ECVEM
European Centre of Vocational Excellence in Microelectronics

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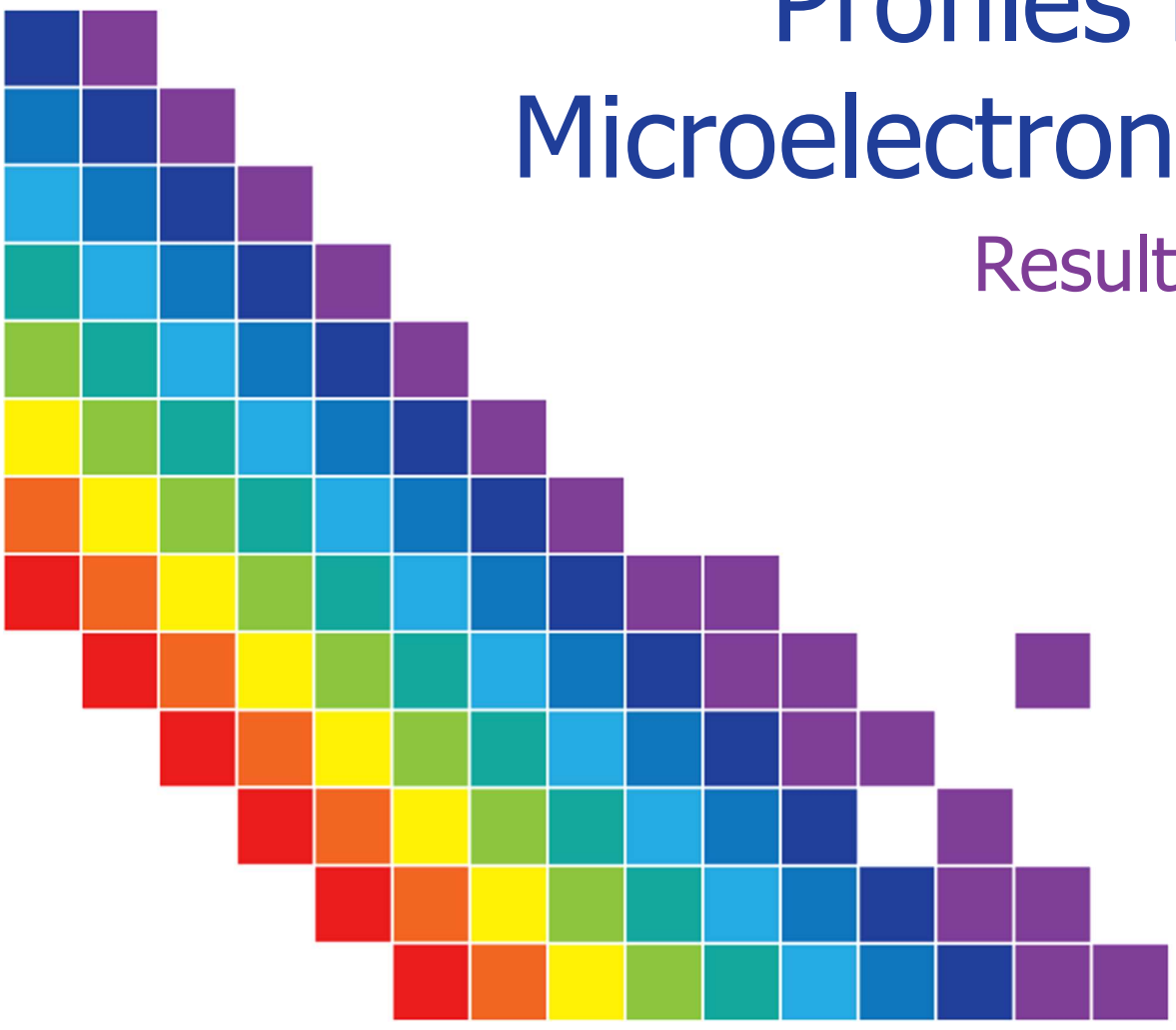
Skills and Occupational Profiles for Microelectronics

Result 2.2



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1. Executive Summary

This report provides an assessment of the occupational profiles needed currently in the microelectronics industry along with the perspective of the sector in the sense of trends, emerging technologies, and dynamics of the required skills and competences. The analysis is based on a multistakeholder approach including the VET providers, companies, industry associations, and research institutes from the ECoVEM platform for EQF levels 3-8 and further on an online survey for the European microelectronics industry (for EQF 3-5 and EQF 6-8). The entire microelectronics value chain in Europe has been involved.

The sources of information were:

- Educational needs analysis by 45 VET providers and 54 companies;
- ESCO profiles and skills in microelectronics;
- Analysis of more than 120 job offers in microelectronics;
- Survey with larger audience from the business/industrials on the skill needs in the next 3 years and beyond representing 10271 employees in the sector of microelectronics;
- Literature survey - New Industrial Strategy for Europe, the Important Project of Common European Interest (IPCEI) on Microelectronics, the German Federal Government's Framework Programme for Research and Innovation 2021–2024.

The conclusions are the following:

Microelectronics is the driver of innovation for a wealth of applications, especially in the field of digitalisation. Microelectronics underpins cutting-edge applications:

- Communication technology
- Industry 4.0
- Smart energy conversion
- Smart health
- Autonomous driving
- High-performance computing
- Artificial intelligence.

In turn, applications are driving the demand for trustworthy and sustainable microelectronics. The recommendations based upon this findings report and the New Industrial Strategy for Europe are to structure the ECoVEM curriculum in the following way:

- Electronic Design Automation
    a. Digital circuits design
    b. Analog circuits design
    c. Hardware/software co-design – embedded systems design
- Specialised processor chips for edge computing, artificial intelligence, and high-performance applications
    a. Application-specific integrated circuits design
    b. Design and fabrication of FPGAs
    c. Artificial Intelligence chips design
- Innovative, intelligent, and connected sensor systems
    a. Internet of Things – sensor-based systems
    b. Smart sensors design and fabrication as key elements of intelligent sensor systems for Industry 4.0
    c. Microsystem design and fabrication

- Intelligent and energy-efficient power electronics
- High-frequency microelectronics
- Medical/health microelectronics
- Interdisciplinary technologies
    a. System integration technologies
    b. Test, verification and validation
- Advanced silicon and beyond
    a. New materials for microelectronics
    b. Graphene electronics
    c. Quantum technology
- Soft skills
    a. Entrepreneurship
    b. Teamwork in a multidisciplinary team

The analysed skills demand results will be the basis of the innovative VET curricula within ECoVEM for the provision of the expected skills supply.

2. Introduction

In the digitalisation era, microelectronics is increasingly pervading our everyday lives and workplace environments. Microelectronic chips are not only found in smart phones, laptops, and office computers, they also regulate our power supply, control the data streams for our mobile internet, and enable secure connected, automated mobility. Microelectronics processors are also the brain in which artificial intelligence takes place. In sectors such as healthcare and industrial manufacturing, microelectronics ensures that services and products meet the highest standards of functionality and quality. This makes microelectronics an important basis for prosperity in the age of digitalisation: by providing services that improve the quality of life and ensure sustainable value creation and jobs.

In the digitalisation era an integrated approach is needed - new partnership between education and work to address the need of synergy between the education and industry, to foster the development of competencies, technological and soft skills for the new jobs in microelectronics. To respond to the needs of the industry for training new skills of the engineers in the multidisciplinary microelectronics, the European Centre of Vocational Excellence in Microelectronics was created with the support of the Erasmus+ programme.

This report identifies and analyses the specific needs and requirements of university teachers, engineers, managers of enterprises in the sector with regard to the feasibility of the European mClouds system and the content of educational and training materials in MECA.

3. Background

Microelectronics is the most rapidly developing science representing the ground of the e-economy and e-society and the continuous training is crucial. Moreover, in nano-era an integrated approach is needed - new partnership between education and work to address the need of synergy between the education and industry, to foster the development of competencies, technological and soft skills for the new jobs in microelectronics. ECoVEM project brings together VET centres, polytechnics, industrial associations, social partners to establish European Cooperation platform of Vocational

Excellence in Microelectronics to tackle the challenges of: digitalisation, artificial intelligence, green technologies, gender equality and technology, integration of migrants.

The EQF levels addressed in ECoVEM project are as follows:

1. Design and fabrication of printed circuit boards (PCB) EQF 3 to 4: trains the profile of "technician" in PCB design and fabrication, 150 hours duration including design of PCB, fabrication of boards, mounting techniques as through hole, surface mounting etc.

2. Microelectronics packaging technologies EQF 3 to 5: provides specialisation in mounting and packaging of devices and integrated circuits (IC), multichip modules, systems in a package, printed circuit boards with total duration of 300 hours covering mounting techniques, assembling, passivation, packaging of chips, multichip modules, system in a package

3. Integrated Circuits Design EQF 4 to 6: provides a first specialisation in microelectronics design total duration 300 hours covering digital, analog or mixed-signal circuits, (information processing and storage, RF and microwaves, sensors and actuators)

4. System design EQF 6 to 8: provides a second specialisation in microelectronics design and engineering with a focus on Research & Innovation total duration 400 hours covering system-on-chip, system–in-package, hardware/software co-design, test of circuits and systems

5. Basics of microelectronics manufacturing EQF 4 to 5: trains the profile of "specialised technician" in microelectronics manufacturing for a total duration of 300 hours covering topics such as: introduction to advanced materials, processing equipment, production process, packaging, testing.

6. Key Competences & Transversal Skills EQF 3 to 8: provides training on transversal skills and competences required by industry, delivered in OER environment for total duration of 100 hours.

The full cycle of design, development, evaluation and implementation of VET is planned for the project lifetime in order to start the exploitation of the new VET programmes. For defining the necessary knowledge, skills and competences the project started with an extensive domain and job analysis.

This report is a deliverable in work package 2 of the ECoVEM project. All partners contributed under the leadership of the task responsible, Technical University of Sofia.

4. Objective

The preliminary need analysis at the stage of the project design was done for each target audience:

- Students and trainees in microelectronics. They need high-quality educational materials and continually brought up-to-date courses, because of the essence of the science - the most rapidly advancing sector nowadays. They need education related to their further work and for the complexity of the knowledge and skills, necessary to successfully perform the tasks in this multidisciplinary area. The virtual mobility will provide them access to the CAD systems and courses existing in other European HE institutions.

