Yearly Monitoring Report 2023

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Abstract

METIS (MicroElectronics Training Industry and Skills) is a Sector Skills Alliance, co-funded by Erasmus+, implementing a strategic approach to sectoral cooperation on skills aiming to bridge the microelectronics skills gap in Europe. It is a 4-year project from November 2019 to October 2023, involving 18 partners from 13 countries, coordinated by SEMI Europe: Industrials (Infineon, Bosch, X- Fab, Arcelik, Graphenea, Summa Semiconductor, Silicon Saxony), training & education organizations (TU Graz, IMEC academy, SBH Sudost, USN, BME and IAL-FVG), social partners (WiTEC and EACG), a regulatory body (CIMEA), and a market research & intelligence firm (DECISION Etudes & Conseil).

The first step of the METIS project, in 2020, has consisted in building an EU sectoral skills strategy and a methodology to monitor and anticipate skills in the European microelectronics industry. A multi- stakeholder's approach has been adopted and 10 Focus Groups, 50 live interviews an online survey and market research have been carried out during the year 2020, leading to a first report entitled "Skills and Occupational Profiles for Microelectronics".

This report is an update of the 2020 report mentioned above. It provides a detailed description of the skills needed by the European microelectronics industry from the beginning of 2021 until 2023. It describes the new job profiles and skills which emerged during this period.

A second report has been published since then, providing an update for the year 2022.

This report is the last report monitoring the skills needed within the framework of METIS and provides an update for the year 2023. It describes the new job profiles and skills which emerged during this period. It also provides a detailed description of the key evolutions since early 2020.

This report also describes the effects of the semiconductors' crisis, the stiff rise of investment in the microelectronic sector and the EU Chips Act on the recruitment policy of the sector.

Then, this report highlights the most critical job profiles and skills as of 2023, as well as the education level required to work in each specialization. It provides the detailed description of the 13 most critical skills sought after on the job market.

This report assesses the impact of emerging technologies on skill needs.

To conclude, this report provides policy recommendations on the topic.

Executive summary

A) Key evolutions since 2020, following previous reports (2022 and 2020)

In 2023, 5 new job profiles have been identified, either because they are new (AI engineers and supply chain experts), or because they had not been identified previously within METIS (System test engineers, verification engineers and Cyber-Physical System designers).

In addition, emerging skills keep becoming more and more important across most of existing profiles, in a continuing trend since 2020: data analysis, artificial intelligence skills, digital skills such as software development…

In terms of job profiles, the need for data specialists is raising at an impressive pace and the associated shortage is worsening in consequence. In 2020, "data scientist" was ranked as the n°15 most critical job profile. In 2023, "data scientist" is ranked in 4th position, just after software engineers, analog / system designers and process engineers. For this particular type of job positions, the semiconductor industry is in competition with many other sectors to attract the best data specialists (digital services, bank, energies, manufacturing industries…).

Although the global shortage of semiconductors is reaching its end and has had less impact on the industry in 2023 than in 2022, 75% of the stakeholders interrogated in 2023 still feel the impact of the global chips' shortage on their recruitment processes. The main consequence of the shortage has been the need for hiring more people, reaching all-time records in some companies. As the need for workforce rises and as the stock of workers remains overall unchanged, this raises the shortage, especially for senior profiles. The shortage in turn leads to a need for companies to offer better hiring conditions (wages, etc.).

Design engineers are also required to adapt designs to the shortage through the design for availability practice/method. Design for availability is about redesigning chips to get around the shortage of some parts of the value chain. These increased needs on the design side also worsen the shortage of design engineers since the beginning of the crisis.

The stiff rise of global investment in semiconductors also encourages companies to hire more, thus increasing the labor shortage. 81% of the stakeholders interrogated in 2023 experience an impact of the investment in semiconductors fabs in Europe on their recruitment policies (compared to 73% in 2022). It especially raises the demand for job profiles linked to production processes: process engineers, maintenance technicians, process technicians, etc.

66% of the stakeholders consulted in 2023 still experience no impact of the EU Chips Act on their recruitment policies, a similar proportion to that of 2022. The main reason given is that it is still too early to see its impact. However, for the first time in 2023, many companies indicate they start to adapt their future recruitment plans in the coming months / years to the prospects they have from the EU Chips Act. The EU Chips Act also acts as a communication campaign and attract new candidates to the semiconductor industry. Finally, among the technological fields that METIS monitors for impact on skill needs, "edge IoT and edge AI" is clearly the one for which an increased interest, demand, and shortage have been observed since 2020.

B) Critical job profiles in 2023

In 2023, "Data specialist" enters the top 5 of the most critical profiles:

1. Software engineer.
2. Design engineer (especially system designers and analog designers).
3. Process engineers.
4. Data specialist (especially machine learning engineers).
5. Maintenance technicians.

Test engineers was until 2022 in fifth position. However, the demand and shortage of Data specialists is deteriorating so fast since 2020 that in 2023, the profile of Data specialist enters the top 5 in fourth position.

Since 2020, both the demand and shortage have significantly raised for 4 profiles:

- Data specialist, moving from the 15th position in 2020 to the 4th position in 2023.
- System designers.
- Analog designers.
- Process engineers.

The situation has therefore worsened since 2020 for these profiles.

On the contrary, the situation seems to have improved for 4 profiles:

- Design engineers in general, and digital design engineers in particular. In 2020, designers were ranking in first position. It is now ranked in 3rd position, and digital design engineers come after data specialists.
- Test engineers.
- Process technicians.
- Robotic engineers.

Machine learning engineers was not identified as a specific profile in 2020 and 2022. In 2023, 38% of the stakeholders interrogated indicate this profile as critical[1].

The severe shortage of senior profiles on specific topics continues.

- Advanced systems architecture designers.
- Systems test engineers.
- Senior analog designer, especially associated with strong programming skills.
- Application engineers. Engineers experts in specific applications fields (automotive…).
- Senior managers in general.

[1] Especially stakeholders from IMEC.

C) Critical skills in 2023

Nine fields of skills are confirmed as the most critical across the different job profiles (relatively stable since 2020). They are mostly associated to digitization and can be considered as digital skills.

1. System architectures: Knowledge of systems architectures: SoC, SiP, complex ASICs… Ability to design such architectures.
2. Data analysis. Increasingly needed by the industry.
3. Artificial Intelligence / Machine learning.
4. Analog design.
5. Knowledge of applications (specificities, linking components, materials, design constraints to apps).
6. Quality – reliability related skills.
7. Security related skills.
8. Hardware / software integration, although less brought forward in 2023.
9. Knowledge of new materials. Especially important for process engineers and material engineers, although this field of skills has been less brought up in 2023 by the interviewed stakeholders.

The results in terms of soft skills are stable since 2020

Overall considered as almost important as technical skills, the most critical soft skills required by the semiconductor industry are teamwork, communication and creativity.

- Teamwork & communication: considering the complexity of the topic, teamwork and collaboration between and within teams become more and more crucial. It is coming through the ability to summarize complex technical topic for non-experts.
- Creativity: it is at the heart of jobs because part of European competitiveness lies in its capacity to remain innovative, its ability to propose new ideas, new processes and new designs using modern technologies.

D) Policy recommendations in 2023

Ranked from the most cited by stakeholders, the policy recommendations were in 2023:

A. Increase the involvement of the microelectronics industry in the education process.

This policy recommendation was at the 1st place in 2020 and remains a priority in 2023. In order to cope with the urgent upskilling and reskilling needs of the industry linked to the shortage and the fast-paced technological evolution, universities, R&D centers, and industrials should work closer on lifelong learning programs:

- Design lifelong learning programs.
- Courses co-designed with the industry.
- Generalize the use of experts from the industry as teachers at the university.
- Develop internships, apprenticeships, PhDs and graduate training programs co-organized (and co-funded?) by universities and companies.
- Promote the industry at universities: Generalize the organization of regular presentations of the microelectronics sector within student bodies.
- Teach microelectronics-related topics at an early stage of the education system.

B. Communication campaigns to improve the image of the sector.

In 2023, this type of policy recommendations was the second most cited by the stakeholders interviewed. The microelectronics industry suffers from a poor image as a sector to work in. People need to know what microelectronic means for our society in order to widen the scope of candidates. Recommendations linked to communications campaigns include:

- Improve the image of the sector toward the EU general public.
- Promote emerging needs of the industry.
- Teach microelectronics-related topics at an early stage of the education system.
- Conduct actions to raise the interest of young people in STEM educations for technical jobs, electrical engineering, and microelectronics.
- Develop new communication channels such as social medias.
- Promote EU programs.
- Enhance diversity in the workforce.

C. Develop clusters and networks favoring dialog between industry and education representatives.

In this third monitoring report, almost all the stakeholders interviewed agreed that the communication between industries and training centers such as universities will be one of the key success factors for the sustainability of the European microelectronics industry.

- Setting up dedicated groups defining and updating the roadmap of skillsets needed.
- Mapping training and courses from European education providers.

D. Favor intra and extra-EU mobility.

This type of policy recommendations was only at the 6th place in 2020 and is at the 4th place in 2023. This is linked to the worsening of the shortage of senior profiles and the necessity for European companies to handle it on the short term. Their only solution is to hire experts from abroad, leading to a need for:

- Pre- and post- arrival services for migrant workers (trainings, language trainings, logistics, networking…).
- An ease of associated administrative procedure.
- A lowering of the limits of teleworking from abroad.
- A further uniformization of degrees and curriculum, beyond what the EU provides.

E. Introduce an EU chip academy.

This type of policy recommendations emerged since 2020 and was not present in the initial version of the METIS Skills Strategy. Stakeholders expressed their need for:

- A unified EU online training platform. Including flexible, modular (virtual / hybrid) academic training offers. This platform would also include a portfolio of micro-degrees especially to answer upskilling needs from SME. A start would consist in regrouping existing trainings across the EU on a single online platform.
- A unified EU online platform for postgraduates' job offering.
- A unified skills monitoring system on an annual basis.

