E4E

Engineers for Europe

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Results of the 2nd Primary and Secondary Research Round: Inputs to the E4E Skill Strategy

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ENGINEERS 4 EUROPE

This text is related to the ENGINEERS EUROPE Primary and Secondary Research produced in the light of the Engineers 4 Europe (E4E) Project (Ref. Nr. 101054872 – E4E – ERASMUS-EDU-20121-PI-ALL-INNO, 2022-2025). This project has been funded with support from the European Commission.

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ENGINEERS 4 EUROPE

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I. Background

This document is the result of a 2nd round of Primary and Secondary Research conducted by the Central Secretariat of ENGINEERS EUROPE and the 12 other partners in the light of the E4E Project and to provide inputs to the European Engineering Skills Strategy, by focusing on the current situation regarding the competence requirements of current and future engineers, the existing skills mismatch and which activities and measures can be taken to facilitate competence developments.

By this research we identified the future needs concerning technical and non-technical skills of engineers in the light of current and future societal challenges, such as the “twin-transition”, i.e. digitalization and sustainability.

The objective of the E4E-project is – geared by the new requirements of the world of work – to prepare better equipped engineers through the acquisition of new competences, covering new knowledge, attitudes and leadership skills to bridge the gap between education and industry while operationalizing EU competence frameworks (Dig Comp, Life Comp, Entre Comp and Green Comp) for engineers.

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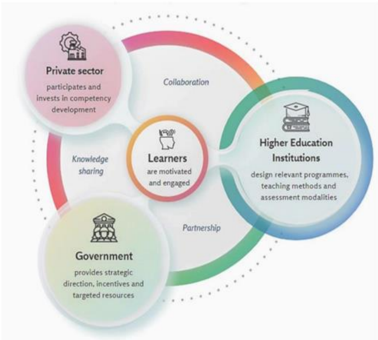
II. Methodology

ENGINEERS EUROPE conducted two European-wide on-line surveys between 15 May and 15 July 2023 and between 7 May and 30 June 2024. The first survey consisted of 33 closed questions, whereas the second survey consisted of 10 questions of which some were open. In total these two surveys received **7.757** completed replies. The results provided a general idea of the current trends and major challenges when it comes to engineering competencies for the future.

The methodology used for the secondary research involved a bibliographic review of various sources : publicly available reports on the internet, conference presentations, outcomes and conclusions, digital press releases, interviews, public agencies and authorities at national and European level related to the subject and taking into account the various stakeholder groups (industry, professional organizations representing the engineering profession, universities and higher education institutions as well as public authorities), as developed by the OECD.



Note: Developed by OECD Secretariat

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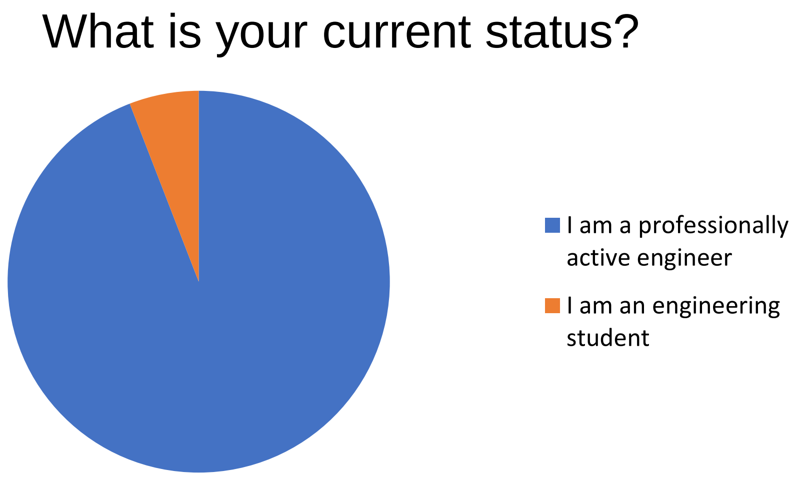
III. Survey Results: Primary Research

The second survey, conducted from May to June 2024 under the Engineers4Europe (E4E) Project, received responses from 6.489 individuals, with 4.712 engineers completing the full survey. This analysis focuses solely on these complete responses. Respondents had the option to skip certain questions, but only those who submitted the survey are included in the 4.712.

The survey was conducted using SurveyMonkey and disseminated through various (social media) channels of the partners in the project and members in the ENGINEERS EUROPE network.

Of the 4.712 respondents, 4.435 are professionally active engineers (94,12%) and 277 of them are engineering students (5,88%).



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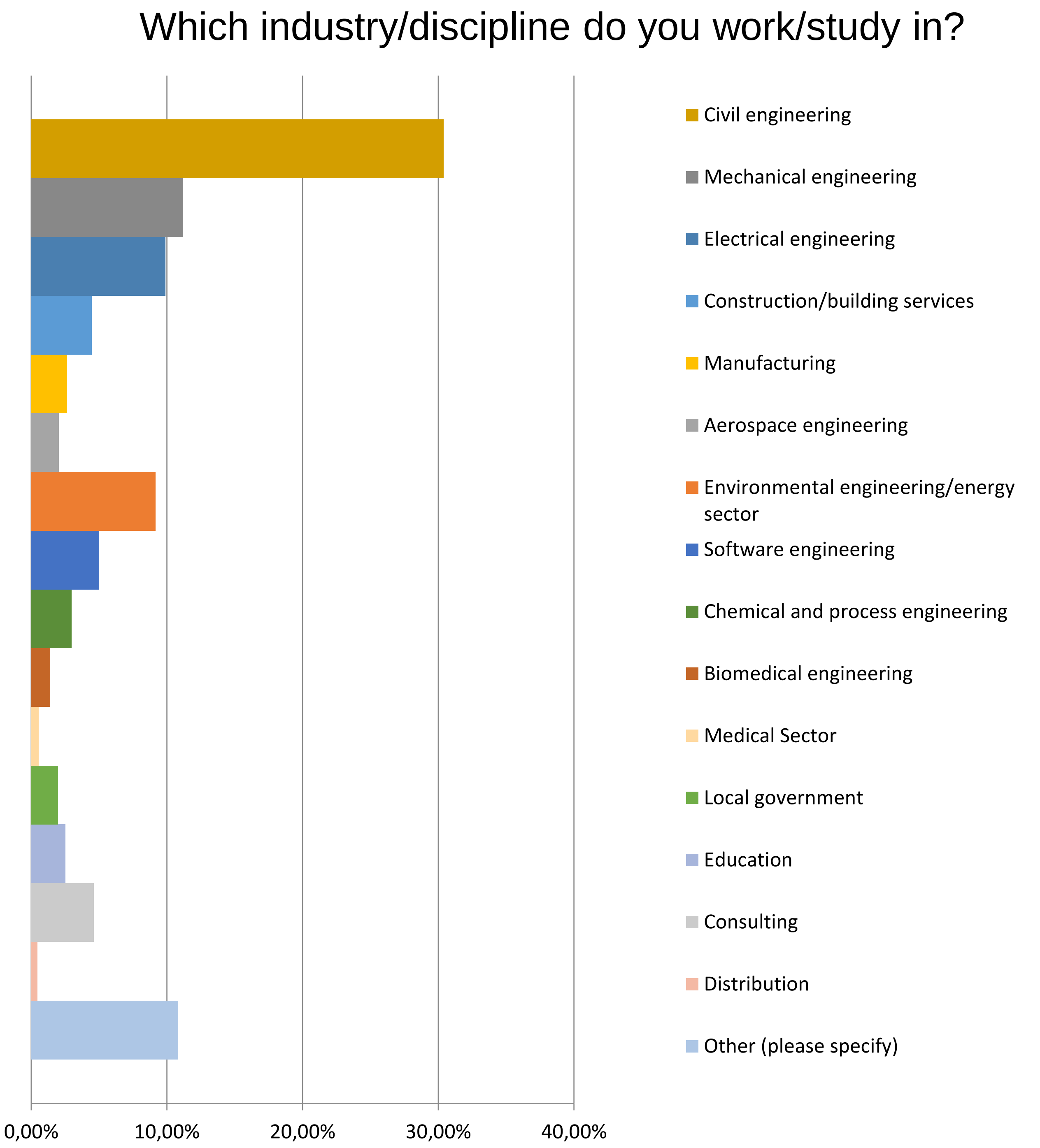
The survey's personal questions inquired about the **industry or discipline** in which the respondents work or study. The top three disciplines are civil engineering (30.39%), mechanical engineering (11.18%), and electrical engineering (9.89%).



Other sectors frequently mentioned include mechatronics, automotive engineering, architecture, telecommunications, and railway engineering.

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The survey then asked respondents which **country** they currently work or study in. Given the overrepresentation of Italian engineers, this analysis weighed the Italian responses to avoid bias. Considering that Italians made up 13% of the European population in January 2023 (Eurostat, 2024), we applied a weighing factor of 0.13 to the Italian responses.

Austria	0,62%	29
Belgium	2,44%	115
Bulgaria	0,49%	23
Croatia	0,02%	1
Cyprus	0,02%	1
Czech Republic	0,51%	24
Denmark	0,11%	5
Estonia	0,15%	7
Finland	0,02%	1
France	0,36%	17
Germany	7,94%	374
Greece	1,68%	79
Hungary	0,04%	2
Iceland	0,04%	2
Ireland	1,17%	55
Italy	52,19%	2459
Kazakhstan	0,00%	0
Latvia	0,04%	2
Lithuania	0,02%	1
Luxembourg	0,02%	1
Malta	0,51%	24
The Netherlands	1,72%	81
North Macedonia	0,06%	3
Norway	0,30%	14
Poland	11,44%	539
Portugal	4,20%	198
Romania	1,29%	61
Serbia	1,63%	77
Slovakia	0,93%	44
Slovenia	0,17%	8
Spain	6,47%	305
Sweden	0,11%	5
Switzerland	1,87%	88
Turkey	0,06%	3
Ukraine	0,00%	0
United Kingdom	0,64%	30
Other	0,72%	34

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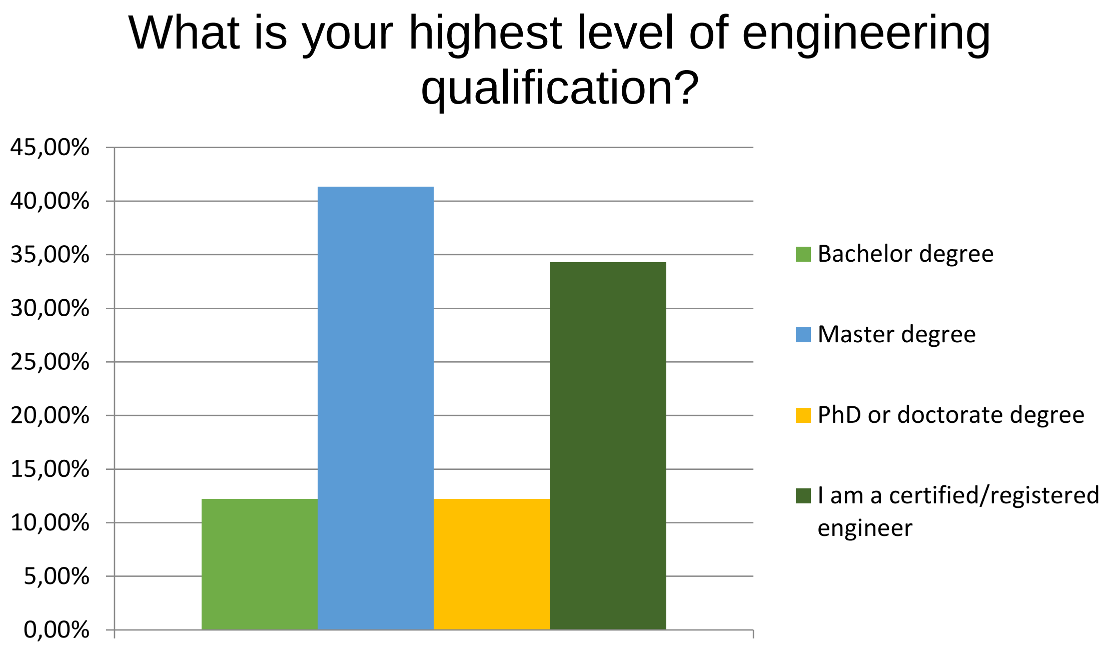
The questionnaire inquired about the **highest level of engineering qualification** achieved by the respondents, excluding those who identified as students. Most respondents have a master's degree in engineering, followed by a significant number of certified or registered engineers.



Regarding professional experience, excluding students, respondents reported an **average of 21 years** in the engineering field.

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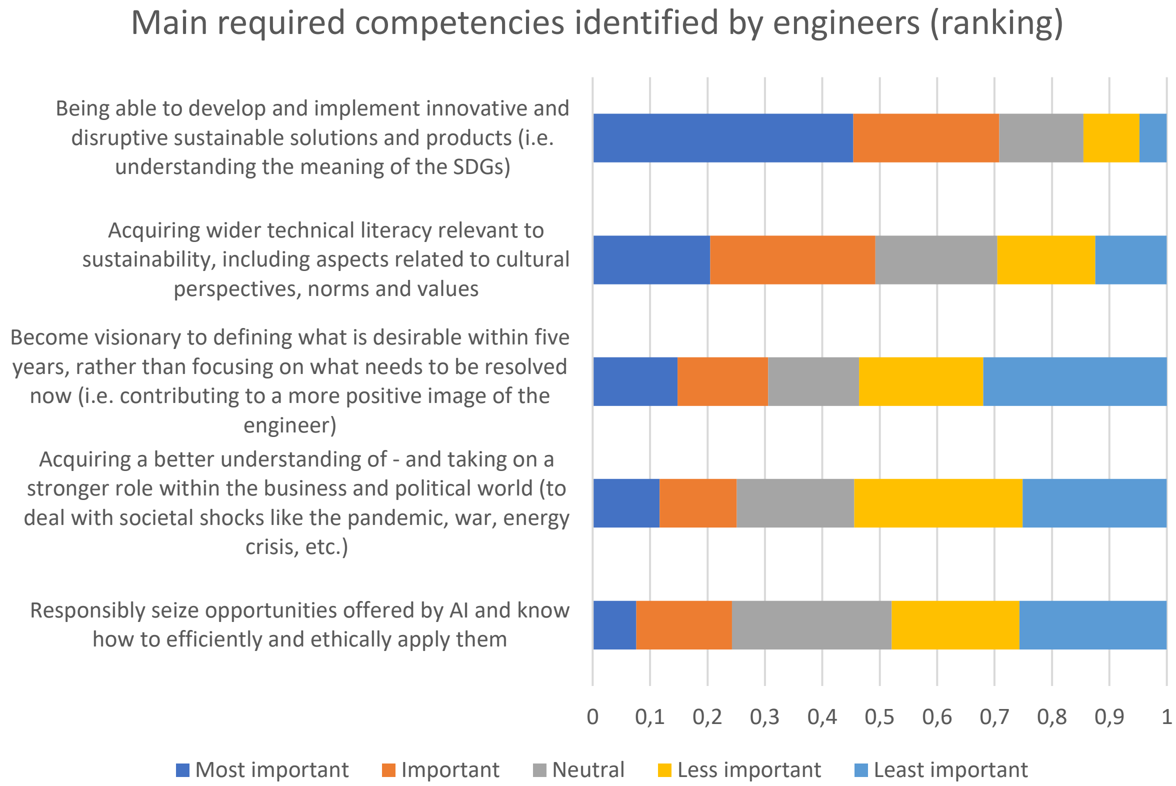
In the sixth question, respondents were asked to rank the **main competencies** they believe are essential for the future of the engineering profession. Italian responses were weighted with a factor of 0.13 in this analysis.



The highest-ranked competency was "being able to develop and implement innovative and disruptive sustainable solutions and products (i.e. understanding the meaning of the SDGs)". Surprisingly, "responsibly seizing opportunities offered by AI and applying them efficiently and ethically" was ranked first by less than 10% of respondents. Most respondents placed "becoming visionary in defining what is desirable within five years, rather than focusing on current issues" last.

When comparing the responses of professionally active engineers and engineering students, no clear differences emerge in the ranking of the competences listed above. Similarly, there are no significant differences in rankings when comparing respondents with bachelor's versus master's degrees, or when comparing engineers in "traditional disciplines" such as civil, mechanical, and electrical engineering with those in "newer fields" like software, environmental, and biomedical engineering.

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An open-ended question asked respondents about **changes needed in engineering education and training programs to better prepare students.** This question was answered by 2749 respondents. Responses in languages other than English, those with no valuable relation to engineering education, and answers like “I don’t know,” “no,” and “nothing” were excluded from the analysis, leaving around 2500 relevant answers.

In the word cloud on the left, the most frequently used terms in respondents' answers are visualized, with the size of each word corresponding to the number of mentions.

The majority of respondents (over 50%) highlight the engineering education should include more **practical** learning and a stronger **connection to the industry**.

The most recurring theme is the need for more practical training and experience during higher education. Alongside this, many respondents highlight the importance of **better collaboration between universities and industry** to align with the evolving labor market and the demand for innovative technologies and products. There is also a call for aligning the curriculum with the “real world” and addressing “real problems,” as opposed to the traditional focus on theoretical classes and exams.

Respondents frequently mention the need for more **job training sessions** and (mandatory) **practice in companies, laboratories, or construction sites**. They strongly advocate for classes taught by engineering professionals rather than a curriculum solely delivered by academics. Additionally, focusing on projects and real work-related situations, along with applicable **regulations and technical standards**, is suggested as a way to gain more hands-on experience.

Internships and apprenticeships, perhaps mandatory, are highly favored, as are practical case studies that help build a **professional network** already during students’ education. Including student organizations is also mentioned to support engineering students' development through collaborative projects with companies. These approaches could additionally provide them with a broader perspective on non-technical aspects, which will be analyzed in detail later.

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Around 10% of respondents emphasize the importance of integrating **digitalization and Artificial Intelligence (AI)** into the engineering education. They argue that new professions will emerge in engineering, and educational institutions should prepare future generations for these advancements. Proficiency with the **latest software, programming, design modelling, and computer simulations** will be essential parts of an engineer's career and should therefore be highlighted during their studies. AI is seen as a tool to optimize work and offer cost and time-saving advantages.

There is a clear consensus that engineering education should stay current with these developments, and professors should be knowledgeable in the latest digital tools. However, some respondents express strong doubts about the use of AI in engineering studies, fearing it may lead to students being lazy and a **lack of understanding of underlying calculations**. Others support the integration of AI but advocate for combining it with the **human aspects** of engineering to ensure engineers remain indispensable.

Around 5% of respondents emphasize the importance of **climate change and energy efficiency** in engineering. Several argue that it is an **engineer's duty to be involved in the green transition** and that this topic deserves more focus in courses, as sustainability impacts on various scales and nearly all sectors. Most of these respondents believe that graduate engineers should be more aware of the **sustainable and economic aspects** of the technical solutions they implement. A significant portion of the responses with a "green focus" are oriented towards the construction sector and energy solutions.

Around 20% of the respondents highlight the importance of **professional and non-technical skills**. There is a clear distinction between professional or soft skills, such as critical thinking, communication, collaboration, and creativity, and non-technical skills from other disciplines, such as business and economic understanding, law, languages, and project management. In the word cloud on the right, the most frequently used terms in these answers are visualized, with the size of each word corresponding to the number of mentions.

About 20% of respondents who mention professional or non-technical skills emphasize **business**, **economics**, and **finance**. These respondents frequently highlight the importance of understanding basic economic and financial principles, as well as business management, for engineers.

Related to these professional skills, **inter- or multidisciplinarity** is mentioned in 3% of the answers. These respondents stress the importance of the **interplay between technology and other disciplines such as social sciences and economics**. They argue that to understand the world behind engineering,

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one must also learn that "the world is not only a mathematical one." Societal development and impact are frequently mentioned, along with **system thinking** and **inter- or cross-construction learning**. The "bigger picture" is also referenced several times to emphasize the importance of a broader perspective within the engineering curriculum. Additionally, working or studying in **multidisciplinary teams** is suggested as a method to broaden engineering students' viewpoints. Open-mindedness and "thinking outside of the box" are considered by some respondents to be beneficial for the engineering curriculum, as well as a holistic approach to projects.

We now shift our focus to the open answers concerning the **structure of engineering curricula** in different European countries, the **competencies and importance of teaching** staff, and **preparation in primary and secondary education**.

There is a notable divide between respondents who advocate for a **modern, innovative curriculum that aligns with technological advancements and societal trends, featuring a high degree of specialization** in contrast with others who prefer a more **traditional engineering curriculum that emphasizes a robust theoretical foundation with a strong focus on mathematics and physics**. These opinions often correspond with the age of the respondent; while younger respondents tend to advocate for a modern, innovative curriculum, the older respondents lean more towards the traditional curriculum.[1]

The first group emphasizes the benefits of incorporating online education, practical labs, and new engineering skills to address future challenges. In contrast, the more traditional perspective often expresses a desire for the pre-Bologna system, where there was no separation between bachelor's and master's degrees. Some advocate for a curriculum longer than five years with a mandatory entrance exam to ensure a high level of professionalism among graduates. This viewpoint frequently critiques the current curriculum for "excessive specialization," arguing that it neglects the foundational engineering knowledge.

However, some respondents advocate for a balanced approach, **maintaining high scientific standards and valuing theoretical engineering knowledge** while also calling for **increased practical study opportunities, including internships and apprenticeships**.

Regarding the competencies of **teaching staff**, there is often a desire for more direct contact between students and professors. Additionally, respondents emphasize the importance of professors staying current with technological trends and suggest that having teaching staff with experience in industry or business would be beneficial. It is worth noting that this preference is particularly common among younger Italian respondents.[2]

Lastly, a small segment of the responses focuses on enhancing motivation for pursuing engineering from **primary and secondary school** levels. This includes promoting engineering careers and improving technical and mathematical preparation. Additionally, the importance of recognizing the profession's **status and the associated social responsibilities** is frequently highlighted.

[1] This is merely an observation, no causal relationship or correlation is being drawn in this analysis.
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Regarding **assessment and examination**, a similar distinction is evident. Some respondents advocate for more specialized and problem-based exams to better prepare students for professional practice and call for a reduction in theoretical exams. Others then argue for more challenging exams as a response to what they perceive as the "simplification of the curriculum," as seen in Italy, for instance.

Apart from the curriculum, attention is given as well to **international collaboration** and the standardization of educational requirements in Europe. "In Europe there is a different concept of what "engineer" means depending on the country are in. [...]. With different training plans ranging from 2 to 5 years." A call is made to push **common European regulation** on the study programs and a push for English taught courses.

Another point raised is the need for increased **student exchanges to foster cooperative networks** and facilitate the sharing of best practices across Europe.

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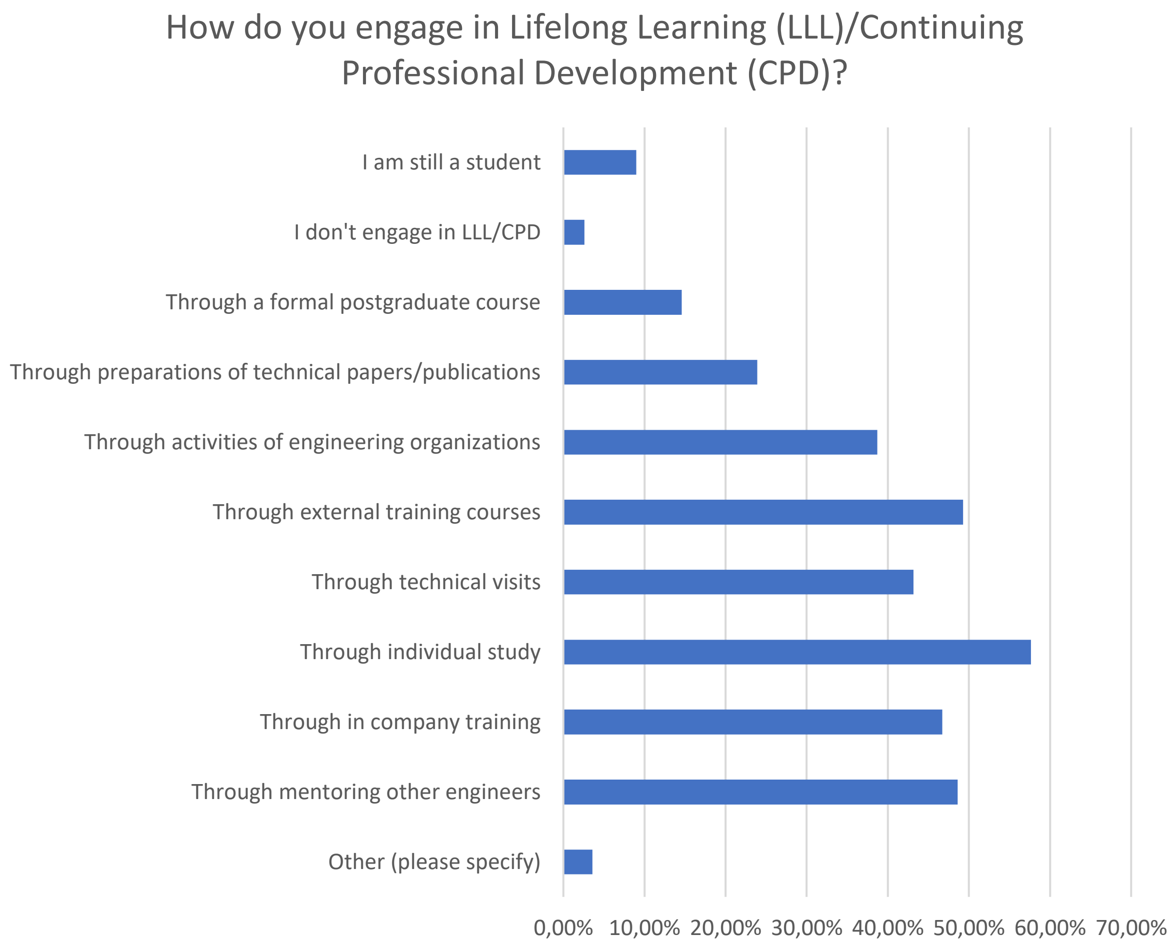
To understand how engineers engage in **Lifelong Learning (LLL) or Continuing Professional Development (CPD)**, the survey allowed respondents to select multiple options. Over half (57.66%) study individually in their field, followed by attending external training courses (49.29%) and mentoring other engineers (48.63%). Italian responses were also weighted in this section.



Of the 4.663 engineers who responded to this question, 148 indicated an additional method of LLL/CPD in the “other” category. "**Learning by doing**" was mentioned several times, accompanied by the belief that every engineer should continuously learn on the job. Other responses included participating in **competitions**, attending or delivering **conferences and meetings,** taking **online courses**, and learning through **project involvement**.

A notable recurring comment was that Italian engineers are regulated in their LLL/CPD activities, being required to earn 30 credits annually to practice their profession. However, this regulation is not always seen positively, with some engineers feeling "forced to take non-relevant training courses to fulfill credit requirements." Additionally, engaging in **politics** and **volunteering activities** (in professional engineering organizations, alumni organizations, etc.) were also mentioned. Lastly, another remarkable comment was the practice of "changing jobs (but not employers) every four years."

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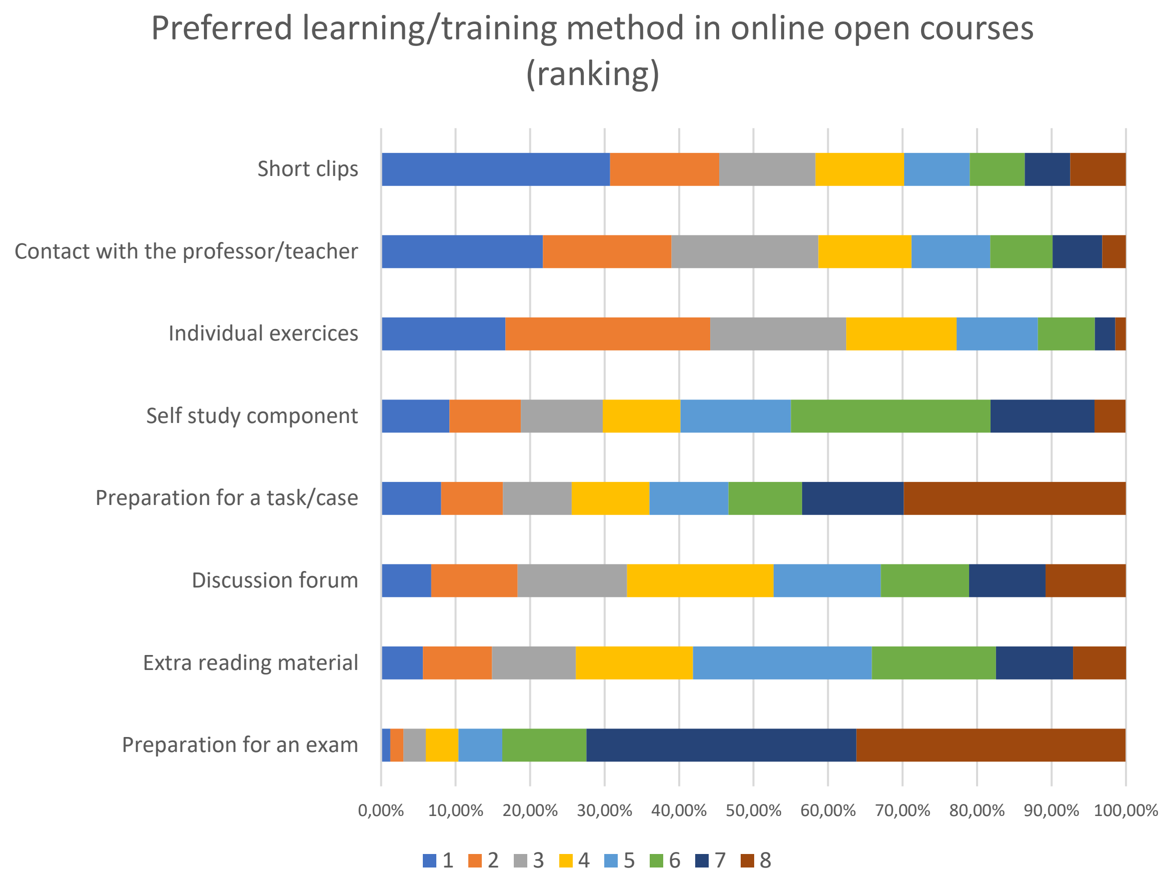
The survey then asked respondents to rank their **preferred training and learning methods in online open courses**. The Italian answers are weighed to avoid bias.



Short clips were the most preferred (ranked first by 30.76% of respondents), followed by contact with the professor/teacher (21.72%) and individual exercises (16.69%). Preparing for an exam was the least favored method.

Based on student responses, discussion forums are rated higher than task/case preparation, with extra reading materials being the least preferred learning method in an online open course.

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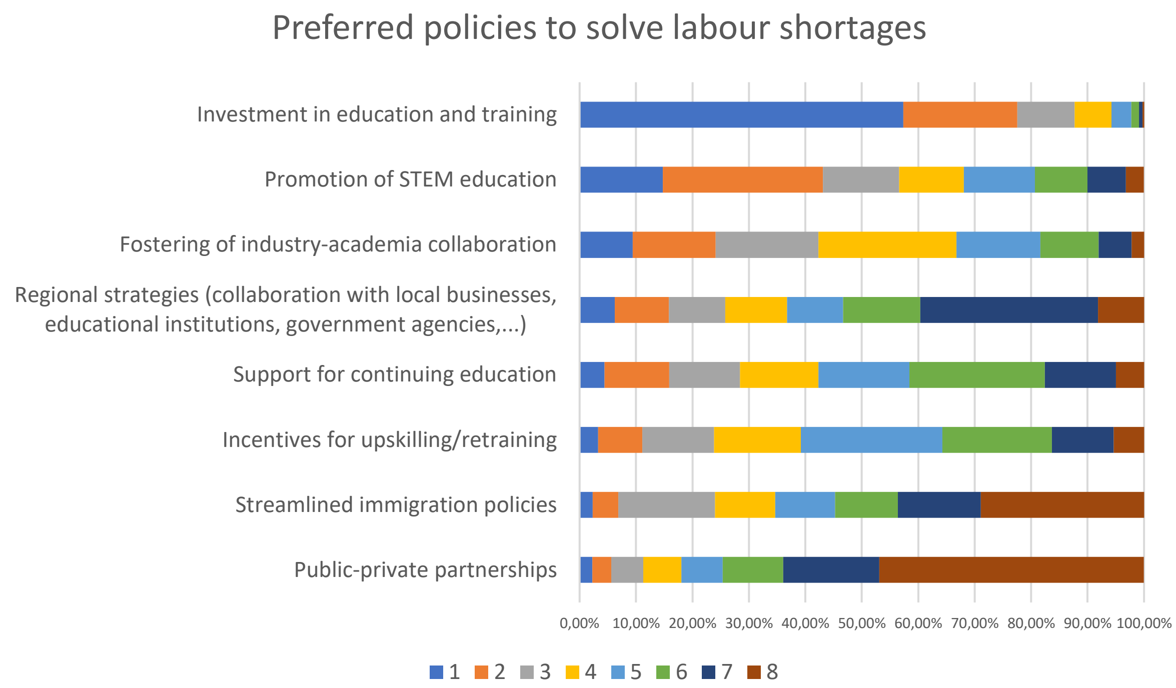
For the tenth question, the survey sought opinions **on effective strategies or policies to address labor shortages**. After weighing the Italian responses, 2.180 respondents answered this question and 392 continued without answering.



When ranking the options, 57.37% of respondents prioritized "investment in education and training," and 14.72% prioritized the "promotion of STEM education." "Streamlined immigration policies" and "public-private partnerships" were mostly ranked last.

When comparing the responses of professionally active engineers and engineering students, no clear differences emerge in the ranking of the competences listed above. Similarly, there are no significant differences in rankings when comparing respondents with bachelor's versus master's degrees, or when comparing engineers in "traditional disciplines" such as civil, mechanical, and electrical engineering with those in "newer fields" like software, environmental, and biomedical engineering.

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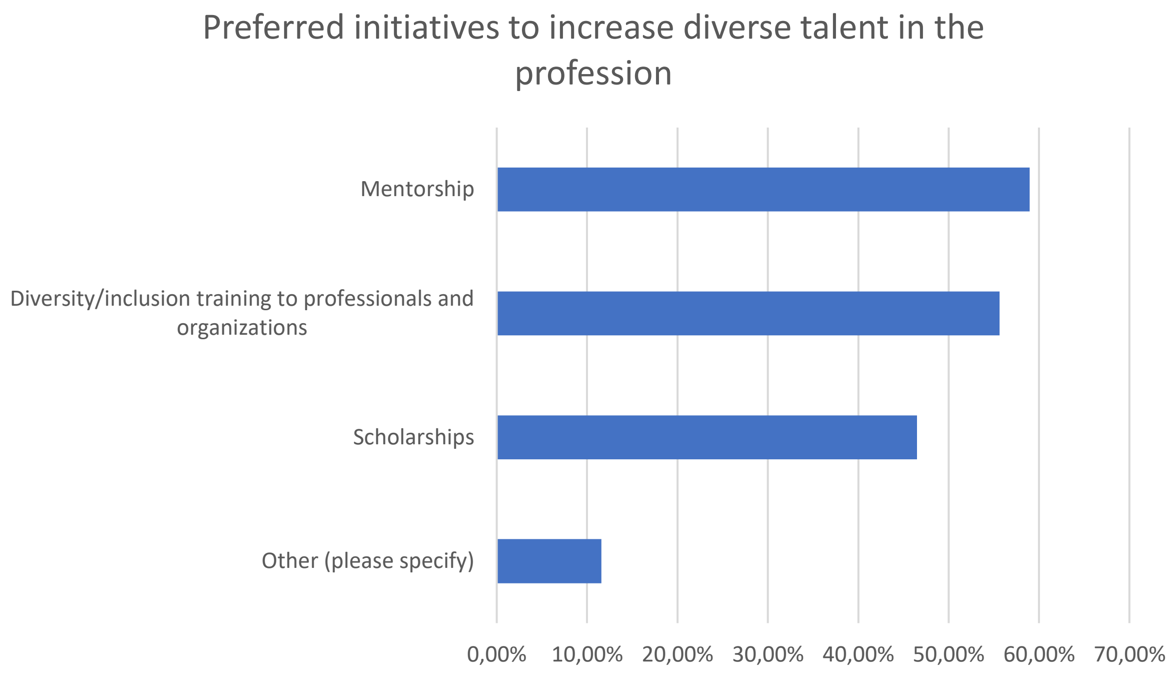
Finally, the survey asked about **preferred initiatives to increase diverse talent** in the engineering profession, clarifying that diverse talent includes underrepresented groups such as women, individuals from different racial and ethnic backgrounds, and individuals with disabilities. Respondents could select multiple answers and provide additional comments.



After weighing the Italian responses, more than half of the respondents supported mentorships and diversity/inclusion training for professionals and organizations. Scholarships were favored by 46.51% of respondents, with over 10% providing additional comments.

Among the 322 additional comments, several recurring themes emerged. Many respondents highlighted that a diverse and inclusive environment benefits everyone and could potentially address part of the labor shortage. **Equal treatment of diverse talent in the workplace, better communication about the profession, and motivating children from a young age** were identified as effective strategies.

Specifically, for female engineers, **promoting and increasing the visibility of successful female engineers, ensuring equal pay, and implementing inclusive marketing strategies** were seen as beneficial. Additionally, **creating accessible spaces, fostering transdisciplinary collaboration, and using inclusive language** were suggested as helpful measures. For older engineers, providing **training and inclusion programs** tailored to those with long careers was recommended.

On the other hand, some critical questions were raised. A number of respondents argued that there is no need for further diversity and inclusion initiatives in the profession or expressed opposition to **artificial modifications and quotas**. Additionally, several respondents emphasized that the primary focus should be on a person's skills, rather than their gender, race, or background.

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IV. Secondary Research Results

1. ENGINEERS EUROPE

1. Industry

In its "Memorandum for the European Elections 2024", **SME United** identifies huge structural difficulties for European small and medium sized-companies to recruit qualified staff, amongst other due to demographic changes. Representatives from across Europe amplify the need for a skilled workforce, whereas the urgent tightness of the labor market also strongly impacts the growth and competitiveness of 2,5 million SMEs, employing approx. 82,4 million people.[3] An increased supply of skilled labor can be achieved by **teaching an entrepreneurial mindset from an early age**. We need future entrepreneurs to create and takeover enterprises, **SME employees with a spirit of initiative and civil servants understanding the nature of entrepreneurs**. Another way to overcome the lack of skilled labor can be in **updating education and training content**, **with a strong support for dual training and apprenticeships**.

This would increase youth employment, overcome skills mismatches and promote lifelong learning to improve employability. Upskilling and reskilling can attract more people at a working age, especially women and youth, into the labor market and keep older workers longer in the market, which will also contribute to ensuring the sustainability of our social protection systems.

CECIMO, the European Association for Manufacturing Technologies, identified in its recent Survey on Skills, that to effectively address this challenge, the EU Member States should establish robust systems for upskilling and reskilling adults, amongst others by financing targeted training initiatives, **i.e. training specifically tailored to the upskilling and reskilling needs of the advanced manufacturing workforce**. Investments should be made addressing the industry's skill demands in three main areas : **production, mechanical/industrial engineering and electrical engineering**, thus ensuring a robust response to evolving technological landscapes.

In order to ensure that training programs are closely aligned with industry needs and remain responsive to the market's demands, CECIMO advocates **adult learning strategies through a holistic collaboration between European and national governments, industries and education and training providers**. This synergy ensures that training programs are closely aligned with industry needs and remain as highlighted in the CECIMO Paper "Transformation of Manufacturing: Embracing Digital and Green Skills." CECIMO further amplifies **the promotion of personalized learning strategies for skills acquired through vocational training in manufacturing**.[4] It is crucial to enhance the appeal of the manufacturing industry to tackle labor deficits, especially among young people and women. This involves raising awareness about the sector's advantages, its facilitating role in driving the digital-

[3] "*SMEs Driving the Transitions*", Memorandum for the European Elections 2024, https://www.smeunited.eu/publications/sme-priorities-for-european-elections-2024-crafts-smes-driving-the-transitions https://www.smeunited.eu/publications/

[4] "*Making Europe the World's Manufacturing Hub*", CECIMO Recommendations for the 2024-2029 EU Institutional Cycle. https://www.cecimo.eu/wp-content/uploads/2024/02/Making-Europe-the-Worlds-Manufacturing-Hub-CECIMO-Strategic-Recommendations-2.pdf

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green transition and the flexible learning pathways and certifications acquired through vocational training.

Developments in information and internet technologies and Industry 4.0 also accelerated the digital transformation of the industry. After the transformations from the "hunting society" (society 1.0), followed by the "agricultural society" (society 2.0) and the "industrial society" (society 3.0), to "the information society" with Industry 4.0 (society 4.0), we have now reached society 5.0 as the "smart society" in which factories have switched to the "smart" concept with a new level of social development, where technology is assimilated and used as a tool to increase human welfare. [5]

2. Universities and Education Providers

Due to the pressing need for action on sustainable development, it is important to include lifelong learning (LLL, or continuing education) in a discussion on **Education for Sustainable Development** (ESD). LLL is about enabling people to access education throughout their lifetime and ensuring that everyone has the knowledge, skills and competences they need to thrive in their personal and professional lives. LLL students may be working professionals or retirees, local or long-distance learners, interested citizens of all ages and all kinds of learners with a varied educational background. As the many opportunities and challenges around LLL in itself merit a fuller discussion, it may suffice to note that **LLL is an area of change for universities**, shaped by new and rapidly changing technologies, in part fueled by the Covid pandemic and by advances in artificial intelligence, and influenced by changing social habits and expectations. **Universities can provide LLL on sustainable development via on-campus and via online learning programs such as MOOCs** (massive open online courses), **SPOCs** (small private online courses), etc., **thus reaching far more and other students than they can otherwise reach.** Micro-credentials, as a way to certify the learning outcomes of short-term learning experiences, are being developed in many cases. **LERU** (League of European Research Universities) sees LLL as an opportunity to strengthen the engagement in their cities and regions on the topic of sustainable development, as on other topics. **LLL courses on campus are regularly used as a means of networking between the academic world, the business world and local government**.[6] Given their important role in educating current and future generations of experts and decision makers, it is logical for LERU (and other) universities **to link the goals of sustainable development to their desired, university-wide outcomes of education**. Clearly, one size does not fit all: different disciplines and different faculties require tailor-made solutions. To accelerate the efforts towards firmly integrating ESD in universities' teaching portfolios, it is essential to conceive this endeavor as a continuous participatory process, where ideally bottom-up and top-down initiatives interact in a synergetic way.

Universities must train the next generation of engineers with a holistic approach encompassing the central role of UNSDGs in their profession, to empower them to develop and implement innovative and disruptive sustainable solutions and products. **They must evaluate the competencies and**

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[5] "*Education 4.0 and University 4.0 from a Society 5.0 Perspective*", Cemal Akturk and Tarik Talan, Computer Engineering Department Gaziantep Islam, Science and Technology University Gaziantep Turkiye and Ceren Cubukcu Cerasi, Management Information Systems Department Gebze Technical University, Kocaeli, Turkey; pp. 577-582, 978-1-6654-1050-2/22/$31.00 ©2022 IEEE.

[6] "*How to Enhance Education for Sustainable Development*", Trends and Good Practice at LERU Universities, March 2024, LERU or the "League of European Research Universities", is a well-established network of research-intensive universities, https://www.leru.org.

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learning outcomes of engineering students against these UNSDGs and include a support and recognition system that values such developments. For that universities must also ensure a broader technical literacy relevant to sustainability amongst future engineers through debates, reflections and discussions. At the same time the **students need to be trained to use and understand AI in the broadest possible sense**, including its ethical, sustainable and economic impact as well as its challenges such as developing critical thinking towards the information delivered by AI.

To make the twin transitions in Europe successful, it will be important **to increase attention on vocational education and training (VET) as well as to increase its attractiveness**. It is essential to see VET institutions as equal partners and important players in educational ecosystems. Priority should be given to supporting STEM-related initiatives at the local and regional level and to take the measures needed to ensure that future cohesion policy planning has a more targeted approach to shortages of STEM skills. Policy reforms in teaching and learning that favor evidence-based pedagogical approaches to fostering interest in STEM also need to be encouraged, such as integrated STEM. Breaking down barriers between STEM disciplines is seen as vital to equipping students with 21st-century skills; however, **the adoption of integrated STEM approaches remains limited across the EU Member States**. The EU STEM Coalition recommends that member states set up a national STEM strategy, which can be done based on best practices from other countries, then adapted to the national as well as regional ecosystems. The European Commission has the opportunity to act as a catalyst for the development and upscaling of new, innovative and effective approaches for providing more context to STEM, increasing uptake and diversity and strengthening Europe's capacity to tackle a range of issues that affect all Member States. These issues have become even more pressing following the new challenges that all Member States are facing, such as the rapid energy transition, shortages of STEM-skilled people and increased skills gaps.[7]

3. Professional Organizations

A common task for Professional Organizations and Education Providers alike, is **to promote a culture of continuous learning and development** for which they could develop and offer professional courses and certifications that allow students to gain the specific skills required in the industry. For this to happen, it is important **to gather regular feedback from alumni who are working in industry to understand the skills that are in demand and the areas where the university can improve**. As key-stakeholders they have an interest to promote and establish a culture of lifelong learning where graduates and non-graduates are encouraged to continuously upgrade their skills through online courses, workshops and conferences. Professional Engineering related Organizations can **help by offering and strengthening career services by providing professional advice for better job placement to young engineers, assist in resume building and interview preparation, specifically tailored to the engineering sector and job market**.

A body such as the *"European Engineering Skills Council"* can serve as an "advisory board" or "think tank" as it will consist of representatives of academia, engineering associations, policy makers and industry professionals who **provide input and formulate recommendations on engineering**

[7] "*Memorandum EU STEM Coalition : Towards better STEM Policies and Implementation – Recommendations for the next steps*", The Hague, (23 February 2024); https://www.stemcoalition.eu/publications/memorandum-towards-better-stem-policies-and-implementation-recommendations-next-steps

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curriculum development to meet industry needs. The Skills Council will invite industry experts to deliver guest lectures and recommend workshops to universities to bridge the gap between theoretical knowledge and practical applications.

In this sense, the Council could become a permanent platform that facilitates continuous interaction between the public and private sectors and **serve as a forum for collaborative discussions on key policy matters regarding education, strategic industry concerns and other initiatives essential for the engineering profession at EU level**. By connecting industry/policymakers/research/other stakeholders, valuable resources can be leveraged in a collaborative project, eventually also with global partners, facilitating the exchange of knowledge and expertise.

4. Governments and Policy Makers

Although there are many studies and toolkits aimed at addressing the gender gap in STEM, the EU seems to lack consistent policies and a unified understanding of STEM and systemic strategies to tackle the gender disparity.

Policy makers must support European companies to put in place strategic actions in order to enhance and maintain their competitiveness. The EU must respond with a renewed focus on technological advancements, streamlined processes, and market-driven strategies to strengthen its work in key sectors within the EU market. A stronger manufacturing industry can help EU industrial ecosystems achieve the necessary transformative changes required by the digital and green transition. This policy agenda should focus on streamlining investments, reducing regulatory burdens and harnessing the potential of both existing technologies and emerging solutions. Such a comprehensive approach aims to give the EU a competitive edge across different industrial ecosystems.

5. Discussion: Dealing with the Twin Transition

5.

Mariana Mazzucato, one of the most influential economists of the decade, saw how European countries were pruning to get out of the crisis.[8] At the same time, they were envious of the big tech industry in Silicon Valley. The mantra was that innovative industries flourish when governments pull back. So they economized, in the name of growth and innovation. However, companies like Google and Facebook just became big because they could rely on massive government investment. Everything that makes the iPhone smart, such as the internet, the GPS, the touch screen or voice recognition, came from military research. Even medical or green innovations such as vaccines or solar panels have been largely funded by taxpayers. **It is not so much human genius as smart government investment that drives innovation**, she provokes. Mazzucato says it was the restructuring policy which caused damage in the economy as well as in society. When her idea of the entrepreneurial state gained traction, her first fans carried the political heart on the right. To win wars, **the state must invest in**

[8] *"Economizing to grow? That's the stupidest thing you can do as a government",* from Mariana Mazzucato, by Ine Renson (6 July 2024). Original title : "*"Snoeien om te groeien? Dat is het domste wat je als overheid kunt doen".* Mariana Mazzucato has thought-provoking ideas on how governments can boost growth and innovation, she advises world leaders such as Joe Biden or Brazilian and South African presidents Lula da Silva and Cyril Ramaphosa. She is hired by the European Commission, chairs international committees dealing with healthcare and the water crisis and is a familiar face at the UN, the World Economic Forum, the World Health Organization and the OECD. There is no world problem she does not seem to be involved in : https://www.standaard.be/cnt/dmf20240705_96336132.

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industry. What conservatives would rather not hear is that in exchange for those risks, **the government should also share in the profits**. They got that wrong in the US. Massive tax money was pumped into Silicon Valley, turning technology companies into monopolies. That has not necessarily been beneficial for society. This reasoning is the common thread running through Mazzucato's books. After shaking up our thinking about the role of government, Mazzucato explored exactly what "value" means in an economy ("*The value of everything*", 2018). In "*Mission economy*" (2021), she argues that **government should mobilize companies to take more risk together**. As with the moon landing back then, **we need to harness immersive missions to tackle big societal problems**. Only, she argued in "*The Big Con*" (2023), **the government lacks knowledge and clout, having outsourced its expertise to an army of consultants**. The book is a stinging indictment of the big consulting firms that the economist says are partly responsible for the breakdown of the state apparatus.

She also reflects on the 17 UN "sustainable development goals", such as climate action or eliminating hunger and poverty. Because that is where the ambition should lie, she argues. It remains too much about hollow slogans. The quest to go to the moon and back was a clear mission, aiming to beat the Russians in the space race. The government involved the private sector through tenders and subsidies, which companies started experimenting with. That led to innovations such as video calling, freeze-dried food and navigation control systems. It is time to apply that approach to humanity's real problems. **Challenges like climate neutrality or the digital divide need to move to the center of industrial strategy**. Her ultimate aspiration is to merge the welfare state and the innovation state. Focusing the economy on a higher goal, by setting up targeted public-private partnerships.

The private sector is very dependent on patents, which come from the state, but what does the state get in return for the monopoly profits generated by patents? The government really does not have to beg companies to come on board. On the contrary, they constantly ask for guarantees, loans, subsidies. There should be something in return. This also goes for the European Green Deal. The green part is okay, but the deal does not sit well. There are too many multinationals, such as food and energy companies, making billions because we make bad deals with them. They get favors, but there are no conditions in return. How do we really steer food companies towards sustainable food production? The "how" matters: how we work together and create value. Take the pandemic. We ended up with eight vaccines. Whereas the mission should have been: vaccinate the world. That only works if you force companies to keep prices low in exchange for subsidies.

Politicians are backtracking on the **Green Deal**, distracted by the discontent in society and we can't really be surprised by that. In many countries, the green economy is a race to the bottom, with low wages and poor conditions. The movements that have been crucial in the past century to ensure that transitions were also good for people and that capitalism is acceptable - no child labor, right to holidays - are seeing their impact wane. Therefore, **the answer to the discontent is not to scale back green policies**. That would be an unforgivable mistake. We should just be at the forefront, fueling a competitive green industry. But **the benefits must flow back to society broadly**. That will not be achieved by preaching and saying, "Trust us, green is good". It does by involving people in that process. **We need to educate our public managers and have the greatest ambition in that**. **Teaching future top officials to think about what a purposeful government is, what a creative bureaucracy looks like, how they can use digital governance for the common good.** Pruning to grow is the stupidest thing you can do as a government. But bright ideas collide with reality. On the table of many European governments is one big motto being heard: "save". They have to, from Europe, forcing countries in strict financial straightjackets into which countries like Belgium, France and Italy will be forced in the coming years. We have to choose the flight forward, but we are being thrown back into the most backward economic thinking ever. We know it doesn't work. The IMF and the World Bank now admit

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that Portugal, Spain, Italy and Greece saved themselves to pieces during the financial crisis. The budget deficit fell, but the debt ratio increased. According to Mazzucato, "**we invest billions in innovation, but that money is thoughtlessly strewn around in some climate projects here and some healthcare there**, hoping it will pay off. We should put that system in order, detect the big problems and their connections, and organize our structures purposefully. **States should streamline the gigantic sums they spend on energy companies, healthcare institutions, SMEs, NGOs, guarantees and loans**. Then the sum becomes greater than the parts. It's about investing smarter. We are not doing that. Europe is spending 2,000 billion on NextGenEU, the recovery plan to emerge stronger from the pandemic. Everyone is submitting plans to get their hands on some of that money. It is raining projects. **Every European project should work to encourage a better environment for entrepreneurship that promotes the development of an entrepreneurial mindset among researchers and other relevant communities**. This includes the provision of mentorship programs, comprehensive training initiatives, and financial support for startups and first time entrepreneurs. Nothing changes for the worse. **We must give wings to new economic thinking to ensure that future civil servants are different in their jobs**."

Another challenge and important discussion point which is being widely considered at present is the place of AI in academic practice. **How widespread is AI at our universities already** ? The use of AI will be explicitly allowed in the master's thesis at the University of Ghent, provided that students use the technology transparently and responsibly, according to Amber Janssens.[9] Five major trends could be identified from a survey undertaken of 17 professors from different disciplines. Especially generative AI, such as **ChatGPT, is already widely used by the majority of teachers for what they themselves describe as *routine tasks***, such as "**quickly formulating a standard reply to an e-mail", "polish papers linguistically", "proofread papers and project applications" or "to prepare PowerPoints for conferences"**. Thanks to AI, a given paper can be uploaded into a model, which automatically turns it into a slideshow. Generative AI is also considered a sparring partner by some professors to find inspiration, e.g. "**to find acronyms for the title of a project application**" or "**to find metaphors for a text or column**". A third trend has to do with "**finding new variants of exam questions, for instance by changing the context of the questions**". Others have given AI a seat at the table during class, for instance **when certain propositions at the students are submitted but remain without response**, they can be submitted to ChatGPT or Gemini. In this way AI gets a voice, but not the last word. Other professors require students to use AI, for example **to generate an image or to improve their language skills**. Many of the professors use AI, specifically **machine learning, to discover neural networks or patterns in datasets** : complex models for which a supercomputer takes up to three months, AI can do as much as 100 to 1000 times faster. In genetic genealogy, AI can be used to build family trees or to predict a protein structure based on the genetic code. Scientific research has become faster and more accurate thanks to technology.

Interestingly, most professors are convinced that they would recognize unauthorised use quickly, as certain sentence structures or words are very typical of AI and rare in certain professional jargon.

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[9] *"AI at the University: We already can't imagine scientific research without it",* by Amber Janssens (2 May 2024). Original title : " *AI aan de universiteit: "We kunnen ons nu al geen wetenschappelijk onderzoek meer voorstellen zonder"* https://www.standaard.be/cnt/dmf20240501_97061959

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"However, now we are still able to recognize AI texts", says Professor Leen Decin (KU Leuven), "but one day we won't know whether something was created by a human or a machine".