- Their teachers and trainers. They need infrastructure, techniques for course delivery allowing easy changes and upgrade because of the fast-developing science of the subject matter, i.e. ICT-based materials. Sharing IT resources and e-learning courses will support them a lot and the project will contribute to the virtual mobility of teaching staff.
- CoVEs management is convinced of the necessity of European dimensions in microelectronics education, particularly with regard to curricular development, interinstitutional co-operation, virtual mobility of students and teaching staff and integrated programmes of study, training and research.
- Future employers need (young) specialists empowered with the new skills necessary for the new jobs in microelectronics sector.
- Practitioners from SMEs in the sector for which the collaboration with VET centres and technical universities in supervising VET students and PhD students will be beneficial for their research activities and innovations in the enterprise.
- From the institutional point of view, the targets are the VET centres providing education and training in microelectronics and the enterprises in the sector. As no single VET school or SME can afford the extremely expensive infrastructures, equipment, and maintenance of clean rooms for microelectronics, collaboration and sharing of facilities and expertise on European level is of high institutional interest for both, VET providers and SMEs.

The first activity in the project was a more precise user need analysis to provide the most appropriate educational resources for meeting them. The objective of the ECoVEM need analysis is to analyse the skills, competences and occupations in microelectronics and its applications, and to recommend the structure of the ECoVEM curriculum.

5. Limitations

The here presented need analysis relies on multiple pillars and on the diversity within the ECoVEM consortium and thus covers the entire microelectronics value chain in Europe: research, education, and industry.

One possible limitation in the need analysis is the well-known problem of surveys or questionnaires with the non-responsiveness. We overcome this limitation by keeping the survey as short as possible and by personally contacting associated stakeholders. In addition, we have used interviews with managers from academia and business, who are typically too busy to answer a questionnaire, to support the survey.

6. Methods of the analysis

A multistakeholder approach covering industry, VET providers, social institutions, and policy makers was used on all levels of the needs analysis: in the definition of questions, in the sample groups, and for the analysis of the results. This is only possible thanks to the excellent partners in the ECoVEM platform.

The sources of information were:

- Literature study - New Industrial Strategy for Europe, the Important Project of Common European Interest (IPCEI) on Microelectronics, the German Federal Government's Framework Programme for Research and Innovation 2021–2024;

- Educational needs analysis by VET providers in ECoVEM and companies;
- ESCO profiles and skills in microelectronics;
- Analysis of job offers in microelectronics;
- Survey with larger audience from the business/industrials on the skill needs in the next 3 years and beyond.

The results from METIS project, on which we planned to rely at the stage of project proposal preparation, are very late and we performed our analysis independently from METIS.

The partners participated with following responsibilities:

Industry representatives together with research institutions were responsible for job analysis and they provided inputs from microelectronics design and fabrication to its applications in other industries (communications, computers, green energy, automotive industry, space technologies, medicine).

VET centres are responsible for educational need analysis and they provided the inputs and methodologies, pinpointing the issues relating to skills and competences. Those inputs were with a clear European perspective and consideration of EU tools as EQF levels and ESCO format.

In order to ensure coherence with the European, regional and national priorities and for anticipating future skill for re-training in microelectronics, the literature study of the strategic documents for regional development, innovation and smart specialisation strategies was performed.

6.1. Questions

What knowledge and skills should provide the VET centres in microelectronics to contribute to Europe's industrial strategy and to Europe's sovereignty?

What skill levels of employees in the sector are the most important for the next three years and beyond?

6.2. Samples

The target groups concerned are:

- college students (for EQF levels 3-5), students in microelectronics engineering (EQF levels 6-8), adults needing re-skilling and up-skilling;
- iVET and cVET teachers and trainers in HRD departments;
- specialists and managers form the business in microelectronics;
- policy makers in VET.

The samples included teachers and trainers at the partner institutions and their alumni, engineers and managers from SMEs and large enterprises in microelectronics and microsystems, electronics packaging and communication from all participating countries and in other European countries.

6.3. Instrumentation

The following instruments and techniques were used for the analysis of skill needs in microelectronics:

- Competence matrix for the educational analysis;
- Literature study of documents for the EU strategy for the next 5-7 years;

- Study of recent job offers in microelectronics;
- Study of skills in ESCO profiles;
- Online survey. Based on the educational analysis and the job analysis from job offers and ESCO profiles, the main skills were identified and a questionnaire for analysis of needs of European industry for the next 3 years and beyond was designed and created with European survey software. It is presented in Appendix 1.

Next section presents the results of the analyses.

7. Results

This section presents in detail the results of the literature study, the educational needs analysis by VET providers and companies in the project and their partners, analysis of skills in existing ESCO profiles, analysis of skills required in the job vacancies in microelectronics, and the survey with specialists and managers from industry on the skill needs in the next 3 years and beyond.

7.1. Educational needs analysis by VET providers and companies

VET centres and companies in the project provided information and collected additional opinions from their educational and business partners on the knowledge, skills and competences of the occupations in microelectronics for EQF levels 3 to 8. A total of 45 VET providers and 54 company respondents were involved in this analysis. The information was collected in a competence matrix. Those inputs were analysed and occupational profiles were defined according to ESCO format and grouped on EGF levels. The results are presented in the following table.

EQF level	Occupation	Description
3	**Microelectronics operator**	• Use a variety of processing equipment per given instruction including vacuum systems, plasma etching systems, thin film deposition systems, laser and precision step measurement systems, manual wire and ribbon bonding tools, various inspection equipment, ovens, pick and place machinery and automated adhesive dispense systems. • Modify/ alter equipment setups as required.
	Electricity and electronic technician	• Perform auxiliary operations in the assembly and maintenance of electrical and electronic elements and equipment, of electrical and home automation facilities, as well as in electrotechnical and telecommunications facilities for buildings, including installation and maintenance of networks for data transmission. • Apply the required techniques, operate with the indicated quality, observe the corresponding occupational risk prevention and environmental protection standards.
	Microsoldering technician	• Soldering and micro-soldering techniques for SMD components and connectors. • Soldering Technology: Through Hole Mounting (THT) and Surface Mount (SMT-SMD, BGA) • Apply different soldering techniques to the repair of the most frequent failures in electronic device. • Knowing and handling of different soldering equipment: hot air guns, soldering iron or soldering iron.
4	**Circuit board repair technician**	• Repair printed circuit boards (PCBs) and equipment that utilizes PCB designs; Troubleshoot electronic assemblies down to the component level to determine cause and remedy of any malfunction using various techniques and equipment. Perform electrical testing using established test processes to validate all remanufactured electronics device functions per OEM specifications. • Read electrical schematics, PCB fabrication and assembly drawings and understand PCB design technologies and PCB layout techniques. • Assembly and installation of new printed circuit boards • Analyse the needs of each job and perform necessary maintenance.

	Test/repair technician for robotic equipment	• Analyse, troubleshoot and root-cause problems in robotic systems. • Disassemble and reassemble robots and/or peripheral equipment to make repairs such as replacement of defective circuit boards, sensors, motors, and user interfaces. • Perform Software and Firmware upgrades to Robotic Drive Units and Sub-assemblies. • Read electronic schematics; • Maintain service records of robotic equipment; Document test process and UUT results.
	Technician in electrical and automatic facilities	• Technical support for industrial automation, electrical engineering, distribution facilities, and photovoltaic solar facilities; • Assemble and maintain telecommunication infrastructures in buildings, low voltage electrical facilities, electrical machines, and automated systems; • Application of current standards and regulations, quality protocols, safety and occupational risks, ensuring their functionality and respect for the environment.
4	**Electric and electronic power systems operator**	• Develop and repair electric and electronic power systems. • Factual and theoretical knowledge in: alternating current, direct current, electronic components, electrical power, alternative energy systems; special power supply systems. • Ability to apply measuring apparatus and techniques, protection against surges and overvoltage; Analyse series and parallel RLC circuits, taking into account the power factor, active and reactive power; Measure the potential difference in a circuit; Use symbology applied to electric and electronic circuits; Use various measurement methods in electrotechnics; Repair and test power systems; Use electronic components for different applications; Identify elements of electrical-electronic components in a machine, industrial equipment or automated line.
	Technician for electric and electronic circuits	• Recognise the logical state and identify the logical variable and logical level; • Apply typical electronic circuits; • Choose components according to their intended use; • Choose and size protections for the circuits; • Select and apply different types of sensors, detectors or actuators; • Perform an automated system using sensors and transducers.
	Repair technician for electric and electronic equipment	• Perform the diagnosis and repair of technical issues on electric and electronic equipment; • Use measuring instruments on electronic equipment and test them; • Identify the internal constitution, specific characteristics and operating principle of the various electromechanical and electronic detection equipment;

		• Select, through the consultation of catalogues of manufacturers, the sensors and transducers to install or replace in real applications, with a view to their automation; • Select and test types of sensors and transducers, according to the type of application; • Recognise the operation of electrical machines, identifying their application and determining their characteristics.
4-5	**Embedded systems specialist**	• Design and implement software of embedded devices and systems from requirements to production and commercial deployment • Develop, code, test and debug system software • Integrate and validate new product designs • Support software QA and optimize I/O performance • Provide post production support • Interface with hardware design and development • Assess third party and open source software
	Internet of Things (IoT) technician	• Design and produce IoT devices like sensor nodes and IoT communication interfaces. • Design an end-to-end IoT architecture • Install and deploy IoT devices for data measurement and data collection like wireless sensor nodes, and wireless actuators. • IoT software/firmware development. • Test and install RF communication interfaces like LoraWan, NB IoT, Wi-fi, Bluetooth and BLE, Zigbee. • Use different cloud systems for collecting data from IoT sensor nodes like AWS, MS Azure, Google Cloud IoT Core, Things Network, My Devices, etc. • Ability for self-installation and maintenance of IoT gateways, concentrators, routers, access points and other networking equipment.
	RF communication systems technician	• Work with a range of RF-enabled devices including cell phone antennas, amplifiers, two-way radios, satellite systems, and internet access points. • Troubleshoot circuits used in RF transmission independently and with site engineers. • Identify and repair faults in finished assemblies making adjustments as required. • Identify the causes of faults and work with on-site teams to implement preventative measures so that they do not happen again.