F. Develop interdisciplinarity and joint degrees in microelectronics.

- Establish combined study courses including not only microelectronics / mechatronics but also other fields such as data analysis, machine learning, marketing & sales, chemistry, biology…
- Promote interfaculty teaching and research exchanges in universities.
- Adapt the training offer by reinforcing certifications.

G. Others

- Raise the public funding of universities and VET providers, in order to adapt to the raising industry needs.
    - Several universities, in France, in Germany, etc. indicate that they see the number of microelectronics students stagnating or even declining in the current context.
    - Given the already long duration to train new talents to handle the current shortage (3-10 years), the stagnation or even the decline of new students in several universities could make the shortage last for more than a decade in Europe…
    - It seems urgent to ensure a significant rise of the capacities to train new microelectronics students in European universities as soon as possible.
- Wages should be more comparable to USA and to wages in other industries to increase the interest.

Table of contents

I. Key evolutions in 2023

A. Several new profiles have been identified

Out of the 58 stakeholders[2] who were interviewed in 2023, 76% answered that they did not observe new profiles in the microelectronics sector since 2022. Instead, they experience existing skills that are becoming more and more important for an increasing number of profiles.

- Existing profiles evolving towards more software development, data analysis, AI skills…
- To a lesser extent: Security, new materials…

However, the remaining 24% of the respondents replied that they did see new profiles emerging in microelectronics, identifying 5 new profiles:

1. AI engineer / ML engineer / Embedded AI engineer. Within this profile, three sub-profiles have been described:
    - AI/ML application engineer. This is the most "traditional" type of AI engineer profile. AI/ML application engineers have the following specific skills:
        - Ability to decide on where application of AI/ML methods is possible and beneficial.
        - Ability to decide on what AI/ML-algorithm is the right one.
        - Ability to decide on suitable HW-platform for effective operation.
    - AI Hardware Engineer / Edge AI engineer. These engineers focus on designing and implementing efficient hardware solutions such as specialized AI chips, neural network accelerators, and custom hardware architectures. They have the knowledge of AI and ML algorithms but are specialized in implementing them on hardware platforms.
    - AI system architect. A senior profile capable of managing a team of AI engineers and designing the whole architecture of a complex AI microelectronics system.

2. Supply chain experts / Logistics specialists / Specialists in Custom and International Logistics. Because of the increased complexity of the semiconductor value-chain, the global chips shortage and the trade wars between the USA and China, the semiconductor industry needs skilled professionals who can manage complex global supply chains while complying with new regulations (VAT treatment across EU countries, green transition) and who can identify potential bottlenecks and vulnerabilities in the supply chain.

[2] 45% did not reply to this question.

Such profile must combine business skills, such as accountability, sales[3], corporate finance, corporate strategy… with an in-depth knowledge of the semiconductor value-chain and a knowledge of process steps in chip technology.

3. System test engineer: As microelectronic systems become more complex, professionals who can efficiently integrate components, perform system-level testing, and ensure interoperability are in demand. Skills in system integration, test development, test automation, and validation are relevant for such profiles.
4. Verification engineer. Different from the test, verification plays an increasingly important role so that the classical ratio of "one verification person for one designer" in the past is moving to a 2 or even 3 to one ratio. A number of mid-sized companies are growing in design verification. As for design, the shortage is especially important for digital mixed signal and analog mixed signal verification engineers.
5. Cyber-Physical System Designer / Embedded systems integrators / Embedded systems developers: This profile is at the frontier of microelectronics. With the proliferation of Internet of Things (IoT) devices, there is a growing demand for professionals who can develop embedded systems. These professionals work on developing and implementing electronic systems that bridge the gap between physical processes and digital control, enabling automation, monitoring, and control of various devices and systems. Among the skills required for such profile, one can find microcontroller programming, firmware development, and system integration.

Finally, as every year, stakeholders identify new profiles associated with emerging R&D topics. More precisely, participants cited the profiles of:

- Advanced packaging.
- 3D device architectures.
- Novel energy solutions specialists.
- Flexible Electronics Engineer: Flexible electronics engineers specialize in developing and manufacturing electronic components, sensors, and circuits that are flexible and can be integrated into wearable devices, flexible displays, and other applications requiring conformable electronics.
- Quantum computing engineers.
- Photonics process engineers.

[3] Including cost-sharing development models.

B. Emerging skills are becoming more and more important for existing profiles

In 2023, when asked which skills needs are being increasingly needed by companies, respondents cited:

1. Machine learning and Artificial Intelligence (AI).
2. Data analysis.
3. Systems design and system architectures (SoC, SiP, SoP, complex ASIC).
4. Analog and Mixed-Signal Design (especially for application, automotive and IoT).
5. Verification.
6. System test. Ability to test microelectronics systems.
7. Project management.
8. Cybersecurity and Hardware Security

The answers emphasized the need for digital skills, because of the rising automation, in almost all jobs: operators, QA engineers, application engineers…

C. New skills have been identified

In 2023, three new skills have been described by the stakeholders interrogated and indicated as important for their activities:

- **Verification.** Different from the test, verification plays an increasingly important role so that the classical ratio of "one verification person for one designer" in the past is moving to a 2 or even 3 to one ratio. A number of mid-sized companies are growing in design verification. As for design, the shortage of verification skills is especially important for digital mixed signal and analog mixed signal verification.
- **Design for Manufacturability (DFM).** With the increasing complexity of microelectronic designs, considering manufacturing processes and constraints early in the design phase is crucial. Professionals with knowledge of DFM principles, yield optimization techniques, and an experience in working closely with fabrication and manufacturing teams are valuable for roles such as design engineer or process engineer.
- **Knowledge of the semiconductor value-chain.** As the semiconductor industry is increasingly complicated, it becomes increasingly difficult to know how to build the supply chain for a new product and to know how to mitigate risks when new technology is being ramped up.

D. Impacts on recruiting policies

1. The global shortage of semiconductors

Although the global shortage of semiconductors is approaching to its end and had less impact on the industry in 2023 than in 2022, 75% of the stakeholders interrogated in 2023 still feel the impact of the global chips' shortage on their recruitment processes[4][5].

The Covid crisis, as well as the stiff rise in the need for semi-conductors, has led to a global shortage of chips that is still present today.

The main consequence on the recruitment policy of the microelectronics sector has been the need of hiring more people, reaching all-time records in some companies. As the need for workforce was large, and the stock of workers unchanged, this led to skill shortages, especially for senior profiles. The shortage in turns leads to a need for companies to offer better hiring conditions (wages, etc.).

Somehow contradictory, the shortage also led to delays in recruitment processes. Indeed, the shortage led to delays in business plans progresses and therefore in hires.

Companies also had to deal with the shortage of semiconductors and substitute unavailable parts with available ones when possible. The process of redesigning products after a shortage is called design for availability by opposition to design for resilience. Design for resilience is about designing products with interchangeable parts in case of a shortage. But these adaptations in terms of design have only started very recently in some large companies. That is why the shortage in semiconductors impacted so harshly the whole production chain.

Finally, companies are also engaging more directly with universities and training organizations to better communicate their needs in the months and years to come, in order to improve anticipation of market needs in terms of training.

2. The exponential rise of global investment in semiconductor fabs

81%[4] of the stakeholders are experiencing a strong impact of the global investment in the semiconductor fabs on their recruitment policy (compared to 73% in 2022). It especially raises the demand for job profiles linked to production processes: process engineers, maintenance technicians, process technicians, etc.

[4] We excluded the professors and researchers from the answers to this question, to provide bias.

[5] In 2022, 87% of the stakeholders interrogated experienced a strong impact of the global shortage on their recruitment policy.

3. The EU Chips Act

66%[6] of the stakeholders consulted in 2023 still experience no impact of the EU Chips Act on their recruitment policies (compared to 87% in 2022). The main reason given is that it is still too early to see its impact.

However, for the first time in 2023, many companies indicate they start to adapt their future recruitment plans in the coming months / years to the prospects they have from the EU Chips Act.

The EU Chips Act also acts as a communication campaign and attract new candidates to the semiconductor industry.

For the remaining 34% of the participants indicating they experience an impact, the nature of this impact of mainly to hire project managers and project engineers with project management skills to be in charge of the following of the investment projects.