A somewhat different opinion is articulated in "The Master's Thesis may go in the trash, it no longer has a right to exist" (Cornelis/Van Vlasselaer)[10] of the University of Brussels, who claim that sticking to the master's thesis is a nostalgic reflex, even with all kinds of substitute forms of work that allow students to have the skills and knowledge they need to write a treatise autonomously (now with the support of generative AI). We need to recognise that there is no longer a place for it in training: every aspect of the research cycle can and will be done by generative AI. What they cite for the master's thesis applies to any paper for which they hope students will transparently indicate that they have engaged generative AI for it. The decree maker is hopelessly lagging behind. **Universities can no longer guarantee that graduates have achieved the required levels of the Qualifications Framework**: **students can meet it by using generative AI (without having the defined skills themselves)**. They hope that nothing like "responsible use of AI" will appear in the European and Flemish directives because that would be a joke. "If we let students graduate based on a body of work that no longer guarantees mastery of the skills a society needs, then the degree universities are delivering, is a lie. Students need to be able to **use generative AI efficiently and correctly** (which is different from "responsibly"), but they also need to have the necessary skills that could be adequately assessed until September 2023 (just before the arrival of generative AI)." The authors claim that if we want to know today whether students have mastered analogue academic skills, this can only be done through examination forms that exclude any application of generative AI. **It is also evident that students have the necessary digital academic skills, in particular training generative AI and interpreting its output. It is the job of higher education to teach them that. Evaluate analogue, digital and hybrid skills separately, but not in a piece of work like the master's thesis, where you cannot distinguish one from the other.** Can't we preserve the finals act by strictly interrogating students after they submit that work ? The authors claim not to be in favour of that aggressive approach, because it doesn't rule out false positives and we don't catch all the real positives with it. If we bury the master's thesis and evaluate the various aspects of academic writing and research in a staggered manner, there is no need for such stressful "questioning". Spreading the aspects throughout the year allows for **large-scale formative evaluation**: students immediately know where they stand and are adjusted. Achieving the skills can then be ticked off summative without an overarching form of examination. Incidentally, this approach fits well with what can already be seen in many programmes: extra guidance sessions for the final thesis, reflection moments in groups, workshops, seminars (or whatever we want to call them) in addition to the traditional guidance by the supervisor (and that role would therefore become superfluous). **Students will only really be helped by removing the master's thesis from curricula completely.** Students will then be guided in achieving their desired learning objectives on a regular basis, no longer dependent on promoters (with individual whims and agendas). **Graduates will have the necessary analogue academic knowledge that society expects from people with higher degrees, and they will be able to handle generative AI efficiently as well as with integrity, as the field of work will later require of them.** "To achieve that, the master's thesis must therefore become a relic."

[10] *"The Master's Thesis may go in the trash, it no longer has a right to exist",* by Gustaaf Cornelis (Professor Philosophy and Moral Sciences, University Brussels VUB) and Marijke Van Vlasselaer (Education Philosopher, University Brussels VUB), G. C. E. M. (29 March 2024). Original title : "De masterproef is dood, ChatGPT is de dader" https://www.standaard.be/cnt/dmf20240328_96905833

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6. Conclusions

1. As the world is in rapid change, this has important consequences for higher education. **The green and digital transitions require** unprecedented innovation with new technologies, processes and practices to drive positive change, as well as **more advanced and widespread levels of knowledge and skills, nurturing awareness, engagement and responsibility of learners**. To fulfil its mission and to respond adequately, **sustainable funding for higher education, enhancement and adjustment of existing policies and instruments, and the development of new ones are needed**. This includes new modalities of education provision, such as micro-credentials, the enhanced use of joint programs, and support for the entrepreneurial and innovation capacities of higher education institutions.

2. Universities should **focus on modernizing and reforming their academic curricula on a regular basis to align with technological advancements** and new emerging standards. These curricula should **incorporate emerging technologies** such as artificial intelligence (AI), machine learning, the internet of things (IoT), and advanced manufacturing techniques. Integration of advanced simulation and modeling tools in the curriculum will provide students with hands-on experience in using the software and technologies prevalent in the industry. The complex reality of the universities today implies that they are places for the formation of the bases of thought, the production of fundamental knowledge and the development of technologies as an implementation of knowledge into reality by launching start-ups and therefore by unfolding new practices.

   By implementing these strategies, universities can deliver engineering graduates who are better prepared to meet the demands of the modern workplace, thereby closing the skills gap and ensuring a more seamless transition from academia to industry. At the same time soft skills require emphasizing, such as communication, teamwork, problem-solving, and project management, all of which are crucial in the workplace.

3. SME's and larger companies alike must engage in- and promote joint research projects with academia in order to address real-world industry challenges. At the same time **companies should help to put in place support-systems by establishing mentorship programs where experienced industry professionals guide and support students** and new graduates. Companies can also support university labs by providing them with industry-grade equipment and tools to ensure realistic training environments. In cooperation with the higher education institutions and VET-providers, they can **offer internships and engage in co-operative education programs as part of the degree requirements to give students hands-on experience**, allowing them to work on real-world problems. This will lead to a better understanding and practical experience of industry scenarios.

4. Professional Organizations in the field of Engineering can **play a role in amplifying the need for lifelong learning**. The value of LLL in society is increasing, especially for all those requiring or desiring new competences to enhance their professional, personal or civic potential. **This includes the provision and recognition of new forms of education, such as micro-credentials**. New learning paths need to be flexible, properly delivered and quality assured. As Professional Organizations they should promote inclusion, upskilling and reskilling, and be aligned with the requirements of learners, the changing society and labor market. A proactive approach geared

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towards **closing the perceived skills gap between university graduates and workplace requirements in engineering, will require the involvement of different key-players** who focus on developing a multi-faceted strategy. The European Engineering Skills Council can by deploying its network assist in providing insights and advice regarding engineering related subjects in this area.

5. Governments and policy makers must **support education providers in** strengthening their contribution to society and their local communities, **responding to the UNSDGs** and the green transition in the area of higher education, to the ongoing digitalization and the combination of physical and online learning and teaching. The information received - from regular feedback of employers and industry representatives regarding the performance of graduates - can be used to **fine-tune and promote educational curricula and training methods**.

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2. ANECA

1. Background

From a holistic point of view, engineering is a strategic sector in any country. Its technological nature and ever-changing reality make it very attractive for the development of professionals with innovative ambitions and curricular progress. Additionally, due to the technological evolutions and revolutions that have been taking place in recent years in various areas such as digitalization and sustainability, there is a profound need for specialized professionals in attractive positions with suitable conditions. However, in the European environment in general, and in Spain in particular, there is currently a significant shortage of professionals, which is already having a negative impact on enterprise development [Econ2023][HAYS2024].

The objective of this work is to analyze the situation of the engineering professional environment in Spain concerning various factors, specifically:

- Dynamics of the labour market
- Most relevant technological trends and competencies for the short and medium term
- Most relevant soft skills from a professional perspective
- Gender gap in engineering
- The situation in universities and engineering-related curricula.

2. Methods

The methodology employed in this study involves a bibliographic review of various sources, including publicly available reports on the internet from consulting entities, government agencies at different levels (local, regional, national), digital press, and academic publications of various types, from conference articles or national and international journals to university academic works related to the subject.

For the selection of technological competencies and soft skills trends, a minimum of 10 different sources have been considered, allowing for a consolidated list of items to be obtained after analysis.

In the case of the university situation concerning engineering, the primary source is the Integrated University Information System provided by the Ministry of Universities.

3. Findings

3.1. Dynamics of the labour market

In general, the **labour** market in Spain is currently in a period of sustained growth since 2020, according to data provided by the Observatory of the Ministry of Labor and Social Economy [OBS2024], reaching an interannual increase of 3.4% in T12024. Additionally, the 24.3 million active workers in 1T2024 represent the highest figure since 2022

Overall, the sources consulted [ADECCO2024][HAYS2024][LK2024] agree that engineering, in general, is one of the sectors with the highest demand for employment, which is entirely consistent with the news regarding the need for engineers in the coming years.

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According to these reports, the most in-demand professions in the field of engineering are related to the following areas.

Table 1: Most demanded profiles in Spanish Engineering market.

Software and Web Developers		**Data Science and AI**
Full Stack Web Programmer or Developer		Data Scientist
Front End and Back End Developer		Data Analyst
Software Developer		Data Architect
UX/UI Expert / Designer		AI Expert
Cybersecurity		**Systems and Cloud Architecture**
Cybersecurity Specialist		Cloud Architect
Security Operations Center Analyst		Platform Engineer
		Blockchain Architect
Automation and Engineering		Information Systems Architect
Automation Engineer		**DevOps and Project Management**
Production Engineer		DevOps Engineer
Maintenance Manager		Project Developer
Mechanical Maintenance Technician		IPP Project Manager
Technical Service Technician		**Logistics and Procurement**
Electrical-Electronic Maintenance Technician		Logistics Expert
Electrical Design Engineer		Procurement Engineer
3D Printer		Logistics Manager
		Demand Planner
Quality and Sustainability		Production Manager
Quality Manager		**Executive Positions and Management**
Quality Engineer		Chief Digital Officer
Health, Safety, and Environment (HSE) Manager		Chief Information Officer
Sustainability Manager		CRM Manager

3.2. Technological competence trends

Technological updates and changes are inherent to engineering in any of its branches, always responding to the reality of society's needs. Therefore, it is mandatory for engineers to be in a continuous process of updating and improving their technical skills.

As mentioned earlier, the rapid pace of technological change needs continuous monitoring of the labour market to discover trends and identify those technologies of greatest interest to engineers. However, the field of engineering is very broad, and although there are common aspects, it must be analysed separately. In this regard, this study will consider the branches of civil engineering, industrial engineering, and IT, as these are the ones that, due to their breadth, can be more easily generalized. For each of them, five different sources have been considered, mainly from consultancies and specialized information websites, which are offered in table XX and the most important skills ordered from greatest to lowest relevance on table YY. The complete set of competences per source can be found on Annex I.

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Table 2: Sources for Hard/Technical Skills

Civil Engineering	Industrial Engineering	IT Engineering
StarUs Insights [StartUs2024]]	Engind[Engind2024]	Telefónica [Siles2024]
EIT [Horner2024]	BERS[Bers2024]	Linkedin[Mood2024]
Pinnacleiit [Pachani2024]	WE Education[We2024]	FutureTodayInstitute[FTI2024]
Deloitte [Meisels2024]	Ekon [Ekon2024]	ComputingD [Contreras2024]
Autodesk [Ragan2024]	AlterTécnica [Alter2024]	FBankinter[Bankinter2024]

Table 3: Top 5 Hard/Technical Skills

Rank	Civil Engineering	Industrial Engineering	IT Engineering
1	Sustainability and Efficiency	Big Data and Advanced Analytics	Artificial Intelligence (including Generative AI)
2	Building Information Modeling (BIM)	Artificial Intelligence (AI)	Sustainability
3	Advanced Robotics	Industrial Internet of Things (IoT)	Quantum Computing
4	3D Printing, Prefabrication and Modular Construction	Sustainability and Renewable Energies	Cybersecurity (Digital Security)
5	Generative AI and Digitalization	Cybersecurity	Edge Computing

The Future Today Institute report provides very valuable information regarding the time frame in which different technological trends will impact various economic sectors. It is important to highlight that the two common trends among the three studied branches, Artificial Intelligence and Sustainability, are also the ones that will have the greatest impact in the short term across most economic sectors.

Figure 1: Impacts of technological trends in industry, source [FTI2024]

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3.3. Soft skill competence trends

Without diminishing the importance of technical skills in the slightest, the comprehensive training and professional development of an engineer require a series of capabilities related to the environment in which they operate and their interaction with the rest of their team, clients, and suppliers. These capabilities are a mix of social competencies, personal attributes, qualities, and attitudes that enable engineers to perform their duties with high effectiveness and are usually referred as *soft skills*. These soft skills are highly appreciated by the employers, therefore the future engineers, and also those in their professional development, has to be trained on them.

To determine the most relevant soft skill, 10 different sources have been analysed, consisting of consulting firms, websites, articles, and academic papers. Specifically, the following sources:

1. APD (Association for Management Progress) [Monroy2024]
2. Linkedin [Brodnitz2024]
3. Forbes [Danao2024]
4. MDPI Education Sciences, [Hirudayaraj2021]
5. Journal of Universal Computer Sciences [Maturro2019]
6. Pontifical University of Comillas [Lozano2024]
7. University of Seville [Perez2024]
8. VII International Congress on Learning, Innovation, and Cooperation [Laso2023]
9. ASELEC consultants [ASELEC2023]
10. San Pablo CEU University

A list of 141 soft skills has been compiled, with the complete list provided in Annex I. They have been analysed and grouped based on similarity, avoiding repetitions. As a result, the following list of soft skills, which can be considered key for the development of the engineering profession, has been derived, listed from most to least relevant.

Table 4: Most demanded soft skills in Spanish labour market

Most demanded soft Skills
Leadership
Communication skills
Teamwork
Problem-solving
Critical thinking
Creativity
Time management
Flexibility and Adaptability
Conflict management
Autonomy

3.4. Gender gap in engineering

The gender gap in the Spanish engineering market remains significant, falling short of an ideal balance [OIE2024]. According to the latest report from the Spanish Engineering Observatory, women are underrepresented across all engineering fields. Women make up only about 20% of the 750,000

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engineers in Spain. Telecommunication Engineering (electrical and electronic engineering) has the lowest percentage of women, at just 12%, followed by Computer Engineering at 16%, and Industrial Engineering at 19%. In contrast, Civil Engineering with 24 and Agricultural Engineering with 34 % have the highest representation of women.

This Spanish situation is homogeneous with the surrounding countries, for example, France, Germany and Italy has a representation of women in engineering of 22%, 18% and 17 % respectively.

It is interesting to observe the distribution over the age range. Generally speaking, it can be noticed that the interest of women on engineering in Spain has had a descending trend as the percentage of women in the <35 range is lower than in 36-45 range in all engineering's but computer science.

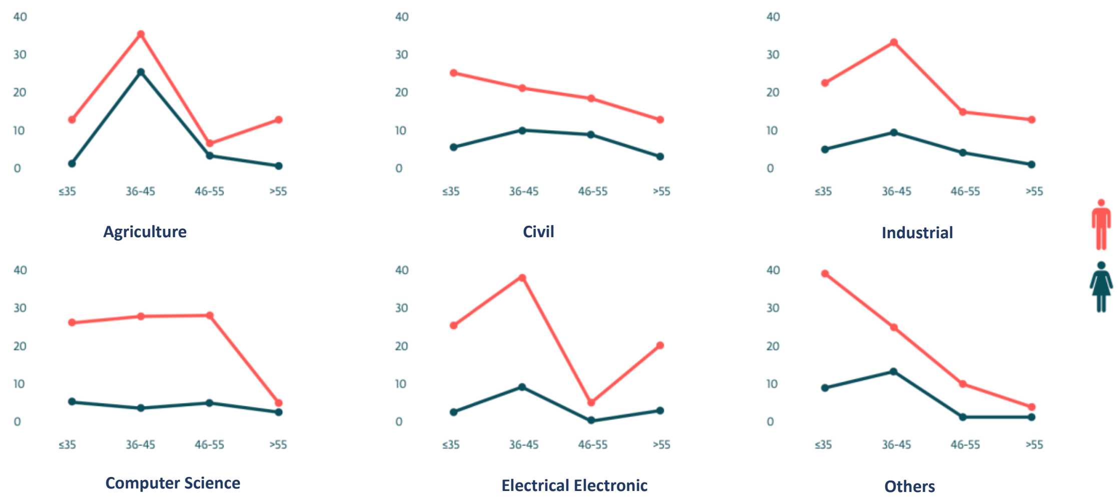

Figure 2: Percentage of women on engineering areas depending on age range in Spain, source [OIE2024].

Analysing the situation at the higher education level, specifically in universities, and considering not only engineering degrees but all STEAM degrees, boys dominate STEM fields, with the gap being especially pronounced in computer science and engineering. Conversely, girls tend to choose degrees in education, health, and social services [Cobreros2024].

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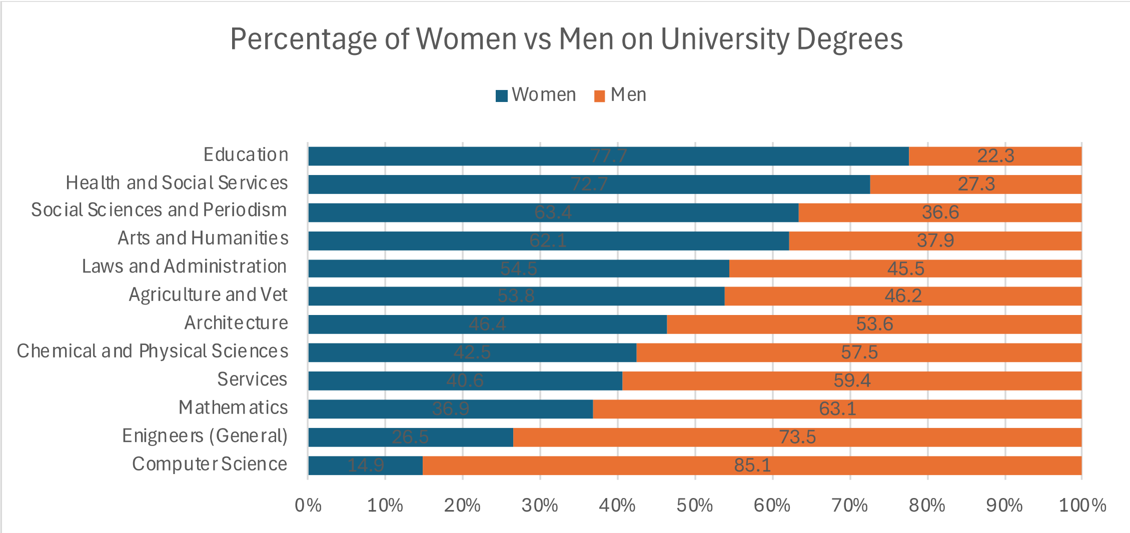

Figure 3: Percentage of women per knowledge areas in university degrees in Spain.

Therefore, the root of the problem (and potentially the solution) lies in primary and secondary education. According to information provided by the Social Observatory of "La Caixa," only 0.7% of teenage girls are interested in pursuing a technological university degree **[**Usart2024**].**

Several reasons have been identified for this situation, the main ones being: [Aragones2024] [Noutary2024**]**

- **Gender stereotypes**: Despite evidence to the contrary, there persists a perception that STEM fields are more suitable for men. This can discourage girls from an early age from becoming interested in these areas and perpetuate women's underrepresentation in STEM.
- **Unconscious biases:** Entrenched stereotypes can lead to unconscious biases in processes such as project funding, hiring, and promotions within STEM fields. These biases can disadvantage women and contribute to their underrepresentation in leadership roles and research.
- **Lack of role models and mentors:** The shortage of women in leadership positions within STEM makes it difficult for young women to find role models and mentors who can guide them in their careers. This is crucial to help overcome the obstacles and challenges they face in a male-dominated environment.
- **Work-life balance imbalance:** Careers in STEM often involve long hours and intensive commitments. Women are more likely than men to opt for reduced hours or part-time work due to family responsibilities. This can limit their opportunities for career advancement and contribute to gender disparity in the workplace.
- **Absence of information**: There is an important lack of knowledge about the real-world applications of engineering particularly those related with social impact.
- **Specific subjects' difficulty level:** The perception of the high difficulty level of fundamental subjects, combined with the curriculum structure where specialized subjects are primarily located in the third and fourth years, may discourage prospective students in general and girls in particular.

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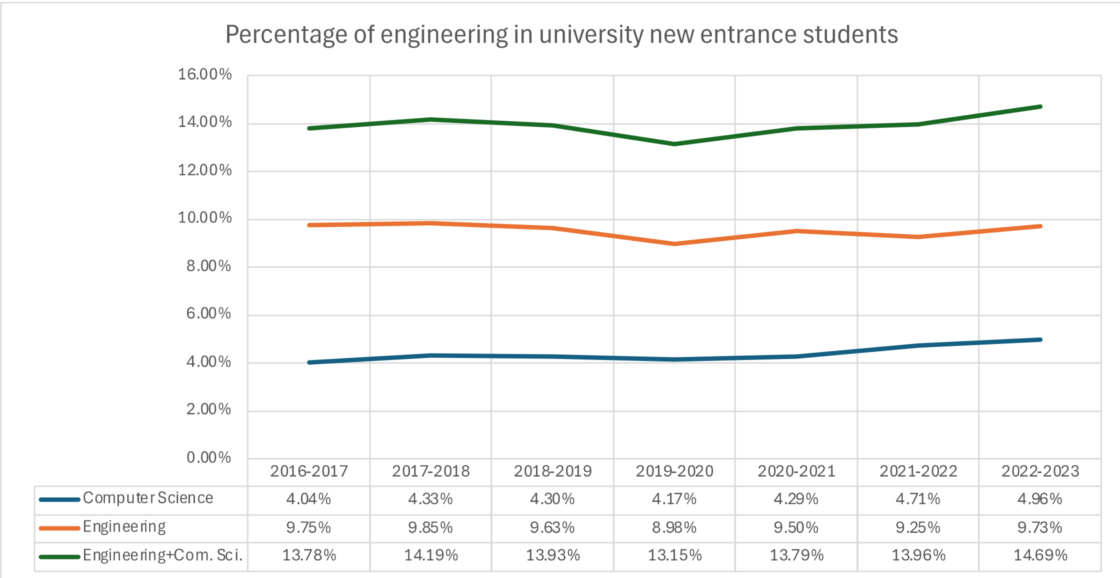
3.5. University situation

In this section, the situation of engineering in Spanish universities is analysed from the perspective of the total number of new admissions. Additionally, a specific focus about women is provided as a continuation of the study from the previous section.

The data has been obtained from the Integrated University Information System (SIIU). It is important to note that in the SIIU, data related to Computer Science degrees are separated from the rest of the engineering degrees for two reasons. The first is historical, as some degrees originate from the old licentiate programs (with French roots) instead of engineering programs (with Anglo-Saxon roots). The second reason is that Computer Science has not been established as a regulated profession, unlike other engineering fields (with the exception of certain specializations).

The most relevant results are presented below, with the full set of tables available in Annex II.

The percentage of new admissions in engineering degrees has remained approximately stable, with a slight improvement, over the past six academic years. The value for the 2023-24 academic year is 14.69%.



	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022	2022-2023
Computer Science	4.04%	4.33%	4.30%	4.17%	4.29%	4.71%	4.96%
Engineering	9.75%	9.85%	9.63%	8.98%	9.50%	9.25%	9.73%
Engineering+Com. Sci.	13.78%	14.19%	13.93%	13.15%	13.79%	13.96%	14.69%

Figure 4: Percentage of engineering students over the total new admissions.

The percentage of women entering engineering studies relative to the total number of new admissions has slightly increased from 2.84% in the 2016-2017 academic year to 3.6% in the 2023-24 academic year. However, this is a vegetative growth that corresponds to the increase in the percentage of women among new university admissions. This can be seen in Figure XX, where the percentage of women studying engineering relative to the total number of women entering the university remains approximately constant at around 18%, with a slight increase in the field of Computer Science from 0.97% to 1.69%.

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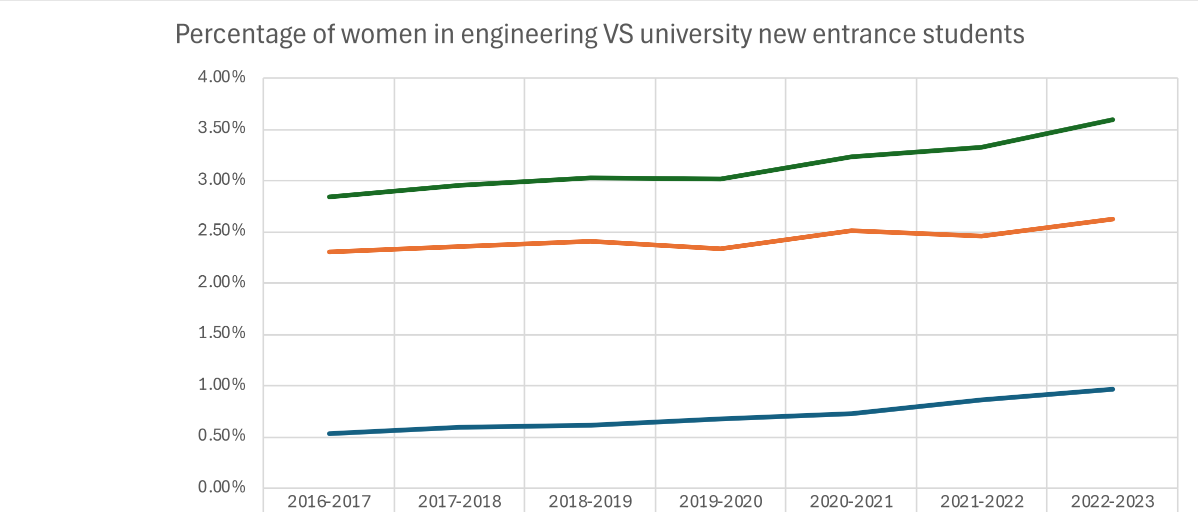
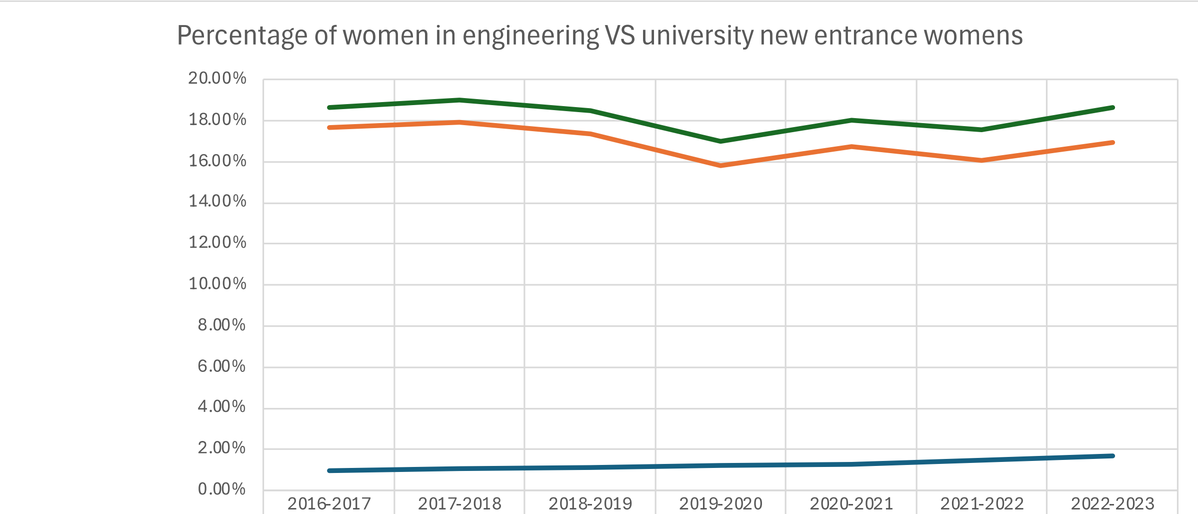


	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022	2022-2023
Computer Science	0.54%	0.60%	0.62%	0.68%	0.73%	0.87%	0.97%
Engineering	2.30%	2.36%	2.41%	2.34%	2.51%	2.46%	2.63%
Engineering+Com. Sci.	2.84%	2.96%	3.03%	3.02%	3.24%	3.32%	3.60%

Figure 5: Percentage of engineering women students over the total new admissions.



	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022	2022-2023
Computer Science	0.97%	1.09%	1.12%	1.20%	1.28%	1.50%	1.69%
Engineering	17.65%	17.91%	17.38%	15.80%	16.74%	16.04%	16.96%
Engineering+Com. Sci.	18.62%	19.00%	18.49%	17.00%	18.01%	17.54%	18.65%

Figure 6: Percentage of women engineering students over the total new women admissions.

4. Conclusions

This section presents the main findings from the report:

1. The labour market in Spain is growing, and there is a high demand for professionals in various fields of engineering. Among them, those related to software development, cloud architectures, AI, sustainability, automation, quality, and cybersecurity stand out.

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2. New technical/hard skills vary depending on the engineering field; however, trends related to sustainability, artificial intelligence, and cybersecurity appear common across all fields covered in this research.
3. There is a general consensus on the importance of soft skills: communication (oral and written), leadership, and teamwork are deemed the most relevant.
4. Women are underrepresented in engineering at both national (Spanish case) and European levels. This underrepresentation is linked to sociological factors and work-life balance issues.
5. Based on the number of new university engineering admissions, the shortage of engineers does not appear to be addressed in the near future, at least in the Spanish context.
6. Policies aimed at attracting children to engineering have not yielded significant results, nor have policies to attract more girls.

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Annex I

Organization	Hard/Technical Skills, Civil Engineering				
Startus-Insights	Building Information Modeling	Green Building Materials	Renewable Energy Integration	Advanced Robotics	Geographic Information Systems (GIS)
	Modular Construction & Prefabrication	Structural Monitoring and Assessment	3D Printing	Advanced Materials	Disaster Management
EIT	3D Printing: Revolutionizing Construction	Drones: Elevating Construction Management	Robotics: Transforming Construction with Efficiency	Off-Site Construction: Modernizing Building Methods	Exoskeletons: Boosting Worker Safety and Productivity
Pinnacleiit	BIM (Building Information Modelling)	Virtual Construction and Building Information Modelling (BIM)	Labour Shortages and Workforce Management	Sustainability and Efficiency	Generative AI and Digitalization
	Prefabrication and Modular Construction 8. Drones and Robotics	3D Printing in Construction	Construction Management Software (CMS)		
Deloitte	Heightened focus on sustainability and efficiency	Advancement of digitalization and generative AI	Differentiated impact of market uncertainty across the residential and nonresidential segments	Change in operating strategies to manage volatility in costs, demand, and customer priorities	New workforce norms to bridge the lingering talent and skills gap
Autodesk	AR and Drone's Impact on the Industry	A Global Rise in Modular	Growth in Robotics, Hybrid Work, Data Tracking, and AR / VR	AI and Data's Impact on the Industry	Continued Investment in Automation and Robotic Technologies

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	The Strength of Industrialized Construction	Greater Integration and Collaboration	Opportunities for Digital Construction and Mass Timber	Investing in Data Quality	Growing Focus on Data Collection and Mental Health in Construction
	Growing Power of Predictive Analytics and Mixed Reality	Continuing Evolution of eXtended Reality in Construction	Robotics, AR, and VR	Robust Digital Strategies and Automation to Streamline Operations	Increased Focus on Preconstruction and Prequalification to Derisk Projects
	A Shift to an Asset-First Approach in Design, Construction, Handover, and Operations	An Increased Focus on Sustainability	Sustainability Issues Will Be at the Core of Corporate Strategy	Power and Importance of Collaboration	Expanding Technology and Modular Construction
	Increased Utilization of BIM, Digital Twins, and Cohesive Digital Workflows	The Crucial Role of Information Management and Connected Data	Automation and the Future of Remote Work in Construction		

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Organization	Hard/Technical Skills, Industrial Engineering				
Engind	New Technologies in Engineering	Big Data and Advanced Analytics	Collaborative Robotics	Sustainability and Energy	Efficiency 3D Printing and Additive Manufacturing
BERS	Intelligent Automation	Collaborative Robotics	Internet of Things (IoT)	Clean Energy and Sustainability	Augmented and Virtual Reality Advanced
	Cybersecurity	Blockchain in the Supply Chain			
W/E Educación Ejecutiva	Automation	Robotics	Sustainability and Renewable Energies	Internet of Things	Additive Manufacturing: 3D Printing
Ekon	Industrial Robotics	Smart Manufacturing	Nanotechnology in Industry	Digital Transformation	Cybersecurity
	Sustainability	Renewable Energies	Circular Economy		
AlterTecnica	Artificial Intelligence	Cybersecurity	Industry 4.0 and 5.0	Decarbonization	Chips and Semiconductors
	Water Treatment				

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Organization	Hard/Technical Skills, ITEngineering				
Telefónica	Robotic Automation	Widespread Application of AI	Cybersecurity	Quantum Computing	Big Data
	5G, Universal Connectivity	IoT and Hyperconnectivity in Devices	Edge Computing		
Linkedin	Platform Engineering	AI	Sustainability	Zero Party Data	Inner Development Acceleration
	Generative AI	Agile Planning	Talent Management and Education	Customer Service and Work Environment	Biometric Security
Future Today	Artificial Intelligence	Bioengineering	Web 3.0	Metaverse	Sustainability, energy and climate
	Robots and Drones	Health Care and Medicine	human-computer interaction	Automation and data collection	Entertainment & Relax
	Financial Services and Insurances	Analytics and customization in sports	Space	Supply Change Logistics	
Bankinter	Artificial Intelligence	Virtual, Augmented, and Mixed Reality	Urban Revolution	Precision Medicine	Education for Innovation
	Sustainability	Space Research	Neuroscience and Neurotechnology	Digital Security	Classical and Hybrid Computing
Computing	Generative AI	Digital Twins	IT-OT Convergence	Edge Computing	Sustainability

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	Container Adoption	Decentralized Infrastructure Management	Hyperconverged Infrastructure	Efficiency and Innovation	Generative AI
	New DevOps Approach	Education and Training			

Organization	Soft Skills				
APD	Problem-solving	Flexibility and adaptability to change	Emotional intelligence and empathy	Communication skills	Ethical responsibility
	Time management skills	Creativity and innovation	Leadership	Ability for continuous learning and development	Persistence and resilience
Linkedin	Communication	Customer service	Leadership	Project management	Analytics
	Management	Teamwork	Sales	Problem-solving	Research
Forbes	Communication	Leadership	Teamwork	Creativity	Time management
	Adaptability	Problem-solving	Work ethic	Critical thinking	Conflict management
MDPI Education Sciences	Leadership	The ability to deliver effective presentations	Global and cultural awareness	The ability to plan and think strategically	The ability to write effectively
	The ability to deal with uncertainty in relating to people and situations	Social responsibility	The ability to communicate across age groups Creativity: coming up with 'out-of-the-box' ideas and solutions	The ability to communicate effectively with diverse groups of people	Time-management
	Ability to handle multiple priorities	Critical thinking	The ability to work under pressure	Focused: the ability to stay focused on a task	Willingness to take initiative

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	Staying/ being organized	Flexibility and adaptability	Curiosity	Self-motivation	Responsibility
	Reliability	The ability to work in teams	Positive attitude		
Journal of Universal Computer Science	Analytical skills	Autonomy	Change management	Commitment/Responsibility	Communication skills (oral / written)
	Conflict management	Creativity creativity, creative thinking.	Critical thinking	Customer orientation.	Decision-making
	Ethics	Fast learner	Flexibility	Initiative	Innovation
	Interpersonal skills	Leadership	Listening skills	Methodical	Motivation
	Negotiation skills	Organizational/Planning skills	Presentation skills	Problem solving skills	Results orientation
	Stress management	Team management	Time management	Willingness to learn	
Universidad Pontificia de Comillas	Communication	Leadership	Honesty	Flexibility	Creativity
	Emotional Intelligence	Problem-Solving Ability	Critical Thinking	Teamwork	Continuous Learning
Universidad de Sevilla	Effective communication	Teamwork and emotional intelligence	Problem-solving	Time management and organization	Adaptability and flexibility
	Leadership and influencing	Empathy and intercultural skills			
CINAIC 2023	Self-reflection	Confidence	Emotional intelligence	Personal presentation	Anticipatory capacity
	Sense of organization	Sense of responsibility	Initiative-taking	Work awareness	Efficiency
	Respect for rules	Ethical sense	Assertiveness	Communication	Leadership
	Teamwork	Acceptance of feedback	Adaptability	Learning to learn	Autonomy
ASELEC	Creativity	Communication	Leadership	Teamwork	Empathy

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	Problem-solving ability	Stress management and control	Emotional intelligence	Critical thinking	
CEU San Pablo	Learning to learn	Adaptability	Persuasion skills	Communication skills	Leadership
	Ability to manage teams in a context of uncertainty	Time management	Empathy	Ingenuity	Analytical thinking
	Resilience	Commitment	Pursuit of the common good		

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Annex II

	Academic Course						
New Admissions	**2016-2017**	**2017-2018**	**2018-2019**	**2019-2020**	**2020-2021**	**2021-2022**	**2022-2023**
Total New Admissions	337105	337055	341995	359111	345108	360028	363494
Computer Science	13612	14610	14693	14981	14809	16968	18026
Engineering	32853	33205	32932	32239	32771	33305	35369
Eng. + Computer Science	46465	47815	47625	47220	47580	50273	53395
Computer Science %	4.04%	4.33%	4.30%	4.17%	4.29%	4.71%	4.96%
Engineering %	9.75%	9.85%	9.63%	8.98%	9.50%	9.25%	9.73%
Eng. + Computer Science %	13.78%	14.19%	13.93%	13.15%	13.79%	13.96%	14.69%

Women in Engineering over New Admissions (W+M)	Academic Course						
	2016-2017	**2017-2018**	**2018-2019**	**2019-2020**	**2020-2021**	**2021-2022**	**2022-2023**
Total new Admissions	337105	337055	341995	359111	345108	360028	363494
Women Computer Science	1806	2016	2114	2443	2504	3120	3523
Women Engineering	7764	7953	8248	8409	8668	8843	9556
Women Eng. + Computer Science	9570	9969	10362	10852	11172	11963	13079
Women Computer Science %	0.54%	0.60%	0.62%	0.68%	0.73%	0.87%	0.97%
Women Engineering %	2.30%	2.36%	2.41%	2.34%	2.51%	2.46%	2.63%
Women Eng. + Computer Science %	2.84%	2.96%	3.03%	3.02%	3.24%	3.32%	3.60%

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Women in Engineering over New Admissions (W)	Academic Course						
	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022	2022-2023
Total new Women Admissions	186116	185348	189534	203988	195812	207614	208553
Women Computer Science	1806	2016	2114	2443	2504	3120	3523
Women Engineering	32853	33205	32932	32239	32771	33305	35369
Women Eng. + Computer Science	34659	35221	35046	34682	35275	36425	38892
Women Computer Science %	0.97%	1.09%	1.12%	1.20%	1.28%	1.50%	1.69%
Women Engineering %	17.65%	17.91%	17.38%	15.80%	16.74%	16.04%	16.96%
Women Eng. + Computer Science %	18.62%	19.00%	18.49%	17.00%	18.01%	17.54%	18.65%

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3. AECEF

1. Background

Several studies have been done in this area and related topics. The work presented here builds on documents published in the past, in particular the publication *A Tuning-AHELO Conceptual Framework of Expected Desired/Learning Outcomes in Engineering*, documents of the European Civil Engineering Education and Training (EUCEET) Association, the *EUR-ACE Framework Standards and Guidelines* (EAFSG) and the TUNING CALOHEE Terms of Reference. Together these present a rather complete overview of the field, reflecting developments in the subject area of Civil Engineering and in society.

This part of the survey concerns degree profiles and the tasks and societal roles graduates will take on. In other words, which are the essential elements that constitute a particular subject area like Civil Engineering in higher education and in the profession? In terms of training, each degree programme in Civil Engineering has its own unique profile based on the mission of the institution and taking into account its social-cultural setting, its student body, and the strengths of its academic staff. These imply regulations and qualifications in professional profiles leading to the relevance of the national or world engineering professional organisations.

The recent methodologies used to define the higher education Civil Engineering programs are based on the student-centred and active learning approaches. Tuning academy, for instance, intends to offer a platform for debate and reflection, which leads to higher education models able to ensure that graduates are well prepared for their societal role, both in terms of employability and as citizens. Graduates need to have obtained as the outcome of their learning process the optimum set of competences required to execute their future tasks and take on their expected roles. As part of their education, graduates should have developed levels of critical thinking and awareness that foster civic, social and cultural engagement.

Using these approaches, Outcome Based Education allows schools to make study programmes comparable, compatible and transparent. These are expressed in terms of learning outcomes and competences. Learning outcomes are statements of what a learner is expected to know, understand and be able to demonstrate after completion of a learning experience. Learning outcomes are expressed in terms of the *level of competence* to be obtained by the learner. Competences represent a dynamic combination of cognitive and meta-cognitive skills, knowledge and understanding, interpersonal, intellectual and practical skills, and ethical values. Competences are developed in the course units and assessed at many different stages of each programme. Some competences are subject-area related (specific to a subject area), others are generic (relevant for many or all in degree programmes).

The initial core competences of the Civil Engineering area were identified in a consultation process involving four stakeholder groups - academics, graduates, students and employers - over a period of around seven years. To make levels of learning by the future civil engineers measurable, comparable and compatible descriptors were defined. Applying descriptors, which cover different areas or ‘dimensions’ of learning: knowledge and understanding, application of knowledge and understanding in relation to problem solving, making judgments, communicating information and conclusions, and finally, knowing how to learn, allow a proper definition of the Civil Engineering program outcomes.

Engineering has classically been defined as the profession that deals with the application of mathematical, scientific and technical knowledge in order to use natural laws and physical resources to help design and

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implement materials, structures, machines, devices, systems and processes that safely accomplish a desired objective. As such, engineering is the interface between mathematical and scientific knowledge and human society. The primary activity of engineers is to conceive, design, implement, and operate innovative solutions – apparatus, process, and systems – to improve the quality of life, address social needs or problems, and improve the competitiveness and commercial success of society.

The original formal use of the term *engineer* applied to the constructor of military engines such as catapults. Later, as the design of civilian structures such as buildings and bridges evolved as a technical discipline, the term *civil engineering* entered the lexicon as a way to distinguish between those specialising in the construction of such non-military projects and those involved in the older discipline of military engineering. As technology advanced, other specialty fields such as *mechanical*, chemical, *electrical* and *electronic engineering* emerged.

In recent years, branches such as biological engineering, food engineering, environmental engineering, and even financial engineering have been added to the specialisations. Interestingly, as these new branches emerge, the complex future challenges demand more interdisciplinary knowledge from all engineers, hence breaking down the barriers between different areas of engineering.

Civil engineering is a professional engineering discipline that deals with the design, construction, and maintenance of the physical and naturally built environment, including works like buildings, bridges, canals, dams and roads. There are several specialisations, like construction, hydraulics, structures, etc. Several other specialisations were created within civil engineering and have gained independent status, such as mining and mechanical engineering. It is the oldest engineering specialisation, and it is intertwined with architecture. Architecture conceives, civil engineering executes.

Civil engineering provides the majority of the infrastructure and significant parts of the public and private facilities that are used in our day to day lives. It is the area of engineering that most affects and transforms the physical world and is the backbone of modern living, with a significant impact on public health and life quality. It is related to buildings, urban planning, environment and materials, running and clean water, and transportation infrastructures. Additionally, most civil engineering projects are unique and have a long design life in contrast to the short lifetime/obsolescence of many manufactured products of other engineering fields.

Civil engineering work has an inherently high degree of complexity, where non-engineering issues dealing with social, political, economic and environmental concerns, as ethical issues, have become far more important than previously, with the emergence of new fields of activity such as Urban and Environmental Planning, Strategic Environmental Assessment, Economic Evaluation of Projects and so on. Also, sustainability calls for civil engineers to be leaders.

Engineering education basically deals with the transfer of theoretical knowledge to engineering applications. With engineers facing challenging expectations, including the ability to address complex societal problems, engineering education must be carefully planned and executed so that the student obtains the necessary competencies to be a successful professional engineer.

This education must include a strong grounding in mathematics and basic science, as well as training in the specialty-specific engineering sciences. Curriculum developments are a delicate balance between keeping up the necessary 'fundamentals', represented by mathematics, basic sciences and core engineering subjects, and their application in engineering design projects and products. Design problems are increasingly complex and

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comprise input and assessment over a broad range of fields, combined to produce an 'optimal' solution that will be acceptable for all parties involved.

The complexity of modern challenges facing engineers also requires that the education include a sound foundation in topics such as economics, communications, team skills, and the current global geo-political environment. Technical developments and the growing complexity of activities have generated strong pressure on the number of subjects to be given in civil engineering programmes and on the volume/content in each of their components. This has encouraged an increased focus on the concept of lifelong learning in education. It becomes imperative 'to learn how to learn', the 'need to know' is being replaced by the 'need to know where to find'.

Furthermore, engineering has a direct and vital impact on people's quality of life. Accordingly, the services provided by engineers require honesty, impartiality, fairness and equity. Engineers must be dedicated in particular to the protection of public health, safety and welfare. They must uphold a standard of professional behaviour, adhering to the highest principles of ethical conduct.

The typical degree programmes in Civil Engineering are denominated in English as:

1. Bachelor with a total of ECTS credits ranging from 180 to 240.
2. Master with a total of ECTS credits ranging from 60 to 120.
3. Integrated Master with a total of ECTS credits ranging from 240 to 300.

Depending on the country, first cycle degrees may be either a three or a four-year programme. In reference to the Bologna Process, first cycle graduates should be both employable and qualified to enter a second cycle programme. Graduation from a first cycle programme, however, does not necessarily signify that the graduate is prepared to enter the practising profession. In some countries, there are two tracks for first-cycle degrees. One is designed to prepare students for more applied careers; these students may not be adequately prepared to enter advanced (second cycle) educational programmes in engineering without additional preparation. The second track is more focused on theoretical and abstract thinking and creative analysis in problem-solving. It sets the ground for continuing on to advanced degrees in engineering.

In general, three years Bachelors are finalised or to enter the practising profession or to pursue studies in Master programmes, while four years Bachelors prepare students for entering the labour market. Furthermore, four years Bachelors have programme learning outcomes more consistent with the ones of the 2nd cycle Qualification Framework of European Higher Education Area (QF-EHEA) or of the level 7 of the European Qualification Framework for Lifelong Learning (QF for LLL) than to the ones of QF-EHEA 1st cycle or EQF for LLL level 6. Of course, if the programme learning outcomes are consistent with those of Master programmes, the level of their achievement cannot be the same as in Master programmes, at least in Master programmes of 300 ECTS credits.

2. Methods

The search presented was based on published investigations, by questionnaire or database analysis, has shown that the titles of the Bachelors also vary and are, for instance, called in English Civil Engineering, Environmental Engineering, Construction Management and Civil and Territorial Engineering. Specialisations or tracks of the Bachelor programmes can be, in accordance with the major theme, called in English Applied Mechanics, Hydraulics, Hydromechanics, Coastal and Harbour Engineering, Geotechnical Engineering, Structures,

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Earthquake Engineering, Geodesy, Transportation Engineering, Materials, Construction, Engineering and Management fields, Structural Engineering, Hydraulics and Environmental Engineering, Geotechnical Engineering, Transport, Infrastructure and Regional Planning, Civil Constructions, Hydrology and Transports and Urban Services.

In terms of their profile, Bachelor programmes can be characterised as:

1. broad programmes covering typical elements of the sector involved, followed later by specialisation in a particular subject area / discipline.
2. specialised programmes focusing (mainly or only) on the subject area involved.
3. broad programmes covering different paradigms, which are /can also be positioned outside the realm of the sector.

Furthermore, with respect to the teaching and learning approach, the investigation has shown that Bachelor programmes can be characterised as:

1. traditional programmes in which the focus is mainly on knowledge acquisition and transfer: the programmes are largely based on lecture classes, which might be supported by seminar groups and, if applicable, limited laboratory work;
2. student-centred programmes, which require active student learning, which is mainly based on seminar/exercise course unit model and, if applicable, extended laboratory work.
    a. Some Bachelor programmes include a work-based learning component like work placement or traineeship. The number of credits ECTS for this part of the programme range from 5 to 20.
    b. Most students in Bachelor programmes are expected to prepare reports or research reports.
    c. Second cycle Master degrees are finalised to enter the practising profession.
    d. Some institutions or countries offer integrated first and second cycle programmes. In some cases, these integrated programmes are a combination of a first and second cycle programme. In other cases (e.g. the UK MEng degree), the programmes are more fully integrated.

More specialised degrees could be offered because students at this level are now focusing more on one technical area. For instance, the English titles identified in the context have been Civil Engineering, Environmental Engineering, Building Engineering, Mathematical Engineering, Construction and Project Management, Structural Engineering, Water Engineering, Architectural Engineering, Structural Engineering and Architecture, Reconstruction and Modernization of Buildings and Facilities, Environmental Protection and Sustainable Development and Engineering Project Management.

Also, Master programmes can have orientations in Structural design and construction, Project management, Rehabilitation and strengthening of civil engineering structures and facilities, Structures, Construction and Geomaterials, and Water Resources. The search has also shown that, in terms of their profile, Master programmes can be characterised as:

1. specialised programmes focusing (mainly or only) on the subject area involved;
2. broad programmes covering typical elements of the sector involved, followed later by specialisation in a particular subject area / discipline.

Furthermore, with respect to the teaching and learning approach, the investigation has shown that Master programmes can be characterised as:

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1. traditional programmes in which the focus is mainly on knowledge acquisition and transfer: the programmes are largely based on lecture classes, which might be supported by seminar groups and, if applicable, limited laboratory work;
2. student-centred programmes, which require active student learning, which is mainly based on seminar/exercise course unit model and, if applicable, extended laboratory work;
3. programmes based on research-driven education;
4. programmes based on applied-driven education.

Most Master programmes have minor or elective subjects with credits of ECTS ranging from 10 to 45. Some Master programmes include a work-based learning component like work placement or traineeship. The number of credits ECTS for this part of the programme range from 5 to 30. All students in Master programmes are expected to prepare a final thesis.

3. Results

Graduates with a degree in one of the engineering fields may enter many different types of organisations. Many engineering programme graduates choose to enter fields such as financial services, sales, or non-engineering management, where their engineering skills can help them succeed. In some cases, graduates choose to form new companies or go into their own private consulting practice. While their technical preparation may be valuable in this case, the graduates' skills in other professional areas may be equally important.

The investigation by questionnaire carried out in the framework of the CALOHEE project has shown that the type of sectors where civil engineering graduates find employment are Private Enterprise, Government (including departments, statutory authorities and government-owned businesses), Local Government and Public Company. With respect to other engineering specialisations, in consideration of their ability to solve important societal problems, civil engineers are privileged for entering public service in policy-making or political roles where their engineering education is instrumental.

Furthermore, due to the civil and criminal responsibility of civil engineering activities, the profession of civil engineer is regulated by government agencies, professional bodies or private organisations in many countries. In this case, in order to become a licensed/registered engineer, graduates may be required to complete a period of supervised work experience and, in some cases, pass one or more examinations. Furthermore, in some countries, the type of work open to graduates with only a first cycle degree may be limited. Some professional organisations in several countries require a second cycle degree or its equivalent to become registered or to practice. Other professional organisations have opposed such a requirement and believe that a first cycle degree is sufficient to enter those professions.

Employment sectors of engineering graduates are mainly Engineering manufacturing and production, Property and construction, Energy and utilities, Environment and agriculture, Government and public administration, Business and management, Banking finance and insurance, Further or higher education or research, but also Charities and voluntary work, IT information services and telecommunication, Physical resources (mining, quarrying, oil, gas, …) and Armed forces and emergency services, Creative arts and culture, Hospitality and social care, Media and publishing, Retail and sales.

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In most cases, first cycle graduates go to work directly for organisations that design, produce, and/or sell products, sub-systems, systems, and/or services. In most such employment, the graduate will begin to work under the supervision of a more senior engineer. The graduates are involved with duties ranging through the full life cycle of these products and services. Such roles might include limited basic research, design of the organisation's products or services, the production of the product or service, selling of the product or services to other technical or non-technical organisations, or the operation, servicing and/or maintenance of the product or service in field applications.

Many first cycle graduates will pursue additional education often leading to second cycle degrees. In some cases, the students will continue their education while being employed as a practising engineer. Graduates with second cycle degrees are less likely to enter positions that primarily focus on the narrow application of engineering methods or positions such as sales engineering and applications engineering. On the other hand, graduates of second cycle programmes are more likely to enter higher level specialised engineering positions with a research focus, more loosely defined problems, and management responsibility.

For Bachelor graduates, the twelve most common jobs identified in the context of the CALOHEE investigation carried have been Civil engineer, Site engineer, Site manager, Site inspector, Project manager, Design engineer, Structural engineer, Geotechnical engineer, Hydromechanics engineer, Health and safety coordinator, Teacher, Technician. The first twelve typical tasks performed by bachelor graduates have been identified in Designing structures, Analysing structural stability of structures, Planning construction of structures, Overseeing construction and maintenance of structures, Testing samples from site and structures, Making cost calculations, Controlling budget, schedule, and quality, Organising and directing, Analysing data and preparing reports, Inspecting job sites, Overseeing construction and maintenance of building structures and facilities, testing (soil, building materials).

For Master graduates, the twelve most common jobs identified have been Engineer, Consultant, Analyst, PhD, Structural engineer, Project manager, Associate, Works engineer, Data scientist, Research engineer, Civil engineer, Site engineer. The first twelve typical tasks performed by Master graduates have been identified in Undertaking technical and feasibility studies including site investigations, Using a range of computer packages for developing detailed designs, Undertaking complex and repetitive calculations, Liaising with clients and a variety of professionals, including architects and subcontractors, Compiling job specs and supervising tendering procedures, Resolving design and development problems, Managing budgets and project resources, Scheduling material and equipment purchases and deliveries, Making sure the project complies with legal requirements, Assessing the sustainability and environmental impact of projects, Designing structures, Analysing structural stability of structures.

EUR-ACE Program Outcomes describe the knowledge, understanding and skills that an accredited engineering degree programme must enable a graduate to demonstrate. They are described separately for both Bachelor and Master degree programmes, with reference to the following eight 'learning areas':

- Knowledge and understanding;
- Engineering Analysis;
- Engineering Design;
- Investigations;
- Engineering Practice;
- Making Judgements;

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- Communication and Team-working;
- Lifelong Learning.

The Civil Engineering competence frameworks that have been considered are:

- the Tuning-AHELO framework;
- the EUCEET framework;
- the International Engineering Alliance (IEA) - Washington Accord framework;
- the ABET framework;
- the Conceiving, Designing, Implementing, Operating (CDIO) Initiative framework;
- the National Society of Professional Engineers framework;
- the American Society of Civil Engineering (ASCE) framework.

The resulting Learning Outcomes descriptors of Master and Bachelor programmes in Civil Engineering have identified the sciences and the engineering disciplines underlying the civil engineering subject area that every graduate should know and understand and the engineering problems / products, processes and systems / issues / activities that every graduate in Civil Engineering should be able to solve / design / investigate / conduct as follows.

- Sciences underlying the civil engineering subject area that graduates should know and understand:
    - Mathematics; Probability and Statistics; Operational Research; Physics; Mathematical Physics; Chemistry; Material Science; Computer Science; Geology and Geomorphology.
- Engineering disciplines underlying the civil engineering subject area that graduates should know and understand:
    - Technical Drawing; Material Science and Construction Materials; Solid and Structural Mechanics; Construction Technology and Organisation; Buildings; Reinforced Concrete Structures; Metallic Structures; Masonry Structures; Timber Structures; Bridges; Structural Dynamics; Assessment and Rehabilitation of Civil Constructions;
    - Soil Mechanics; Geotechnical Engineering; Slope Stability; Retaining Structures; Underground Structures; Tunnelling;
    - Fluid Mechanics; Hydraulics; Hydraulic Constructions; Water Supply and Infrastructures; Coastal Engineering; River Engineering; Hydrology; Water Management;
    - Urban and Regional Infrastructures; Design of Transportation Infrastructures (Roads, Railways, Airports); Transportation Techniques and Economics; Traffic Engineering *(only at Master level)*;
    - Environmental Engineering; Safety Engineering; Sanitary Engineering;
    - Economics and Management.
- Engineering problems / products, processes and systems / issues / activities that graduates in civil engineering should be able to solve / design / investigate / conduct:
    - Civil & Industrial Buildings; Bridges; Reinforced Concrete Dams; Metallic Structures; Brick and Timber Constructions;
    - Roads; Railways; Airports; Ports; Interconnecting infrastructures; Cableways;
    - Hydraulic Constructions; Water Supply and Sewage Systems; Works for Hydraulic Protection of the Territory; Waste Disposals and Sanitation Works;
    - Foundations; Retaining Structures; Earthworks; Underground Works; Artificial and Natural Slopes;
    - Information Technologies in Civil Engineering.

