E4E

Engineers for Europe

September 1, 2022 - August 31, 2025

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

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Executive Summary

The research findings reproduced in this paper provide a snapshot of the issues which are at the heart of the E4E project objectives, i.e. to address the continuously increasing requirements with regard to the engineering profession and the engineering education. This calls for an enforced multi-stakeholder cooperation between education providers, engineering professionals and the industry.

Challenges for the Profession:

More young people can be attracted to the engineering profession by exposing them at an early stage to the contributions engineers make to society every day. It is also very important to increase the number of female engineers and to attract more diverse talent to the profession from under-represented groups through scholarships, the development of mentorship and diversity/inclusion training to existing professionals.

Another crucial issue which was highlighted in this report is the wider set of requirements a modern engineer must meet. Despite the main role of an engineer is still finding technical solutions, employers expect that engineers will also take part in communication with different (often international) stakeholders, become active team members, show high level of critical-thinking, independency in solving problems. Future generations of engineers will not only need to be catalysts of technical innovation, but will also play a leading role in addressing various social issues.

Despite facing challenges such as skills shortages, there are numerous opportunities emerging. The engineering profession is going through a phase of rapid evolution, with the development of the virtual world and AI, which causes the disappearance of old concepts and the appearance of new ones.

When envisioning the evolution of the engineering profession, it's crucial to consider these emerging trends, advancements in technology and the need for sustainability and energy efficiency. Interdisciplinary approaches are also rapidly growing in importance and high quality engineering services will play a crucial role in reaching the aims of the European Commissions Green Deal. Considering this, it is essential to adapt the teaching programs of engineering to the new demands of the job market. Measures and activities in schools and non-school areas must be intensified in order to stimulate technical education and enthusiasm for technology and to increase acceptance of technology in society. Universities will have to find new ways to attract students to their technical studies and to reach out to the so-called Generation Z (born between 1997 and 2012) or, in the future, Generation Alpha (born between 2010 and 2020). Young people absorb information in a completely different way and also have completely different expectations and ideas about their work and their later professional life.

The future of engineers looks nevertheless promising, with significant job growth expected in various sectors. An increased emphasis on sustainability and environmental concerns, in combination with a greater use of automation and AI in engineering processes will become the most important changes in the engineering profession for the next five years (2023-2027). Major areas for innovation and technological development will be renewable energy and green infrastructure. As technology continues to advance and industries become more complex, the demand for skilled engineers is set to rise.

Challenges for Education providers and other Stakeholders :

Due to the fast and ongoing technical developments in engineering it is not possible anymore to gather all the required skills and competences for a professional lifetime during University education alone. Life-long learning (LLL) combined with professional experience becomes increasingly important. This can only be reached by a close cooperation of all stakeholders in the engineering education and profession.

Nowadays LLL is universal for the majority of professions due to the speed with which modern technologies are developing. The engineering profession is at the top of the list of important professional and technical skills. Mandatory courses in the formal curriculum for professional engineers remain critically important for maintaining the high level of our engineers. But in order to deal with the complex and global societal challenges, future engineers need to be equipped with a new set of competences and upskill themselves all the time. This is what LLL is about. Microcredentials and post-graduations are crucial for engineers to quickly get up to speed on the latest trends and developments, so they can accompany the evolution of their areas of expertise. Short-term learning formats enable the flexible and demand-oriented acquisition of competences. At the same time, micro-credentials are a solution to the increased demand for shorter courses, both online and hybrid formats (blended learning) and are becoming more important in the context of continuing education for engineers who are already working.

We must continue to foster and encourage collaboration between engineering professionals, academia, and industry through networking events, conferences, and knowledge-sharing platforms. Universities/technical schools and the industry are to develop a formal or informal curriculum that aligns with the needs of the job market. The role of business in programs of reskilling and upskilling can be to directly drive such efforts and define the approach. Irrespective of whether future engineering curricula are formal, or through instruments that can be plugged into a formal qualification structure, a significant challenge is how learning is organized to be synergized with industry requirements. The skills and competences required by engineers are well established, but they need refinement.

A non-negligible share of newly created jobs will be in completely new occupations, or existing occupations undergoing significant transformations in content and skill requirements. Partnerships between industry and educational institutions, together with investments and increased funding in R&D in emerging technologies, are considered the two most effective tools for addressing digital, green, resilience and entrepreneurship skill shortages in the engineering profession. Modern employers demand engineers who show a set of high level professional competencies. This trend gives a great responsibility to engineering Higher Education Institutions (HEIs), who need to develop the demanded skills. Continuous professional development (CPD) programs, industry-academia partnerships and regular skill assessments to identify emerging skill needs, are essential. Additionally, promoting interdisciplinary education, providing relevant internships and apprenticeships, and encouraging LLL can help bridge the gap between required skills and available talent.

The people surveyed in this research seem to acknowledge that LLL and specialized training is required, with universities providing the fundamentals and key principles, with technical associations and professional bodies providing information to engineers on upcoming trends, and other providers such as VET schools to provide specialized hand-on courses for specific skills. Engineering is experiencing exciting transformations driven by technological advancements, sustainable goals, and the move towards digitization.

Educational institutions and engineering programs should also include soft skill development courses (proficiency in presentation, organization, leadership, conflict resolution, empathy, social awareness, etc.) in their curricula. This should be made in a way to combine it with technical skills avoiding an overcrowded curriculum. Critical thinking, collaboration and communication skills are considered the most significant soft skills to work successfully in the engineering profession for making a promising career. Engineers are best served with competency-based learning and by an assessment of their learning outcomes as the sum of what he/she is expected to know, understand and be able to demonstrate after completion of a learning experience, i.e. knowledge, skills and wider competences (attitudes). It is also widely acknowledged that engineering education should prepare engineering students by exposing them to emerging technologies and their potential applications and that students require more practical and hands- on experience through internships and apprenticeships.

Companies can create a favourable environment for engineering entrepreneurship and startup ventures. Together with governmental bodies they can provide for financial support, set-up mentoring programs and offer access to networks and resources for aspiring engineering entrepreneurs, particularly with endeavours focused on sustainability. Fostering closer collaboration between industry and government agencies will ensure policies and regulations are conducive to growth and that industry focuses on the correct priorities.

Meeting the UN Sustainable Development Goals:

HEIs need to keep up with the societal evolutions and monitor modern engineering trends, because technologies nowadays are changing very quickly and it is important to give students knowledge that will be relevant, not only in the short term, but also in the more distant future. To better prepare engineers for the challenges of the 21st century, the incorporation of sustainability principles in formal engineering education and training courses is considered paramount. This will require changes in curricula and CPD. Those should provide the means to support the adaptation of the SDGs into an engineer’s everyday practice.

Traditional engineering disciplines such as mechanical, civil, electrical, and chemical engineering will continue to be vital, but emerging fields like renewable energy, artificial intelligence, data science, and robotics will become increasingly important. To meet these evolving needs, educational institutions and training centers will develop programs that cover these emerging areas of engineering, ensuring that graduates are well-prepared for the challenges and opportunities that lie ahead. Interviewees in this research also expect formal education to set the base line on matters of ethics and sustainability for the new engineers as well as for professional bodies and technical chambers and associations to provide follow-up sessions on the matter.

It is important for engineering education to find ways to educate engineers that can incorporate sustainable values into technology development. Such trends give us hope that future engineers will actively join the SDGs implementation and development of new sustainable and ecology-friendly technologies. The embracement of the SDGs needs to be adopted by higher education providers as the primary framework steering engineering education, despite the fact that students already seem to have a high level of consciousness and understanding of ecological problems.

1. The European context

1.1 Analysis by ENGINEERS EUROPE

1. Introduction :

The operational objective of the "Engineers for Europe" (E4E) project is to bridge the gaps between education, training and industry, while operationalising EU competence frameworks. In the light thereof, a European Engineers Skills Council has been established, which aims to become an international, sustainable and ongoing observatory for the analysis and forecasting of engineering competences to meet new career profiles and from which lifelong educational needs will emerge.

With the involvement of academic authorities, stakeholders and experts from the world of work, the Council will aim at designing a monitoring methodology to gauge the dynamics, challenges and opportunities of the engineering profession, presenting and discussing examples of innovative and effective practices at half-yearly meetings. Through its Working Groups this robust "alliance" will publish reflections and recommendations on the evolving engineering profession, providing guidance to local, national and European authorities, as well as to public and private institutions which are interested.

In Europe, ten thousands of engineering students finish university education every year. They enter the labour market with sets of competences based on their personal experiences and their studies.

This preliminary and first Research Report is an attempt to try to find answers if they are really prepared for the jobs society needs and - if not - what recommendations can be made? What are the demands of the employers and are these graduates truly equipped to fully engage with these expectations? Are universities up to speed? Do we have sufficient evidence to answer those questions, can they be compared and can we identify and formulate solid recommendations? Can we pull together the requirements from industry and can we see them reflected back into education? Which future technologies, according to industry, will be in demand and are likely to be adopted in the years to come? Which disciplines are likely to decrease or increase in demand across industries?

Of course, not all these questions can be answered all at once, but in this paper we have made a first indicative attempt, based on a survey, three interviews with representatives of respectively research, business and the academic field, a focus group meeting, existing literature and publications.

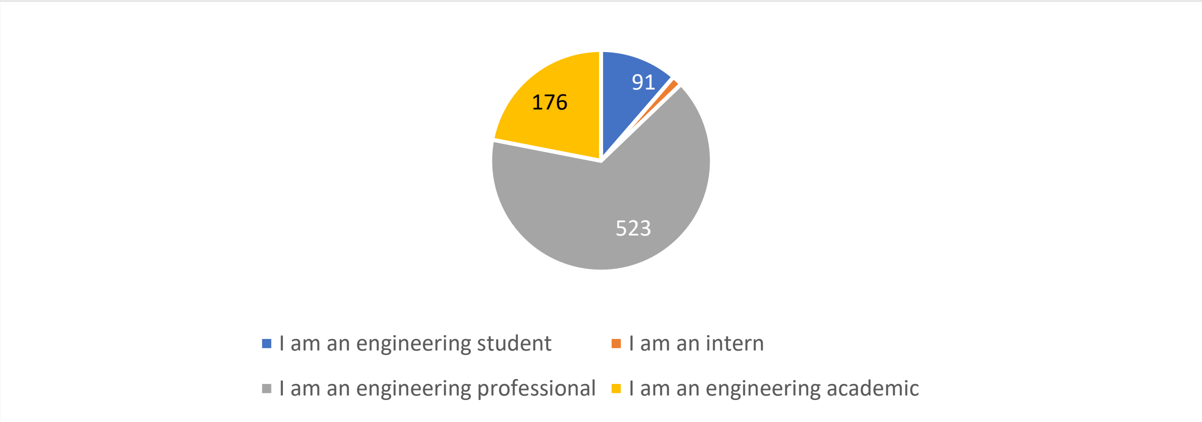
By this research ENGINEERS EUROPE wishes to demonstrate its leading role in the E4E project and to assist European policy shaping through independent study and engagement as an impartial adviser.

2. Quantitative Research

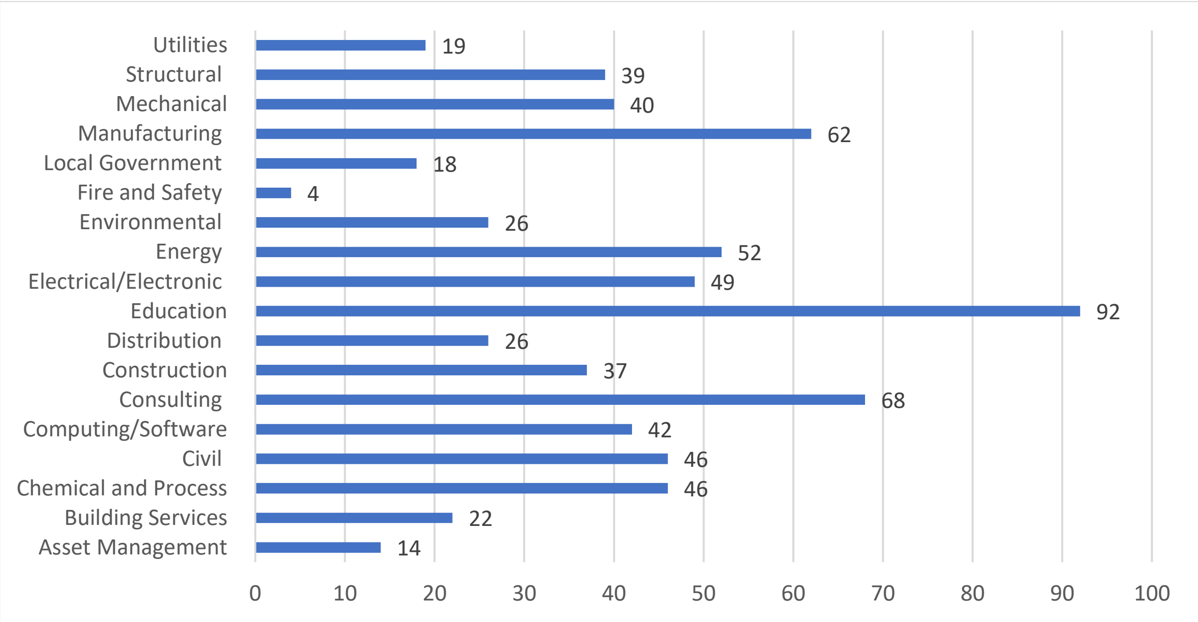
2.1 E4E-Survey

From 15 May 2023 till 14 July 2023 ENGINEERS EUROPE launched two on-line surveys Europe-wide, consisting of 33 closed questions addressing individual engineers. 3045 fully completed answers from the ENGINEERS EUROPE network were received, of which we filtered out the **802** applicable ones for the 7 countries represented in the E4E-consortium: **Belgium, Germany, Greece, Spain, Ireland, Portugal and Slovakia**. Because some questions occurred in both surveys, we represent herewith the outcome to 20 of them. This is a small sample and must be considered exploratory, but they do shed a light on perceptions of the issues in question. The resulting hypotheses from these answers seem to be validated by research.

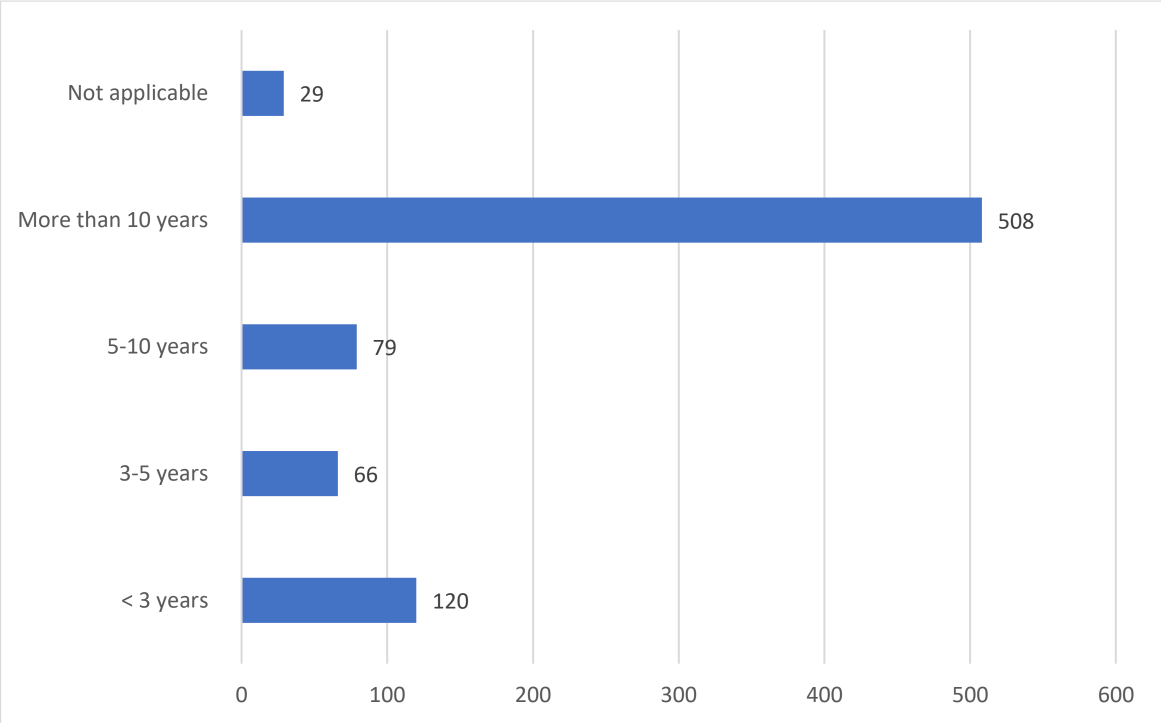
1. Please select the option that best describes your status:



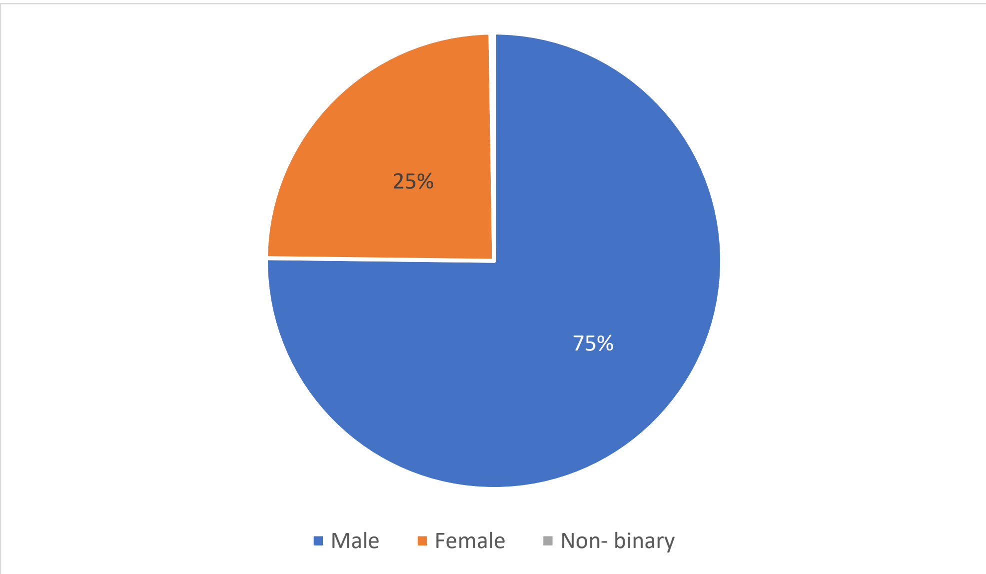
2. Which industry or sector do you work in?