II. Most critical job profiles

A. Offer vs Demand on the job market in 2023

In this third yearly monitoring report, as in 2022, stakeholders have been asked to identify to:

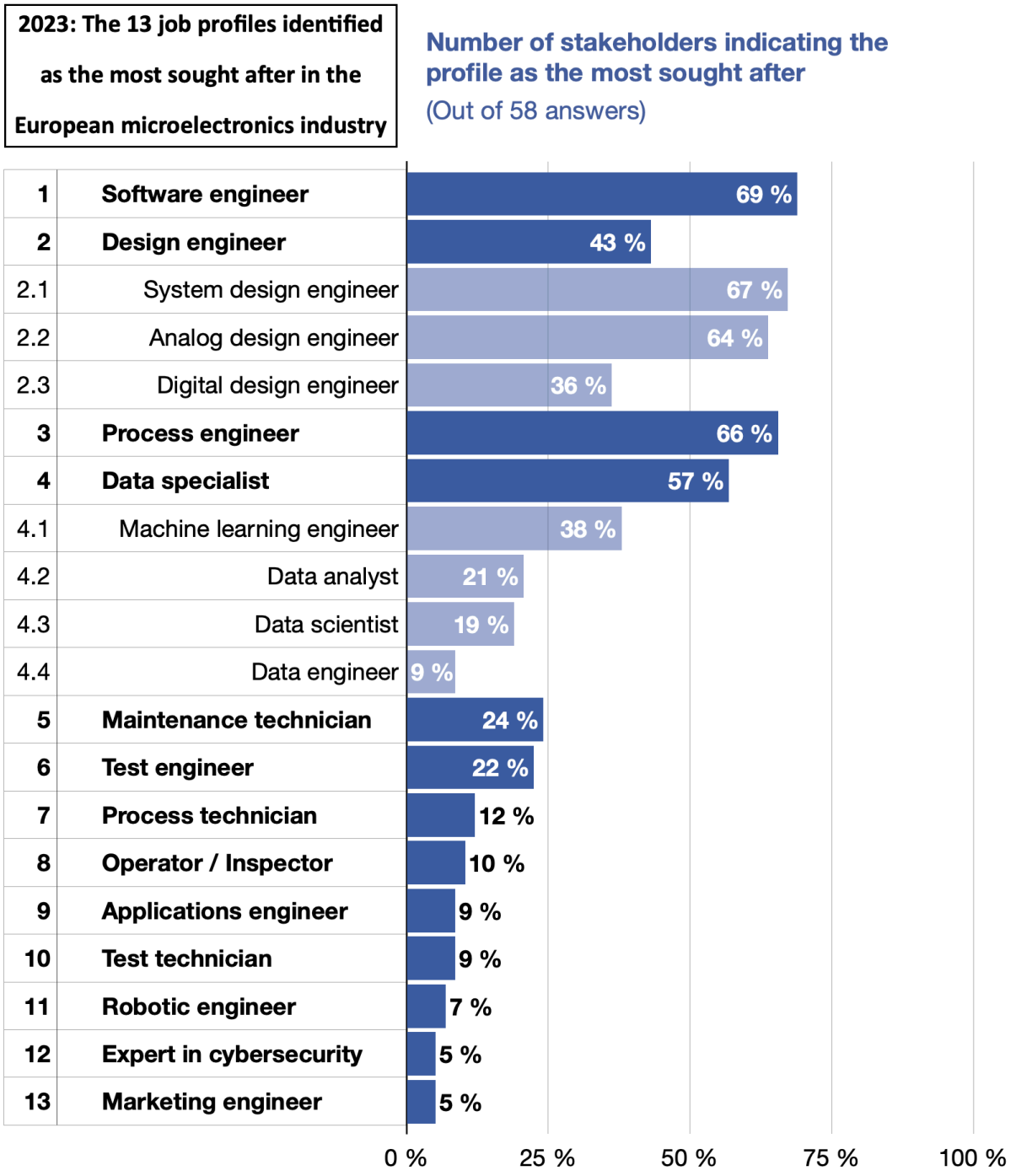
- Identify the job profiles that are the most sought-after by the industry (high demand).
- Identify the job profiles that are the most difficult to fill (high shortage).

Below is a summary of the answers to both questions:

[6] We excluded the professors and researchers from the answers to this question, to provide bias.

N°	Job profile	Alternative names / Description	EQF at entry level	Number of stakeholders identifying the profile as one of the most sought after	Number of stakeholders identifying the profile as difficult to fill
1	**Software engineer**	Controls and software engineer, Software developer, Solution engineer, Computer software engineer, Embedded/Firmware/Cloud software engineer, Software designer, Software design engineer	6-7	40	13
2	**Design engineer**	Designer	6-7	25	7
2.1	System design engineer	System designer, Product Architect, System Architect (HW/SW), System Development Engineer, HW/SW co-designer, System expert	7	39	14
2.2	Digital design engineer	Digital designer	7	21	5
2.3	Analog design engineer	Analog designer, Analog/Analog IC/Mixed-signal/ RF-IC Design Engineer	6-7	37	14
3	**Data specialist**		6-7	34	8
3.1	Data analyst	Experts at collecting, analyzing, and interpreting data to uncover insights and make informed business decisions	6-7	12	6
3.2	Data scientist	They use advanced statistical modeling techniques and machine learning algorithms to extract deep insights from complex and large datasets	6-7	11	7
3.3	Data engineer	They design, build, and maintain the systems and pipelines that enable the storage, processing, and retrieval of data.	6-7	5	3
4	**Process engineer**	Manufacturing engineer	6-7	34	6
5	**Maintenance technician**		5-6	14	8
6	**Test engineer**	Component Verification & Validation Engineer / Lab-Verification & Validation Engineer / Field Service Engineer	6-7	13	9
7	**Process technician**	Manufacturing technician	5-6	7	1
8	**Operator / Inspector**		5-6	6	3
9	**Applications engineer**	Application engineering expert, Field applications engineer, Product development engineer, Product Manager, Requirement engineer, Industry 4.0 expert, Industrial power electronics expert, Supply chain manager with basic SC material knowledge	6-7	5	13
10	**Test technician**		5-6	5	5
11	**Robotic engineer**	Automation engineer	6-7	4	4
12	**Expert in cybersecurity**	Similar to the security skills required for software engineer, but with a deeper knowledge level	7	3	5
13	**Marketing engineer**	Digital Marketing expert	7	3	5

Ranking of the job profiles indicated as the most sought-after in 2023 (high demand)

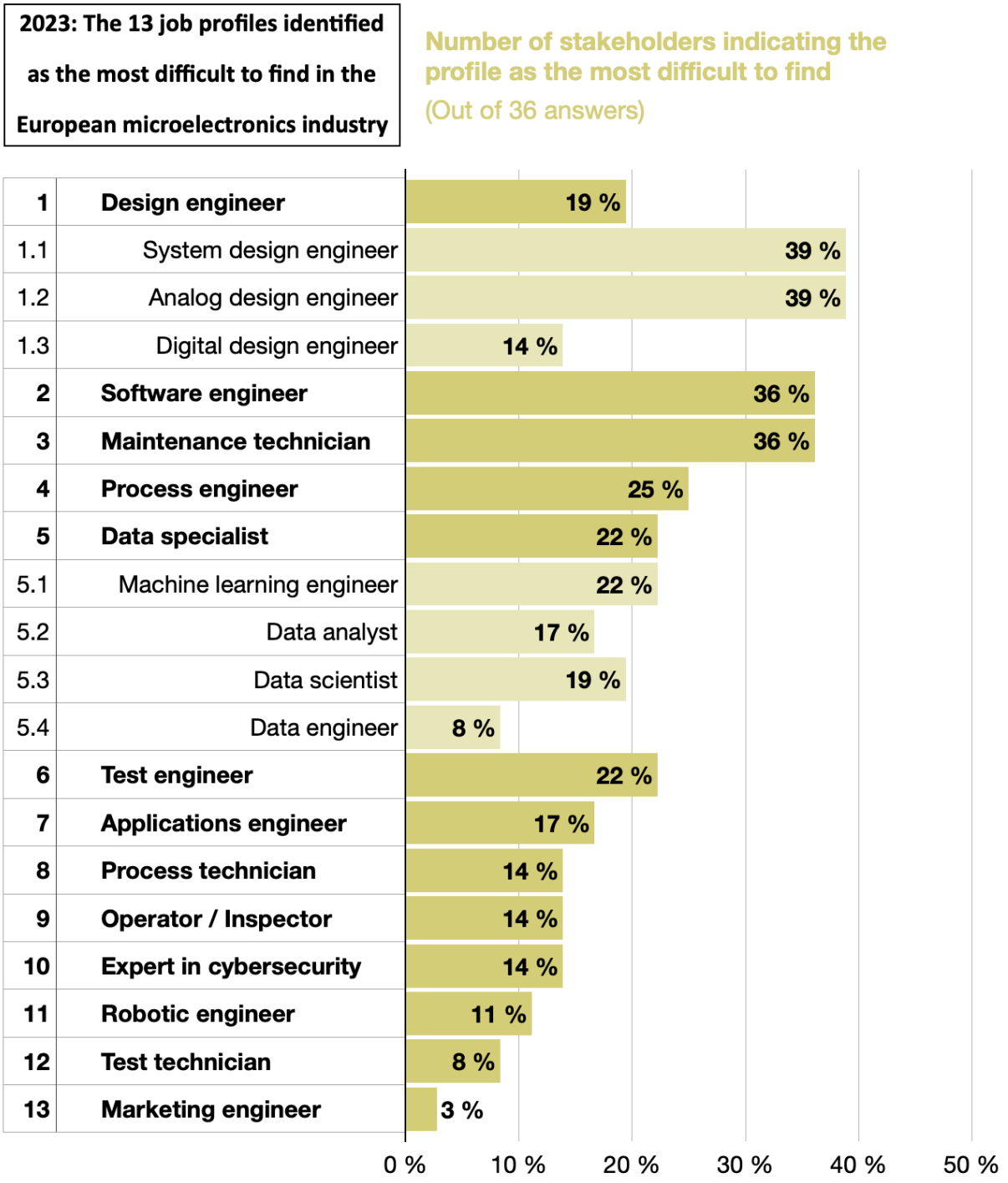


For this question, all the stakeholders were not limited in their choice of answers and could choose between several job profiles. This is why the totals exceed 100%.

Source: METIS Yearly Monitoring Report 2023 / DECISION Etudes & Conseil

Just as last year's report pointed out, the job profiles the most sought after in the European microelectronics industry are software and design engineers. This confirms the growing importance of software in the microelectronics industry.

