developments.

An opportunity for Europe

Regarding pure machine learning applications, the EU seem clearly distanced by the USA, but also by China, in terms of industrial players and data ownership (required to train Convolutional Neural Networks and build new commercial applications).

A major opportunity for the EU lies in edge AI chips, an emerging technology field that will play a key role in the coming decade and where the EU as the capacities and the knowledge to gain significant market shares worldwide. Therefore, regarding edge AI:

- There is a need to develop education to train engineers and scientists in both embedded software, AI algorithms and the design of electronic components (three core skills that need to be combined). It will be a key success factor for the EU to lead the future edge AI applications.
- There is also an opportunity to develop Open-Source platforms for edge computing and IoT, to favor the development of edge AI chips solutions in the EU.

Job profiles identified as the most sought-after and difficult to find by industrial players in line with the development of edge AI

No	Job	Job profile	Comments
1	Design engineer or designer	Product development engineer e.g., Electrical design engineer, electrical project engineer, electrical product engineer	Develop new hardware components/systems; Modeling for performance simulations
2	Robotic engineer	Electrical automation engineer, controls and robotic engineer, control system engineer, PLC programmer engineer	
3	Software Engineer	Controls and software engineer, software developer, solution engineer, computer software engineer	Algorithm and computational coding; Network infrastructure support for tooling

Skills identified as the most sought-after and difficult to find by industrial players in line with the development of edge AI

Table: *#1* Design engineer or designer

No	Skills	Level of criticality for the competitiveness of companies 0 = Low 10 = High	Level of difficulty to find 0 = Easy 10 = Hard
1	Software integration / Integration with Software / HW/SW integration	8	9

2	Familiar with design for manufacturing, design for assembly, design for test, design for inspection approaches, optimize complex and advanced designs for manufacturability	8	9
3	Proficient with analogue and digital electronic design, RF design, power supply design; knowledge in analytical tools such as ETAP, schematic, spice simulation; understanding in hardware description languages, e.g., VHDL	6	7
4	Knowledge in control systems using PID loops, embedded Firmware, Object Oriented languages: C, C++, C#, Java	6	7

Table: #2 Job Profile: Robotic Engineer

No	Skills	Level of criticality for the competitiveness of companies 0 = Low 10 = High	Level of difficulty to find 0 = Easy 10 = Hard
1	Program and code automated and/or embedded systems, e.g., C, C++, C#, Python, Arduino, Raspberry, PLC Ladder Logic, MS.NET, and Object-Oriented Programming	7	9
2	Familiar with industrial safety systems and safety-critical software tools	8	8
3	Strong computer science fundamentals, programming, databases, machine learning, digital twins	7	8

Table: #3 Job Profile: Software Engineer

No	Skills	Level of criticality for the competitiveness of companies 0 = Low 10 = High	Level of difficulty to find 0 = Easy 10 = Hard
1	Software integration / Integration with Software / HW/SW integration	8	9
2	Familiar with databases (e.g., SQL), big data technologies (e.g., Spark, Dask), machine learning techniques	8	7
3	Develop software code in C, Visual C, C++, C#, .NET, Java, JavaScript, Python, Matlab	8	5

4	Plan and execute software version upgrade releases and custom interfaces, utilize other platform's APIs and open-source utilities for fully integrated solutions	7	5

Proposals for training modules

For METIS training, the target learners are:

- At entry level (no experience in a similar position, except internships and apprenticeships).
- Covering education levels from EQF 4 (High school diplomat), to EQF 5 (College-based higher education), EQF 6 (bachelor's degree), and EQF 7 (Master's degree).

Table: Identified knowledge needed & recommendations for training modules in line with the development of Edge AI

Field	Knowledge	Potential training
Data	**Understanding of data integrity ->** ensuring quality, ensuring unbiased data source and collection **Data security and privacy ->** use of data collected by big AI platforms, safeguard privacy **Data analysis skills ->** interpret large volume data, be aware of potential biased conclusion led by biased data	- Data science: data integrity, analytics, assessment - Data security by design - Data privacy by design - Data privacy in cloud computing
Climate change and Sustainability	Knowledge on **climate change** -> any AI applications should not generate more emissions and have no negative impacts on climate change; AI engineers should aim to minimum energy consumption and protect the environment. **Sustainable development goals** (SDG) -> any AI applications should aim to contribute to achieving SDGs; all engineers should be aware of challenges and understand that their work should contribute to SDGs	- Climate action - Social Development Goals
Diversity	Developer should be aware of diversity. Diversity is a must. A team should consist of people with diverse background as people with different background will see things differently. Any AI service should be able to serve to all, not only works for a certain group.	- Awareness of diversity - Impact of diversity on AI
Social inclusion	All engineers should be aware that not everyone has the same digital skills. Systems and applications developed should serve for all groups of people, not only for certain groups. For example, AI may result in job losses. Developers should be aware of such issues.	- Principle of social inclusion

Table: Identified skills needed & recommendations for training modules in line with the development of Edge AI

Field	Skills	Potential training
Creativity	Creativity is essential for students to come up with new ideas, new designs, new technologies, new applications. A course should aim at inspiring students to apply their knowledge to develop innovative ideas	Design thinking module
Understanding impact of AI	AI can lead to an overfitted world to citizens -> engineers/developers should be aware of the consequences of their developments. Application of AI will have impacts on the job market, and social and economic development -> engineers should be able to assess impacts	Understanding of the impact of AI/ Big Data
Critical thinking	Students and engineers will be influenced by many technologies and ideas. They need to be able to identify what they want, select needed ideas and technologies	Critical thinking
Presentation	An AI engineer should be able to explain how AI module works. It is particularly important to communicate how AI works to non-experts/users	Communications to non-experts
Teamwork and interpersonal skill	AI is a bit subject. Any AI development may need a team with different expertise. Therefore, AI engineers should: - Be able to work with people with diverse profiles - Self-evaluation of strengthen and weakness - Be able to assess other people and to be able to liaise with experts (e.g., lawyers)	Teamwork and interpersonal skills
Ethics	AI engineers should be aware of ethics issues. AI is not perfect. There are biased algorithms for example	Introduction on ethics issues in AI

METIS

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