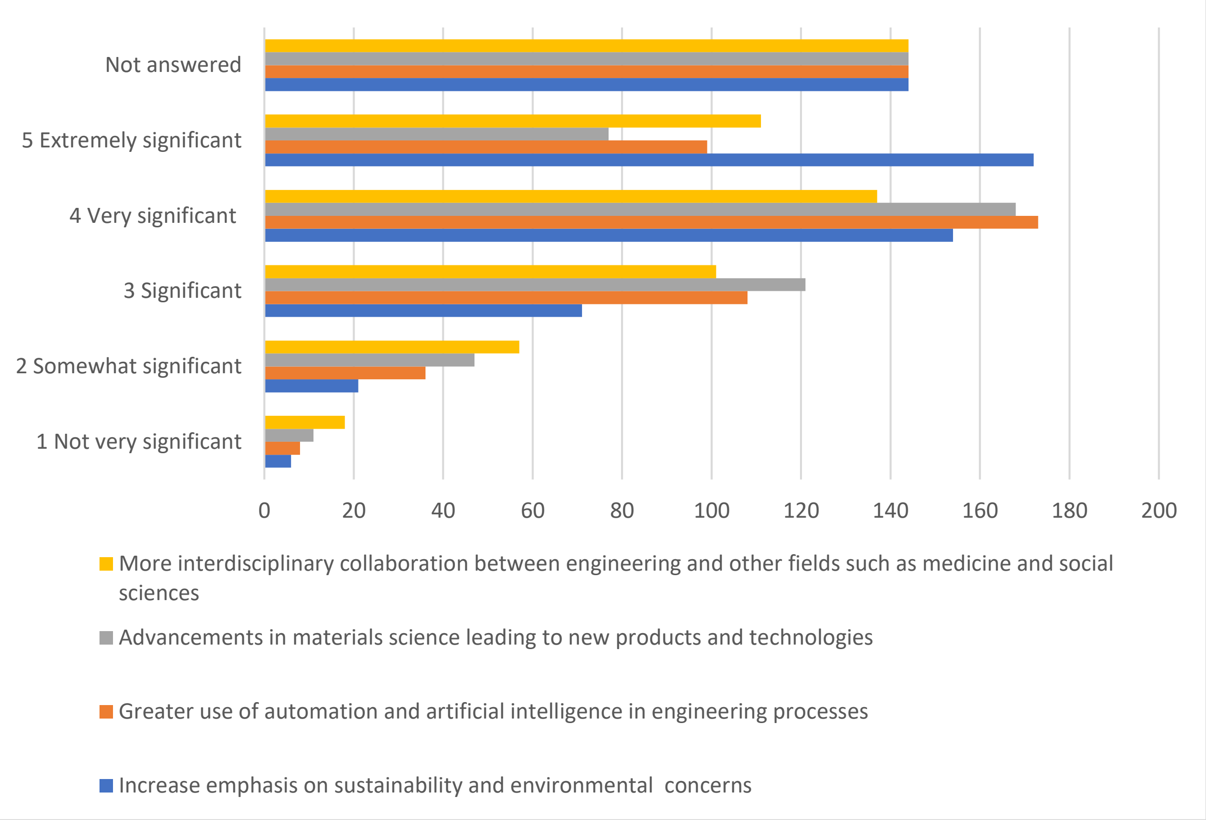
3. How many years of experience do you have in the engineering profession or related field?



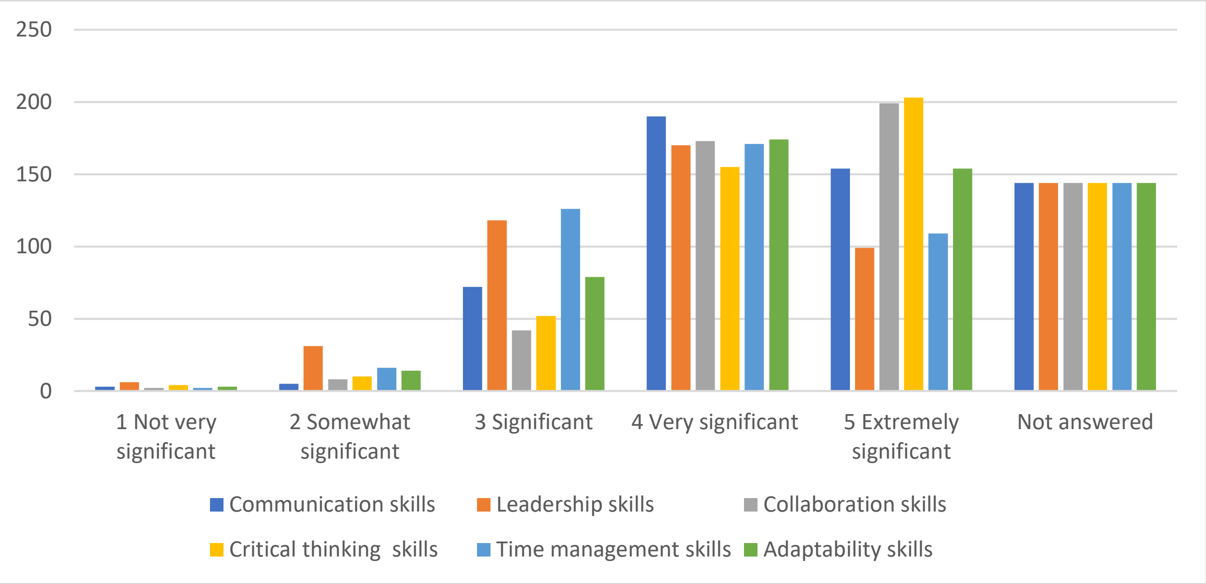
4. What is your gender?



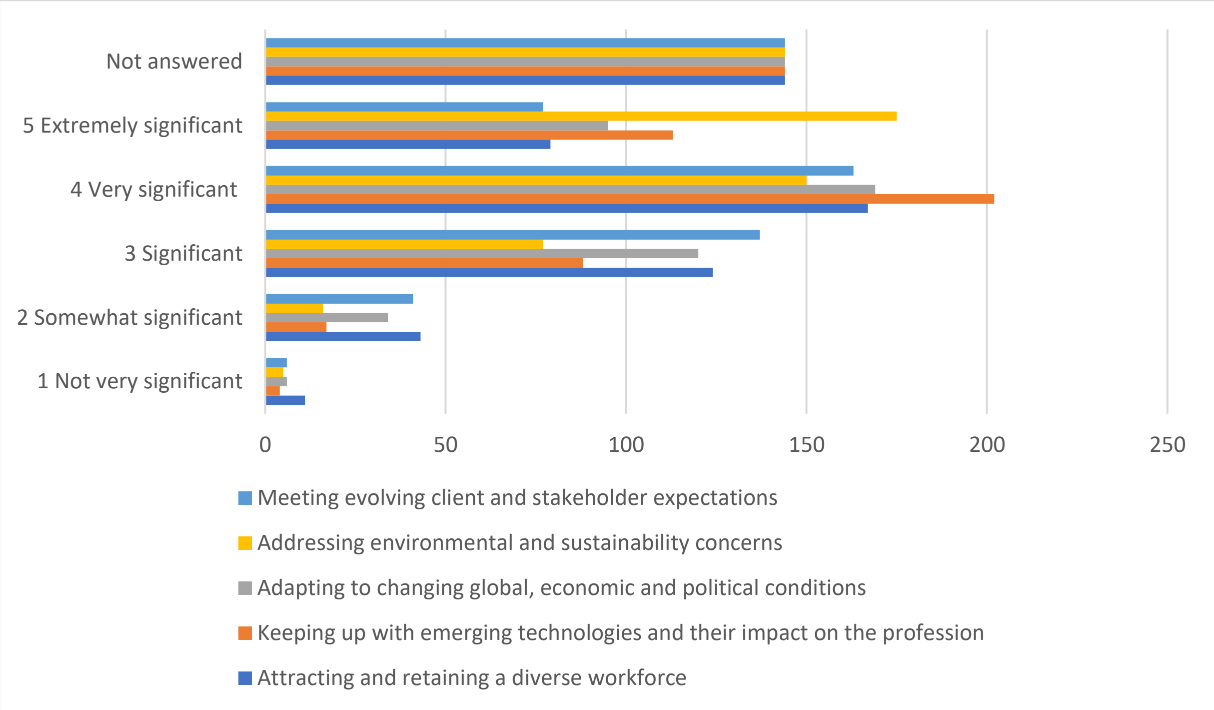
5. Using a scale from 1 to 5, where 1 indicates "not very significant" and 5 indicates "extremely significant", please rate the perceived or expected potential changes in the engineering profession over the next five years:



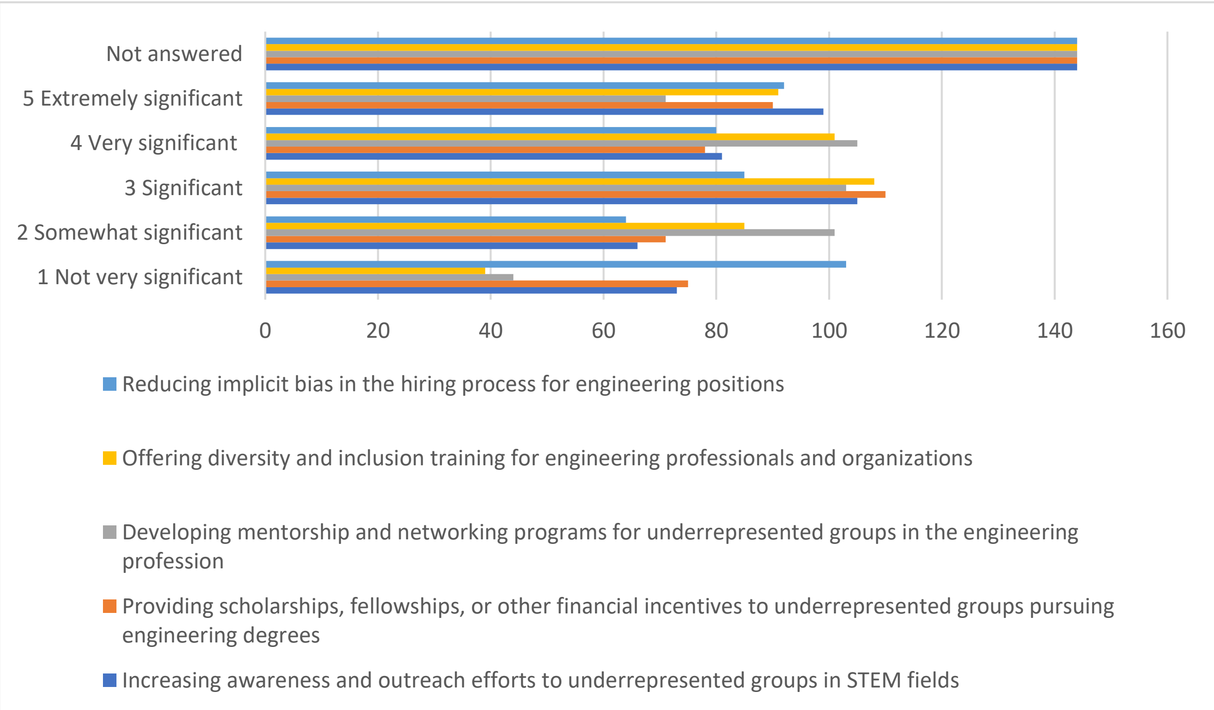
6. Using a scale from 1 to 5, where 1 indicates "not very significant" and 5 means "extremely significant", please rate the soft skills needed for working successfully in the engineering profession to make a promising career.



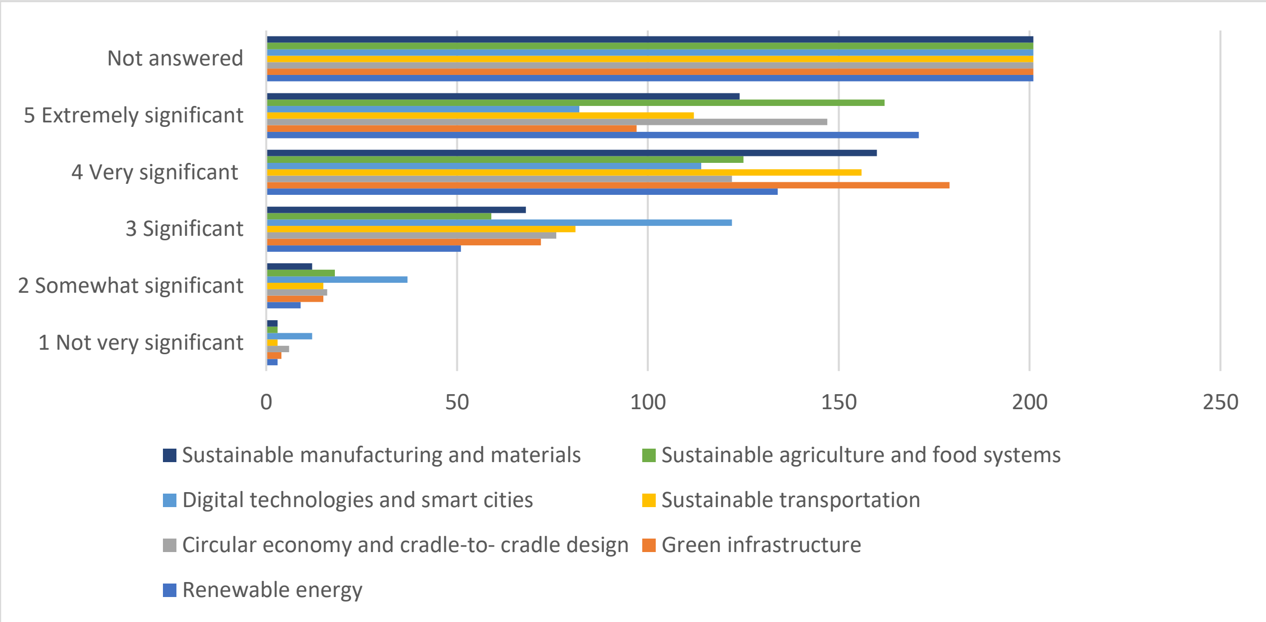
7. **Using a scale from 1 to 5, where 1 indicates ”not very significant” and 5 means ”extremely significant”, please rate the following challenges and opportunities the engineering profession encounters while adapting to the changing demands for skills and competencies.**



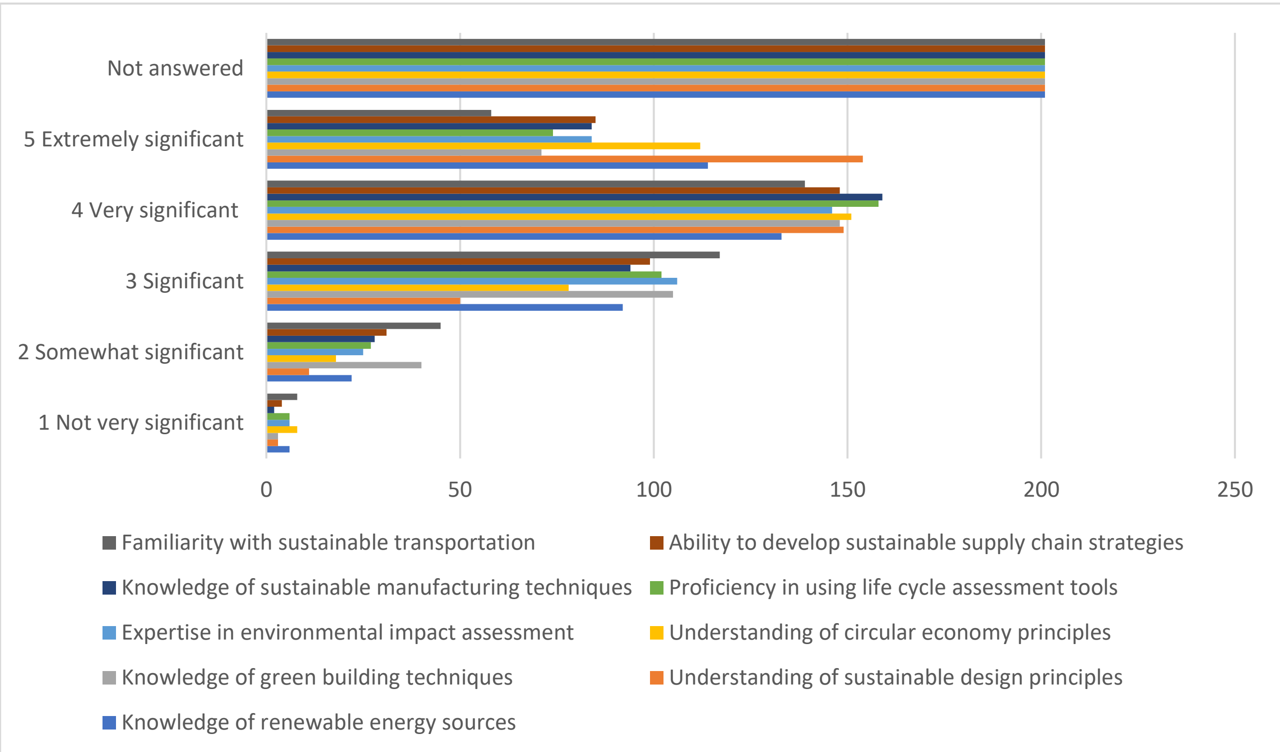
8. **Please rank the following initiatives in order of priority for attracting more diverse talent to the engineering profession:**



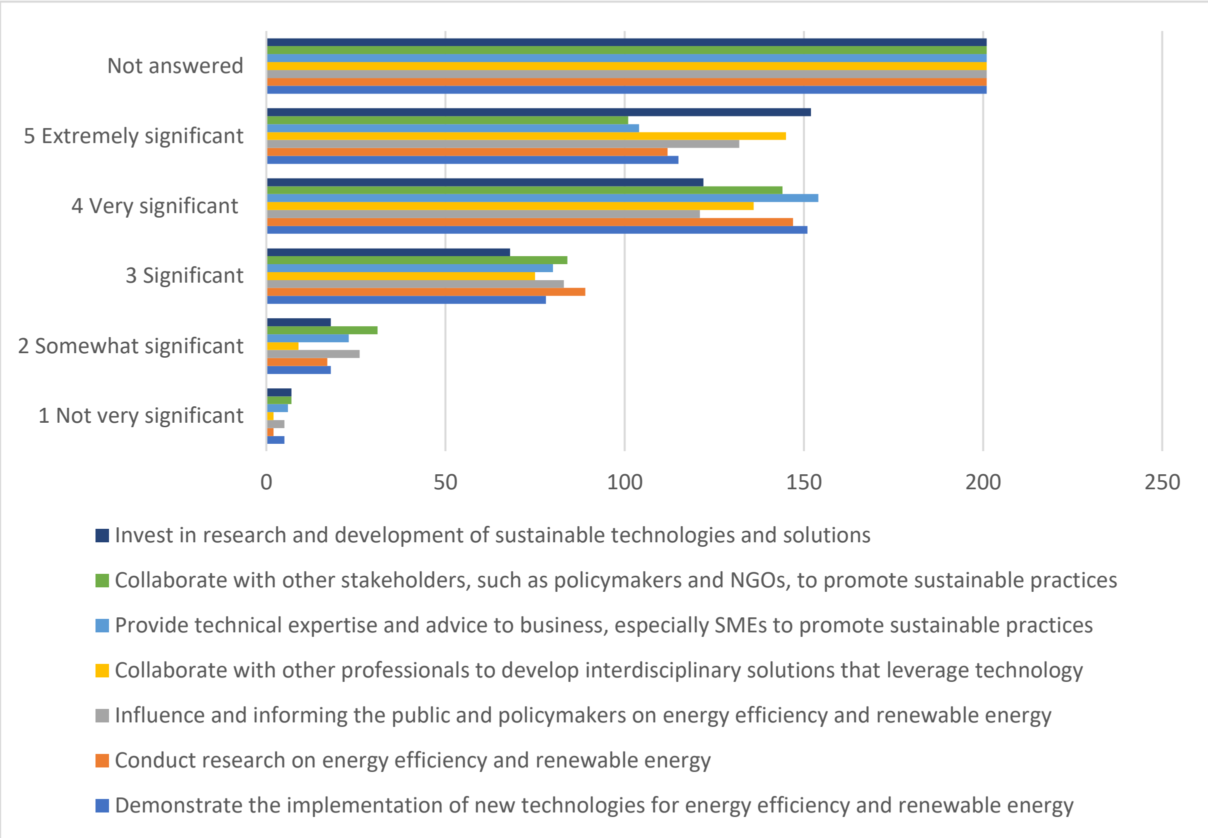
9. Using a scale from 1 to 5, where 1 indicates ”not very significant” and 5 means ”extremely significant”, please rate what are the most promising areas for innovation and technological development in the engineering profession to promote sustainable practices and SDGs.