Ranking of the job profiles indicated as the most difficult to fill in 2023 (high shortage)



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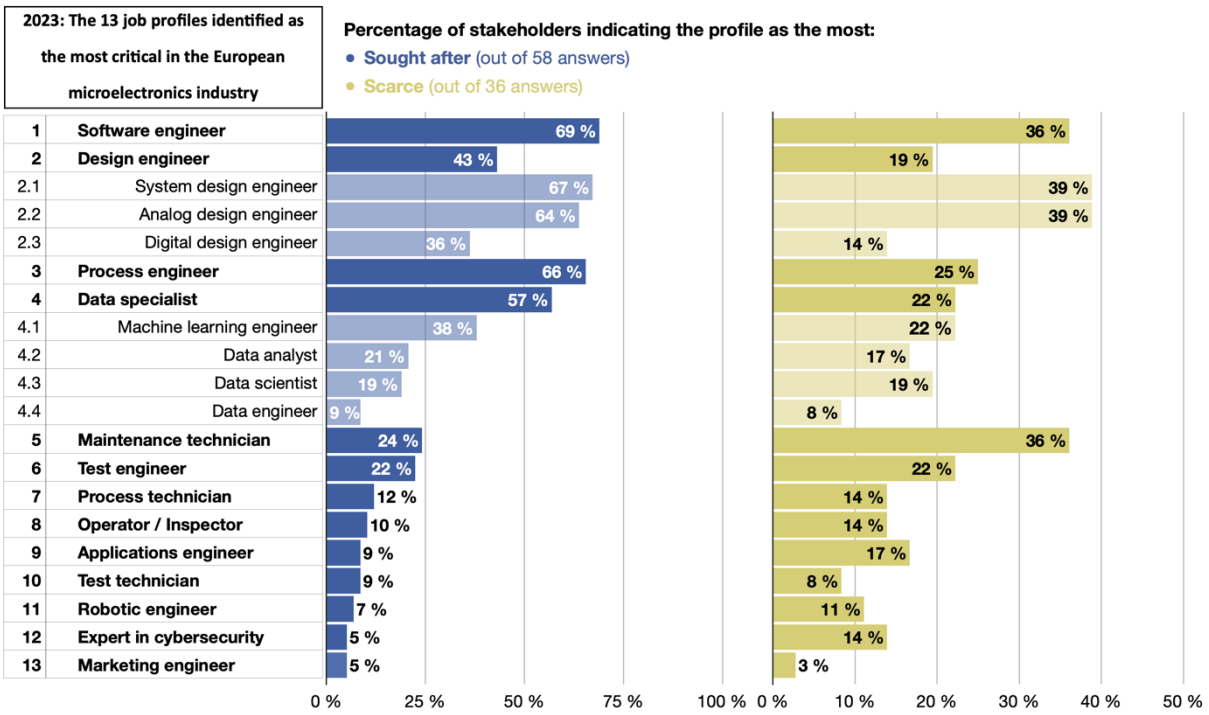
Finally, the visual below enables to compare the job profiles that are the most sought after and the ones for which it is the most difficult to find skilled candidates on the current European job market.



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Source: METIS Yearly Monitoring Report 2023 / DECISION Etudes & Conseil

Some profiles are not the most sought-after but face a shortage particularly sever:

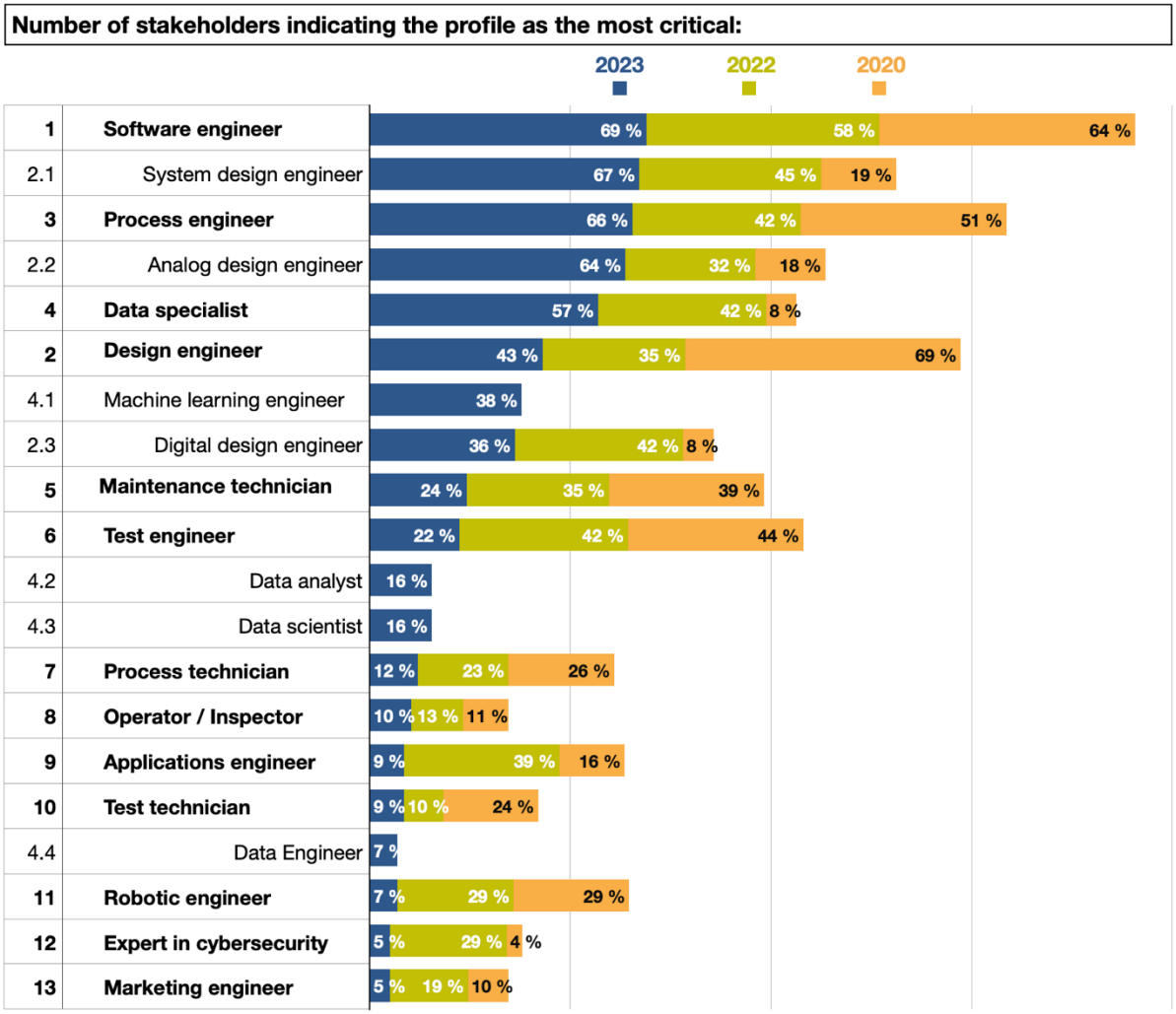
1. Maintenance technician. Such profiles are especially difficult to find because of the night and day shifts, as well as the rising technicity of their associated skills due to technological advances.
2. Test engineers.
3. Application engineers.
4. Expert in cybersecurity.

Other positions indicated as sought after by a few stakeholders:

- Verification engineer.
- Antenna / advanced RF designer.

Finally, across the job profiles, project managers positions are particularly in tension.

B. From 2020 to 2023: Evolution of the shortage of job profiles on the European job market



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Methodology note:

The most critical job profiles are the job profiles that are both:

- *The most sought-after by the industry.*
- *The most difficult to fill.*

Source: METIS Yearly Monitoring Report 2023 / DECISION Etudes & Conseil

Overall, the shortage of job profiles in Europe continues since 2020, with no major signs of improvement.

A new profile enters in the top 5 of the most critical job profiles in 2023: Data specialist. The top 5 in 2023 is the following:

1. Software engineers: Embedded, Software/Firmware, Machine Learning.
2. Design engineers: Especially system & analog designers.
3. Process engineers[7].
4. **Data specialist.**
5. Maintenance technician.

Since 2020, both the demand and shortage have significantly raised for 4 profiles:

- Data specialist, moving from the 15th position in 2020 to the 4th position in 2023.
- System designers.
- Analog designers.
- Process engineers.

The situation has therefore worthened since 2020 for these profiles.

On the contrary, the situation seems to have improved for 4 profiles:

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- Test engineers.
- Process technicians.
- Robotic engineers.

Machine learning engineers was not identified as a specific profile in 2020 and 2022. In 2023, 38% of the stakeholders interrogated indicate this profile as critical[8].

The severe shortage of senior profiles on specific topics continues:

- Advanced systems architecture designers.
- Systems test engineers.

[7] For industrial pilot lines, stakeholders interrogated indicate their needs for production engineers who can tackle the process problems and work with the production processes so that they are cost-effective and move towards reliable high-yield manufacturing processes. In addition to technical training, a production development and optimization training would be needed to have the right skills available.

[8] Especially stakeholders from IMEC.

- Senior analog designer, especially associated with strong programming skills.
- Application engineers. Engineers experts in specific applications fields (automotive…).
- Senior managers in general.