		• Model creation, assembly, tuning, and plan development as well as modifying antenna prototypes, parts, and assemblies. • Maintain documentation of test cases. • Perform routine antenna capability tests. • Instruction customers on how to properly use the equipment.
	Electronics/ Microelectronics maintenance technician	• Corrective maintenance • Maintenance documentation • Diagnosis of malfunctions and failures • Preventive maintenance. • Executing operation tests, adjusting equipment and elements, to put into service the equipment or systems.
5	**PCB Design Technician**	• Design and create printed circuit board (PCB) layouts from inputs received from engineering (electrical, mechanical) • Place and route components ensuring that all electrical and physical specifications meet the specific design requirements for each PCB design. • Ensure that all requirements for manufacturing and assembly are met. • Develop and generate drawings and documentation to facilitate PCB fabrication and assembly. • Rework PCB designs when engineering design changes occur and assist the design team with ideas to resolve issues. • Perform drawings and documentation updates per the instructions of engineering changes requests. • Create component ECAD library footprints and/or schematic symbols as required for design projects.
	Programmer of microcontrollers	• Select the adequate programming language; • Apply the use of different modes of operation of counters/timers; • Build programmes that use data transfer and processing instructions, as well as test and function instructions; • Elaborate flowcharts; • Apply the main instructions of the used microcontroller.

5	**Technician for microcontrolled systems**	• Develop microcontrolled systems using electronic components: build a structure of a microcontrolled system; connect sensors and actuators to a microcontroller; connect electronic components to a microcontroller; • Build a system that requires monitoring from a microcontroller; • Compile and test a programme in a microcontrolled system; • Elaborate flowcharts; • Apply the main instructions of the used microcontroller.
	Programmer of logic controllers	• Use the most adequate programming language for the task; • Dexterously use the selected programming software; • Carry out programmes with logic operations, timers and counters; • Select different constructive solutions of a programmable logic controller; • Carry out a description of the operation of an automated system using grafcet; • Develop small programmes for programmable logic controller; • Configure programmable sequential systems by selecting and connecting the elements that compose it; • Recognise the utility of sequential circuits; • Configure, select and check the operation of the programmed sequential system by adjusting the devices and applying safety standards.
	Test technician	• Diagnose types and causes of mechanical malfunctions of equipment; • Identify the procedures associated with assembly, operation and maintenance of various types of equipment; • Use different types of measurement and analysis equipment; • Diagnose the malfunctions of the mechanical systems, interpreting their symptoms; • Create functional diagram blocks of machines and equipment, interpreting element planes and sets of machines and equipment, principle diagrams, and circuit schematics.
	Maintenance technician	• Verify the functionality of the equipment; • Detect damaged components in machines and automated lines; • Perform maintenance and repair machinery and accessories; • Perform assembly and disassembly of mechanical and electromechanical elements of machines, interpreting the technical documentation supplied by the equipment manufacturer.

6	**BSc in microelectronics**	• Developing analogue and digital electronic design, RF design, power supply design; • Skills in analytical tools such as ETAP, applications of schematic, spice simulation; • Hardware description languages. • Design and manufacturing, assembly, testing and inspection. • Optimize complex and advanced designs for manufacturability.
	Mechatronic engineer	• Skills in CAD, PLC programming, statistics and data processing tools. • Determining how a system should work and how changes in conditions, operations, and the environment will affect outcomes. • Capability to identify measures / indicators of system performance and the actions needed to improve or correct performance, relative to the goals of the system.
	Manufactures printed circuit boards.	• Technologies to develop printed circuit boards; • Technologies to manufacture printed circuit boards; • Processes to create printed circuit boards.
	Run and assemble printed circuit boards.	• Assemble and solder components on printed circuit boards; • Handle soldering tools correctly; • Assemble the components correctly on the printed circuit board; • Solder wiring components and conductors; • Operate with tools, materials and equipment related to the production of printed circuits; • Run printed circuit boards; • Assemble and solder components on printed circuit boards; • Apply antioxidant treatment.
	Photovoltaic (PV) cells fabrication and characterization technician	• Energy, Electricity, Renewable electricity and Photovoltaic (PV) market. • Basic Physics of photovoltaic cell, Semiconductors properties, p-n junction and photovoltaic cell, Outstanding characteristics of crystalline silicon for PV applications • The different semiconductor materials used for the different PV cell technologies. • Electrical and optical characterization of silicon solar cells
	Design of printed circuit boards	• Builds simple electrical circuits; • Recognizes the building blocks in the electrical scheme; • Installs the most common software printed circuit board design products; • Relies on technological maps for the production of electronic products; • Selects a suitable controller· Implements interrupt management systems at the controllers;

6		• Selects a suitable smoothing filter scheme· Calculates the filter elements· Examines a smoothing filter; • Draws electrical drawings and diagrams; • Measures electrical quantities; • Knows the main groups of analog and digital electronic devices and their parameters; • Knows the principle of operation of analog-digital converters (ADCs) and digital-analog converters (DAC); • Uses application software to draw design and technological documentation;
	Integrated circuit design engineer	• Carry out the specification, implementation, documentation and tuning of electronic, instrumentation and control equipment and systems, considering both the technical aspects and the corresponding regulatory standards. • Design analogue and digital electronic circuits, analogue-to-digital and digital-to-analogue conversion, radio frequency, power supply and electrical energy conversion circuits for telecommunication and computer applications. • Design at the layout level integrated circuits, simulate their behaviour, interpret the results, and characterize the performance of the integrated circuit obtained.
	Electronic system engineer	• Research, design, and develop electronic systems; Preparation, development and approval of projects in the field of electronic engineering. • Design and analysis of electronic circuits for telecommunication services and systems. • Application of electronics as a support technology in other fields and activities. • Design interface, data capture and storage devices and terminals. • Programmable device and specialized description languages. • Analyse and design combinational and sequential circuits, synchronous and asynchronous, and to use microprocessors and integrated circuits.
6	**Constructor of electronic equipment**	• Select suitable components for schematics and PCB layout and place them according to device specific use case. • Skill to calculate PCB track width and distance between them. Place components according to thermal requirements. • Manufacturing skills: Match all specific requirements for manufacturing and assembly; Generate files for manufacturing; Ability to work with machines in matter to produce fully working PCB. • Perform specific device hardware testing to unsure it works according to the requirements

	FPGA programmer	• Set up the program environment depending on the specificity of the FPGA development board; • Choosing and connecting a large number of basic logic blocks; • Writing the suitable description program on Verilog or VHDL language; • Creating graphical programming models.
7	**Photovoltaic cell and module fabrication expert**	• Physics of solar cells, Semiconductors properties, The different PV cell technologies, • Advanced skills in microelectronics, materials and photovoltaics: Semiconductor doping, diffusion and p-n junction formation; Thin film deposition (PECVD, PVD, ALD, oxidation…): antireflective and passivation coatings; Optical, physico-chemical and electrical characterization. • Advanced skills in industrial and lab-scale fabrication and characterization equipment: Silicon production and purification; Silicon crystallization and wafering; Different silicon PV cell architectures; PERC cell fabrication process; Chemical cleaning and texturization; Recombination mechanisms, gettering, surface and bulk passivation of defects; Metallization: serigraphy and belt furnace, photolithography. • PV module manufacturing, characterization and accelerated ageing
	Technical expert for photovoltaic systems	• Strive to optimise energy production from photovoltaic systems, and reduce production expenses and environmental strain; • Monitoring and characterization (system and modules) and data processing. • Different structures (fixed, tracker, vertical, floating); Optimization for different latitudes and different climates; Sizing of systems; Performance and degradation of the various components. • Environmental measurements and quality control; Soiling and cleaning strategies / technological solutions. • Safety of installations and people.
	MSc in microelectronics	• Advanced skills in microelectronics technologies: lithography, epitaxy, ion implantation, layer deposition, etching etc. • Ability to design integrated circuits and systems, PCBs, multichip modules • Skills associated to advanced packaging (SiP, Advanced IC substrates (Flip chip-based packages), Stacking technologies (2.5D & 3D), embedded die) • Skills related to testing and reliability.

8	**Space mission designer/manager**	• Design a complex technological/research project (goals definition, work plan design, scheduling, resource planning, etc.). • Strong skills in practical application of data processing techniques (AI, statistics, etc.) and tools. • Manage technological risks
	Photovoltaic material expert	• Production, ultrapurification and crystallization of solar grade silicon. • Advanced skills in electronic-grade silicon material properties. • Sawing of bricks and wafers and characterization of Si bricks and wafers (impact and characterization of impurities). • proactivity in orienting technological solutions; design-thinking.
	Photovoltaic cell expert	• Advanced skills in industrial and lab-scale manufacturing equipment • Different silicon PV cell architectures and fabrication processes; Emitter formation: diffusion furnace; Thin film deposition: PECVD, LPCVD, PVD, ALD; Plasma for PV; Oxidation; Metallization: serigraphy.
	Photovoltaic module expert	• Characterization and ageing of PV cells • Advanced knowledge in reliability and durability of PV modules; International standards ; extreme climate applications; natural ageing, outdoor accelerated ageing.
	Researcher in a R&D department of companies in applied microelectronics	• Microelectronics and design of application specific integrated circuits (ASICs). • Conceive, design, implement and adopt a substantial process of research or creation. • Perform a critical analysis and evaluation and synthesis of new and complex ideas.
5-8	**R&D project manager**	• Project funding acquisition (funding opportunities search, project design, competitive project proposal writing). • Project management (schedule management, team management, results delivery, etc.). • Comprehensive skills in all modern office and communication technologies.

7.1.1. Summary

The occupational profiles in microelectronics defined by the educational need analysis with 45 VET providers and 54 companies are as follows:

EQF 3	EQF 4	EQF 4-5	EQF 5	EQF 6	EQF 6-7	EQF 7	EQF 8
Microelectronics operator Electricity and electronic technician Microsoldering technician	Circuit board repair technician Technician in electrical and automatic facilities Electric and electronic power systems operator Technician for electric and electronic circuits Repair technician for electric and electronic equipment	Embedded systems specialist Internet of Things (IoT) Technician RF communication systems technician Electronics/ Microelectronics maintenance technician	PCB Design Technician Programmer of microcontrollers Technician for microcontrolled systems Programmer of logic controllers Test technician Maintenance technician	BSc in microelectronics Mechatronic engineer Manufactures printed circuit boards. Run and assemble printed circuit boards. Photovoltaic (PV) cells fabrication and characterization technician Design of printed circuit boards	Integrated circuit design engineer Electronic system engineer Constructor of electronic equipment FPGA programmer	MSc in microelectronics Photovoltaic cell and module fabrication expert Technical expert for photovoltaic systems	Space mission designer/manager Photovoltaic material expert Photovoltaic cell expert Photovoltaic module expert Researcher in a R&D department of companies in applied microelectronics

R&D project manager occupational profile is defined for EQF levels 5-8.