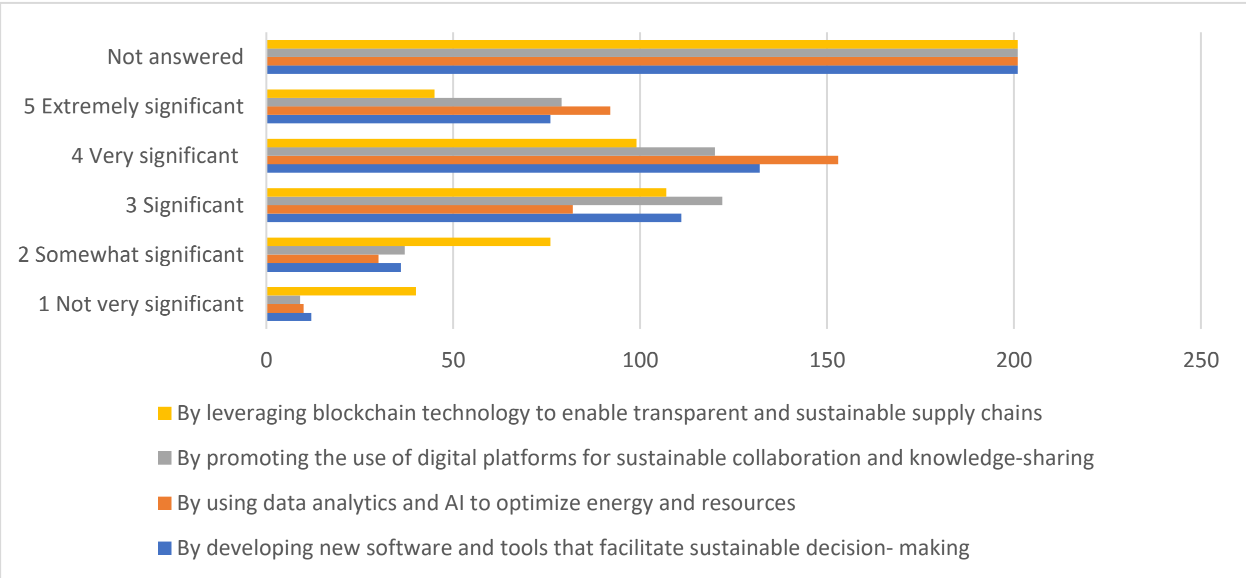
10. Using a scale from 1 to 5, where 1 indicates ”not very significant” and 5 means ”extremely significant”, please rate the main technical skills and competencies that engineers will need to develop to contribute to the transition to a more sustainable economy.



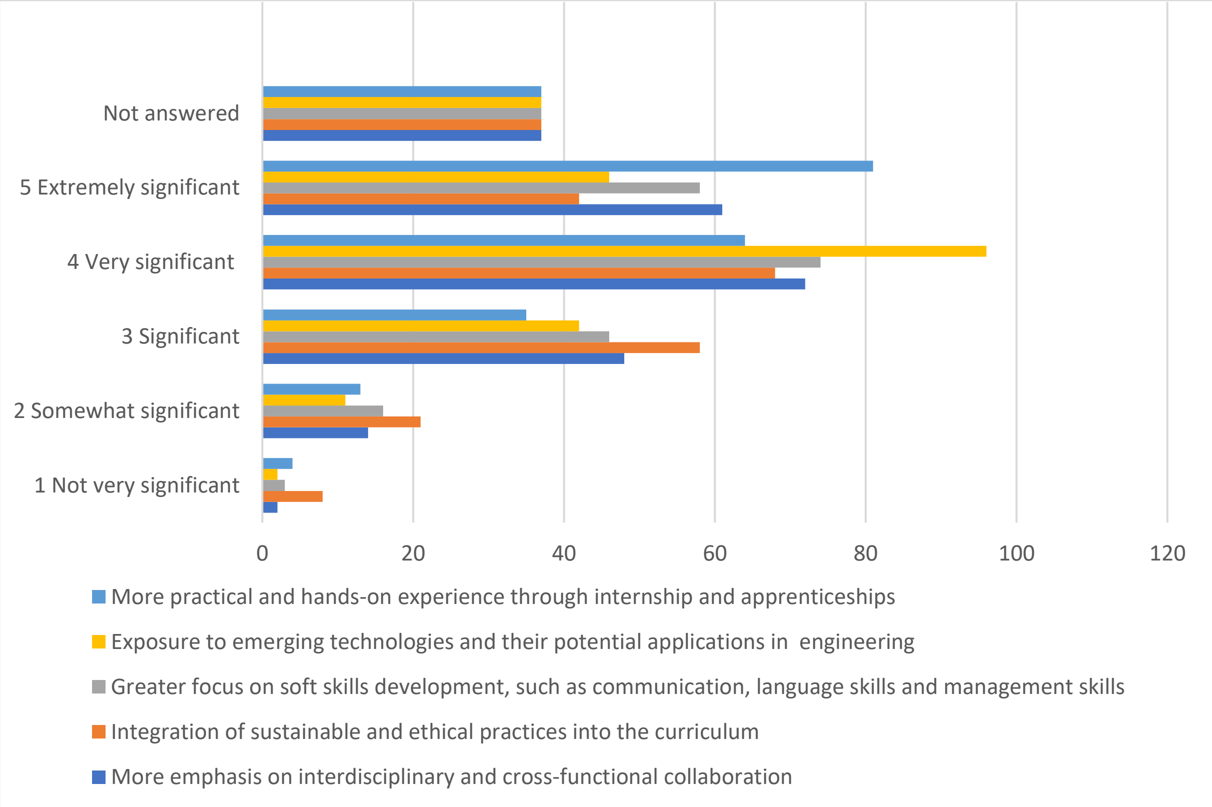
11. Using a scale from 1 to 5, where 1 indicates "not very significant" and 5 means "extremely significant", please rate what societal role engineers can play in promoting green energy and energy efficiency.



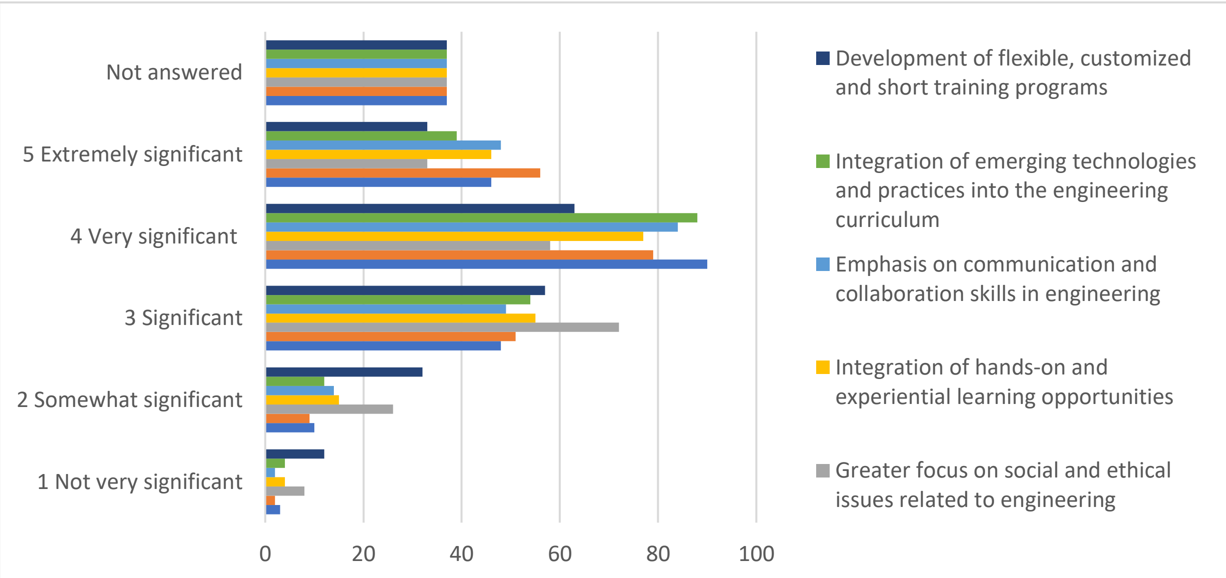
12. Using a scale from 1 to 5, where 1 indicates "not very significant" and 5 means "extremely significant", please rate how you think the engineering profession can leverage the potential of digital technologies to support SDGs and promote sustainable practices.



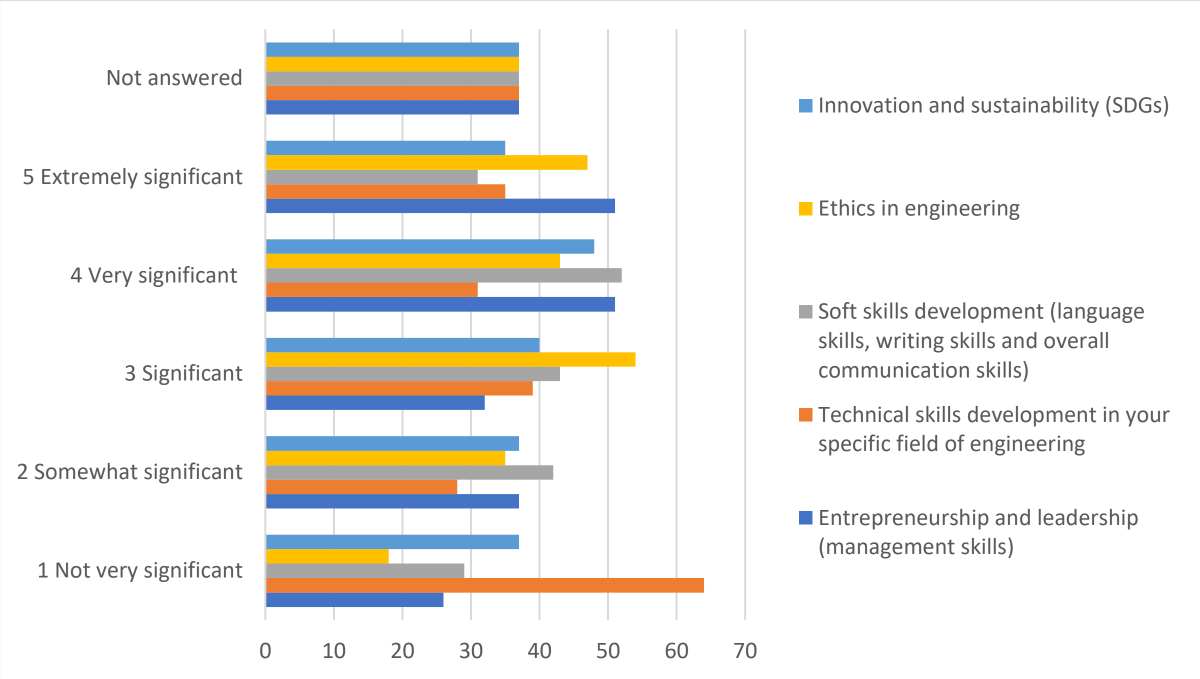
13. Using a scale from 1 to 5, where 1 indicates "not very significant" and 5 means "extremely significant", please rate what changes should be made to the engineering education and training programs to better prepare students for the evolving nature of the profession.



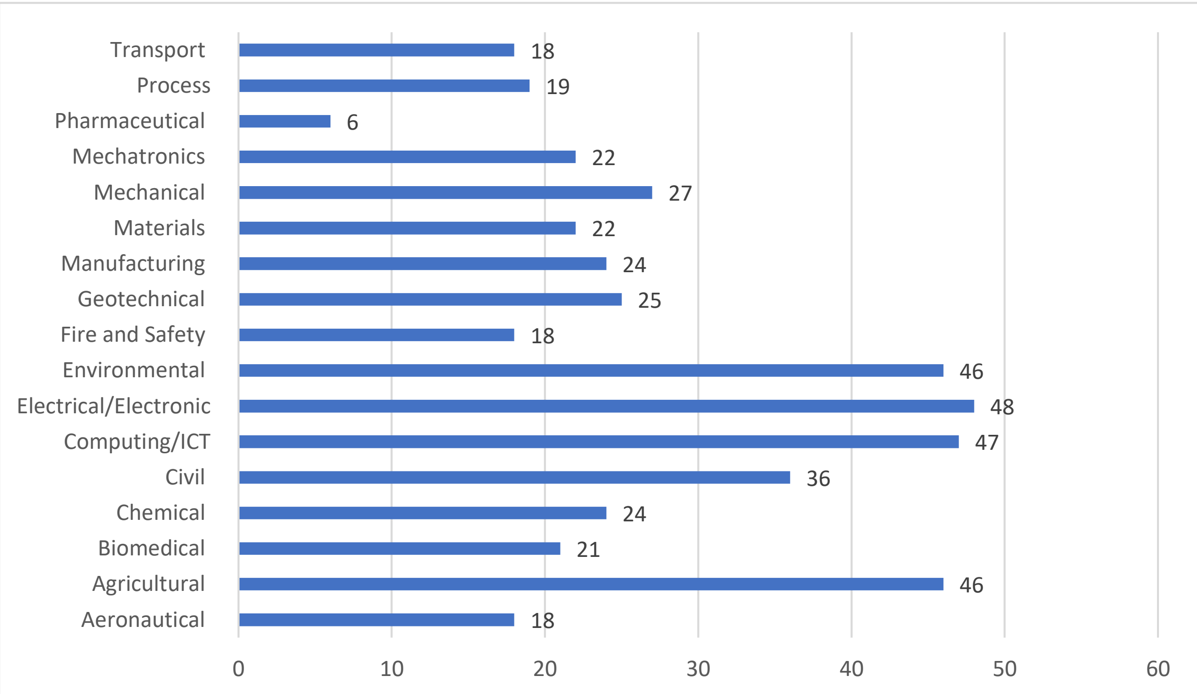
14. Using a scale from 1 to 5, where 1 indicates "not required" and 5 means "paramount", please rate what new approaches to formal engineering education and training are necessary to prepare engineers for the challenges of the 21st century.