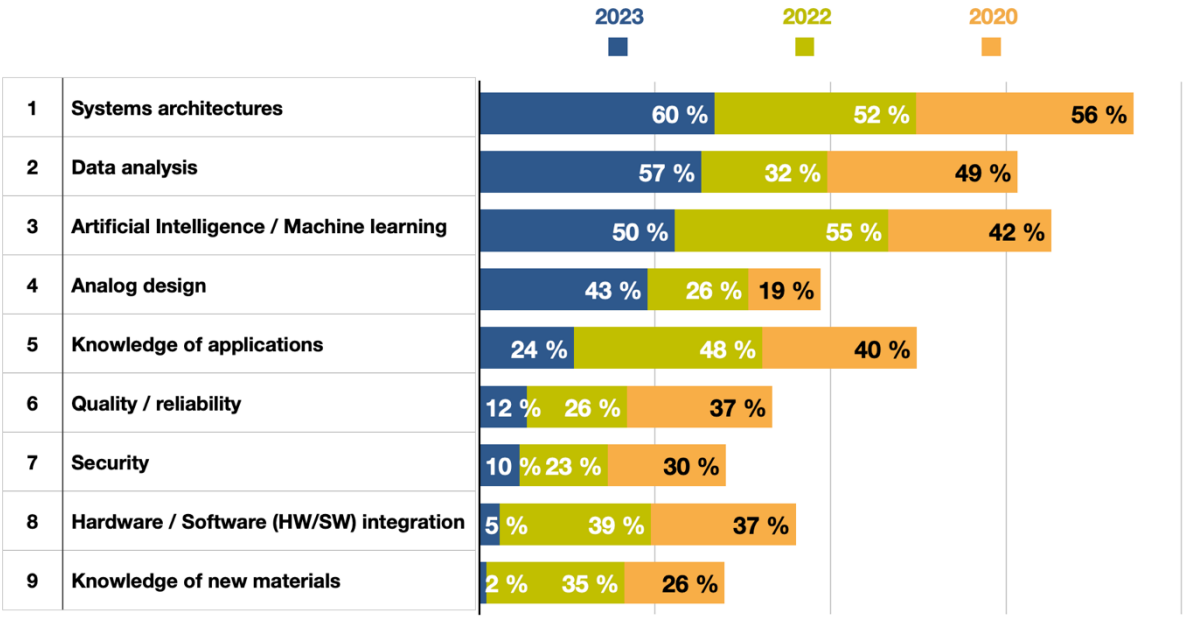
Finally, as in 2020, a few stakeholders mentioned their need for “Power electronics engineers” (also named Power management engineer / Energy efficient specialist). Power efficiency is a critical factor in microelectronics, particularly for battery-powered devices and energy-constrained applications. Skills in power management, low-power design techniques, power optimization, and energy harvesting are required for such profiles.

III. Most critical skills

A. Technical skills

This chapter summarizes the skills and knowledge identified as the most critical for the European microelectronics industry from 2020 to 2023. The most critical skills and knowledge are the ones that are defined as the most sought-after by the industry and the most difficult to fill.

2023-2022-2020: Number of stakeholders indicating the skills as critical:



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Source: METIS Yearly Monitoring Report 2023 / DECISION Etudes & Conseil

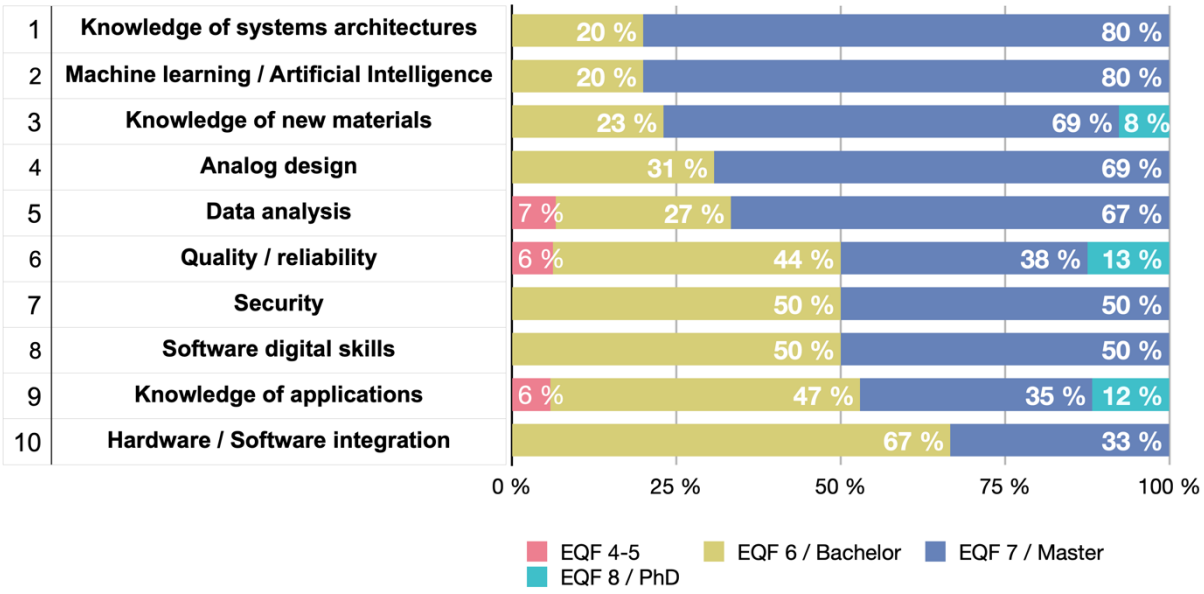
Nine fields of skills are confirmed as the most critical across the different job profiles (relatively stable since 2020). They are mostly associated to digitization and can be considered as digital skills.

1. System architectures: Knowledge of systems architectures: SoC, SiP, complex ASICs… Ability to design such architectures.
2. Data analysis. Increasingly needed by the industry.
3. Artificial Intelligence / Machine learning.
4. Analog design.
5. Knowledge of applications (specificities, linking components, materials, design constraints to apps).
6. Quality – reliability related skills.
7. Security related skills.
8. Hardware / software integration, although less brought to the fore in 2023.
9. Knowledge of new materials. Especially important for process engineers and material engineers, although this field of skills has been less brought to the fore in 2023 by the stakeholders interrogated.

Other skills indicated as critical by a few stakeholders in 2023:

- **Project management.**
- **Verification.**
- **Process integration.** Knowledge of process integration in chip technology. Especially required for process engineers.

Minimum educational level from which the skill is required
(17 stakeholders interrogated in 2022 and 2023)



Source: METIS Yearly Monitoring Report 2023 / DECISION Etudes & Conseils

The assessment of minimum educational level from which the skill is required is done since 2022. The results are the same in 2022 and 2023 and are therefore presented in an aggregated form.

Specializations that require the most education to enter in are the same as the most critical specializations stakeholders look for. For example, Knowledge of systems architectures require for 80% of the stakeholders at least an EQF 7 level (equivalent to a master's degree), which is the highest rate found in the results. And this is also the 2nd most critical specialization for respondents this year.

Participants mentioned that the shortage of qualified and experienced workers in the semiconductor industry have forced companies to find alternatives to fill the gap in their workforce and therefore to recruit more and more from EQF 6 levels (equivalent to a bachelor's degree) instead of a EQF 7 levels.

Nowadays EQF 6 level are easier to find on the market compared to master's degrees which are more difficult to obtain.

There is an obvious need for the introduction of more diplomas specialized in these critical specializations and especially the introduction of less qualified diplomas (EQF 5/6 instead of 7) to increase the workforce specialized in these critical subjects and thus satisfy microelectronics companies.

1. Machine learning / Artificial Intelligence

Knowledge and skills associated to machine learning are increasingly required for the majority of the profiles of the microelectronics industry today and will become more and more important, especially in line with the development of I4.0. These are especially important for software engineers that must be trained to a diversity of AI tools so that they have a wide view of the topic. Tools such as Keras, Torch, Tensorflow, Colab, Jupyter, Python, Lua, Matlab…

Educational level (EQF): Trainings to be provided from EQF 4 to EQF 7.

Associated job profiles:

- Main profiles concerned: Software engineers and Data scientists.
- Also, very important for Test engineers, Design engineers, Process engineers and Material engineers.
- Etc.

Content / sub-skills and sub-knowledge:

- Ability to select and use the machine learning toolsets for manufacturing (design, automation, etc.), and/or ERP.
- General introduction course on AI (at EQF 4-5): Fundamental knowledge and understanding of AI tools.
- Understanding of how to replace basic skills in production by machine learning algorithms to increase competitiveness and to facilitate innovation.
- Understanding of the impact of AI applications: It can lead to an overfitted world for citizens and engineers/developers should be aware of the consequences of their developments. Application of AI will have impacts on the job market, and social and economic development.

Beyond AI and machine learning, software skills are becoming more and more important for most microelectronics job positions: Robotic engineers, materials engineers, process engineers, power electronics engineers, RF engineers, etc. For instance, for RF and hardware engineers, software programming has become a very basic requirement in job descriptions currently. Up to the early 2000s', microelectronics technological developments were very hardware intensive (70% hardware VS 30% Software). In the early 2020s', this ratio as shift to ratio 70% for software and 30% for hardware. In certain technology (e.g., AI), software may be even more important than hardware in the semiconductor sector. However, in the semiconductor sector, many people may still not value skills in software as much as hardware, considering software skills as easier to learn which is not true as software engineering cover a very wide range of skills and knowledge.

2. System architecture

"System architecture" regroups the skills and knowledge associated to microelectronics systems: System-on-Chip (SoC), System-in-Package (SiP) and System-on-Package (SoP).

- A System-on-Chip (SoC) consists of a serie of blocks (processor, memory and caches, wireless system interfaces, network interfaces, sensor and actuators…) integrated on the same die. SoC designs also include application software and runtime systems.
- System-in-Package (SiP) has evolved as an alternative approach to SoC for electronics integration because this technology provides advantages over SoC in many market segments. In particular SiP provides more integration flexibility, faster time to market, lower R&D cost, lower NRE cost, and lower product cost than SoC for many applications. SiP is not a replacement for high level, single chip, silicon integration but should be viewed as complementary to SoC. For some very high-volume applications SoC will be the preferred approach. Some complex SiP products will contain SoC components.
- System-on-Package (SoP)[9] goes one step beyond the other approaches in overcoming both the fundamental and integration shortcomings of SoC and SIP, which are limited by CMOS processing and the shortcomings of current packaging. While silicon technology is great for transistor density improvements from year to year, according to Moore's Law, it is not an optimal platform for system integration of RF, optical, and certain digital components, as stated above. The SoP is akin to Moore's Law for integrated circuits, integrating transistors: it integrates thin film components at microscale in the short term and nanoscale in the long run for mixed-signal electronic and bioelectronics systems.