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4. Conclusions

Given the research undertaken, it is proposed that each Civil Engineering program should adopt a set of learning outcomes/competences required for the Civil Engineering professionals. It may be the existing standards or any other recognised by society, in general, and by professional organisations, by companies and by accreditation agencies. According to the choice made the Civil Engineering program outcomes should comply with the adopted framework.

Most Civil Engineering programs (Bachelor or Master) do not comply with the indicators of existing frameworks. Most lack references to the Civic, Social and Cultural Engagement descriptors. Concerning the existing qualification frameworks, some examples of missing exact compliance are related to the wording presented and described in the program's descriptions. To be noted the general similarity in terms of intended learning outcomes of all the programs analysed either for level 6 (bachelor) or level 7 (master). Nevertheless, obtaining a common training framework seems impossible due to the words used and the concepts addressed by each institution. Comparability is possible with the evaluation of the intended learning outcomes using an accepted framework for Civil Engineers, academically and professionally, as terms of reference.

A possible following step may be to address the proper management of engineering students assessment to define assessment methods for each of the learning outcomes of the Civil Engineering program. The choice of assessment method is generally a personal prerogative without preliminary verification by any colleague or academic body. Therefore, clear rules within each institution about how to properly assess students should be designed. Continuing Professional Development (CPD) training should be mandatory and periodic for Civil Engineering teachers and professionals.

Considering past and recent research the use of machine learning to assess students should also be considered to clarify the procedures in global terms without individualising by each teacher the assessment for each competence. Another conclusion from this study is that the choice of assessment is controversial among academics. Following a Chinese proverb, “You find 1000 teachers, and you will find 1000 different ways of assessing”. It is recommended that either there is an institutional body to evaluate a priori the appropriateness of each proposed assessment or there is proper teacher training to administer assessment or if there are transparent and effective rules to design the assessment methods.

It should be taken into account that education assessment of Civil Engineering students' learning is an ongoing and evolutionary process. New and updated forms of assessment are needed to keep in line with society requirements and with the development of digital tools available for academic and administrative staff and for students. Validity, reliability and standards are aspects that should be a constant concern for academics and for students. The digital context may allow for more appropriate, more fair, more authentic and more accessible modes for assessing Civil Engineering students achievements in terms of competences.

Finally, the assessment should consider that “one size does not fit all” either in terms of the diversity of learning outcomes or related to the learning styles of each student. Therefore, a diversity of assessment methods should be considered for each learning outcome in Engineering programs. Also, it should be considered that a student is not a number but a person. Assess derives from Latin “assidere” which means to “sit with”. It would probably be the best assessment choice if teachers could sit with each student and individually verify the learning. Digital tools will certainly help this individualisation of assessment, either through e-portfolios or through automatic verification of evidence of learning, like machine learning algorithms.

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In terms of Sustainability and UNSDGs a possible path could be to connect to the GreenComp: European Sustainability Competence Framework. GreenComp is a Competence framework to promote learning on environmental sustainability provided by the Joint Research Centre JRC, the European Commission's science and knowledge service. It describes competences for citizens and it is thus formulated in terms of ‘descriptors’ that can be applied independently of education level and learning setting – formal, non-formal and informal.

Further work and specific reflections for Civil Engineers are thus required by specific educational settings and it is an interesting challenge. The published GreenComp booklet, besides an introduction and definitions, contains both explanations and examples of statements for Knowledge /Skills /Attitudes connected with each for each of its twelve descriptors. The GreenComp conceptual model defines «Sustainability means prioritising the needs of all life forms and of the planet by ensuring that human activity does not exceed planetary boundaries». Also a «sustainability competence empowers each one to embody sustainability values, and embrace complex systems, in order to take or request action that restores and maintains ecosystem health and enhances justice, generating visions for sustainable futures.».

In terms of embracing complexity in sustainability in Civil Engineering, critical thinking may be used to assess information and arguments, identify assumptions, challenge the status quo, and reflect on how personal, social and cultural backgrounds influence thinking and conclusions. Civil Engineering can focus on how the disciplines and practice adapt to changing social needs, new knowledge /awareness and theoretical underpinnings of value frameworks. Given the results it is clear that connecting Competence Frameworks with the GreenComp is a very useful exercise which can help enhance a wider approach, even going beyond environmental sustainability and integrate with the concept of sustainable education as a framework of sustainable development goals for Civil Engineers.

Some examples of connections or adaptation of the existing competence frameworks for Civil Engineering with the GreenComp Framework are:

- Design: Safe, sustainable and of low impact designs;
- Define and describe key aspects of safety, sustainability and impact on society and the environment related to Civil Engineering phenomena and to the ethical obligation and social responsibility of professional engineers.
- Civil Engineering designers should reconsider priorities: valuing sustainability and critical thinking.

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4. ECEC

1. Introduction

The European Council of Engineers Chambers is an international organisation consisting of 17 member states which are represented by their civil and chartered engineering chambers. Its aim is to represent these chambers at the European level and accommodate the diverse views of its members.

Data collection for this research was conducted on a broad geographical and institutional basis in cooperation with the individual member chambers. In the previous research round, the ECEC Secretariat contacted one representative per member state for individual interviews. The interviewees were asked to provide their perspectives on future developments and current needs for engineers in Europe. Given the success of this approach last year, the same interviewees were asked to provide updated insights on the same topics and additional questions in light of current events. They were sent a detailed summary of last year's answers and asked to contribute new thoughts and practices. The participating countries were Austria, Bulgaria, Germany, Montenegro, Poland, Croatia, Slovenia and Spain. The Portuguese ECEC member, Ordem dos Engenheiros, being an E4E partner, conducted its own research.

Secondary research was based on studies and relevant papers provided by the partner chambers, including position papers, manifestos, and studies. A total of eight secondary research papers were obtained and included in this research.

The definition of SDGs and Green Deal implementation landscape in view to VET and business ecosystem differs within ECEC member countries, but the research very clearly shows that SDG and Green Deal topics are very rapidly gaining further importance.

This is closely connected to the fast technological developments and innovations in this area. Skills requirements are therefore very much in the field of digital and green transformation, combined with the basis of a high-quality professional education/qualification in the different areas of expertise. Reaching SDGs and the Green Deal targets is also connected to quality competition in public procurement of engineering services, as this provides the implementation in the daily work of professionals, so that expertise in this field is also an important skills requirement.

The complex climate and societal challenges also raise the demand for holistic approaches and ethical "conscious engineering" in the public interest.

The regulatory situation has a major influence on providing a framework to enhance conscious engineering as well as engineering mobility and the possibilities of green knowledge transfers and on. It also plays an important role in realising the innovation potential in the profession as it can enhance or hinder developments.

2. Quantitative indicators on the evolving nature of the engineering profession

The status of Building Information Modelling Adoption in Slovakia

Researchers from three different faculties and universities in Slovakia published an academic research paper on the status of Building Information Modeling (BIM) adoption in Slovakia on November 30, 2023. In this study, the authors evaluated national and international developments concerning digitization in the construction sector and presented findings regarding developments, future needs, and potential challenges. The authors

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recognize that BIM implementation varies by region and that cultural dimensions influence the application of this tool. They provide a broad overview of BIM usage in Slovakia.

When Building Information Modeling was first introduced in Slovakia in 2011 as part of a digitization strategy, only 13% of professionals said they would follow this strategy, compared to 54% in 2016. (Funtík et al 2023, 2) In the years leading up to the 2020s, this number continued to increase. The total number of BIM adoptions in Slovakia reached 21.08% in 2022, with a 4% increase since 2016. It is criticized that Slovakia has not yet introduced a national BIM implementation strategy, as countries that are required to adapt to BIM standards (US, UK, CZ, DE) have seen a higher increase in BIM adoption over the same period. (Funtík et al 2023, 12)

BIM has mainly established itself in building design rather than infrastructure design (27.78% compared to 8.82%). Among professions, structural engineers in Slovakia lead with a 33.3% adoption rate, closely followed by architects/engineers at 28.9%. In comparison, HVAC and MEP engineers, site managers, and land surveyors are below the average BIM implementation rate of 21.1%. The increasing interest in using BIM is also evident in a 6% decrease in people not interested in using this method over three years. Within a project cycle, BIM is most often used in the development phase (41.3%) and the design process (29%), while the construction phase reports only an 11.3% BIM usage. (Funtík et al 2023, 12-15).

The paper also finds that most BIM users have developed expertise in this method on their own initiative. The request for BIM is still very low, though it is currently increasing. The requirement for BIM mainly stems from employers (21.52%), business partners (8.52%), or superior institutions (1.35%). A significant 68.61% of BIM users have chosen to adopt it of their own will. Even within the supply chain, this number remains low, as up to 68.34% of companies participating in the survey report that they have never received a request for BIM delivery. (Funtík et al 2023, 17)

3. Employment rates of STEM university graduates in Austria

A study on the overall employment rate and challenges in the labour market for STEM graduates in Austria was published in February 2024 and is discussed below.

The study shows an overall stable labour market situation for university graduates in recent years, along with steady unemployment rates. The study shows an overall stable labour market situation for university graduates in recent years, with steady unemployment rates. Among STEM graduate students, the employment rate is highest among computer scientists and engineers, with an impressive 93% employment rate three years after graduation. A significant difference is seen by gender. The employment rate of women 10 years after graduation is lower in all STEM fields compared that of men. In architecture and engineering, the employment rate of women is 10 percentage points lower than that of men, the lowest result in all STEM fields. Gender gaps are also evident in gross monthly salaries of STEM graduates working full-time. Generally, engineering graduates are well-paid, showing the highest salaries among STEM professions 10 years after graduation, shared with computer science. Pay gaps between men and women already begin with starting salaries six months after graduation. The difference at this point is 16% in favour of men in the entire STEM field but is likely higher in engineering as this area is continuously male dominated. The salary advantage only increases over time. For men, salaries in STEM fields increase by 50% between six months and 10 years after graduation, while salaries for women only increase by 40%. (Dibiasi et al 2024, 103-115)

4. Qualitative descriptions of the evolving nature of the engineering profession

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ECEC Manifesto

The European Council of Engineers Chambers (ECEC) published its Manifesto for the European Parliament elections on May 6, 2024. In this document, the ECEC outlined five key demands for the next European Parliament:

1. Support and promotion of the New European Bauhaus (NEB).
2. Provision of adequate professional regulations for engineers regarding qualifications, independence, and responsibility.
3. Implementation of a Common Training Framework for Civil Engineers.
4. Introduction of a special chapter for intellectual services within the EU Public Procurement Directives.
5. Adoption of Building Information Modelling (BIM) as essential to keep the market open for SMEs.

These demands reflect the profession's move towards greener practices (NEB), better regulation (CTF and public procurement directives), and increased digitization (BIM).

5. Climate, soil & society. Tipping points for a sustainable future – Positions on responsible planning and design

The Austrian Federal Chamber of Chartered Engineering Consultants (BKZT) released a position paper titled "Klima, Boden & Gesellschaft" (Climate, Soil & Society), addressing responsible planning and design. The paper emphasizes the high responsibility engineers hold in maintaining quality standards amidst climate change. It highlights that Austria has reached its limit on soil sealing capacities, advocating for the sensible use of sealed soil areas and restricting further soil consumption to mitigate flooding and heat island effects.

Further demands of the BKZT concerning developments in the engineering profession will be introduced in the chapters below.

Questionnaires

For this round of research, last year's interviewees were asked to update their answers from last year and answer a set of additional questions. The results of these questionnaires will be presented in the following points and reflect various perspectives of professional engineers.

Role of engineers

Respondents highlighted the critical role engineers play in addressing modern challenges. Across all responses, engineering is seen as essential for creating and organizing sustainable solutions. Engineers are crucial for the green transition and must be involved not only in implementation but also in decision-making regarding sustainability.

Sustainable Development

Sustainable development and achieving the Sustainable Development Goals (SDGs) are central themes in answers to the questionnaire. The chamber representatives identified various changes in engineering driven by the climate crisis. The German participant remarked engineering involvement in the development of renewable energy technologies, advancements in green technologies such as energy storage and electric vehicles,

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pollution control and resource management. This list is extended by answers from the Montenegrin participant, who pinpointed these developments in improving energy efficiency and designing eco-friendly infrastructure.

While most respondents were optimistic, the Bulgarian respondent expressed scepticism about fully integrating SDGs into engineering due to time and resource constraints, though they acknowledged engineers' unique capability to address these challenges. This underscores the growing responsibility of engineers in today's social and political climate.

The Slovene chamber emphasized that decisions on sustainable materials should involve expert engineers and not be made top-down. They criticized the trend of categorizing materials as universally sustainable or unsustainable without nuance.

To underline these (positive) developments of sustainable engineering, participants were asked to name concrete cases of best practice examples:

- Smart City initiatives, enhancing urban infrastructure, energy use, transportation and waste management, as well as innovative water management solutions.
- German energy transition (Energiewende).
- Reuse of industrial by-products such as fly ashes, contributing to the circular economy.

The BKZT in its position paper also names examples: (BKZT 2024, 13-14)

- The sponge city principle, capturing water, storing it and using it for nearby trees and other plants is proven to prevent flooding during heavy rainfall, improves the urban climate and contributes to the resilience of the entire urban ecosystem.
- Integrated Water resources Management (IWRM), a holistic approach to water management considering social and ecological factors at a regional level.
- 15-minute city, describing a city in which all everyday trips can be made in less than 15 minutes due to an interconnected system of sustainable transportation methods such as by foot, by bike or by public transport.

Digitisation, computerisation and new technologies

There is a significant trend towards digitalization and computerization within the engineering profession. Increased use of digital tools in design, construction, and administration, along with the rise of remote work since the COVID-19 pandemic, are notable developments. The integration of AI, robotics, and automation is becoming more prevalent, particularly in mechanical engineering. Building Information Modeling (BIM) is increasingly standard for large projects, as can also be seen in the Slovakian research paper by Funtík et al from 2023. Connected to this development, however, is an important ethical concern regarding data protection when using AI and machine learning applications.

Political and economic influences

The current political landscape, especially within the European Union (EU), also impacts the engineering profession. From an outside perspective as a non-EU member state, the Montenegrin respondent warned that significant gains by far-right parties in the most recent EU election could lead to shifts in EU policies. Concerns regarding potential effects on funding priorities towards sustainable construction, low-impact environmental regulations and a potential decrease of international mobility for engineers were raised.

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Similarly, economic factors are a cause of concern for participants. Three participants pointed out that the dominance of large company monopolies poses challenges for smaller design firms.

On the other hand, the German participant remarked developments of the legislator to promote sustainability and green technologies as well as the combatting of monopoly systems and providing a free market. Conversely, Polish and Bulgarian respondents warned of potential overregulation becoming the norm.

6. Opportunities

Recent developments in the engineering profession present numerous opportunities for various stakeholders, contributing to a landscape rich with potential.

Opportunities for engineers

The adoption of digital technologies such as Artificial Intelligence (AI) and the Internet of Things (IoT) can significantly increase efficiency and sustainability in engineering projects. Engineers can leverage these technologies to optimize processes, reduce waste, and enhance the precision of their work. The digitization of the building sector through Building Information Modeling (BIM) is a transformative development (Funtík et al 2023). BIM enhances energy efficiency in construction and renovation projects, contributing to overall project sustainability. It is estimated that full-scale digitization through BIM could result in annual cost savings of up to 21% in certain project phases, underscoring the economic and environmental advantages of adopting such technologies. (Funtík et al 2023, 2) The integration of these technologies not only improves energy efficiency but also reduces errors and mitigate workers shortages, as noted by the German Federal Chamber of Engineers (BIngK 2024, 5)

Developments toward more sustainable professional practices also present opportunities for engineers. Engineers specializing in renewable energy systems and sustainable materials are pivotal in driving climate-resilient infrastructure and influencing future legislation. Expertise in sustainable materials and setting best practices can aid in establishing new standards for climate-resilient infrastructure. Sustainable development relies heavily on engineering expertise.

Opportunities for chambers and other professional associations

Professional associations play a crucial role in promoting ethical standards and continuous professional development among engineers. By offering workshops and certification courses, they ensure engineers stay abreast of technological advancements and ethical practices, fostering a culture of lifelong learning. In the German example, professional supervision and CPD are mandatory, ensuring high-quality services, professional independence and reducing the burden on state organs. (BIngK 2024, 2). Enrico Letta in his report "Much more than a market," explicitly stresses the important role of social partners in addressing todays challenges and also professional chambers are in many countries regarded as part of this social dialogue (Letta 2024, 144).

Opportunities in legislation

One research partner explained how legislation emphasizing sustainability provides a conducive environment for engineers to innovate and implement ecological solutions. Such regulations foster growth in tech-driven initiatives and encourage the adoption of sustainable practices across various sectors. Currently, sustainable solutions are often not implemented as they are less likely to bring short-term benefits of economic or political

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success. However, in the long-term, sustainable practices are proven to be much more beneficial, which is why policy makers need a holistic and future-oriented approach. (BKZT 2024, 3)

7. Needs

The engineering profession must evolve to meet the demands of a rapidly changing world. Responses from eight experienced engineers highlight the necessary changes and developments to ensure that engineers are equipped with the skills, knowledge and ethical standards required in the future.

Skills development

Among hard skills development, the participants named the following:

- New technologies: Proficiency in AI, machine learning, automation, robotics, data analytics, and Building Information Modelling (BIM) was emphasized by five participants.
- Cybersecurity: Knowledge of cybersecurity frameworks is essential to ensure data protection, as noted by the German participant.
- Theoretical and Mathematical Skills: Despite the rise of digital tools, three respondents stressed the importance of critical evaluation of computerized results.
- Sustainability knowledge: Engineers need a deep understanding of renewable energy systems, sustainable materials, circular economy principles, and sustainable design practices. Systems thinking and lifecycle analysis of materials are crucial. Sustainability cannot be oversimplified; therefore, engineers should be educated in complex systems connecting environmental, social and economic factors.
- Legal knowledge: Familiarity with building and civil law, procurement law, environmental policies and regulations, climate modelling, and environmental impact assessments is increasingly important.
- Interdisciplinarity: Engineers should be equipped with interdisciplinary skills and be able to evaluate social and other factors in their choices. Engineers should be continuously exposed to international best practices, which would enable them to adopt a more globalised approach to engineering and increase cultural sensitivity.

Although traditional engineering education focuses on hard knowledge, the importance of soft skills cannot be underestimated, as can be seen in the following points:

- Adaptability: Engineers must adapt to evolving standards in sustainability, digital transformation, and technological advancements. Lifelong learning is essential in this context.
- Networking: Strong national and international networking skills, including multilingual communication, are important for exchanging expertise.
- Diversity (intercultural) Management: In order to increase gender diversity and diversity in general – which is also regarded as a way to fight the lack of engineers - professional engineers require diversity management skills.
- Communication: The importance of communicating complex facts not only to clients but also to political stakeholders and the public is rising, especially in fields of green and digital transition
- Project Management and Entrepreneurship: Skills in project management, business development, and financial management are increasingly necessary as requirements in self-employment are growing in complexity.

Ethical developments

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To establish ethical practices in the engineering profession, regular updates to ethical codes are necessary to address modern challenges such as building lifespan and sustainability standards. Engineers must adhere to binding sustainable practices to maintain ethical standards, ensuring that clients comply with these regulations. Furthermore, engineers can only act ethically if they are kept independent in a free market, allowing them to uphold the highest professional standards without undue influence.

Chambers should not only make continuous professional development to larger companies with financial means to visit these seminars, but make sure that courses are financially accessible also to smaller firms.

Sustainable developments

The Austrian Federal Chamber of Chartered Engineering Consultants (BKZT) emphasizes the need to standardize sustainable practices within the engineering profession. They advocate for reusing existing buildings and pre-built areas rather than sealing natural soil, and they call for a comprehensive soil protection framework to prevent unnecessary new construction and land expansion. Revising building standards to prioritize energy efficiency and sufficiency is crucial to meet climate protection targets. Additionally, implementing a circular economy to reduce waste and raw material demand is essential, requiring collaboration across all engineering disciplines to create a resource-conserving economy. (BKZT 2024, 4-10)

BIM implementation strategies

The Slovakian research paper, even though it calls directly for BIM in digitisation strategies, also recognises that BIM implementation also varies in terms of social factors. When setting BIM standards, it is important to incorporate cultural and economic dimensions into the theoretical framework, as these factors have a vital influence on IT usage and attitudes towards computerisation and digitisation. (Funtík et al 2023, 19)

The German Federal Chamber of Engineers (BIngK) calls for significant investment in BIM education and a funding framework to make these tools accessible, particularly for SMEs. This approach aims to mitigate financial risks and promote widespread adoption of digital technologies in the engineering sector. (BIngK 2024, 5)

Multi-stakeholder partnerships

Engineers should actively engage with diverse stakeholders, including communities, governments, and industries, to promote sustainability. Multi-stakeholder partnerships must ensure the independence of engineers and operate transparently and clearly. These partnerships should establish incentives for investing in sustainable practices, education, and training, fostering a collaborative environment that supports the transition to a sustainable future.

Demands for legislators

Legislators play a crucial role in shaping the framework within which engineers operate, and several key demands have been identified to effectively address contemporary challenges.

Laws should be grounded in the practical experiences of engineers to ensure feasibility and implementability, requiring direct involvement of engineers in legislative processes. This collaborative approach ensures more effective and realistic outcomes based on practical knowledge.

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Legislation should avoid one-size-fits-all solutions. Tailored approaches are necessary to avoid one-size-fits-all solutions, particularly when evaluating the sustainability of materials, as highlighted by Slovenia. Legislators must also give engineers the legal grounding to maintain the highest possible engineering standards. The German participant highlighted the importance of stringent regulations concerning the profession itself, as did the Luxembourgish chamber calling for an end to professional deregulation (OAI 2024, 1-5). On the other hand, both the Polish and the Bulgarian chamber representatives asked for a stop to overregulation – including standardization - when carrying out their work and thus leaving room for innovation and alterative solutions.

The German Federal Chamber for engineers in its position paper calls on the European legislators to further promote small and medium-sized enterprises (SMEs) in order to enhance free market access and combat monopoly systems. Another demand from the chamber was to reduce bureaucracy when applying for funding and a non-discriminatory access to SMEs to public procurement procedures. (BIngK 2024, 3) Free market access is also demanded in a similar position paper by the Luxembourgish ECEC member Order of architects and Consulting Engineers (OAI), who demanded protection of the free market to enable and independent engineering profession. (OAI 2024, 1) Transparency in public procedures and parliamentary involvement in standardization are also vital. (BIngK 2024, 4)

Adequate training possibilities need to be supported by legislation. Currently, degree programmes throughout Europe vary, leading to skill deficits for certain graduates and unsatisfying standards in some of today's engineers. The BIngK as well as the ECEC in its position paper therefore demand the support of a common training framework at European level in order to ensure the necessary quality engineering education and increase engineers' mobility, which can also be a tool to handle the lack of engineers in certain areas. (BIngK 2024, 6) (ECEC 2024, 4). The European Court of Auditors in its "Special Report 10/2024: The recognition of professional qualifications in the EU" supports such pro-active approaches and critizises that the potential of the tool of "common training principles" has yet been hardly used (European Court of Auditors 2024, 51).

The OAI (Luxembourgish chamber) called for a revised public procurement directive to include design service contracts in construction policies. (OAI 2024, 1-3) Enrico Letta, former Prime Minister of Italy, echoed this need in his document "Much more than a market," advocating for transparent, competitive, and sustainable procurement strategies that support high-quality and affordable social services. He emphasized shifting from a lowest-price concept to a holistic value-for-money approach, considering quality, life-cycle costs, and social benefits. (Letta 2024, 42-46) Similarly, the ECEC's 2024 Manifesto demanded a special chapter for intellectual services within the Public Procurement Directive to promote fair and quality-based procurement. (ECEC 2024, 5)

8. Challenges

Rapid technological advancements

Respondents found that the rapid pace of digital transformation is outstripping educational updates, leading to a skills gap. Engineers must quickly adapt to new technologies such as AI and BIM. Among BIM implementation, a clear disparity between the individual project development areas can be seen based on the Slovakian study on the status of Building Information Modeling. While the development and design processes both lie above the average in terms of BIM application, the construction sector reports a below average adoption rate of 11.3%. Compared to other process fields, the construction sector is deemed to be a rather conservative sector, that is partly resistant to the use of online tools. (Funtík et al 2023, 15)

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Concerns were also raised by the German participant on data privacy breached through insensible use of Artificial Intelligence and machine learning. Legally ensuring open access to BIM in public procurement is an essential prerequisite to keep the market remains open also for SME and avoid monopolies.

Challenges to BIM adoption

The paper on the use of Building Information Modelling in Slovakia also defined potential challenges in BIM implementation.

There are cultural and organisational challenges that might influence BIM adoption. This stems from a difference in organizational structure and cultural context, grounding a different culture of building. The authors also criticized the lack of research on this topic, as BIM research is usually kept within certain regions. (Funtík et al 2023, 3)

Issues could also arise in certain legal traditions, as the implementation under risks of liability issues, intellectual property rights and standard contract clauses are not clearly assessed. (Funtík et al 2023, 3)

The survey which was carried out as part of the research for the evaluation of Slovakian BIM implementation also defined the barriers in the implementation of BIM. The most common answer was the missing standards and recommended workflows, the costs, the lack of engineering professions as well as the lack of time. All statements were chosen by more than 30% of respondents to the survey. Standards and workflows are essential for BIM use in order to establish a structured framework for data interchange, quality assurance and heightened efficiency. The financial factor also plays a vital role for over 38.3% of respondents. This [fear] is associated with a lack of straightforward ROI assessment and cost-benefit analysis of BIM. (Funtík et al 2023, 18-19)

Continuous learning and its shortages

Although CPD has established itself as an important way of staying updated in ones profession, a limitation of resources such as time or financial means can hinder this development. German and Polish respondents explained how many engineers face constraints due to parallel responsibilities and economic disparities affecting their access to education and technology.

Challenges to sustainable practices

The BKZT in its position paper states that the implementation of a sustainable building and construction culture is being made difficult due to blockades from legislators. Even though sustainable practices are proven to bring long-term benefits to all citizens, many actors of politics follow a individualistic approach bringing short-term economic benefits. As an example, the author describes legal hurdles to achieving a circular economy due to current construction and waste legislation. There is a need for rapid compliance with European legal requirements under the new construction Products Regulation as well as the Declaration of performance and CE marking for construction products made from secondary building materials.

Challenges to ethical practices

The implementation of ethics codes by chambers and other professional organisations is made difficult when engineers are not obliged to membership to engineering chambers. Chambers also report that it is difficult to find the right incentives to encourage a culture supportive of continuous learning, especially in countries, where such programs pose an economic factor.

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Client demands

Client demands can conflict with sustainable or ethical practices, which is why clear standards must be established to close the disparity with clients. One respondent also shared that balancing immediate project demands with long-term skills development remains a challenge for many engineers.

Legislative and economic barriers

The Slovene participant raised concerns as to the exclusion of engineers in legislation and decision-making processes. Instead, legislators find generalised solutions, harming the problem-solving potential inherent to engineers.

Difficulties also arise where there is economic or political instability. Monopoly systems make it difficult for smaller design firms to establish themselves. Ethical and sustainable engineering is only possible under a free market, as remarked by two chamber representatives.

9. Conclusions and Recommendations

- While University education - often supplemented by professional practise requirements and/or professional access examination - provides for the basic essentials to pursue the engineering professions, the rapid (technical) developments especially in the fields of digital applications / AI and sustainability and green transition - but also in other areas – and the manifold societal challenges **lead to the clear need for adequate offers of Continuous Professional Developments measures in these fields.**
- These urgent hard skills requirements need to be complemented by a framework that enables professional engineers to provide excellent engineering solutions with a holistic and conscious approach for the complex challenges they have to address. On one hand, **this can be enhanced by CPD measures that are also focused on soft skills such as adaptability and interdisciplinary networking**. **Additionally, this also requires adequate legal and practical working frameworks**. For example, **the standardization system has to be more open to alternative solutions in order to enhance engineering innovation; public procurement procedures on all regional levels have to be based on quality competitions instead of price competition** in order to ensure good and sustainable solutions for projects all over the EU; the **legal framework (including self-regulation) has to ensure the professional independence of engineers enabling them to take conscious decisions that are also in the public interest**.
- Working in such a framework requires hard and soft skills that go beyond the classical engineering skills, eg far into **legal skills** (public procurement law, building law, standardization and its legal impacts, warranties etc) and other hard and soft skills to help them come to ethical /conscious decisions**.**
- Enhancing engineering mobility e.g. by common training frameworks, Mutual Recognition Agreements with Third Countries are important tools to fight the lack of engineers in certain areas and at the same time open new markets and cooperation possibilities for engineering professionals. Taking these chances requires (new) **intercultural skills** (interdisciplinary cooperation in a much broader spectrum than is common today, broader adaptability to work with workers / colleagues of other cultures and languages, diversity and anti-discrimination management etc).
- In this context it is also important to stress that the low rate of gender diversity in engineering professions has not considerably changed during the last year. For professional engineers that are in leading roles **Diversity Management in engineering offices is therefore another relevant CPD topic.** This can help to release the market potential of women in engineering. It is also regarded important to

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find new measures to raise the interest of children / young people – and also with a special focus on girls, who are still going into STEM education less often than boys - in engineering careers.

- Finally, it is important to mention that the ECEC research shows, that the political situation in the EU and in the national countries is a major factor for the direction of the development of the engineering profession and that there are fears that e.g. right-wing majorities could hinder developments towards green transition. This leads to a rising necessity to keep up the political dialogue with political stakeholders on all regional levels on a daily basis and **thus to provide CPD measures to support and broaden the communicative abilities of engineering professionals.**

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Annex – Questionnaire (to complement interview results) 2024

Current needs, trends and wants of and for Engineers in Europe in 2024

1. With regard to the latest EU elections, how will the engineering profession change within the next 5 and 10 years?
2. And based on this, what are the emerging technical and transversal skills and competencies required in the engineering profession?
3. What is the role of the engineering profession in the implementation of Sustainable Development Goals and the goal of Climate neutrality by 2030?
4. Which new skills and competencies might be needed in order to achieve the Sustainable Development Goals and climate neutrality by 2030?
5. How can engineers be trained to become "conscious engineers" who prioritize ethical and sustainable practices in their work?
6. Which factors might challenge the developments of new skills and competencies in 2024 and the years to come?
7. How should policies correctly be addressed, and which initiatives are needed for a more digital, green and resilient practice of the engineering profession?
8. Are you aware of any case studies and best practice example which showcase the positive/negative development of current engineers from the past year(s)?
9. In general: What engineering education and training programs are needed for aspiring engineers?

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5. Engineers Ireland

1. Background to Engineers Ireland

With over 28,000 members from every engineering discipline, Engineers Ireland is the voice of the engineering profession in Ireland. Established in 1835, Engineers Ireland is one of the oldest and largest professional bodies in the country. Members come from every discipline of engineering and range from engineering students to fellows of the profession.

Our responsibility is to

- Promote knowledge of engineering
- Establish and maintain standards of professional engineering and engineering education
- Provide opportunities for Continuing Professional Development (CPD)
- Maintain standards of professional ethics and conduct
- Ensure that professional titles are granted to qualified candidates
- Act as the authoritative voice of the engineering profession in Ireland

Our Vision Statement

Engineers Ireland: a community of creative professionals delivering sustainable solutions for society.

Our Mission Statement

Engineers Ireland is an institution that enables the engineering community to progress in their professional development and make a sustainable impact on society, advocates for the profession, quality assures education and encourages future generations of engineers.

2. Introduction

The engineering profession is undoubtedly one of the most crucial industries in Ireland, and it is no secret that the country has been heavily investing in innovation and technology. As a result, the engineering sector in Ireland has been experiencing steady growth in recent years. Engineers Ireland has conducted extensive research to provide a comprehensive overview of the industry's current state. The annual "Engineering: Barometer Report" is an invaluable resource for understanding engineering employment, infrastructure and careers, engineering education, and sustainability in Ireland.

According to the findings of Engineers Ireland, the engineering profession has played a pivotal role in Ireland's economic growth and development. The demand for engineers has increased significantly, and this has resulted in almost 6,000 new engineering jobs being expected in 2024. However, the number of engineering graduates remains consistent at around 6,000 students[11]. Finding experienced engineers has become one of the biggest challenges facing the engineering profession in Ireland.

[11] HEA, 2023

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Despite this challenge, Engineers Ireland has been working hard to promote engineering as a career choice, when polled 92% of the public view engineers as highly competent, the highest of any profession. It is important to highlight the importance of sustainability in the engineering profession and the need for engineers to be equipped with the necessary skills to design and implement sustainable solutions.

The engineering profession is critical for driving innovation, infrastructure development, and economic growth in Ireland. While there are some challenges facing the industry, the future looks bright with the continued focus on innovation and technology in the country.

3. Trends in the Engineering Profession in Ireland

Engineering in Ireland remains critical to ensuring that our infrastructure, our economy, and our public services can support living standards and sustainable growth – from clean water supplies and safe buildings to renewable energy and new manufacturing technologies. The engineers work extends beyond blueprints and equations—it touches lives, transforms communities, and safeguards our future. Employers seek engineers with the right skills: fundamental knowledge, effective communication, and problem-solving.

In 2022, the Central Statistics Office (CSO) undertook a national census. The title engineer is not a protected term in Ireland and is used in numerous industries, making the identification of the exact number of engineers employed in Ireland a challenge. The CSO data, however, reveal that the largest proportion of engineers employed here are civil engineers (8,907), the second largest, electrical engineers (7,560), and the third, mechanical engineers (5,927). There are now 61,353 people employed in engineering and technical engineering roles in Ireland, an increase of 30% from the figure in 2016. The occupations included in this total are based as closely as possible on Engineers Ireland's criteria for accreditation.

Ireland is the European location of choice for growing numbers of industrial engineering and technology companies in manufacturing, research and innovation. It is tenth in the European league table of the most attractive investment opportunities for Foreign Direct Investment (FDI), according to the European Attractiveness survey in May 2022. Dublin ranked fourth of Europe's most attractive investment cities over the next three years. Ireland's business-friendly environment, tax regime, education system, and quality of life were all cited by respondents as top drivers of its attractiveness. Ireland’s rating around sustainability-related factors was exceptionally strong, with the majority saying we perform as well as, or better than, the European average for the availability of skills to facilitate sustainability projects.[12]

4. Challenges in the Engineering Profession in Ireland

Gender gap: Engineering has remained a male-driven profession, with only about 12% of engineering professionals in Ireland being female. This highlights the need to increase diversity and bridge this gender gap.

Skills shortage: There’s an ongoing shortage of skilled engineers. The skills shortage within the construction and engineering sectors is a result of the 2008 financial crisis, which led to significant emigration. The demand for engineers now exceeds the available talent pool, particularly in specialised areas such as data analytics,

[12] How Ireland’s attractiveness is bolstering FDI performance | EY Ireland

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cybersecurity, and renewable energy. Ireland already ranks third in the rate of third-level education attainment globally, with about 6,000 engineering graduates per year[13]. However, emigration remains a common career path for Irish graduates. This is illustrated on the government "Critical Skills Occupation List", which lists 24 disciplines of engineering professionals as a shortage[14].

Companies are upskilling, maintaining hybrid work models, and attracting talent from overseas to address this issue. 79% of engineering employers expect a hybrid model of working with the flexibility to work from home, site and the office as required going forward. This work-life balance increases work opportunities for people with caring responsibilities. Most engineers attracted from overseas come from Brazil, India, and South Africa, they are attracted to Ireland because of global investment, high salaries, supportive environment and continuous learning.

Despite these challenges, the profession remains robust in terms of remuneration, job opportunities, and outlook. Engineers play a critical role in Ireland's success, contributing to sustainable solutions and societal well-being.

5. Opportunities in the Engineering Profession in Ireland

Infrastructure Development: Ireland is investing in infrastructure projects such as roads, bridges, public transportation, sustainable energy, and utilities to match the expanding population. Civil engineers, transportation planners, and project managers play crucial roles in these developments.

Research and Innovation: Ireland hosts several research centres and institutions focused on technology, biopharma, and renewable energy. Engineers can contribute to cutting-edge research in areas like artificial intelligence, sustainable materials, and medical devices. Facilities like Ireland National Advanced Manufacturing Training Centre of Excellence (AMTCE) in Dundalk, Ireland, provide exciting opportunities for engineers and learners in the manufacturing sector. From apprentices to lifelong learning, AMTCE offers upskilling in a vast spectrum of engineering sectors like, Pharma, Robotics, BioPharma, and cyber security.

Foreign Direct Investment (FDI): Multinational companies establish their European headquarters in Ireland due to its favourable business environment, skilled workforce, and strong engineering capabilities. Engineers can find opportunities in sectors like tech, pharmaceuticals, and manufacturing[15].

Renewable Energy: Ireland aims to achieve a significant increase in renewable energy by 2030. With huge developments planned for offshore wind. Engineers specialising in wind, solar, and hydroelectric power can contribute to this transition.

Data Centres and ICT: With major tech companies having data centres in Ireland, opportunities exist for electrical engineers, network specialists, and data centre managers.

6. Quantitative Indicators: A focus on Green, Digital, Entrepreneurial and Resilience Skills

[13] Engineering barometer | Engineers Ireland
[14] Critical Skills Occupations List - DETE (enterprise.gov.ie)
[15] Engineering jobs in Ireland, careers updated daily- Jobs.ie

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Engineers Ireland conducts an annual Salary Survey of members, focusing on salaries and employment benefits. Since 2023, the survey includes questions asking respondents to expand on the different skills engineers will need to develop in the coming 10 years under the headings; Green, Digital, Entrepreneurial and Resilience Skills.

Green Skills

Responding to the question "Over the next 10 years, what Green skills will engineers need to develop?, *Sustainability* and *Carbon Accounting* were ranked highest, as in 2023. *Sustainable Design* moved up somewhat compared to 2023, while *Biodiversity* ranked significantly higher than 2023.

Rank	Topic	% of 469 responses	Rank 2023
1	Sustainability	19	1
2	Carbon Accounting	12	2
3	Sustainable Design	9	5
4	Life Cycle Analysis	7	3
5	Renewables	6	6
6	Sustainable Materials	5	6
7	Circular Economy	4	6
8	Environmental	3	6
9	Biodiversity	2	27
10	EIA	2	12
10	Green Energy	2	0
10	Green Procurement	2	6
10	Green Technologies	2	0
10	SUDS	2	6
11	Carbon Reduction	1	4
11	Climate	1	0
11	ESG	1	12
11	Net zero	1	12
11	Offshore	1	0
11	Recycling	1	6

Digital Skills

Responding to the question "Over the next 10 years, what Digital skills will engineers need to develop?, *Artificial Intelligence, Building Information Modelling (BIM),* and *Data*, once again make up the top three critical skills, however, in 2024 *AI* represents the top skill for almost half of all respondents compared to less than one-fifth in 2023.

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Digital Skills

Rank	Topic	% of 702 responses	Rank 2023
1	AI	47	2
2	BIM	12	1
3	Data	7	3
4	Coding	5	4
5	Programming	4	9
5	Software	4	5
7	Automation	2	7
7	Communication	2	13
7	Cyber Security	2	0
7	Machine Learning	2	0
11	Revit	1	11
11	3D	1	12
11	CAD	1	16
11	Cloud	1	15
11	Remote	1	8
11	Digital Twin	1	15
11	Microsoft Suite	1	8
11	Parametric Design	1	16
11	Modelling	1	10
11	AR/VR	1	6

Entrepreneurial Skills

Responding to the question "Over the next 10 years, what Entrepreneurial skills will engineers need to develop?, *Financial Acumen, Innovation* and *Start Up* skills were ranked highest.

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Entrepreneurial Skills

Rank	Topic	% of 257 responses	Rank 2023
1	Financial Acumen	17	1
2	Innovation	13	3
3	Start Up	9	4
4	Business Acumen	8	
5	Communication	7	
6	Leadership	6	
7	Business Development	5	
8	Critical Thinking	4	
9	People Management	4	
10	Management	3	5
10	Commercial Awareness	3	
12	Adaptability	3	
12	Marketing	3	
12	Networking	3	

Resilience Skills

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Responding to the question "Over the next 10 years, what Resilience skills will engineers need to develop?, *Adaptability* and *Mental Wellness* were the top two responses, the same as 2023. Notably, in third place under Resilience skills was *CPD/Learning*.

ENGINEERS IRELAND **Resilience Skills**

Rank	Topic	% of 176 responses	Rank 2023
1	Adaptability	16	1
2	Mental Wellness	15	2
3	CPD/Learning	13	0
4	Stress Management	11	5
5	Communications	11	4
6	Problem Solving	6	0
6	Change	6	7
8	Remote	5	2
9	Emotional Intelligence	4	0
10	Negotiation	3	7

7. Conclusion

Engineering remains a strong element of the Irish economy despite continued skills shortages. The field of engineering in Ireland is experiencing exciting transformations driven by technological advancements, sustainable goals, and the move towards digitisation. This is creating new engineering opportunities in infrastructure, offshore wind, and cybersecurity. By embracing these trends and overcoming obstacles, engineers in Ireland can shape a promising future and contribute to the country's sustainable growth.

The engineering profession in Ireland has numerous open doors, particularly in the fields of innovation, technology, and renewable energy. The Irish government's commitment to renewable energy and favourable business environment makes the country an appealing destination for engineering companies.

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6. FEUP/UPorto

1. Introduction

The Engineers for Europe (E4E) project is not an academic endeavour but an operational answer to the many challenges of the engineering profession in Europe. An integral part of the project is the design of a mechanism to gauge the dynamics of the profession: such "monitoring tool" should be able to capture the dynamics and trends of the profession as a whole. By being a European project concerning the engineering profession "at large", the methodology should not be too granular and specific, precisely to identify trends that affect the profession across industries, functions and countries.

Unlike thorough literature reviews required for academic papers or publications, the goal is to investigate the evolution of the engineering profession from an operational perspective. The E4E project includes a variety of partners, each representing a different facet of the engineering profession. Thus, the methodology used for the secondary research provides a common ground for E4E partners to gauge the dynamics, challenges and opportunities of the engineering profession, culminating in the yearly Engineering Skills Strategy.

1.1. The E4E project

The role of engineering in shaping our social and economic interactions has become increasingly important. Nowadays, engineering is crucial in designing and delivering products and services related to health, education, transportation, mobility, infrastructure, water, sanitation and telecommunication. The profession's importance has been further amplified by the digital and green transformations, which have created new opportunities and challenges in Artificial Intelligence, the Internet of Things, and the process of green growth, circular economy and decarbonization.

Despite the growing importance of engineering, significant asymmetries, mismatches, and polarization have undermined the profession's potential impact. Official statistics, data, and empirical evidence illustrate how there is a shortage of engineers in Europe, which is chronically needed to meet the 2030 and 2050 targets. Additionally, there is a lack of reliable data and information about the profession's dynamics and trends.

The focus on technical skills for engineers has led to skill polarization dynamics, creating a considerable gap in transversal skills. Employers are increasingly seeking multidisciplinary and soft skills in engineers. There is also a growing distance between the world of education and the world of work in engineering. Lack of integration among HE, VET, and Industry to upskill and reskill engineers has further exacerbated these issues.

The skills mismatch in the domain of soft skills and transversal competences is widening and Europe is facing an "engineering innovation and competitiveness challenge" with competitive pressures from the USA and Asia. These factors make it even more urgent to reinforce the profession and take steps to address these challenges.

E4E aims to establish a well-organized and long-lasting partnership between the education sector, including higher education + vocational training and the engineering profession, represented by professional organizations and industry players. The primary objective is to enhance the innovation and resilience of European engineers by enabling them to acquire new competencies and skills such as digital, green, resilient and entrepreneurial ones.

There are three primary objectives of E4E:

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1. Contribute to strengthening the capacity of the engineering profession to address EU's societal challenges and priorities, such as digital and green transformations and decarbonization.
2. Bridge the gap between education, training and industry in the engineering field.
3. Implement EU competence frameworks, including DigComp, LifeComp and EntreComp, in the context of the engineering profession.

1.2. Aim of this document

This document reports UPORTO's second round of secondary research as described in "The E4E Common Methodology to Assess, Anticipate and Monitor the Evolution of the Engineering Profession with a Focus on Competences", which will be incorporated in deliverable 2.4 "E4E Skills Strategy: Anticipating Skill Requirements for the Engineering Profession". This second round included the period of August 2023 till August 2024, with a focus on literature review related with skills shortages and gaps in the engineering professions.

2. Methods

The methodology used for the secondary research was based on the search of relevant keywords in document databases (SCOPUS, Web of Science) and the search for most recent policy documents in reference institutions. The search was limited to the most recent period, that is, covering the years of 2020 and 2024. A closer attention was given to references from the years 2023 and 2024.

Due to its broader scope of documents catalogued, the SCOPUS database (https://www.scopus.com) was used as the source of references. Beyond this database, we searched on the websites of national and international bodies regulating the engineering profession such as the World Federation of Engineering Organizations (WFEO), Engineers Ireland, Engineers Australia, American Society for Engineering Education, among others, for policy documents, reports and other types of guidelines relative to the thematic of skills for engineers. No significant document dated from 2023 and 2024 was found.

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Table 1 shows the searches done in the SCOPUS database, where the search terms for "Title, abstract, keywords" and the results provided are identified. The search period was from 2020 to the present. We have analysed the references per title and abstract and selected the articles from

Table 2 for a more in-depth analysis presented in the next section. The articles from the years 2023 and 2024 were analysed first and only relevant articles from previous years were then analysed. From the 21 articles analysed, 71% address skills from LifeComp, 33% from GreenComp, 29% from EntreComp and 24% from DigComp frameworks.

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Table 1 - Document searches in the SCOPUS database.

Data source (results)	Search keywords
SCOPUS (41 results)	"Skills for engineers"
SCOPUS (13 results)	"engineering profession" AND "evolution"
SCOPUS (0 results)	"emerging skills" AND "engineering profession" OR "engineering industry"
SCOPUS (86 results)	"engineering industry" OR "engineering profession" AND "competencies"
SCOPUS (2 results)	"engineering profession" AND "hard skills"
SCOPUS (9 results)	"engineering profession" AND "soft skills"
SCOPUS (7 results)	"engineering profession" AND "sustainable development goals"
SCOPUS (0 results)	"engineering profession" AND "sustainable development goals" AND "skills development"
SCOPUS (0 results)	"engineering profession" AND "conscious engineering"
SCOPUS (0 results)	"engineering profession" AND "ethical practices"
SCOPUS (3 results)	"engineering profession" AND "skills and competencies"
SCOPUS (0 results)	"engineering profession" AND "changing nature"
SCOPUS (120 results)	"engineering profession" AND "challenges" OR "opportunities"
SCOPUS (1 result)	"engineering education" AND "training programs" AND "evolving nature"
SCOPUS (5 results)	"engineering education" AND "training programs" AND "engineering profession"
Scopus (1,278 results)	"sustain*" AND "engineer" AND "skills"

Table 2 - References analysed.

Authors	Year	Title	Life Comp	Green Comp	Dig Comp	Entre Comp
Irons, A.	2023	Digital skills to enhance engineering			X	
Varney, P. et al.	2023	Fostering Employability Skills for Engineers With Serious Games: A Gamified GBL Concept	X			X
Hansen, I. et al.	2023	Towards Industry 5.0: Developing Knowledge and Skills in a Research and Innovation Lab	X			X
Leung, S. L. et al.	2021	A New Approach to Equip Students to Solve 21st-Century Global Challenges: Integrated Problem-Based Mechanical Engineering Laboratory	X	X	X	
Borkovskaya, V. G. et al.	2020	Sustainability risk management: The case for using interactive methodologies for teaching, training and practice in environmental engineering and other fields		X		
Aliu, J. et al.	2022	Developing emotionally competent engineers for the ever-changing built environment	X			

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Keusters, G. et al.	2024	Empathic Ability as a Driver for Project Management	X			
Keusters, G. et al.	2022	Improving the performance of civil engineering projects through the integrated design process	X			
Neves, V. O. et al.	2023	Challenges on the Brazilian Information Systems Education: The Professors' Perspective			X	
Jaimes-Acero, Y. C. et al.	2023	Soft Skills Requirements for the Engineering Sector: The Case of the Mechanical Engineering Industry	X			X
Allain, S. & Rabb, R. J.	2023	Developing Engineer Systems Competencies with a Nexus of Engineering, Law, and Policy	X			
Koromyslova, E. et al.	2023	Closing the professional skills gap for engineering graduates: Recent trends in higher education	X			X
Eggleston, A. G. & Rabb, R. J.	2023	Developing and Scaling Engineering Communication (EC) for New Engineering Education	X			X
Van den Broeck, L. et al.	2023	Students' and lectures perceptions on the importance, training, and assessment of professional and lifelong learning competencies	X			X
Berglund, A.	2023	Online courses for teaching engineering professionalism	X			
Munsamy, M. et al.	2023	The development and validation of a digital leadership competency scale			X	
Heldal R. et al.	2024	Sustainability competencies and skills in software engineering: An industry perspective		X		
Isaac S. et al.	2024	Exploring Engineering Students' Perception of Sustainability and Ethics in Their Curriculum Across Disciplines	X	X		
Narong, D.K.	2024	A system-based framework for engineering education as sustainable development		X		
Henry, R. et al.	2024	Engineering Skills to Respond to SDGs: A Survey of Employers, Academics, and Students	X	X		
Bueno, A. et al.	2024	Industry 4.0 Skills in Industrial Engineering Courses: Contributing to the Role of Universities Toward Sustainable Development	X	X	X	

4. Secondary Research Discussion

None of the articles analysed makes a systematic literature review to the European landscape, which would be a far more enriching source of information. But some present results from national or regional surveys which are closely related to the European Union marketplace and provide insights to what skills gaps exist in

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engineering education. Furthermore, in a globalized economy and since the onset of the Bologna process, engineering education is far more similar across different nations that before. We will look more carefully to three of the articles for the breadth of their analysis and the generalization of the conclusions that they have taken.

Koromyslova et al. (2023) presented a research paper that discussed how higher education has responded to the existing gap between employers' expectations and qualifications of recent college graduates in professional skills reported by national surveys of employers. The article is restricted to the United States of America, where less than 50% of employers evaluate college graduates as proficient in competencies such as professionalism/work ethic, oral/written communications, teamwork/collaboration, leadership, and other related skills. Yet, 80% of college graduates believe they are proficient in these skills when entering their first workplace (NACE 2015, 2018). The paper presents a two-fold analysis of Engineering/Industrial/Operations Management undergraduate programs offered by ABET-accredited Colleges of Engineering in higher education institutions in the United States. The analysis includes a review of the program's curricula and published course catalogues to determine the degree to which professional skills are incorporated into these programs.

The authors argue that since the publication of the Grinter report in 1955, engineering curricula have become more scientific and hard skills oriented. As the technical content increased, the space for other knowledge and skills decreased. In recent decades, this has led to concerns of employers, who are usually very satisfied with their new engineer's technical preparation but are dissatisfied with the ability of those new hires to function effectively in a professional environment. Professional skills have long been listed as some of the most important skills necessary for a successful engineering career, yet there has been little change in academia toward improving graduate professional skills.

According to the literature surveyed by Koromyslova et al. (2023), some engineering programs count on co-curricular activities, such as professional and honour societies, networking events, internships or extracurricular engineering design competitions, to engage students in professional skill development. Some engineering programs tack additional requirements in professional skills onto engineering sciences courses. Others rely on industry-sponsored and or service-learning activities to enhance student skills.

The first part of Koromyslova et al.'s study concludes that there is evidence in the literature that engineering professional programs are attempting to address professional skills in curricula, however, there is much work needed.

In the second part of the study, they analysed the curricula of 60 Engineering programmes for seven components of the ABET student outcomes related to professional skills sets: professionalism, ethics, oral communication, written communication, teamwork/collaboration, and leadership. They have found that Written Communication category is the most widely addressed category in both Engineering Management (EM) and Mechanical Engineering (ME) programs. However, Oral Communication is a weaker category for the ME programs. By the contrary, the Teamwork/Collaboration category is one of the lowest for the EM programs (10%), and no specific courses related to this category are offered in the ME programs. This finding supports the observation that although engineering programs require group work/projects, it appears that teamwork/collaboration skills are expected to be cultivated by students on their own or through practice. Teamwork and Collaboration are precisely the skills most valued by employers (Henry et al., 2024).

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They finish their article with recommendations on improving professional skills for engineering education. These skills should be integrated with technical content to show their importance to the profession, and these skills should be practised and developed throughout the curriculum, for example, through active learning or game base learning (Varney et al., 2023) techniques. In addition, for effective instruction, engineering faculty should receive additional training in professional skills, or efforts should be made to collaborate with professional skills faculty to offer the appropriate training in professional skills tied to technical content.

The 2023 article by Alastair Irons addresses the changes introduced by the latest version of the Accreditation of Higher Education Programmes (AHEP4) to Engineering programs in the United Kingdom. The document released by the Engineering Council introduces challenges for the future such as sustainability, EDI, and cybersecurity. The article analyses the work done to embed digital skills in the engineering curricula of the University of Sunderland. With the onset of Industry 4.0 all engineering disciples will be more digital in nature. While employers are investing heavily in the digitalization of the services they provide, they don't have the expertise in-house and can't recruit engineers who have the requisite breadth of digital skills. The need for digital skills is growing across all aspects of life – from digital living to digital learning to using digital skills in employment. It is not only software engineers or data engineers that require digital skills, but engineers from all engineering disciplines, from civil to electrical to mechanical engineering, must have digital skills to perform in today's engineering environments.

The author enumerates the different levels of digital capability in terms of digital skills in engineering ranging from:

- Digital awareness – appreciate there are digital skills that can be applied in engineering, but not really sure how to make best use of these;
- Digital Literacy – the ability to use digital technologies to undertake basic tasks such as finding information on the Internet, basic creation of documents and artefacts, ability to communicate using digital technologies and the use of digital technologies to support engineering tasks;
- Digital Competency – the use of digital technologies, tools and techniques to make engineering tasks more effective;
- Digital Proficiency – advanced use of digital skills to make engineering tasks more efficient and effective – moving towards using digital technologies to enhance the knowledge base in engineering and / or to design and create advanced engineering solutions

From the employer's perspective there are several options to consider in terms of addressing the digital skills gap:

- Do nothing and hope that any digital skills issues will pass by;
- Recruit expertise – engineering professionals with the requisite digital skills;
- Identify the digital skills required and train / re-train employees through a programme of Continued Professional Development (CPD);
- Work with universities and training providers to ensure graduates and new recruits have the appropriate digital skills.

Clearly, the first option is not recommended. The third and fourth options are preferable as they guarantee that new hires are qualified and existing personnel are continuously up-skilling and re-skilling according to the work demands.

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In terms of the role of universities in developing the digital skills of engineering students, the first step is to provide adequate skills to enable efficient learning. This could be achieved through soft-landing programs where students learn how to digitally interact with the learning environment (for example, how to structure a report, how to use software such as OneNote, how to embed tables in documents, how to use statistical software such as SPSS). Likewise, the tutor must understand the level that students are at in terms of their digital skills abilities and also appreciate what it is students know about digital skills in the context of engineering.

So, for a learning environment that enables learning to be effective, we need to make the best use of educational technology. We need tutors who understand and can apply digital pedagogies, and the students or learners need to have the digital skills to make the best use of the learning materials.

More and more engineers are expected to take control of their CPD and learning and to manage that learning as careers progress. One of the AHEP4 (F18) expectations is to "Plan and record self-learning and development as the foundation for lifelong learning/CPD". So, a particular digital skill for CPD could be the use of an e-portfolio to record experience or the use of digital badges to show the CPD journey.