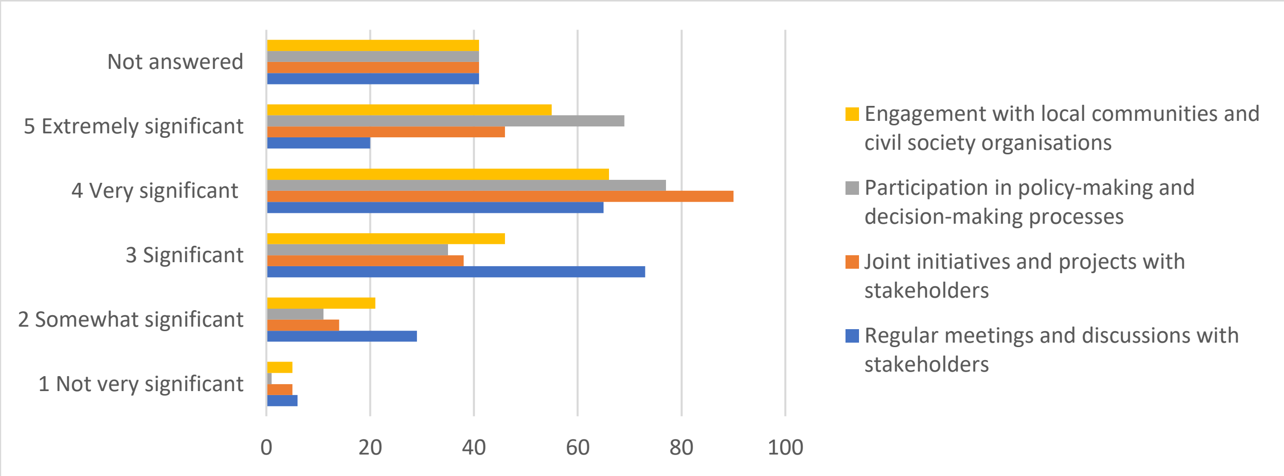
15. Please rank the following CPD courses in order of priority, 1 being your top priority choice:



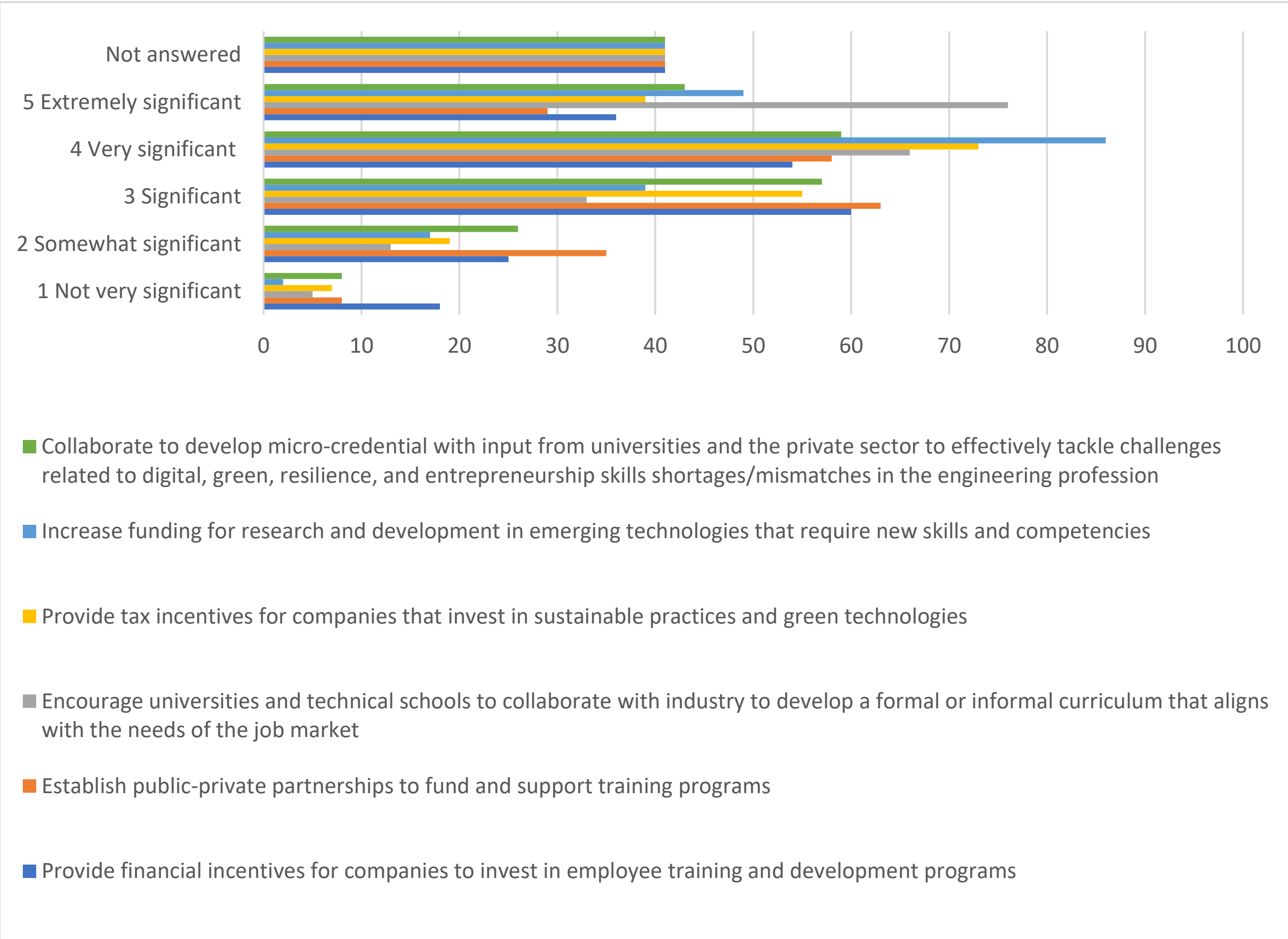
16. In your opinion, which engineering discipline will have a serious concern due to the future shortages of skilled engineers (3 options max.)?

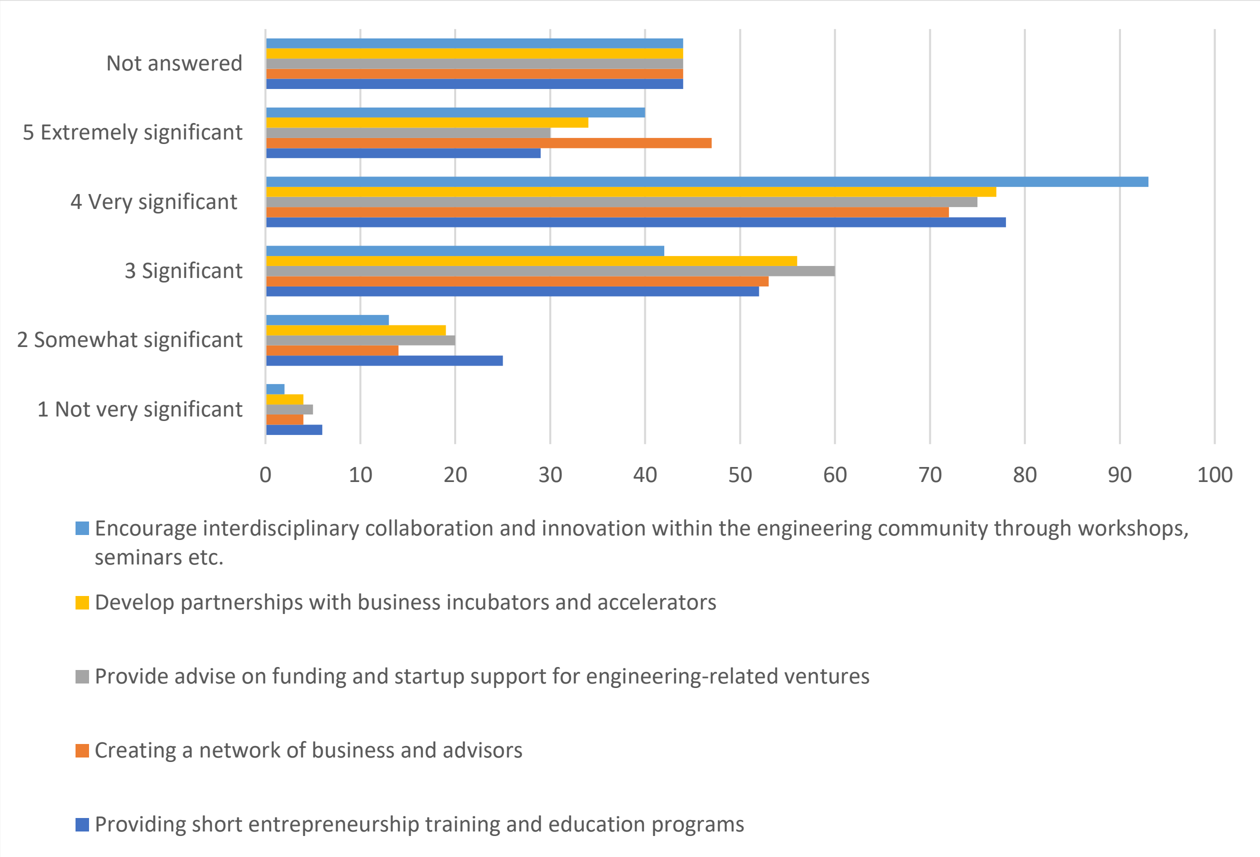


17. Using a scale from 1 to 5, where 1 indicates" not effective" and 5 means "extremely effective", please rate how can engineering professionals better collaborate with other stakeholders, such as policymakers, NGOs, and civil society organizations, to achieve SDGs?

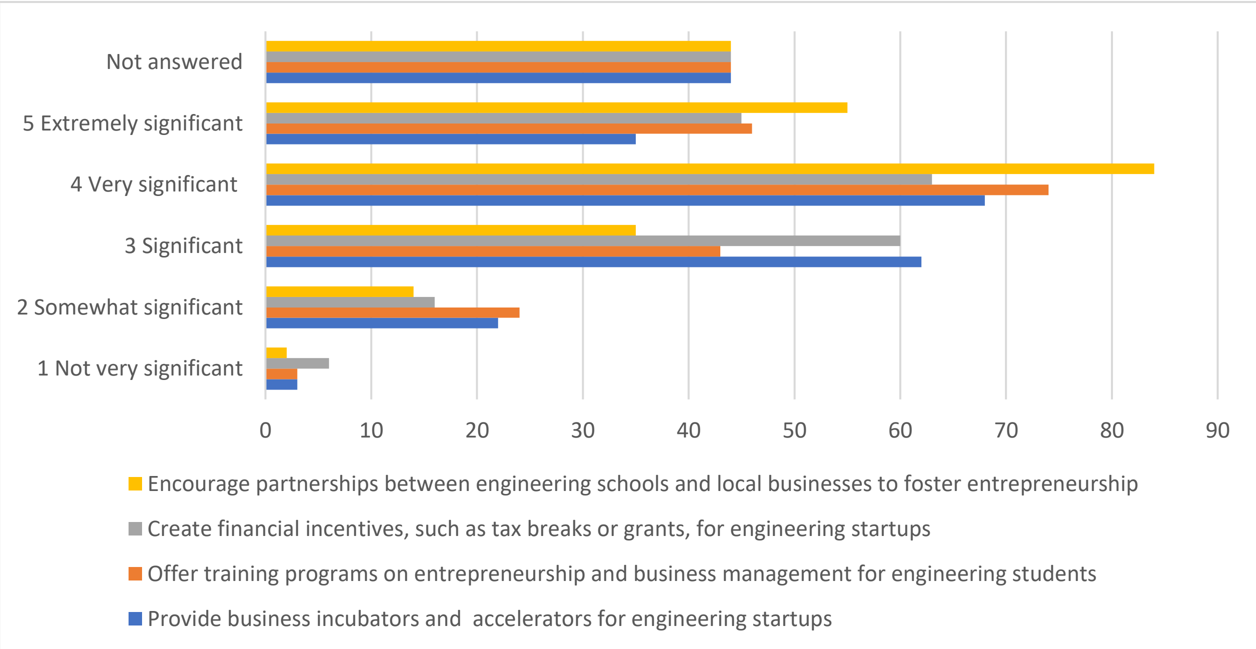


18. Using a scale from 1 to 5, where 1 indicates" not effective" and 5 means "extremely effective", please rate the following policies and initiatives at regional and national levels to address digital, green, resilience, and entrepreneurship skills shortages/mismatches in the engineering profession





20. Using a scale from 1 to 5, where 1 indicates" not effective" and 5 means "extremely effective", please rate the specific measures you believe should be taken to encourage an entrepreneurial mindset among engineers.



2.2 Interviews

2.2.1 Digitalization : The Voice of a Researcher on Artificial Intelligence

In this research, we sought guidance and inspiration from forward-thinking people such as Yoshua BENGIO, one of the founders of Artificial Intelligence. Prof. Yoshua BENGIO is professor of computer science at the University of Montreal and scientific director of the Montreal Institute for Learning Algorithms. Back in 2017, he was one of the initiators of the *Montreal Declaration*, which called for more ethical artificial intelligence. Along with Geoffrey HINTON and Yann LeCUN, Yoshua BENGIO won in 2019 the "TURING Prize", pretty much the Nobel Prize in computer science, for their role in the development of *"deep learning*", the branch of AI that led to unprecedented breakthroughs since 2010. In 2022, BENGIO was the most cited scientist in the world[1].

Being one of the founding fathers of Artificial Intelligence, he is today very worried about his invention. In 10 years, systems could already be smarter than us, he believes. "*I always thought we should try to imitate human intelligence. Now I think that would be a big mistake*".

"I didn't take the dangers of AI seriously, I thought: that's too far away."
Interview with Mr Yoshua BENGIO

How can we understand the radical changes our world is undergoing?

About five years ago, big companies like Facebook and Google started competing with each other in buying up AI start-ups. It became clear then that we had to switch tracks. This was no longer a purely intellectual exploration for science, we had to really think about how the technology would be used. But the momentum that the technology has entered in 2023 scares BENGIO outright. "DE STANDAARD" talked to him via video link about the baffling developments in recent months and his growing concerns.

What is your biggest concern?

The uncertainty and extent of the damage that can be done if we build machines that are smarter than ourselves. The technology can also be abused or used in an unwise way. Both scenarios could have catastrophic consequences.

When did you get the feeling that things were going faster than you expected?

It happened gradually, over the past few months, as I became more familiar with Chat GPT and later GPT-4 and thought and talked about it with colleagues from all over the world. BENGIO himself was the founder of the technology behind language models like GPT-3.5 (the AI system that drives ChatGPT) and its successor GPT-4, when 20 years ago he started training neural networks (computer programs inspired by how brain cells work) by feeding them with text. We started with very small data sets and very small neural networks, but the results were interesting anyway. In 2014, a new element was added: an attention mechanism, which allows the language model to better take context into

[1] We herewith reproduce an Interview by Dominique DECKMYN with Prof. Yoshua BENGIO, published in the Belgian newspaper, "De Standaard" in the weekend-edition of 1-2 July 2023. Original text was in Dutch.

account. When we did that at university, it worked just a little better than existing systems, but it wasn't really impressive. But Google built a bigger neural network, trained it on more data and did some good engineering on it. The result was stunning. Then we started to see the effect of scaling up: we don't actually need to modify the recipe of those neural networks that much, we just make them bigger, train them longer and on more data and they get amazingly better.

So, what exactly was it that you had not seen coming?

I thought the systems, even with so much training data, would fail when faced with new questions. But that turns out not to be the case. You can still get the systems to fail, but you already have to make a real effort to do so. Many people would also fail to answer the same questions correctly. So, I realised that we have reached some really important milestones. We passed the Turing test, the moment when you can no longer tell humans and machines apart when you interact with them by typing text. Officially that hasn't happened, but in practice this is what we see happening.

In recent months, concerns about developments have been growing. What is currently going wrong?

In fact, something good is just happening: more people are becoming aware of the dangers that may lie ahead. First it was the people who designed the technology and set up the companies around it. But politicians have also started getting involved, which is very important. I am convinced that there are ways to build secure AI systems - systems over which we cannot lose control, and which can really help humanity. The problem is: if we know how to build safe AI systems, then we also know how to build the dangerous ones – so, how do we prevent such a thing from happening ? And that is a political question, not a technical one.

Europe is working on an AI Act. Are we on the right track?

I fear that this is a very cumbersome instrument, when everything is evolving very fast now. We need a regulatory body that can quickly update its rules when new potential dangers emerge. There is also an interesting Canadian bill, which splits the role of the law and of the regulatory body in a flexible way. But these laws were designed even before ChatGPT and before the current debate about the loss of control and the threat to democracy. More checks on those potential dangers need to be built in. I understand that the G7 committee on AI guidelines will consider all the dangers and that is good.

Several AI industry frontrunners, such as OpenAI boss Mr Sam ALTMAN, openly state that they see great dangers and are pushing for regulation. How sincere is ALTMAN in this?

I don't know him well enough to answer that. He looks sincere, but on the other hand: declaring that regulation is needed and then saying that European legislation cannot possibly be respected does not sound very coherent.

Open AI did not invent the technology behind ChatGPT, but it was the first to market. Was that irresponsible?

We don't actually know exactly what's in their system. But we have indications that they brought together several existing elements - as happens more often - and they did that remarkably well. I think they certainly started with a strong intention to address the risks, including the risk of loss of control.

I read that they might let that concern wane a bit because of commercial pressures and the race they are in now, but I cannot say that for sure.

Yann LeCun, that other godfather of AI, thinks it is pointless to worry about superintelligence at this point, because we are still miles away from it.

That's not what he's saying, I think. I think he agrees that we are on a track that will lead to machines that are smarter than us. And not just in a century's time. Maybe that horizon is a bit further away for him than for me, but that's not a fundamental disagreement. As I understand it, LeCUN thinks we need not worry because we will be able to solve the problem when it presents itself. I personally think the stakes are far too high not to be as cautious as possible.

You signed the open letter calling for a six-month pause in the development of the most advanced AI systems in March 2023. Would that help?

Yes, but it won't happen. Even before the letter was published, I knew it would never happen. But the letter had a positive impact: it sparked discussion. That's an impressive achievement.

So what should happen now?

Geoff HINTON said a few weeks ago: we need to spend as much on improving algorithms as on making sure they are safe and that we protect the public. Researchers cannot do that on their own, we need to work with lawyers, with people who understand ethics, specialists in cybersecurity and in nuclear, biological and chemical weapons.

The big AI systems that are now evolving so fast, like GPT-4, can they be made safe?

The problem is not with the architecture, although we can always improve it. It is mainly the way the systems are trained that needs to change. And I have some ideas about that. One way to make systems secure is to guarantee that they have no "*agency*" (the ability to take initiative), that they don't even have a notion of their own purpose or plan. All they do is try to understand how the world works and use that knowledge to help us solve questions.

Systems like GPT-4 seemed to have no "agency", they just answer questions. But suddenly systems like AutoGPT are coming out, which turns ChatGPT into a kind of autonomous acting assistant. Is that what you call agency?

Yes, It is very easy to take something that serves as a kind of oracle that only answers questions and turn it into an agent. After all, the agent only needs to know: of all the possible actions I can take, which action will help me achieve my goal? And when you have the answer to that question, you take that action.

So AutoGPT is dangerous?

Not as it is now. Not much work has been put into it to make it right. And ChatGPT is not that smart yet. But suppose we go one step above GPT-4 in quality, let's say GPT-5 or something, then it could become dangerous. I regret not to have taken action sooner. I think that there is a psychological obstacle preventing us from seeing something so contrary to the goal we are working towards. And that is why I have not done what I had to do. These dangers have been known for 10-20 years, but we were not taken seriously because people like me thought: ah, that is still far too far in the future, we don't even have an idea yet of what such AI systems will look like, so how can we do anything about it today? But now the situation is different, now it is right in front of us. There are still a lot of technical obstacles with the current language models, but I believe they can be solved in no time. For instance, that systems like ChatGPT make up facts every so often, so-called "hallucinations", for example. That can be contained, a lot of people are working on that at the moment. And even in their current state, with all their flaws, those systems can be useful. All the people I see around me are using them. We broadly understand what is missing from those systems. Work is underway on algorithms that can improve that. Maybe we can solve all the problems in three to five years, and that is what worries me. Now, it remains possible that something else, something fundamental, is still missing that we don't see right now. That would actually be a good thing then, because it would give us more time to adapt. But what if, on the contrary, things happen faster than expected, as was the case last year?

You believe that superintelligence, an AI system that surpasses humans, could be here in 10 years?

Yes, as do many of my colleagues.

However, other researchers say there are still too many unresolved issues, that it will take much longer.

Absolutely. And had you asked me that question a year ago, I would have said 20 to 100 years. Now I say: 5 to 20 years.

So how do you look at your own research now? Do you find it dangerous?

My research has certainly helped to bring us where we are today. All those questions I ask myself every day: what is the best use of my time to minimize the risks and maximize the benefits for all humanity?

It sounds like you are really struggling with that.

You are right. There are no easy answers here.

Your research would make it possible for AI systems to think more like us, but you don't actually think that's a good idea anymore?