The skills corresponding to each profile are determined in the preceding table.

7.2. ESCO profiles and skills in microelectronics

ESCO profiles and the skills and knowledge for the professions in electronics and manufacturing were analysed and those relevant to microelectronics and its applications are presented in this section. The Source is: https://ec.europa.eu/esco/portal/occupation?resetLanguage=true&newLanguage=en

7.2.1. Occupations

	Code	Description	Alternative label
Engineers			
Electronics engineers	ISCO-08 code 2152	Electronics engineers conduct research on, design, and direct the construction functioning, maintenance and repair of electronic systems, and study and advise on technological aspects of electronic engineering materials, products or processes. Tasks include: (a) advising on and designing electronic devices or components, circuits, semi-conductors, and systems; (b) specifying production or installation methods, materials and quality standards, and directing production or installation work of electronic products and systems; (c) establishing control standards and procedures to ensure efficient functioning and safety of electronic systems, motors and equipment; (d) organizing and directing maintenance and repair of existing electronic systems and equipment; (e) designing electronic circuits and components for use in fields such as aerospace guidance and propulsion control, acoustics, or instruments and controls; (f) researching and advising on radar, telemetry and remote control systems, microwaves and other electronic equipment; (g) designing and developing signal processing algorithms and implementing these through appropriate choice of hardware and software; (h) developing apparatus and procedures to test electronic components, circuits and systems.	• electronics engineering specialist/expert/ adviser/consultant • electronic technology engineering expert • electronic technology engineer • electronic technology engineering specialist • electronic technology engineering consultant

Microelectronics engineer	2152.1.6	Microelectronics engineers design, develop, and supervise the production of small electronic devices and components such as micro-processors and integrated circuits.	• microelectronic technology engineer; • microelectronics design engineer • microelectronic technology engineering expert/ consultant; • microelectronic engineering consultant/ • specialist/ adviser; • microprocessor engineer.
Microsystem engineer	2152.1.7	Microsystem engineers research, design, develop, and supervise the production of microelectromechanical systems (MEMS), which can be integrated in mechanical, optical, acoustic, and electronic products.	• microsystem technology engineering consultant/specialist/expert/adviser • microsystem engineering adviser/ consultant/specialist • MEMS engineer • microelectromechanical systems engineer
Technicians			
Electronics engineering technicians	ISCO-08 code 3114	Electronics engineering technicians perform technical tasks to aid in electronic research and in the design, manufacture, assembly, construction, operation, maintenance and repair of electronic equipment. Tasks include - (a) providing technical assistance in research and development of electronic equipment, or testing prototypes; (b) designing and preparing blueprints of electronic circuitry according to the specifications given; (c) preparing detailed estimates of quantities and costs of materials and labour required for the manufacture and installation of electronic equipment, according to the specifications given; (d) monitoring technical aspects of the manufacture, utilization, maintenance and repair of electronic equipment to ensure satisfactory performance and ensure compliance with specifications and regulations; (e) assisting in the design, development, installation, operation and maintenance of electronic systems;	• signal processing technician • electronics engineering technologist • digital electronics engineering technician • technologist in electronics engineering • control and instrumentation technician • technician in electronic equipment • communication electronics engineering technician • industrial electronics engineering technician • electronic equipment technician • technician in electronics engineering • electronics engineering assistant

		(f) planning installation methods, checking completed installations for safety and controls or undertaking the initial running of the new electronic equipment or system; (g) conducting tests of electronic systems, collecting and analysing data, and assembling circuitry in support of electronics engineers.	
Microelectronics engineering technician	3114.1.6	Microelectronics engineering technicians collaborate with microelectronics engineers in the development of small electronic devices and components such as micro-processors, memory chips, and integrated circuits for machine and motor controls. Microelectronics engineering technicians are responsible for building, testing, and maintaining the microelectronic systems and devices.	• micro-electronics engineering technician • microelectronic equipment technologist • technologist in microelectronics • microelectronic systems technologist • microelectronics technician • microelectronics process engineering technician
Microelectronics Design			
Microelectronics designer	8212.3.6	Microelectronics designer engineers focus on developing and designing microelectronic systems, from the top packaging level down to the integrated circuit level. Their knowledge incorporates system-level understanding with analogue and digital circuit knowledge, with integrating the technology processes and an overall outlook in microelectronic sensor basics. They work with other engineers, material science specialists and researchers, to enable innovations and continuous development of already existing devices.	• microelectronics circuit engineer/ designer • microelectronics system engineer/ designer • microelectronics packaging design engineer • microelectronics hardware designer/ engineer • microelectronics technology/ manufacturing design engineer
Integrated circuit design engineer	2152.1.6.1	Integrated circuit design engineers design the layout for integrated circuits according to electronics engineering principles. They use software to create design schematics and diagrams.	• analog and mixed signal design engineer • engineer of integrated circuits • integrated circuit designer/ engineer • mixed signal IC design engineer • IC designer • analog IC design engineer

Embedded system designer[1]	2511.4	Embedded system designers translate and design requirements and the high-level plan or architecture of an embedded control system according to technical software specifications. ***What is the difference between embedded software and software engineer?*** *Embedded engineers write code, but unlike software engineers, they need a deep understanding of the hardware it runs on. An embedded engineer knows the schematics of hardware and how chip datasheets relate to the code written for them. Embedded software is usually self-contained and only runs a single program.*	• embedded systems developer • embedded system programmer • embedded software developer
Technology/Manufacturing			
Manufacturing engineer	2141.3.1	Manufacturing engineers design manufacturing processes for different kinds of production processes. They integrate those specificities and constraints posed by the industry or the product being produced with general and wide-spread manufacturing engineering principles into the design and planification of manufacturing processes.	• manufacturing engineering specialist/ adviser/ consultant/ expert • manufacturing technology engineering expert/ specialist/ engineer/ adviser/ consultant • manufacture engineer • manufacturing process engineer
Semiconductor processors	8212.3.6	Semiconductor processors manufacture electronic semiconductors as well as semiconductor devices, such as microchips or integrated circuits (IC's). They may also repair, test, and review the products. Semiconductor processors work in cleanrooms and therefore need to wear a special lightweight outfit that fits over their clothing to prevent particles from contaminating their worksite.	• microchip assembler • processor of semiconductors • semiconductor manufacturing inspector • semiconductor processing practitioner • semiconductor assembler • semiconductor packages sealer • semiconductor manufacturing inspector • microchip fabricator • integrated circuit operator

[1] Embedded Software Engineering is the process of controlling various devices and machines that are different from traditional computers, using software engineering.

Assembling/Packaging			
Microelectronics smart manufacturing engineer		Microelectronics smart manufacturing engineers design, plan and supervise the manufacturing and assembly of electronic devices and products, such as integrated circuits, automotive electronics or smartphones, in an Industry 4.0 compliant environment.	
Electrical and electronic equipment assemblers	ISCO-08 code 8212	Electrical and electronic equipment assemblers assemble or modify, according to procedures strictly laid down, components of electrical, electromechanical and electronic equipment. Tasks include : (a) assembling component parts and electrical and electronic systems and positioning, aligning and fastening units to assemblies, subassemblies or frames using hand or power tools, soldering and micro-welding equipment; (b) reviewing work orders, specifications, diagrams and drawings to determine materials needed and assembly instructions; (c) recording production and operational data on specified forms; (d) operating wire-coiling machines to wind wire coils used in electrical equipment and components such as registers, transformers, armature wires, electric motors and generators; (e) inspecting and testing completed components and assemblies, wiring installations and circuits, and rejecting faulty assembly components.	• electronic equipment products assembler • assembler of electronic equipment • electronic equipment products wirer/assembler • electronic equipment fabricator • electronic equipment production operative • electronic equipment products production operative • electronic equipment products wirer • electronics assembler • electronic equipment products assembly worker
Electronic equipment assembler	8212.3	Electronic equipment assemblers are responsible for the assembly of electronic equipment and systems. They assemble electronic components and wiring according to blueprints and assembly drawings. They may assist in quality inspection and equipment maintenance.	
Assemble microelectronics		Build microelectronics using microscopes, tweezers, or pick-and-place robots, such as SMT machines. Slice substrates from silicon wafers and bond components onto the surface through soldering and bonding techniques. Bond the wires through special wire bonding techniques and seal and encapsulate the microelectronics.	• building microelectronics • assembling microelectronics
Test			

Test microelectronics		Test microelectronics using appropriate equipment. Gather and analyse data. Monitor and evaluate system performance and take action if needed.	• analyse microelectronics • testing microelectronics
ICT test analyst	2519.5	ICT test analysts work in testing environments, assessing products, checking for quality and accuracy, or creating tests scripts. They design tests which are then implemented by testers.	• IT test analyst • test designer
ICT system tester		ICT system testers perform testing activities and some test planning activities. They may also debug and repair ICT systems and components although this mainly corresponds to designers and developers. They ensure that all systems and components function properly before delivering them to internal and external clients.	
Quality Assurance			
Quality engineer	2149.2.7	Quality engineers define quality standards for the creation of products or services. They check to make sure the products and services are in compliance with the quality standards and they coordinate quality improvements.	• quality assurance engineer/inspector • quality control inspector • product inspector • product quality monitor • quality systems engineer • customer quality engineer
Quality engineering technician	3119.15	Quality engineering technicians work with quality engineers or managers to analyse and solve quality problems and improve productivity. They examine machines for imperfections and inspect products to make sure they meet the standards. They also provide personnel with training in inspection techniques and prepare inspection plans.	• quality technician/ specialist/ expert/ technologist • quality technology specialist
Materials for Microelectronics			
Materials engineer	2149.9	Materials engineers research and design new or improved materials for a diverse number of applications. They analyse the composition of materials, conduct experiments, and develop new materials for industry-specific use that can range from rubber, to textiles, glass, metals, and chemicals. They advise companies in damage assessments, quality assurance of materials, and recycling of materials.	• material engineer • materials engineering adviser/specialist • material testing technology studies scientist • material testing technology studies analyst