Knowledge of system architectures will become more and more important especially in line with the development of IoT and I4.0. Engineers with knowledge of the systems / co-design are also more and more required for automotive applications to reduce vehicle architecture costs and increase functionality by decreasing the number of discrete components and favoring the use of standardized microelectronic components and embedded systems and platforms.

Educational level (EQF): Trainings to be provided from EQF 5 to EQF 7.

Associated job profiles:

- System design engineer.
- Design engineer.
- In the absence of a System expert, teamwork between application engineers, design engineers and other engineering job profiles.

[9] "Packaging: Past, Present and Future", Rao R. Tummala, *Endowed Chair, Professor & Director of NSF-ERC, Packaging Research Center, Georgia, Institute of Technology, Atlanta, USA. ©2005 IEEE. 2005 6th International Conference on Electronic Packaging Technology.*

Content / sub-skills and sub-knowledge:

- Knowledge of systems architectures: system-on-chip and system-in-package. Interdisciplinary understanding of how the various system levels are interlinked and affect the overall performance.
- Understanding of the whole design and product life cycle.
- Ability to design both ICs, ASICs, systems-on-chips, system-in-package and system-on-package.
- Ability to optimize architectures.
- Ability to link and adapt design architectures to the end-using applications of systems (automotive, I4.0, etc.).

3. Knowledge of applications

Content / sub-skills and sub-knowledge:

- Ability to link and adapt technical aspects of a product (materials to use, design architecture, type of connectivity tools to integrate, etc.), to its end-user market(s) and application(s) (I4.0, automotive, etc.).
- Knowledge of applications and associated technical requirements, to build solution-oriented products.

Illustrations:

- A good knowledge of ADAS tools, other automotive developments or Industry 4.0 applications can be required for system engineer experts but also for software engineers.
- A good knowledge of automotive applications and associated technical requirements is required for the development of magnetic sensors development for the automotive industry: Safety, standards, Requirement Management and Change & Configuration Management.
- A material engineer needs to be able to link specific requirements on new materials with applications (e.g., high quality of images).

Educational level (EQF): Trainings to be provided from EQF 6 to EQF 7.

- Specific courses should be dedicated to specific applications. For instance, Industry 4.0 could have dedicated courses and be taught as a concept as a whole, regrouping all its associated sub-topics. On the contrary, sub-topics required for Industry 4.0 (like virtual prototyping, big data analyses, machine learning techniques, VR and AR techniques, Quality 4.0, advanced manufacturing machines) are often taught in separate curricula, even under the management of different faculties in universities, making the links between the sub-topics less clear for students. All of the relevant sub-topics could be

brought together under one curriculum, or specialization on EQF level 6-7, preferably on level 7.

Associated job profiles:

- Application engineer.
- Materials engineer.
- System design engineer.
- Design engineer.
- Software engineer.

4. Hardware / Software integration

HW/SW integration is a skill depicted as very difficult to find and long to acquire (many years) by many stakeholders. Hardware and software co-design will become more and more important especially in line with the development of IoT and I4.0.

Educational level (EQF): Trainings to be provided from EQF 6 to EQF 7.

Associated job profiles:

- System design engineer.
- Design engineer.
- Software engineers.

5. Knowledge of new materials

New materials are becoming increasingly important in microelectronics: polymers, shape-memory materials, composites, materials for additive manufacturing, garbitol, etc. Microelectronics engineers must have knowledge not just on traditional material engineering, but additionally on chemical and physical sciences (e.g., nanostructures).

Educational level (EQF): Trainings to be provided from EQF 5 to EQF 7. Process and material engineers graduated at EQF 6 and EQF 7 must both have received these trainings. These training are also a plus for other types of microelectronics engineers at EQF 6 and EQF 7.

The main skills and knowledge associated are:

- Knowledge of new materials: polymers, shape-memory materials, composites, materials for additive manufacturing, garbitol, gallium nitride. etc. Understanding of material properties, and the need to modify the integration flow.
- Knowledge in chemical and physical sciences (e.g., nanostructures). Basic knowledge in chemistry (missing in many curricula).
- Environmental awareness associated to traditional and new materials.

- Ability to link a material with production processes, product(s) specification(s) and end-user applications.

6. Data analysis

Data analysis skills and knowledge are increasingly required for nearly all profiles of the microelectronics industry today. They are especially important for data scientists and software engineers. Several companies report a lack of software engineers with good skills in data analysis.

Educational level (EQF): Trainings to be provided from EQF 4 to EQF 7. Every graduate at EQF 6-7 should have received initial trainings in this field.

Associated job profile:

- Nearly all profiles.
- Mainly Data scientists, Software engineers and Test engineers.
- But also, any engineer dealing with hardware: Process engineers, RG engineers, Robotic engineers, etc.
- Etc.

Content / sub-skills and sub-knowledge:

- Data management: SQL, etc.
- Data visualization: Tableau, etc.
- Data integrity: Ability to ensure integrity of data, particularly when using large volume of data. Knowledge of the techniques to assess the quality of data.
- Data Security & Privacy by design: Ability to ensure security of data & data privacy. Including IP protection.
- Data analysis: Ability to interpret and make sense of large volume of data. Knowledge of potential biased conclusion led by biased data.
- Machine learning / Artificial intelligence.
- Algorithm optimization. This skill is increasingly sought-after by industrials.
- Performance Data Analysis: Analyzing performance data.

7. Quality / reliability

Knowledge associated to quality / reliability (manufacturing quality control) is more and more needed by the microelectronics industry, especially to transfer prototypes into mass production.

Meanwhile, functional safety and reliability are increasingly important within manufacturing processes. For instance, reliability and functional safety are two of the four main domains where increased skills are required for microelectronics engineers in line with the development of automotive electronics, with security and cost management (according to the focus group on automotive organized by METIS).

- Reliability: The strong impulse in the search for improving the reliability of components, systems and, in particular, designs even more than in innovation itself. This makes the system design more and more difficult and also asks for advanced testing systems to assess the reliability of the components. This implies a greater importance of test technicians and engineers and their associated skills for microelectronics companies serving the automotive industry.
- Functional Safety (Quality): Vehicle safety is an aspect linked to the improvement of reliability and led to the introduction of Functional Safety and the ISO 26262.

Educational level (EQF): Associated skills and knowledge must be acquired for graduates at EQF level 7 (at EQF 6 is a plus, depending on profiles).

The main skills and knowledge associated are:

- Basic knowledge on quality engineering.
- Quality assessments (skill): Knowledge of the methodology of quality (Quality 3.0 and 4.0), and ability to use Quality tools (including quality tools associated to I4.0).
- Reliability analyses: Multidisciplinary knowledge in failure analyses, physics of failure.
- Robustness of microelectronics: Electromagnetic compatibility (EMC), electromagnetic interference (EMI), electrostatic discharge (ESD), aging, radiation hardness...
- Deep understanding of measurements and a physical sense of statistics.
- Analytical knowledge in reliability.
- Functional safety.

8. Analog design

Also named Analog / Analog IC / RF-IC Mixed-signal design (analog-to-digital converters (ADC), digital-to-analog converters (DAC)).

Analog design is one of the skills for which the European microelectronics industry face the greatest shortage currently. A progressive but very significant shortage as emerge in the industry during the past 20 years for this profile, due to the aging workforce and the lack of new graduates trained in analog design. Even though there is the trend of digitalizing signals as fast as possible, there still remains this small part of "analog", where there are too few experts available within every company.

The shortage is particularly high for this job profile as it takes a particularly long time to develop good analog design skills and about 20 years to become good analog designer. This cannot only be done by education, but there are also many practical skills needed.

Educational level (EQF): Trainings to be provided from EQF 5 to EQF 7.

Associated job profiles:

- Analog design engineer.
- Design engineer.

Content / sub-skills and sub-knowledge:

- Mixed Signal Design: Proficient with analogue and digital electronic design, noise, signal integrity, etc.

9. Security

Skills associated to Security, Cybersecurity and Security-by-design will be very important for software engineers (EQF 6-7 engineers). These skills will become more and more important in line with the development of Industry 4.0, but also in line with automotive innovations. Security is one of the four main domains where increased skills are required in line with the development of automotive electronics (with reliability, functional safety and cost management), according to the focus group on automotive organized by METIS, especially as a tightening of the security rules applied to microelectronics in the Automotive segment is foreseen in Europe during the coming years and due to an increased external connectivity. For a test engineer, this will become more and more important equally from SW and HW side. From the aspect of test engineering concept, the testing of security on devices themselves (code, hardware) and the closeness of a system is becoming more and more important.

Educational level (EQF): Trainings to be provided from EQF 5 to 7. Associated skills and knowledge are very important for Expert in cybersecurity / Software engineers / Robotic engineers / Process engineers / Test engineer. Associated skills and knowledge are a plus for other engineering profiles.

Associated job profiles:

- Expert in cybersecurity.
- Software engineers.
- Robotics engineers.
- Process engineers.
- Test engineer.

Content / sub-skills and sub-knowledge:

- Combined knowledge between hard and software necessary.
- Security by design (Especially important for IoT and I4.0.): Know-how and applicability of secure protocols necessary.
- Skills used for cyber-physical (production) systems like diagram a network for security.
- Cybersecurity:
    - Advanced intrusion detection and prevention.
    - Advanced skills in forensics.
- Reverse engineering for the prevention of industrial spying (especially for test engineers).
- Ability to investigate the possible failures originated from improper use of malicious codes (highly for robotic engineers). Identify risks, issues, potential defects, or defects in any phase of the software life cycle, managing them through closure
- Data integrity: Ability to ensure integrity of data, particularly when using large volume of data. Knowledge of the techniques to assess the quality of data.
- Data Security & Privacy by design: Ability to ensure security of data & data privacy. Including IP protection.
- Safety issues.