Throughout my career, I have thought we should take inspiration from humans, try to imitate our own intelligence. Now I think that's a mistake. It is important to understand how the brain works, but building machines that are very similar to humans would be a big mistake in many ways. In science fiction, we see androids and AI systems that are more or less like humans, but mechanical. Like Data in Star Trek. I don't think that picture is accurate. For a start, machines are essentially immortal, because they can copy their program code and state. We are fundamentally different. We design those machines because we want to build tools that help us. But we may be creating a new species that is dangerous to us and even to the survival of our own species. In the past, many species went extinct, usually because a smarter species came along. In the last few centuries, we have caused the extinction of about a thousand species. Not because we wanted them dead, but because they stood between us and more land or more money.

So, you currently believe it is better that we never reach that superintelligence?

I'm not saying that. If we reach that superintelligence safely, it could help us with many of the challenges facing humanity, such as disease, climate change, poverty and economic inequality: problems we are making no or hardly any progress on. But we need to do it in a safe way. And right now, we don't actually know how to do that. So we need to take it slowly and work on measures that can limit the damage. The other problem is: even if I, or someone else in a few countries, decides to slow down, there are still people in other countries who do not. So, what do we do about that? One of the things my friend and colleague Yann LeCUN says, and with which I agree, is that we will probably need the help of some AI systems to protect us from possible loose AI's. So there we are: we need those systems, but at the same time we don't want them. And if they do turn up somewhere, we need them to protect us from them. It's like nuclear weapons, isn't it? Nuclear weapons are dangerous, but if someone else is going to build them, then we need them too. We have to learn to deal with that.

Should we worry about the future?

Worrying in itself is not useful. We need to act. Firstly, to understand these issues better, because there is a lot we don't understand yet. A good indication of this is that there is so much disagreement among researchers. In addition, we need to provide regulation, international agreements, to get on a path to safety and fairness, with the intention of better protecting the public.

Do governments still have time to act? There are already open source versions that anyone can just download and further edit. Surely you can't stop that anymore?

No, current systems are still too stupid to be really dangerous. Yes, they can be used for disinformation. But the really big dangers are still a few years ahead of us, so it's not too late. But we will have to draft legislative measures much faster than we did, for example, against climate change. In that, we were far too slow.

2.2.2 Green: The Voice of a Captain of Industry in the Automotive Sector

Luca DE MEO, the new President of the European automotive umbrella organization ACEA, does not spare his criticism of the EU. While the European Union started to regulate its automotive sector ever more strictly - just think of the ban on new diesel and petrol cars from 2035, or the tightened emissions standards since dieselgate - manufacturers stayed on the sidelines for too long, says Luca DE MEO, the CEO of RENAULT and, since this year, the president of ACEA, the mouthpiece for the European automotive sector.[2]

"To make e-cars, we still need to sell a lot of internal combustion engines."
Interview with Mr Luca DE MEO, CEO RENAULT

We are facing a fundamental transition to low-carbon technology and are coming under pressure from all sides, says the Italian CEO of the French carmaker in an interview with some European media, including De Standaard. DE MEO wants the automotive sector to weigh in more on the debates,

[2] We herewith reproduce an Interview by Korneel DELBEKE with RENAULT CEO Mr Luca De MEO, published in the Belgian newspaper, "De Standaard" on 12 June 2023. Original text was in Dutch.

because if it does not get a hearing in Brussels, billions of investments risk going the wrong way, it sounds.

This puts the Euro-7 emissions standard, which the Commission wants to introduce from 2025, in the spotlight. Among other things, this should reduce nitrogen dioxide emissions by 35% and harmful particulate emissions by 13%. But the latest Euro 6 cars have already reduced particulate emissions by 80%. With the Euro 7, that would be 84%, says DE MEO. For those limited environmental gains (CO_2 emissions will even rise, it sounds, ed.), the industry has to invest billions and car prices will continue to rise at a time when purchasing power is under pressure. This is all the more true for cheaper entry-level models. DE MEO cites an "independent study" showing that the average new car will increase in price by some EUR 2,000, which is four to 10 times more than the Commission's calculations. Developing the Euro 7 will only divert manufacturers' attention and resources from the much-needed transition to electric cars, according to DE MEO. However, we can keep the stricter emission standards for brakes and tyres, as these are also useful in electric cars, he says.

Critics, such as environmental umbrella "Transport & Environment", then point out that while the industry calls the new standards "unaffordable", Europe's largest carmakers are paying record dividends. DE MEO cannot speak for his colleagues, but says that at RENAULT, he has had "no money to pay dividends" for several years - partly due to the big losses in Russia after the invasion. But however, you spin it, money does not grow on trees and what we invest in Euro 7 is not going to electrification. And that while China is coming on strong with electric cars and is meanwhile a generation ahead in developing the supply chains for them.

To meet this challenge, Europe must pull together and urgently set out an ambitious strategy, says DE MEO. Introducing rules and imposing fines if they are not met is not yet a strategy. Regulation is only one part of the story. The challenges, from infrastructure, to energy provision and data use, are crucial in this, but go wider than just the car industry. We are not questioning the target and the investments have already been made. We are just asking for a bit more flexibility, like on emissions standards. It is a strange paradox: to invest enough money in the transition, we will still have to make a lot of money from the combustion engine.

2.2.3 Knowledge Migration: The Voice of Academia and Business Associations

Too much administration and regulation keep foreign talent away from our country (Belgium). Internationalization policy could be smarter.[3]

As an open economy without natural resources in the heart of Europe, we are by definition heavily dependent on foreign countries. The international embedding of higher education and scientific research at our universities is a conditio sine qua non to maintain prosperity and welfare and

[3] We herewith reproduce an article which was co-authored by Jan DANCKAERT (Rector, Flemish University Brussels, VUB), Hans MAERTENS (Deputy Director, Flemish Network of Companies, VOKA), Luc SELS (Rector, Katholieke Universiteit Leuven, KUL), Pieter TIMMERMANS (Director, Federation of Belgian Enterprises, FEB), Rik VAN DE WALLE (Rector, Ghent University, UGent), Jan VAN DER GOTEN (Head of Strategic Partnerships, J&J), Herman VAN GOETHEM (Rector, Antwerp University), Bernard VANHEUSDEN (Rector, Hasselt University), Koen VERLAECKT (Secretary General, Flemish Interuniversity Council, VLIR) and published in the Belgian newspaper, "De Standaard" on 29 June 2023. Original text was in Dutch.

strengthen our innovative power. The same goes for our companies, which are strongly committed to exports and attracting foreign direct investment.

The need for highly qualified employees at universities and knowledge-intensive companies has long been unable to be met by domestic supply. The increasing tightness in the labour market, with a scarcity of STEM profiles in particular, is assuming the proportions of a real war for talent, which according to all forecasts will drag on for years.

Our country urgently needs to become more attractive to foreign talent. The legislative framework and related administrative processes are in some cases more of an inhibiting factor than an incentive for internationalization. Government departments are often too out of touch with the needs of knowledge actors. Transposition of European regulations is often late, leading to avoidable woeful mistakes.

Our internationalization policy needs to be smarter. This requires a joining of forces between governments, knowledge institutions and companies: consistent, predictable, aligned across levels of competence and based on co-creation. To this end, we formulate a number of concrete tasks for our governments at federal and state level and call on all public and private knowledge actors in Flanders and Brussels to endorse this plea.

A first yardstick is the regulation of knowledge migration. The procedures for attracting knowledge workers from outside the EU were recently adjusted in a positive direction, but we continue to run into obstacles. Not surprisingly, foreign knowledge workers opt for our neighbouring countries. Administrative processing times for dealing with combined residence-work permits and visa applications are too long, and digital processes are not aligned enough. Family reunification is sometimes difficult. A "fast track" procedure for highly skilled profiles could provide relief.

Knowledge security is a second yardstick. International cooperation requires universities and companies to be able to reliably assess potential risks. Think of unwanted technology transfer or human rights violations. We therefore call for the federal and regional governments to work together to create a knowledge security desk that provides validated advice within realistic deadlines. Protecting and safeguarding our knowledge potential must be an essential part of our economic security policy.

A third yardstick is the language regime in higher education. It hinders the influx of foreign talent, among teachers, students and researchers. We call for the necessary flexibility, without questioning its basic principles. This can be perfectly achieved through a number of rule-free pilot projects for courses and personnel categories to be defined in consultation between universities, the business world and the government.

Taxation is the fourth yard. The federal partial exemption from pass-through withholding tax for researchers is an important lever for stimulating innovation and attracting foreign investment. We call for this measure to be at least consolidated and extended where possible as part of the announced fiscal reforms. Moreover, some counterproductive rules in the reformed expatriate tax benefit regime for incoming researchers should be axed.

Finally, we call for the government to be more active in ensuring a warm welcome (soft landing) for incoming knowledge workers. It would be advisable to develop a network of so-called expat centers, which, as a single point of contact, would be the direct point of contact for knowledge workers and their families, without them having to figure out for themselves which service to turn to. It is also important to have sufficient capacity and a good spread of international schools across Flanders. We call on our policymakers to join us in working on these yards that remove barriers to knowledge migration and strengthen our competitive position vis-à-vis neighbouring countries.

Transversal: The Voice of a Captain of Industry in the Aerospace Sector

On 8 June 2023, at the ENGINEERS EUROPE National Members' Forum in France, Mr. Daniel BOURIC, Plant Director at THALES Alenia Space, focused in his presentation on Corporate Social Responsibility (CSR) and the engineering competences for the future. The THALES Group - with 77.000 employees (approx. 50% in France) in 68 countries worldwide and EUR 17,6 billion of sales in 2022 - plans to recruit 4.000 students as interns with a potential conversion into full-time contracts. In 2018, one third of new hires at THALES were women. In France every year some 40% of interns in engineering are converted into unlimited employment contracts.

In the Q&A which followed with the representatives of the Engineering Professional Organizations of 33 countries, it was acknowledged that a good technical engineering education (hard skills) will still be the backbone of the competence of future engineers, but that the technical abilities and capabilities need to be completed with other (soft) skills which impossibly can all be part of the academic engineering curricula : from creativity, communication and foreign language skills to digital and AI competences, data literacy, sustainability, entrepreneurship, etc. Therefore, Life-Long-Learning (LLL), Continuous Professional Development (CPD) and on-the-job training are paramount in enhancing these competences after entering the labour market, especially as industry is apart from hiring specialists, also increasingly searching to recruit all-round graduates.

As to the question how the engineering profession will evolve over the next 5 to 10 years, he acknowledged the opinion of the National Professional Engineering Organizations, i.e. National Members of ENGINEERS EUROPE[4] who identified the following major challenges :

- The formation of an engineer is and will be changing ever more : this requires re-education, up-skilling, reskilling of currently professionally active engineers especially in the field of green energy, AI, cybersecurity and sustainability.
- Enhance and promote the image of the profession to attract more young people (STEM) in order to better meet the market demand for engineers.
- Soft skills to become a method in the way hard skills are being taught without prolonging the duration of the formal engineering education.

3. Qualitative Research

3.1. Image and Standing

Engineers dream about making things better, they see possibilities; they are curious and ask questions like *"how does it work", "what will happen if"*, etc.; they are creative problem-solvers and have a

[4] https://www.engineerseurope.com/membership-list

passionate vision on how something should work; they work together with other smart people such as chemists, physicians, astonomers, etc. to design and create new things. From research to real-world applications, engineers constantly discover how to improve our lives by creating new solutions that connect science to life in unexpected, forward-thinking ways. Few professions turn so many ideas into so many realities; few have such a direct and positive effect on people's everyday lives and society counts on them and their imagination to help us meet the needs of the 21st century. Yet, until a few years ago, this does not seem to be reflected in the overall general perception society has of who engineers are.

From Current Perception	**To a New Perception**
Builders, operators, planners	Designers, creators and inventors
Computer people	Many types of engineers
Geeks and nerds	Creative professionals, imagineers
White males	People of all backgrounds
Boring	Dynamic and exciting work, that makes a difference
Too difficult to learn	Challenging but worth the effort
A man's job	Engineering is a field for men and women
Not as prestigious as a scientist	A prestigious job that makes the world a better place
Less lucrative than law or medicine	Supports a very comfortable lifestyle

A strong positioning statement like this one is required for all public communications, be it in advertising, recruitment, presentations, etc. and should be shared with the public at large in order to set engineers apart from other professions and to make a clear case why engineering matters. Whereas this opinion was expressed by the US "National Academy of Engineering", back in 2008[5], even Europeans will acknowledge 15 years later that a longer term image-effort is required, if in the future Europe wishes to have a sufficient number of engineers.

Engineers are seen as leading figures in the modern world, as they are constantly pushing boundaries with creative solutions to difficult questions. They are also highly sought after for their problem-solving skills, making their skillset invaluable to many industries. We may conclude that though the overall image of the engineer is not entirely negative, there is a lack of understanding of the contribution of engineers in the public perception. Compared to other professions (medicine, law, architecture, etc.), engineering is held in high regard by the public. Public polling over the years has also consistently revealed that the public considers engineers to be ethical - yet, there remains a knowledge gap about the profession. The public perception of engineers is positive, but most individuals are not completely aware of how engineering affects their lives. In addition, engineers don't get much coverage in the media unless there is a catastrophic infrastructure failure. So what's the problem? Engineers aren't doing enough to educate the public.[6] Albeit that this observation is beyond the scope of the E4E-project, it may be one of the reasons why there is a shortage of engineering graduates in many European countries as related to all the engineering work that can or needs to be done.

[5] "*Changing the Conversation : Messages for Improving Public Understanding of Engineering*", National Academy of Engineering, Washington DC, 2008
[6] https://www.nspe.org/resources/pe-magazine/may-2013

3.2. Education and Competences

Educational instruments to measure "capability" and "quality" of students, including engineering students, are often restricted and limited to verifying the evidence of what is learned and at what level. It is process oriented, but in this sense, these instruments are more backward- than forward looking : they lack the focus on future needs of both society and the graduated engineer in that society. Peer review can be a helpful- but can also be a doubtful model, since peers may not be well informed about modern methods and approaches in examining the variation of requirements over time.

Present instruments for measuring quality offer limited evidence about the real quality and relevance of degree programmes and their performance. However, if academic and professional experts can agree on a set of required learning outcomes, they should also be able to measure performance in a comparative perspective and in international contexts.

In this perspective reference can be made to the *TUNING Academy*[7] and in particular to CALOHEE, the "*Comparable Achievements of Learning Outcomes in Higher Education in Europe*"[8]. It has, amongst other disciplines, defined the core competences and the "learning outcome descriptors" for civil engineering programs for first and second cycles of higher education, based on a merger of the EQF for Life-Long-Learning and the QF for the EHEA in terms of dimensions. Learning outcomes are defined in that document as statements of what a learner is expected to know, understand and be able to demonstrate after completion of a learning experience. These learning outcomes are grouped in terms of knowledge, skills and wider competences (attitudes). Some competences are subject-area related (specific to a subject area), while others are generic (relevant for many degree programmes).

Most institutions of higher education measure learning in credit hours, meaning that they are very good at telling how long a student sat in a particular class, but not what the student actually learned. The timing is fixed, but the learning can be variable. A report from the Carnegie Foundation think-tank acknowledged that the credit hour, also known as the Carnegie unit, was "miscast as a measure of student learning".[9] Competency-based learning flips time-based learning on its head, and centres on mastery of a subject, regardless of the time it takes to get there. From a debate held in the light of the *"5th International Conference of the Portuguese Society for Engineering Education"* on 6 July 2023, engineering students[10] felt that engineering programs do not address sufficiently the sustainability issues, theories, concepts, case studies, problem approaches and desired necessary competences. None of the students said they were aware of the GreenComp Sustainability Framework[11] and that

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[7] The Tuning Academy (http://tuningacademy.org) is an International Higher Education and Research Centre for the development and enhancement of the quality of learning, teaching and assessment in higher education, focusing on the competences for intellectual development, employability and citizenship in a global context. It had its origin in successful large scale innovative projects carried out under the direction of the University of Deusto Bilbao (Spain) and the University of Groningen (The Netherlands) since 2000. The aim of the Tuning Academy is to be an organisation which is permanently aware of social demands and future needs, playing a key role in Higher Education through research, experimentation, educational innovation and support for decision making in policy on education and employment. Ref. : Prof. Robert Wagenaar,*"REFORM ! TUNING the Modernisation Process of Higher Education in Europe : A Blueprint for Student-Centred Learning*", 2019.

[8] https://www.calohee.eu

[9] Elena Silva, Taylor White and Thomas Toch, "*The Carnegie Unit: A Century-Old Standard in a Changing Education Landscape*", Stanford, CA: Carnegie Foundation for the Advancement of Teaching, 2015.

[10] https://cispee2023.uminho.pt

[11] https://joint-research-centre.ec.europa.eu/greencomp-european-sustainability-competence-framework_en

teachers did not present, nor had themselves, any formal training on sustainability. In addition, students outside the related engineering programs stated there was not any training or education concerning artificial intelligence or automation in the curriculum.

In the **European Commission**'s *"Communication on a European Strategy for Universities"*[12] it is explicitly stated that universities have a key role to play in preventing skills mismatches and bottlenecks that risk hindering Europe's recovery, and in enabling the development of learners as creative and critical thinkers, problems solvers and active and responsible citizens equipped for lifelong learning (LLL). (…) The digital transition gives universities a fundamental role in equipping students and researchers with the digital skills and competences needed in the new reality and in the promotion of innovation and new technologies. Subsequently, in 2022, the **European Council** made a *"Recommendation on a European approach to micro-credentials for LLL and employability"*[13]. Therefore, Continuing Professional Development (CPD) is critical in maintaining engineering competence throughout the engineer's career. Together with changes in education curricula, CPD provides an ideal means to support the adaptation of the United National Sustainable Development Goals (UN SDGs) into everyday practice.

A key component in establishing the qualifications is the European Engineering Education Database (EEED), listing the institutions of engineering higher education in European countries represented within ENGINEERS EUROPE and their engineering programmes[14], which are all recognized by ENGINEERS EUROPE as fulfilling the typical education requirements for the EUR ING title[15]. The EEED is an authoritative source of information about national engineering education systems and educational institutions and it is used by major European industries in aeronautics, automotive, power- and information technologies, etc. for cross checking engineers' applications, but also by international/regional membership/registration bodies to check the status of European degrees. ENGINEERS EUROPE will continue to develop these offerings to inform and enhance the standing and reputation of the professional engineer in Europe and because it has a role to play in communicating the importance of the role of engineers for the development of European economic and industrial activities.

3.3. Opportunities

The European Economic and Social Committee's (EESC) contribution to the European Commission's work programme for 2023[16] describes the challenges and opportunities in the European arena, including:

• Social cohesion
• Innovation
• Climate change mitigation
• Energy union (RePowerEU)
• Re-industrialisation : e.g., Artificial Intelligence (AI), etc.