			• material testing technology scholar/scientist/researcher/research analyst/ research scientist
Microelectronics materials engineer		Microelectronics material engineers design, develop and supervise the production of materials that are required for microelectronics and microelectromechanical systems (MEMS), and able to apply them in these devices, appliances, products. Microelectronics material engineers aid the design of microelectronics with physical and chemical knowledge about metals, semiconductors, ceramics, polymers, and composite materials. They conduct research on material structures, perform analysis, investigate failure mechanisms, and supervise research works.	• microelectronics material designer/ engineer • microelectronics material technology engineering developer/ expert/ adviser/specialist/consultant • engineer specialised in microelectronics materials
Equipment for Microelectronics			
Equipment engineer	2144.1.6	Equipment engineers design and maintain the machinery and equipment in manufacturing facilities. They design machinery that adjusts to the manufacturing requirements and processes. Moreover, they envision the maintenance of the machines and equipment for uninterrupted functioning.	equipment engineering adviser/ specialist/ consultant/ expert • equipment technology engineering specialist/ consultant/ expert • equipment engineering consultant • equipment technology engineer
Electrical equipment production supervisor	3122.4.4	Electrical equipment production supervisors coordinate, plan and direct the production process of electrical equipment. They manage labourers working on the production line, oversee the quality of the assembled goods, and perform cost and resource management.	• electrical equipment production line supervisor/ manager • electrical equipment manufacturing supervisor/ manager • electrical equipment production manager • production supervisor in electrical equipment manufacturing
Commissioning engineer	2149.5	Commissioning engineers supervise the final stages of a project when systems are installed and tested. They inspect the correct functioning of the equipment, facilities and plants to make sure they meet the requirements and specifications. They perform the necessary verifications and give approval to finalise the project.	

Maintenance and repair engineer	2141.7	Maintenance and repair engineers focus on the optimization of equipment, procedures, machineries and infrastructure. They ensure their maximum availability at minimum costs.	• machine engineer • mechanical engineer • production engineer • plant repair engineer • repair engineer • maintenance engineer • maintenance and repair superintendent/ manager • equipment engineer • plant maintenance engineer

7.2.2. Skills and Knowledge

Occupation	Essential skills and competences	Essential Knowledge
Microelectronics engineer		
Microelectronics engineer	• design microelectronics • adjust engineering designs • approve engineering design • design prototypes • develop electronic test procedures • model microelectronics • operate scientific measuring equipment • perform scientific research • prepare production prototypes • read engineering drawings • report analysis results • test microelectronics	• design drawings • electricity principles • electronic equipment standards • electronic test procedures • electronics • engineering principles • integrated circuits • microassembly • microelectronics • microprocessors
Microsystem engineer	• design microelectromechanical systems • approve engineering design • use technical drawing software • adjust engineering designs • design prototypes • prepare production prototypes	• Not described in ESCO. In the educational need analysis the knowledge necessary for microsystem engineer is defined.

	• develop microelectromechanical system test procedures • test microelectromechanical systems • operate scientific measuring equipment • analyse test data • abide by regulations on banned materials • conduct quality control analysis • perform scientific research	
Technician		
Electronics engineering technician	• read assembly drawings • adjust engineering designs • align components • fasten components • apply soldering techniques • configure electronic equipment • assemble electronic units • prepare production prototypes • conduct performance tests • test electronic units • use testing equipment • assist scientific research • inspect quality of products • interpret electronic design specifications • liaise with engineers	• circuit diagrams • design drawings • electronic components • electronic equipment standards • electronic test procedures • electronics • integrated circuits • printed circuit boards • types of electronics
Microelectronics engineering technician	• adjust engineering designs • align components • assemble microelectronics • fasten components • inspect quality of products • prepare production prototypes • read assembly drawings • read engineering drawings • solder electronics • test microelectronics	• circuit diagrams • design drawings • electronic equipment standards • electronic test procedures • electronics • integrated circuits • microassembly • microelectronics • microprocessors • microsensors

Microelectronics Design		
Integrated circuit design engineer	• design electronic systems on a chip • design integrated circuits • create technical plans • customise drafts • liaise with engineers • use CAD software	• CAD software • electronic components • electronic equipment standards • electronics • integrated circuit types • integrated circuits technology • semiconductors
Microelectronics designer	• design electronic systems • design integrated circuits • design circuits using CAD • approve engineering design • create a product's virtual model • customise drafts • design prototypes • design sensors • develop assembly instructions • develop product design • draft bill of materials • integrate new products in manufacturing • interpret electronic design specifications • model sensor • prepare assembly drawings • provide technical documentation • read assembly drawings • read engineering drawings • review drafts • use CAD software • use CAM software	• CAD software • CAE software • circuit diagrams • design drawings • electrical engineering • electricity principles • electronic components • electronics • engineering principles • environmental engineering, legislation, threats • integrated circuits • manufacturing processes • microassembly • microelectronics • microsensors • printed circuit boards • quality standards • semiconductors • sensors
Embedded system designer	• analyse software specifications • create flowchart diagram • create software design	• ICT communications protocols • embedded systems • engineering control theory

	• define technical requirements • develop creative ideas • interpret electronic design specifications • provide ICT consulting advice	• real-time computing • signal processing • systems development life-cycle • task algorithmisation • tools for software configuration management
Technology/Manufacturing		
Semiconductor processor	• produce semiconductor crystals • slice crystals into wafers • clean wafers • polish wafers • imprint circuit design onto wafers • load electronic circuits onto wafers • monitor machine operations • monitor manufacturing quality standards • read assembly drawings • ensure conformity to specifications • inspect semiconductor components • remove defective products • report defective manufacturing materials • carry out measurements of parts • meet deadlines • wear cleanroom suit	• electronics • integrated circuits • microassembly • microelectronics • semiconductors
Assembling/Packaging		
Microelectronics smart manufacturing engineer	• read engineering drawings • develop assembly instructions • assemble printed circuit boards • apply advanced manufacturing • apply soldering techniques • solder electronics • perform resource planning • draft bill of materials • integrate new products in manufacturing	• manufacturing processes • production processes • technical drawings • industrial engineering • engineering principles • electronic equipment standards • quality standards • quality assurance methodologies • quality assurance procedures

	• prepare assembly drawings • assess the life cycle of resources • ensure health and safety in manufacturing • liaise with engineers • monitor plant production • analyse production processes for improvement • define manufacturing quality criteria • inspect quality of products • perform risk analysis • set quality assurance objectives	• environmental legislation • environmental threats • electronics • microassembly • microelectronics • nanoelectronics
Electronic equipment assembler	• align components • apply assembly techniques • apply health and safety standards • apply soldering techniques • assemble electronic units • carry out measurements of parts • ensure conformity to specifications • fasten components • monitor manufacturing quality standards • read assembly drawings • remove defective products • report defective manufacturing materials • solder electronics	• circuit diagrams • electrical equipment regulations • electronic equipment standards • electronics • integrated circuits • printed circuit boards • quality standards • types of electronics
Test		
Material testing technician	• apply safety procedures in laboratory • maintain test equipment • operate scientific measuring equipment • perform laboratory tests • record test data • report test findings • use testing equipment	• health, safety and hygiene legislation • quality standards
Materials for Microelectronics		

Microelectronics materials engineer	• abide by regulations on banned materials • apply soldering techniques • join metals • inspect semiconductor components • test materials • dispose of soldering waste • test microelectromechanical systems • read engineering drawings • record test data • analyse test data • report analysis results • provide technical documentation • perform data analysis • perform laboratory tests • perform chemical experiments	• electrical engineering • electronics • semiconductors • manufacturing processes • mathematics • physics • chemistry • environmental legislation • environmental threats • microelectronics • microassembly • microsystem test procedures • sensors • precision measuring instruments • types of metal • types of plastic • basic chemicals
Equipment for Microelectronics		
Equipment engineer	• define technical requirements • execute analytical mathematical calculations • execute feasibility study • assess financial viability • interpret technical requirements • manage engineering project • perform scientific research • use technical drawing software	• engineering principles • engineering processes • manufacturing processes • mathematics • production processes • project management • technical drawings
Electrical equipment production supervisor	• follow production schedule • inspect quality of products • interpret electrical diagrams • keep records of work progress • meet deadlines • meet productivity targets • monitor manufacturing quality standards	• electrical discharge • electrical engineering • electrical wiring diagrams • electricity principles • supply chain management

	• monitor stock level • perform resource planning • read assembly drawings • read standard blueprints • supervise staff • supervise work • troubleshoot	
Maintenance and repair engineer	• advise on efficiency improvements • conduct quality control analysis • conduct routine machinery checks • create solutions to problems • inspect industrial equipment • inspect machinery • maintain equipment • maintain machinery • manage budgets • perform machine maintenance • perform test run • resolve equipment malfunctions • troubleshoot • use testing equipment • work safely with machines • write technical reports	• engineering principles • engineering processes • maintenance and repair • mechanics • quality assurance procedures
Commissioning engineer	• check system parameters against reference values • analyse test data • collaborate with engineers • conduct quality control analysis • ensure conformity to specifications • ensure fulfilment of legal requirements • ensure public safety and security • liaise with quality assurance • present reports • read standard blueprints	• project commissioning • quality assurance procedures • quality standards • safety engineering

	• record test data • test performance of power plants • troubleshoot • use measurement instruments • use testing equipment • write work-related reports	
Quality Assurance		
Quality engineer	• analyse test data • define quality standards • identify improvement actions • identify process improvements • inspect quality of products • perform risk analysis • recommend product improvements • set quality assurance objectives • support implementation of quality management systems • undertake inspections • write inspection reports	• quality assurance methodologies • quality assurance procedures • quality standards • test procedures
Quality engineering technician	• conduct performance tests • ensure compliance with company regulations • ensure compliance with legal requirements • execute software tests • inspect material • inspect quality of products • oversee quality control • perform test run • set quality assurance objectives • undertake inspections • write inspection reports	• quality assurance methodologies • quality assurance procedures • quality standards • test procedures

7.2.3. Summary

The main occupations in microelectronics according ESCO are:

Technicians EQF 3-5	Engineers EQF 6-8
• Electronics engineering technicians • Microelectronics engineering technician • Assembler of microelectronics • Electrical and electronic equipment assemblers • Electronic equipment assembler • Quality engineering technician • Test microelectronics	• Electronics engineers • Microelectronics engineer • Microsystem engineer • Microelectronics designer • Integrated circuit design engineer • Embedded system designer • Manufacturing engineer • Semiconductor processors • Microelectronics smart manufacturing engineer • ICT test analyst • ICT system tester • Quality engineer • Materials engineer • Microelectronics materials engineer

7.3. Analysis of skills in job offers in microelectronics

Analysis of skills required in 123 job offers in microelectronics was done Europewide

- Sources:

https://ec.europa.eu/eures/portal

https://www.eurojobs.com/

https://www.euroengineerjobs.com/

https://www.eurobrussels.com/

https://www.jobs.bg/

https://www.jobtiger.bg/

The skills are summarised in the following table.