B. Soft skills

About soft skills, the results of this yearly monitoring report confirm the results of 2020.

Soft skills are overall considered as almost as important as technical skills. This result is confirmed by a study from MIDAS (Ireland) published in 2021: "*Electronics Sector Resources Skills Needs*". According to this report, "Engineers are typically known and hired for their advanced technical capabilities, so soft skills can sometimes be ignored, even by management in technical environments". That is why this study calls for more soft skills training in the future.

The most critical soft skills required in 2022 are as follows:

1. **Teamwork & communication:** Topics are becoming Increasingly complex, so teamwork and collaboration between teams are now crucial. The ability to summarize complex topics for non-experts is also important.
2. **Creativity:** Innovation capacity, ability to propose new ideas, new processes, new designs, to use new technologies, new applications, agile thinking, business thinking for R&D.

Since the COVID crisis the wellbeing of juniors is being increasingly taken into account, including in the HR processes, whether in terms of mental health, home working, etc.

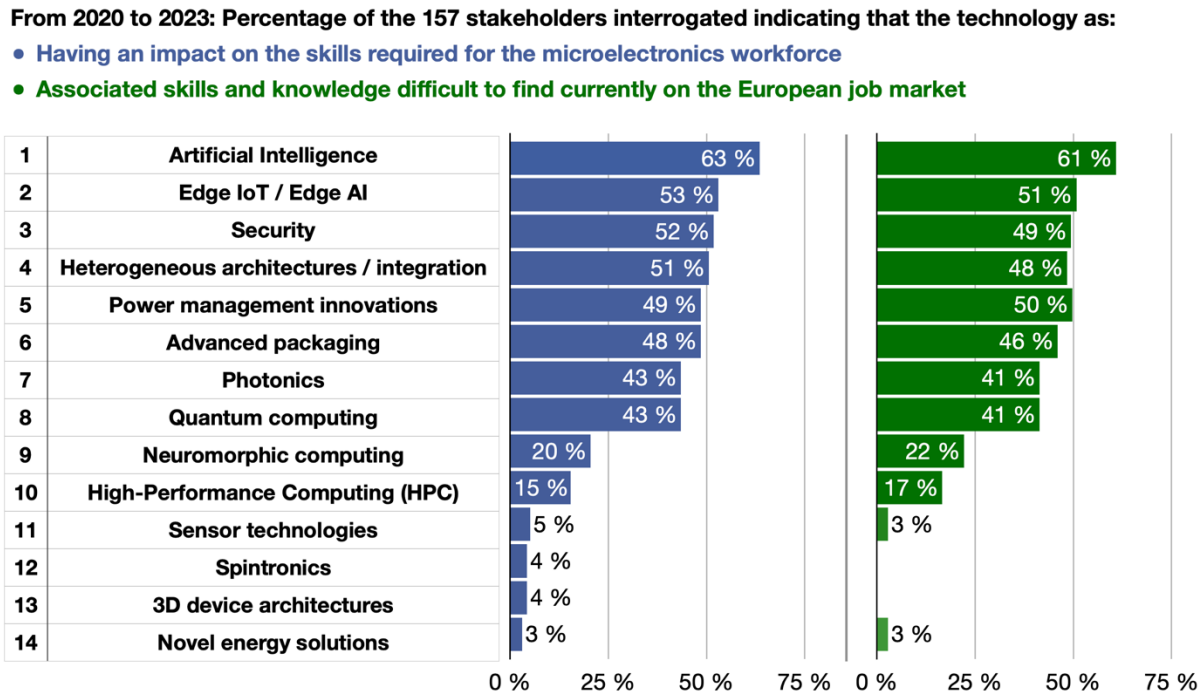
IV. Impact of emerging technologies on skills needs

The microelectronics sector and the skills required for its workers have evolved drastically in the last years due to innovation waves. This trend will carry on in the coming decades. The Moore's Law has been the most impactful technological trend for the past 50 years, leading to cost reduction of computational power and miniaturization of microelectronics. For instance, in 2001, 8-bit microprocessors with 64 kb of memory were used in white goods. In 2011 those figures were 1 GHz for TV with 4 GB of memory. However, the Moore's Law is coming to an end. Ever rising investment and R&D costs are required to progress in the Moore's Law and the "last node" (1 nanometer chip), should be produced by 2030. Over the coming decade and for Europe especially, innovation drivers for the microelectronic sector should come from more than Moore developments.

Technologies assessed in METIS over the 2020-2023 period

Technology	Description
Artificial Intelligence	Tiny Machine Learning (ML), Deep Learning (DNN, CNN), Low-power hardware for ML...
Edge IoT / Edge AI	Design of emerging systems (SoC, SiP, complex ASIC) and modules for Edge IoT and Edge AI
Power management innovations	Power computing, power management innovations, ultra-low power MCU
Security	Cybersecurity by design, lightweight cryptography, post-quantum cryptography, etc.
Advanced packaging	SiP, Fan-In, Fan-Out, WL CSP, Advanced IC substrates (Flip chip-based packages), Stacking technologies (2.5D & 3D), embedded die.
Heterogeneous architectures / Integration	
Photonics	Integrated photonics, photonic interconnection networks...
Quantum computing	
Neuromorphic computing	
High-Performance Computing (HPC)	

Results over the 2020-2023 period



Source: METIS Yearly Monitoring Report 2023 / DECISION Etudes & Conseil

The diagram above shows the ranking of 14 technological fields by the 157 stakeholders interrogated since 2020, answering the two following questions:

- Is the technology having an impact on the skills required for the microelectronics workforce?
- Are the associated skills and knowledge difficult to find currently on the European job market?

The answers of the past 4 years have been aggregated as the same results have been obtained every year.

The only variation in the results since 2020 is the continuous rise of the technology “Edge IoT / Edge AI” both in terms of skills required and in terms of difficulty to find such skills. In 2020, this field of technology was only ranked in 6th position. It is ranked in in second position, just behind “Artificial Intelligence”, since 2021.

V. Policy recommendations

This year, no stakeholder mentioned the necessity to sponsor state-of-the-art manufacturing infrastructures in the EU, which is logical given the numerous initiatives since 2020 and especially the EU chips act.

A. Enhance life-long learning programs and increase the involvement of the microelectronics industry in the education process

This proposition was the 1st most cited in 2020. It is the 1st in 2023.

Design lifelong learning programs. More and more microelectronic companies are using lately digitalized systems to calibrate the micro components, so it would need to have lifelong learning trainings in updating peoples' skills at least in the field of digitalization. In order to go further in the cooperation between industrials and education providers, initiatives to develop life-long training and to combine study and training in a single workplace should be developed:

- Courses co-designed with industry: Strengthen collaboration between microelectronics companies and educational institutions, such as universities and technical schools, to align curriculum with industry needs (relevant courses, practical cleanroom processing, summer job placements, thesis works, the development of joint research projects…).
- Generalize the involvement of universities and VET providers in career-long/life-long training within companies, to design life-long training programs, blurring the lines between initial and vocational training. Companies should provide enabling framework to motivate continuing learning through HR management (e.g., raising awareness, training, etc.), involving VETs and universities. Currently, except a few countries in the EU, work-based learning is not integrated into the overall education-industry partnership.
- Develop universities' applied courses directly in companies' factories and involve university teachers in companies' facilities (to present them the last manufacturing processes, etc.).
- Generalize co-funded and co-organized projects between universities and companies. Universities and industrials should cooperate more intensive on enabling innovative (arise from research) applications.

Develop internships, apprenticeships, PhDs and graduate training programs co-organized (and co-funded?) by universities and industrials. Three to six months internships at the early stages of studies should be generalized.

Generalize the use of experts from the industry as teachers at the university. Industrials should provide experts to give lectures at universities to give the students a better insight into the needed skills for working in microelectronics industry.

Promote industry at university. Increase the number of initiatives to promote the semiconductor industry jobs variety in universities.

Teach microelectronics-related topics at an early stage of the education system.

- Train energy efficiency and semiconductor to high school students.
- Train more software skills at a lower education's level.
- Push digitalization in schools.
- Introduce semiconductor at early stage of the education system.

Build / develop gateways for newcomers in the microelectronics industry.

- Facilitate student sponsorship programs so that the microelectronics industry can support scholarship (fees) of future entrants (Tax rebate, etc.).
- Develop dedicated "gateway" programs to "fast train" non-STEM graduates.

B. Communication campaigns to improve the image of the sector

This proposition was the 4th most cited in 2020. It is the 2nd in 2023.
The microelectronics industry suffers from a poor image as a sector to work in. People should associate the microelectronics sector with Europe and not only with Silicon Valley and Taiwan or Asia. A set of initiatives should be organized to promote KETs and microelectronics to the public and attract young students:

- **Raise the importance of semiconductors in society through communication campaigns**.
    - Promote the sector as an attractive and viable option for young talents, emphasizing its innovation, sustainability, and impact on various industries, as well as highlighting the financial attractiveness of the sector[10].
    - Exposure to the critical aspects in society microelectronics contribute. Let the young people know that it is not all "Apps, Social Media and software" but also enabler for a majority of technological innovations in the fields of healthcare, safety…
    - Make technical jobs attractive again, like maintenance technicians, operators, engineers.

[10] Study from MIDAS (Ireland) published in 2021: "*Electronics Sector Resources Skills Needs*".

- **Conduct actions to raise the interest of young people in STEM educations for technical jobs, electrical engineering and microelectronics**.
    - Promote the typical job positions STEM students could pretend to in the microelectronics industry and the associated career evolutions.
    - A more intense lobbying on the microelectronics industry's career opportunities is needed.