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12 https://education.ec.europa.eu/document/commission-communication-on-a-european-strategy-for-universities, 18 January 2022.
13 https://www.consilium.europa.eu/en/press/press-releases/2022/06/16/council-recommends-european-approach-to-micro-credentials/ ,16 June 2022.
14 https://www.engineerseurope.com/what-engineers-europe-eeed
15 https://www.engineerseurope.com/what-eur-ing-certificate
16 https://www.eesc.europa.eu/en/our-work/publications-other-work/publications/european-economic-and-social-committees-contribution-2023-european-commissions-work-programme

The spike in energy costs and economic uncertainty make addressing these matters even more necessary and challenging. The EESC calls for the mobilisation of both public and private financing to facilitate investments in research and innovation, education, training and technical infrastructure. Also entrepreneurship represents a key competence for improving our European competitiveness and our innovation will have to focus on the development of a social and green economy, even more so in the context of a post pandemic recovery.

Engineers need not just be the creators of things but also creators of employment and economic activity. To do this requires a re-positioning of how engineers think about their role in society and how society thinks about engineers. The decreasing lifecycle of ever more complex technologies emphasises the need for up-skilling engineering talent, using a combination of academic and work-based training for the entire career of the engineer, including commitment to self-study. Governments need to ensure that legal, commercial and employment supports, are flexible to facilitate greater entrepreneurial and technology driven activities.

3.4 Challenges

Corporate leaders are prone to suggest that academic or institutional inertia is real and that educational infrastructure fails to keep pace with the technological transformation of the economy, but the onus is on companies just as much as it is on higher education to respond more rapidly and urgently to the changing nature of work.

As the **Massachusetts Institute of Technology** (MIT), economist Erik BRYNJOLFSSON said : “*Investing in new technology can often be easier for companies than negotiating the organizational challenges that come with reskilling workers*”,[17] whereas Mike DEREZIN, Vice President of **LinkedIn**, states that companies can stay ahead in the talent war by recruiting from within.[18] The company **FutureFit** works with the OECD (Organization for Economic Cooperation and Development) and McKinsey to help people, companies and governments leverage intelligence to identify transition pathways.[19] With recommendation and matchmaking algorithms, FutureFit has a personality profiler as well as a profile parser to make sense of candidates’ resumes and profile data and match them to open jobs. It also layers on a skills gap analyser and learning recommendation app, so that users can access filtered learning content from 30.000 institutions in order to fill those skills gaps. “Sky Hive’s Human Capital Operating System” calls its approach “quantum labour analysis” to encapsulate the notion that it is analyzing a workforce at its most granular level.[20] “*People don’t know their own skills, and employers don’t know the skills of their workforce. They know job descriptions and roles and that is it*,” says Sean HINTON, founder and CEO of **Sky Hive**. “*They may not even understand how the skills required for a certain role are changing*”.[21]

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[17] Lauren Webber, “*Why Companies Are Failing at Reskilling*”, The Wall Street Journal, 19 April 2019, https://www.wsj.com/articles/the-answer-to-your-companys-hiring-problem-might-be-right-under-your-nose-11555689542

[18] Fast Company, 14 June 2019, https://www.fastcompany.com/90363915/companies-can-stay-ahead-in-the-talent-war-by-recruiting-from-within-says-this-linkedin-vp.

[19] FutureFit AI, “*AI for the Future of Work & Skills*”, 2020, https://www.futurefit.ai/

[20] Sky Hive, “*The World’s Reskilling Engine*”, 2020, https://www.skyhive.io/en-ca/enterprise

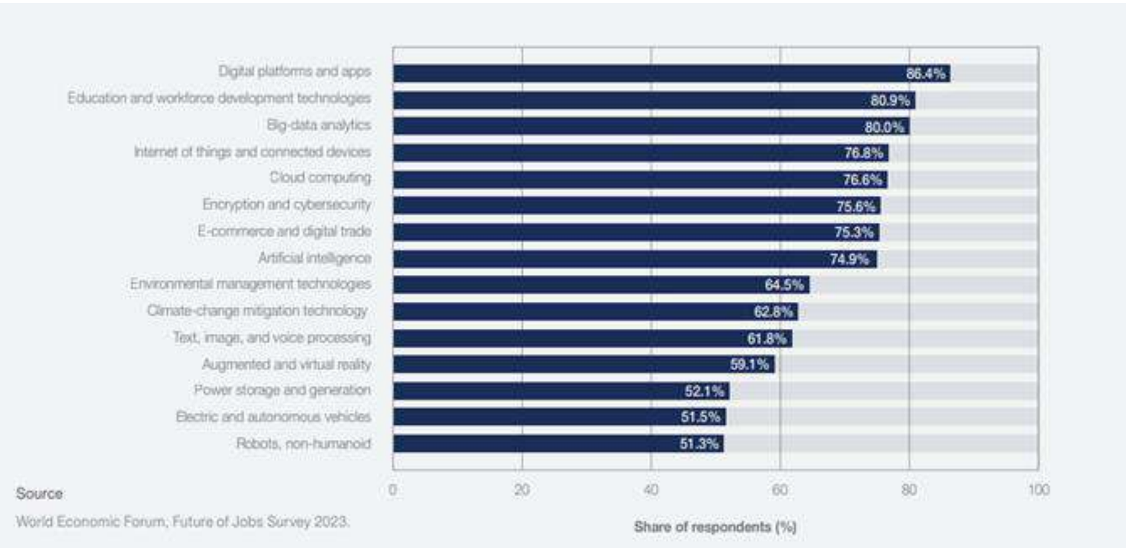
[21] Sky Hive team, interview of 12 February 2020 with Michelle R. Weise, in “*Long Life Learning : Preparing for Jobs that don’t even Exist yet*”, 2021

Over the past five years, the **World Economic Forum**[22] (WEF) has tracked the arrival of the future of work, identifying the potential scale of worker displacement due to technological automation and augmentation, alongside effective strategies for empowering job transitions, from declining to emerging jobs. At the core of their reports and its analysis, is the "*Future of Jobs Survey*", a unique tool which assesses the short- and long-term trends and impact of technological adoption on labour markets.

The data outlined in the following pages tracks technological adoption among firms alongside changing job requirements and skills demand. These qualitative survey responses were further complemented by granular data from new sources derived from privately-held data that tracks key jobs and skills trends. Together, these two types of sources provide a comprehensive overview of the unfolding labour market trends, as well as an opportunity to plan and strategize towards a better future of work.

The past years have seen a clear acceleration in the adoption of new technologies among the companies surveyed. Figure 1 below presents a selection of technologies organized according to companies' likelihood to adopt them by 2027. Cloud computing, big data and e-commerce remain high priorities, following a trend established in previous years. However, there has also been a significant rise in interest in encryption, reflecting the new vulnerabilities of the digital age, and a significant increase in the number of firms expecting to adopt non-humanoid robots and artificial intelligence (AI), with both technologies slowly becoming a mainstay of work across industries. These patterns of technological adoption vary according to industry.

Figure 1: Technology adoption 2023-2027: Technologies ranked by the share of organizations surveyed who are likely to adopt this technology over the next 5 year



As demonstrated in Figure 2, AI is finding the most broad adaptation among the Digital Information and Communications, Financial Services, Healthcare, and Transportation industries. Big data, the Internet of Things and Non-Humanoid Robotics are seeing strong adoption in Mining and Metals, while the Government and the Public Sector industry shows a distinctive focus on encryption. These new

[22] World Economic Forum,"*The Future of Jobs Report*", October 2020 and May 2023; https://www3.weforum.org/docs/WEF_Future_of_Jobs_2023.pdf

technologies are set to drive future growth across industries, as well as to increase the demand for new job roles and skill sets.

Such positive effects may be counter-balanced by workforce disruptions. A substantial amount of literature has indicated that technological adoption will impact workers' jobs by displacing some tasks performed by humans into the realm of work performed by machines. The extent of disruption will vary depending on a worker's occupation and skills set.

Data from the Forum's "Future of Jobs Survey" show that companies expect to re-structure their workforce in response to new technologies. In particular, the companies surveyed indicate that they are also looking to transform the composition of their value chain (55%), introduce further automation, reduce the current workforce (43%) or expand their workforce as a result of deeper technological integration (34%), and expand their use of contractors for task-specialized work (41%).

A new wave of AI systems may also have a major impact on employment markets around the world. Shifts in workflows triggered by these advances could expose the equivalent of 300 million full-time jobs worldwide to automation, **Goldman Sachs** says (Briggs and Kodnani). They further estimate that, of those occupations that are exposed, roughly a quarter to as much as half of their workload could be replaced. But not all that automated work will translate into layoffs, the report says. "*Although the impact of AI on the labour market is likely to be significant, most jobs and industries are only partially exposed to automation and are thus more likely to be complemented rather than substituted by AI*"[23]. In addition, jobs displaced by automation have historically been offset by the creation of new jobs, and the emergence of new occupations following technological innovations accounts for the vast majority of long-run employment growth. For example, information-technology innovations introduced new occupations such as webpage designers, software developers and digital marketing professionals.

A recent study by economist David Autor, Professor at MIT [24] found that 60% of today's workers are employed in occupations that didn't exist in 1940. This implies that more than 85% of employment growth over the last 80 years is explained by the technology-driven creation of new positions. Generative AI can streamline business workflows, automate routine tasks and give rise to a new generation of business applications, says Kash Rangan, senior U.S. software analyst in **Goldman Sachs** Research[25]. The technology is making inroads in business applications, improving the day-to-day efficiency of knowledge workers, helping scientists develop drugs faster and accelerating the development of software codes, among other things. As more generative AI tools are developed and layered into existing software packages and technology platforms, Goldman Sachs sees businesses across the economy benefiting, from enhancing office productivity and sales efforts, to the design of

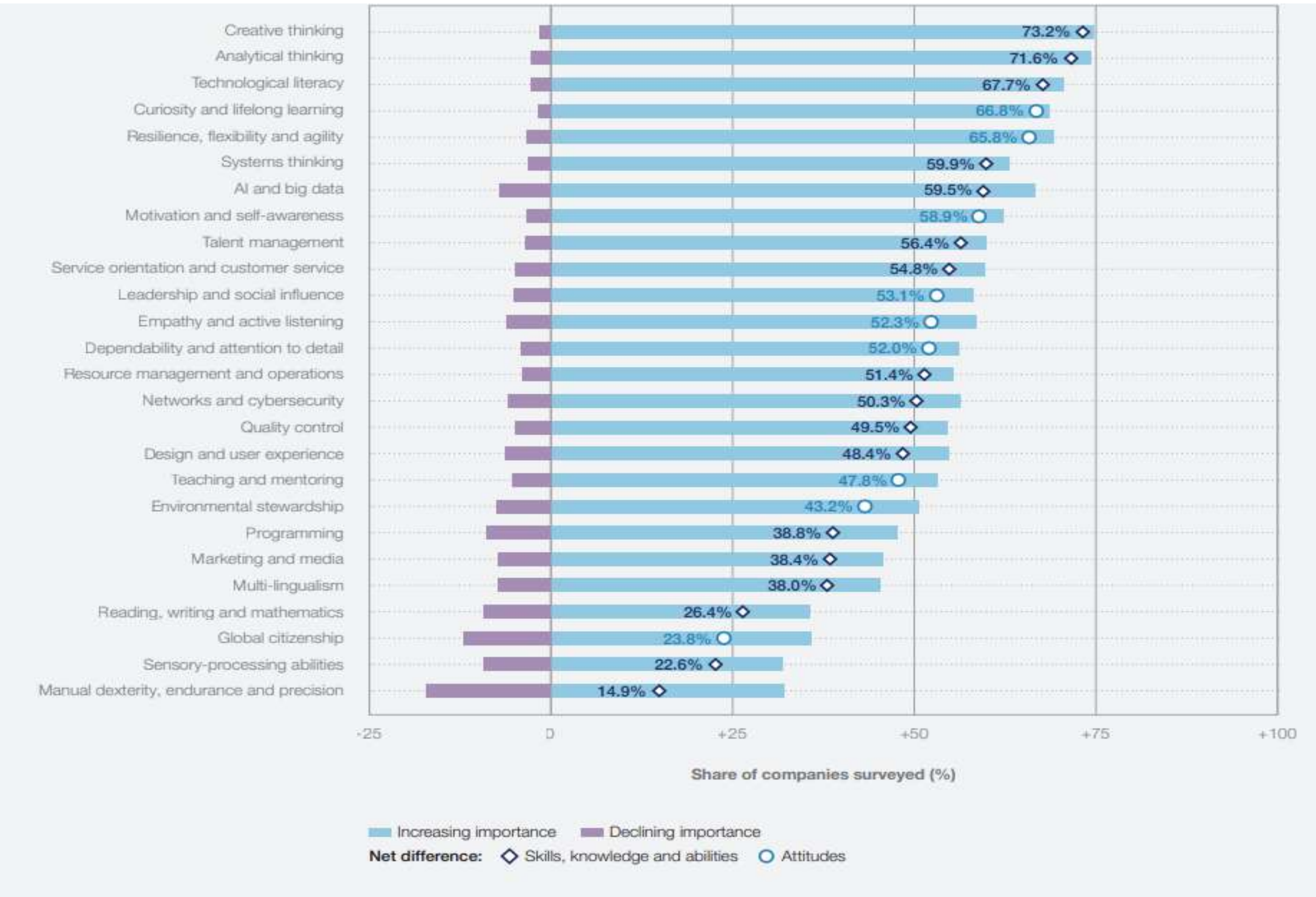
[23] https://www.goldmansachs.com/intelligence/pages/generative-ai-could-raise-global-gdp-by-7-percent.html This article is being provided for educational purposes only. The information contained in this article does not constitute a recommendation from any Goldman Sachs entity to the recipient, and Goldman Sachs is not providing any financial, economic, legal, investment, accounting, or tax advice through this article or to its recipient. Neither Goldman Sachs nor any of its affiliates makes any representation or warranty, express or implied, as to the accuracy or completeness of the statements or any information contained in this article and any liability therefore (including in respect of direct, indirect, or consequential loss or damage) is expressly disclaimed.

[24] "*How AI could help rebuild the middle class*", by Greg Rosalsky, Molly Messick and dave blanchard, 17 may 2023. https://www.npr.org/2023/05/16/1176516094/artificial-intelligence-david-autor-chatgpt-labor

[25] "*Are we on the cusp of a generative ai revolution*?", Goldman Sachs research, 21 February 2023. https://www.goldmansachs.com/intelligence/podcasts/episodes/02-21-2023-sheridan-rangan.html

buildings and manufactured parts and detecting cyber fraud. While much is unknown about how generative AI will influence the world economy and society, and it will take time to play out, there are clear signs that the effects could be profound.

Figure 2: Share of organizations surveyed by the WEF which consider skills to be increasing or decreasing in importance, ordered by the net difference.



Job disruption is counter-balanced by job creation in new fields, the so called "jobs of tomorrow". Over the coming decade, a non-negligible share of newly created jobs will be in wholly new occupations, or existing occupations undergoing significant transformations in terms of their content and skills requirements. The World Economic Forum's "Jobs of Tomorrow" report, authored in partnership with data scientists at partner companies LinkedIn and Coursera[26], presented in 2020 for the first time a way to measure and track the emergence of a set of new jobs across the economy using real-time labour market data.

The data from this collaboration identified 99 jobs that are consistently growing in demand across 20 economies. Those jobs were then organized into distinct professional clusters according to their skills similarity. This resulting set of emerging professions reflects the adoption of new technologies and increasing demand for new products and services, which are driving greater demand for Green

[26] https://www.coursera.org

Economy jobs, roles at the forefront of the data and AI economy, as well as new roles in engineering, cloud computing and product development (Figure 3).

Figure 3: Top 20 job roles in increasing and decreasing demand across industries

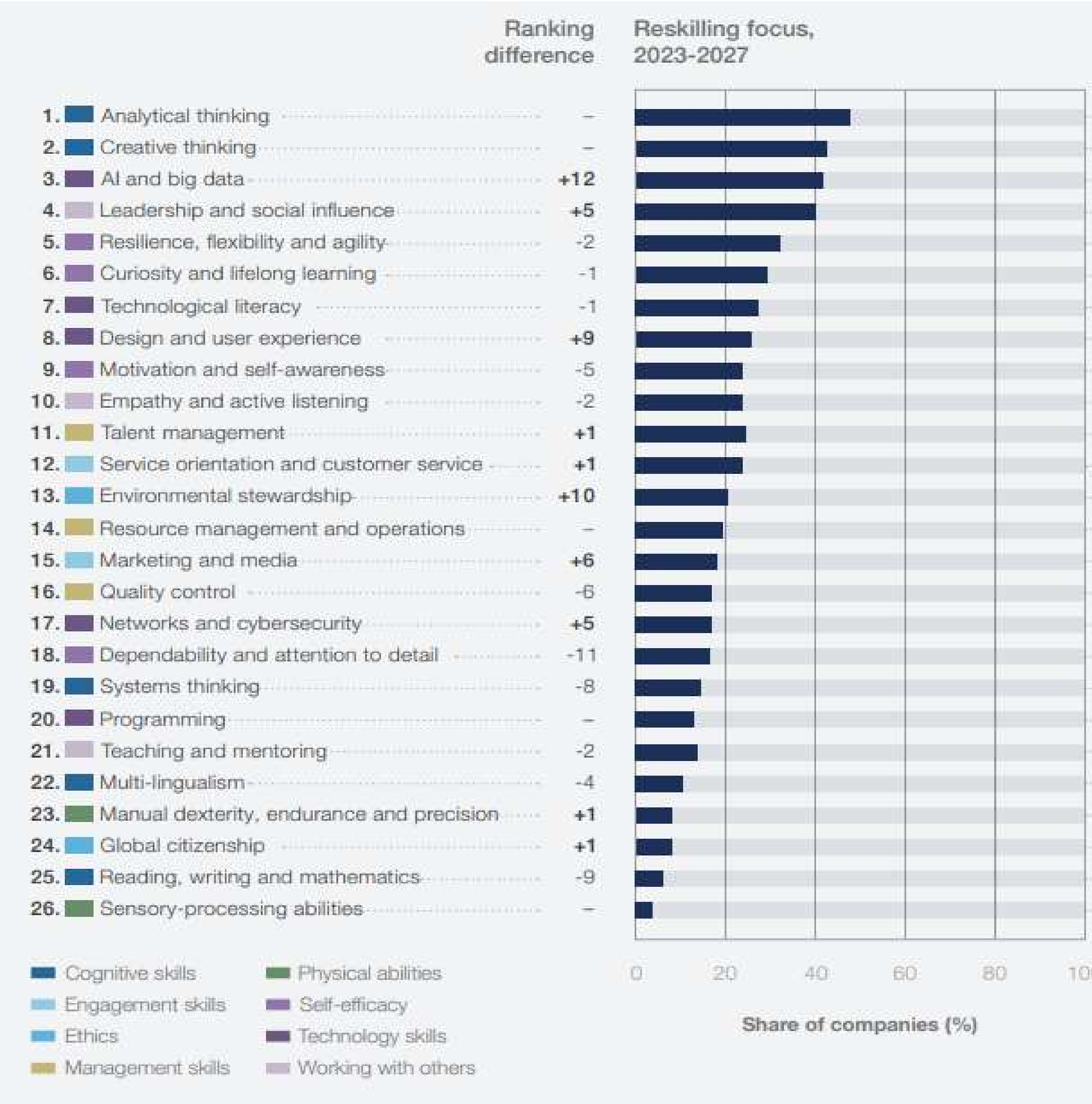
	Increasing demand		Decreasing demand
1	Data Analysts and Scientists	1	Data Entry Clerks
2	AI and Machine Learning Specialists	2	Administrative and Executive Secretaries
3	Big Data Specialists	3	Accounting, Bookkeeping and Payroll Clerks
4	Digital Marketing and Strategy Specialists	4	Accountants and Auditors
5	Process Automation Specialists	5	Assembly and Factory Workers
6	Business Development Professionals	6	Business Services and Administration Managers
7	Digital Transformation Specialists	7	Client Information and Customer Service Workers
8	Information Security Analysts	8	General and Operations Managers
9	Software and Applications Developers	9	Mechanics and Machinery Repairers
10	Internet of Things Specialists	10	Material-Recording and Stock-Keeping Clerks
11	Project Managers	11	Financial Analysts
12	Business Services and Administration Managers	12	Postal Service Clerks
13	Database and Network Professionals	13	Sales Rep., Wholesale and Manuf., Tech. and Sci.Products
14	Robotics Engineers	14	Relationship Managers
15	Strategic Advisors	15	Bank Tellers and Related Clerks
16	Management and Organization Analysts	16	Door-To-Door Sales, News and Street Vendors
17	FinTech Engineers	17	Electronics and Telecoms Installers and Repairers
18	Mechanics and Machinery Repairers	18	Human Resources Specialists
19	Organizational Development Specialists	19	Training and Development Specialists
20	Risk Management Specialists	20	Construction Laborers

Source

Future of Jobs Survey 2020, World Economic Forum.