Jobs	Knowledge and Skills
Junior CAD/PDK Engineers Microelectronics	• Good knowledge of electronic devices and semiconductor theory. • Experience with CAD systems in Electronics (Cadence IC, Cadence OrCAD, Protel or similar); • Exposure to Cadence IC (Virtuoso Layout, Schematic or Skill programming language) is a plus;
Semiconductor Design Enablement Engineers	• Good knowledge of electronic devices and semiconductor theory. • Experience with CAD systems in Electronics (Cadence IC, Cadence OrCAD, Protel or similar); • Exposure to Cadence IC (Virtuoso Layout, Schematic or Skill programming language) is a plus;
Electronics Engineer	• Strong interest in and knowledge of Electronics; • Good knowledge and hands-on experience with embedded and mixed-signal systems; • Proficient use of CAD for schematics.
Photolithography Engineer	• A strong background in photolithography manufacturing processes
Analyst Semiconductor Modules	• BOM analysis and costing for OSATs or Assembly & Test • Entrepreneurial mind-set, open-mindedness, progressive nature, demonstrated problem solving
Senior Test Development Engineer RF/AMS	• Strong know-how in semiconductor RF and mixed-signal-testing (ATE) is desired • Good understanding in functional testing of RF-Transceivers (including Base-Band) • Solid Software skills
Digital Design Engineer	• Good knowledge of VHDL, Verilog, or SystemVerilog
Senior Mixed-Signal Verification Engineer	• Knowledge of microelectronic devices and common analog/mixed-signal circuits • Experience with common simulation tools (Cadence, Mentor, and Synopsys) of advantage

	• Knowledge of power electronics and automotive applications • Knowledge of verification techniques for analog & mixed-signal IC common architectures and behavioural modelling languages like Verilog-A, Verilog- AMS, SystemVerilog is a plus
Senior Expert Sensor Test	• Expert in test handling technologies for Semiconductors. • major suppliers in this field and understand the MEMS market
Product Development Engineer	• Good understanding of MOSFETs and/or HEMTs • Solid knowledge of statistics and electric data analysis
Principal Development Engineer for Power Semiconductor Devices SiC	• Power semiconductor technology, preferably in industrial environment
Elektronics/ Assembly / Production	• Assemble and wire electrical equipment in accordingly to the technical documentation • Set up switching gear, including for automation technology
Test Engineer	• Software quality assurance and agile development processes. • Test management tools
Test Engineer	• Experience in writing clear, short and detailed test plans and test cases • Experience in Agile / Scrum development processes • Knowledge of continuous integration and continuous development.
Electrical CAD Engineer	• Knowledge of PCB design principles • Willingness to develop PCB design skills • Knowledge of electronic systems in theory and practice, including EMC/EMI • Knowledge of the Mentor Graphics system • Knowledge of simulation of printed circuit behaviour - HyperLynx
Research Positions	
PhD Research Fellowship in Microelectronics	• Experience with sensor technology, preferably radar • Knowledge and understanding of CMOS processing hardware design and related implementation techniques
Research Assistant / Doctoral Researcher	• Extensive knowledge of semiconductor technology, microsystem technology and sensor technology • In-depth understanding of physical fundamentals and relationships • Practical experience in using FEM (Finite element methods)
Master/Diploma Thesis: Spintronics - Development of CMOS-compatible Materials, Metrology and Devices	• Increase the functionality of their products by use of microsystems (MEMS, MOEMS, CMOS) with innovative features and smaller dimensions.

In the solar photovoltaics energy sector (PV), microelectronics is strategic to contribute increasing competition in the PV sector in Europe. Since 2010, the PV production has moved to Asia and the PV costs of production have kept on decreasing constantly. Aiming to work on EU's value added in the PV sector, two key elements need to be taken into consideration: the development of GigaFab's and the fabrication of very high efficiency cells.

Nowadays, the PV sector is coming back to Europe with 4 GigaFab:

- One in Catania (Italy) which started in 2019 (1500, then 2000 3Sun employees - ENEL Green Power),
- A second one promoted by the Norwegian REC in Hambach in Moselle (France) (1,500 employees, then 2,500)
- A third one, a Swiss MeyerBurger initiative for a gigaFab in Thalheim and Freiberg in Germany which is being finalized (300 employees recruited initially).
- A fourth one in Spain (Sevilla) for 5GW led by Greenland and the Fraunhofer ISE with the entire photovoltaic production chain.

7.3.1. Summary

The summarised skills from the job vacancies showing the actual needs of the industry are mostly in microelectronics design. This is not surprising because the design is done mostly in Europe and in the world and manufacturing is concentrated in TSMS. The skills in the job offers are the same identified by the education provider.

7.4. Labour-market survey results

On the basis of the educational analysis and the job analysis from job offers and ESCO profiles, the main skills were identified and a questionnaire for analysis of needs of European industry for the next 3 years and beyond was designed and created with European survey software. It is presented in Appendix 1.

The questionnaire was published with a link of the project Web site. Enterprises in the sector of microelectronics were reached to participate in the online survey for needs analysis and competences definition. The questions were for concrete EGF levels and occupations. The main questions were:

- In your opinion, what are the needs of the industry in the following domains in a short-term perspective (within 3 years)?
- In your opinion, what are the needs of the industry in the following domains in a long-term perspective (more than 3 years)?
- How many people from the microelectronics sector with which profile do you plan to employ in the next 3 years?

We have collected answers from 63 companies which have not participated in the educational need analysis. These companies represent 10271 employees. The survey will be continued at least until the project end in order to update the information on skill needs and to adapt regularly the training courses to the labour market needs.

The conducted survey is representative for the future of the microelectronics industry in Europe, because it covers numerous companies of different size across Europe, see Figure 1. Among the large companies participating in the survey are Infineon Austria,

Schneider Electric France and Sensata Bulgaria, and among the micro and small companies are multiple start-ups responsible for a better regional development.

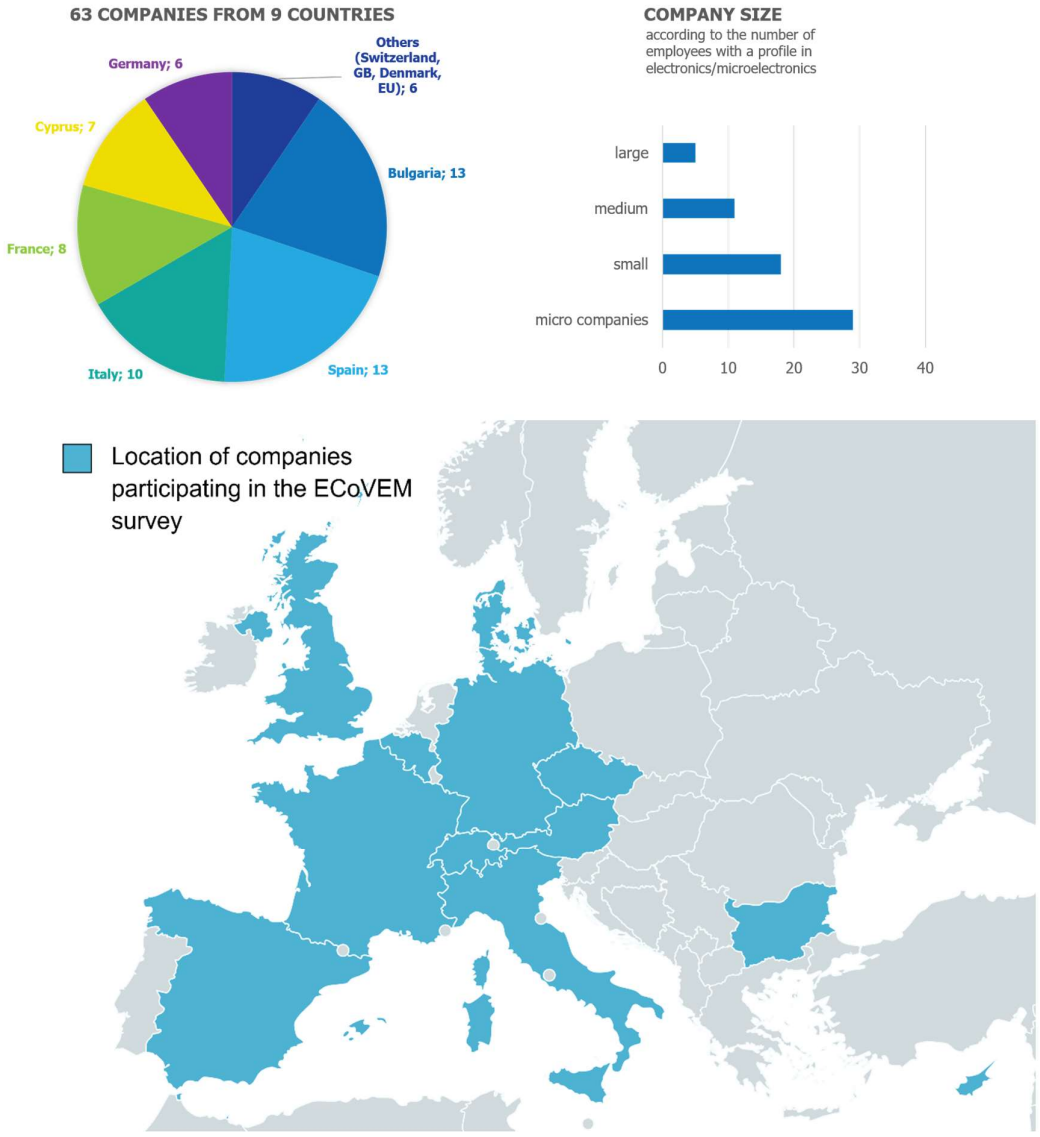

Figure 1: Geographical distribution of respondents in Europe

The results of the questions for employment preferences of companies and their needs of up-skilling and re-skilling the employees are presented in Fig. 2

On what geographical level does your company typically recruit? (Multiple answers are possible)

		Answers	Ratio
regional		46	70.77 %
national		30	46.15 %
international		26	40.00 %
No Answer		0	0.00 %

Would your company rather re/upskill an employee or recruit a new one?