At the University of Sunderland, the decision to integrate digital skills into the curriculum was driven by the professional body requirements, employer requests and student expectations as well as through the regular programme review process. Colleagues in the Engineering School had the opportunity to discuss and debate the opportunities and issues associated with the coverage of digital skills and where to embed digital skills in the curriculum to ensure that the digital skills were contextualized to be relevant to the engineering programmes. As a programme team colleagues

- identified the coverage of digital skills already in place;
- identified new areas for digital skills in the context of engineering;
- enhanced coverage in non-digital skill specific modules;
- added a new core digital skills for engineering module in first year

Henry et al. (2024) prepared a professional skills survey was designed, drawing on previous European-level research (Beagon et al. 2022), the results of which provide valuable localised insights for educators into the most important skills for the next generation of engineers to achieve the SDGs. They also reveal some variance in the views of employers, academics, and students.

Students provided the most responses (over half, 54.9%) and academics almost one quarter (23.0%). Employers (mostly multinationals and SMEs (8.9%) and nationals (4.3%)) provided the remainder of the responses. Overall awareness of the SDGs measured on a five-point Likert scale (from 5—extremely aware to 1—not at all aware) was 3.2 (somewhat to moderately aware). Unsurprisingly, the highest (4.1) was amongst academics. The lowest levels of awareness were amongst SMEs and students (2.8 each).

Respondents rated importance on a five-point Likert scale (from 5—very important to 1—not important) for 53 competences in six competency sets. All are rated as being of at least some importance, with an average rating of 3 or more. The five most important competences (Table 3) overall had ratings greater than 4.5. Though the original work of Beagon et al. (2022) considers a wide range of skills pertaining to sustainability, which also include entrepreneurship skills, almost all top 5 skills of Table 3 fall in the LifeComp framework set of skills. An interesting observation refers to the relative position of the skills in each category.

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While academics rank Problem Solving first, employers, in general, rank Communication and Teamwork as more important.

Table 3 - Importance of Competences by Category—Ranked 1–5, according to Henry et al. (2024).

Category	Top 5 Most Important
Academic	1 = Problem Solving; 2 = Teamwork / 2 = Critical Thinking; 4 = Respect for Others; 5 = Collaboration / 5 = Communication
Employer–Multinational	1 = Problem Solving /1 = Communication; 3 = Respect for Others; 4 = Collaboration; 5 = Critical Thinking / 5 = Teamwork / 5 = Technical Skills
Employer–National	1 = Communication; 2 = Teamwork; 3 = Critical Thinking / 3 = Sustainability Awareness /3 = Time Management
Employer–SME	1 = Problem Solving / 1 = Communication /1 = Teamwork; 4 = Adaptability; 5 = Collaboration / 5 = Time Management
Student	1 Problem Solving; 2 Communication; 3 Respect for Others; 4 Teamwork; 5 Time Management
All	1 Problem Solving; 2 Communication; 3 Teamwork; 4 Respect for Others; 5 Critical Thinking

Coloured font is used to illustrate similarities/differences between categories. Each competence is allocated a colour; its rank for each category is shown in the same colour. Three competences are shown in black font; each of these only appears once in the table.

5. Conclusions

This document reports the second round of secondary research done by UPorto and which will be incorporated in deliverable 2.4 “E4E Skills Strategy: Anticipating Skill Requirements for the Engineering Profession”.

The latest literature on the engineering skills gaps was analysed. The main source of information resulted from the SCOPUS database. Policy documents, white papers, guidelines and reports from Engineering professional bodies and accreditation agencies were not identified for 2023-2024 and were thus not included.

The main takeaway from the literature review is that although there have been considerable efforts from higher education institutions to close the skills gap, there is still much work to do. It is necessary to include more professional skills in program curricula and to train faculty to use them along with technical and scientific core skills. The perception universities have of the importance of skills is markedly different from the perception employers have. Academics prioritize technical skills, while employers emphasize teamwork and communication.

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7. IVEPE-SEV

1. Introduction

The engineering profession in Greece is experiencing significant transformation, driven by advancements in technology, evolving industry demands, and educational reforms. This evolution is reflected in the growing number of engineering graduates, increasing research outputs, and the expanding roles of vocational education and training (VET) programs. Moreover, professional bodies and industry trends play a critical role in shaping the engineering landscape. This paper provides a comprehensive analysis of the quantitative and qualitative aspects of these changes, explores emerging opportunities, highlights the preferred non-technical skills, and identifies the needs to overcome associated challenges.

This version comes to update the corresponding country report for Greece prepared in July 2023 and to provide a clear, structured, and comprehensive overview of the evolving nature of the engineering profession in Greece, addressing quantitative and qualitative aspects, opportunities, preferred skills, and necessary actions to overcome challenges. In this edition, following the guidelines of "The E4E Common Methodology to Assess, Anticipate and Monitor the Evolution of the Engineering Profession with a Focus on Competences", we updated the content based mainly on the opinions of experts from the academic field, renowned engineers from the world of work from various branches of industry, representatives of bodies and chambers and policy advisors of associations such as BSE, which is one of the most important social partners, representing the world of employment. Their positions, which are reflected in this study, emerged after de-listing, qualitative analysis and synthesis of the opinions expressed in the 6 focus groups organized online by IVEPE - SEV during the period September 2023 - July 2024. At the same time, we integrated actions and developments held in Greece for the engineering profession in the last year.

2. Quantitative Indicators on the Evolving Nature of the Engineering Profession in Greece

The engineering profession in Greece has seen significant changes over recent years, driven by educational advancements, industry demands, and technological innovation. Here, we provide a detailed analysis of quantitative indicators that reflect these changes from the perspectives of higher education, vocational education and training (VET), professional bodies, and industry.

Higher Education

The number of engineering graduates in Greece has been steadily increasing. In 2020, around 15,000 students completed engineering programs, reflecting a growing interest in the field (Hellenic Statistical Authority, 2021). Greek universities have made significant contributions to engineering research. In 2021, engineering faculties produced over 2,000 research papers, many published in high-impact journals (Hellenic Ministry of Education, 2022). Participation in EU-funded research projects of international collaborations has increased. In 2021, Greek institutions were involved in over 100 Horizon 2020 projects, securing substantial funding for research and development.

Vocational Education and Training (VET)

Enrolment in engineering-related VET programs has been on the rise, with over 20,000 students enrolled in 2022 (National Organization for the Certification of Qualifications and Vocational Guidance, 2022). This trend

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continued in 2023-24, with a growing interest in upskilling through vocational training. VET graduates in engineering fields enjoy high employment rates VET graduates in engineering fields enjoy high employment rates, with over 80% securing jobs within six months of graduation, indicating strong demand for practical engineering skills in the job market.

Professional Bodies

The Technical Chamber of Greece (TEE-TCG) has over 100,000 registered engineers, demonstrating a robust professional community. Each year, more than 5,000 engineers participate in continuing education and professional development programs, emphasizing the importance of lifelong learning and skill enhancement (Technical Chamber of Greece, 2022).

Industry

The demand for engineers varies by sector. In 2023, the construction sector accounted for 25% of engineering job postings, while the IT sector accounted for 20% (Hellenic Federation of Enterprises, 2023). The renewable energy sector has also seen significant growth, representing 15% of engineering job opportunities, up from 10% in 2018. Engineering job opportunities are predominantly concentrated in major urban centers like Athens, Thessaloniki, and Patras, which host most of Greece's industrial and technological hubs.

These quantitative indicators illustrate the dynamic nature of the engineering profession in Greece. The increasing number of graduates, rising research outputs, high employment rates for VET graduates, and a strong professional community position the profession well to meet the demands of modern industries. The concentration of job opportunities in urban areas and the significant role of sectors such as renewable energy and IT highlight areas of growth for future engineers.

3. Qualitative Descriptions of the Evolving Nature of the Engineering Profession in Greece

This section provides a qualitative analysis of the evolving nature of the engineering profession from the perspectives of higher education, vocational education and training (VET), professional bodies, and industry.

Higher Education (HE)

Greek universities are updating their engineering curricula to incorporate modern technologies and interdisciplinary approaches. New courses emphasize digital skills, sustainable practices, and innovative problem-solving methods, reflecting a shift towards holistic and future-oriented education.

There is a growing trend towards international collaboration in higher education. Greek engineering faculties participate in numerous exchange programs, collaborative research projects, and joint degrees with prestigious international universities. This exposure enhances the global competence of Greek engineering students.

Universities are increasingly focusing on research and innovation, establishing research centers and laboratories to foster cutting-edge projects. This focus is evident in the rising number of patents filed and active participation in EU-funded research programs

Vocational Education and Training (VET)

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Industry-Relevant Training: VET programs in Greece are aligned with industry needs, focusing on practical skills and hands-on training. Partnerships between VET institutions and industry ensure that training is relevant and up-to-date, bridging the gap between education and employment. This alignment helps bridge the gap between education and employment, making VET graduates highly employable. VET programs are adapting to include training for sectors like renewable energy, automation, and IT.

The main advantage of VET system in Greece is that it can change its curriculum faster than HE and to provide UpToDate skills and knowledge, especially in the informal education sector in which it can rapidly offer specialized tailor-made training programs based on the educational / work needs. By incorporating new technologies, VET institutions prepare students for evolving job market demands. VET institutions are more evenly distributed across Greece than higher education institutions, providing access to quality technical education in various regions, including rural and less-developed areas.

Worth mentioning as good practices are some training and certification programs implemented in Greece at the level of non-formal education. The Public Employment Service (DYPA) through the European development fund allocated many resources for training and certification programs "Upskilling - reskilling programs in all sectors of the economy with an emphasis on digital and green skills", many of which also related to the upskilling-reskilling of engineers. This also shows the national strategy that has emerged as a necessity, for people who have studied technical subjects such as engineers, to be trained in non-technical subjects and strengthened with skills that will help them in their career path. Another good example of VET (non-formal) initiative took that place in 2023-24 is the program "Engineers in Action" that was launched by Metlen's Corporate Social Responsibility department (one of the most significant Greek industry). This successful training initiative program is in its 6th cycle and aims to feed the talent pool of the company and the Greek industry with highly trained and experienced engineers. Finally, a training intervention implemented in 2023-24 that worths mentioning, is the "Skills4Job" training initiative. The Skills4Jobs initiative is a program developed by the Hellenic Federation of Enterprises (SEV) and impended by IVEPE-SEV to address the skills gap in the Greek labor market. The initiative aims to enhance the technical and soft skills of participants, aligning them with the needs of modern industries. The program offers specialized training courses, s for Technicians and Engineers (Electrical, Mechanical, Automation) all over Greece (Thrace, Thessaly, Central Greece, etc). This course includes 3 months of training, career guidance, and practice. Successful participants are provided with employment opportunities within SEV member companies (employment rate after the program is more than 80%). Moreover, broader objectives with Skills4Jobs include fostering sustainable economic growth and improving the competitiveness of Greek industries by ensuring that the workforce is well-equipped with relevant skills. This initiative is part of SEV's efforts to create a positive business environment and promote job creation through private sector-led growth. IVEPE-SEV, the educational branch of SEV and a licensed Lifelong Training Center, has been a reference model in the field of professional training in Greece since 1980 and through innovative programs mainly for technicians and engineers strengthens people and businesses with know-how and skills.

As a general conclusion regarding the points that need improvement in the Greek education system and the training system, it is that in the engineering programs the apprenticeship or practical training system is not particularly developed in relation to many European countries (no dual system or similar). This creates a difficulty in gaining real work experience and connecting with the world of work. However, as engineering students receive a high-level education, they are in great demand from the labor market, especially in well-paid research fields, especially from companies outside of Greece. This reinforces the phenomenon of brain drain at

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the level of engineers that Greece has been experiencing since the beginning of the financial crisis in 2008. In the long term, of course, even this phenomenon has some positive impact on the country, as a percentage of engineers return to the production machine of Greece bringing new know-how.

Professional Bodies

Professional bodies, such as Technical Chamber of Greece (TEE-TCG), offer various training programs, workshops, and seminars to keep engineers updated with the latest advancements. These programs cover topics from new technologies to regulatory changes and soft skills development. Professional bodies advocate for engineers' interests and ensure adherence to professional standards. They actively participate in policy-making processes and work closely with the government to shape relevant regulations that affect the engineering profession. Finally, professional bodies facilitate networking and collaboration through conferences, forums, and events, fostering a sense of community among engineers.

Industry

The engineering profession in Greece is heavily influenced by technological advancements. The IT, renewable energy, and construction sectors are rapidly evolving, driven by technological innovations. Engineers must continually update their skills to keep pace with these changes, integrating technologies like IoT, AI, and blockchain. By means of sectoral focus, The IT and renewable energy sectors lead the engineering evolution in Greece. These sectors are more advanced in adopting new technologies and practices, with significant investments in areas like solar and wind technologies and digital transformation. In terms of geographical distribution, there are regional disparities in the evolution of the engineering profession Major urban centers are hubs of innovation and engineering activity, with greater access to resources and opportunities than rural areas. Efforts are being made to reduce these disparities through regional development programs.

There is a growing emphasis on sustainability and environmental responsibility in engineering practices. Engineers in Greece are increasingly involved in projects that focus on sustainable development, energy efficiency, and environmental conservation. This shift reflects global trends and the need to address climate change and environmental challenges. The creation of new university faculties such as that of Environmental Engineering shows the country's focus on creating engineers with a greater environmental awareness who will help achieve Sustainable Development Goals.

The above qualitative indicators of the evolving nature of the engineering profession in Greece highlights the significant transformations taking place across higher education, VET, professional bodies, and industry. These changes are driven by technological advancements, global trends, and the need for sustainable development. By adapting to these changes, the engineering profession in Greece is poised to meet the future demands of the economy and society.

4. Opportunities of the Evolving Nature of the Engineering Profession in Greece

The engineering profession in Greece is witnessing significant evolution, driven by technological advancements, economic shifts, and global trends. These changes are creating numerous opportunities across various sectors, presenting a promising future for engineers in the country. This section provides an analysis of the demand for engineers in different industry sectors, the emerging opportunities, and the profiles of engineers that are increasingly in demand.

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Demand and opportunities for Engineers by Industry Sector

The renewable energy sector is experiencing rapid growth due to Greece's commitment to reducing carbon emissions and increasing the use of clean energy. There is high demand for engineers specializing in solar, wind, and hydroelectric power. Engineers can work on designing and implementing renewable energy projects, conducting research and development, and maintaining and optimizing existing energy systems.

The IT sector in Greece is expanding, driven by digital transformation initiatives across industries. There is a strong demand for software engineers, network engineers, and cybersecurity experts. Engineers can engage in software development, IT consulting, network infrastructure design, and cybersecurity management. The growing tech startup ecosystem also provides numerous opportunities for innovation and entrepreneurship.

The construction sector remains a significant part of the Greek economy, with ongoing projects in urban development, transportation, and tourism infrastructure. Civil, structural, and environmental engineers are in high demand. Engineers can work on designing sustainable buildings, bridges, roads, and other infrastructure projects. The focus on green construction practices and smart city initiatives also opens new avenues for engineers.

Greece's strategic location and its role as a global shipping hub create a steady demand for naval architects, marine engineers, and mechanical engineers specializing in maritime technologies. Engineers in **Maritime and Shipping sector** can engage in shipbuilding, maintenance, port automation, and logistics management, contributing to the modernization of Greece’s maritime industry.

The **manufacturing sector** is evolving with a focus on automation and process optimization. Electrical, mechanical, electronics, automation, production and industrial management engineers are in demand to improve productivity and efficiency. Engineers can work on automation projects, quality control, product design, and development of advanced manufacturing technologies.

The healthcare sector is also growing, with increasing investments in medical technologies and healthcare infrastructure. **Biomedical** engineers are in demand for their expertise in medical device development and healthcare technology innovation. Engineers can engage in developing medical devices, hospital equipment management, and research in healthcare technologies.

Emerging Opportunities appear in Sustainability and Environmental Engineering, Smart Technologies and IoT and Research and Development (R&D)

The emphasis on sustainability is creating new opportunities for environmental engineers. They can work on projects related to waste management, water resources management, and environmental impact assessments. The integration of smart technologies and the Internet of Things (IoT) in various sectors is opening opportunities for engineers with expertise in electronics, automation, and data analytics. Finally, there is a growing focus on R&D in engineering, driven by both public and private sector investments. Engineers can engage in cutting-edge research in fields such as nanotechnology, materials science, and renewable energy technologies.

We can conclude that the evolving nature of the engineering profession in Greece presents a lot of opportunities across different sectors. The demand for engineers is strong in renewable energy, IT, construction, maritime, manufacturing, and biomedical engineering. Emerging fields such as sustainability,

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smart technologies, and R&D offer new avenues for professional growth. Engineers with multidisciplinary skills, digital proficiency, sustainability focus, and innovative thinking are particularly well-positioned to take advantage of these opportunities.

Engineering Profile in Demand

Engineers with **multidisciplinary skills** that span across traditional boundaries are in high demand. For example, an engineer with expertise in both mechanical engineering and software development is highly valuable in the automation and robotics sectors.

Proficiency in **digital tools, data analysis, and programming** is increasingly important. Engineers who can leverage big data, AI, and machine learning to solve complex problems are highly sought after.

Engineers with a strong **focus on sustainability and green technologies** are in demand across various sectors, particularly in construction, energy, and environmental engineering.

There is a growing appreciation for engineers who demonstrate **innovative thinking** and **entrepreneurial skills.** The ability to develop new products, start tech ventures, and drive technological advancements is highly valued.

Preferred Non-Technical Skills and Competencies of Engineers in Demand from Greek Industries

A view steadily gaining ground in the world of work in Greece is that technical ability alone is insufficient for employability and career success. Greek industries increasingly value engineers who possess a blend of technical and non-technical skills. These non-technical skills, often referred to as "soft" or "professional skills" or better described by LifeComp framework as Life Competencies, are essential for the future engineers and will be in high demand from Greek employers/industries. Among them, most of the participants in our focus groups, highlighted the following:

Engineers must have the skills to **communicate** complex technical concepts clearly and concisely to non-technical stakeholders, including clients, management, and team members. Written communication skills are essential for drafting reports, proposals, and documentation that are clear and professionally presented, and presentation Skills are essential to present their ideas, designs, and findings to diverse audiences. Engineering projects often require interdisciplinary **collaboration** across various disciplines. The ability to work effectively with professionals from different backgrounds is highly valued. Engineers are usually team supervisors / leaders and the capacity to **resolve conflicts** amicably and maintain a cooperative team environment is crucial for successful project execution. Being a **supportive and reliable** team member who supports colleagues and contributes to a positive team dynamic is also highly appreciated. Experienced engineers who can **mentor** junior colleagues and foster a **culture of continuous learning** are highly valued. Engineers are expected to analyze complex problems, identify root causes, and develop innovative solutions. **Strong analytical thinking** is critical for effective decision-making weighing pros and cons and make informed choices under pressure. The ability **to think creatively** and propose novel solutions to engineering challenges is increasingly important in a competitive industry landscape. Engineers who can align technical projects with broader organizational goals and demonstrate strategic thinking are in short supply and naturally in high demand by the job market. Since the engineering field is constantly evolving, engineers who stay **resilient** in the face of obstacles and challenges and able to embrace change **(Adaptability and Flexibility skills)** and can adapt to new technologies,

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methodologies, and changing market conditions are highly sought after. A commitment to **continuous learning** and staying updated with industry trends and advancements is essential for career longevity. Ethics, Integrity, Accountability, and Professionalism are highly appreciated characteristics from the market, and since engineers work in multinational companies and projects, cultural awareness and respect - utilization of diversity are skills that future

Greek industries highly value engineers who possess a well-rounded skill set that includes strong non-technical competencies. Communication, teamwork, problem-solving, leadership, adaptability, cultural awareness, and professionalism are all crucial for success in the modern engineering profession. By developing these soft skills, engineers can enhance their effectiveness, advance their careers, and contribute more significantly to their organizations and society.

5. Needs to Overcome the Challenges of the Evolving Nature of the Engineering Profession in Greece

The changes in the engineering profession come with their own set of challenges. To effectively navigate and overcome these challenges, several needs must be addressed across various sectors including education, industry, and governmental policies.

The need for enhanced education and training arises. Engineering curricula need to be continuously updated to include emerging technologies and practices. This includes incorporating new technical subjects such as artificial intelligence, renewable energy technologies, and advanced manufacturing processes but at the same time subjects or pedagogical methods that promote non-technical skills. The education world must focus on practical, hands-on training through internships, co-op programs, and industry partnerships can help engineering students gain real-world experience. Establishing lifelong learning opportunities for engineers to update their skills and knowledge regularly is essential. This can be facilitated through professional development courses, online learning platforms, and certification programs.

There is also the need to strengthening and promote industry-academia collaboration in joint research initiatives that can drive innovation and ensure that academic research is aligned with industry needs. The industry suggests that academic institutions should focus in shaping curricula that meet the evolving demands of the job market. Having as standard practice the internship and apprenticeship programs, academia can provide students with practical experience and help bridge the gap between education and employment.

Increasing government funding and grants for engineering education and research can support innovation and development in Greece. At the same time, providing tax incentives and subsidies for companies investing in R&D through collaborations with engineering schools is a proposal from the market for overcoming challenges and motivating stakeholders to work together in the country's development. Streamlining regulatory processes and reducing bureaucratic hurdles can facilitate the timely execution of engineering projects.

Since there is an increasing need for engineers in the market, promotion actions of engineering education must implement. Early education programs introducing and promoting STEM education at the primary and secondary school levels and awareness campaigns showing the importance and opportunities within the engineering profession, can spark interest in engineering careers from an early age and attract more students to the field.

Development of life competencies, digital and entrepreneurial skills through formal or non-formal / informal education and training can prepare engineers for the demanding nature of modern engineering work.

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Upgrading educational, training, and research facilities with state-of-the-art equipment and technologies can enhance the learning and research experience is needed for ensuring that students and professionals have access to the latest research, tools, and technologies since this is crucial for staying current in the field and overcoming challenges to come.

Expanding distance learning opportunities can provide access to quality engineering education for students in remote areas that have no easy physical access due to distance from engineering schools.

Initiatives to encourage more women to pursue engineering careers can help address gender imbalances in the profession. Developing and implementing policies that promote diversity and inclusion within educational institutions and workplaces can create a more equitable environment for all engineers.

Addressing the needs to overcome the challenges of the evolving nature of the engineering profession in Greece requires a multifaceted approach. By enhancing education and training programs, strengthening industry-academia collaboration, providing government support, promoting STEM education, developing soft skills, upgrading infrastructure, addressing regional disparities, and promoting diversity and inclusion, Greece can effectively navigate the changing landscape of the engineering profession. These efforts will ensure that Greek engineers are well-equipped to meet the demands of modern industries and contribute significantly to the country's economic and technological development.

6. Further research

At the time that the situation for the future of engineering in Greece is captured through this report, a large survey of the TEE/TKM is being conducted in parallel on the profession of engineering in Central Macedonia. In a sense, the results of the research will also reflect the reality in Greece as a whole, if we consider the fact that Central Macedonia has the privilege of being, at all levels of economic and social life, a micrograph of the whole country and reflects approximately 20% of the industrial economic activity and absorption of engineers in the Greek area. At the same time, IVEPE-SEV with the support of Hellenic Federation of Enterprises (SEV) plans to implement a large-scale survey on the profession of engineer and the skills that companies are looking for in them, in the 1st half of 2025. We therefore expect the recording of new important conclusions in the next edition of this report.

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8. KU Leuven

1. Introduction

To understand the recent trends in modern engineering education, it is important to analyse the global situation in the world labour market in general. The Future of Jobs (2023) report made the following key conclusions:

- **Technology adoption** will remain a key driver of business transformation in the next five years. More than 85% of organisations surveyed cite increased adoption of new and advanced technologies and increased digital access as trends that are likely to drive transformation in their organisations.
- Within technology adoption, **big data, cloud computing and AI** feature highly on likelihood of adoption. More than 75% of companies intend to implement these technologies in the next five years.
- **Analytical thinking and creative thinking** remain the most important competencies for workers in 2023.
- Employers estimate that 44% of workers' competencies will be disrupted in the next five years. **Cognitive competencies are reported to be growing in importance fastest**, reflecting the growing importance of solving complex problems in the workplace. According to the companies surveyed, the importance of creative thinking is growing slightly faster than analytical thinking. Technological literacy is the third fastest growing core competency. Self-assessment competencies rank above working with others in terms of growth rate of importance of competencies reported by businesses. The social-emotional attitudes whose importance businesses believe is growing fastest are curiosity and lifelong learning; resilience, flexibility and agility; motivation and self-awareness. Systems thinking, artificial intelligence and big data, talent management, and service and customer service orientation round out the top 10 growing competencies.
- **Six in 10 workers will require training before 2027**, but only half of workers are seen to have access to adequate training opportunities today. In 2023-2027, the highest priority for competencies training will be analytical thinking, which on average will account for 10% of training initiatives. The second priority for staff development is the development of creative thinking, which will account for 8 % of competencies development initiatives. Training employees to use artificial intelligence and big data ranks third among companies' competencies development priorities over the next five years and will be a priority for 42% of companies surveyed. Employers also plan to focus on developing employees' leadership and social influence competencies (40% of companies); resilience, flexibility and agility (32%); and curiosity and lifelong learning (30%).
- The competencies whose importance companies believe are growing fastest are not always reflected in corporate competencies development strategies. In addition to the top-ranked cognitive competencies, there are two competencies that companies prioritise far more than their current importance to their employees would suggest: AI and big data, and leadership and social influence. Companies rank AI and big data 12 places higher in their upskilling strategies than in basic competencies assessments and report that they will invest about 9% of their reskilling efforts in them - more than in the more highly rated creative thinking, indicating that while AI and big data are included in fewer strategies, they tend to be a more important element when they are included.

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2. Competencies needed for the modern engineer

In this chapter, we have outlined which professional competencies are considered to be the most important for engineers from the perspectives of employees (Fleming et al. 2023; Maturro et al. 2019), students (Bae et al. 2019) and teachers (Beagon & Bowe 2023), based on recent literature.

Fleming et al. (2023) analysed a large sample (n=26103) of job advertisements and found that the most frequently sought professional competency is problem-solving; the most frequently sought technical competencies across disciplines are Microsoft Office software and computer-aided design software. Although not the most frequently requested competencies, job advertisements including the Python and MATLAB programming languages paid significantly higher salaries than those without.

Certainly, the required competencies may vary from one engineering field to another. For example, Maturro et al. (2019) made a systematic mapping study in software engineering and identified 30 main categories of professional competencies based on 44 papers. At least half of the studies selected mention five competencies: communication, teamwork, analytical, organizational, and interpersonal competencies (see Table 1).

Professional competencies	Freq.	%
Communication competencies	40	91
Teamwork	30	68
Analytical competencies	24	55
Organizational/Planning competencies	24	55
Interpersonal competencies	23	52
Leadership	21	48
Problem-solving competencies	21	48
Autonomy	19	43
Decision-making	15	34
Initiative	14	32
Conflict management	14	32
Change management	13	30
Commitment/Responsibility	13	30
Stress management	13	30
Customer orientation	12	27
Flexibility	12	27
Ethics	11	25
Results orientation	11	25
Time management	11	25
Innovation	10	23
Presentation competencies	10	23
Creativity	9	20
Critical thinking	9	20
Negotiation competencies	9	20
Listening competencies	8	18
Motivation	8	18
Willingness to learn	8	18
Fast learner	7	16
Team management	5	11
Methodical	4	9

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Table 1. Main categories of professional competencies and number of times they appear in the selected papers (Maturro G. et al., 2019).

In addition, Maturro et al. (2019) compiled a table of definitions of the most demanded professional competencies that were mentioned in their study (see Table 2). The list of references is presented in Table 3.

Professional competency category	**Definition**
Communication competencies	Communicate orally and written in simple, concise, unambiguous, and easily understood way [ref 1 in Table 3]. The set of competencies that enables a person to convey information so that it is received and understood [ref 2 in Table 3]. The ability to convey information so that it is well received and understood [ref 3 in Table 3]. The ability to communicate effectively with others [ref 4 in table 3].
Conflict management	The ability to solve conflicts of interest in work situations [ref 1 in Table 3].
Customer orientation	The ability to identify and meet the needs of its customers [ref 1 in Table 3].
Teamwork	The ability of an individual who is good at working closely with other people [ref 2 in Table 3]. The ability to work effectively in a team environment and contribute toward the desired goal [ref 3 in Table 3]. The ability to cooperate with other teammates during teamwork [ref 4 in Table 3].
Analytical competencies	The ability to understand and explain each part of a whole, to know better than nature, functions, causes, among others [ref 1 in Table 3]. The ability to break a situation down into its component parts, recognize what needs to be done and plan a suitable course of action in a step-by-step way [ref 2 in Table 3]. The ability to think logically, analyse and solve problems [ref 4 in Table 3].
Organizational/Planning competencies	The ability to sort, prioritize and control the execution of their tasks according to plan, and the resources under their responsibility [ref 1 in Table 3]. The ability of an individual to assess and prioritize tasks and ensure that they are completed in a timely manner [ref 2 in Table 3]. The ability to efficiently manage various tasks and to remain on schedule without wasting resources [ref 3 in Table 3]. The ability to make people work efficiently [ref 4 in Table 3].
Interpersonal competencies	The person's ability to behave in ways that increase the probability of achieving the desired outcomes [ref 2 in Table 3]. The ability to deal with

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	other people through social communication and interactions under favourable and inauspicious conditions [ref 3 in Table 3].
Problem-solving competencies	The ability to evaluate a situation and to identify an appropriate solution that meets the customers' needs [ref 2 in Table 3]. The ability to understand, articulate, and solve complex problems [ref 3 in Table 3]. The ability to think logically analyse and solve problems [ref 4 in Table 3].
Autonomy	The capacity to govern themselves by their own means [ref 1 in Table 3]. The individual's capability to operate with a reduced level of supervision to plan and successfully complete tasks independently [ref 2 in Table 3]. The ability to carry out tasks with minimal supervision [ref 3 in Table 3]. The ability to complete work independently [ref 4 in Table 3].
Decision-making	The ability to judge alternatives and take appropriate decisions [ref 1 in Table 3]. The ability to make sensible decisions based on available information [ref 3 in Table 3].
Initiative	The ability to propose and / or take any action without the need for others to come to ask or say [ref 1 in Table 3]. The ability to be active and optimistic to meet challenging work [ref 4 in Table 3].
Change management	The ability to adapt and work effectively with different situations and face of change [ref 1 in Table 3]. The ability of an individual to accept changes in the carrying out of tasks without showing resistance [ref 2 in Table 3]. The ability to accept and adapt to changes when carrying out a task without showing resistance [ref 3 in Table 3].
Commitment/Responsibility	To be responsible for the work [ref 4 in Table 3].
Ethics	The ability to follow a set of rules and precepts of value, order, and morality [ref 1 in Table 3].
Results orientation	The ability to achieve and/or exceed sales goals and/or objectives [ref 1 in Table 3].
Innovation	The ability to identify and create new ideas and opportunities [ref 1 in Table 3]. The ability to produce or propose imaginative and practical solutions to business problems [ref 2 in Table 3]. The ability to come up with new and creative solutions [ref 3 in Table 3]. To have creative thinking to put forward new ideas [ref 4 in Table 3].
Critical thinking	The ability to determine carefully and deliberately accepted, refutation suspension of the trial about a particular piece of information [ref 1 in Table 3].

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Listening competencies	The capacity to consider what the interlocutors are reporting [ref 1 in Table 3].
Fast learner	The ability to adapt to new tasks, roles, or challenges effectively and with ease [ref 2 in Table 3]. The ability to learn new concepts, methodologies, and technologies in a comparatively short timeframe [ref 3 in Table 3]. To have interest in learning and have the ability of self-learning in short time [ref 4 in Table 3].
Methodical	The ability to use a set of steps, neatly arranged, set by methods (techniques) to solve a particular issue or problem [ref 1 in Table 3].

Table 2. Definitions of some professional competencies (Maturro et al. 2019).

Ref.	Bibliographic data
1	Vale, L., Bessa, A., Vasconcelos, P.: Relevant Skills to Requirement Analysts According to the Literature and the Project Managers Perspective, in 2010 Seventh International Conference on the Quality of Information and Communications Technology, 2010, pp. 228–232.
2	Ahmed, F.: Software Requirements Engineer: An Empirical Study about Non-Technical Skills, Journal of Software, Vol. 7, No. 2, pp. 389–397, Feb. 2012.
3	Ahmed, F., Capretz, L. F., Campbell, P.: Evaluating the Demand for Soft Skills in Software Development, IT Professional, 14, 1, pp. 44–49, 2012.
4	Jia, J., Chen, Z., Du, X.: Understanding Soft Skills Requirements for Mobile Applications Developers, 2017 IEEE International Conference on Computational Science and Engineering (CSE) and IEEE International Conference on Embedded and Ubiquitous Computing (EUC), 2017, pp. 108-115.

Table 3. Bibliographic data of selected papers (Maturro et al. 2019)

While the two previous studies focused on professional competencies from the employers' perspective, Bae et al. (2019) were interested in the students' understanding of what is required for their careers, how to develop competencies through diverse experiences, and who can assist them with their career preparation. To illuminate students' employability, they organised interviews with 13 civil engineering students and implemented a deductive analytic approach. An employability framework was used as a theoretical lens to explore civil engineering students' perceptions and experiences of preparing for their careers by using five key elements: professional competencies, experience, career development learning, emotional intelligence, and degree-specific knowledge. This study identified three themes that explicated civil engineering students' development of employability. Civil engineering students (1) improved their employability by developing career motivation inside and outside the classroom, (2) developed professional competencies and emotional intelligence through out-of-class activities, and (3) acknowledged the importance of professional competencies but varied in their perceptions about learning them in class.

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Among other results, a table of the professional competencies that most of the surveyed students consider as important for their future career was compiled. Table 4 illustrates the five professional competencies, along with their definitions and an example quote from the interview transcripts, that many participants (>80%) identified as important for their career preparation. The number of students who discussed a particular professional competency is indicated by the n-value.

Professional skills	Definition	Example excerpts
Working in teams (n = 13)	Student believed in the importance of, or had an experience with, working with different members in a team.	Learning how to work in groups is another really big thing [. . .] I used to be that person if someone wasn't doing their part, I wanted to avoid confrontation, so I would just either pick up their slack and go from there, but it really is not beneficial at the end. Knowing how to work in a team and knowing how to give very good constructive criticism to somebody, you know like "Hey, you're not, maybe I can help you with this if you're not understanding it," you know just more interactions like, that I feel because I feel lot of people do struggle with that in terms of a group setting.
Good oral communication (n = 13)	Student believed in the importance of, or had an experience with, verbally exchanging information by clearly understanding their own thoughts and thoughts of others.	Seeing those communications skills and seeing times where people didn't have them, and seeing how it delayed the process in trying to figure out a problem really made me understand that communications [are] definitely number one for me.
Willingness to learn (n = 12)	Student believed in the importance of, or had an experience with, proactively engaging in learning new things.	I definitely went into [the internship] still not knowing a lot of things. You learn a lot from your classes, but there's a lot you don't know too. So the ability to learn and to know where to look for the answers and kind of be able to find the answers, I think has been probably the most helpful thing college has taught me.
Ability to manage others (n = 12)	Student believed in the importance of, or had an experience with, directing other people to accomplish a goal.	Encouraging somebody that no matter what the problem is, there's a solution. A lot of times, I guess, in construction especially, the first solution you come up with may not be where you end up, and so at least having somebody patient and willing to stick it out and understand that we'll get there is the most important thing.
Independent working/autonomy (n = 11)	Student believed in the importance of, or had an experience with, working autonomously and independently on a task.	I didn't like the managers breathing down my neck getting things done. I kind of laid out as a leader what I expected to be done, gave suggestions and stuff along the way, but did give the employees [who] were working with me a lot of freedom and getting to that.

Table 4. Professional competencies indicated by civil engineering students as important for their career (Bae et al. 2019)

However, as Beagon & Bowe (2023) marked, transformation [of engineering education programs] will only be successful if faculty fully engage in all curriculum design aspects; however, little is known about how faculty view professional competencies. This understanding is critical if we wish to support and encourage their participation in the transformation effort. In their study Beagon & Bowe revealed the qualitatively different ways faculty conceptualize professional competencies. Phenomenography (a qualitative research methodology that maps the different ways in which people experience, conceptualize, perceive, or understand a phenomenon) was selected as the most appropriate method to showcase the variations in faculty conceptions. The study selected 19 interview participants from 273 responses to an online survey. Faculty revealed their conceptions of professional competencies in six ways: communication competencies, technical competencies, enabling competencies, a combination of competencies, interpersonal behaviours, and acting professionally. Beagon and Bowe conclude in the following way: "Findings revealed a tension between technical and nontechnical competencies. The study highlights that engineering education must focus on behaviours and interactions between people rather than technical competencies alone. Further, there was a gendered difference in conceptions between women and men with women more likely to consider professional competencies to be inclusive of behavioural aspects". They identified six hierarchical conceptions of

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professional competencies: communication, technical, enabling, combination, interpersonal and acting professionally (see Table 5).

Variation	Category A - Communication	Category B - Technical	Category C - Enabling	Category D - Combination	Category E - Interpersonal	Category F - Acting professionally
Purpose	To *communicate* verbally and in written form and to make your voice heard	To have discipline-specific technical skills you can *use as an engineer*	To enable a person *to be successful* as an engineer	To have a mix of technical and other skills *to function* as an engineer	To *work with other people*, to have good relationships with your peers	To *act professionally* toward people and society
Benefit	Personal benefit	Industry benefit	Personal benefit	Personal and industry benefits	Personal and industry benefits	Personal, industry, and societal benefits
Type	Non-discipline-specific	Discipline-specific technical	Non-discipline-specific	Discipline-specific and non-discipline-specific	Non-discipline-specific	Non-discipline-specific
	SKILLS	SKILLS	SKILLS	SKILLS	BEHAVIOR	SKILLS and BEHAVIOR
	Verbal and written communication	Technical discipline-specific skills	Communication, present an argument, solve problems	Combination of skills	Attitude toward others. Respect and courtesy	Attitude, responsibility ethics, and integrity

Table 5. Six hierarchical conceptions of professional competencies according to faculty of TU Dublin (Beagon & Bowe 2023)

Moreover, the conceptions of the faculty are not stable. They transition from one category of description to another (see Table 6).

Transition	Description of qualitative differences between ways of experiencing
Communication → Enabling	This difference is characterized by a transition into awareness that good (non-discipline specific) skills can be of benefit to the person and not necessarily just for industry. They are the skills to "enable" an engineer to be successful in their own personal development and career. The transition is to accept the critical importance of these non-discipline-specific skills in succeeding as an engineer.
Technical → Combination and Enabling → Combination	A change occurs in this transition by crossing a threshold that recognizes the value of both discipline-specific and non-discipline-specific skills. Now, both types of skills are recognized as critical to function as an engineer and have both personal and industry benefit.
Enabling → Interpersonal	The transition from moving from an enabling category to interpersonal category is to move from an internal facing perspective (on an individual level) to an outward facing perspective, that of the importance of working with others. Engineers need to be able to work in teams in industry, and thus appreciating the importance of behaviors such as attitudes, respect, and courtesy are the key distinctions in this transition.
Combination → Acting professionally	The combination category already recognizes the importance of both discipline-specific and non-discipline-specific skills, but the transition to acting professionally is to place a focus on the importance of an engineer's actions on other people and also on society in regard to their professional work. This includes both the use of the skills they have developed, but also their behavior toward others and their attitude and worldview toward society and the implications of their work.
Interpersonal → Acting professionally	A change occurs here in crossing the threshold that values both discipline-specific and non-discipline-specific skills. It is recognized that although interpersonal skills are critically important, an engineer also needs a sound foundation in discipline-specific technical skills. Further, the transition to acting professionally includes aspects of one's character and worldview, it is not limited to developing skills, but reflects behavioral traits. Fundamentally, engineers need to be able to design artifacts safely by having excellent discipline-specific skills, coupled with excellent interpersonal skills to work with others to deliver projects and do so in a way that showcases responsible attitudes, ethics, and integrity toward people and society.

Table 6. Overview of transitions between categories (Beagon & Bowe 2023)

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Their study also expands on who benefits from the development of the competencies. The aspect 'benefit' is visualised in Figure 1.

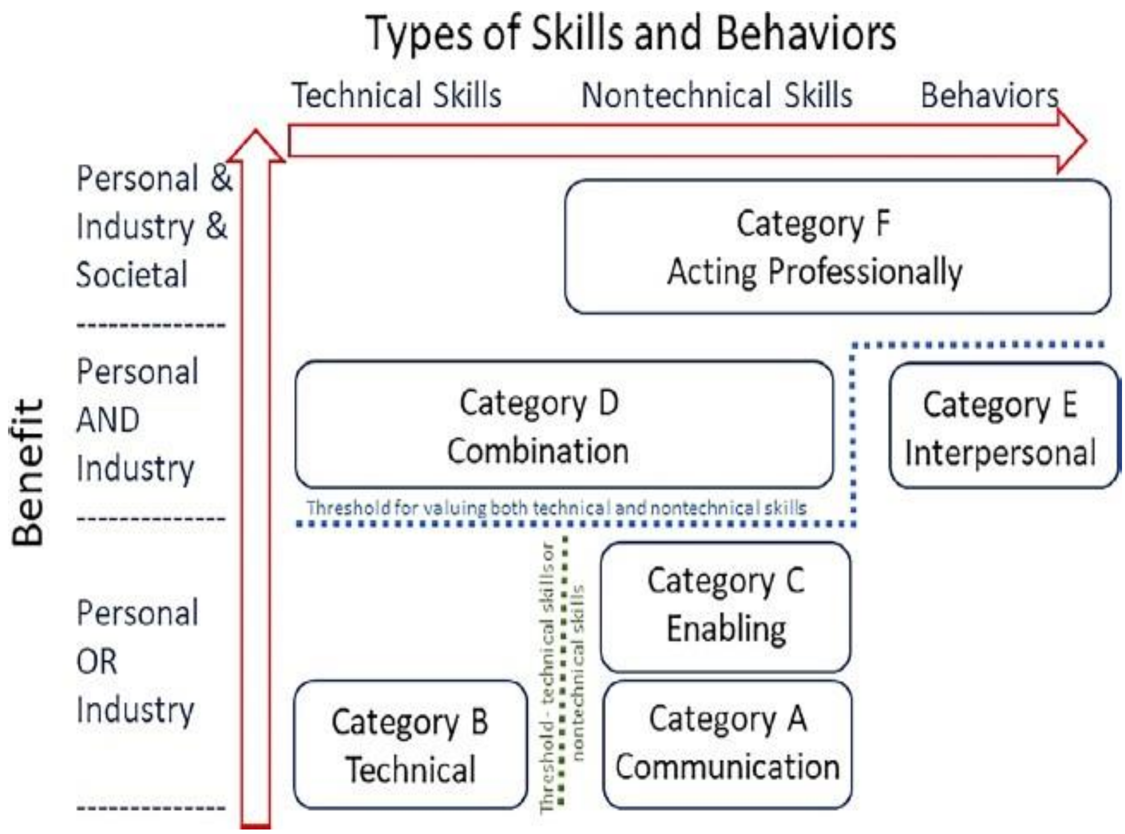

Figure 1. Visualisation of the six conceptions of professional competencies as a function of who benefits. (Beagon & Bowe 2023)

3. Methods of teaching professional competencies to future engineers

In the previous chapter we emphasised the importance of professional competencies for the employability of modern engineers. This raises the question of what training methods and tools should be used to develop these competencies in future professional engineers. That is why in this chapter we have reviewed three recent academical publications that propose instruments for teaching professional competencies.

Mikhridinova et al. (2022) developed a 5-step model for developing the relevant professional competencies out of international and interdisciplinary project tasks (see Figure 2),

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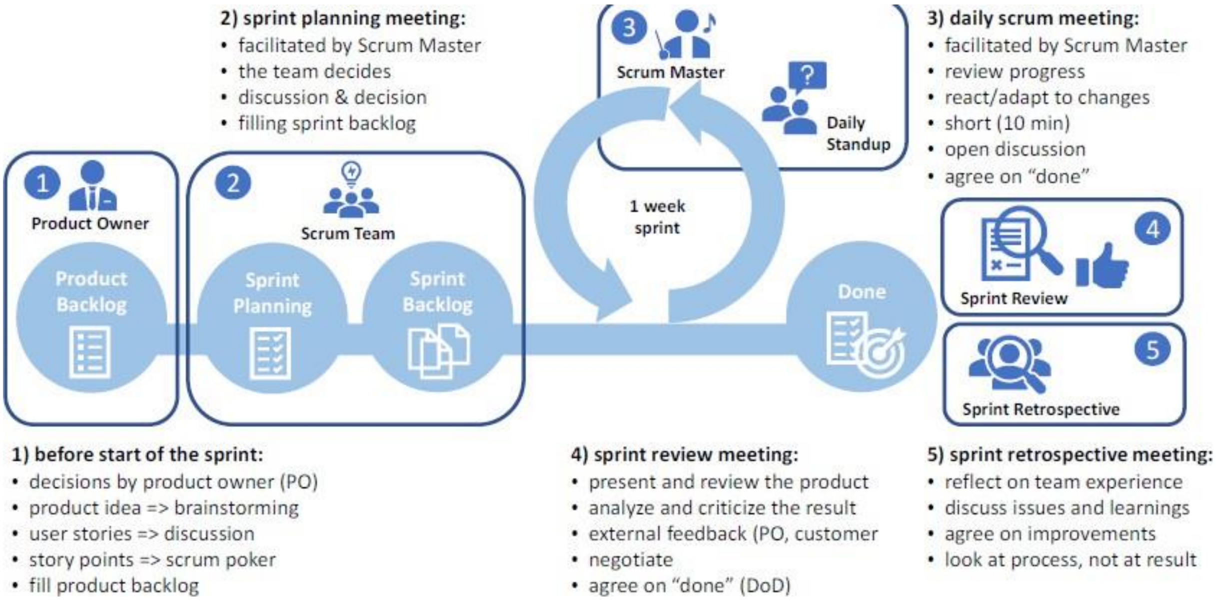

Figure 2. The 5-step model for designing international and interdisciplinary cross-border projects where students from different backgrounds and cultures can train technical, professional and global competencies. (Baizhanova et al. 2022)

The effectiveness of team-based learning has been analysed by Lai et al. (2020). This study focused on 165 students who were enrolled in a freshman-level programming course in the Fall of 2019. At the end of the team-based learning, there were some modest gains in critical thinking and external motivation.

Another approach to improve the professional competencies of future engineers, is proposed by Chen et al. (2022). They incorporated modelling-eliciting activities (MEA) into an online engineering course. MEA-activities focus on guiding learners to discover and define design problems based on a real challenge. Like problem-solving in the real world, the MEA guides learners through simplification, assumption, assessment, simulation, and prototype. This series of operations is essentially in line with the structured thinking in engineering. The participants in this study were 147 junior undergraduates majoring in mechanical engineering. The improvement of the competencies 'critical thinking' and 'collaboration' of the experimental group was significantly better than that of the control group.

4. Conclusions

As can be seen from recent studies, professional competencies are very important for engineers. And despite the differences in the importance of various professional competencies, the main conclusion is that the development of these competencies is a very important task for higher education institutions.

This raises the question of what methods can be used to teach professional competencies. Recent research studies indicate that good results have been obtained by project-based learning, team-based learning and the inclusion of modelling-enabling activities in engineering courses.

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Appendix – Evidence table

No	Author, year, study title,	Problem statement	Methodology	Key Findings	Limitations
1	Fleming G. C., Klopfer M., Katz A., Knight D. (2024). *What engineering employers want: An analysis of technical and professional skills in engineering job advertisements.* Journal of Engineering Education. DOI: 10.1002/jee.20581	The purpose of this study is to determine how industry employer-sought professional and technical competencies vary among engineering disciplines and levels of education.	Using a large sample (n=26,103) of mined job advertisements, we use the O*NET competencies database to determine the frequencies of different professional and technical competencies for biomedical, civil, chemical, electrical, environmental, and mechanical engineers with bachelor's, master's, and PhD degrees.	The most frequently sought professional competency is problem-solving; the most frequently sought technical competencies across disciplines are Microsoft Office software and computer-aided design software. Although not the most frequently requested competencies, job advertisements including the Python and MATLAB programming languages paid significantly higher salaries than those without.	This study analyzes job advertisements scraped from one point in time (April 2021), therefore reflecting the job market at that point in time. As the job market is rapidly changing and inflation is rapidly increasing in the United States, the available types of jobs and their associated salaries can change. Additionally, reseachers were limited to only being able to use one job advertisements website because of the terms of service for other (and possibly more popular) job advertisements websites, such as indeed.com or LinkedIn.
2	Maturro G., Raschetti F., Fontán C. (2019). *A Systematic Mapping Study on Soft Skills in Software Engineering.* Journal of Universal Computer Science. DOI: 10.3217/jucs-025-01- 0016	To participate in software development projects, team members may need to perform different roles and be skilled in diverse methodologies, tools and techniques. However, other competencies, usually known as "professional competencies" are also necessary. Reseachers report the results of a systematic mapping study to identify existing research on professional competencies in software engineering and to determine what professional competencies are considered relevant to the practice of software engineering.	Based on the guidelines provided in (Kitchenham B. et al., 2016), the steps taken for this mapping study were: 1) Definition of research questions, 2) Search of the relevant literature, 3) Selection of relevant studies, 4) Data Extraction 5) Data aggregation and synthesis. After applying an explicit mapping protocol, 44 papers were finally selected, and 30 main categories of professional competencies were identified.	At least half of the studies selected mention five competencies: communication, teamwork, analytical, organizational, and interpersonal competencies. We also identified the data collection methods commonly used for research on this topic: job advertisements and surveys were the main ones.	Several threats to validity have been identified for this systematic review. First, the keywords used in the search strings as alternative names to "professional competencies" may not be all the possible options. In our case, we used the different names found in the literature when writing the background section. Second, we only accessed the set of databases that were available to us There are other bibliographic databases and therefore we could have missed some important studies about the subject. Third, because of the lack of a formal and unified definition of what a "soft competency" is, it is arguable whether some of the competencies reported as "professional" are actually professional competencies. In this case, we counted as "professional competencies" all the competencies mentioned as such in the selected studies..

No	Author, year, study title,	Problem statement	Methodology	Key Findings	Limitations
3	Bae H., Polmear M., Simmons D.R. (2022). *Bridging the Gap between Industry Expectations and Academic Preparation: Civil Engineering Students' Employability.* Journal of Civil Engineering Education. DOI: 10.1061/(ASCE)EI.2643-9115.0000062.	Employability, defined as developing capabilities for successful and sustainable career development, can help explain students' preparedness for the workforce. While prior studies identified various competencies needed for employment from the perspective of working professionals, it is unclear if students understand what is required for their careers, how to develop competencies through diverse experiences, and who can assist them with their career preparation.	To illuminate students' employability, this study used interviews with 13 civil engineering students and a deductive analytic approach. An employability framework was used as a theoretical lens to explore civil engineering students' perceptions and experiences of preparing for their careers by using five key elements: professional competencies, experience, career development learning, emotional intelligence, and degree-specific knowledge.	The findings indicated (1) students developed career motivation inside and outside the classroom; (2) students participated in school organizations and internships to improve professional competencies and emotional intelligence; and (3) students expressed uncertainty about learning professional competencies in class. The findings highlight the importance of students' development of career motivation, participation in out-of-class activities, and the role of educators in facilitating career preparation. These findings imply management and academia can help improve students' employability by communicating knowledge and competencies required in the workforce and bridging the gap between industry expectations and academic preparation.	This study purposefully selected universities that award a high number of engineering degrees, and these universities are public research universities. This study is thus limited in its ability to show whether students from universities with relatively fewer career development opportunities have comparable access to, and awareness of, internships and professional student organizations.

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4	Beagon U., Bowe B. (2023). *Understanding professional skills in engineering education: A phenomenographic study of faculty conceptions.* Journal of Engineering Education. DOI: 10.1002/jee.20556	For engineering programs to address the needs of society, graduates must have the competencies to tackle future challenges. Transformation will only be successful if faculty fully engage in all curriculum design aspects; however, little is known about how faculty view professional competencies. This understanding is critical if we wish to support and encourage their participation	Phenomenography was selected as the most appropriate method to showcase the variations in faculty conceptions. The study selected 19 interview participants from 273 responses to an online survey.	Faculty revealed their conceptions of professional competencies in six ways: communication competencies, technical competencies, enabling competencies, a combination of competencies, interpersonal behaviors, and acting professionally.	The outcomes are contextual to faculty teaching engineering programs in Ireland and, thus, are not representative of all engineering faculty, as language and local social and political factors can be influential. Furthermore, reseachers did not collect information on the race of the respondents to the survey and, thus, did not select participants for racial diversity. While we were mindful of gender diversity, we cannot illuminate the ethnic diversity of the participants in the study.

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No	Author, year, study title,	Problem statement	Methodology	Key Findings	Limitations
		in the transformation effort. This novel study reveals the qualitatively different ways faculty conceptualize professional competencies.			
5	World Economic Forum. (2023). *Future of Jobs Report 2023*.	the World Economic Forum's bi-annual Future of Jobs Report has tracked the labour-market impact of the Fourth Industrial Revolution, identifying the potential scale of occupational disruption and growth alongside strategies for empowering job transitions from declining to emerging roles.	The core of the 2023 Future of Jobs Report is based on a unique survey-based data set covering the expectations of a wide cross-section of the world's largest employers related to job trends and directions for the 2023—2027 period.	Analytical thinking and creative thinking remain the most important competencies for workers in 2023.	The report uses data from only 803 companies from 27 industry clusters

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6	Mikhridinova N., Ngereja B. J., Pinilla L.S., Wolff C., Petegem W.V. (2022). *Developing and improving competence profiles of project teams in engineering education.* SEFI 50th Annual conference of The European Society for Engineering Education. DOI: 10.5821/conference-9788412322262.1374	This concept paper reflects an ongoing research on designing students' team projects in engineering education with a focus on professional competencies development. The core idea is to relate project tasks with relevant team situations and team roles which require and train certain sets of professional competencies.	The paper proposes: a) a model for developing the relevant professional competencies out of project tasks, and b) an approach to relate individual competence profiles of team members with an overall team competence profile.	A core assumption is that if a team is formed, individual competences are aggregated in a certain way to form a single team competence profile. However, in the case of professional competencies this aggregating is more complex than simply adding competency levels, e.g., professional competencies in teams are a result of specific combinations of competences. Understanding these effects is relevant for project management and engineering education. The paper proposes a first draft of a systematic framework for investigating such effects and for making them usable for the design of student	This is a concept paper. No effectivity measurements are done.

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No	Author, year, study title,	Problem statement	Methodology	Key Findings	Limitations
				projects in engineering education. It also provides insight into an example of an agile cross-border project conducted fully online and using the scrum method.	