Although a minority of companies believe that AI and big data has been overemphasized as a core skill and will decline in importance to workers, a net 59% of companies predict it will grow in importance, and many companies see it as a strategic priority. Though generative AI has the potential to displace jobs, the focus placed on training workforces to exploit AI and big data indicates the opportunities for new roles which harness its potential to help achieve business goals.

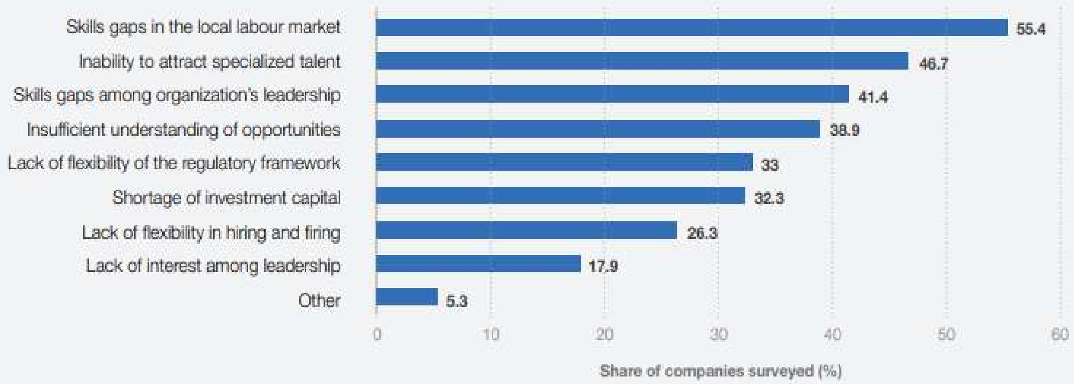
Figure 4: Reskilling and upskilling, 2023-2027 - Aggregated rankings of reskilling and upskilling priorities reported by WEF surveyed organizations. The ranking differences is relative to the ranking of skill importance in 2023. The graph also shows the share of companies which include each skill in their reskilling and upskilling strategies for 2023 to 2027.



A third dimension of the reskilling and upskilling landscape – besides the skills needed for work and the training strategies identified by employers – is the range of upskilling and reskilling choices, made by individual learners. Research conducted by Coursera for the 2023 WEF Future of Jobs Report suggests that these choices often differ from business priorities. Individual learners on Coursera have mainly focused on building technical skills such as programming, resource management and operations, networks and cybersecurity. These choices sometimes align with the skills businesses seek but many of these skills are foundational to achieving higher proficiencies in sought-after skills such as AI and big data, leadership and social influence… Even so, discrepancies persist, and job-seekers can more effectively use online learning platforms to close skill gaps and meet employer requirements, especially as traditional qualifications become less important.[27] Historically, individuals on the Coursera platform have prioritised developing technical or "hard" skills associated with lucrative careers in programming and data analytics. Increasingly, however, emerging technologies such as generative AI are reshaping workforce demands, and employers are placing greater emphasis on "soft" skills. These skills allow companies to respond to change and are resistant to automation.

The ability of global companies to harness the growth potential of new technological adoption is hindered by skills shortages. Figure 5 shows that skills gaps in the labour market and the inability to attract the right talent, remain among the leading barriers to the adoption of new technologies.

Figure 5: Perceived barriers to the adoption of new technologies



Source
Future of Jobs Survey 2020, World Economic Forum.

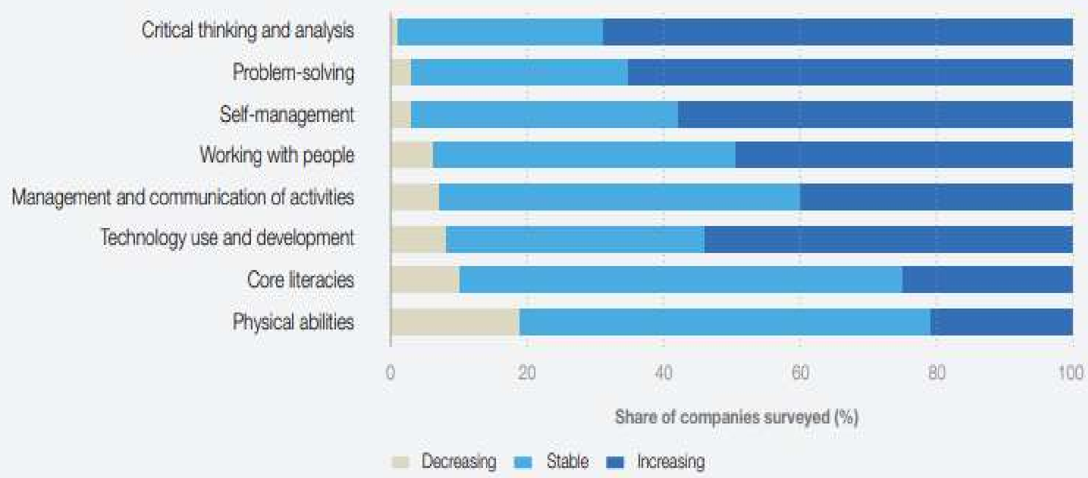
In the absence of ready talent, employers surveyed through the "Future of Jobs Survey" report that, on average, they provide access to reskilling and upskilling to 62% of their workforce, and that by 2025 they will expand that provision to a further 11% of their workforce. However, employee engagement into those courses is lagging, with only 42% of employees taking up employer-supported reskilling and upskilling opportunities.

Skill shortages are more acute in emerging professions. Asked to rate the ease of finding skilled employees across a range of new, strategic roles, business leaders consistently cite difficulties when hiring for Data Analysts and Scientists, AI and Machine Learning Specialists as well as Software and Application Developers, among other emerging roles. While an exact skills match is not a prerequisite to making a job transition, the long-term productivity of employees is determined by their mastery of key competencies. The WEF report takes stock of the types of skills that are currently in demand as well as the efforts underway to fill that demand through appropriate reskilling and upskilling. The report also tracked the cross-functional skills which are in increasing demand. Figure 6 shows the top skills and skill groups which employers see as rising in prominence in the lead up to 2025. These include groups such as critical thinking and analysis, as well as problem-solving, which have stayed at the top of the agenda with year-on-year consistency.

[27] World Economic Forum,*The Future of Jobs Report*, May 2023, pp. 42-44.

Figure 6: Perceived skills and skills groups with growing demand by 2025, by share of companies surveyed

A. Relative importance of different skill groups



B. Top 15 skills for 2025

1	Analytical thinking and innovation	9	Resilience, stress tolerance and flexibility
2	Active learning and learning strategies	10	Reasoning, problem-solving and ideation
3	Complex problem-solving	11	Emotional intelligence
4	Critical thinking and analysis	12	Troubleshooting and user experience
5	Creativity, originality and initiative	13	Service orientation
6	Leadership and social influence	14	Systems analysis and evaluation
7	Technology use, monitoring and control	15	Persuasion and negotiation
8	Technology design and programming		

Source

Future of Jobs Survey 2020, World Economic Forum.

Newly emerging are skills in self-management such as active learning, resilience, stress tolerance and flexibility.

A number of companies have in recent years experimented with a range of approaches to reskilling and upskilling. The role of business in such a programme can be to directly drive such efforts and define the approach to reskilling and upskilling. In other cases, businesses can be in a supporting role, agreeing to redefine their approach to hiring and accept candidates who have been reskilled through new types of credentials.

In one example, telecommunication company AT&T has worked with Udacity to create 50 training programmes designed to prepare individuals for the technical careers of the future which are distinctively relevant to AT&Ts future workforce and digital strategies.[28] In particular, these strategies include courses focused on skills in web and mobile development, data science and machine learning. To date AT&T has spent over $200 million per year to design this internal training curriculum, known as "T University", and has already achieved over 4.200 career pivots with 70% of jobs filled internally by those that were reskilled. In a similar effort, SHELL launched an online education effort titled the "Shell.ai Development Program"[29], which focuses on teaching artificial intelligence skills to its employees.

The below Figure 7 shows that 60% of businesses believe they can see return on investment within one year of funding reskilling for the average employee.

Figure 7: Probability distributions for the expected duration of upskilling or reskilling training programs from 2023 to 2027, and how long organizations surveyed expect to subsequently wait for a return on this investment.

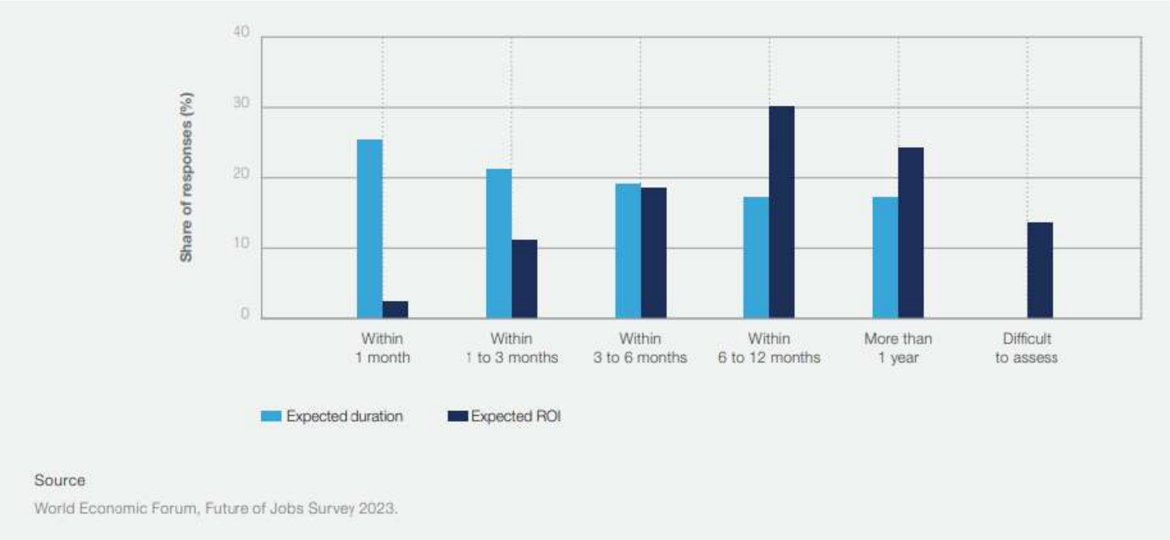
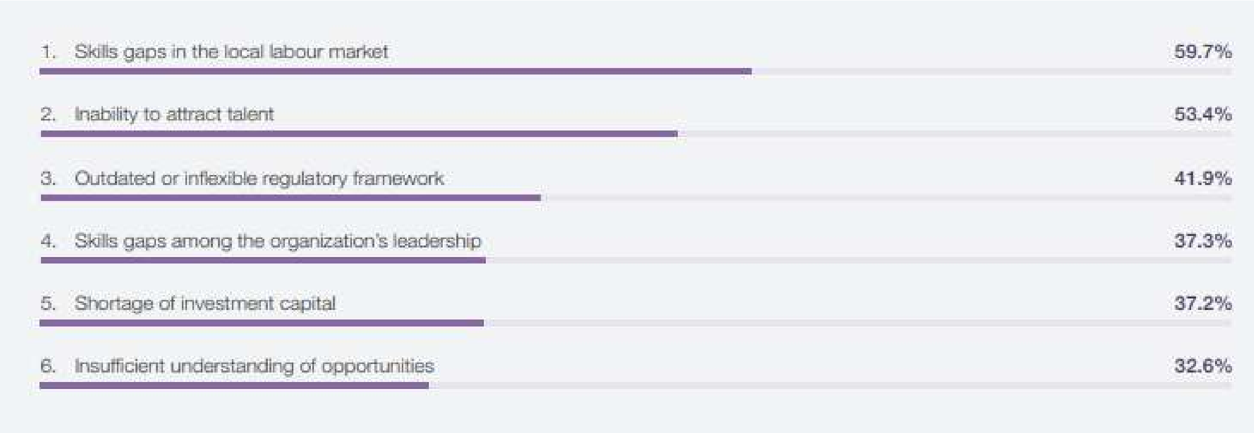


Figure 8: Expected composition of Training Providers 2023-2027

[28] https://www.udacity.com/get-hired/att
[29] https://www.shell.com/energy-and-innovation/digitalisation/digital-technologies/shell-ai.html

Figure 9: Barriers to Business Transformation 2023-2027 - Share of organizations surveyed expecting these factors will limit the transformation of their business.



Skills gaps in the local labour market are seen as a greater barrier to business transformation (60%) than a shortage of investment capital (37%), by companies in virtually every industry[30].

4. Conclusions and Recommendations:

ENGINEERS EUROPE conducted an on-line survey between 15 May and 15 July 2023. For the seven countries being part of the E4E consortium, 802 answers were collected of which 75% were filled out by male respondents. A large majority (88%) of respondents were professionally active and 65% of respondents had acquired more than 10 years of professional experience, be it in the industry or educational sector. The outcome of the survey seems to be congruent and consistent with the research conducted. Following conclusions can be drawn:

1. A **strong positioning statement** about the profession of engineer is required for all public communications to make a clear case why engineering matters. To entice young people to learn more about engineering, it's going to take more engagement from engineers.

2. Engineers are best served with **competency-based learning** and by an assessment of their **learning outcomes** as the sum of what he/she is expected to know, understand and be able to demonstrate after completion of a learning experience, i.e. knowledge, skills and wider competences (attitudes).

3. An increased emphasis on **sustainability and environmental concerns** in combination with a greater use of **automation and AI** in engineering processes will become the most important changes in the engineering profession for the next five years (2023-2027). Major areas for innovation and technological development will be Renewable Energy and Green Infrastructure whereby the most important technical competences that engineers will need to contribute to the transition of a more sustainable economy are **the understanding of sustainable design and circular economy principles**.

[30] World Economic Forum, *The Future of Jobs Report*, May 2023, p. 49.

4. To better prepare engineers for the challenges of the 21st century, the **incorporation of sustainability principles in formal engineering education** and training courses is considered paramount. **Changes in education curricula and CPD** will provide the means to support the adaptation of the SDGs into everyday practice. It is overall widely acknowledged that engineering education and training programs should better prepare engineering students by exposing them to emerging technologies and their potential applications in engineering and that students require more practical and hands- on experience through **internships and apprenticeships**.

5. Universities/technical schools and the industry are to develop **a formal or informal curriculum that aligns with the needs of the job market**. The role of business in programs of reskilling and upskilling can be to directly drive such efforts and define the approach.

6. **Critical thinking, collaboration and communication skills** are considered the most significant **soft skills** to work successfully in the engineering profession for making a promising career.

7. A majority of our E4E survey respondents strongly amplified the promotion of diversity and inclusion policies and **the encouragement of experimental and problem-based learning opportunities** to develop ethical decision making skills.

8. In order to attract more diverse talent to the engineering profession from under-represented groups, scholarships, the development of **mentorship and diversity/inclusion training** to professionals and organizations, are identified as being significant.

9. The role that engineers can play in promoting Green Energy and efficiency are to demonstrate the implementation of new technologies for energy efficiency and renewable energy and the provision of technical expertise and advice to business, especially SME's, **to promote sustainable practices**.

10. A non-negligible share of **newly created jobs** will be in completely new occupations, or existing occupations undergoing significant transformations in content and skills requirements.

11. Engineering disciplines with a serious concern in the future because of the shortage of engineers are identified as **electrical/electronic, ICT and agronomic /environmental engineering**.

12. Skills gaps in the local labour market are seen as a greater **barrier to business transformation** (60%) than a shortage of investment capital (37%), by companies in virtually every industry.

13. **Partnerships** between industry and educational institutions, together with investments and increased funding in **R&D in emerging technologies**, are considered the two most effective tools for addressing digital, green, resilience and entrepreneurship skill shortages in the engineering profession.

14. **Entrepreneurship** represents a key competence for improving the European competitiveness and R&D will have to focus on the development of a social and green economy. Professional

Engineering Organizations can encourage the entrepreneurial mindset among engineers and support and promote entrepreneurship amongst their members by advocating **interdisciplinary collaboration** through workshops and seminars and by providing short entrepreneurship training courses.

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1.2 Analysis by Association of European Civil Engineering Faculties (AECEF)

1. Introduction

"*Definition of SDGs and Green Deal implementation landscape in your country across the VET and business ecosystem*".

AECEF is an European Association of Civil Engineering Faculties (www.aecef.net). Therefore, the scope of this text Is to address Higher Education of Civil Engineers. The text was prepared to present advances in the adaptation of Civil Engineering undergraduate and graduate education and of the continuing professional development training programs to the consequences of the United Nations Sustainable Development Goals initiative. Several events took place and AECEF was promoter of the conference on 12 November 2021 entitled "The Role of Education of Civil Engineers in the Implementation of SDGs (Sustainable Development Goals)".