		Answers	Ratio
re/upskill an existing employee		33	50.77 %
recruit new skilled person		30	46.15 %
No Answer		2	3.08 %

What do you need the up/reskilling for? (Multiple answers are possible)

		Answers	Ratio
soft skills		35	53.85 %
technical skills		62	95.38 %
No Answer		0	0.00 %

Figure 1: Importance of regional development of VET and life-long learning for the microelectronics industry

7.4.1. Skill needs for technicians (EQF levels 3-5)

What are the needs of your company for Technicians (EQF 3-5) in the following domains on a short-term point of view (within 3 years)?	High or Mandatory	Average	Low	Not relevant for our company
Assembling circuits and MCMs and microsoldering	21%	29%	12%	38%
PCB assembling	23%	30%	14%	33%
MEMS assembling	17%	23%	18%	42%
Internet of Things (IoT) technician	38%	24%	9%	29%
Installation and repair of electronic systems	38%	30%	12%	20%
Electronic power systems installation maintenance	32%	23%	14%	32%

Table 1:Technician needs within the next 3 years

What are the needs of your company for Technicians (EQF 3-5) in the following domains on a long-term point of view (in more than 3 years)?	High or Mandatory	Average	Low	Not relevant for our company
Assembling circuits and MCMs and microsoldering	17%	18%	14%	52%
PCB assembling	23%	23%	12%	42%
MEMS assembling	17%	21%	12%	50%
Internet of Things (IoT) technician	29%	26%	9%	36%
Installation and repair of electronic systems	32%	18%	21%	29%

Electronic power systems installation maintenance	29%	20%	11%	41%

Table 2: Technician needs beyond the next 3 years

Table 3 shows a similar distribution of the needs for technician as Table 2. We notice an increase in the answer ”none”, or rather ‟ cannot say” by about 10% in all occupations. One possible reason might be the difficulty to plan beyond 3 years. Another possibility is that in microelectronics it is expected to replace simple technical skills by machines rather soon. The most needed skill is the installation and reair of electronic systems. The repair should even become more important with the green transition.

Technicians (EQF 3-5)	**Short term**		**Long term**	
	total	interest	total	interest
Assembling circuits and MCMs and microsoldering	1.4	2.2	1.3	2.2
PCB assembling	1.6	2.2	1.6	2.3
MEMS assembling	1.3	2.1	1.3	2.2
Internet of Things (IoT) technician	2.0	2.6	1.8	2.5
Installation and repair of electronic systems	2.0	2.5	1.9	2.3
Electronic power systems installation maintenance	1.6	2.3	1.7	2.5

Table 3: Comparison of needs for technician skills: The data is the same as in Table 2 and 3. The numbers are arithmetical averages of the answers for the needs when we assign Mandatory=4, High=3, Average=2, Low=1, None=0. The higher ave rage value is for the case of omitting the inputs “None”, since those companies usuall y have a different field of expertise**.**

Table 4 shows the same data as in Table 2 and 3 in a different format, where it is easier to compare the short and the long term answers. The answers for the needs are assigned numerical values (Mandatory=4, High=3, Average=2, Low=1, None=0) and then the average from all 66 answers to the survey is taken: once counting the answer “None” (the lower average value, which we will call total average), and once without counting the “Nones” (the higher average value that we will call the interest average). The total average shows the need for a specific occupation across the entire field of microelectronics represented in our survey. The interest average shows the need for a specific occupation by companies in the matching field of expertise, since typically companies answer “None” if they are not in the field. The difference is quite pronounced for the occupation “MEMS assembling”, for example. Not the entire sector needs such technicians, but if a company is in this field, the interest is high.

Table 4 shows again the little change in results for the near future and the time beyond the next 3 years.

7.4.2. Skill needs of engineers (EQF levels 5-8)

What are the needs of your company for Engineers (EQF 6-8) in the following domains on a short-term point of view (within 3 years)?	High or Manda-tory	Average	Low	Not relevant for our company
PCB design and fabrication	30%	21%	17%	32%
Programming of microcontrollers / PLC	42%	24%	14%	20%
FPGA design	17%	23%	20%	41%
Analog integrated circuit design	29%	24%	14%	33%
Digital integrated circuit design	36%	18%	12%	33%
Power integrated circuit design	27%	20%	18%	35%
Test and characterization of IC and systems	39%	23%	14%	24%
Multichip module development (design and technology)	26%	24%	18%	32%
Microsystems development (design and technology)	35%	24%	14%	27%
Assembling and packaging technologies	21%	26%	24%	29%
Embedded systems development	56%	18%	6%	20%
Photovoltaic systems design	20%	9%	20%	52%
Photovoltaic cells technology, reliability and testing	18%	11%	20%	52%
Development of IoT systems	52%	14%	14%	21%
Sensors development	48%	18%	12%	21%
Electronic equipment for space systems development	21%	12%	17%	50%

Table 5: Engineer needs within the next 3 years

Table 5 shows the collected answers for the needed occupations for EQF 6-8 within the next 3 years. The most wanted profiles, which cover the entire microelectronics sector are (the ones with the lowest percentage in "Not relevant"): embedded system development, development of IoT systems, sensors development, and programming of microcontrollers. All of these point towards the growing automatization of everyday life, like smart cities, smart cars , smart industry.

Here we see why in the METIS deliverable programming is said to be a very important skill for this sector. However, programming for microelectronics is specific to embedded systems and microcontrollers, as we see in our results.

What are the needs of your company for Engineers (EQF 6-8) in the following domains on a long-term point of view (in more than 3 years)?	High or Manda-tory	Average	Low	Not relevant for our company
PCB design and fabrication	30%	20%	8%	42%
Programming of microcontrollers	44%	17%	6%	33%
FPGA design	21%	15%	11%	53%
Analog integrated circuit design	26%	21%	12%	41%
Digital integrated circuit design	29%	27%	5%	39%
Power integrated circuit design	24%	18%	14%	44%
Test and characterization of IC and systems	33%	21%	8%	38%
Multichip module development (design and technology)	27%	20%	11%	42%
Microsystems development (design and technology)	38%	14%	11%	38%
Assembling and packaging technologies	21%	18%	18%	42%
Embedded systems development	48%	17%	9%	26%
Photovoltaic systems design	20%	6%	17%	58%
Photovoltaic cells technology, reliability and testing	23%	6%	28%	53%

Development of IoT systems	45%	12%	14%	29%
Sensors development	44%	15%	12%	29%
Electronic equipment for space systems development	24%	5%	11%	61%

Table 6: Engineer needs beyond the next 3 years

The result for the future needs of the companies are similar to the immediate needs. We notice again a rise in the percentage of "not relevant" answers. Those include also "cannot say" and empty answers, so we interpret it as a difficulty for the companies to plan, especially in the Covid crisis…

Engineers (EQF 6-8)	Short term		Long term	
	Total	Interest	Total	Interest
PCB design and fabrication	1.7	2.4	1.7	2.6
Programming of microcontrollers / PLC	2.1	2.5	2.1	2.8
FPGA design	1.3	2.0	1.3	2.3
Analog integrated circuit design	1.7	2.4	1.7	2.4
Digital integrated circuit design	1.9	2.6	1.9	2.7
Power integrated circuit design	1.6	2.2	1.5	2.3
Test and characterization of IC and systems	2.0	2.5	1.9	2.6
Multichip module development (design and technology)	1.5	2.1	1.6	2.4
Microsystems development (design and technology)	1.8	2.4	1.8	2.6
Assembling and packaging technologies	1.5	2.1	1.4	2.2
Embedded systems development	2.4	2.8	2.4	2.8
Photovoltaic systems design	1.1	2.2	1.1	2.3
Photovoltaic cells technology, reliability and testing	1.1	2.2	1.2	2.3
Development of IoT systems	2.3	2.8	2.2	2.7
Sensors development	2.2	2.7	2.2	2.7
Electronic equipment for space systems development	1.2	2.3	1.1	2.5

This last table 7 shows again the total average and the interest average, as defined above. Something that was not so clearly visible in Table 5 and 6, but here is the increase of the interest average for most of the occupations. Only development of IoT doe not rise!

This table also shows which are the niche occupations, specific only for a part of the microelectronics sector. These are occupations with low total average, but a high interest average, like the photovoltaic systems development or the space systems.

7.5. Literature study results

To analyse the present skill needs we made an educational need analysis and analysis of job offers and ESCO profiles. To anticipate the needs of skills I the next 3 -7 years we made a survey with the business for their recent and future needs and we performed a literature study of strategic documents for the new industrial strategy for Europe, the German federal government's framework programme for research and innovation 2021–2024, the documents of the important project of common European interest (IPCEI) on microelectronics.

With its Strategy on Shaping Europe's Digital Future, the Commission set out its vision for how Europe can retain its technological and digital sovereignty and be the global digital leader. The New Industrial Strategy for Europe stresses on the importance of training and retraining people for the transition to green economy and digitalisation.

It stays: "A competitive industry depends on recruiting and retaining a qualified workforce. As the twin transitions gathers speed, Europe will need to ensure that education and training keep pace. Making lifelong learning a reality for all will become all the more important: in the next five years alone, 120 million Europeans will have to upskill or reskill.

This reflects the importance of skills for the twin transitions and the opportunities they can create for people. Moving to a low-carbon economy is expected to create more than 1 million jobs by 2030, while there are already currently 1 million vacancies in Europe for digital technology experts. At the same time, 70% of companies report that they are delaying investments because they cannot find the people with the right skills.

For industry workers, digitisation, automation and advances in artificial intelligence will require an unparalleled shift in their skill set. Retraining and reskilling have to be a major part of our social market economy. Our higher and vocational education and training systems will also need to provide more scientists, engineers and technicians for the labour market."