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7	Lai, J., Kesterson, C. , Selim, M. (2020). *Planting a soft skills seed in a first-year introductory programming class using team-based learning.* Conference: 12th International Conference on Education and New Learning Technologies. DOI: 10.21125/edulearn.2020.1610	In order to better implement professional competency development in university curricula, educators are now adjusting their typical lecture-based courses to more interactive class sessions. The Team-Based Learning (TBL) methodology, colloquially referred to as the "flipped classroom," is an emerging teaching philosophy for improving student learning and understanding of class material through group efforts.	This study focuses on 165 students who were enrolled in a freshman-level programming course in the Fall 2019. The students were all asked voluntarily to fill a "Soft Skills Survey" in the second week of the semester that consisted of 38 questions evaluating various categories of professional competencies. At the end of the semester, the same survey was given and both were used to evaluate the effectiveness of TBL on students' professional competencies. The conducted survey is designed to assess five overarching factors within the TBL framework: The first is how group work improves individual motivation; the second is how group work stimulates academic growth; the third is the individual student's creative and critical thinking competencies; the fourth is the value of group work for their overall education; the last is confidence in their own academic competencies. Traditionally, the effectiveness of TBL has been assessed through grades and numeric measures of performance; however, TBL was designed to both enhance learning as well as team collaboration and critical thinking competencies. These two surveys were conducted to assess the "professional competencies" outcome gains.	The results of this study show small-scale improvements over a range of professional development competencies as a result of the TBL delivery of the introductory programming course. The categories of growth included motivation, academic growth, critical thinking, and self- efficacy. Slight decline in group/peer learning competencies coupled with student feedback revealed areas of improvement to the TBL structure of this course.	This study focuses only on those students who were enrolled in a freshman-level programming course

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No	Author, year, study title,	Problem statement	Methodology	Key Findings	Limitations
8	Chen G.X., Qu X.P., Huang L.P., Zhou C. and Qiao M.Y. (2022). *Modeling-Eliciting Activities in an Online Engineering Course for Improving Conceptual Learning, Professional Skill, Interaction.* IEEE Access, 2022, Vol.10, p.87767-87777. DOI: 10.1109/ACCESS.2022.3199690	This empirical research aims to propose and examine an online teaching approach that embeds modeling-eliciting activities (MEA).	The instruments used to collect data included conceptual learning tests, design report evaluations, learning reflection analyses, and interaction statistics.	The findings suggested that the MEA-embedded online courses have signi_cant advantages for improving learners' conceptual learning and professional competencies. The proposed approach guides the learners to make appropriate decisions and practical actions, enhancing their critical thinking. The MEA inspires learners' positive attitudes and high participation, providing an emotional basis for group collaboration.	This empirical study contains two limitations. Firstly, the online course content of this experiment is the practical teaching module of an engineering course. Secondly, this study is limited to the undergraduates at the same level.

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9. Newport Group

1. Introduction

The document underscores the critical role of engineers in addressing societal and environmental challenges, advocating for enhanced engineering education, and the adoption of new technologies and ethical practices to ensure a future-ready workforce capable of contributing to Europe's sustainable development goals.

The study examines the state of the engineering profession across various sectors in Slovakia, highlighting its strong ties to the automotive industry and challenges such as a skills gap and competitive market dynamics.

The research also addresses the implementation of the Sustainable Development Goals (SDGs) and the European Green Deal in Slovakia, outlining national strategies and initiatives aimed at fostering sustainable development and improving infrastructure resilience. It explores the impact of globalisation and technological advancements on the profession, stressing the need for interdisciplinary collaboration and lifelong learning to meet evolving industry demands.

During the research, 51 sources were utilized (national reports, position papers, analyses, policy briefs, agendas, and university studies, as well as the private sector and consulting companies' researches). A set of inclusion and exclusion criteria was established to ensure the selection of relevant articles and reports. These criteria include relevance to the research topic, publication date (most of the data is no later than 2019), peer-reviewed status, and geographic focus (Europe and the Slovak Republic).

The objective of the research is to develop a robust methodology that captures the multifaceted nature of the engineering profession, taking into account the acquisition of essential skills and country contexts.

By gaining insights into the evolving nature of the engineering profession, this research addresses several key aspects. Firstly, it aims to identify emerging trends in the industry, such as the increasing demand for digital skills, the integration of sustainable practices, the need for resilience in the face of unforeseen events, and the importance of fostering an entrepreneurial mindset among engineers. These trends shape the engineering field's skill requirements, educational strategies, and professional development needs. Secondly, the research provides information about the state of the engineering profession across industries, functions, and countries (specifically, the Slovak Republic). Additionally, understanding the dynamics of the engineering profession helps policymakers, educational institutions, and industry leaders align their strategies and resources to better support engineers.

Through this initiative, Europe can ensure a robust and future-ready engineering workforce that contributes to societal progress, economic growth, and sustainable development.

2. Slovakian context within the engineering profession

According to Slovak Investment and Trade Development Agency's (SARIO) statistics (2022), the mechanical engineering industry (MEI) in Slovakia is closely linked to the automotive industry (76% automotive OEMs & suppliers). But it is not only connected to the automotive industry, there are other

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industrial segments in demand of production capacities such as metalworking (11%), machinery & equipment (12%), and other transport vehicles (1%).

Here are some key aspects that are specific to the engineering industry in Slovakia:

1. As it was mentioned Slovakia has a strong presence in the ***automotive sector***, with several major automakers and automotive component manufacturers operating in the country. The engineering industry in Slovakia is closely tied to the automotive industry, providing expertise in areas such as vehicle design, production technologies, and manufacturing processes.
2. Slovakia has a well-developed industrial ***machinery and equipment sector***, which includes the production of machinery, equipment, and components used in various industries. Engineering companies in Slovakia specialize in designing and manufacturing industrial machinery, production lines, and automation systems.
3. Slovakia has a diverse ***energy sector***, including traditional fossil fuel-based energy production as well as renewable energy sources. Engineering companies in Slovakia play a crucial role in designing, constructing, and maintaining energy infrastructure, including power plants, renewable energy installations, and transmission systems.
4. Slovakia has a ***strong manufacturing base***, and precision engineering is an important aspect of the industry. Engineering companies in Slovakia specialize in precision manufacturing techniques, CNC machining, tooling, and the production of high-precision components for various industries.

At the same time, the Slovak engineering market faces challenges such as a skill gap, limited market size, competition, and economic factors (SARIO, 2020). These lead to a competitive landscape. Companies strive to differentiate themselves, explore international markets, and adapt to changing economic conditions. The market is characterized by competitiveness, internationalisation, and adaptability.

Slovakia boasts a vast network of engineering companies despite being a small country. The largest concentration of these companies is found in the western part of the country. This comes as no surprise, considering that the capital city of Slovakia, Bratislava, is located in this region. Furthermore, this area is known for its highly developed supply chains, efficient transportation systems, and strong collaborations with neighbouring countries. However, the challenge that that companies met is exactly because of collaboration the best workers are being poached by those neighbouring companies, which causes the 'brain drain'.

3. Definition of SDGs and Green Deal implementation in Slovakia across the VET and business ecosystem

SDGs implementation in Slovakia

The 2030 Agenda for Sustainable Development, initiated by the United Nations in 2015, is a comprehensive global framework aimed at fostering sustainable development worldwide. This agenda is structured around 17 Sustainable Development Goals (SDGs), addressing various critical global challenges. In 2018, Slovakia developed a national strategy to implement the 2030 Agenda, translating the 17 SDGs into specific national actions through six National Priorities for Action, approved by the government. The National Priorities for the Implementation of the 2030 Agenda were adopted by the

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Resolution of the Government of the Slovak Republic No 273, of 13 June 2018. National priorities are laid down by the participatory process implemented in early 2018. These priorities include:

1. Education for a Life in Dignity
2. Transformation Towards a Knowledge-Based and Environmentally Sustainable Economy
3. Poverty Reduction and Social Inclusion
4. Sustainable Settlements, Regions, and Landscapes in the Face of Climate Change - This priority addresses the need for sustainable development in urban and rural areas, particularly in response to climate change challenges.
5. Rule of Law, Democracy, and Security
6. Good Health - Promoting public health and overall well-being is recognized as a crucial aspect of sustainable development.

The Ministry of Investments, Regional Development, and Informatisation of the Slovak Republic (MIRRI SR[1]) is responsible for the internal aspects of the agenda, focusing on domestic policy implementation. Meanwhile, the Ministry of Foreign and European Affairs of the Slovak Republic (MZVEZ SR[2]) handles the external dimension, ensuring alignment with international standards and cooperation.

The Statistical Office of the Slovak Republic[3] is instrumental in setting evaluation indicators, which are aligned with standards set by the UN Statistical Commission and the European Union's Statistical Office (Eurostat) to monitor progress.

The Government Council for the 2030 Agenda for Sustainable Development serves as the coordinating body, integrating efforts across multiple sectors. It includes representatives from various ministries, the National Council of the Slovak Republic, the judiciary, academia, non-governmental organisations, the private sector, regional self-governments, and trade unions. This council, with its 35 members. The status of the council and the list of members are indicated under the link: https://mirri.gov.sk/sekcie/cko/horizontalny-princip-udrzatelny-rozvoj-2014-2020/aktuality/rada-vlady-pre-agendu-2030-pre-udrzatelny-rozvoj/ .

Challenges persist in the national priorities of Education for a Life in Dignity and Transformation Towards a Knowledge-Based and Environmentally Sustainable Economy in the context of changing demographics and a globalized world. While there have been positive trends in some indicators, several issues remain. For instance, although Slovakia has a lower rate of early school leaving compared to the EU average, it has not yet achieved the targets set under the Europe 2020 strategy. Additionally, Slovakia significantly lags behind the EU average in lifelong learning participation rates, an area highlighted by the Covid-19 pandemic as needing re-evaluation in terms of educational content and delivery methods.

In the shift towards a knowledge-based and environmentally sustainable economy, Slovakia also falls behind the EU average in several key areas. These include the share of renewable energy in total gross consumption, investment in research and development, and the recycling rate. These gaps highlight ongoing challenges in aligning with broader EU sustainability and development goals.

The country faces significant challenges in the national priorities of Sustainable Settlements, Regions, and Landscape in the Face of Climate Change; Rule of Law, Democracy, and Security; and Good Health. Environmental issues are affecting the economy, employment, and the quality of life for Slovak citizens[4]. Slovakia struggles with poor air quality, which is below the EU average, low waste recycling rates,

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inadequate protection of ecosystems, and negative trends in sustainable mobility, energy availability, and access to drinking water and sanitation. Agricultural pollution and environmental liability also contribute to water and soil pollution.

Slovakia ranks low among EU countries in public and business perceptions of judicial independence[5]. Public trust in the police is declining, and the Corruption Perception Index has stagnated. Additionally, only a small percentage of citizens report incidents of violence, crime, or vandalism in their neighbourhoods. There remains an urgent need for systemic reforms in several internal mechanisms of the country's democratic system.

Green Deal Implementation

Aspects of sustainable development are increasingly becoming integral to national, regional, and local strategies in Slovakia. Environmental protection, for example, is managed by the Ministry of Environment of the Slovak Republic[6] and its regional offices, in coordination with the Ministry of Investments, Regional Development, and Informatisation. Local authorities are typically responsible for implementing sectoral policies. Sustainable development initiatives span urban and rural areas, addressing issues such as environmental protection, social justice, community development, walking and cycling infrastructure, public transport, greenhouse gas emissions, water purification, and the preservation of local identity. These initiatives also promote local cooperation, public-private partnerships, and participation in public and international funding projects, including architectural and urban design competitions.

In 2021, Slovakia launched a new 10-year environmental protection strategy called "Greener Slovakia – Environmental Policy Strategy of the Slovak Republic"[7], developed by the Institute of Environmental Policy under the Ministry of the Environment with input from 160 experts across various sectors. This strategy, set to be implemented by 2030, focuses on water and biodiversity protection, climate change mitigation, air quality improvement, and the promotion of a green economy. It aims to enhance the protection of national parks and forests, with plans for 75% of the area of national parks to be free from human intervention by 2030. The strategy also includes goals for increasing green public procurement to 70% by 2030 and integrating environmental education into formal education.

The principles of Slovakia's green infrastructure align with the NECONET (National Ecological Network) and the territorial environmental sustainability system (ÚSES)[8]. Ecological networks are coherent systems of natural or semi-natural landscape elements managed to support or restore ecological functions, thereby preserving biodiversity and promoting sustainable resource use. In Slovakia, these networks operate at multiple levels, with NECONET at the national level and ÚSES at interregional, regional, and local levels. The ÚSES toolkit, particularly in peripheral zones, is crucial for developing green infrastructure, which is also a priority in urban planning. Urban green spaces are known to improve ecological integrity and public health, reducing air pollution, moderating temperatures and absorbing noise. Studies show a positive correlation between green spaces and public health, including reduced obesity rates and improved psychological well-being and stress levels.

The 2030 Environmental Strategy of Slovakia outlines several key projects aimed at developing urban green infrastructure. These projects include initiatives such as greening public spaces and rooftops, increasing rainwater collection, integrating nature with transportation projects, expanding city parks and

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urban green areas, and promoting biodiversity in urban settings. While these initiatives aim to create ecological networks and protect biodiversity, the outcomes have not always been positive. Statistics indicate that approximately 60% of the world's ecosystems are degraded or overburdened, and only 17% of biotopes and species, along with 11% of key ecosystems, are in good condition and protected by European legislation. This issue is also evident in Slovakia (Izakovičová & Świąder, 2017).

In the context of sustainable urban development in Slovakia, the concept of mixed-use planning is essential. Traditional city plans often consist of coloured polygons representing various functional purposes, such as residential, commercial, industrial, agricultural, cultural, sports, and green areas, each with different levels of protection. However, a monofunctional approach can lead to some areas being underutilized for significant portions of the day, and in some cases, structural shifts may result in the total abandonment of certain areas. To mitigate these issues, planners often use the mixed-use principle, where different parts of buildings are utilized for various purposes. For example, basements or lower floors may be designated for commercial, industrial, or institutional uses. While designing an entire city based on the mixed-use principle may not address all challenges, it can significantly reduce the extent of housing-only areas and shorten commuting distances

4. Quantitative indicators on the evolving nature of the engineering profession in Slovakia

Over the last years, the engineering profession has undergone certain changes. First and foremost, we cannot forget about the impact of the COVID-19 pandemic, which hit the world and completely disrupted the established order (Krause, Spitzley, & Pflitsch, 2020). Currently, Europe and the rest of the world are grappling with the consequences of this pandemic. One of the primary areas affected by this is the alignment of skills in the labour market and the preparedness of university graduates. With the shift to online learning, university programs have lost their practical component. As a result, newly minted engineers entering the job market lack the necessary skills. Not only do new graduates feel the mismatch in their skills, but also old-school engineers who graduated years ago do not keep up with rapid technologies. Furthermore, engineering skills are becoming increasingly specialized and tailored to meet the demands of the times. This applies to areas such as digitisation, green and environmental trends, communication, entrepreneurship, life-long learning, etc (Langie & Craps, 2020; Hadgraft & Kolmos, 2020; Semerikov et al., 2020; Cedefop, 2018). Moreover, there is a growing demand for soft skills among workers worldwide as the engineering profession such as a lot of others is no more 'closed-circled', but interdisciplinary. Engineers are working alongside professionals from diverse domains, such as biology, medicine, social sciences, and business, etc. to solve complex problems (Van den Beemt, 2020). The ability to communicate efficiently is crucial for achieving intercompany cooperation and the right approach.

The paradigm shift in robotics and automation is also the new reality for engineers. For instance, practices such as computer simulation have started replacing physical testing. Although these two approaches coexist for now, perhaps engineers will soon rely on simulation. But like any shift, this one also requires new competencies.

Meanwhile, technical knowledge still forms the foundation of engineering practice (Langie & Craps, 2020). Engineers are expected to possess a strong understanding of mathematics, physics, and the

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specific technical knowledge relevant to their field of specialisation. Whether it is civil engineering, mechanical engineering, electrical engineering, or any other discipline, a solid grasp of fundamental concepts and principles is essential.

Slovakia keeps up with trends and how engineering is evolving in Europe, in the same way it is in the country. And as now it is the time of globalisation, engineering problems are not problems of only one specific country or region anymore.

One common form of skill mismatch is a shortage of specific industrial skills. As industries adopt new technologies and practices, engineers may find themselves lacking the necessary expertise in emerging areas, especially this applies to elder engineers who graduated before that level of digitalisation.

The consequences of skill mismatch are detrimental to both individuals and the industry as a whole. For individuals, skill mismatch leads to unemployment, underemployment, or a sense of professional dissatisfaction. For employers, it occurs as a result of productivity losses, increased training costs, and difficulties in finding qualified candidates for open positions.

Table 1 provides an overview of the required skills for the engineering profession, encompassing both the current requested skills and the anticipated future skills. It highlights the diverse skill set that engineers need to possess to excel in their roles and adapt to the evolving demands of the industry.

Table 1 Comparison of Current Skills and Future Skills for Engineers (EC Skill Agenda, 2020; Beagon et al., 2023; OECD, 2021; Tabas, Beagon & Kövesi, 2019)

Required Skills	Current Requested Skills	Future Upgraded Skills
Technical Knowledge and Expertise	Proficiency in engineering principles, mathematics, and sciences	Advanced knowledge of emerging technologies such as AI, IoT, and renewable energy systems
Problem-Solving	Analytical thinking, critical reasoning, and troubleshooting	Creative problem-solving and innovation in complex and ambiguous situations
Communication	Effective verbal and written communication skills, collaboration, and teamwork	Strong presentation skills and ability to communicate technical concepts to non-technical stakeholders
Project Management	Planning, organisation, and project management methodologies	Agile project management and adaptability to changing project requirements
Digital Literacy	Proficiency in using engineering software, data analysis, and programming	Data analytics, cybersecurity, and knowledge of automation and robotics
Multidisciplinary Approach	Ability to work across diverse disciplines and integrate knowledge	Cross-cultural competency and interdisciplinary collaboration

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Sustainability	Knowledge of sustainable engineering practices and environmental regulations	Expertise in a circular economy, green technologies, and sustainable design
Ethical Considerations	Understanding of professional ethics and social responsibility	Ethical implications of emerging technologies, AI ethics, and data privacy

From this, it follows that if we continue to train current and future engineers in the way it is done, then we cannot avoid a skills mismatch. To address skill mismatch, it is crucial for engineering professionals, educational institutions, and industry stakeholders to collaborate and adapt to changing skill demands by updating curriculums, creating and disseminating courses, expanding engineering networks and engaging policymakers.

5. Qualitative descriptions of the evolving nature of the engineering profession

The engineering profession is at a pivotal juncture, shaped by rapid technological advances, evolving educational paradigms, and a heightened focus on ethical and social responsibilities. This evolution highlights the growing role of engineers not only as problem solvers and innovators but also as stewards of societal and environmental well-being.

Technological Advances

Emerging technologies such as Industry 4.0, artificial intelligence, renewable energy systems, and advanced manufacturing techniques are profoundly influencing the engineering landscape. These technologies are not only expanding the scope of engineering but also transforming the tools and methods used in the field. For instance, engineers are increasingly utilising advanced simulation tools, digital twins, and AI-driven analytics to design and optimize complex systems (Melnikova et al., 2020). The integration of these technologies necessitates a shift towards a more holistic approach in engineering practice, where technological proficiency is coupled with an understanding of systemic and interdisciplinary contexts.

Skill Set Requirements

The evolving technological landscape demands a new set of skills and competencies from engineers. Beyond traditional technical skills, there is a growing emphasis on "soft skills" such as leadership, communication, and teamwork. These skills are crucial for navigating multidisciplinary and multicultural work environments, where engineers often work alongside diverse teams to solve complex global challenges (Munir, 2021). Additionally, engineers must develop global competence, which includes an awareness of and sensitivity to cultural diversity, enabling effective collaboration in international projects.

Work Environment

The work environment in engineering is shifting towards more collaborative and flexible models, facilitated by advances in digital communication and remote work technologies. Project-based learning and real-world problem-solving are becoming integral components of engineering education and

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professional practice. This shift reflects a broader trend towards interdisciplinary and team-oriented approaches to engineering challenges, where diverse perspectives and expertise are leveraged to develop innovative solutions. The increasing prevalence of remote work has further catalyzed changes in communication styles and collaboration.

Education and Training

Engineering education is evolving to address the demands of the modern workforce and the challenges of the 21st century. Educational programs are increasingly incorporating experiential learning, interdisciplinary projects, and a focus on sustainability and ethics. Capstone projects and integrated learning modules are widely used to provide hands-on experience and foster critical thinking skills, there is also a growing recognition of the need for lifelong learning and continuous professional development, as engineers must keep pace with rapidly evolving technologies and methodologies (Caratozzolo et al., 2022). For instance, embracing new pedagogical frameworks such as Education 4.0, which integrates digital tools and active learning strategies to enhance student engagement and learning outcomes.

VET education including engineering education in Slovakia is predominantly provided at the upper secondary level. Pre-school and Primary school educational levels provide for mostly general education. Lower secondary level vocational programs have a small number of learners. Lower secondary, upper secondary as well as post-secondary levels of VET in Slovakia are provided by secondary vocational schools, or SOŠ – stredná odborná škola. System of VET is highly regulated thanks to strict regulation and extensive curricula. System of secondary vocational schools consists mainly of public schools

During the years after 2010, the public debate shifted and the problem of decreasing number of VET students and increasing share of students of humanities, the employers started to indicate the unbalance on the labour market, which has continuously started to affect also the tertiary level (Cedefop, 2016). Therefore, with the legislative change in 2015 the system of Dual education was introduced in the school year 2015/2016. It was piloted in close cooperation with Wirtschaftskammer Österreich and was based on German and Austrian models. The change brought deeper involvement of companies in VET as well as raising focus of practical education and regulation of VET based on the needs of the labour market. Increasing role of social partners in shaping the sector varies from planning and defining the curricula, accreditation process, planning and approving the numbers of educational places, etc.

To become an engineer through the VET system in Slovakia, individuals typically follow a specific educational pathway. After completing compulsory basic education, students can choose to enroll in a secondary vocational school specialising in engineering or a related field.

Professional Roles and Specialisations

The engineering profession is witnessing the emergence of new specialisations driven by technological innovations and societal needs. Fields such as renewable energy engineering, biomedical engineering, and cybersecurity are expanding rapidly, reflecting the growing importance of addressing global challenges such as climate change, healthcare, and digital security. Traditional engineering roles are also evolving, with a greater emphasis on systems thinking, sustainability, and ethical considerations. This evolution is reshaping the expectations and responsibilities of engineers, who are now seen not only as

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technical experts but also as innovators and leaders capable of addressing complex social and environmental issues.

Ethical Considerations

There is an increasing emphasis on ethics, sustainability, and social responsibility within the engineering profession. Engineers are expected to consider the broader societal and environmental impacts of their work, aligning their practices with the principles of sustainable development and social justice (Barakat, 2015). This includes a focus on ethical decision-making, responsible innovation, and the promotion of equity and inclusivity in engineering solutions. The integration of ethical considerations into engineering education and practice is essential for preparing engineers to navigate the complex moral and ethical dilemmas that arise in the context of technological and industrial advancements.

Globalisation

Globalisation is reshaping the engineering profession by diversifying the workforce and promoting international collaboration. Engineers are increasingly working in multicultural and multinational teams, which enhances the exchange of knowledge and fosters innovation. However, this trend also presents challenges related to cultural competency and inclusivity, as the profession seeks to address underrepresentation and promote diversity within the field.

Globalisation has significantly impacted the engineering profession, promoting international collaboration and cultural diversity within the workforce. This phenomenon is especially evident in Slovakia, where efforts to internationalize engineering education and adapt to global standards are ongoing. Here’s an in-depth look at how globalisation is influencing engineering in Slovakia, including the methods and challenges involved.

Globalisation and Its Impact on Engineering

Globalisation has transformed the engineering profession into a globally interconnected field. Engineers are increasingly engaged in multinational projects, requiring them to navigate diverse cultural and regulatory environments. This global engagement necessitates competencies in foreign languages, cultural awareness, and the ability to work across borders. For instance, the adoption of International Financial Reporting Standards (IFRS) in Slovakia exemplifies how global standards influence local practices, enhancing the comparability and transparency of financial information across borders (Rebetak & Bartosova, 2021).

Slovak universities are increasingly offering engineering programs in English to attract international students and prepare local students for global careers. For example, the Slovak University of Technology in Bratislava provides courses in English, focusing on technical terminologies and practices from various engineering disciplines (Pavla, 2021). This initiative helps students develop language skills crucial for participating in international projects and enhances their employability in multinational corporations.

Methods of Internationalisation

1. Strong language education system
2. Study abroad programs

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3. Active collaboration with foreign institutions and lots of exchanges and mobilities

The internationalisation of engineering education in Slovakia, while beneficial, presents several challenges:

- Cultural integration can be challenging for students and faculty. There is a need for training in intercultural communication and sensitivity to ensure effective collaboration and integration (Zelenkova, 2018).
- Quality assurance (This includes maintaining rigorous accreditation processes and continuous evaluation of educational outcomes)

6. Opportunities

The Growth of Job Places

According to European Labour Authority, Directorate-General for Employment, Social Affairs and Inclusion (2021) the employment level of researchers and engineers is expected to grow by a further 15% between 2018 and 2030 and plus during this time, more than 1 million new jobs for researchers and engineers will be created. That means that, firstly, engineers from different fields will be in a hight demand, and, secondly, it will require more education programs to prepare that number of future workers.

Anyway, for engineers from the industry, it is a great opportunity to take advantage of the expected growth in the profession. With the projected increase professionals in these roles can expect a plethora of job opportunities. For industry generally it fosters innovation by tapping into a larger pool of professionals. Secondly, it enhances problem-solving capabilities, allowing engineers to address complex challenges effectively. Fourthly, it drives industry growth and attracting investments.

Energy Efficiency and Renewable Energy

Engineers can contribute to energy efficiency efforts by designing and implementing technologies that reduce energy consumption in various sectors (WEF, 2023). This includes developing smart building systems that incorporate energy management and automation to optimize energy usage (UNESCO, ICEE & Central Compilation and Translation Press, 2021). Engineers can also design energy-efficient HVAC (Heating, Ventilation, and Air Conditioning) systems, lighting solutions, and insulation techniques to minimize energy wastage.

Moreover, engineers can play a key role in the development and implementation of renewable energy technologies. They can design and optimize solar power systems, including photovoltaic (PV) panels and solar farms, to harness the energy from sunlight. Engineers can also contribute to the advancement of wind energy technologies, such as the design of wind turbines and wind farm layouts, to capture wind energy and convert it into electricity.

In addition to solar and wind, engineers can explore other renewable energy sources such as hydroelectric, geothermal, and biomass. They can design and develop systems that harness the energy

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from water, utilize geothermal heat, or convert biomass into bioenergy. Engineers can optimize the efficiency and reliability of these systems, ensuring the sustainable generation of renewable energy.

Furthermore, engineers can contribute to the development of energy storage technologies. They can design and optimize energy storage systems such as batteries, pumped hydro storage, or compressed air energy storage. These storage solutions are essential for ensuring a stable and reliable supply of renewable energy, enabling the integration of intermittent energy sources into the grid.

Robotics and Automation in Construction

Engineers can leverage robotics and automation to automate repetitive and labour-intensive tasks in construction. They can design and develop robotic systems that can perform tasks such as bricklaying, concrete pouring, material handling, and site inspections. These robots can work with precision, speed, and consistency, reducing reliance on manual labour and improving overall construction efficiency (Cordero-Guridi, Cuautle-Gutiérrez, Alvarez-Tamayo & Caballero-Morales, 2022).

Additionally, engineers can utilize AI algorithms and machine learning techniques to enable robots to learn from data and adapt to changing construction environments. This can improve the flexibility and adaptability of robotic systems, making them more capable of handling complex construction tasks and dynamically adjusting to project requirements.

Furthermore, engineers can contribute to the development of autonomous construction vehicles and equipment. This includes autonomous cranes, excavators, bulldozers, and drones, which can operate with minimal human intervention.

Engineers can also implement advanced sensing technologies in construction projects. This includes the use of LiDAR (Light Detection and Ranging) scanners, 3D imaging, and drones for site surveying, mapping, and monitoring. These technologies enable engineers to gather accurate data, detect potential issues, and facilitate efficient project planning and management. Moreover, engineers can contribute to the integration of robotics and automation with Building Information Modeling (BIM) systems. By combining robotics, automation, and BIM, engineers can optimize construction processes, enhance collaboration between stakeholders, and enable real-time monitoring and control of construction activities.

7. Needs

In response to the rapidly evolving landscape of the engineering profession, several key needs have emerged that can contribute to the success of engineers in the digital era. One crucial requirement is the provision of VET programs for engineers. These trainings serve as valuable opportunities for professionals to update their skills, stay abreast of industry advancements, and enhance their knowledge in specific areas. They can also cater to the needs of experienced engineers by offering digital and automation upskilling programs, ensuring they remain competitive in the digital transformation of industries.

Another area where VET can significantly benefit engineers is in the use of simulation technologies. By providing trainings on simulation tools and methodologies, engineers can leverage these powerful tools to model and analyze complex systems, optimize designs, and predict performance. This enhances their problem-solving capabilities, improves efficiency, and reduces costs in their projects. However, in

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practice, simulation is currently only beginning to take root in the engineering profession, and is only sometimes combined with physical testing. In the future, this link between the industry and the use of simulation testing needs to be strengthened (Poort & Fatemi, 2021).

There is a need for new disciplines and updated university curricula in engineering education. Traditional engineering disciplines must adapt to include coursework and practical experiences that reflect the emerging technologies and challenges of the digital era (Beagon, et al., 2023).

One of the notable trends in the engineering profession is the increasing demand for engineers with multidisciplinary knowledge and skills (Tseng, Tran, Minh Ha, Bui & Lim, 2021). The proliferation of digital technologies and automation has significantly transformed the engineering profession and will continue to do so in the future.

One of the major impacts of digital technologies and automation is the increased emphasis on digital literacy and proficiency in engineering. Engineers now need to possess a strong foundation in computer-aided design (CAD), computer programming, data analysis, and simulation tools. Proficiency in these digital tools and technologies is essential to design, model, and optimize complex systems efficiently (Deloitte, 2022; OECD, 2019). Moreover, the integration of automation and robotics in engineering processes has led to a shift in the skills required. They must understand how to leverage automation technologies to improve efficiency, productivity, and safety in various engineering domains (Deloitte, 2022).

Given the rapid pace of technological advancements and evolving sustainability challenges, engineers must cultivate adaptability and a commitment to lifelong learning. Continuous professional development is crucial for engineers to stay updated with the latest advancements, emerging trends, and best practices. By embracing adaptability and lifelong learning, engineers can contribute to innovation and drive sustainable development in Europe.

In addition to technical expertise, engineers are increasingly expected to possess strong communication, teamwork, and leadership skills. Collaboration across disciplines and cultural boundaries has become essential for successful engineering projects (Deloitte, 2022). The ability to work effectively in diverse teams and navigate intercultural contexts has become crucial for engineers (Handford, Van Maele, Matous & Maemura, 2019). It means that as engineering is becoming a multidisciplinary and multicultural profession it will require skills that can afford individuals to communicate effectively and positively. In this case, a new generation of engineers needs to be tolerant, they need to be able to manage stress, manage conflicts, learn from others, and have an understanding of the common purpose. They must navigate cultural differences, understand local contexts, and ensure that their projects are inclusive, equitable, and respectful. They must navigate cultural differences, understand local contexts, and ensure that their projects are inclusive, equitable, and respectful. By embracing cultural competence, engineers can contribute to the goals of reduced inequalities, responsible consumption and production, and sustainable cities and communities (Handford, Van Maele, Matous & Maemura, 2019).

Various trends are expected to shape the future engineers. Business services, including financial and insurance activities, information and communication technology (ICT), healthcare, media, and wholesale and retail, are anticipated to contribute significantly to employment growth in this occupation (Cedefop,

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2019). Manufacturing, particularly in the automotive industry, will also experience strong employment growth due to the adoption of new automation technologies and increased research intensity. Education and health sectors will see an expansion in demand for researchers and engineers due to the growing technology intensity in healthcare and the emphasis on STEM education.

The increasing importance of electronics in various industries, such as automotive and building construction, will result in a rising demand for skills related to electronic development and manufacturing, potentially impacting classical mechanical engineering skills. Emerging technologies, like marine renewable energy, will require interdisciplinary skillsets combining expertise in areas such as power electronics, mechanical engineering, hydraulics, automation, and computing (Cedefop, 2019; UNESCO, 2021).

The VET system plays a significant role in developing specialized skills for engineers and science professionals, enabling them to acquire both sector-specific and transferable competencies. This includes essential abilities such as business acumen, leadership, and management expertise. To enhance the level of in-house training, national authorities can provide targeted support to companies that have advanced training practices emphasising competence development and effective learning outcomes.

To address skill shortages and expedite the implementation of suitable training approaches in emerging industries requiring highly specific skill sets, partnerships and collaborative efforts among government authorities, social partners, and other stakeholders are crucial. The establishment of partnerships can offer effective solutions in these cases. The European Skills Council for the maritime technology sector serves as a valuable example, providing lessons and inspiration for fostering cooperation and addressing skill challenges.

Partnerships also have the potential to facilitate training and learning experiences "outside of the classroom". This can involve study visits, knowledge sharing through voluntary associations, or spending time in different employers or associations. Such initiatives are particularly relevant for skill sets that draw expertise from multiple sectors, like developing eco-friendly knowledge in architecture (Kalck, 2015, as cited in Capefop, 2019).

Considering the growing demand for highly qualified engineers, it is essential to make STEM/MINT subjects more appealing to young people. This requires efforts to increase the attractiveness and quality of these subjects throughout primary, secondary, and higher education. Additionally, teacher training programs play a crucial role in making STEM subjects more engaging by enabling teachers to connect scientific and engineering concepts with current issues and developments. However, it is essential to support these efforts with effective career guidance for students.

In order to promote diversity in the workforce and encourage women to pursue science and engineering professions, certain countries like Norway, Germany, and the Netherlands have placed special emphasis on making these fields more attractive to women (Caedefop, 2019). The European Commission is also taking steps to support the advancement of women in STEM professions. They are funding a resource hub that provides policymakers, experts, and prospective professionals with policy briefings, best practices, experiences, and other relevant information to promote the inclusion and progression of women in STEM careers (GenPORT, 2016, as cited in Capefop, 2019).

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Slovakian context of the engineering needs within the profession

The engineering profession in Slovakia is at a crucial juncture, facing several key challenges that need to be addressed to ensure sustainable growth and alignment with global standards. One significant area of focus is the internationalisation of engineering education. This effort is crucial for attracting international students and enhancing the global competitiveness of Slovak engineers. Institutions like the Faculty of Civil Engineering at the Slovak University of Technology have initiated courses taught in English, aimed at fostering a more inclusive and globally oriented educational environment. This initiative is part of broader efforts to innovate teaching methods and curriculum design, making them more relevant to the needs of a globalized workforce. These courses not only cover technical knowledge but also emphasize the importance of cross-cultural communication and international professional standards, which are increasingly crucial in a connected world (Pavla, 2021).

In parallel, there is a pressing need to enhance the quality and effectiveness of technical and vocational education and training (TVET) in Slovakia. The rapidly changing landscape of the European labour market demands a workforce equipped with not just technical skills, but also soft skills such as effective communication, foreign language proficiency, and digital literacy. The Slovak education system has been undergoing reforms aimed at modernising curricula and pedagogical approaches to better prepare students for the challenges of the modern workplace. For instance, projects like the "Model for improving the quality of graduates and job applicants in the European labour market," developed by the Dubnica Institute of Technology and the University of SS. Cyril and Methodius[9], focus on enhancing key competencies among students. These competencies include critical thinking, problem-solving, and the ability to adapt to technological advancements (Hrmo, Miština, & Krištofiaková, 2016).

Financial stability and access to capital are also critical challenges for engineering firms in Slovakia. The engineering sector, a cornerstone of the country's industrial output, faces difficulties related to weak capital structures and high risks associated with financing. This situation limits the ability of companies to invest in innovation and expansion. There is a need for developing robust financial strategies and exploring alternative financing options to support the growth and competitiveness of Slovak engineering firms. Such measures could include government incentives, partnerships with foreign investors, and innovative funding mechanisms like venture capital or public-private partnerships.

8. Challenges

Workforce Evolution and Skill Gaps

The rapid advancements in technology and automation are significantly transforming the workforce, creating a need for engineers to continually adapt to new roles and skill requirements. As automation and AI technologies become more prevalent, many traditional engineering tasks are being altered or replaced, necessitating a shift towards more specialized and technologically advanced skills. This evolution in the workforce demands continuous education, training, and upskilling to ensure that engineers remain relevant and competitive in the job market (OECD, 2021).

One of the critical challenges is the existing skills gap in the engineering field, where the demand for specific technical skills outpaces the supply of qualified professionals. This gap is particularly evident in areas related to digital technologies, data analytics, cybersecurity, and sustainable engineering practices.

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To bridge this gap, educational institutions and industries must collaborate to develop curriculum and training programs that align with the evolving needs of the industry. As engineering innovations increasingly intersect with complex ethical and social issues, engineers are tasked with addressing concerns related to privacy, security, and the societal impacts of new technologies. The development and deployment of technologies, such as AI, biotechnology, and autonomous systems, often raise ethical dilemmas, including issues of fairness, accountability, and transparency.

Fourth Industrial Revolution

The advancement of technology calls for today's engineering to work and compete in a work atmosphere full of automation, virtual and borderless world. Accordingly, engineering graduates need to be prepared for jobs that never exist for the last 10 or five years. As a preparation to take up the Fourth Industrial Revolution challenges, there is a growing demand for engineers to master certain skills to be able to secure their career. Ones who put their effort to learn new things and acquire certain skills not only make themselves confident and self-assured, but also are getting an advantage when attending job interviews (Kamaruzaman, Hamid, Mutalib, & Rasul, 2019).

One of the primary challenges is the technological complexities associated with the integration and convergence of emerging technologies. The 4IR brings together technologies such as artificial intelligence, robotics, Internet of Things, big data analytics, and advanced automation (Abioy et al., 2021; Mishra et al., 2016).

AI will change the nature of work as it replaces and alters components of human labour. Policies will need to facilitate transitions as people move from one job to another, and ensure continuous education, training and skills development (OECD, 2021). Integration and interoperability of AI technologies with existing infrastructure will be challenging. Engineers must address the seamless integration of AI systems with devices and data platforms. Interoperability standards and compatibility testing are necessary to ensure effective collaboration between AI systems and existing engineering systems. Finding the right balance between human expertise and AI capabilities is a challenge. User-friendly interfaces and intuitive workflows are necessary for seamless human-AI interaction.

The transformation of the workforce is another significant challenge. As automation and AI replace and alter components of human labour, engineers need to adapt to new roles and skill requirements. Continuous education, training, and upskilling are crucial for engineers to remain relevant in the changing job market.

Ethical considerations pose a critical challenge in the 4IR era. Engineers must navigate complex ethical dilemmas, autonomous systems, data privacy, and algorithmic bias. Ensuring transparency, accountability, and fairness in the design, development, and deployment of technologies is vital. Ethical frameworks, guidelines, and responsible innovation practices can help engineers address these challenges and ensure the ethical use of technology (Floridi et al., 2018; Jobin, Ienca, & Vayena, 2019).

The development of policy and regulatory frameworks is crucial to address the challenges and risks of the 4IR. Governments and regulatory bodies need to adapt quickly to the evolving technological landscape to safeguard public interest, protect privacy, ensure data security, and address potential

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societal impacts. Collaborative efforts between industry, academia, and policymakers are necessary to establish flexible, adaptive, and inclusive regulatory frameworks (OECD, 2021).

Climate Change

One significant challenge for engineers is the need to design and construct resilient infrastructure capable of withstanding the impacts of climate change. Rising sea levels, increased frequency and intensity of storms, and changing precipitation patterns pose risks to coastal areas, transportation networks, water supply systems, and other critical infrastructure. Engineers must consider these climate-related risks in the planning, design, and maintenance of infrastructure to ensure their longevity and functionality (Pörtner, 2022).

Another challenge is the integration of renewable energy sources and the transition to low-carbon technologies. Engineers are tasked with developing and implementing sustainable energy solutions, such as solar, wind, and hydropower systems, to reduce reliance on fossil fuels and mitigate greenhouse gas emissions (Masson-Delmotte et al., 2022).

Engineers must address the need for efficient water management in the face of changing climate patterns. This includes designing and implementing water storage and distribution systems, wastewater treatment facilities, and flood management strategies that account for variations in precipitation, droughts, and changing hydrological patterns. The development of sustainable water management practices and technologies is crucial for ensuring water availability, minimising water waste, and adapting to water-related challenges (Ujile, 2020).

Additionally, engineers will face challenges related to climate-related hazards and risk assessment. They must develop comprehensive risk assessment methodologies to evaluate the vulnerability of infrastructure and communities to climate-related hazards, such as floods, heatwaves, and wildfires. This involves incorporating climate projections, modeling techniques, and resilience strategies into engineering practices to enhance preparedness, response, and recovery (Ujile, 2020). For instance, integrating renewable energy systems, implementing smart grids, designing carbon capture and storage technologies, and developing advanced monitoring and control systems. The engineering profession will face the challenge of managing the inherent complexity of these technologies, ensuring their reliability, interoperability, and resilience, and addressing potential risks and unintended consequences.

In conclusion, climate change will be requiring engineers to develop resilient infrastructure, integrate renewable energy, manage water resources, assess climate-related risks, and consider social and ethical dimensions of climate change.

Infrastructure Resilience and Aging

Many countries around the world face aging infrastructure systems that require significant attention, renovation, and maintenance. This challenge arises from the fact that infrastructure, such as bridges, roads, dams, and water supply systems, built decades ago, was not designed to accommodate modern demands, changing environmental conditions, and increased population densities.

One of the key issues related to infrastructure resilience and aging is the deterioration of materials and structural components over time. As infrastructure ages, it becomes more susceptible to wear and tear,

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corrosion, fatigue, and other forms of degradation. For instance, bridges and roads may develop cracks, corrosion, and structural deficiencies, posing risks to public safety and transportation efficiency. Similarly, water supply systems may suffer from leaks, pipe bursts, and decreased reliability, affecting water availability and quality.

To address these challenges, engineers are focusing on developing innovative solutions and strategies. Retrofitting existing infrastructure is a common approach, involving the strengthening and modification of structures to improve their performance and extend their lifespan. This may include techniques such as adding steel reinforcements to bridges or using advanced repair materials for road surfaces.

In addition to retrofitting, engineers are incorporating advanced monitoring technologies to assess the condition of aging infrastructure in real-time. These technologies include sensors, remote sensing techniques, and data analytics that enable engineers to detect early signs of deterioration and proactively plan maintenance and repairs. Continuous monitoring can help identify potential vulnerabilities and prioritize infrastructure investments.

Moreover, sustainability considerations are being integrated into infrastructure design and construction practices. This involves using eco-friendly and durable materials, incorporating energy-efficient features, and implementing green infrastructure solutions. Sustainable design principles not only enhance the resilience and longevity of infrastructure but also contribute to minimising the environmental impact and resource consumption associated with infrastructure projects.

Public-private partnerships (PPPs) and innovative financing mechanisms are also being explored to address the financial challenges of infrastructure resilience and aging. By involving private sector entities, governments can leverage their expertise and resources to fund and deliver infrastructure projects more efficiently. PPPs can enable the adoption of new technologies and innovative approaches, speeding up the renovation and modernisation of aging infrastructure.

By doing so, they aim to ensure the safety, reliability, and longevity of critical infrastructure systems that support economic growth and societal well-being.

Working with new materials

In the future, advancements in scientific research and technology are constantly uncovering novel materials with unique properties and characteristics. Breakthroughs in fields such as nanotechnology, biomaterials, and composite materials are paving the way for the discovery and development of materials that offer enhanced mechanical strength, improved electrical conductivity, superior thermal properties, or superior chemical resistance. These new materials have the potential to revolutionize various industries, including aerospace, automotive, electronics, healthcare, and energy. Moreover, the growing demand for sustainability and environmental consciousness is driving the search for eco-friendly materials. As engineers seek alternatives to traditional materials that have negative ecological impacts, they are exploring bio-based materials, recycled materials, and materials with reduced carbon footprints. The engineering profession is embracing the challenge of finding and utilising materials that are renewable, biodegradable, or recyclable, aiming to minimize waste generation, energy consumption, and environmental pollution.

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In addition, the increasing complexity of engineering applications necessitates the development of specialized materials. There is a need to design materials that can withstand extreme conditions, such as high temperatures, corrosive environments, or intense mechanical stresses. New materials with exceptional properties, such as high-temperature alloys, superconductors, or smart materials, are being developed to meet these demanding requirements.

One significant challenge is the limited understanding and knowledge surrounding these materials. New materials often emerge from breakthroughs in scientific research or advancements in manufacturing techniques. Engineers must grapple with a lack of established design guidelines, material properties, and long-term performance data. This necessitates a cautious and iterative approach, including rigorous testing and simulation to comprehend and harness the capabilities of these materials effectively.

Another key challenge is the integration of new materials into existing manufacturing processes and infrastructure. This means that it will be necessary to ensure compatibility with existing machinery, tools, and techniques, or develop new methods to accommodate the unique properties of these materials. Compatibility issues may arise due to variations in thermal expansion, processing temperatures, or chemical reactions. Engineers must also consider the cost implications of adopting new materials, as initial manufacturing setup costs can be high, and supply chain disruptions or limited availability may affect production scalability.

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10. Ordem dos Engenheiros

1. INTRODUCTION

The Ordem dos Engenheiros (OE) is a professional public association representing engineering graduates who practice the profession of engineer. Its main mission is to contribute to the progress of engineering, stimulating the efforts of its members in the scientific, professional and social fields, as well as compliance with the rules of professional ethics. It's divided into regions, namely the South, Center, North, Madeira and Azores. Each region has district delegations and respective secretariats, facilitating proximity to society and members.

Every year, OE develops a theme for public discussion, with 2024 being the year of Gender Equality in Engineering.

OE is organized into 17 specialties, namely: Aeronautical and Space Engineering, Agronomic, Environmental, Food, Biomedical and Bioengineering, Civil, Electrotechnical, Forestry, Geospacial, Geological and Mining, Computer, Materials, Mechanical, Naval and Oceanic, Chemical and Biological, Industrial Engineering and Management and Safety and Quality; and 23 Specializations, which confer the Professional Title of Specialist on their members.

Since 2002, a system of continuous training actions has been set up, in which each region promotes training actions in the various engineering disciplines, with the aim of updating the knowledge of its members. This training is extended to members of the Professional Associations of the PALOP (Portuguese-speaking African countries).

In 2014, the OE also created the Training Action Accreditation System, the OE+AcCEdE® System, with the aim of guaranteeing the quality of the training offered to engineers by accrediting continuous training actions, promoting the periodic updating of engineer's knowledge and skills for the proper exercise of their profession. Any training action from HEI's and Continuous Education Enterprises that have a duration between 8 hours and 1 year are eligible for receiving the OE+AcCEdE® System Accreditation.

The OE is implementing VALOR^E, a system for the professional development of engineers, based on:

- Verification of competencies;
- Experience and specific practices in Engineering Acts;
- Lifelong learning;
- Appropriate ethical and deontological behavior;
- Practices, attitudes, resources and others that enhance the Engineer.

Its objectives are: to create a certified Curriculum Vitae (CV), by verifying the practice of engineering acts; to position the Engineer as a professional of superior recognition, by adopting innovative criteria in addition to those currently used by the reference institutions; to reinforce public confidence in Engineers, ensuring that they have the competences that the OE recognizes; to reinforce the importance of the OE as a professional association and its image in society, based on the competence, quality and public and social notoriety of its members.

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2. QUANTITATIVE INDICATORS ON THE EVOLVING NATURE OF THE ENGINEERING PROFESSION

According to the OE's data, it can be seen in Table 1 that in the years 2022 and 2023, OE issued a total of 2060 and 1851 Training Certificates for training actions distributed between the various regions and the Accreditation System OE+AcCEdE®.

Table 1: Total number of certificates issued in training actions promoted by the OE and through the Accreditation System OE AcCEdE®.

	South	Center	North	Azores	Madeira	OE+AcCEdE®	Total
Total number of trainees (2022)	718	484	53	500	92	213	2060
Total number of trainees (2023)	696	736	72	115	8	224	1851

Tables 2 and 3 show the areas of engineering in which the aforementioned certificates were issued.

Table 2: Training carried out in the Specialties in 2022.

	South	Center	North	Azores	Madeira	OE+AcCEdE®	Total
Agronomy	---	---	1	---	---	1	2
Environment	---	---	---	2	---	---	2
Civil	2	7	9	14	---	5	37
Electrotechnics	---	2	---	---	---	4	6
Floresty	---	---	---	---	---	---	0
Geospacial	1	---	---	---	---	---	1
Geology and Mining	---	---	---	---	---	---	0
Informatics	4	2	---	---	---	---	6
Materials	1	---	---	3	---	---	4
Mechanics	---	---	---	---	---	4	4
Naval	---	---	---	---	---	---	0
Chemistry and Biology	---	---	---	---	---	1	1
Transversal	12	---	12	---	---	1	25
Total	20	11	22	19	0	16	----

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Table 3: Training carried out in the Specialties in 2023.

	South	Center	North	Azores	Madeira	OE+AcCEdE®	Total
Agronomy	---	---	1	---	---	1	2
Environment	---	2	1	---	---	2	5
Civil	1	10	9	2	1	7	30
Electrotechnics	---	2	4	---	---	2	8
Floresty	---	---	---	---	---	---	0
Geospacial	---	1	---	1	---	---	2
Geology and Mining	---	---	---	---	---	---	0
Informatics	3	---	---	---	---	---	3
Materials	---	---	---	---	---	---	0
Mechanics	---	---	---	---	---	4	4
Naval	---	---	---	---	---	---	0
Chemistry and Biology	---	1	---	---	---	3	4
Transversal	17	2	12	---	---	1	32
Total	21	18	27	3	1	20	----

As can be seen, transversal skills are those in which there are more training actions, followed by continuous training actions in the area of Civil Engineering.

3. QUALITATIVE DESCRIPTORS OF THE EVOLVING NATURE OF THE ENGINEERING PROFESSION

OE organized a series of Conferences entitled “Captação e Vinculação de Talento na Engenharia” (Attracting and Connecting Talent in Engineering) throughout 2024, with the presence of leaders from some of the country's largest public and private engineering companies, Higher Education Institutions (HEI’s), science, technology and innovation centers, business associations and student associations, a public discussion that revealed the lack of qualified human resources in the areas of Engineering in Portugal, coupled with the current and future lack of interest among young people in higher education in this technical-scientific area in the very near future, which weakens the national production system and the economy and will jeopardize the country's development in the very short term. To this end, some companies are already developing measures to retain young talent.

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The main conclusions of the conferences, divided by general conclusions, opportunities, needs and challenges and supported by the secondary research carried out, were:

General conclusions:

- Engineers have a high capacity for adaptation (added value); A good engineer very easily becomes a good manager (for example);
- Innovation centers don't feel a drop in the "quality" of engineers coming into the market, but they do feel a cultural difference, boosted by the pandemic; Some engineers tend to have difficulty adapting to change or leaving their comfort zone;
- There is room in the job market for both 3-year and 5-year graduates, each with their own skills: for field work it's great to have a 3-year graduate, but for conceptual work a 5-year graduate is preferable. If companies start hiring only 3-year engineers ("half engineers") because there is a shortage of talent, there will later be a problem because there will no longer be any Portuguese development/design engineers ("full engineers");

Opportunities:

Since the pandemic, people have started to value their personal lives more with flexible working hours or flexibility for remote working, where possible, motivation, interaction between people, appreciation in the workplace, etc.

- Attracting/retaining talent requires:
  - Schools have do be a part of the talent attraction (engineering colleges and secondary schools, at least);
  - Companies need to change their mentality and culture, which needs to be more flexible and informal, with less bureaucracy and hierarchisation (One company mentioned that it has 60% Millenials and 15% Generation Z; the company's mentality needs to be adapted to the younger employees wants and needs);
  - If possible, companies should promote internal rotation/mobility to other countries;
  - Companies must make employees feel valued;
  - Companies should promote better work-life balance;
  - Companies should offer their workers other benefits, such as daycare;
  - Valorisation of the engineer's career - Adequate salary;
  - Companies need to invest in training and updating their employees;
  - Close relationship between schools and companies;
  - Partnership working models;
  - Give preference to internal recruitment before external recruitment, promoting career progression for those who are interested.
- On a political level, to motivate young people to return/stay in the country, it was suggested:
  - Investing in medium/long-term strategic planning instead of the current short term, setting priorities;
  - Making it easier for young people to obtain housing;
  - More and better tax measures for young people (e.g. youth tax);
  - Strengthening Portugal's economic and business fabric, in order to boost companies' competitiveness;

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  - Valuing young people;
  - Rethink the concept of progress (progress is often thought of as linear);
  - Redefining the concept of a successful company;
  - Showing that engineering is the basis of society, and that it can help assert certain positions in the country;
  - Eliminating the feeling of "precariousness";
  - Qualification policies and support for young people starting their careers are essential.
- When young people look for work, they try to identify with the company's values and place a lot of value on the atmosphere in the workplace and empathy with coworkers;
- Large companies are more comfortable these days, as they are more attractive because they are large, geographically dispersed, can do various types of activities to motivate their workers, and promote a better work-life balance (young engineers these days want/prefer to have different experiences and relevant projects);
- More initiatives should be promoted, such as the presence of secondary schools that go to universities for laboratory classes, so that students can interact with the reality of an engineering course; some HEI's already have "open days", where they welcome parents and potential future students;
- Companies are increasingly looking for professionals with a balance between ethics, emotional intelligence and holistic knowledge, who value sustainability and social responsibility. More often, what gives advantage to a future employee is their individual and personal journey throughout their studies, as well as the school where they were trained;
- Young people should be shown what an engineer does, because many don't know, possibly before they reach secondary school (social media can help shape the opinions of future students);
- Perhaps teachers' careers could be more flexible, with older teachers moving closer to management, to facilitate the rejuvenation of the teaching staff, which in turn would make it easier for students to get closer to the teachers;

Needs:

- HEI's are an open system, with losses from admission to the final diploma. As such, we need to work on the efficiency of this open system in order to reduce the losses in the training process;
- There is still a big gap in attracting women to engineering that needs to be adressed (perhaps this is a cultural problem);
- We need to create more scholarships, support students and develop the process of lifelong learning through collaboration between companies and HEI's;
- There should be an integrated approach to attracting talent, even at a territorial level (including the whole country, rather than just the big centres);
- There needs to be more integration of higher education into previous education (secondary and basic education, perhaps from 9th grade onwards, showing the role of engineering), so that students make a more informed choice about what they want to do in the future; It also needs to be shown in secondary education, for example, that everyone has an active role in society, everyone is a citizen of the world and of their own country;
- There needs to be mixed career guidance teams in schools (in terms of representation of professional areas);

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- Teaching must adapt to today's reality; it can no longer be 19th century teaching, 20th century teaching staff for 21st century students;
- Higher education teaching staff needs pedagogical training adapted to the interests of today's students;
- Soft skills are increasingly necessary/critical, and are what differentiate people from machines (empathy, resilience, communication, leadership, teamwork, problem-solving, sustainability, critical thinking, flexibility, adaptation, problem-solving skills, etc); Engineering degrees should also include learning new programmes;

Challenges:

- The problem of retaining and attracting talent cuts across several professional areas, although it is most noticeable in the field of engineering, since engineering is the basis of countries' development;
- Depending on the area of engineering, there can be different problems: for some areas the problem is attraction, for others it's retention;
- There are two sides in the problem of attraction and retention: in the short term, the problem is retaining talent; in the long term, it's regenerating qualified company staff;
- Engineers can easily change employers;
- Investments are not constant, which leads to fluctuations in the needs of the various companies;
- Enterprises in Portugal, for the most part, can't compete with companies from abroad in terms of the conditions offered to their workers, except for a few larger companies;
- Approximately 44 % of Portuguese entrepreneurs have a 9th grade education, which means they take fewer risks and hire fewer engineers (for a small or medium-sized company, an attempt at innovation that could go wrong is a big risk; also, an engineer also requires a higher salary);
- There is a misplaced belief that older people (over 50) have been trained a long time ago, their skills are outdated and they no longer have the same abilities as a young graduate;
- It's easier for young people to emancipate themselves abroad, since Portugal is the country with the 4th highest tax burden (low wages Vs current cost of living Vs minimum wage Vs taxes);
- HEI's are having trouble attracting students for master's degrees. Nowadays, graduates prefer to enter the job market straight away and then complement their training with a postgraduate course, rather than doing a master's degree;
- The teaching staff must promote changes in teaching methods;
- Some of the teaching staff in higher education, aged around 40/50, don't have yet a secure position, meaning that it is difficult to promote the rejuvenation of the teaching staff.