- **Enhance diversity in the workforce** *The microelectronics sector's talent pipeline is not diverse and inclusive enough, women participation going down from 40% to 10% along the occupational hierarchy (McKinsey & SEMI data aggregated, 2018).*
    - Expose as many young women as possible to what means microelectronics in terms of empowering them that they can also do it: in Bachelor, Master's degree and PhD.
    - Organize communication campaigns on diversity to high school students

- **More communication channels** need to be used where/when young people are present in their free time, such as social and professional medias.

- **Promote EU programs** to technology skills to young engineers to join in such training and on site On-the-Job-Training (OJT).

But some stakeholders are convinced that students are not sufficiently attracted by the microelectronics industry in Europe because of the relatively small size of the industry compared to other regions. Therefore, according to them, **initiatives to build a stronger microelectronics value chain in Europe are the best way to attract students to microelectronics.**

C. Develop clusters and networks favoring dialog between industry and education representatives

This proposition was the 3rd most cited in 2020. It is the 3rd in 2022.

Such clusters and networks are required to enable universities to be in close contact with local companies to understand their needs.

More precisely, several stakeholders pledge for the organization of forums of discussions between the microelectronics industry and universities & VET representatives to identify synergies and actions at the European level[11]. Such a forum would be in charge of:

- Setting up dedicated groups defining and updating the roadmap of skillsets needed.
- Mapping training and courses from European education providers, especially to enable SMEs to know where to recruit students for each profile. Today, large companies have the capacity to actively look for information about courses provided by universities across Europe, but it is harder for SMEs.
- More starting positions for students to secure supply of new professionals.

D. Favor intra and extra-EU mobility

This point came in 6th place of importance in 2020. In 2023, It is the 4th most cited policy recommendation by respondents. The semiconductor crisis has indeed produced a major shortage in workforce, especially in the EU.

For many companies and job profiles, recruitments that used to happen locally now tends to be EU-wide or even world-wide for senior profiles. For such profiles, European actors then have no choice but to look for non-EU talents.

The profile of Verification engineer is a good example. There is currently almost no graduates with the qualifications for this profile in Western Europe, while North Africa (Tunisia, Morocco), India or Eastern Europe (Serbia, Romania) are offering good offshore opportunities.

But many factors still make it difficult for EU factories to attract non-EU citizens. To make it easier, respondents have many propositions:

Make it easier to hire non-EU citizens:

- Ensure that skills assessments are undertaken as part of the pre- and post-arrival services offered to migrant workers, offer bridging training courses, including language training, to upskill potential migrant ICT specialists and provide guidance to employers wishing to recruit microelectronics workers from abroad.
- Easier access to labor market of international experts and specialists. Facilitate professionals moving into Europe (tax incentives, Visa, etc.).

[11] https://www.reuters.com/world/asml-boss-calls-greater-academic-industrial-collaboration-europe-2023-09-04/

- Making more efficient legal regulations and framework for employing workforce outside of the EU.
- Increase the pre-professional international accreditation of the engineering degree and the Professional Development Programs international independent accreditation (ENAEE is strongly focused in this area).
- Remove the limits of teleworking from abroad (amendments / exceptions to tax legislative).

Uniformization of degrees across the EU

- Is still currently easier to hire locally because of the remaining differences between what universities offer in Europe, and it is difficult for companies (especially SMEs) to understand these differences between EU educational systems.
- Enhance exchange programs of students at the European and international level.
- Generalize English as the training language in European Universities.

Shortage of senior profiles

- More flexibility regarding seniority of profiles – huge investment in terms of promotion of these career paths and education in required areas.
- Develop a plan on how to attract engineers with New Skills to work in the Electronics Sector, e.g., re-training.

Shortage of technicians

- Investigate an apprenticeship program to be put in place to help increase the supply microelectronics technicians on the mid-term.

E. Build an EU Chip Academy

This recommendation has become very popular since 2020.

Numerous different degrees already exist in the microelectronic field in the EU. However, it can be difficult for firms, students or workers to get their way around and find the formation that best fits their needs.

The EU Chip Academy would:

- Regroup existing trainings, including micro-degrees, across the EU in a single online platform. This platform would be supported by a collaboration between RTO, universities and Industry.
- Propose Flexible, modular (virtual / hybrid) academic training. This could be done in a first step by putting together already existing formats, offers and buildings from universities.
- Be associated to a skills monitoring and forecasting tool: A skills monitoring system should be set up at the EU level to enhance the understanding of current and future skills needs.
- Introduce a centralized European job platform to fluidify the job market.

F. Develop interdisciplinarity and joint degrees in microelectronics

This proposition was the 5th most cited in 2020. It is the 6th in 2022.

Proposals for interdisciplinarity or joint degrees in microelectronics

FIELD OF STUDY	PROPOSAL OF JOINT DEGREE					
	1	2	3	4	5	6
Microelectronics / Electro engineering / Mechanics / Mechatronics	V	V	V	V	V	V
Data science / Software / Informatics / Data engineering / Data analysis	V					
Artificial Intelligence / Machine Learning		V				
Program management / Supply chain management			V			
Marketing / Sales / Communication				V		
Chemistry / Material science (Polymer etc.)					V	
Biology / natural science						V

As the table above shows, actors in the chips industry would like to have more interdisciplinary profiles. The table sorts by importance the different combinations of subjects.

For example, the joint degree the most sought-after combines microelectronics / mechatronics one the one hand, and data science on the other hand. As data specialists are increasingly sought after in microelectronics, their profiles are also in great demand in other

fields, such as finance and/or insurance. It would be important to link microelectronics with data sciences to better prepare future generations and broaden the scope of future workers.

Skills related to Artificial Intelligence / Machine learning are so increasingly demanded that a profile of microelectronics AI engineer, with a dual training in both microelectronics and machine learning (master's specialization), is emerging as a need from the industry. The curriculum of such AI engineer would be:

- Dual bachelor: Mechatronics / Data science.
- Dual Master: Microelectronics / Machine Learning.

One of the issues faced by the semiconductor industry is the difficulty to find workers with a strong understanding of the semiconductor industry and technologies, but also skilled in business-related area. The joint degree combining semiconductor with mark marketing, sales or communication would answer this need.

Regarding the need for joint degrees combining microelectronics and chemistry: typical courses linking microelectronics with chemistry and material sciences would be: Chemistry of materials for semiconductors, Physics to new semiconductor technology information…

Interdisciplinary profiles could be achieved by establishing combined study courses, by introducing other domain modules and by promoting interfaculty teaching and research exchanges.

G. Other policy recommendations

- Raise the public funding of universities and VET providers, in order to adapt to the raising industry needs.
  - Several universities, in France, in Germany, etc. indicate that they see the number of microelectronics students stagnating or even declining in the current context.
  - Given the already long duration to train new talents to cope with the current shortage (3-10 years), the stagnation or even the decline of new students in several universities could make the shortage last for more than a decade in Europe…
  - It seems urgent to ensure a significant rise of the capacities to train new microelectronics students in European universities as soon as possible.
- Adjust European wages to attract the workforce
  - European wages are below the US average.
  - Similarly, European semiconductor wages are often below the wages offered by other industries for similar profiles such as data scientists...
  - European semiconductor wages should be adjusted to attract worldwide talents.

VI. Annex 1 – List of European iVET and cVET providers

Organization name	Type	Nationality	iVET	cVET
ENTER Network	Platform / Network	The EU	Yes	
CEA Leti	RTO	France	Yes	
IMEC	RTO	Belgium	Yes	Yes
Leibniz Institute for High Performance Microelectronics (IHP)	RTO	Germany	Yes	
SUMCO	Company	Japan	Yes	
TU Graz	University	Austria	Yes	Yes
TU Wien	University	Austria	Yes	
Mead education	VET	Switzerland	Yes	Yes
Linkedin learning	Platform / Network	The USA	Yes	
Aalto University	University	Finland	Yes	
University of Turku	University	Finland	Yes	
Helsinki and Oulou University	University	Sweden	Yes	
VTT	RTO	Finland	Yes	
Dresden Chip Academy (SBH)	VET	Germany	Yes	Yes
Berufliches Schulzentrum für Elektrotechnik Dresden	VET	Germany	Yes	
Berufsakademie Sachsen	VET	Germany	Yes	
TU Dresden	University	Germany	Yes	
TU Freiberg	University	Germany	Yes	
TU Chemnitz	University	Germany	Yes	
Institut für Mikroelektronik Stuttgart	RTO	Germany	Yes	
Ulm University	University	Germany	Yes	
HAW Hamburg	University	Germany	Yes	Yes
FH-Westkuste	University	Germany	Yes	
Qualifizierung für Mikroelektronik Dresden GmbH (QFMD)	VET	Germany		Yes
DIU - Dresden International University	University	Germany		Yes
Education and Training Boards	VET	Ireland		Yes
MIDAS Electronic Systems Skillnet	Platform / Network	Ireland		Yes
Ecovem	Platform / Network	The EU	Yes	Yes
METIS	Platform / Network	The EU	Yes	Yes
Europass	Platform / Network	The EU		Yes
VDI/VDE	Platform / Network	Germany		Yes
Fraunhofer Group for Microelectronics	RTO	Germany		Yes
IEEE	Platform / Network	International		Yes
Europractice (via USN)	Platform / Network	The EU	Yes	
University of Oslo (via USN)	University	Norway	Yes	
NTNU Trondheim (via USN)	Platform / Network	Norway	Yes	
USN Vestfold	University	Norway	Yes	
European Microelectronics Academy (EMA) (Via BME)	Platform / Network	The EU		Yes
European Semiconductor Cluster (ESiC) (Via BME)	Platform / Network	The EU		Yes
All major manufacturing semi companies provide: AMS, etc.	Company	International		Yes
TNO	RTO	Netherlands		Yes