At the end of 2018, the European Commission approved the „Important Project of Common European Interest (IPCEI) on Microelectronics" under state aid law. This allowed four European Member States, France, Germany, Italy and the United Kingdom to jointly support transnational cooperation projects with major synergies in microelectronics – for the first time until the end of first industrial deployment. With the „IPCEI on Microelectronics", France, Germany, Italy and the United Kingdom intend to maintain and further expand European competencies in this field. They also want to ensure that the entire microelectronics value chain is reliably available to local players. For ECoVEM project, we analysed the research areas in which the largest companies in these three countries are focused in order to anticipate the skills that will

be needed in the future. These are in energy efficient chips, power semiconductors, sensors, advanced optical equipment and compound materials. Moreover, the IPCEI project defines areas for PhD thesis work and ECoVEM project covers WGF level 8.

In line with the New Industrial Strategy for Europe the German federal government's framework programme for research and innovation 2021–2024 foresees measures for Europe's and national sovereignty: "Other world regions are undertaking massive efforts in developing their own technological resources: the USA, for example, is promoting the establishment of new chip factories, including through the use of state incentives. Taiwan, Korea and China are also investing public funds in its own microelectronics capabilities in order to catch up with the world leaders and reduce dependencies. The same is true for Europe: it can only keep up and create a level playing field by having its own competencies." The main technological conditions for a sustainable digital sovereignty defined in the plan are:

- Electronic Design Automation (EDA)
- Specialised processors for edge computing, artificial intelligence, and high-performance applications
- Innovative, intelligent, and connected sensor systems
- High frequency electronics for communication and sensor technology
- Intelligent and energy-efficient power electronics
- Interdisciplinary technologies and topics
- Selected systems for microelectronics production
- Advanced silicon and beyond.

The recommended structure of the ECoVEM curriculum is organised on the basis of the directions for development of the European microelectronic industry in the cited above strategic documents.

8. Conclusions

Microelectronics is the driver of innovation for a wealth of applications, especially in the field of digitalisation. Microelectronics underpins cutting-edge applications:

- Communication technology
- Industry 4.0
- Smart energy conversion
- Smart health
- Autonomous driving
- High-performance computing
- Artificial intelligence.

In turn, applications are driving the demand for trustworthy and sustainable electronics.

Many interesting conclusions have been made upon the results of the educational and job analysis with involvement of a total of 45 VET providers and 117 respondents from industry:

- All the proposed occupational profiles are considered to fulfil a more than average need in short term.

- In long term the industry will need even more skills and competences in the proposed topics.
- Effective communication with groups, presentation techniques, project management and survival on the labour market are considered as highly important by almost all respondents.

9. Recommendations

The recommendations based upon the findings report and the New Industrial Strategy for Europe[2] are to structure the curriculum in the following way:

- Electronic Design Automation
    d. Digital circuits design
    e. Analog circuits design
    f. Hardware/software co-design – embedded systems design
- Specialised processor chips for edge computing, artificial intelligence, and high-performance applications
    d. Application-specific integrated circuits design
    e. Design and fabrication of FPGAs
    f. Artificial Intelligence chips design
- Innovative, intelligent, and connected sensor systems
    d. Internet of Things – sensor-based systems
    e. Smart sensors design and fabrication as key elements of intelligent sensor systems for Industry 4.0
    f. Microsystem design and fabrication
- Intelligent and energy-efficient power electronics
- High-frequency microelectronics
- Medical/health microelectronics
- Interdisciplinary technologies
    c. System integration technologies
    d. Test, verification and validation
- Advanced silicon and beyond
    d. New materials for microelectronics
    e. Graphene electronics
    f. Quantum technology
- Soft skills
    c. Entrepreneurship
    d. Teamwork in a multidisciplinary team

As it is planned in the ECoVEM project, VET centres in collaboration with the industrial partners and regional authorities will analyse further the mismatch of regional job offer and available workforce will be analysed and measures for strengthening mobility of VET students and employees will be proposed. The partners will also identify practices of concrete examples of policies and initiatives at regional and national levels addressing skills shortages and mismatches. Those examples will provide tangible cases to operationalise skills anticipation strategies at local levels.

[2] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0102

10. References

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Platforms with job vacancies

- https://ec.europa.eu/eures/portal
- https://www.eurojobs.com/
- https://www.euroengineerjobs.com/
- https://www.eurobrussels.com/
- https://www.jobs.bg/
- https://www.jobtiger.bg/

11. Appendix.

Questionnaire for the survey with the industry

Labour market needs in microelectronics from industry representatives for the ECoVEM project

Fields marked with * are mandatory.

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Within the ECoVEM project sponsored by EACEA, we have the opportunity to develop training courses in the sector of microelectronics. In order to meet the industry and employment market requirements we would like to get your feedback as an actor of this environment. The questionnaire will take you no more than 10 minutes. Please, provide answers only for the domains of your expertise.

We remind you that all information collected through this document will be treated confidentially. Your opinion is very important to us and we will do our best to meet your expectations. Thank you!

Information about your company

* Name of the company:

* In which European country is located your company?

* How many employees with a profile in electronics/microelectronics currently work at your company?

Only values between 1 and 3000 are allowed

What is your position in the company?

- ○ Researcher
- ○ Technician
- ○ General Manager
- ○ Engineer
- ○ Group Leader
- ○ Other

Please specify your occupation:

100 character(s) maximum

How many people from the microelectronics sector with which profile do you plan to recruit in the next 3 years?

Please fill in numbers in the table.

EQF stands for European Qualification Framework. For more information, see europa.eu/europass/en/description-eight-eqf-levels

	Freshly graduated	> 3 years of work experience
Basic Education (EQF 3-4)		
Technicians (EQF 4-5)		
Higher Education (EQF 6-7)		
PhD (EQF 8)		

On what geographical level does your company typically recruit? (Multiple answers are possible)

- [ ] regional
- [ ] national
- [ ] international

Would your company rather re/upskill an employee or recruit a new one?

- ( ) re/upskill an existing employee
- ( ) recruit new skilled person

What do you need the up/reskilling for? (Multiple answers are possible)

The specification of the technical skills takes place in the next sections.

- [ ] soft skills
- [ ] technical skills

Does your company provide or does it intend to provide work-based training? (Multiple answers are possible)

- [ ] Yes, apprenticeships for technicians
- [ ] Yes, internships for students
- [ ] Yes, other
- [ ] No

Please specifiy the type of work-based training:

Relevant technical skills in the next 3 years

What are the needs of your company **for Technicians (EQF 3-5)** in the following domains on a **short-term** point of view (**within 3 years**)?

EQF stands for European Qualification Framework. For more information, see europa.eu/europass/en/description-eight-eqf-levels

	None	Low	Average	High	Mandatory	Can not say
* Assembler of circuits and MCMs and microsoldering	( )	( )	( )	( )	( )	( )
* PCB assembling	( )	( )	( )	( )	( )	( )
* MEMS assembling	( )	( )	( )	( )	( )	( )
* Internet of Things (IoT) technician	( )	( )	( )	( )	( )	( )
* Installation and repair of electronic systems	( )	( )	( )	( )	( )	( )
* Electronic power systems installation maintenance	( )	( )	( )	( )	( )	( )

Other relevant occupations/skills for Technicians (EQF 3-5):

What are the needs of your company **for Engineers or PhDs (EQF 6-8)** in the following domains on a **shor t-term** point of view (**within 3 years**)?

EQF stands for European Qualification Framework. For more information, see europa.eu/europass/en/description-eight-eqf-levels

	None	Low	Average	High	Mandatory	Can not say
* PCB design and fabrication						
* Programming of microcontrollers / PLC						
* FPGA design						
* Analog integrated circuit design						
* Digital integrated circuit design						
* Power integrated circuit design						
* Test and characterization of IC and systems						
* Multichip module development (design and technology)						
* Microsystems development (design and technology)						
* Assembling and packaging technologies						
* Embedded systems development						
* Photovoltaic systems design						
* Photovoltaic cells technology, reliability and testing						
* Development of IoT systems						
* Sensors development						
* Electronic equipment for space systems development						

Other relevant occupations/skills for Engineers and PhDs (EQF 6-8):

Relevant technical skills beyond the next 3 years

What are the needs of your company **for Technicians (EQF 3-5)** in the following domains on a **long-term** point of view (**in more than 3 years**)?

EQF stands for European Qualification Framework. For more information, see europa.eu/europass/en/description-eight-eqf-levels

	None	Low	Average	High	Mandatory	Can not say
Assembler of circuits and MCMs and microsoldering	○	○	○	○	○	○
PCB assembling	○	○	○	○	○	○
MEMS assembling	○	○	○	○	○	○
Internet of Things (IoT) technician	○	○	○	○	○	○
Installation and repair of electronic systems	○	○	○	○	○	○
Electronic power systems installation maintenance	○	○	○	○	○	○

Other relevant occupations/skills for Technicians (EQF 3-5):

What are the needs of your company **for Engineers or PhDs (EQF 6-8)** in the following domains on a **long-term** point of view (**in more than 3 years**)?

EQF stands for European Qualification Framework. For more information, see europa.eu/europass/en/description-eight-eqf-levels

	None	Low	Average	High	Mandatory	Can not say
PCB design and fabrication	○	○	○	○	○	○
Programming of microcontrollers / PLC	○	○	○	○	○	○
FPGA design	○	○	○	○	○	○
Analog integrated circuit design	○	○	○	○	○	○
Digital integrated circuit design	○	○	○	○	○	○
Power integrated circuit design	○	○	○	○	○	○
Test and characterization of IC and systems	○	○	○	○	○	○
Multichip module development (design and technology)	○	○	○	○	○	○

Microsystems development (design and technology)	○	○	○	○	○	○
Assembling and packaging technologies	○	○	○	○	○	○
Embedded systems development	○	○	○	○	○	○
Photovoltaic systems design	○	○	○	○	○	○
Photovoltaic cells technology, reliability and testing	○	○	○	○	○	○
Development of IoT systems	○	○	○	○	○	○
Sensors development	○	○	○	○	○	○
Electronic equipment for space systems development	○	○	○	○	○	○

Other relevant occupations/skills for Engineers and PhDs (EQF 6-8):

Thank you for your time!

You can follow the developments in ECoVEM at www.ecovem.eu

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