4. CONCLUSIONS AND RECOMMENDATIONS

Retaining and attracting talent is a cross-cutting problem in various professional areas, most perceivable in engineering, which is the basis for the functioning and development of society. This problem has two dimensions: short and long term.

Nowadays, there is an increasing need for an integrated approach between the various stages of education and the job market, in order to attract more students to the field of engineering, through initiatives that show the role of an engineer to young people and to society.

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There is also a need to encourage upskilling, reskilling and the updating of engineers' knowledge, in a joint effort between companies, continuing education bodies and HEI's. Companies themselves should also encourage, incentivize and promote their employees to enter into upskilling, reskilling and knowledge updating programs. Considering the current dynamism of the job market, there is a pool of talent being wasted because older people are considered to have outdated skills and no longer have the same capabilities as a young graduate.

Companies are increasingly valuing the HEI where each one obtains a diploma and the individual background of each person, appreciating skills/characteristics such as emotional intelligence, ethics, social responsibility, sustainability, critical thinking, etc.

It's important to note that the younger generations are placing increasing importance on the balance between their personal and professional lives, flexible working arrangements (including, where possible, working in a hybrid model), the possibility of career progression, valorization of their work, etc. Companies therefore need to adapt to the expectations and needs of their employees, promoting a more informal and flexible culture, with less bureaucracy and hierarchy.

On a political level, it is advisable to focus on setting priorities and defining medium and long-term strategic plans. It is also necessary to redefine the tax measures to strengthen the companies competitivity and attract more entrepreneurship in engineering areas.

Finally, HEI's are considered an open system, with losses from the moment of admission to the time of the final diploma, so it is essential that the teaching staff be rejuvenated, with pedagogical training adapted to the new reality of today's students.

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11. REHVA

1. Introduction

REHVA is The Federation of European Heating, Ventilation and Air Conditioning Associations. REHVA is an umbrella organization that represents over 120,000 HVAC designers, building services engineers, technicians, and experts across 26 European Countries.

In this report, we provide the perspective on the future of the engineering profession in the HVAC sector in the countries that REHVA represents:

1. BULGARIA
2. ROMANIA
3. LATVIA
4. ITALY
5. FRANCE
6. MOLDOVA
7. SPAIN
8. BELGIUM
9. UNITED KINGDOM
10. DENMARK
11. ESTONIA
12. HUNGARY
13. FINLAND
14. SERBIA
15. LITHUANIA
16. NORWAY
17. PORTUGAL
18. POLAND
19. SLOVENIA
20. SLOVAKIA
21. CZECH REPUBLIC
22. SWEDEN
23. SWITZERLAND
24. TÜRKIYE
25. GERMANY
26. NETHERLANDS

When it comes to the implementation landscape of the SDGs and the Green Deal in Europe, the Vocational Education and Training (VET) sector and the business ecosystem play crucial roles.

VET Sector: the VET sector plays a significant role in preparing the current and future workforce with the necessary skills and knowledge to contribute to sustainable development and the green economy. VET institutions and programs can incorporate sustainability and green skills into their curricula to ensure that learners are equipped with the competencies needed for sustainable practices in various sectors.

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Training Programs: VET institutions can develop specialized training programs that focus on sustainability, renewable energy, resource efficiency, circular economy, and other green technologies. These programs can provide practical skills and knowledge for individuals to contribute to the implementation of the SDGs and the Green Deal.

Skills Development: VET can play a pivotal role in upskilling and reskilling the existing workforce to meet the demands of the green economy. By identifying skill gaps and offering relevant training opportunities, the VET sector can support the transition towards sustainable practices across different industries.

Business Ecosystem: the business ecosystem, including both large corporations and SMEs (Small and Medium-sized Enterprises), plays a crucial role in driving sustainable development and the implementation of the Green Deal. Businesses can integrate the SDGs and the Green Deal principles into their strategies, operations, and products/services.

Sustainable Practices: businesses can adopt sustainable practices such as reducing greenhouse gas emissions, implementing energy-efficient measures, adopting circular economy principles, promoting responsible supply chains, and ensuring social and environmental responsibility throughout their operations.

Innovation and Investment: the Green Deal offers opportunities for businesses to innovate and develop new sustainable solutions and technologies. By investing in research and development, businesses can contribute to achieving the SDGs and the goals of the Green Deal while also fostering economic growth and competitiveness.

Collaboration and Partnerships: collaboration between businesses, government entities, VET institutions, and civil society organizations is crucial for the successful implementation of the SDGs and the Green Deal. Partnerships can facilitate knowledge sharing, joint initiatives, and the exchange of best practices, creating a more supportive ecosystem for sustainable development.

In summary, the implementation landscape of the SDGs and the Green Deal in Europe across the VET and business ecosystem involves integrating sustainability into VET curricula, upskilling the workforce, adopting sustainable practices in businesses, fostering innovation and investment, and promoting collaboration and partnerships for effective implementation.

2. Quantitative indicators on the evolving nature of the engineering profession: evolving of the HVAC engineering profession

It's important to note that specific quantitative data may vary depending on the country, market conditions, and available studies. Overall, these are the key aspects to consider from a European perspective for what concern the HVAC sector that REHVA represents:

- **Energy Efficiency Regulations**: the EU has been at the forefront of implementing energy efficiency regulations to reduce carbon emissions and promote sustainability. Directives like the Energy Performance of Buildings Directive (EPBD) and the Ecodesign Directive have influenced the HVAC industry by setting efficiency standards for heating and cooling equipment. Compliance with these regulations has driven the demand for energy-efficient HVAC systems and has influenced engineering practices in the region.

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- **Renewable Energy Integration**: the EU has been actively promoting renewable energy integration, such as solar, wind, and geothermal, into building designs. This integration involves the use of heat pumps, solar thermal systems, and other technologies. Quantitative information on the installation rates of renewable energy systems integrated with HVAC engineering solutions can provide insights into the evolving nature of the profession in the EU region.
- **Building Energy Performance**: the EU has set targets and established frameworks to improve the energy performance of buildings. This includes initiatives like Nearly Zero-Energy Buildings (nZEB) and the Energy Performance Certificate (EPC) system. Quantitative data on the number of nZEB-compliant buildings, EPC ratings, and the energy performance improvements achieved can reflect the evolving nature of HVAC engineering practices in the EU.
- **Professional Associations and Certifications**: professional organizations and certification bodies in the EU, such as REHVA (Federation of European Heating, Ventilation, and Air Conditioning Associations) and its national-level member associations, offer certifications and conduct surveys to gauge industry trends. Despite the fact this isn't something currently done, monitoring the number of certified HVAC engineers and industry surveys conducted at the national level by such organizations could provide quantitative insights into the evolving nature of the profession in the EU.
- **Research and Development Funding**: the EU invests in research and development to drive innovation in the HVAC sector. Funding programs like Horizon Europe and LIFE Clean Energy Transition support projects related to energy efficiency, smart buildings, and sustainable technologies. Quantitative information on R&D funding allocated to HVAC-related projects can indicate the evolving nature of the profession and the industry's commitment to innovation in the EU region.

3. Qualitative descriptions of the evolving nature of the engineering profession: Evolving of the HVAC engineering profession

The general insights into the evolving nature of the HVAC engineering profession in the European Union (EU) region as agreed by the leading experts are as follows:

- **Energy Efficiency and Sustainability**: one of the significant trends in the HVAC engineering profession in the EU is the increasing focus on energy efficiency and sustainability. With the aim of reducing carbon emissions and achieving climate targets, there has been a growing demand for energy-efficient HVAC systems and renewable energy integration. HVAC engineers are expected to design, install, and maintain systems that minimize energy consumption while maximizing performance.
- **Renewable Energy Integration:** the EU has been promoting the integration of renewable energy sources into HVAC systems. This includes incorporating technologies such as solar thermal, geothermal, and heat pumps to provide heating and cooling solutions. HVAC engineers are required to have knowledge and expertise in designing and optimizing these systems to utilize renewable energy effectively.
- **Indoor Air Quality and Health**: there is an increasing emphasis on indoor air quality and its impact on occupant health and well-being. HVAC engineers are expected to design systems that provide proper ventilation, filtration, and air purification to ensure a healthy indoor

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environment. This includes addressing issues such as humidity control, pollutant removal, and thermal comfort.

- **Smart Building Integration**: the rise of smart building technologies has influenced the HVAC engineering profession. Integrated building management systems, Internet of Things (IoT) devices, and advanced controls are being used to optimize HVAC system operation, enhance energy efficiency, and enable remote monitoring and control. HVAC engineers are required to have knowledge of these technologies and their integration into building systems.
- **Regulatory and Environmental Standards**: the EU has implemented various regulations and standards to promote energy efficiency, reduce greenhouse gas emissions, and ensure the safe operation of HVAC systems. HVAC engineers need to stay updated with these regulations, such as the European Union's Ecodesign Directive and Energy Performance of Buildings Directive (EPBD), to comply with the requirements and incorporate them into their designs.
- **Skills and Training**: the evolving nature of the HVAC engineering profession in the EU demands continuous learning and skill development. HVAC engineers are encouraged to stay updated with the latest technologies, energy-efficient practices, and environmental standards through professional development courses and certifications. This includes gaining knowledge in areas such as advanced controls, energy modelling, and building simulation.

It's important to bear in mind that the HVAC engineering profession can vary across different EU countries due to variations in climate, building regulations, and market conditions. Therefore, it's advisable to consult specific regional or national sources for more detailed and up-to-date information on the evolving nature of the HVAC engineering profession in a particular EU country.

4. Opportunities, Needs, Challenges, and Recommendations for the Engineering Profession in the HVAC Sector

To be able to provide the perspective of the HVAC sector REHVA has conducted a study among its Member Associations and has elaborated a specific questionnaire that aims to outline the evolution of the Engineering profession in the HVAC sector.

In this section, you will find the methodology used to conduct the study as well as the results from each country.

METHODOLOGY

The questionnaire has been shared with our Member Associations, our REHVA Supporters Committee representatives as well as the Educational and Training Committee representatives. We have gathered a total of 20 replies that provides a country’s perspective of the HVAC sector.

To build our questionnaire and collect results REHVA applied the following methodology:

1. Define the Objectives:

REHVA clearly defined the objectives of the questionnaire, which include assessing, anticipating, and monitoring the evolution of the Engineering Profession in the HVAC sector. We have specified that the questionnaire aims to gather quantitative indicators on the evolving nature of the engineering profession in the HVAC sector across the 26 countries represented by REHVA and emphasize the relevance of the

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questionnaire for the EU-funded project E4E and its goal of providing a clear vision for the Engineers Profession needs and challenges.

2. Develop Questionnaire Structure:

We have created a simple Google Form to collect accurate information in a limited amount of time. Furthermore, we have divided the questionnaire into sections corresponding to the identified key themes ensuring that the questions are clear, concise, and easily understandable by the respondents. We then included a mix of multiple-choice questions, rating scales, and open-ended questions to gather both quantitative and qualitative data.

3. Quantitative Indicators:

Besides REHVA developed questions that elicit quantitative data regarding the evolving nature of the engineering profession in the HVAC sector and we have decided to use rating scales or numerical input fields to quantify the responses.

4. Qualitative Insights:

Through the open-ended questions, REHVA gathered qualitative insights and opinions from the respondents. It was essential to encourage respondents to share their experiences, challenges, and recommendations related to the engineering profession in the HVAC sector. These insights that we have collected can provide valuable context and help in understanding the quantitative indicators.

5. Dissemination and Data Collection:

REHVA disseminated the questionnaire among its members in the 26 represented countries. We have utilized various channels, such as email, online platforms, and social media, to reach the totality of our network.

6. Data Analysis:

REHVA performed quantitative analysis by aggregating and summarizing the quantitative data obtained from multiple-choice and rating scale questions. Furthermore, the results are elaborated in this report by country to provide the reader with a consolidated view of each of the countries represented by our organization.

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RESULTS ANALYSIS

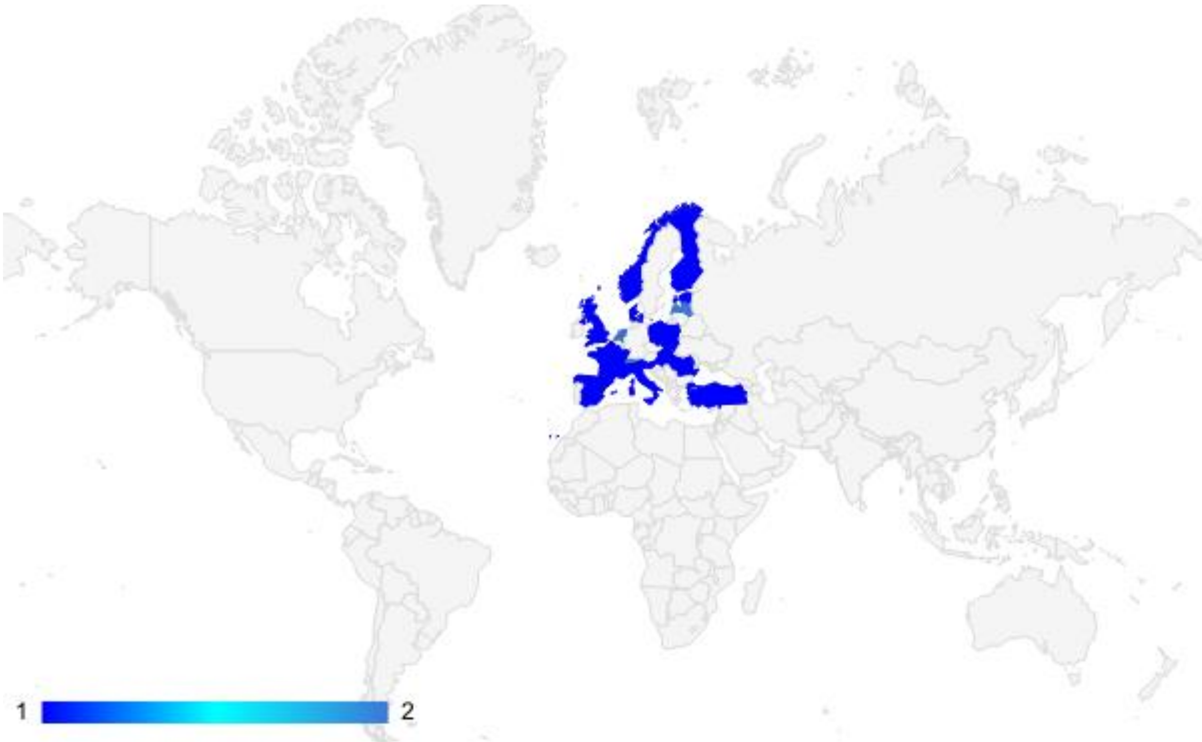

Figure 1: Countries represented

REHVA gathered 20 replies from 17 countries:

- Denmark
- Estonia
- Finland
- France
- Hungary
- Italy
- Latvia
- Netherlands
- Norway
- Poland
- Romania
- Slovakia
- Slovenia
- Spain
- Switzerland
- Turkey
- UK

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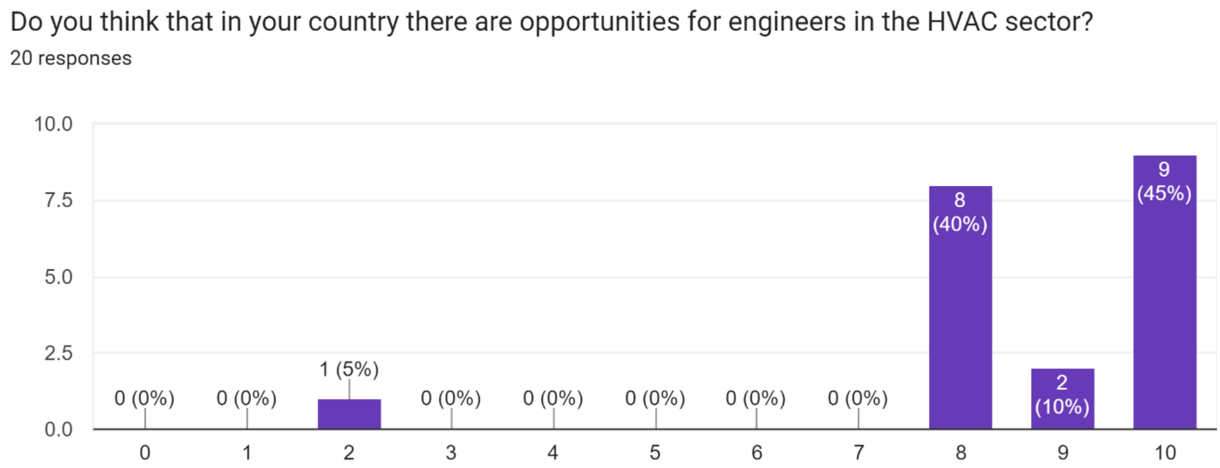
As a first question to our network REHVA has requested to rate from 0 to 10 the Countries' opportunities in the HVAC sector for engineers being 0 *None* and 10 *Satisfying amount to cover the market offer*.

Figure 2: question 1



We can state that for the countries represented the majority thinks that there are enough opportunities to cover the market offer. An isolated case is France which the opportunities have been scored as '2'.

In the second section of the questionnaire, our Members have been asked to provide a brief country perspective on the needs, challenges, and recommendations of the engineering profession in the HVAC sector.

We have decided to showcase the results per country to better focalize on the national dimension and take into consideration that specific quantitative data may vary depending on the country, and market conditions.

In the following section, we, therefore, provide a country fiche for each respondent identifying the main needs, challenges, and recommendations for the engineering profession in the HVAC sector.

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DENMARK

Needs

In the HVAC sector in Denmark, the engineering profession has several main needs that have been identified. These needs revolve around three key areas: knowledge of rules, regulations, and standards, practical experience, and education.

Sufficient knowledge of rules, regulations, and standards: In the HVAC sector, it is crucial for engineers to have a strong understanding of the rules, regulations, and standards that govern the design, installation, and operation of heating, ventilation, and air conditioning systems. This includes knowledge of Danish building codes, energy efficiency requirements, indoor air quality guidelines, and environmental regulations. Engineers need to stay updated with the latest revisions and amendments to ensure compliance and to deliver safe and efficient HVAC solutions.

Lack of practical experience: Another important need in the HVAC engineering profession is practical experience. While theoretical knowledge is essential, practical experience allows engineers to apply their knowledge effectively in real-world scenarios. It helps them understand the practical challenges, complexities, and nuances of HVAC system design, installation, and maintenance. Practical experience also enables engineers to develop problem-solving skills and learn from real-life situations, ultimately enhancing their competence and expertise in the field.

Need for education: Continuous education plays a crucial role in the HVAC engineering profession. Technology and industry practices in the HVAC sector are constantly evolving, driven by factors such as energy efficiency goals, sustainability, and advancements in HVAC systems and controls. Engineers need to stay updated with the latest developments, emerging trends, and best practices. Continuing education programs, workshops, seminars, and professional certifications provide opportunities for engineers to enhance their knowledge, acquire new skills, and stay abreast of the latest industry standards and technologies.

Additionally, the HVAC sector in Denmark has a growing focus on sustainable and energy-efficient solutions. Engineers need to have a strong foundation in sustainable HVAC design principles, energy modeling, and renewable energy integration. They should be familiar with concepts such as heat recovery, passive cooling strategies, and optimizing HVAC systems for reduced energy consumption and environmental impact.

Challenges

The main challenges identified are as follows:

All is being computerized, and manual checks are ignored: The HVAC industry is increasingly adopting automation and computerized systems for the design, installation, and operation of HVAC systems. While automation brings efficiency and accuracy, there is a risk of overreliance on computerized

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processes, leading to the neglect of manual checks. This can result in errors or oversights that may compromise the safety, performance, and efficiency of HVAC systems. Engineers need to find a balance between utilizing computerized tools and conducting manual checks to ensure the reliability and quality of HVAC installations.

Economic pressure prioritizes cost over quality: The HVAC industry, like any other sector, faces economic pressure, with a focus on cost reduction and maximizing profits. In such a climate, there is a risk of prioritizing financial considerations over quality. This can lead to compromises in the selection of equipment, materials, and installation practices, potentially compromising the performance, energy efficiency, and durability of HVAC systems. Engineers need to advocate for the importance of quality and long-term value to ensure that HVAC projects meet the required standards and deliver optimal performance over their lifespan.

Cross-technical knowledge is lacking: The HVAC sector is multidisciplinary, requiring knowledge and expertise across various technical domains. This includes an understanding of thermodynamics, fluid mechanics, electrical systems, control systems, and building science. However, there is often a lack of cross-technical knowledge among HVAC engineers. This can hinder effective collaboration and communication between professionals from different disciplines involved in HVAC projects, leading to suboptimal designs and inefficient system integration. Encouraging interdisciplinary training, promoting knowledge sharing, and fostering collaboration among professionals from different technical backgrounds can help address this challenge.

Recommendations:

To address the needs, collaboration between industry stakeholders, educational institutions, and professional organizations is crucial. Industry professionals should participate in knowledge-sharing initiatives, mentorship programs, and industry-academia partnerships. This collaboration can help bridge the gap between theoretical knowledge and practical experience, improve educational programs, and ensure that the engineering profession in the HVAC sector in Denmark remains competent, innovative, and adaptable to evolving industry requirements. In addition, according to our Danish members, it is essential to focus on qualifications. It is essential to emphasize the importance of continuous learning and professional development within the HVAC engineering profession. Companies should encourage and support engineers to pursue upskilling opportunities. To ensure a high level of competence and knowledge among HVAC engineers, it can be beneficial to introduce mandatory upskilling requirements. Companies in the HVAC sector could be required to send their engineers to relevant qualification courses periodically. This would help address any gaps in knowledge, keep professionals updated with the latest industry developments, and enhance the overall quality of HVAC engineering services.

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ESTONIA

Needs

1. Building physics: Building physics plays a crucial role in designing and maintaining energy-efficient HVAC systems. It involves understanding how heat, moisture, and airflow interact within a building. The need for expertise in building physics arises from the requirement to optimize heating, ventilation, and air conditioning systems to ensure energy efficiency, occupant comfort, and indoor air quality.
2. Renovation of buildings: Estonia, like many other countries, has a significant number of existing buildings that need renovation and modernization. These buildings often have outdated HVAC systems that are not energy-efficient. The engineering profession in the HVAC sector needs to address the renovation of buildings by upgrading or replacing HVAC systems, improving energy efficiency, and integrating renewable energy sources where possible.
3. Moisture safety: Moisture management is critical for maintaining the durability and indoor air quality of buildings. Moisture-related issues can lead to growth, structural damage, and health problems. The engineering profession in the HVAC sector needs to focus on designing and implementing moisture control strategies, such as proper ventilation, vapor barriers, and moisture-resistant materials, to ensure the long-term safety and performance of buildings.
4. Additional insulation of the building envelope: Adequate insulation of the building envelope is essential for reducing heat loss or gain, improving energy efficiency, and enhancing occupant comfort. The engineering profession needs to address the need for additional insulation in existing buildings, as well as ensure that new construction projects meet high insulation standards. This may involve conducting energy audits, recommending insulation materials and techniques, and promoting energy-efficient building practices.

Overall, the Engineering Profession in the HVAC sector in Estonia needs to prioritize building physics, renovation of buildings, moisture safety, and additional insulation of the building envelope to enhance energy efficiency, indoor air quality, and occupant comfort. By addressing these needs, the profession can contribute to sustainable and resilient building practices in Estonia.

Challenges

1. Finance for renovation: One of the significant challenges in the HVAC sector is the availability of finance for building renovations. Renovating buildings to improve their energy efficiency and upgrade HVAC systems can be expensive. Lack of access to financing options or limited financial resources can hinder the implementation of necessary renovations. The engineering profession in the HVAC sector needs to navigate this challenge by exploring financing mechanisms, such as government grants, subsidies, low-interest loans, or innovative financing models, to make renovation projects more financially feasible for building owners.
2. Policy challenges: Policy frameworks and regulations play a crucial role in driving energy efficiency and sustainable practices in the HVAC sector. However, the implementation and effectiveness of policies can pose challenges. In Estonia, the engineering profession may face

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challenges related to inconsistent or inadequate policies, complex regulatory requirements, or a lack of clarity in standards and guidelines. It is important for professionals to stay updated with the latest policies, advocate for favorable regulations, and actively engage with policymakers to address these challenges and create an enabling environment for sustainable HVAC practices.

3. Availability of skilled blue-collar workers: The HVAC sector relies heavily on skilled blue-collar workers who can install, maintain, and operate HVAC systems effectively. However, the availability of skilled workers can be a challenge. Estonia, like many other countries, faces a shortage of qualified HVAC technicians and tradespeople. The engineering profession needs to work towards bridging this skill gap by promoting vocational training programs, apprenticeships, and professional development opportunities. Collaboration with educational institutions and industry stakeholders is essential to attract and train a skilled workforce to meet the demands of the HVAC sector.

Recommendations:

Professional education: Continuous professional education and training are essential for engineers in the HVAC sector to stay updated with the latest technologies, practices, and standards. The profession should emphasize the importance of lifelong learning and encourage engineers to participate in training programs, workshops, and industry conferences. Collaborating with educational institutions and industry associations can help develop specialized HVAC curricula and certification programs that align with the evolving needs of the industry. By promoting professional education, the engineering profession can enhance the competency and expertise of HVAC engineers in Estonia.

Investment in R&D: Investing in research and development is crucial for innovation and advancement in the HVAC sector. The engineering profession should encourage, and support R&D initiatives aimed at developing energy-efficient HVAC technologies, sustainable building materials, and smart control systems. Collaboration between industry, academia, and research institutions can foster innovation and drive the adoption of cutting-edge technologies in Estonia's HVAC sector. By investing in R&D, the profession can contribute to the development of sustainable, cost-effective, and high-performance HVAC solutions.

Industry collaboration and knowledge sharing: Collaboration among professionals, industry stakeholders, and policymakers is vital for the growth and development of the HVAC sector. The engineering profession should promote knowledge-sharing platforms, industry associations, and forums where experts can exchange ideas, best practices, and lessons learned. Collaborative efforts can help address common challenges, advocate for favourable policies, and foster a culture of innovation and continuous improvement in the HVAC sector.

Public awareness and outreach: Increasing public awareness about the importance of energy efficiency, indoor air quality, and sustainable HVAC practices is crucial. The engineering profession can play a vital role in educating the public through campaigns, workshops, and outreach programs. By raising awareness about the benefits of energy-efficient HVAC systems and promoting sustainable building practices, the profession can drive demand for greener solutions and contribute to a more sustainable built environment in Estonia.

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FINLAND

Needs

1. Hybrid systems: Hybrid systems in the HVAC sector combine multiple energy sources and technologies to optimize energy efficiency and reduce environmental impact. Finland, being a country with varying weather conditions, requires HVAC systems that can adapt to different seasons and integrate renewable energy sources effectively. The engineering profession needs to focus on developing and implementing hybrid systems that combine technologies such as heat pumps, solar energy, biomass, and district heating to provide efficient heating, cooling, and ventilation solutions. This involves designing system configurations, control strategies, and integration methods that maximize energy savings and reduce greenhouse gas emissions.
2. Demand response: Demand response refers to the ability of HVAC systems to adjust their operation based on changes in electricity demand and grid conditions. It involves shifting energy consumption to off-peak hours or reducing energy usage during peak demand periods. In Finland, where energy markets and electricity pricing mechanisms are evolving, demand response capabilities are increasingly important. The engineering profession needs to integrate demand response features into HVAC systems, such as smart controls and monitoring systems that can communicate with the grid. This allows buildings to participate in demand response programs, contribute to grid stability, and achieve cost savings by optimizing energy consumption.
3. Demand-based ventilation: Demand-based ventilation is an approach where ventilation rates are adjusted based on the actual occupancy and air quality requirements of a building. Finland has stringent regulations and guidelines for indoor air quality, and demand-based ventilation systems can help ensure a healthy and comfortable indoor environment while minimizing energy waste. The engineering profession should focus on designing and implementing ventilation systems that use sensors, occupancy detection, and air quality monitoring to dynamically adjust ventilation rates. This helps optimize energy consumption, reduce unnecessary ventilation when spaces are unoccupied, and maintain excellent indoor air quality.

Challenges

1. Being under the main contractor: In some construction projects, the engineering profession in the HVAC sector may face challenges when they are subcontracted under the main contractor. This can lead to reduced control over the design, installation, and quality of HVAC systems. It may also result in limited involvement in decision-making processes, making it challenging to implement best practices and ensure optimal performance. The profession needs to navigate this challenge by actively engaging with main contractors, advocating for their expertise and contributions, and striving for collaborative working relationships that prioritize effective HVAC system design and installation.
2. Divided contracts: Divided contracts occur when different aspects of a construction project, including HVAC systems, are subcontracted to multiple entities. This fragmentation can lead to coordination difficulties, communication gaps, and potential conflicts between different

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subcontractors. The engineering profession needs to address this challenge by actively participating in project planning and coordination processes, establishing effective communication channels with other subcontractors, and promoting collaborative working relationships. By emphasizing the importance of coordination and integration among different subcontractors, the profession can mitigate the challenges associated with divided contracts.

3. Low respect: The engineering profession in the HVAC sector may sometimes face challenges related to low respect or recognition for their expertise and contributions. This can arise from a lack of understanding of the complexity and importance of HVAC systems in ensuring occupant comfort, energy efficiency, and indoor air quality. To address this challenge, the profession needs to proactively promote the value and significance of their work. This can be achieved through educational outreach, awareness campaigns, and engagement with stakeholders, policymakers, and the public. By raising awareness and fostering a culture of respect for the engineering profession, the challenges related to low respect can be mitigated.

Recommendations

Broad education: The engineering profession in the HVAC sector should prioritize broad education to equip professionals with interdisciplinary knowledge and skills. HVAC systems are increasingly integrated with other building systems, such as electrical, mechanical, and control systems. By having a broader understanding of these interconnected systems, engineers can design and implement more efficient and integrated HVAC solutions. Collaborating with educational institutions to develop comprehensive curricula that cover various aspects of building science, energy management, and sustainability will help address this recommendation.

Utilization of data-driven buildings: The engineering profession should embrace data-driven approaches in the design, operation, and maintenance of HVAC systems. Advancements in sensor technologies, data analytics, and building management systems offer opportunities to collect and analyze real-time data on building performance and occupant behavior. By utilizing this data, engineers can optimize HVAC system performance, identify areas for improvement, and make informed decisions to enhance energy efficiency and occupant comfort. Promoting the use of data-driven tools and technologies will enable more effective and efficient HVAC solutions.

Smart buildings: Smart building technologies, including Internet of Things (IoT) devices, can significantly impact the HVAC sector. The engineering profession should focus on integrating smart building technologies with HVAC systems to enhance energy efficiency, occupant comfort, and operational performance. This involves designing and implementing advanced control systems, leveraging real-time data for automated optimization, and utilizing predictive maintenance techniques. By embracing smart building concepts, engineers can contribute to the development of intelligent and sustainable HVAC solutions.

Hybrid systems: The engineering profession should actively promote and implement hybrid HVAC systems in Finland. Hybrid systems integrate multiple energy sources, such as renewable energy technologies (solar, geothermal, biomass) and conventional systems (heat pumps, district heating), to achieve higher energy efficiency and reduce carbon emissions. Engineers should focus on designing and optimizing hybrid systems that are tailored to the specific needs of buildings, considering factors like

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climate conditions, energy availability, and building usage patterns. Encouraging the adoption of hybrid systems will contribute to Finland's sustainability goals and energy transition.

FRANCE

Needs

1. More society recognition: The engineering profession in the HVAC sector requires greater recognition and appreciation from society. HVAC engineers play a crucial role in ensuring energy efficiency, indoor air quality, and occupant comfort in buildings. However, their contributions are often undervalued or not fully understood by the general public. By raising awareness about the importance of the HVAC profession and its impact on sustainability and public health, society can better recognize and appreciate the work of HVAC engineers. This can be achieved through public outreach campaigns, educational initiatives, and highlighting the role of HVAC professionals in creating healthier and more sustainable built environments.
2. More training opportunities throughout the professional life: Continuous professional development is essential for HVAC engineers to stay up-to-date with the latest technologies, regulations, and industry best practices. The profession needs more training opportunities throughout an engineer's professional life to enhance their skills and knowledge. This includes both technical training related to HVAC systems, energy efficiency, and sustainability, as well as broader professional skills such as project management and communication. Employers, professional associations, and educational institutions should collaborate to provide ongoing training programs, workshops, and certifications to support the professional growth of HVAC engineers.
3. More material recognition (higher salaries): Material recognition, in the form of higher salaries, is an important aspect of attracting and retaining talent in the HVAC engineering profession. Highly skilled HVAC engineers contribute significantly to the design, installation, and operation of energy-efficient and sustainable HVAC systems. It is important to address the wage gap and ensure that HVAC engineers are compensated fairly for their expertise and contributions. Employers, industry associations, and policymakers should work together to establish competitive salary structures that reflect the value and complexity of the work carried out by HVAC engineers. This will help attract and retain skilled professionals in the field.

Challenges

1. Attracting young engineers: One of the primary challenges for the HVAC engineering profession in France is attracting young talent to the field. To address this challenge, more society recognition and awareness of the HVAC sector's importance and impact on sustainability and public health are necessary. Additionally, offering competitive salaries and benefits can help attract young engineers who have a wide range of career options. By showcasing the rewarding and impactful nature of the HVAC profession, actively engaging with educational institutions, and promoting career opportunities, the sector can attract a new generation of talented engineers.

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2. Staying up to date in a highly evolving environment: The HVAC industry is constantly evolving, driven by advancements in technology, changing regulations, and the emergence of new practices. Staying up-to-date with these developments poses a significant challenge for engineers. They need to continually update their knowledge and skills in areas such as energy efficiency, product innovation, building controls, Building Information Modeling (BIM), and sustainable design practices. Engaging in professional development activities, attending industry conferences, participating in training programs, and actively seeking information about the latest trends and regulations can help HVAC engineers remain up-to-date and competitive in the industry.
3. Providing continuous education throughout professional life: Continuous education and lifelong learning are crucial for HVAC engineers to maintain their professional competence and adapt to industry advancements. The challenge lies in establishing mechanisms and opportunities to educate engineers throughout their entire professional life. The HVAC industry, including employers, professional associations, and educational institutions, can play a key role in providing accessible and relevant training programs, certifications, workshops, and seminars. By investing in professional development initiatives and creating a culture of learning, the profession can support engineers in expanding their skills, staying abreast of industry developments, and advancing their careers.

Recommendations

Highlight the importance of HVAC: The engineering profession in the HVAC sector should actively work towards highlighting the importance of HVAC systems in buildings. This can be achieved through public awareness campaigns, educational initiatives, and industry advocacy. By showcasing the impact of HVAC systems on energy efficiency, indoor air quality, occupant comfort, and sustainability, the profession can raise awareness among stakeholders, including building owners, architects, developers, and policymakers. Emphasizing the crucial role of HVAC systems will help position them as valuable investments rather than mere cost centers.

Address competition and drive-up quality: The HVAC sector in France often faces intense competition, which can lead to a focus on cost reduction rather than quality and performance. The engineering profession should advocate for higher standards and best practices in HVAC design, installation, and maintenance. This can be achieved through industry collaboration, establishing professional codes of conduct, and promoting certifications that ensure the competence and expertise of HVAC professionals. By driving up quality, the profession can build trust and demonstrate the value that well-designed and properly installed HVAC systems bring to buildings.

Maximize the value of HVAC systems: HVAC systems should be viewed as opportunities to add value to real estate and minimize the carbon footprint of buildings. The engineering profession should promote the integration of energy-efficient HVAC solutions, renewable energy technologies, and sustainable design practices. By demonstrating the potential energy savings, improved occupant comfort, and enhanced environmental performance of HVAC systems, professionals can position them as investments that contribute to the long-term value and sustainability of real estate. Collaboration with architects, developers, and other stakeholders is crucial in leveraging HVAC systems to their fullest potential.

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HUNGARY

Needs

1. Reduce energy prices: Energy prices have a significant impact on the affordability and sustainability of HVAC systems in Hungary. The engineering profession in the HVAC sector needs to work towards reducing energy prices to make energy-efficient solutions more financially viable for consumers. This can be achieved through advocating for favorable energy policies, promoting renewable energy sources, and implementing energy-saving measures. Collaboration with policymakers, energy providers, and consumer organizations can help address this need and create a more affordable energy landscape for HVAC systems.
2. Improve comfort: The engineering profession should prioritize improving occupant comfort in buildings. Comfort plays a vital role in ensuring productivity, health, and well-being. HVAC systems need to be designed and operated to provide optimal thermal comfort, humidity control, and air distribution. This involves employing advanced control strategies, considering individual preferences and diverse building usage patterns, and addressing thermal comfort standards. By focusing on enhancing comfort, the profession can contribute to creating healthier and more productive indoor environments in Hungary.
3. Enhance indoor air quality (IAQ): Indoor air quality is a crucial factor in maintaining a healthy and comfortable indoor environment. The engineering profession should emphasize the importance of IAQ in HVAC system design and operation. This includes adopting ventilation strategies that provide adequate fresh air exchange, implementing air filtration and purification technologies, and ensuring proper maintenance practices. By prioritizing IAQ, the profession can help reduce the risk of indoor pollutants, allergens, and airborne diseases, thereby promoting the health and well-being of building occupants.
4. Increase deep renovations: Deep renovations involve comprehensive and energy-efficient retrofits of buildings, including their HVAC systems. The engineering profession should focus on increasing the rate of deep renovations in Hungary. This requires developing expertise in energy-efficient HVAC system design, integration of renewable energy sources, and innovative insulation and building envelope solutions. Collaboration with architects, contractors, and building owners is essential in promoting deep renovations and making them economically feasible. By advocating for deep renovations and providing the necessary expertise, the profession can contribute to the energy transition and sustainability goals in Hungary.

Challenges

1. Operational Cost: One of the significant challenges for engineers in the HVAC sector is to optimize operational costs. This involves finding ways to enhance energy efficiency and reduce energy consumption in heating, cooling, and ventilation systems. Energy costs can be a significant burden for building owners and occupants, so engineers need to employ innovative design techniques, select efficient equipment, and implement advanced control systems to minimize energy usage while maintaining optimal indoor comfort.

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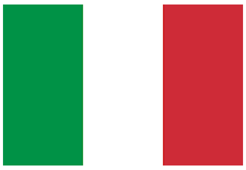
2. Comfort and IAQ Measurements: Ensuring occupant comfort and maintaining good indoor air quality are crucial considerations in HVAC engineering. Engineers need to monitor and manage various parameters such as temperature, humidity, airflow, and air quality to create a comfortable and healthy indoor environment. Challenges arise in accurately measuring and controlling these factors, especially in large and complex buildings. Engineers must utilize advanced sensors, monitoring systems, and predictive analytics to assess and regulate comfort and IAQ effectively.
3. Renovation of Existing Buildings: Hungary, like many countries, has a significant number of aging buildings that require renovation to meet modern energy efficiency standards and enhance occupant comfort. Retrofitting existing HVAC systems can be challenging due to structural limitations, outdated equipment, and complex integration requirements. Engineers need to develop strategies for retrofitting HVAC systems, including upgrading equipment, improving insulation, and optimizing airflow distribution. Balancing the need for energy efficiency, cost-effectiveness, and minimal disruption during renovations poses additional challenges.

Recommendations

One of the key recommendations for the engineering profession in the HVAC sector in Hungary is to utilize energy and comfort simulation tools for building design and optimization. Energy and comfort simulations involve using computer models and advanced software to analyse and predict the performance of HVAC systems in buildings.



ITALY

Needs

1. Energy Efficiency and Sustainability: There is a growing demand for engineers who can design and implement HVAC&R systems that prioritize energy efficiency and sustainability. This includes developing innovative solutions to reduce energy consumption, optimize building performance, and integrate renewable energy sources into HVAC systems.
2. Technological Advancements: With rapid advancements in technology, engineers in the HVAC sector need to stay updated and skilled in the latest tools, software, and equipment. This includes expertise in automation, smart controls, data analytics, and the integration of Internet of Things (IoT) devices to enhance system performance, monitoring, and maintenance.
3. Indoor Air Quality and Health: There is an increasing emphasis on indoor air quality and health considerations in HVAC system design. Engineers are needed to ensure proper ventilation, filtration, and air purification to maintain healthy and comfortable indoor environments. This includes expertise in air quality testing, understanding and implementing relevant codes and standards, and designing systems that mitigate risks associated with pollutants and contaminants.
4. Retrofitting and Upgrading Existing Systems: Many buildings still rely on outdated HVAC systems that are energy-inefficient and require upgrades or retrofits. Engineers are needed to assess existing systems, identify areas for improvement, and propose cost-effective solutions for

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optimizing performance and energy efficiency. Retrofitting also involves integrating new technologies into existing infrastructure and ensuring compatibility and seamless operation.

5. Regulatory Compliance and Environmental Regulations: HVAC engineers need to stay informed and compliant with local and national regulations regarding energy efficiency, emissions, and environmental standards. This includes understanding and implementing guidelines such as sustainable protocols certification, building codes, and industry-specific regulations to ensure HVAC systems meet the required standards and contribute to sustainable practices.

Challenges

1. Energy Transition and Decarbonization: One of the key challenges for engineers in the HVAC sector is navigating the energy transition and supporting decarbonization goals by 2030 and 2050. This includes finding innovative ways to reduce greenhouse gas emissions from HVAC systems, transitioning to renewable energy sources, and designing energy-efficient solutions while maintaining optimal comfort levels.
2. Evolving Regulations and Standards: Engineers in the HVAC sector must constantly stay updated with evolving regulations and standards. Compliance with energy codes, environmental regulations, safety guidelines, and industry-specific standards poses a challenge as these requirements change over time. Keeping abreast of new regulations and adapting designs accordingly can be a complex task.
3. Technological Advancements and Complex Systems: HVAC systems are becoming increasingly complex due to technological advancements and integration with other building systems. Engineers need to stay updated on the latest technologies, such as advanced control systems, smart building automation, and energy management software. Navigating the integration of these technologies and ensuring interoperability can be challenging.
4. Skills Gap and Workforce Development: The HVAC sector requires skilled engineers who can design, install, operate, maintain and commissioning sophisticated HVAC systems. However, there is a growing concern about a skills gap and the need for workforce development in the industry. Addressing this challenge involves promoting STEM education, providing specialized training programs, and attracting young talent to the field.
5. Cost Constraints, Budget Limitations and incentives: Cost considerations often pose challenges for engineers in the HVAC sector. Balancing the need for energy-efficient and sustainable designs with budget limitations can be demanding. Engineers must find cost-effective solutions that provide long-term benefits while working within project constraints and client budgets.

Recommendations

Continuous Education and Skill Enhancement: Encourage engineers to pursue continuous education and stay updated with the latest advancements in HVAC technology, energy efficiency practices, and environmental regulations. This can be achieved through professional development courses, workshops, and certifications.

Embrace Sustainable Practices: Promote the integration of sustainable practices in HVAC design and operation, such as energy-efficient systems, renewable energy sources, and environmentally friendly refrigerants. Engineers should prioritize sustainability to align with the country's goals for reducing carbon emissions.

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Foster Collaboration and Interdisciplinary Approach: Encourage collaboration between engineers, architects, building professionals, and other stakeholders involved in the HVAC sector. Emphasize the importance of interdisciplinary teamwork to optimize system performance, energy efficiency, and indoor air quality.

Promote Research and Innovation: Encourage engineers to engage in research and innovation to drive advancements in HVAC technology. This can include exploring new materials, improving system controls, and developing cutting-edge solutions for energy optimization and indoor comfort.

Enhance Awareness of Indoor Air Quality: Educate engineers and stakeholders about the significance of indoor air quality and its impact on occupant health and comfort. Emphasize the importance of designing and maintaining HVAC systems that prioritize air filtration, ventilation, and pollutant control.

Advocate for Energy-Efficient Retrofits: Promote the retrofitting of existing HVAC systems to improve energy efficiency and reduce environmental impact. Encourage engineers to identify retrofit opportunities, develop cost-effective solutions, and advocate for the benefits of upgrading outdated systems.

Embrace Digitalization and Smart Technologies: Encourage engineers to leverage digitalization, automation, and smart technologies to optimize HVAC system performance, predictive maintenance, and energy management. Stay updated with emerging technologies and their potential applications in the HVAC sector. Moreover, associations in the HVAC sector play a crucial role in creating opportunities for networking and professional growth.

LATVIA

Needs

1. Excellent skills in BIM designing and use of appropriate software: Building Information Modeling (BIM) has become increasingly important in the construction and engineering industries. BIM allows engineers to create 3D models of buildings, including their HVAC systems, which helps in better design, coordination, and collaboration among different stakeholders. Proficiency in BIM software, such as Autodesk Revit, is highly valued in the industry, as it enables engineers to optimize HVAC system designs, improve energy efficiency, and reduce costs.
2. Knowledge of new HVAC technology based on renewable energy sources: As the world shifts towards sustainable practices, the HVAC sector is also embracing renewable energy sources. Engineers working in this field need to stay updated on the latest advancements in HVAC technology, particularly those related to renewable energy sources like solar, geothermal, and wind.

Challenges

1. New or improved skills in BIM design and appropriate investment in software and training: Building Information Modeling (BIM) is an advanced design and documentation process that

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integrates multiple aspects of building design and construction into a collaborative digital model. The HVAC engineers in Latvia need to acquire or enhance their skills in BIM design to effectively contribute to the overall building design process. This includes understanding how HVAC systems integrate with other building components and coordinating their design within the BIM environment. Furthermore, investments in software and training are crucial to enable engineers to work proficiently with BIM tools and stay updated with the latest industry standards.

2. Skills to design HVAC technologies based on renewable energy sources: As the demand for sustainable energy solutions grows, HVAC engineers in Latvia must possess the knowledge and skills to design heating, ventilation, and air conditioning systems that utilize renewable energy sources. This involves understanding the principles and operation of technologies such as geothermal heat pumps, solar thermal systems, biomass boilers, and heat recovery systems. Engineers should be capable of assessing the feasibility of incorporating renewable energy sources into HVAC designs and optimizing their performance for energy efficiency.
3. Skills to design sustainable buildings with energy efficiency solutions for various certification marks: Latvia, like many other countries, emphasizes sustainable building practices and encourages the use of energy-efficient solutions. HVAC engineers need to be familiar with certification programs such as BREEAM (Building Research Establishment Environmental Assessment Method) and LEED (Leadership in Energy and Environmental Design) and their requirements. They should possess the knowledge and expertise to design HVAC systems that contribute to achieving the necessary certification levels. This involves optimizing energy consumption, selecting environmentally friendly refrigerants, implementing advanced control strategies, and integrating smart building technologies.
4. Improved skills to cooperate with the design team and investors to achieve sustainability and energy efficiency goals: Collaboration and effective communication with other members of the design team, including architects, structural engineers, and electrical engineers, are vital for successful HVAC system design. HVAC engineers in Latvia must develop improved skills in interdisciplinary collaboration to ensure seamless integration of HVAC systems with other building elements. They need to work closely with investors, architects, and project managers to align sustainability and energy efficiency goals, considering factors such as budget constraints, occupant comfort, and long-term maintenance requirements.

Recommendations

Comprehensive System Analysis: Conduct a thorough analysis of the building's requirements and user needs to determine the appropriate HVAC system size and capacity. Avoid over-designing systems that may lead to unnecessary complexity and higher costs. A detailed analysis helps identify the optimal balance between functionality, energy efficiency, and cost-effectiveness.

Tailored Design Approach: Employ a tailored design approach that takes into account the specific requirements of each project. Rather than relying solely on standardized solutions, engineers should evaluate the building's unique characteristics, including orientation, occupancy patterns, and thermal loads. This allows for the design of HVAC systems that are precisely suited to the building's needs, avoiding unnecessary complexities or excessive automation.

Simplified Control Strategies: Opt for simplified control strategies that are intuitive and easy to operate for building occupants. While automation and advanced control systems have their benefits, it's

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important to strike a balance and not overload the building with complex automation features. Implement user-friendly control interfaces that provide basic control options while maintaining energy efficiency and comfort.

NETHERLANDS

Needs

1. Design of Nearly Zero Energy Building (NZEB) and Zero Energy Building (ZEB) Installations for Buildings:With the increasing emphasis on energy efficiency and sustainability, there is a need for HVAC engineers in the Netherlands to specialize in designing NZEB and ZEB installations. These buildings aim to minimize their energy consumption and rely on renewable energy sources to achieve net-zero or near-zero energy consumption. HVAC engineers need to have in-depth knowledge of energy-efficient technologies, such as heat pumps, energy recovery systems, advanced insulation, and ventilation strategies to design highly efficient HVAC systems that align with the overall energy goals of NZEB and ZEB buildings.
2. Installing Heat Pump (HP) Systems:Heat pumps are gaining popularity as an efficient heating and cooling solution that reduces reliance on fossil fuels. HVAC engineers in the Netherlands should have the expertise to design, install, and optimize heat pump systems. This includes understanding the different types of heat pumps, such as air-source, ground-source, and water-source heat pumps, and their compatibility with various building types. They should also be knowledgeable about refrigerant selection, system sizing, integration with other HVAC components, and the efficient operation of heat pump systems.
3. Integrating Smart Building Systems with the Grid: Smart building systems play a crucial role in optimizing energy consumption and demand response in buildings. HVAC engineers need to possess the skills to integrate HVAC systems with smart building technologies and grid management systems. This involves understanding protocols for data exchange, such as BACnet and Modbus, and utilizing advanced control strategies to manage HVAC systems based on real-time data, energy pricing, and grid demands. Integrating HVAC systems with the grid allows for better load balancing, energy efficiency, and participation in demand response programs.
4. Analytical Skills and Presentation Skills: HVAC engineers in the Netherlands should have strong analytical skills to assess building energy performance, conduct energy modeling, and perform life-cycle cost analyses. This includes proficiency in energy simulation software, such as EnergyPlus or TRNSYS, to evaluate the impact of HVAC system design choices on energy consumption and comfort. Additionally, presentation skills are important for effectively communicating complex technical concepts to stakeholders, including clients, architects, project managers, and regulatory bodies.
5. Up-to-Date Knowledge of Rules, Standards, and Laws: The HVAC industry is subject to various rules, standards, and regulations that govern energy efficiency, indoor air quality, and environmental considerations. Engineers need to stay up-to-date with the latest rules, standards, and laws, such as the Dutch Building Decree, energy performance certificates (EPC), and environmental requirements.

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Challenges

1. Limited Capacity of the Education System: The capacity of the education system in the Netherlands may be insufficient to meet the growing demand for skilled HVAC engineers. As a result, there may be a delay in delivering competent professionals to the industry. This challenge highlights the need for increased investment and resources in HVAC engineering education programs to ensure an adequate supply of skilled engineers.
2. Shortage of Training Facilities for Practical Installing Skills: Practical training facilities play a crucial role in developing hands-on skills for HVAC professionals. A shortage of such training facilities can hinder the ability of aspiring engineers to gain practical experience. To address this challenge, there is a need for more investment in training infrastructure and partnerships between educational institutions and industry players to provide comprehensive practical training opportunities.
3. Limited Understanding of Circular and Sustainable Practices: While the concept of circularity and sustainability is gaining traction, many individuals and companies in the HVAC sector may still lack knowledge and understanding of how to implement these practices effectively. This challenge requires greater awareness and education campaigns to promote circular and sustainable HVAC design, installation, and maintenance practices. The industry needs to invest in disseminating information and providing guidance to professionals on incorporating circular and sustainable principles in their work.
4. Inability to Change User Mindsets: HVAC professionals may face difficulties in changing the behavior and mindset of end-users. Despite advancements in technology and energy-efficient solutions, users may resist adopting new practices or may not fully understand the benefits. Overcoming this challenge requires broader public awareness campaigns to educate users about the necessary changes in behavior and the advantages of energy-efficient HVAC systems. Collaboration between industry associations, government bodies, and educational institutions can help drive these campaigns.
5. Lifelong Learning to keep up with changes: The HVAC sector is continuously evolving, with new technologies, regulations, and practices emerging. To stay up-to-date and maintain competence, HVAC professionals need to engage in lifelong learning. Continuous professional development programs, training courses, and industry collaborations can provide opportunities for engineers to acquire new skills, stay abreast of advancements, and adapt to changing industry needs.
6. Integration of AI in the HVAC Sector: The emergence of artificial intelligence (AI) presents both opportunities and challenges in the HVAC industry. While AI can enhance system performance, energy efficiency, and predictive maintenance, integrating AI into existing HVAC infrastructure requires specialized knowledge and expertise. The challenge lies in understanding how to effectively use AI algorithms, data analytics, and machine learning techniques in HVAC system design, operation, and optimization. Investment in research and development, collaboration between AI experts and HVAC engineers, and sharing of best practices can help overcome this challenge.

Recommendations

Collaboration with Psychologists and Influencers: To effectively change the mindset of customers, users, and governments, it is beneficial for HVAC professionals to collaborate with psychologists and influencers. Psychologists can provide valuable insights into human behavior, motivations, and decision-

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making processes, helping engineers understand how to effectively communicate the benefits of sustainable and circular HVAC practices. Influencers, on the other hand, have the ability to reach and influence a wide audience. Engaging with influencers who advocate for sustainability and circularity can help raise awareness and promote positive changes in behavior.

Education and Awareness Campaigns: To promote sustainable and circular practices in the HVAC sector, there is a need for extensive education and awareness campaigns. HVAC professionals, industry associations, and educational institutions should collaborate to develop and deliver comprehensive educational programs that highlight the importance of sustainability and circularity. These campaigns should target not only professionals but also end-users, government bodies, and policymakers. By increasing awareness and knowledge about sustainable HVAC practices, these campaigns can drive the adoption of eco-friendly solutions.

Emphasize Cooperative Approaches: Cooperation among HVAC professionals, companies, and stakeholders is crucial for driving sustainable change. By promoting cooperation over competition, professionals can share knowledge, best practices, and resources to collectively work towards a sustainable and circular future. Encouraging collaboration through partnerships, industry networks, and knowledge-sharing platforms can foster innovation, accelerate progress, and create a more supportive and unified industry.

Policy Advocacy and Government Engagement: HVAC professionals should actively engage with government bodies and policymakers to advocate for sustainable policies and regulations. By participating in industry associations and relevant committees, engineers can contribute their expertise to shape regulations that promote energy efficiency, sustainability, and circularity. Engaging in dialogues and providing technical insights to policymakers can help create an enabling environment for sustainable HVAC practices.

Continuous Professional Development: Lifelong learning is essential for HVAC professionals to stay updated with emerging technologies, regulations, and best practices. Engineers should actively seek out training opportunities, attend workshops, and participate in industry conferences to enhance their knowledge and skills. Continuous professional development programs should be promoted by industry associations and employers to support the growth and competence of HVAC professionals.

Embrace Technological Advancements: HVAC professionals should actively explore and embrace technological advancements, including AI, to optimize system performance and energy efficiency. Investing in research and development, collaborating with technology providers, and sharing experiences and case studies can help engineers understand how to effectively integrate AI and other emerging technologies into HVAC systems.

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NORWAY

Needs

1. Consultants: Expertise and Knowledge: Consultants in the HVAC sector need a deep understanding of HVAC systems, energy efficiency, sustainability, and regulatory requirements. They should stay updated with the latest technologies and best practices to provide effective consulting services to clients.
2. Energy Modeling and Analysis: Consultants need access to advanced energy modeling tools and software to perform accurate energy analysis, simulations, and optimization of HVAC systems. This enables them to provide energy-efficient and cost-effective solutions to clients.
3. Sustainable Design: With an increasing focus on sustainability, consultants need to incorporate sustainable design principles into their HVAC projects. This includes considerations such as renewable energy integration, energy recovery systems, and smart building technologies.
4. Contractor Companies: Skilled Workforce: Contractor companies require a skilled and knowledgeable workforce capable of installing, maintaining, and servicing HVAC systems. This includes expertise in system installation, electrical wiring, controls programming, and troubleshooting.
5. Safety Standards and Training: Contractor companies need to prioritize safety in HVAC installations and maintenance. Adequate training, certification, and adherence to safety standards are essential to ensure the well-being of workers and the public.
6. Collaboration with Consultants: Contractors should establish strong collaborative relationships with HVAC consultants to ensure accurate implementation of design plans and effective coordination throughout the project lifecycle.
7. Energy Companies: Renewable Energy Integration: Energy companies need to actively promote the integration of renewable energy sources, such as solar, wind, and geothermal, into HVAC systems. This involves providing incentives and support for renewable energy adoption in residential, commercial, and industrial buildings.
8. Demand Response Programs: Energy companies can play a crucial role in implementing demand response programs that optimize HVAC system usage based on electricity demand. By incentivizing load shifting and energy conservation, they can reduce peak energy demand and promote energy efficiency.
9. Smart Grid Integration: Energy companies should explore opportunities to integrate HVAC systems with smart grids. This enables real-time communication and coordination between energy suppliers and consumers, allowing for efficient energy management and load balancing.
10. Municipalities: Supportive Policies and Incentives: Municipalities should develop and implement supportive policies and incentives that encourage the adoption of energy-efficient HVAC systems. This can include building codes, tax incentives, grants, and subsidies to promote sustainable practices and technologies.
11. Collaboration with Industry: Municipalities can collaborate with HVAC professionals and industry associations to develop energy efficiency programs, conduct audits, and provide technical

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guidance to building owners and operators. This partnership ensures that HVAC systems in public and private buildings align with sustainability goals.

12. Facility Management: Data-driven Decision-making: Facility managers need access to real-time data on HVAC system performance, energy consumption, and maintenance requirements. This enables them to make informed decisions regarding system optimization, predictive maintenance, and energy conservation measures.
13. Proper Maintenance and Service: Facility managers should prioritize regular maintenance and service of HVAC systems to ensure optimal performance and energy efficiency. This includes scheduling inspections, filter replacements, and cleaning procedures as per manufacturer recommendations.
14. Occupant Comfort and Indoor Air Quality: Facility managers should focus on maintaining a comfortable and healthy indoor environment. This involves monitoring and managing temperature, humidity, ventilation, and air quality parameters to promote occupant well-being.

Challenges

1. Fragmented Goals of Different Industries: The HVAC sector interacts with various industries, including construction, energy, and facility management. However, these industries often have fragmented goals and priorities. For example, the construction industry may focus on cost reduction and short-term goals, while the energy industry emphasizes energy efficiency and long-term sustainability. This fragmentation can lead to conflicts and challenges in aligning objectives, making it difficult for HVAC engineers to design and implement holistic and optimal HVAC solutions.
2. Lack of Common Information: The absence of a centralized platform or database for sharing information and best practices in the HVAC sector can hinder progress. Access to reliable and up-to-date information, such as energy consumption data, system performance data, and case studies, is crucial for HVAC professionals to make informed decisions and implement energy-efficient solutions. The lack of a common information-sharing platform makes it challenging for engineers to access the necessary knowledge and learn from each other's experiences.
3. Low Acknowledgment for Technical Work: In the HVAC sector, there is often a lack of acknowledgment and recognition for good technical work, particularly for activities such as simulations, modeling, and advanced design analysis. These tasks require specialized skills and expertise, but their importance may be undervalued or overlooked. The limited recognition for such technical work can demotivate engineers and hinder the adoption of advanced technologies and practices that can significantly improve HVAC system performance and energy efficiency.
4. Limited Collaboration and Communication: Effective collaboration and communication among stakeholders in the HVAC sector, including engineers, architects, contractors, and facility managers, is crucial for successful project outcomes. However, challenges can arise due to siloed working environments, lack of interdisciplinary communication, and limited coordination between different professionals involved in a project. This can lead to misunderstandings, delays, and suboptimal HVAC system designs and installations.
5. Rapid Technological Advancements: The HVAC sector is experiencing rapid technological advancements, including the integration of smart technologies, IoT devices, and advanced controls. Keeping up with these advancements and understanding how to leverage them

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effectively can be challenging for HVAC engineers. Continuous professional development and investment in training programs are necessary to ensure engineers have the necessary skills and knowledge to design, install, and maintain technologically advanced HVAC systems.

Recommendations

Enhance Knowledge Sharing: Facilitate better sharing of knowledge and information within the HVAC sector. This can be achieved through the establishment of centralized platforms or databases where professionals can access and contribute to a wealth of industry-specific knowledge, best practices, case studies, and technical resources. Encouraging collaboration among engineers, architects, contractors, and facility managers will foster a culture of knowledge exchange and promote continuous learning.

Promote Open Access to Simulation Models and Practical Tools: Encourage the development and sharing of simulation models, practical tools, and software used in HVAC engineering. By making these resources accessible and reusable, engineers can leverage existing models and tools to improve their design processes, system analysis, and energy efficiency calculations. Establishing a platform for sharing such models and tools can significantly enhance the efficiency and effectiveness of HVAC engineering practices.

Collaborative Research and Development: Encourage collaborative research and development initiatives among academia, industry, and government bodies. By fostering partnerships, joint projects, and knowledge transfer programs, the engineering profession can benefit from cutting-edge research and innovative solutions. Collaborative efforts can focus on developing new simulation models, tools, and technologies that address specific challenges in the HVAC sector, enabling engineers to design more energy-efficient and sustainable systems.

POLAND

Needs

1. Condensed and Well-Written Guidelines (GBs): There is a need for condensed and well-written guidelines related to hot topics in the HVAC sector, such as Indoor Environmental Quality (IEQ) and decarbonization. These guidelines should provide clear and practical information on best practices, standards, and regulations pertaining to IEQ improvement and decarbonization strategies. The availability of such guidelines would help HVAC professionals navigate complex topics and ensure compliance with the latest industry standards.
2. Actual Description of Possible Actions for HVAC Professionals Related to EU Policy: With the European Union (EU) implementing policies and regulations that impact the HVAC sector, there is a need for an actual description of possible actions for HVAC professionals to align with these policies. Clear and concise information on how EU policies affect HVAC system design, installation, and operation can help professionals understand their roles and responsibilities in meeting the requirements. This includes information on energy efficiency standards, renewable energy integration, and carbon reduction targets.

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3. More Links to Valid Information about Innovations in HVAC Sectors: Access to valid information about innovations in the HVAC sector is crucial for professionals to stay updated with the latest technologies, trends, and research findings. There is a need for more curated and reliable sources of information, such as websites, databases, and research papers, that provide HVAC professionals with relevant and up-to-date knowledge about innovative HVAC solutions. These resources should cover advancements in energy efficiency, smart technologies, indoor air quality improvements, and sustainable HVAC practices.

Challenges

1. Adjustment to New EU Policy Regarding Decarbonization and Energy Efficiency: The EU's policies and regulations related to decarbonization and energy efficiency pose a significant challenge for the HVAC sector in Poland. Meeting the targets set by these policies requires a fundamental shift in the design, installation, and operation of HVAC systems. HVAC professionals need to adapt their practices to comply with stricter energy efficiency standards, incorporate renewable energy sources, and embrace low-carbon technologies.
2. Shift from Fossil Fuels: The transition away from fossil fuels in the HVAC sector is another significant challenge. Poland has traditionally relied on coal for heating and energy production, and shifting to alternative energy sources poses technical and economic challenges. HVAC professionals need to explore and implement renewable energy solutions, such as heat pumps, solar thermal systems, and biomass boilers, while ensuring the compatibility and efficiency of these systems with existing infrastructure.
3. Lack of Well-Educated Professionals: The shortage of well-educated professionals, including installers, presents a significant challenge for the HVAC sector in Poland. Adequate knowledge and skills are crucial for the successful implementation of energy-efficient and decarbonization measures. To address this challenge, there is a need to strengthen vocational education and training programs that focus on HVAC technologies, renewable energy integration, and energy-efficient practices. Collaboration between educational institutions, industry associations, and government bodies is essential to bridge this skills gap.
4. Use of Building Information Modeling (BIM) in Each Project: The adoption and integration of Building Information Modeling (BIM) in HVAC projects pose a challenge for the engineering profession. BIM enables a collaborative and data-driven approach to building design, construction, and operation. However, its implementation requires not only technological capabilities but also changes in workflows, collaboration practices, and information sharing. HVAC professionals need to acquire the necessary BIM skills and expertise to effectively leverage this technology and realize its benefits in their projects.

Recommendations

The main recommendation for the engineering profession in the HVAC sector in Poland, "thinking globally working locally," emphasizes the importance of adopting a global mindset while focusing on local actions. Here are the main recommendations based on this principle:

Embrace International Best Practices: HVAC professionals should stay informed about international best practices, standards, and regulations related to decarbonization, energy efficiency, and sustainable

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HVAC systems. By keeping up with global trends and benchmarks, professionals can gain valuable insights and apply relevant strategies in their local projects.

Tailor Solutions to Local Context: While global best practices are important, it is crucial to adapt and customize HVAC solutions to the specific needs and conditions of the local context in Poland. Factors such as climate, building types, infrastructure, and regulatory frameworks vary across regions. HVAC professionals should consider these local factors when designing and implementing systems, ensuring optimal performance and efficiency in local environments.

Collaborate with Local Stakeholders: Collaboration with local stakeholders, including government bodies, industry associations, contractors, architects, and facility managers, is essential for successful implementation of sustainable HVAC solutions. Engage in dialogues, partnerships, and knowledge-sharing initiatives to foster local collaboration and exchange expertise. Collaborative efforts can lead to the development of region-specific guidelines, codes, and practices that align with both global objectives and local requirements.

ROMANIA

Needs

1. Specialized Trainings on Specific Topics: There is a need for specialized training programs that focus on specific topics within the HVAC sector. These programs should cover areas such as energy efficiency, renewable energy integration, indoor air quality, advanced HVAC system design, and smart building technologies. Providing targeted and up-to-date training opportunities will enhance the knowledge and skills of HVAC professionals in Romania, enabling them to implement sustainable and efficient HVAC solutions effectively.
2. Increased Use of Digitalization Tools: The HVAC sector can benefit from the increased use of digitalization tools, such as Building Information Modeling (BIM), simulation software, data analytics, and automation technologies. These tools facilitate efficient design processes, performance analysis, energy modeling, and predictive maintenance. Encouraging the adoption and utilization of digitalization tools among HVAC professionals in Romania will improve project efficiency, accuracy, and overall system performance.
3. Mutual Recognition of Professional Qualifications: The mutual recognition of professional qualifications across different countries is important for HVAC professionals who may work on projects or seek job opportunities outside of Romania. Establishing mutual recognition agreements with other countries ensures that the qualifications, skills, and certifications obtained by HVAC professionals in Romania are recognized and respected internationally. This promotes professional mobility and facilitates cross-border collaboration in the HVAC sector.

Challenges

1. Lack of Specialists: The HVAC sector in Romania suffers from a shortage of skilled and specialized professionals. This shortage can be attributed to various factors, including limited availability of

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educational programs focused on HVAC engineering, lack of awareness about career opportunities in the field, and limited investment in workforce development. The scarcity of specialists poses a challenge in meeting the demand for HVAC expertise, leading to delays in project implementation and potentially compromising the quality of installations and system performance.

2. Lack of Integrated Design: The lack of integrated design approaches is a challenge in the HVAC sector in Romania. Integrated design involves collaboration among different disciplines, including architects, engineers, HVAC specialists, and other stakeholders, to optimize the design and performance of HVAC systems within the overall building design. Insufficient integration during the design phase can result in suboptimal system performance, increased energy consumption, and higher costs. Overcoming this challenge requires improved coordination and communication among professionals involved in the design process.
3. Lack of Continuous Training to Stay Up-to-Date: The HVAC industry is constantly evolving, with new technologies, regulations, and best practices emerging. However, the lack of continuous training opportunities hampers the ability of HVAC professionals in Romania to stay up-to-date with the latest advancements. Continuous training is essential for professionals to enhance their knowledge, acquire new skills, and adapt to changing industry standards and requirements. The absence of robust training programs limits the ability of professionals to implement energy-efficient and sustainable HVAC solutions effectively.

Recommendations

Collaborate with Universities: The HVAC industry should establish stronger collaborations with universities in Romania. This can be achieved through partnerships, joint research projects, and engagement with university faculty and students. By fostering closer ties with academia, the industry can benefit from the latest research, access to emerging talent, and opportunities for knowledge exchange.

Longer Internships or Scholarships: Provide longer internships (paid) or scholarships to students in the HVAC field. Instead of short-term internships, consider offering internships of no less than six months to allow students to gain in-depth industry experience. Longer internships provide students with an opportunity to apply their theoretical knowledge in real-world scenarios, develop practical skills, and gain exposure to industry practices. Similarly, scholarships can help students focus on their studies without the need for part-time work, enabling them to fully engage in their academic pursuits.

SLOVAKIA

Needs

1. Designing of HVAC Systems: There is a need for expertise in designing HVAC systems that are energy-efficient, reliable, and compliant with local regulations and standards. HVAC engineers should possess a deep understanding of system components, load calculations, equipment selection, duct design, and control strategies. Designing HVAC systems that meet the specific

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requirements of different building types and occupancy conditions is crucial for achieving optimal thermal comfort and energy performance.

2. Energy Audit Calculations: Energy audits play a significant role in identifying energy-saving opportunities and optimizing HVAC systems' performance. HVAC professionals need skills and knowledge in conducting energy audits, performing energy calculations, analyzing data, and recommending energy-efficient solutions. This includes assessing building envelopes, evaluating system efficiencies, identifying potential energy-saving measures, and estimating the return on investment for energy efficiency improvements.
3. Work with Relevant Software: Proficiency in working with relevant software tools is essential for HVAC professionals in Slovakia. This includes software for load calculations, energy modeling, system simulation, and energy audit calculations. Being skilled in using software tools specific to the HVAC industry enhances the accuracy and efficiency of system design, performance analysis, and energy optimization.
4. Building Information Modeling (BIM): Building Information Modeling (BIM) is an advanced digital tool that enables the collaborative design, construction, and operation of buildings. HVAC professionals should possess the necessary skills to work with BIM software and effectively integrate HVAC systems into the overall building model. Collaborating with architects, structural engineers, and other stakeholders within a BIM environment ensures the coordination and optimization of HVAC designs.

<u>Challenges</u>

1. Not Enough Young Graduates: One of the main challenges is the scarcity of young graduates entering the HVAC engineering profession in Slovakia. This can be attributed to various factors, such as a lack of awareness about the field, limited educational programs that focus on HVAC engineering, and a preference for other engineering disciplines. The shortage of young talent entering the profession can lead to a lack of fresh perspectives, innovation, and succession planning.
2. Not Enough Skilled Workforce: The availability of a skilled workforce is crucial for the successful implementation of HVAC projects. However, there is a challenge in finding professionals with the necessary skills, knowledge, and experience in the HVAC sector in Slovakia. This shortage of skilled workers can hamper project delivery, impact system performance, and limit the industry's ability to meet growing demand.
3. Not Enough Software Implementation in Some Aspects: The adoption and utilization of software tools for energy calculations, load analysis, and system design are crucial in the HVAC sector. However, there may be a challenge in the widespread implementation of such software tools in Slovakia. Limited awareness, training, and access to relevant software can hinder the efficiency and accuracy of energy calculations, system design, and performance analysis.
4. Strict Deadlines and Budget Constraints: Strict deadlines and budget constraints are common challenges faced by HVAC professionals in Slovakia. Balancing the need for timely project completion and adherence to budgetary constraints can put pressure on engineering professionals. In some cases, this can compromise the quality of HVAC system design, installation, and performance optimization, as insufficient time and resources may limit the thoroughness of engineering processes.
5.

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Recommendations

Promote Software Adoption and Training: Encourage the adoption and utilization of software tools in the HVAC sector in Slovakia. This can be achieved through awareness campaigns, workshops, and training programs that highlight the benefits and functionalities of various software tools used in energy calculations, load analysis, system design, and simulation. Collaborate with software providers to offer training resources and support for HVAC professionals.

Include Software Tools in Education Curricula: Collaborate with educational institutions to integrate software tools into the HVAC engineering curricula. Ensure that students receive hands-on training and practical experience in using relevant software tools throughout their educational journey. By incorporating software tools into the curricula, students will develop the necessary skills and familiarity with these tools, better preparing them for the industry.

SLOVENIA

Needs

1. Hourly Simulations of Buildings and Systems: There is a need for expertise in conducting hourly simulations of buildings and HVAC systems. Hourly simulations provide detailed insights into the thermal performance, energy consumption, and occupant comfort of buildings under different conditions. HVAC professionals in Slovenia should possess the knowledge and skills to perform accurate simulations using software tools, considering variables such as weather data, occupancy patterns, and equipment performance.
2. Competence in Life Cycle Assessment (LCA) and Life Cycle Cost (LCC) Analysis: There is a need for skills in conducting Life Cycle Assessment (LCA) and Life Cycle Cost (LCC) analyses for HVAC systems. LCA assesses the environmental impact of systems throughout their life cycle, while LCC evaluates the total costs associated with system operation, maintenance, and replacement over its lifespan. These analyses help investors make informed decisions regarding sustainable and cost-effective HVAC solutions.
3. Retro-Commissioning Practices: Retro-commissioning is the process of optimizing existing HVAC systems to improve energy efficiency, performance, and occupant comfort. There is a need for expertise in retro-commissioning practices in Slovenia. HVAC professionals should possess the knowledge and skills to assess and analyze the performance of existing systems, identify opportunities for improvement, and implement appropriate measures to enhance system efficiency and functionality.

Challenges

1. Ageing Workforce: One of the primary challenges is the ageing workforce in the HVAC sector. Many experienced professionals are approaching retirement age, leading to a potential loss of

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valuable knowledge and expertise. The shortage of skilled and knowledgeable professionals to fill these positions poses a challenge for the industry in Slovenia.

2. Limited Adoption of Digital Trends: The HVAC sector in Slovenia has been moderately present in adopting digital trends, such as Building Information Modeling (BIM). BIM offers numerous benefits, including improved collaboration, visualization, and efficiency in design, construction, and operation. The industry's slow adoption of digital technologies hampers the realization of these benefits and may lead to inefficiencies and missed opportunities for optimization.
3. Low Value/Prices and Poor Service: The HVAC sector in Slovenia faces a challenge related to the perception of low value or pricing, which can result in poor service quality. Clients may prioritize cost over quality, leading to subpar installations, inadequate maintenance, and inefficient system performance. This challenge can hinder the industry's ability to provide optimal solutions, meet energy efficiency targets, and deliver long-term value to clients.

Recommendations

Strict Quality Control and Actions Against Mistakes/Fraud: Implement robust quality control measures within the HVAC sector to ensure adherence to standards and regulations. Establish clear protocols for detecting and addressing mistakes, fraud, or any form of misconduct. This can involve regular inspections, audits, and monitoring of projects. Take appropriate actions, including disciplinary measures and legal procedures, when violations are detected, ensuring accountability and maintaining professional integrity.

Upskilling of Engineers: Invest in the upskilling and professional development of engineers in the HVAC sector. Provide comprehensive training programs, workshops, and seminars to enhance their technical knowledge, problem-solving skills, and understanding of emerging trends and technologies. The Chamber of Engineers can play a vital role in organizing and delivering these programs, ensuring that they address the specific needs and challenges of HVAC professionals.

Increase Pricing of Engineering Services: Advocate for a fair and realistic pricing structure for engineering services in the HVAC sector. Price engineering services at a level that reflects the value and expertise provided. This will attract a more qualified and skilled workforce to the industry, as well as encourage professionals to deliver high-quality services that meet clients' expectations and sustainability requirements. Communicate the long-term benefits of investing in quality engineering services to clients to justify higher pricing.

SPAIN

Needs

1. Training: There is a need for continuous training and professional development programs in the HVAC sector in Spain. The field of HVAC is constantly evolving, with new technologies, regulations, and best practices emerging. Ongoing training is essential to ensure that HVAC

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professionals stay up-to-date with the latest advancements, industry standards, and technical skills required to deliver high-quality services. Training programs should cover topics such as energy efficiency, renewable energy integration, building automation, and emerging HVAC technologies.

2. Legislative Stability: The HVAC sector in Spain requires legislative stability to provide a predictable business environment for professionals and companies. Frequent changes in regulations and policies can create uncertainty and hinder long-term planning and investment in the industry. Stable and consistent legislation helps create a favorable framework for the growth of the HVAC sector, enabling professionals to make informed decisions and implement sustainable solutions.
3. Good Practices: Encouraging and promoting good practices is crucial for the engineering profession in the HVAC sector in Spain. This includes implementing energy-efficient designs, adhering to industry standards, adopting proper installation and maintenance practices, and ensuring the highest level of service quality. Sharing best practices among professionals and companies within the HVAC sector helps improve overall industry performance, customer satisfaction, and sustainability.

<u>Challenges</u>

1. Decarbonization of Thermal Facilities: One of the main challenges is the decarbonization of thermal facilities in Spain. With the increasing focus on reducing greenhouse gas emissions, there is a growing need to transition from fossil fuel-based heating and cooling systems to low-carbon or renewable alternatives. This requires the engineering profession to develop and implement innovative solutions, such as heat pumps, solar thermal systems, and district heating networks, while ensuring optimal system performance, energy efficiency, and cost-effectiveness.
2. Development of the Renewable Gas Market: The development of the renewable gas market is another challenge for the HVAC sector in Spain. Renewable gases, such as biogas, biomethane, and hydrogen, have the potential to play a significant role in decarbonizing the heating and cooling sector. However, the infrastructure for producing, distributing, and utilizing renewable gases is still in its early stages. HVAC professionals need to navigate the technical, regulatory, and economic complexities of integrating renewable gases into HVAC systems, including gas boilers and combined heat and power (CHP) plants.
3. EU Harmonized Energy Certifications: Achieving EU harmonized energy certifications presents a challenge for the HVAC sector in Spain. The EU has established energy certification schemes, such as Energy Performance Certificates (EPCs), to assess and compare the energy performance of buildings. Ensuring the accurate and consistent application of these certifications requires coordination and alignment among stakeholders, including HVAC professionals, building owners, energy auditors, and regulatory authorities. Achieving harmonization across different regions and ensuring compliance with evolving EU regulations are ongoing challenges.

<u>Recommendations</u>

Continuous professional development, embracing digitalization, specialized training on decarbonization, energy efficiency and sustainability, soft skills development, and fostering collaboration and knowledge sharing will contribute to a highly skilled and competent workforce in the HVAC sector.

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SWITZERLAND

Needs

1. Addressing Limited Scope Perception: The HVAC engineering profession in Switzerland is perceived by students as having a limited scope. It is crucial to address this misconception and showcase the diverse and multidisciplinary nature of the HVAC field. Emphasize the wide range of opportunities and challenges that HVAC engineers encounter, including energy efficiency, renewable energy integration, indoor air quality, system design, and building automation. Promote the importance of HVAC engineering in creating sustainable and comfortable indoor environments.
2. Professional Courses for Continuous Formation: There is a strong need for more professional courses and continuous education programs tailored specifically to the HVAC sector in Switzerland. These courses should cover emerging technologies, energy efficiency standards, regulations, system design methodologies, and advancements in building automation. Collaborate with industry associations, educational institutions, and professional organizations to develop and deliver comprehensive and up-to-date training programs. These courses will help HVAC professionals stay current with the latest industry trends and enhance their skills throughout their careers.
3. Simplifying Complexity: The HVAC sector in Switzerland often deals with complex systems, technologies, and regulations. Simplifying this complexity is a key need for the engineering profession. Develop resources, guidelines, and best practice documents that break down complex concepts into understandable terms. Promote standardized approaches, methodologies, and tools that simplify design, installation, and maintenance processes. This will help professionals navigate the complexity more efficiently and ensure consistent quality in HVAC projects.
4. Enhancing Image and Perception: Improve the image and perception of the HVAC engineering profession in Switzerland. Showcase successful case studies, innovative projects, and the positive impact of HVAC engineering on energy efficiency, sustainability, and occupant comfort. Collaborate with educational institutions and career advisors to promote the diverse opportunities and benefits of pursuing a career in HVAC engineering. Emphasize the importance of HVAC professionals in creating environmentally friendly and healthy living and working spaces.
5. Collaboration with Other Building Project Partners: Strengthen collaboration with other partners involved in building projects, such as architects, contractors, electrical engineers, and facility managers. Enhance communication, coordination, and cooperation among different disciplines to ensure integrated and optimized building designs. Promote cross-disciplinary training and knowledge sharing to foster a holistic approach to building projects. Collaborative efforts will result in more efficient designs, reduced conflicts, improved project outcomes, and enhanced client satisfaction

Challenges

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1. Bad Image: One of the challenges is the perception of a bad image associated with the HVAC engineering profession. This negative perception may stem from a lack of awareness about the importance and complexity of HVAC systems and the contributions of HVAC engineers. Overcoming this challenge requires promoting the significance of HVAC engineering in creating sustainable, energy-efficient, and comfortable indoor environments. Highlighting successful projects and the positive impact of HVAC engineering can help improve the profession's image.
2. Reputation for Lower Wages and Stress: The HVAC engineering profession may be perceived to offer lower wages compared to other engineering fields. This perception, along with a reputation for high stress levels, can deter potential talent from pursuing a career in HVAC engineering. Addressing this challenge involves raising awareness about the rewarding aspects of the profession, such as opportunities for professional growth, job stability, and the positive impact on society. Highlighting the importance of work-life balance and stress management can also help attract and retain skilled professionals.
3. Lack of Labor: The HVAC sector in Switzerland faces a challenge in attracting and retaining a sufficient number of qualified professionals. The demand for HVAC engineers often exceeds the available workforce, leading to labor shortages. This can impact project timelines, quality, and overall industry growth. Strategies such as promoting the HVAC profession among students, offering competitive wages and benefits, and providing attractive career development opportunities can help address the labor shortage challenge.
4. Cost and Time Pressure: HVAC projects often face significant cost and time pressures, which can impact the engineering profession. Tight project budgets and compressed timelines may lead to compromises in design, installation, or maintenance, affecting system performance and energy efficiency. Overcoming this challenge requires effective project management, collaboration with stakeholders, and a focus on delivering high-quality solutions within the given constraints.
5. Lack of Quality in Cooperation: Collaboration among different stakeholders, including architects, contractors, and facility managers, is crucial for successful HVAC projects. However, the lack of quality in cooperation can hinder project outcomes and impact the reputation of the engineering profession. Establishing clear communication channels, fostering collaborative relationships, and promoting knowledge sharing among project partners can help overcome this challenge.

Recommendations

Foster a Culture of Innovation: Encourage HVAC professionals to think outside the box and foster a culture of innovation within the industry. Promote creativity, problem-solving, and the exploration of new ideas and approaches. Encourage professionals to stay updated with the latest advancements and trends in the HVAC sector, and provide opportunities for them to apply innovative solutions to real-world projects. Collaboration with research institutions and fostering partnerships with technology providers can help drive innovation in the HVAC sector.

Focus on Efficiency: Place a strong emphasis on energy efficiency in HVAC system design, installation, and operation. Provide training and resources that highlight the importance of energy-efficient solutions, including equipment selection, system optimization, and controls strategies. Educate professionals on the latest energy efficiency standards, regulations, and best practices to ensure that HVAC systems contribute to the overall sustainability goals of Switzerland.

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Foster Collaboration and Knowledge Sharing: Promote collaboration and knowledge sharing among HVAC professionals in Switzerland. Establish platforms for networking, information exchange, and collaboration, such as industry conferences, workshops, and online communities. Encourage professionals to share best practices, success stories, and lessons learned to foster a culture of continuous learning and improvement.

TURKEY

<u>Needs</u>

1. Better Implementations of Indoor Air Quality (IAQ): There is a need for improved implementations of indoor air quality measures in Turkey. HVAC professionals should focus on designing and implementing systems that provide optimal indoor air quality, considering factors such as ventilation rates, filtration, humidity control, and pollutant management. This includes adherence to international standards and guidelines for IAQ, as well as the incorporation of innovative technologies and strategies to ensure healthier indoor environments.
2. Testing, Adjusting, and Balancing (TAB) and Commissioning (Cx): The industry requires more emphasis on proper testing, adjusting, and balancing of HVAC systems, as well as commissioning processes. TAB ensures that HVAC systems operate as intended and perform efficiently, while commissioning ensures that systems are installed, function, and are maintained properly throughout their lifecycle. HVAC professionals need to acquire the necessary skills and knowledge in TAB and Cx to ensure optimal system performance, energy efficiency, and occupant comfort.
3. Energy Management: Energy management is a significant need in the HVAC sector in Turkey. HVAC professionals should focus on developing energy-efficient designs, implementing advanced control strategies, and promoting energy-saving measures in HVAC systems. This includes optimizing system operations, integrating renewable energy sources, utilizing energy recovery technologies, and implementing energy monitoring and management systems. Energy management practices can help reduce energy consumption, lower operational costs, and contribute to sustainability goals.
4. Acoustics: The need for expertise in acoustics is important in the HVAC sector in Turkey. HVAC professionals should consider acoustics in system design to ensure acceptable noise levels and provide acoustic comfort in various spaces. This includes proper selection of equipment, ductwork design, noise control measures, and compliance with noise regulations and standards. Addressing acoustical challenges will contribute to creating comfortable and noise-controlled indoor environments.
5. Passive Fire Protection: There is a need for improved passive fire protection measures in HVAC system design and installation. HVAC professionals should incorporate fire protection strategies to prevent the spread of fire and smoke through ductwork, equipment rooms, and building penetrations. This involves proper fire-rated ductwork, fire dampers, smoke control systems, and compliance with fire safety codes and regulations. Implementing passive fire protection measures ensures occupant safety and protects property from fire hazards.

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6. Renewable Integration: The integration of renewable energy sources in HVAC systems is crucial in Turkey. HVAC professionals should be knowledgeable about renewable energy technologies, such as solar thermal, geothermal, and biomass, and their integration into heating, cooling, and ventilation systems. This includes proper sizing, integration strategies, and optimization of renewable energy systems to maximize energy efficiency and reduce reliance on fossil fuels.

Challenges

1. Less Interest of Young Engineers and Lack of Resources: There is a noticeable decrease in the interest of young engineers to pursue a career in the HVAC sector in Turkey. This leads to a lack of resources and a shortage of skilled labor in the industry. To address this challenge, it is important to promote the HVAC profession among students, raise awareness about the opportunities and rewards it offers, and enhance vocational training programs to attract and retain young talent. Encouraging internships, mentoring programs, and partnerships between industry and educational institutions can help bridge the gap and create a sustainable workforce.
2. Missing Strongly Enforced Regulations and Unfair Competition: The absence of strongly enforced regulations in the HVAC sector allows for unfair competition in various dimensions. This includes inadequate licensing requirements, insufficient monitoring of industry practices, and inconsistent enforcement of quality standards. To overcome this challenge, it is crucial to advocate for stricter regulations, improved industry oversight, and enforcement mechanisms. Collaborating with industry associations, professional organizations, and regulatory bodies can help establish fair competition practices and ensure compliance with quality and safety standards.
3. Lack of Passion and Responsibility for a Better Future: There is a prevailing lack of passion and responsibility among some engineers in the HVAC sector to contribute to building a better future. This can lead to shortcut applications, subpar workmanship, and a lack of holistic approaches in project design and implementation. It is essential to promote a culture of professionalism, ethical responsibility, and long-term thinking among HVAC professionals. Encouraging sustainability principles, emphasizing the importance of energy efficiency and environmental protection, and fostering a sense of pride in delivering high-quality work can help address this challenge.
4. Preparedness for Adaptation to Digitalization and Climate Change: The HVAC sector is experiencing significant changes due to digitalization and the challenges posed by climate change. The rapid integration of digital technologies, such as building information modeling (BIM), energy management systems, and smart controls, requires engineers to be prepared and equipped with the necessary skills. Additionally, the HVAC sector needs to adapt to the changing climate conditions, including increasing heatwaves, extreme weather events, and rising energy efficiency requirements. Providing comprehensive training programs, promoting continuing education, and fostering collaboration between industry and academia can help HVAC professionals adapt to these changes and stay ahead of the curve.

Recommendations

Restructure the Engineering Profession: To meet the new needs of the HVAC sector, it is crucial to restructure the engineering profession. This can be achieved by reviewing and updating regulations, licensing requirements, and professional standards to align with the evolving industry demands.

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Collaboration between industry stakeholders, professional organizations, and regulatory bodies is essential in defining the competencies, qualifications, and responsibilities of HVAC engineers. Restructuring the profession will ensure that engineers have the necessary skills and knowledge to address the current and future challenges of the HVAC sector.

Develop Comprehensive Trainings: Developing comprehensive trainings is vital to equip HVAC engineers with a common sense and holistic background. These trainings should cover technical knowledge, practical skills, and a broader understanding of the HVAC industry, including energy efficiency, sustainability, indoor air quality, and emerging technologies. Collaboration with industry associations, educational institutions, and international experts can help design and deliver effective training programs that meet global standards and foster a culture of continuous learning and improvement.

Regulate Efforts for the New Generation: Efforts to nurture a new generation of HVAC engineers should be regulated and protected within society. This involves creating a supportive environment that encourages young engineers to pursue careers in the HVAC sector. Establish mentoring programs, internships, and apprenticeships to provide practical experience and guidance. Collaborate with educational institutions to incorporate industry-relevant curriculum and practical training opportunities. Protecting the interests of the new generation of engineers ensures their professional growth and shields them against unfair competition.

Promote Ethical Practices and Professionalism: Emphasize ethical practices and professionalism among HVAC engineers. Foster a culture of integrity, responsibility, and accountability in the profession. Develop codes of ethics and professional conduct to guide engineers in their work. Encourage continuous professional development and participation in industry associations to stay updated on industry advancements and best practices. By promoting ethical behavior and professionalism, the engineering profession can build trust, enhance its reputation, and contribute to the betterment of the HVAC sector in Turkey.

Collaboration and Knowledge Sharing: Foster collaboration and knowledge sharing among HVAC professionals, industry associations, and academia. Establish platforms for networking, information exchange, and collaboration, such as conferences, workshops, and online communities. Encourage participation in research projects, industry forums, and international conferences to facilitate the sharing of ideas, experiences, and best practices. Collaboration and knowledge sharing will drive innovation, foster industry growth, and enhance the overall professionalism of the engineering profession in the HVAC sector.

UNITED KINGDOM

<u>Needs</u>

1. Skilled Workforce: There is a growing demand for skilled HVAC engineers and technicians who possess the knowledge and expertise to design, install, commission, and operate low carbon HVAC systems. This includes proficiency in energy-efficient technologies, renewable energy

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integration, smart controls, and building automation systems. To meet this need, it is essential to promote HVAC engineering as an attractive career choice and provide comprehensive education and training programs that equip professionals with the necessary skills.

2. Knowledge of Low Carbon HVAC Systems: With the increasing focus on sustainability and the transition to low carbon solutions, HVAC professionals in the UK need to be well-versed in designing, installing, and operating low carbon HVAC systems. This includes understanding energy-efficient HVAC technologies, such as heat pumps, district heating, and cooling systems, energy recovery ventilation, and advanced controls. Providing training and continuing professional development opportunities specific to low carbon HVAC systems is crucial to meet this need.
3. Awareness of Regulations and Standards: HVAC professionals need to be well-informed about the relevant regulations and standards governing the design, installation, and operation of HVAC systems in the UK. This includes energy performance standards, building codes, safety regulations, and environmental requirements. Continuous education and training programs should cover these regulations and standards to ensure compliance and high-quality HVAC system implementations.

<u>Challenges</u>

1. Interoperability and Integration: One of the challenges is achieving seamless integration of HVAC systems with other building safety and efficiency systems. Buildings are becoming increasingly complex, with various interconnected systems, such as fire safety, security, and energy management. Ensuring that HVAC systems can effectively integrate and interact with these systems requires coordination among different disciplines, standardized communication protocols, and interoperable technologies. The challenge lies in designing and implementing HVAC systems that can seamlessly interact with other building systems to enhance overall safety and efficiency.
2. Complexity of Building Regulations: Building regulations in the UK are constantly evolving to address safety, energy efficiency, and environmental concerns. Keeping up with the complex and changing regulations poses a challenge for HVAC professionals. Compliance with multiple regulations, codes, and standards can be demanding and time-consuming. HVAC professionals need to stay updated with the latest requirements and ensure that their designs and installations meet the prescribed standards. This challenge requires continuous education, training, and access to up-to-date information on building regulations.
3. Performance Verification and Testing: HVAC systems play a crucial role in ensuring building safety, occupant comfort, and energy efficiency. However, verifying and testing the performance of these systems can be challenging. It requires specialized equipment, expertise, and a comprehensive understanding of system operation. HVAC professionals need to conduct thorough commissioning and testing procedures to ensure that the systems are installed and operating correctly. This challenge lies in having access to the necessary resources and expertise to conduct performance verification and testing effectively.

<u>Recommendations</u>

Client Education and Awareness: The engineering profession should focus on educating clients about the critical performance of HVAC systems in low carbon buildings. This involves raising awareness about

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the impact of HVAC systems on energy efficiency, indoor air quality, occupant comfort, and overall building performance. Engage with clients through workshops, seminars, and educational materials to explain the importance of well-designed and properly maintained HVAC systems in achieving low carbon goals. This will help clients make informed decisions and prioritize the performance of HVAC systems in their building projects.

Performance Metrics and Reporting: Develop standardized performance metrics and reporting mechanisms that highlight the critical aspects of HVAC systems in low carbon buildings. Clearly communicate the energy efficiency ratings, indoor air quality parameters, and occupant comfort metrics to clients. Provide easy-to-understand reports that demonstrate how HVAC systems contribute to achieving sustainability targets and maintaining a healthy indoor environment. This will enable clients to evaluate and compare the performance of different HVAC systems and make informed choices.

5. HVAC engineering profession’s conclusions and recommendations

When envisioning the evolution of the HVAC engineering profession, it's crucial to consider emerging trends, advancements in technology, and the need for sustainability and energy efficiency. Based on the profession’s needs, opportunities, and challenges identified by our Members the following consolidated recommendations for the future of HVAC engineering are worth keeping salient:

- **Embrace Smart and Connected Systems**: HVAC systems are becoming increasingly interconnected and intelligent. Engineers should familiarize themselves with smart technologies, such as IoT (Internet of Things) devices, sensors, and data analytics. These systems can optimize energy usage, enable remote monitoring and control, and provide valuable insights for maintenance and performance improvements.
- **Focus on Energy Efficiency**: energy efficiency is a critical aspect of HVAC engineering. Engineers should stay updated on the latest energy-efficient technologies, such as high-efficiency heat pumps and advanced control strategies. Designing HVAC systems with a strong emphasis on energy efficiency will help reduce operational costs and environmental impact.
- **Incorporate Renewable Energy Sources**: with the growing emphasis on sustainability, HVAC engineers should consider integrating renewable energy sources into system designs. This can involve incorporating solar thermal systems, heat pumps, or integrating HVAC systems with building-level renewable energy systems. Understanding the interaction between renewable energy technologies and HVAC systems will be crucial.
- **Emphasize Indoor Air Quality (IAQ)**: indoor air quality has gained significant attention due to its impact on occupant health and well-being. HVAC engineers should prioritize IAQ considerations by designing systems that enhance ventilation, filtration, humidity control, and pollutant monitoring. Familiarity with advanced filtration technologies and air purification systems will be essential.
- **Stay Updated on Building Codes and Standards**: building codes and standards play a crucial role in shaping the HVAC industry. It is important for HVAC engineers to stay updated on the latest codes and standards related to energy efficiency, ventilation rates, refrigerant usage, and environmental regulations. Adhering to these codes ensures compliance and helps engineers design systems that meet the required standards.
- **Develop Skills in Building Information Modeling (BIM)**: building Information Modeling is a collaborative approach that integrates 3D modeling and data management for building design

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and construction. HVAC engineers should acquire skills in BIM software and methodologies to improve collaboration with architects, structural engineers, and contractors. BIM facilitates accurate design, clash detection, and efficient coordination among various disciplines.

- **Enhance Communication and Collaboration**: HVAC engineers should strengthen communication skills and foster collaboration with other professionals involved in the building design and construction process. Effective communication with architects, mechanical engineers, electrical engineers, contractors, and facility managers is crucial for successful project execution and optimal HVAC system integration.
- **Invest in Continuous Learning**: the HVAC industry is evolving rapidly, with advancements in technology and new research findings. HVAC engineers should actively engage in continuous learning, attending conferences, workshops, and training programs to stay updated on the latest trends, best practices, and technological advancements. Engaging in professional societies and networking with peers can also facilitate knowledge sharing.

By embracing emerging technologies, prioritizing energy efficiency and sustainability, and adapting to changing industry requirements, HVAC engineers can contribute to creating healthier, more efficient, and environmentally friendly buildings.

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  - HP4ALL https://cordis.europa.eu/project/id/891775/results
  - NEWCOM https://cordis.europa.eu/project/id/754148/results
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These sources provide a comprehensive foundation for understanding the skills HVAC engineers need to develop in response to the new EPBD revision. They cover theoretical knowledge, practical applications, standards, and the latest research and developments in the field.

ANNEX II - RESEARCH UPDATE 2024: ENERGY PERFORMANCE OF BUILDINGS DIRECTIVE (EPBD)

The new revision of the Energy Performance of Buildings Directive (EPBD) can significantly impact the HVAC engineering profession in several ways:

- Increased Demand for Energy-Efficient Solutions: the EPBD aims to improve the energy efficiency of buildings, thus creating a demand for HVAC systems that are more energy-efficient. Engineers will need to design and implement solutions that reduce energy consumption and emissions.

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- Implementation of Smart Technologies:the directive promotes the integration of smart technologies in buildings to monitor and control energy usage. HVAC engineers will need to incorporate advanced control systems, IoT devices, and data analytics to optimize the performance of HVAC systems.
- Retrofitting Existing Buildings:there will be a significant focus on retrofitting existing buildings to meet new energy efficiency standards. HVAC engineers will play a crucial role in upgrading and optimizing older systems to comply with these standards.
- Renewable Energy Integration:the EPBD encourages the use of renewable energy sources. HVAC engineers will need to design systems that integrate renewable energy technologies such as solar thermal, geothermal, and heat pumps.
- Enhanced Professional Skills and Knowledge:the revisions may necessitate additional training and certification for HVAC professionals to stay updated with new technologies, regulations, and best practices in energy efficiency and sustainability.
- Focus on Indoor Environmental Quality (IEQ):there is an increasing emphasis on maintaining high indoor environmental quality. HVAC engineers will need to balance energy efficiency with maintaining optimal indoor air quality, temperature, and humidity levels.
- Compliance and Documentation:HVAC engineers will be responsible for ensuring that their designs and installations comply with the new EPBD standards. This includes providing detailed documentation and performance reports to demonstrate compliance.
- Lifecycle Assessment and Cost-Effectiveness: the directive may emphasize the importance of lifecycle assessment and cost-effectiveness of HVAC systems. Engineers will need to consider the long-term impacts and benefits of their designs, focusing on sustainability and total cost of ownership.
- Innovation and R&D:the push for higher energy performance standards will drive innovation in HVAC technologies. Engineers will need to stay engaged with ongoing research and development to implement cutting-edge solutions.

Overall, the new EPBD revision will drive the HVAC engineering profession towards greater sustainability, efficiency, and the adoption of innovative technologies. HVAC engineers will need to adapt to these changes through continuous learning and by embracing new design and operational strategies. In light of the new EPBD revision, HVAC engineers will need to enhance a variety of skills to meet the directive's goals and requirements.

Key skills that will need improvement include:

Energy Efficiency and Sustainability Expertise

Understanding Energy Performance Metrics:

Knowledge of energy performance standards and how to measure and improve them.

Sustainable Design Principles:

Incorporating sustainable practices into HVAC system design and operation.

Knowledge of Smart Technologies and Automation

IoT Integration:

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Implementing and managing Internet of Things (IoT) devices for building automation systems.

Advanced Control Systems:

Designing and utilizing sophisticated control systems to optimize HVAC operations.

Renewable Energy Systems

Integration of Renewables: Designing HVAC systems that effectively incorporate renewable energy sources like solar thermal, geothermal, and heat pumps.

Energy Storage Solutions: Understanding and implementing energy storage technologies to balance supply and demand.

Retrofitting and Upgrading Existing Systems

Retrofitting Techniques:

Skills in upgrading existing HVAC systems to improve energy efficiency.

System Assessment: Evaluating current systems and identifying areas for improvement.

Indoor Environmental Quality (IEQ) Management:

Air Quality Control:

Ensuring optimal indoor air quality while maintaining energy efficiency.

Thermal Comfort:

Designing systems that maintain comfortable indoor temperatures and humidity levels.

Data Analysis and Performance Monitoring

Data Analytics:

Analyzing building performance data to optimize HVAC system operation.

Predictive Maintenance: Using data and analytics to predict and prevent system failures.

Compliance and Documentation

Regulatory Knowledge:

Staying updated with EPBD requirements and ensuring all designs and installations comply.

Documentation Skills:

Providing thorough documentation and performance reports to demonstrate compliance.

Lifecycle Cost Analysis and Management

Cost-Benefit Analysis:

Evaluating the long-term costs and benefits of different HVAC solutions.

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Lifecycle Assessment:

Considering the environmental and economic impacts of HVAC systems over their entire lifecycle.

Project Management and Collaboration

Interdisciplinary Collaboration:

Working effectively with architects, builders, and other engineers to integrate HVAC systems into building designs.

Project Management:

Managing projects to ensure they meet energy performance goals, stay on budget, and are completed on time.

Innovation and Continuous Learning

Staying Updated:

Keeping up with the latest advancements in HVAC technologies and energy efficiency practices.

Research and Development:

Engaging in R&D to develop and implement new, innovative solutions.

By improving these skills, HVAC engineers will be better equipped to meet the challenges and opportunities presented by the new EPBD revision, leading to more energy-efficient, sustainable, and high-performing building environments.

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12. TU Dublin

1. Introduction

Following on from the first TU Dublin ‘snapshot’, which offered more generalized considerations and examples of what competence emphases are evident in Ireland, and exemplars of where/how they are being explored. Moreover, the report considered the literature and in particular, what exemplars are influential in an Irish context.

The emphasis in this snapshot is to explore the four specific competences within the proposed E4E curriculum and where and how they are being explored specifically. This snapshot will offer an Irish impetus for the evolving micro-credentials being developed in work package 3.Furthermore, a reflection on the second primary research (survey) will also be considered asa barometer for where the Irish HEI curricula re focusing.

As a general backdrop to both the snapshot, and indeed, the E4E project itself, the CESAR White Paper[1], *Engineer of the Future*, considers engineering education at universities of science and technology in Europe and how they are contributing to address global challenges.It highlights how topical the E4E project is, and how beneficial it’s outputs will be in leveraginga synergistic implementation across the 4 E4E curriculum competences. The CESAR white paper considers the evolution of engineering education and examines how it equips engineersof the future to contribute to a world in constant evolution. The White paper, in chapter 2, underlines the great impact that the green and digital transitions have on engineeringeducation and the need for engineering students to grasp the key opportunities emerging with the twin transitions. In chapter 3, the importance of interdisciplinarity, within institutions, through interfaculty collaboration, and innovative teaching approaches such as problem-based learning (PBL) and challenge-based learning (CBL) are considered. Such environments are conducive to prioritizing skills for solving real-world complex problems, entrepreneurial competencies, social awareness, and improving interdisciplinary collaboration as a norm.

2. E4E competence priorities

The E4E curriculum is articulated in four key areas through operationalization of relevant EU frameworks, namely LifeComp, GreenComp, DigComp and EntreComp. The following sections highlight how the different E4E curricula priorities are catered to in an Irish context.

2.1. DigComp

In considering ongoing digital curricula, strategic intent and research activities in an Irish context, a priority on information and data literacy, communications, digital content creation, and underpinning skills in terms of problem solving is emphasised.

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[1] CESAR White Paper Engineer of the Future (Engineering Education at Universities of Science & Technology in Europe to Tackle Global Challenges (2024) https://doi.org/10.5281/zenodo.10972834

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2.1.1. Irish exemplars realising DigComp in HEI

In a general context, this competence is well catered for. Resources are available in many HEIsto facilitate under/post-graduate engagement. For instance, the University of Limerick facilitates online resources that afford in-depth appreciation of the intention behind DigComp[2]. Whereas in the University of Galway, a specific module offering (SC3303) offers learning about the Digitalisation of the Future (basic concepts & terminology) and resource- specific content (step-by-step videos) to develop new digital skills for work and for everyday living, in line with the five Competence Areas of the EC's Digital Competence Framework for Citizens, DigComp. 2.2 (2022)[3]. The Digital Skills Hub[4] (or digi-skills.ie) is a digital resources website aimed at students and staff of Irish third-level institutions, created and curated in 2022 by the Dublin City University Teaching Enhancement Unit (TEU) as part of the Irish Universities Association's Enhancing Digital Teaching and Learning (EDTL) project. This hub has compiled a variety of free apps, websites, blog posts, documents, guides, courses, articles,and other resources that aim to aid university students and staff in enhancing and improvingtheir digital and online learning and teaching experience. The resources on the hub have been divided into five categories based on the European Digital Competencies Framework: "information and data literacy", "communication and collaboration", "digital content creation", "safety", and "problem-solving". Use the tags page to begin searching the hub, and check out the contacts page if you want to get in touch with the hub's creators.

The European Commission has monitored Member States' progress on digital and published annual Digital Economy and Society Index (DESI) reports since 2014. Each year, the reports include country profiles helping Member States identify areas for priority action and thematicchapters providing an EU-level analysis in the key digital policy areas. The most recent report(2022)[5] indicates Ireland's position in Europe across several indicators, stressing how important the digital economy is to Ireland.

Figure 1 illustrates the progress of Member States as regards the overall level of digitalizationof their economy and society over the 5 years 2017-2022. For each country, the figure showsthe relation between its DESI 2017 scores (horizontal axis) and the DESI average yearly growthin the period 2017-2022 (vertical axis). DESI scores clearly show an overall convergence pattern in the EU between 2017 and 2022. The blue line in the figure is the estimated patternof convergence. Countries that are located above the blue line grew more than expected by the convergence curve and are therefore 'overperforming'. Ireland is in the top 5 in that regard.

2 University of Limerick (https://www.ul.ie/ctl/what-digcomp)

3 University of Galway: https://www.universityofgalway.ie/courses/micro-credentials/micro-credentialslisting/digitalcompetences/

4 https://digi-skills.ie/category/digcomp-all-areas/

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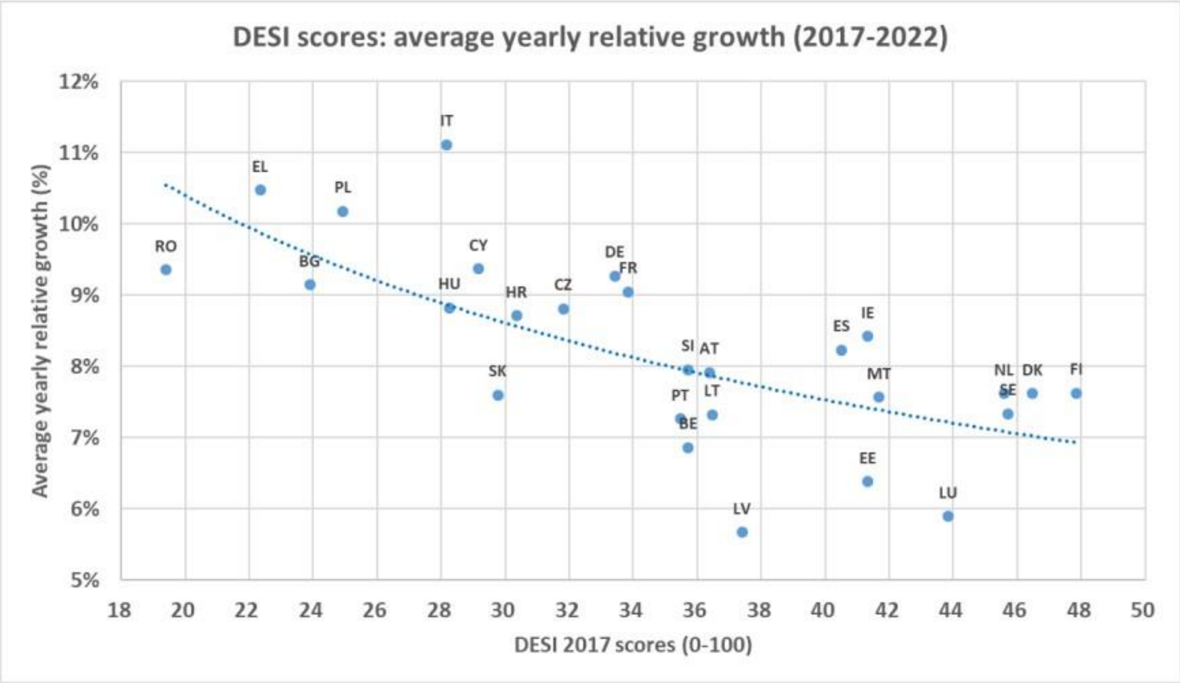
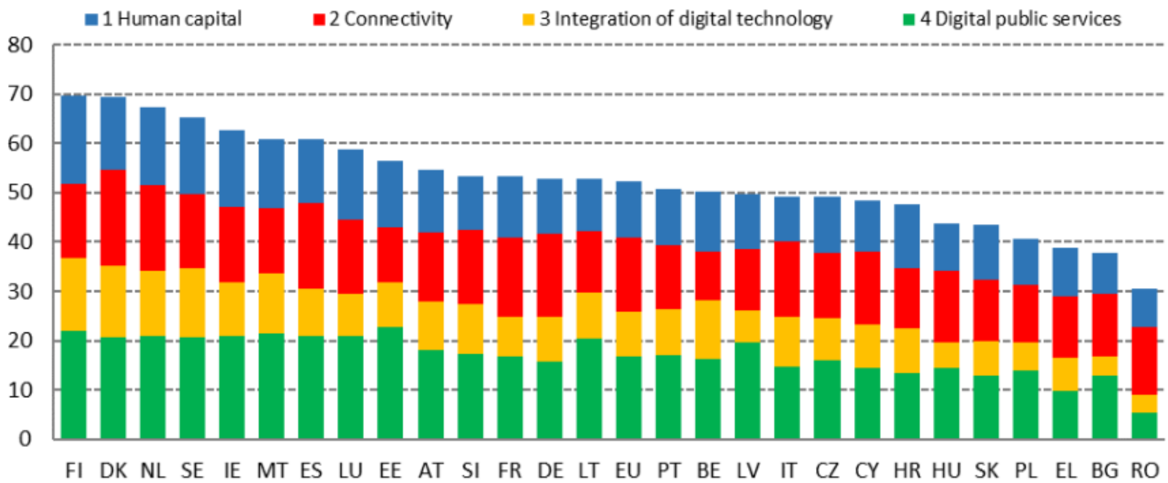


Source: DESI 2022, European Commission

Figure 1: Digital Economy and Society Index – Member States' relative progress in the period 2017-2022[5]

Figure 2 below, shows the 2022 DESI ranking of Member States. As illustrated, across the metrics of human capital (emphasizing how important digital skills are as they underpin howwe interact and how modern work is conducted), connectivity, integration of digital technology, and digital public services, Ireland is ranked 5th.



Source: DESI 2022, European Commission

Figure 2: Digital Economy and Society Index, 2022[5]

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Looking closer to the human capital concern, the report[5] highlights that Ireland has the thirdmost internet user skill, it ranks third in terms of digital skill and ranks 6th in terms of basicdigital content creation skills. While these indicators present a favourable picture of Ireland,the report[5] highlights that digital adoption and advanced digital skills needed to embrace thetransformation are critical to more secure, in-demand tech careers. Digital skills are alsoessential to the survival and growth of businesses. As routine tasks are becoming increasinglyautomated, there is a risk of job loss for workers performing mainly such tasks. Therefore, a growing number of workers will need to gain new skills to work in tandem with (digital)technologies. The Council of European Professional Informatics Societies (CEEPIS), in its survey among its network about the awareness of the European Digital Competence Framework for Citizens (DigComp) framework[6], aimed to find out how aware the CEPIS community is about the use of the DigComp framework in their countries. The questions were about the use of the framework by the national governments, educationsector and industry. CEPIS members were also asked to name the key benefits and challengesthat they saw in applying DigComp. CEPIS members are mostly aware of the government's use of DigComp (77% of responding countries), with 50% of the surveyed countries reportinguse of DigComp in the education sector, and 45% in industry. In an Irish perspective, it was primarily used in developing the Adult Literacy, Numeracy and Digital Literacy (ALND) strategy by SOLAS, the Further Education and Training Authority of Ireland.

To realise the societal benefits of DigComp, those that are expected to facilitate the associated competences need to be trained accordingly. Irish Universities are addressing theDigComp framework practically. The *Enhancing Digital Teaching and Learning in Irish Universities project* is led by Trinity College, Dublin, and funded through the HEA's Innovationand Transformation Programme. By employing the DigCompEdu (Digital Competence Framework for Educators)[7], the Irish Universities Association (IUA), and the Enhancing DigitalTeaching and Learning in Irish Universities project (EDTL), aims to enhance the digital attributes and educational experiences of Irish university students. The project is enabling theuse of digital technologies across the teaching and learning process. The project aims to mainstream digital in teaching and learning activities in Irish Universities, by addressing the professional development of all who teach or support teaching and learning.

2.2. GreenComp

2.2.1. Irish exemplars realising GreenComp in HEI

Skills for Sustainability - The International Labor Organization (ILO) has estimated that the shift towards energy sustainability by 2030 will result in the creation of nearly 25 million jobsand the loss of about 7 million globally. Of the jobs lost, 5 million could be recovered throughlabour reallocation. This forecast is supported by an annual 8% increase in green job listings onLinkedIn over the five years leading up to 2022. However, the global pool of green talent hasonly expanded by 6% each year. Consequently, at the current international pace, there won'tbe enough human capital to achieve climate goals.

5 https://digital-strategy.ec.europa.eu/en/library/digital-economy-and-society-index-desi-2022

6 Awareness of the DigComp framework among the CEPIS community: https://cepis.org/digcomp-report-2021/

7 https://joint-research-centre.ec.europa.eu/digcompedu_en

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Although more workers are moving into green jobs than leaving them, the overall number transitioning is still quite low. Employers are actively seeking these emerging skills. In February 2023, the World Economic Forum reported a tenfold surge in the number of job postings with "sustainability" in the title over the past decade, totaling 177,000 in 2021. The Irish Government aims to halve greenhouse gas emissions by 2030 and achieve net zero by 2050. As outlined in section 7 of the National Climate Plan 2023[8], Higher and Further Education will fully cater to the demand for a wide array of low carbon skills across the economy. The Plan also highlights the need for continuoushorizon scanning to pinpoint job opportunities arising from the green transition, aligning them with existing training programs, and identifying areas where new educational courses are necessary. In a recent Irish Skills report [9] identifying skills and knowledge needs for the transition to a low carbon economy to inform training and programme development. A range of common sustainability skills needs appear related to GreenComp.
These include:

An Introductory to Sustainability: Many reports highlight that the majority of Irish businessesare either yet to develop the required skills for sustainability, or at best, only have basic competencies. Recommendations are given for awareness raising and developing training, webinars and programmes on how SMEs could reduce carbon emissions, what this will meanfor their organisations and how they could begin to plan for it. As well highlighting key concepts related to sustainability, assisting and enabling businesses, especially SMEs indeveloping sustainability plans and implementation of activity within their organisations.

Corporate sustainability strategy skills: The reports highlight that many organisations, including many larger organisations, have still to develop a sustainability strategy and setting KPIs for ESGs. Most do not have someone tasked with identifying environmental sustainabilitypriorities and implementing measures and reporting, indicating a potential demand forupskilling in this area. Although this would appear to the case for smaller enterprises there are indications that larger organisations may be reporting over-confidence in this area also, indicating an opportunity to upskill across all sizes of organisations.

Leadership skills: Related to sustainability strategy skills above. National reports highlight a lack of leaders with suitable sustainability skills among Irish businesses when it comes to driving sustainable transformation, indicating upskilling needs for organisation leaders to set sustainability goals, incorporate sustainability into the organisation and create opportunities to bring people together and generate innovative solutions.

Digital skills to support sustainability: Digital solutions can contribute to a lower carbon footprint, reduced use of natural resources and materials, sustainability of the life cycle (including in the supply chain), and extension of product life cycle etc. Although many organisations researched in many of the reports see digital skills as key in accelerating sustainability efforts, most have yet to harnesses the technology, again indicating an upskilling need in this area.

Sustainable finance skills: Financial skills relating to investment and access to finance for sustainability, such as grants to SMEs to finance training needs is identified. Dedicated courses for financing ventures and business growth, such as in the bioeconomy, is one example highlighted as well as recommendations for educating finance specialists at business schools.

[8] gov - Climate Action Plan 2023 (www.gov.ie)
[9] Skills for Sustainability A headline review of national and international reports identifying skills needs for transition to a low carbon economy

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Carbon management and reporting skills: Reports sampled see a growing need in this area. Initially larger organisations, followed by smaller enterprises, will be required to report on sustainability measures. A driver for upskilling will be the Corporate Sustainability Reporting Directive (CSRD) of which there would appear to be a general lack of awareness across manyorganisations, as well as a lack of usage / awareness of sustainability standards and frameworks. Larger organisations and Irish-owned business see a need in this area and indicates a potential demand to support organisations prepare for reporting.

Managing waste, efficiencies, circular economy and design: Among other issues, Irish organisations see waste management, energy and water efficiency as particularly important.Education in Circular economy and bioeconomy and energy efficiency design skills are called for requiring these to be contextualised for each business and training programmes should aim at enabling and fostering a culture of circularity/ green economy together with recommendations for introductory webinars on how SMEs could reduce carbon emissions.

Developing Circular Economy skills and mindsets - together with Life cycle analysis to measureand quantify environmental or social impacts of products, services, and business models throughout their life cycles —repeats across reports as a key upskilling need to be embedded in training and programme development.

Universities play a pivotal role in addressing climate and biodiversity emergencies. IUA universities possess the expertise and, given adequate resources, the ability to assist Ireland in fulfilling its legal commitments as outlined in the Climate Action and Low Carbon Development (Amendment) Act 2021[10], which is further emphasized in the Climate Action Plan 2023 and detailed in the 2023 Public Sector Climate Action Mandate[11].

Through research, education, campus operations, and ongoing collaboration with businesses and government agencies, IUA universities are significantly contributing to a fair transition towards a low carbon society—a role that can be enhanced with greater investment and support. Recognizing sustainability as a strategic priority, our universities have integrated sustainability goals into their core institutional strategies. In 2021, TU Dublin made a landmark decision by appointing Ireland's first Vice President for Sustainability, a move followed by three additional senior Vice President appointments within IUA universities.

IUA universities are ideally positioned to serve as a driving force for comprehensive climate action throughout society. They are at the forefront of Ireland's initiatives to tackle climate change and serve as exemplars for the public sector. By operating as dynamic "living laboratories" for societal change, universities can motivate actions to confront the climate crisis and seize the benefits that arise from a rapid and effective transition to a low carbon society.

10 Climate Action and Low Carbon Development (Amendment) Act 2021 (irishstatutebook.ie)

11 gov - Public Sector Climate Action (www.gov.ie)

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IUA Sustainability Working Group

The role of the Irish University Association (IUA) Sustainability Working Group is to bring together expertise from the IUA universities to identify, develop and deliver agreed tangible actions to progress towards adopting a systems-wide approach to sustainability and sustainable development across all IUA universities.

- IUA Sustainability Working Group shall provide a forum for:
- The development of common sustainability related policies and practices whereappropriate
- The sharing of information and best practices regarding sustainability
- Providing sectoral-level submissions to national policy consultations and representation on government advisory groups as appropriate
- Engaging with relevant stakeholders to communicate and increase the impact of the work of the Group.

The EPA-IUA Campus Living Labs Project[12], a two-year collaborative initiative between theEnvironmental Protection Agency (EPA) and the IUA, aims to transform university campuses into prime testing grounds for effective waste management and recycling interventions. The project's goal is to provide evidence that will enhance campus sustainability programs and promote systemic changes to reduce waste and improve recycling rates. As part of the Campus Living Labs, various pilot programs have been launched at IUA member universities, including "The Waste Game," an interactive onlineeducational tool, trials for reusable coffee cups, a tool for measuring food waste reduction, and student-centered workshops on managing bulky waste, as well as bike andtextile repairs.

The synthesis report [13]'Education for Sustainable Development: Co-Creating Common Areas of Need and Concern' is a recent publication derived from two workshop sessions conducted by Green-Campus Ireland and UCC Green Campus in November 2021. It aims to pinpoint the prevalent challenges and prospects within our present educational framework regarding the incorporation of a thorough Education for Sustainable Development (ESD) curriculum in all tertiary-level institutions in Ireland.

ESD is designed to furnish learners with the necessary knowledge, pivotal skills, and values central to sustainability. It enables individuals to make well-informed choices and actively contribute as citizens in tackling the complex global issues tied to climate change, guided by the Sustainable Development Goals.

The workshops convened delegates from 15 diverse institutions nationwide, engaging in candid dialogues to unearth the barriers to ESD and explore joint solutions. Both students and faculty members were encouraged to participate in these sessions, promoting transparent communication and substantial peer-to-peer cooperation.

12 Campus Living Labs | Irish Universities Association (iua.ie)

13 Education for Sustainable Development: Co-Creating Common Areas of Need and Concern

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The key challenges to the implementation of an ESD curriculum as identified by workshopparticipants include:

- **Lack of free time** available to students and staff to engage with sustainability.
- **Insufficient resources** and support available to teaching staff (including funding andtraining).
- **Lack of skills** and knowledge amongst staff to integrate sustainability into theirteachings.
- **Inadequate support** for ESD from higher-level management.
- **Difficulty engaging** with individuals who lack an interest in sustainable development.

Principal opportunities available to facilitate the creation of the ESD curriculum include:

- **Developing comprehensive professional development training** around sustainability,with an emphasis on peer-to-peer learning.
- **Utilising the existing Green-Campus Network** to facilitate the development of aninter-disciplinary ESD curriculum.
- **Developing a standard for ESD** across all further and third-level institutions.

This report highlights the critical role of collaboration and unity in achieving sustainability goals. The community is at the heart of climate activism, and by pooling resources, expertise, and knowledge, we can bolster one another and make substantial strides toward our common sustainable development objectives. As climate change poses a universal challenge, it is onlythrough united efforts that we can alleviate its most severe consequences.

The necessity of student involvement in the curriculum development process is evident. As pivotal participants in tertiary education, students provide distinct perspectives on the academic landscape of Ireland. Engaging students as partners and addressing their perspectives and issues allows for the creation and implementation of an inclusive and compelling ESD curriculum.

By arming our faculty and students with essential knowledge, they become poised to serve ascatalysts for change within their fields, institutions, and communities. Despite the considerable hurdles in establishing a uniform ESD curriculum, there are numerous promising prospects to aid its development, which promises to enrich both the pedagogical and learningexperiences in Ireland.

2.3. EntreComp

2.3.1. Irish exemplars realising EntreComp in HEI

Entrepreneurship is increasingly recognized as a valid and popular career path. The 2019 GEMReport on Entrepreneurship in Ireland[14] revealed that nearly 20% of adults aspire to becomeentrepreneurs, a significant increase from 9.8% in 2006. This shift is partly due to the ongoingdigitalization of the SME sector, which has levelled the playing field for numerous entrepreneurs.

[14] 2019 GEM Report on Entrepreneurship in Ireland

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Consequently, possessing capital and premises is no longer a strict requirement for starting abusiness. What's crucial now are drive, knowledge, ambition, and innovative ideas.

It is vital to nurture the potential of young people early on. A variety of programs, backed bygovernment departments, agencies, and businesses, are in place to foster entrepreneurial skills in youth. Notable initiatives include the Young Social Innovators (YSI) awards, aiming toengage with half of the country's secondary schools in innovation-thinking, and Junior Achievement Ireland (JAI), which delivers entrepreneurship education to over 60,000 students each year.

The 'Entrepreneurship Education: A Road to Success' report[15] by the European Commission in 2015 analyzed 91 studies across 23 countries. The evidence suggests that entrepreneurship education is effective.

The report indicates that students who receive entrepreneurship education are more inclinedto establish their own businesses, which are often more innovative and successful than thosefounded by individuals without such educational backgrounds. Furthermore, it reveals that alumni of entrepreneurship education programs are less likely to be unemployed and more likely to have stable employment. They tend to secure better positions and earn higher incomes compared to their counterparts.

European Commission's Entrepreneurship Education

The 'Entrepreneurship Education: A Road to Success' report, alongside other EU projects andstudies, underscores that being entrepreneurial transcends merely starting and managing a business. It encompasses the capacity and determination to transform ideas into reality.

It's about:

- Creativity
- Innovation
- Risk-taking
- Ability to plan and manage projects
- Achieve objectives
- Awareness of context and
- Ability to identify, create & seize opportunities.

These are skills that can also be put to use by employees to provide innovative inputs within organisations (so called intrapreneurs). The skills can also be used to address wider societal issues, not just commercial applications (e.g. social entrepreneurship) and indeed in personal and family life.

15 https://op.europa.eu/en/publication-detail/-/publication/c6590fd6-3e54-4989-bbe0-21d9785dff54

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The National Skills Strategy 2025 for Ireland[16], unveiled by the Department of Education andSkills in January 2016, pledges to craft an Entrepreneurship Education Policy Statement. Thisstatement will guide the creation of entrepreneurship guidelines for educational institutions.

The Department already promotes enterprise within schools by fostering a fundamental graspof scientific concepts, business methodologies, and by encouraging active, collaborative learning. Enhancements in ICT skills within the updated primary curriculum, alongside a robust arts education, nurture creativity, innovation, and the essence of entrepreneurial thought and action. Entrepreneurial skills are also a key component of the new Junior Cycle Framework, with numerous schools engaging in commendable initiatives like mini-company creation and otherentrepreneurial projects during the transition year. These skills, combined with proficiency ina second modern language, are crucial for lifelong learning and cultivating an enterprising culture.

Educators have the liberty to augment these with targeted entrepreneurship education resources. In primary education, entrepreneurship can be integrated either directly during discretionary curriculum time or indirectly through subjects like Drama, Art, Oral Language, Creative Writing, or group projects. At the secondary level, it can be woven into Business Studies or Transition Year initiatives. A recent OECD report[17] focused on Ireland's latest trends in entrepreneurship training. The report emphasized that such training has increasingly been delivered through online platforms over the last two decades, a shift that was significantly hastened by the COVID-19 pandemic. This encompasses both "closed" training programs, which have an intake process similar to traditional training schemes, and "open" programs, accessible to anyone at any time.

The prevailing trend is to provide training modules via "open" online learning portals, featuring diverse content like articles, short videos, games, and self-tests for self-directed learning. The shift to online learning offers numerous benefits for entrepreneurs and governments alike. A growing body of evidence suggests that online formats can be as effective as traditional face-to-face classroom settings, and ongoing technological advancements continue to present opportunities for enhanced outcomes. The incorporation of gamification in entrepreneurship training is on the rise, supported by evidence of its ability to boost motivation, engagement, and learning outcomes.

Experimenting with micro-credentials:

Micro-credentials is a tool that has emerged in recent years to certify learning outcomes and experiences. They are usually offered for short-term entrepreneurship training programmes regardless of the learning setting (i.e. formal, non-formal, informal). They are currently most frequently used in formal learning settings such as university programmes and as stand-alone credentials such as the Entrepreneurial Skills Pass (ESP). The ESP is an online micro-credential that provides an international qualification to young entrepreneurs, particularly students between the ages of 15-19 years old who have entrepreneurial experience. It was developed by JA Europe in collaboration with the European Commission and is based on practical entrepreneurship experience, mentoring, self-assessments via an online portal and a final examination to earn the micro-credential.

[16] https://www.gov.ie/en/publication/69fd2-irelands-national-skills-strategy-2025-irelands-future/

[17] Recent developments in entrepreneurship training Implications for inclusive entrepreneurship in Ireland 2022

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Micro-credentials afford participants a more flexible approach to obtaining specific competencies need for business creation and development in addition to transversal skills. Moreover, micro-credentials support lifelong learning by encouraging people to upskill and develop new skills. For example, the Propel programme in Saskatchewan (Canada) aims to support solo entrepreneurs with up to four years of business operation in upskilling and offers the possibility of micro-credentials to several course modules (e.g. Financial Management, Sales and Marketing)

Entrepreneurship Exemplar:

Focusing on the entrepreneurship competence, the GROWTHhub[18] project is a collaborative initiative between TU Dublin and South East Technological University (SETU), funded by the Irish Government under HCI initiative in 2020.

The mission of GROWTHhub is to:

- Encourage an entrepreneurial mindset for new ways of thinking, education, research, and engagement.
- Create an environment with a stimulating culture of idea generation, exploration, and implementation.
- Positively impact students, the regional economy, and Ireland as a nation.
- Be a multi-disciplinary, institution-wide hub.
- Promote innovative approaches to identifying and solving needs and problems.
- Use opportunity recognition as a driving core concept.
- Recognise that all members of an innovation-oriented ecosystem can benefit bycooperation.

The GROWTHhub project is all about helping everyone in TU Dublin to build growth thinking and entrepreneurial behaviour into their daily lives. Their 3-year mission is to givestudents and staff the opportunity and skills to view the world through the lens of 'Opportunity Awareness'. To see potential solutions to the problems that we and those around us encounter every day. They are building a network of people and resources to help students and educators. They are introducing programmes to help students of every discipline and at all levels to practice creativity and innovation.

2.4. LifeComp

2.4.1. Irish exemplars realising LifeComp in HEI

The LifeComp framework describes nine competences (P1-3, S1-3, L1-3) that are structured in 3 intertwined competence areas: Personal, Social, and Learning to learn.

In focusing on the social competence, the *Empathy Studio* at the University of Galway is the first of its kind in Ireland. The Studio combines the science of human behaviour with the art of human-centred design and utilise and 'me' and 'we' empathy into action approach[19]. The Studio offers consideration of the deeper layers of the human experience, using technology and human simulation in increasingly intimate ways that capture the essence of our real, messy, human selves.

18 https://www.tudublin.ie/connect/partnering-with-us/growthhub/news-events/entrecomp-what-is-it- and-how-can-i-use-it.php

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Another key component in the realization of the social competence is collaboration. Specific exemplars of collaborative learning include the Innovation Academy[20] (University College Dublin UCD)). UCD's Innovation Academy offers multidisciplinary courses where students from different fields collaborate on real-world challenges, such as creating start-ups or solving societal problems. Through group projects, students learn to work with people from diverse academic backgrounds, enhancing both their entrepreneurial and teamwork skills. Another example is the Cooperative Education Programme[21] at the University of Limerick (UL) where UL's Cooperative Education Program integrates work placements into many degree programs. During these placements, students collaborate with industry professionals, working as part ofteams in sectors like engineering, science, and business. This real-world collaboration teaches students how to adapt to professional team environments. Relatedly, the National University of Ireland Galway (NUI Galway) and its Community-Based Learning emphasizes service learning, where students collaborate with community organizations to address societal issues. Students in fields like social science, law, and health sciences work in teams to develop solutions for real community challenges, gaining collaborative experience while making a social impact. Other examples include TU Dublin's Design and Architecture Studios22, where architecture students regularly work in collaborative studio environments where they co-create projects. These studios simulate professional design settings, requiring students to collaborate on urban planning, architecture, and product design. The emphasis is on group critique, peer feedback, and collaborative iteration. It is noteworthy that not all of these collaboration projects include or involve engineering. With regard to learning to learn competences, in Irish universities, the "learning to learn" approach is integrated into engineering education to help students develop critical thinking, problem-solving, and independent learning skills. Some exemplars worth highlighting include the problem based learning (PBL) in engineering offerings at University of Limerick23. Students are given real-world engineering problems to solve, rather than being provided with traditional lectures. This encourages students to research independently, collaborate with peers, and develop solutions. PBL helps students learn how to learn by pushing them to seek out knowledge actively and develop self-directed study habits. Reflective Learning Portfolios24 are utilised in Trinity College Dublin. These portfolios help students assess how they learn best, identify gaps in their knowledge, and adjust their study methods accordingly.

19 https://www.universityofgalway.ie/ideaslab/ourstory/empathystudio/#:~:text=The%20Empathy%20Studio%20at%20the,we'%20empathy%20into%20action%20approach https://www.universityofgalway.ie/ideaslab/ourstory/empathystudio/#:~:text=The%20Empathy%20Studio%20at%20the,we'%20empathy%20into%20action%20approach.

20 https://www.innovationacademy.ie/learn-with-us/

21 https://www.ul.ie/cecd

22 https://www.tudublin.ie/explore/faculties-and-schools/engineering-built-environment/architecture-building-and-environment/

23 https://researchrepository.ul.ie/articles/conference_contribution/Implementing_reflective_writing_in_a_problem-based_learning_civil_engineering_programme/19809871?file=35239798

24 https://www.tcd.ie/academicpractice/resources/resources_a_z/Reflective_learning/

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Alternative teaching models that encourage diverse learning methodologies (by engaging non-standard modalities), include the Engineering Design Studio initiatives at TU Dublin, where the studio environment encourages students to independently research, experiment, and iterate their designs, fostering a strong sense of responsibility for their learning. Or Maynooth University, where a critical skills module[25] is offered to first-year engineering students. The module is designed to help them develop effective learning strategies, problem- solving skills, and critical thinking abilities. This course focuses on teaching students how to approach engineering problems in a structured way, evaluate sources of information, and develop their ability to learn independently. Another initiative is the Loop Reflect Platform[26], a platform utilised at Dublin City University, where engineering students reflect on their learning experiences and progress throughout their course(s). This reflection process helps them identify strengths and areas for improvement in their learning strategies. In Irish universities, "learning to learn" is embeddedinto engineering programs through self-directed projects, problem-based and project-based learning, reflective practices, and independent research. These methods encourageengineering students to become active, independent learners who can adapt to new challenges and continuously evolve in their field.

3. Engineering Curricula Opportunities

Engineering curricula opportunities are plentiful and need to evolve. The following arerecommendations for universities:

- Ensure engineering curricula encompass a broader perspective, focusing on next- generation engineering skills such as managing complex interconnected systems, teamwork with strong interpersonal skills, and the ability to advocate within society and influence the market.
- Design student-centered engineering curricula where students actively participate in shaping their study and research paths, allowing them to personalize and tailor their curriculum to their individual competencies and interests.
- Incorporate curriculum opportunities within an inclusive and diverse setting that involves external stakeholders, especially civil society representatives (public authorities, local authorities, NGOs), and companies through internships, company meetings, entrepreneurship tracks, or hackathons.
- Balance fundamental disciplines that focus on theoretical teaching with specialty disciplines that offer a high percentage of elective courses and are adapted to future technologies.
- Implement varied teaching and learning methods and depend on diverse pedagogical approaches such as Problem-Based Learning (PBL) and Case-Based Learning (CBL), as well as international experiences and internships.
- Emphasize the development of adaptable and critical thinking skills and adjust evaluation methods and milestones to suit the new, complex learning environments.

Another observation evident in this review is that while the Irish Universities are evidently addressing the competences required of the Dig/Life/Green/Entre-Comp frameworks, holistic offerings that embrace the frameworks are lacking. One way to address this is if programmes were to apply the frameworks to specific contexts so that holistic (framework) appreciation is applied to a specific focus.

25 https://www.maynoothuniversity.ie/critical-skills

26 https://reflect.dcu.ie/

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13. VDI

1. Introduction

Germany is in the midst of a structural change that is caused on the one hand by the digital transformation, but which also has to find answers to the challenge of the necessary management of climate change - in other words, a green transformation. More precisely:

The structural change brought about by the digital transformation, that is fundamentally changing the way people live, work and do business. After the steam engine, the assembly line and the computer, the digital transformation now makes intelligent factories possible, which is why this further development is called the fourth industrial revolution, or Industry 4.0 for short. The core of the intelligent factory is the intelligent linkage of people, machines and workpieces, which is to take place with the help of modern sensor-actuator technologies and the connection of different systems via the internet - worldwide and in real time. Accordingly, Industry 4.0 is not only about interconnected production processes, but about the even more intensive linkage of entire value chains.

In view of the increasingly visible effects of climate change and the growing public pressure to consistently explore ways to mitigate climate change (keyword "Fridays for Future"), sustainability issues are becoming increasingly important. The goal of sustainability is to shape the way we produce and consume under the aspects of resource conservation, environmental protection and social responsibility. Taking these aspects into account, the Green Economy can be understood as a comprehensive ecological modernisation of the entire economy that reduces resource consumption, increases energy and raw material productivity, reduces emissions and changes product designs.

Dealing with sustainability challenges in this way, the resulting transformation towards a green economy is not only an answer to the challenges posed by climate change, scarce resources and environmental pollution, but also opens up considerable economic opportunities for a country like Germany, especially through the production and export of innovative sustainable technologies and processes.

Germany has derived so-called sustainability goals from Agenda 21 and regularly monitors the achievement of these goals. (https://dashboards.sdgindex.org/profiles/germany/indicators).

In terms of current and future competence requirements, both the digital transformation and the green transformation play an important role because they help to secure and ideally expand Germany's international competitiveness as an attractive business location.

This becomes evident in the multifaceted discussion about Future Skills that has been taking place in Germany for several years. The Stifterverband, for example, has defined a basic Future Skills Framework with a total of 21 competences in four different categories. The framework reflects the view of German companies and public sector authorities (Stifterverband 2021):

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- ***Traditional competencies*** (These are the basic building blocks for the professional success of individuals, but also for the success of organisations. These include basic competencies such as problem-solving and resilience).
- ***Digital key competencies*** (competencies that enable people to navigate and actively participate in a digitalised environment)
- ***Technological competencies*** (include those competencies that are particularly important for the design and efficient use of technologies)
- ***Transformative competencies*** (are central to being able to tackle and solve the major social challenges of our time, such as climate change or the COVID 19 crisis. The focus here is on competencies such as mission orientation and innovation competency, which help to unite many people behind a common goal and thus unleash entirely new strengths).

This framework thus includes competencies that are intended to enable people to act and make decisions in a so-called VUCA world. A VUCA-World is characterized by volatility, uncertainty, (high) complexity and ambiguity. Acting professionally requires for the individual the ability to act successfully in future unknown and in itself changing (emergent) situations and being self-organized (Ehlers 2019).

The following remarks in this snapshot refer to Germany, unless otherwise stated.

2. Quantitative indicators on the evolving nature of the engineering profession

If we are to approach the quantitative changes in the engineering profession, we must first take a central look at the labour market for engineers. The high numbers of engineering graduates have been absorbed by the labour market in recent decades and have reached record levels in the last few years. According to the microcensus of the German Federal Statistics Office (DeStatis), nearly 2.5 million engineers are employed in Germany (figures for 2020) - around half of them in traditional engineering professions (See Figure 1).

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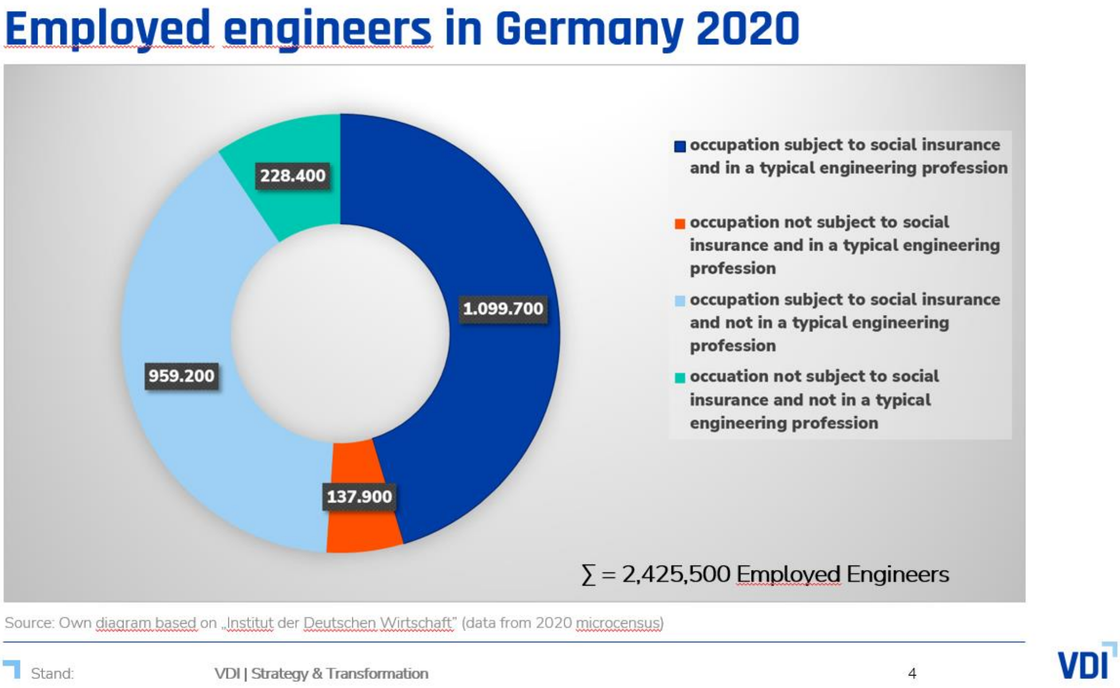

Figure 1: Employed engineers in Germany 2020

The enormous growth in the number of engineers on the German labour market is due to the economic growth period that lasted until 2020. For example, in 2005 there were only just under 1.4 million engineers working in Germany.[1]

The enormous demand for engineers due to the digital transformation as well as the green transformation is already leading to a decoupling of the engineering labour market from the ups and downs of economic growth. The economic slowdown, which occurred at the latest with the Corona pandemic, hardly slowed down the development on the engineering labour market (VDI 2020).

Nevertheless, the consequences of the global economic slowdown led to slight dents in economic growth in 2022 at the latest with the effects of the Ukraine war. Rising energy prices, inflation and interest rates are having impacts. Despite the economic slowdown, bottlenecks in the engineering labour market remain high, but have decreased in individual occupational categories - see for example Table 1 for the 4th quarter of 2023 (IW/VDI 2024).

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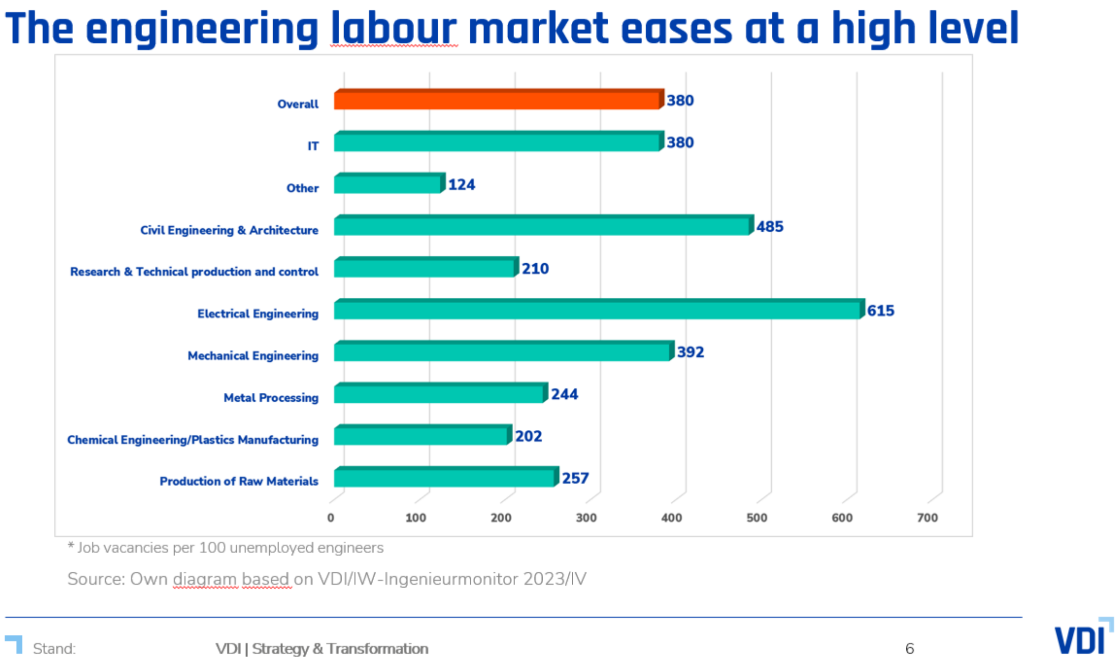

Table 1: Shortages in Engineering Professions in Germany Q4/2023

The economic decline is reflected in the key figures for job vacancies, unemployment and shortage ratios. In the fourth quarter of 2023, the total number of job vacancies fell by 6.6 per cent year-on-year to 159,100. Despite the economic effect, however, there is still a high level of job vacancies, as the total number in the fourth quarter of 2023 is even significantly higher than in the corresponding quarter before the coronavirus crisis in 2019 at 117,400. In the fourth quarter of 2023, an average of 41,837 people were looking for a job in an engineering or IT profession each month - an increase in unemployment of 15.8 per cent compared to the previous year.

If the number of vacancies is set in relation to the number of unemployed, the shortage ratio in engineering and IT occupations is calculated. In the fourth quarter of 2023, the shortage ratio was 380 vacancies per 100 unemployed people - a significant shortage, although the shortage ratio reached a much higher record of 471 in the fourth quarter of 2022.

The biggest shortages are in the engineering professions of energy and electrical engineering (shortage ratio 615) and construction/surveying/building services engineering and architecture (485). In third place are the engineering professions of mechanical and automotive engineering (392), followed by computer science (380). These four occupational categories are particularly important for digitalisation and climate protection.

In the coming years, digitisation and climate protection will significantly increase the need for employees in engineering and IT. In Figure 2 a tendency towards IT is already visible in the number of students in engineering and IT. In addition, a strong increase in demographic replacement demand is to be expected. In 2015, a study by VDI together with the Institute of the German Economy (IW) found

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that by 2029, when the strong baby boomer generation retires, 710,000 engineers will no longer be available on the labour market due to their age (Koppel 2015). The forecasts made at that time are confirmed in the present.

It is therefore also of concern that the number of first-year students in engineering sciences and IT has fallen sharply in recent years. This is also a consequence of demographic change, as a result of which the number of school leavers eligible to study is declining (See Figure 3). Since the shortening of the time it takes to graduate from secondary school will be reversed, a further reduction in the number of students can be expected in the engineering sciences in Germany in the coming years.

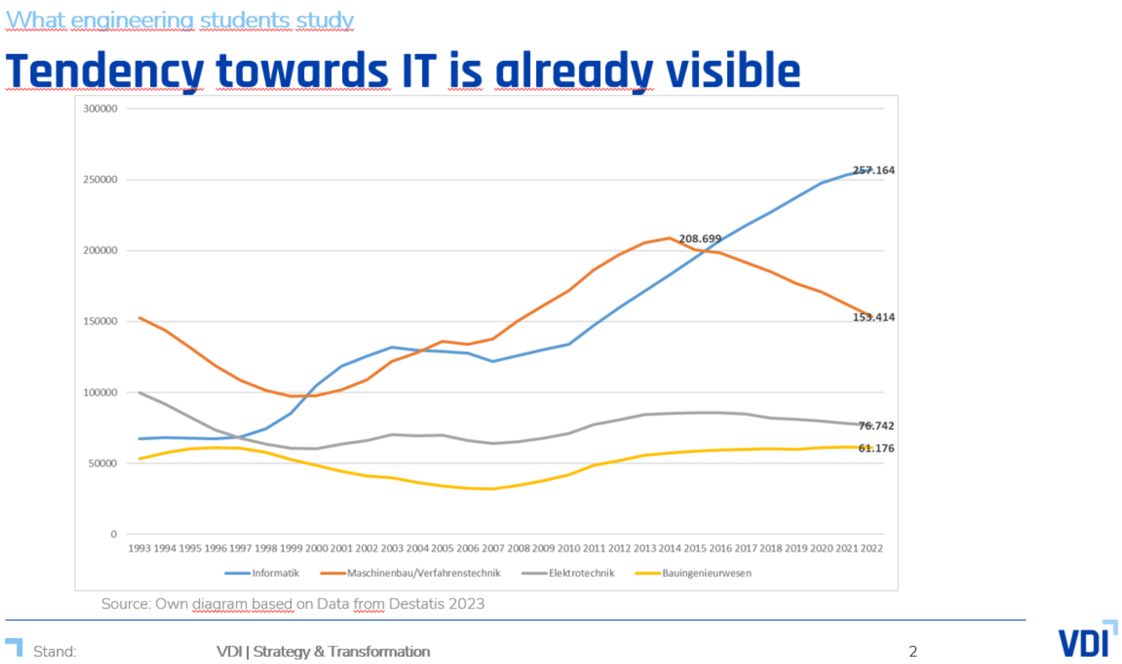

Figure 2: Students in engineering and IT in Germany 1993-2022

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ENGINEERS 4 EUROPE

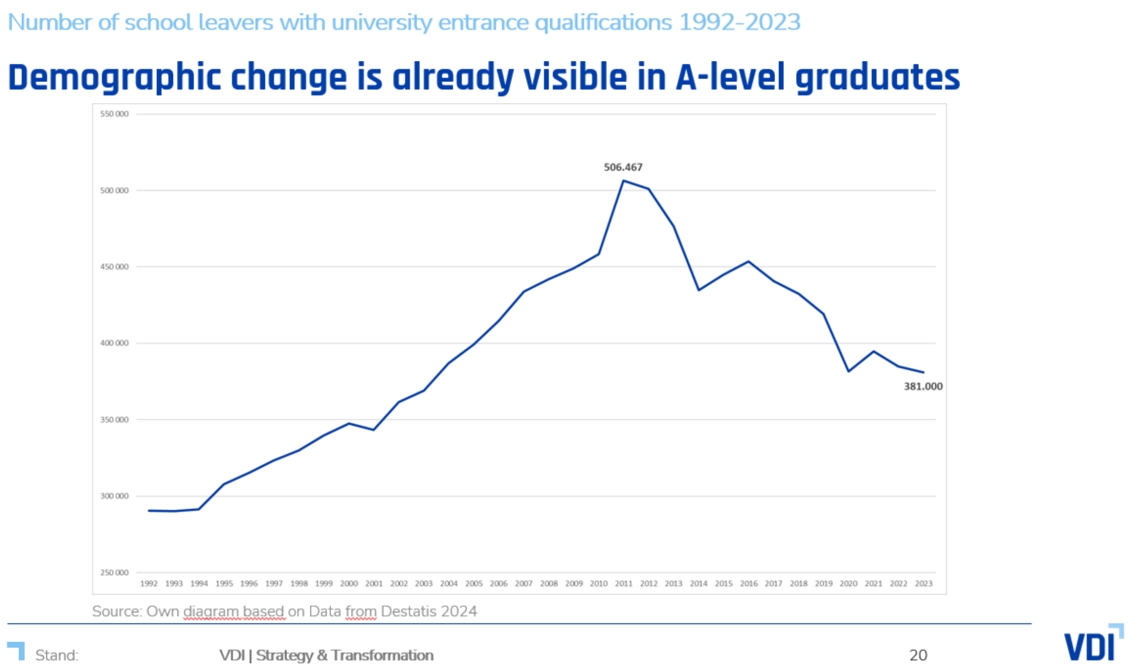

Figure 3: Number of school leavers with university entrance qualifications in Germany 1992-2022

2. Qualitative descriptions of the evolving nature of the engineering profession

1. General Remarks

Engineers play a central role in technology design and development and are therefore one of the most important professions in digitalisation and the green transformation.

The digital transformation and the emergence of new digital business models also affect the world of work under the conditions of demographic change. The digital age will lead to an increasing shift from production work to knowledge work (Spath et al. 2013). As a result, job profiles will change in such a way that employees will work less in production or manufacturing in the future, but will primarily coordinate, control and monitor the entire production process (Spath et al. 2013, VDMA 2015). They will thus take on a role that can be described as "experience bearer and decision maker".

The shift from production work to knowledge work also implies another change. In production work, routine or physically demanding tasks are automated by sensor-controlled robots. This means that workers can potentially be replaced by machines. However, the possibility of complete automation is given for very few activities. If, for example, the execution of the activities requires a distinctive perceptive faculty, the use of difficult motor skills and creativity as well as social intelligence, humans are (still) needed (Frey & Osborne 2013). Developments in robotic sensing technology in recent years are likely to lead much more to work environments in production where close human-machine collaborations (for example, through the use of so-called "cobots") become possible. New digital technologies will provide individual support and assistance to workers in production.

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A new working world designed in this way will probably lead to a positive employment balance. According to a study by the Institute for the Future of Work (IZA), the use of labour-saving machines in Europe destroyed a combined total of just under 1.6 million jobs between 1999 and 2010, many of them in manufacturing (Gregory et al. 2019). However, over the same period, automation has created almost twice as many new jobs. The bottom line is that Europe has gained around 1.5 million jobs through technological progress, many of them in services and software development.

New Work thus also represents a solution to the already described challenge of demographic change in Germany. It enables productivity increases despite a foreseeable decline in the number of people employed in these areas.

The elimination of routine activities will make lifelong learning even more important - both for skilled workers and for engineers. Lifelong learning - understood as a concept of self-responsible informal learning with a work design conducive to learning and with further training demanded and promoted by the employer - can protect employees both from increasing wage pressure and from unemployment. The automation of work processes opens up new scope for employees, which includes opportunities and risks. One of the risks is that the permanent availability of digital technologies makes it possible to dissolve the boundaries of work in terms of both space and time. However, these new opportunities come up against a new generation of workers who give high priority to a work-life balance.

2. What does that all mean for the competencies an engineer needs in the future?

In order to approach this question, interviews were conducted with selected persons who have an engineering degree and work in companies, whether in management, head of department or as a project engineer. In the following, the answers are presented as a synthesis along selected questions of the proposed interview guide.[2]

How will the engineering profession develop in the next 5 to 10 years? What new technical and interdisciplinary skills and competences are needed for the engineering profession?

In the next 5 to 10 years, according to the overwhelming opinion of all interviewees, new topics will play a role in the engineering profession. Artificial intelligence and the use of chatbots, such as ChatGPT, will be decisive. Artificial intelligence is seen as an "increase in the knowledge base", which still needs to be given a plausibility check. In perspective, results must be able to be evaluated and judged with the most diverse factors... under which they have come into existence... The same applies to new technologies.

Knowledge acquired in engineering education, for example, forms a basis for professional action. However, one must also be able to recognise gaps in knowledge and quickly acquire new knowledge. Accordingly - it was said - engineering studies prepare you for the world of work by "teaching and practising learning" but also by "teaching the ability to survive" in a rapidly changing world with constantly new challenges.

Accordingly, it is often said that one might only need a fraction of the knowledge imparted in engineering education in one's later professional activities, but that one can always fall back on a broad

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basic knowledge. The necessary specialised competencies will no longer be so much subject-related in importance, but rather refer to the fact that one can design at interfaces and thus work as an engineer across disciplines. Engineers - according to a complementary view - are thus active in design by putting together puzzle pieces from the enlarged knowledge background, be it methodically or by bringing together people from different subject levels in a structured and objective-oriented way.

How do hard and soft skills differ in their importance for the engineering profession?

Accordingly, soft skills will also increase in importance for successful professional action as an engineer. For example, communication: one must have the ability to always be able to interact and communicate between different people and departments. In the context of the introduction of AI technologies, it is also pointed out that communicative skills - for example in customer contact - will become more important. Here, a need for further development is seen in the engineering profession, which is often characterised by numbers, data and facts, but increasingly also by (soft) skills in communication, whether as a networker in the sense described above or in order to advance concerns or technical solutions in a professional environment.

What role does the engineering profession play in implementing the Sustainable Development Goals?

The importance of the engineering profession for the achievement of sustainability goals is emphasised by all interviewees. In the future - as some of the interviewees said - sustainability will become an industry standard. The engineer is initially assigned a passive role as an implementer of technology that is oriented towards customer requirements. If the fulfilment of sustainability goals is specified in tenders, then as an engineer one will try to develop the best possible technical solution, for example, to design a machine that is as energy- and resource-efficient as possible. Only when we have fundamentally established sustainability in technical standardisation, for example, will the engineering approach change in the long term. An example of this is the design of products that increasingly have to meet the criterion of recyclability. It will be exciting to see how the purely economically oriented economic system develops.

The engineer who wants to change something in this current system still has to reckon with considerable resistance. Accordingly, this aspect also requires the development of resilience as a competency, i.e. the ability to deal with resistance and, if necessary, to use it constructively.

However, the topic of sustainability and what the engineering profession can contribute to it is also considered from the perspective of attracting young talent. Generation Z will - it is believed - be more likely to want to take up a job here as a result of companies taking sustainability seriously than in companies that are more likely to be seen as non-sustainable.

How can ethical and more sustainable methods become more part of the daily work of engineers?

As already described, the engineer sees himself first and foremost as an implementer of technology who develops the best possible technical solution based on customer requirements. Accordingly, it is often criticised that the engineer is at the end of a decision-making chain. One approach to solving this would be to involve the engineer in decision-making processes at an earlier stage. For this, the engineer needs communicative soft skills and the ability to network.

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Critically, however, it is noted that in the corporate context it is not only a matter of individual decisions, but that these - if taken under ethically controversial aspects - may well also concern the material existence of the individual person. Although it is possible to resolve this tension by changing jobs - which seems quite easy in the current context of a shortage of skilled workers - it is a considerably comprehensive step in individual cases, especially for experienced engineers.[3]

How can education and training programmes for engineers and students better prepare them for the changing demands of the profession?

In general, the high quality of engineering education in Germany was emphasised by all respondents. The degree programme had prepared graduates for professional activities as engineers and also for a range of other jobs (for example, in management, etc.).

In order to establish a stronger connection to professional activity, the dual study programme is emphasised. This can combine an early introduction to everyday professional life in companies with studies. The alternation of study and practice phases can create an early ability to act professionally. However, an early commitment to a company and the subsequent lack of incentives for further vocational training (e.g. taking up a Master's degree) or further education is seen critically, also due to the high earning opportunities possible at a very early stage.

The need for further education at every level of professional experience is a consistent theme among all respondents. Due to the rapid pace of change, engineers constantly need to continue their education. Formal and non-formal training formats tend to be replaced by fast informal training paths in order to find technical solutions for current challenges as quickly as possible. In this context, so-called learning ecosystems are being introduced, especially in larger companies, which function as a kind of knowledge management system and are also intended to establish contact with experts on a topic within the organisation. Accordingly, it will also be possible to strategically integrate universities, vocational schools and other education institutions. The aim is to break down the learning barriers that in the vast majority of cases prevent working people from undertaking planned further education.

How can policies and initiatives help to develop the necessary competences?

Since few of the respondents have direct insights or are affected, the feedback on this question is rather restrained. In general, two strands of statements can be filtered out:

1. Education policy in Germany is treated too poorly - too little money flows into the system.
2. Young people are hardly enthusiastic about technical professions any more.

From both statements, one can derive the demand that more needs to be invested in education but also in enthusiasm for technology.

3. Opportunities

Germany is driven by a strongly diversified economic structure based on industry. Core sectors are the automotive industry, the chemical industry, mechanical engineering, but also the electrical engineering industry. Figure 5 provides an overview of the most important industrial sectors in Germany.

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Wirtschaftszweig *Activity sector*	Zahl der Unternehmen *Number of enterprises* 2018	Beschäftigte in Tsd.[1] Jahresdurchschnitt *Employees in 1'000[1] yearly average* 2018	2019	%-Änderung zum Vorjahr *%-change to previous year*	Umsatz[1] Mrd. EUR *Turnover[1] bn EUR* 2018	2019	%-Änderung zum Vorjahr *%-change to previous year*
Maschinenbau *Mechanical engineering*	6 653	1 052	1 064	1,2	232	229	- 1,7
Elektroindustrie [2] *E&E industry [2]*	4 676	880	888	1,0	193	190	- 1,8
Kraftwagen und Kraftwagenteile *Motor vehicles, trailers and semi-trailers*	1 041	801	801	0,0	300	307	2,2
Chemische Industrie *Chemical industry*	1 263	300	301	0,4	116	112	- 3,5
Ernährungsgewerbe *Food products and beverages*	5 427	478	487	1,8	144	149	3,1
Verarbeitendes Gewerbe *Manufacturing*	38 222	5 467	5 506	0,7	1 501	1 484	- 1,1

[1)] Daten für fachliche Betriebsteile von Unternehmen mit 50 und mehr Beschäftigten. / *Data for kind-of-activity units with 50 and more employees.*
[2)] Ohne Datentechnik./ *Without information technology.*
Quelle/*Source*: Statistisches Bundesamt, ZVEI, VDMA/*Federal Statistical Office, ZVEI, VDMA*

Source: VDMA 2020

Table 2: The largest industrial sectors in Germany

This strong industrial base - which is predominantly small and medium-sized - together with a diverse higher education landscape provides the foundation for a strong innovation base. Engineering education in Germany is recognised worldwide and of high quality, which can be documented not least by the continuously increasing number of students of foreign origin (See Figure 4). In this context, engineering education in Germany is strong both in basic research (for example in the universities) and in applied research and knowledge application (for example via the universities of applied sciences).

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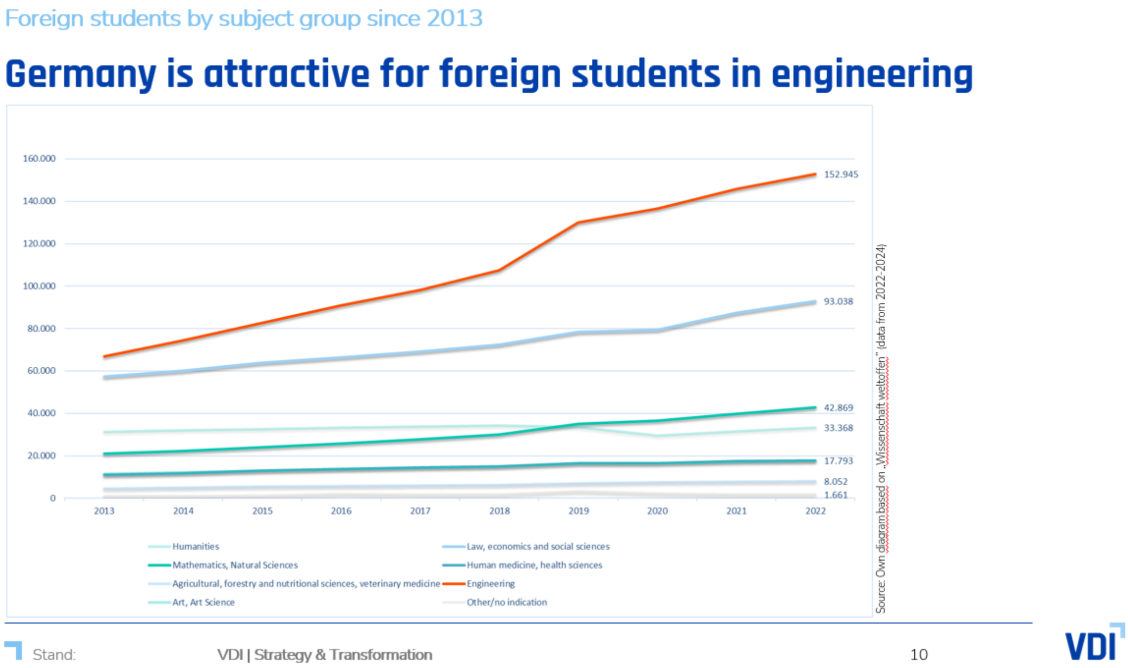

Figure 4: Foreign Students by subject group 2013-2022

4. Needs

In order to position itself successfully for the future, Germany needs to make some efforts - despite the excellent conditions described in the previous sections. In particular, the topic of lifelong learning needs to be increasingly filled with life. Because: On the one hand, there are intense discussions about how to align engineering education with the new requirements resulting from the digital and green transformation. On the other hand, those engineers who are already in professional life must also adapt to these new requirements and continue their education accordingly.

In addition, there is a need for ways in which the increasing requirements and newly added competences can be taught within the framework of the respective engineering education. This corresponds with the realisation that it is no longer enough to have a sufficient technical skill.

5. Challenges

The increasing shortage of skilled workers in technical professions is currently seen as a major challenge in Germany. This concern, often expressed by companies, together with the recognition that demographic change will weaken the potential labour workforce in the coming years, is fuelling a discussion at all levels of society.

The following theses emerge:

- Young people need to be more enthusiastic about technology and technical topics. This begins with the integration of the topic into everyday school and non-school life and continues with the question of how universities must position themselves in a forward-looking way in their knowledge transfer.

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- A consistent issue is that more young girls and women need to be persuaded to enter technical professions and study engineering.
- It follows from the requirements described above that lifelong learning must be given a high priority. However, in-company and vocational training often plays a subordinate role in day-to-day work.
- The immigration and integration of foreign skilled workers is seen as a further element in the mix and a challenge.

6. Conclusions and Recommendations

The following conclusions and recommendations can be drawn from the challenges described:

- Measures and activities in schools and non-school areas must be intensified in order to stimulate technical education and enthusiasm for technology. The aim here is not only to encourage pupils to take up technical studies at a later stage, but also to increase acceptance of technology in society (detailed in VDI 2023).
- Universities are increasingly affected by the declining student numbers that are inevitably a consequence of demographic change. At the same time, they also have to find new ways to attract students to their technical studies. They will then meet a generation of young people who absorb information in a completely different way and who also have completely different expectations and ideas about the subject matter of their work and their later professional life. Here, universities and other stakeholders must think of completely new ways to reach the so-called Generation Z (born between 1997 and 2012) or, in the future, Generation Alpha (born between 2010 and 2020). This is where the topic "purpose-driven" plays a major role and also opens up the possibility of getting more young girls excited about technology (IW/VDI 2022).
- In the context of further education, the topic of micro-crendentials play a major role from the point of view of higher education institutions. (https://www.hrk-modus.de/projekt/zukunftswerkstaetten/microcredentials/). Short-term learning formats should enable the flexible and demand-oriented acquisition of competencies. This concept of micro-credentials has become a discourse on lifelong learning and academic further education - both in Germany and and academic continuing education - both in Germany and Europe. Micro-credentials are currently being discussed as a solution to the increased demand for shorter courses, both online and hybrid formats, such as blended learning (Gaebel et al. 2021). The topic of micro-crendentials will become more important in the context of continuing education for engineers who are already working.
- The prerequisite for teaching and acquiring new competencies in higher education and professional contexts will be a change in the mindset of engineers. In order to "survive" in a VUCA world characterised by a high degree of uncertainty and fast pace, a fundamental understanding of the importance of these competencies for (one's own) professional success is required. As with all changes in personal attitudes or trained behaviours, this will be a long-term process.

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