The topics mostly addressed of the set of SDGs were SDG6 - Clean water and sanitation, SDG7 - Affordable and clean energy, SDG8 – Decent work and economic growth, SDG9 – Industry, innovation and infrastructure, SDG11 – Sustainable cities and communities, SDG13 – Climate action, SDG14 – Life below water and SDG15 – Life on land. These important issues were investigated to underline the relevance and impact of the qualification of Civil Engineers (future and active) in the development of a sustainable world.

Another relevant initiative was the association participation in the projects of the TUNING academy (www.academy.org) in the area of defining necessary qualification frameworks of the competences of the Civil Engineers to handle the UNSDGS and the Green Deal implications for society and for professionals. Related with the EU Green Deal the strategy was to consider the Green Competence Framework for Sustainability (GreenComp - https://joint-research-centre.ec.europa.eu/greencomp-european-sustainability-competence-framework_en) and the possible changes in the existing competence framework for Civil Engineers in the bachelor and master levels (levels 6 and 7 of the European Qualification Framework).

As a result of the working group activities of the AECEF members in the project three - non exclusive - options to proceed were:

a) Incorporate GreenComp requirements while adapting its descriptors in the Civil Engineering (CE) framework;

b) Create specific new competence(s) to add to the existing CE framework (possibly adding new dimensions);

c) Join GreenComp with the existing CE framework by emphasizing where to incorporate learning outcomes when designing specific programmes.

The third option was chosen and some of the competence descriptors that were adapted were Critical Reflection, Judgements, Synthesising, Design, Creativity, Knowledge, Ethics, Decision Making, Communication, Team Working, Leadership and Professional Development. Civil Engineering will probably need to focus on the way in which the discipline and its practice is adapting to changing social needs, new knowledge /awareness and theoretical underpinnings of value frameworks.

A concrete example for CE is, from the CE competence framework, the Dimension 3: Design, Subset 2 L6_3.2 Safe, sustainable and of low impact designs "Define and describe key aspects of safety, sustainability and impact on society and environment related to civil engineering phenomena and to the ethical obligation and social responsibility of professional engineers" means that the designer should reconsider his priorities: valuing sustainability and critical thinking. This exists in the example of GreenCom on its page 39.

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

Most significant ones for AECEF in Civil Engineering are for the last five years:

- Number of programs of CE (bachelor, master and doctoral)
- Number of graduates
- Number of CDP programs including online
- Number of registered professionals, national and European
- Number of CE EUR ING certificates
- Number of non-European CE registered professionals
- Number of CE conferences, national and European
- Number of CE funded projects by EU
- Salaries of CE professionals, national and European

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

- Quality of CE media news
- Promotion of Rehabilitation projects
- Events created by CE related initiatives like the New Bauhaus
- Media related with CE impact with Sustainability
- Associations and organisations dedicated to CE and Sustainability

4. Opportunities

The introduction of educational programmes focusing on the protection of the environment and the sustainable development in the CE curricula is a very challenging procedure due to two main factors:

a) The fact that, historically, engineers played a very active role in economic development, and during some periods they actually formed the leading force, without although equally developing their social structure as well.

b) It is nowadays demanded by CE to have broader knowledge, skills and attitudes than the traditional ones, which used to focus mainly on the construction sector. There is an intense demand for engineers to provide sustainable and environmentally friendly solutions under the concept of EU Agenda 2030 and the Green Deal.

The next stage needs the world's engineering experts on power generation and transmission, electric vehicles, hydrogen fuel cells, artificial intelligence for energy systems management, urban design for energy efficiency and public transport, and related specialists. Diplomats, rather than engineers, have been at the forefront at UN climate summits for the past 24 years. The time for engineers to take centre stage has arrived.

Moreover, the importance of educating engineers, to successfully deliver on the UNSDGs, is highlighted in the recent UNESCO report on engineering: "Engineering education plays a crucial role in overcoming the challenges posed in achieving the SDGs. Achieving these goals necessitates a shift in engineering education away from a focus on academic technical knowledge towards a much broader interdisciplinary and complex problem-solving approach that combines societal and sustainable problem analyses with academic technical knowledge and solutions."

5. Needs

The promotion of interdisciplinary knowledge and research in the field of environment and sustainable development for CE are:

• The provision of a high-quality education and training to promote a positive attitude and behaviour regarding the sensitive issues of environmental protection and sustainable development for CE.

• The training of new graduates and professionals aiming at the upgrade of the human potential of the CE in the context of a dynamic economic and technological development policy.

• The intensive specialisation in the relevant vital issues aiming at the formation of well-equipped graduates from the CE programme and providing them with suitable means for professional careers in the public or private sector or for the continuation of their postgraduate studies at the doctorate level and mostly for CPD of active CE.

6. Challenges

CE Engineering Education (EE) and CE Continuing Engineering Education (CEE) are crucial in handling the scale and complexity of the gap between existing solutions and the needs facing our planet. Civil engineers are uniquely placed to act on this opportunity. Lifelong learning has developed and can continue to develop global initiatives to address those twenty-first century challenges threatening the survival of human kind through collaboration, design, creative thinking and engineering. The implementation has shown that it may motivate the CE engineering community and influence a majority of stakeholders to engage with a framework of global sustainable development.

CE EE and CEE can influence in the short term the involvement of the engineering community and related sectors to a global commitment in implementing this call to service. This change and improvement can be mostly achieved via education and training of the engineering community around the world, as CE and related stakeholders have a major influence in the world's development. It is crucial that within a global and international arena that CE engages in sustainable measures to ensure a future for the world. Some initiatives, like SERINA and the Porto Declaration, can act as beacon and motivation for all and especially for active engineers and for future engineers. The contribution of these initiatives can arise from examples of related activities, the role of online learning in CE CEE sustainable courses, some guidelines for CE online sustainable courses and the provision of CE training and education for a sustainable world.

CE in some countries have compulsory periodic CEE and continuing professional development (CPD) to keep their status as engineers. Professional organizations, government agencies, companies, non-governmental organizations and policy makers can transform the competences of active Civil Engineers through CPD and CEE to include those related with sustainability. The transformation can be achieved by legislation, by incentives (time or money), by awareness campaigns or by creation of available modules. Civil Engineers are used to attend this type of training given the fact that their profession is evolving constantly.

A possible incentive to engage active Civil Engineers in CPD and in CEE on topics of sustainability can be the recognition of qualifications on sustainability. The title of CE sustainable engineer maybe awarded to those willing to be trained. The title could bring prestige to the engineer, higher employability and an increase in salaries. This CPD and CEE can be formal learning, organized and structured through formal evaluation and assessment in traditional education systems or non-formal learning embedded in planned activities containing important learning elements. The overarching aim of enhancing sustainability CE competences is to have in place a system to document and to validate the competences that will be easily recognized by companies, professional organizations and society.

Another possible improvement is to have mandatory sustainability education and training for Civil Engineering programs. Currently, professional qualification frameworks of engineers already require competences in the area of sustainability. The problem is that many engineering programs from academia do not comply fully with the demands of the CE professional qualification frameworks and many CE graduates do not have the necessary sustainability competences in terms of knowledge, skills and attitudes. In this case of transforming the CE higher education programs may be only viable through the intervention of legislative branches.

7. Conclusions and Recommendations

The role of Civil Engineers in the global effort to implement the Sustainable Development Goals and of the GreenComp framework is of outmost importance. This is why we need to invest in adapting the CE education of the new engineers so that they can understand the concept of the sustainable development goals and they can contribute to the process of their implementation. Many CE higher education institutions from all over the world, acknowledging the necessity to respond to the societal changes and are focusing on the adaptation of their CE study programs to be as much as possible compatible with the implementation of the Sustainable Development Goals and of the GreenComp framework.

Several initiatives have shown that it is possible to gather examples and case studies valuable for preparation of CE future graduates and CE active engineers in the area of sustainability. A possible solution is to have stakeholders to furnish databases with CE examples and CE case studies, of CE training programs and of CE initiatives that can bring hope for those concerned with the future. That can bring hope and optimism while developing an active mind set about respect of UNSDG and of GreenComp enacting its implementation in planning and executing future CE projects.

Adapting to change is one of the most difficult and complex human challenges to navigate successfully. Yet no person or community has any immunity for change. The dawn of the third decade of the 21st Century has swiftly heralded unimaginable shifts and challenges across the globe without exception. So too, it has revealed signs of tremendous accomplishments, of ingenuity and of adaptability, buoyed by resilient human spirit and by desire to succeed against immense adversity. Against this backdrop, the decade ahead for Civil Engineers could hardly be more significant, demanding, and exciting for the best of Civil Engineers and of academics as problem solvers.

As CE students, professionals, educators and administrators, one can look to the enormity of 2030 deadline targets of the UNSDGs with a renewed sense of purpose, urgency and optimism, knowing that the world has demonstrated its ability to adapt at a scale of unprecedented solving measures at the blink of an eye.

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1.3 Analysis by Federation of European Heating, Ventilation, and Air Conditioning associations (REHVA)

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.

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.

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.

- **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.

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 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.

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 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.

RESULTS ANALYSIS

REHVA gathered 20 replies from 17 countries:

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

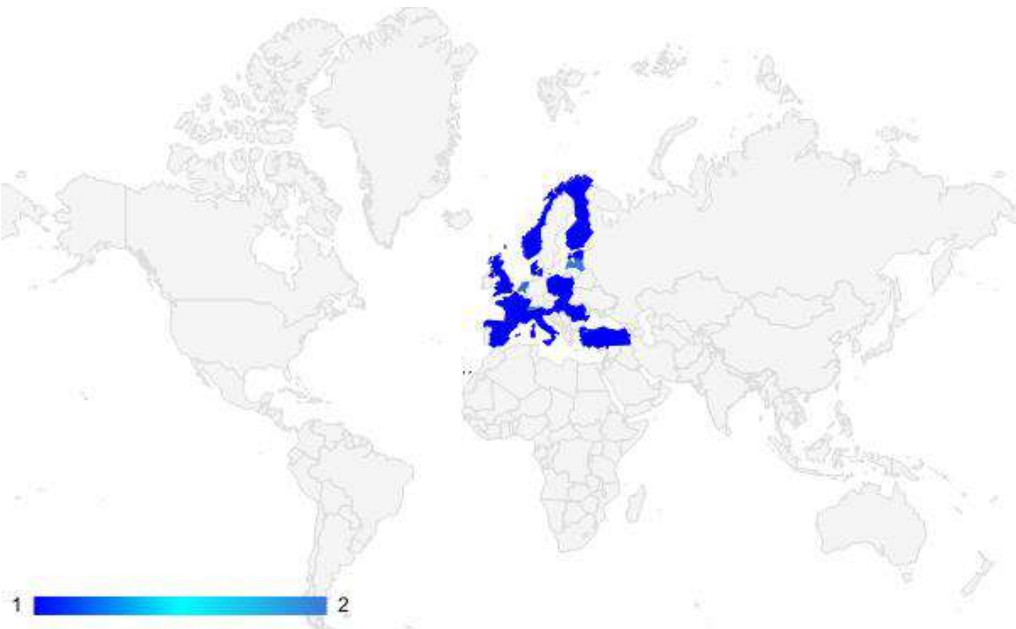

Figure 1: Countries represented

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*.

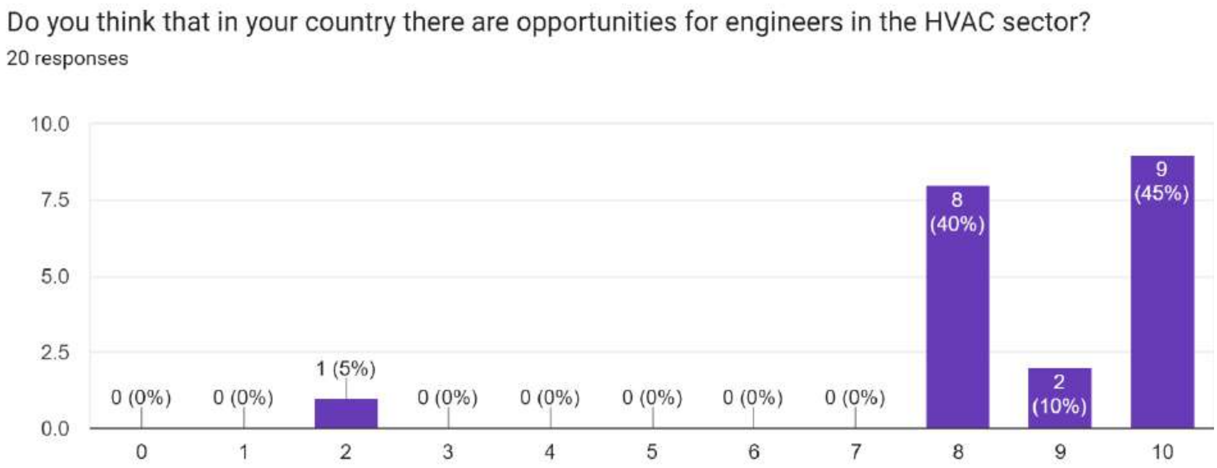

Figure 2: question 1

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.

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 modelling, 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 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.

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 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 favourable 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.

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 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 analyse real-time data on building performance and occupant behaviour. 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 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.

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 centres.

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.

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 favourable 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.

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 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.

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 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 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.

<u>Challenges</u>

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-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.

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.

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.

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.

2. 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.

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.

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.

3. 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.

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.

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.

4. 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.

Collaboration with Industry: Municipalities can collaborate with HVAC professionals and industry associations to develop energy efficiency programs, conduct audits, and provide technical guidance to building owners and operators. This partnership ensures that HVAC systems in public and private buildings align with sustainability goals.

5. 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.

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.

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 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.
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.

<u>Recommendations</u>

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 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

<u>Needs</u>

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 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 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

Challenges

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.

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 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 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.

Challenges

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.

Recommendations

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.

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

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.

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

Needs

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.
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. 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 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.

Challenges

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.

Recommendations

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 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.

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 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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1.4 Analysis by European Council of Engineers Chambers (ECEC)

Introduction

The ECEC is the European umbrella organisation of 17 national engineering chambers and represents over 300.000 chartered engineers in Europe. The focus of its research is therefore the **perspective of professionally active highly educated independent state-authorized engineering professionals** - that very often also represent the employers' side - in a European cross-section.

The snapshot thus provides the summary of a broad regional spectrum of views on the future of engineering and does not take into account or focus on specific national aspects of HE, VET, business ecosystem, regulatory situation, etc.

For the primary research, the ECEC Secretariat conducted individual in-depth interviews with one representative per member organisation to gather the professional and personal insights on the future developments and current wants and needs for engineering in Europe. This produced a total of 11 individual interviews, a copy of the structure of the interviews is provided in the Annex. The interview was held in an open-question format, the answers of the participants were not prompted in the questions, providing for free and independent answers. The participating countries were Austria, Bulgaria, Croatia, Cyprus, Germany, Hungary, Poland, Portugal, Slovakia, Slovenia and Spain. The Portuguese impact was gathered in the format of a group discussion of several individuals, also taking into account the aspect of diversity.

In total, 16 participants were registered.

The secondary research was held on the basis of national and European documents. This included project reports, survey analysis, reports of international organisations and position papers. A total of 7 secondary research papers were obtained and included in the research.

Equality / Diversity in Engineering

In regard to quantitative indicators on the evolving nature of the engineering profession, the ECEC has – based on three different research papers - put a focus on the considerable potential that lies in the enhancement of equality measures in engineering profession and education.

YesWePlan!
The Erasmus+ project "YesWePlan!" was conducted from November 2019 to April 2022 by European chambers and professional organisations in cooperation with Universities with the aim of critically examining gender equality in the field of Architecture and Civil Engineering. The result was "Compendium 4 in 1" – a comprehensive collection of the YesWePlan! project outputs: recommendations for stakeholders, country situation results of the participating countries, a Career Tracker and a collection of Best Practice Examples.

Five countries participated in the project and were assessed in the collection of data: Austria, France, Germany, Slovenia and Spain.

The research results showed, that the percentage of women in civil engineering is low: In 2019, women made up 1,20% of all civil engineers in Austria, 23,74% in Slovenia, 16,30% in Spain, a rough estimation of 20% in France and a rough estimation of 10% in Germany. The large discrepancy and variety between the countries is provided due to the different regulatory situations and definitions of civil engineers (e.g. in Austria only self-employed authorized professionals fall under the definition of civil engineers).

The number of female graduates of civil engineering is also quite diverse, depending on the different regulatory surroundings of education and professions: In Austria, data from 2008 to 2019 shows a large increase of women graduates from 16,67 to 32,84%; in Slovenia a decrease from 41,35 (2011) to 30,59% (2019); in France a steady number of 27,50%; and in Germany an increase from 2013 to 2017 from 29 to 31% of graduates. For Spain, such data could not be obtained.

The data shows a range of diversity in European countries that is mainly due to differences in the regulatory and professional surroundings, which can also be applied to other engineering professions.

What is noticeable in all cases, however, is that women make up a much smaller number of civil engineers, especially in regard to self-employed work, and that the number of female graduates is in general increasing. In view to the urgent lack of engineers in Europe and the increasingly important aspect of diversity for gathering optimized sustainable engineering solutions this shows the huge potential of measures to attract more women for engineering professions.

Observatorio de la ingeniería

Observatorio de la ingeniería is a Spanish study analysing the current reality of Spanish engineering, the future prospects of the sector and the needs for the competitive development of Spanish companies. The study also puts a focus on the role and potential of women in Spanish engineering. The first edition of the study was published in 2022.

The paper reports on various topics concerning working conditions of engineering professionals in Spain, frameworks and developments of new jobs and a future forecast for needs of Spanish engineers in the upcoming years.

Spain currently has approximately 750 000 engineers, which is a larger number of engineers for every thousand inhabitants (15,7%) in comparison to France or Italy (15,4 and 11%). Of these, women make up approximately 20%. This broader perception of engineers as opposed to civil engineers shows an increase of the number of women working in engineering as compared to the YesWePlan! study results. A particularly low number is presented for women in Telecommunications engineering (12%), computer engineering (16%) and industrial engineering (19%).

At the same time the study reveals that there is a significant lack of engineers in Spain, where 200,000 new engineers will be needed the next 10 years. This fully supports the results of the YesWePlan! study in regard to the importance of attracting more women to the profession.

UNESCO Engineering Report

UNESCO has published two landmark reports on engineering, the second being published in March 2021 and carries the title Engineering or Sustainable Development: Delivering on the Sustainable Development Goals.

The report shows the crucial role of engineering in achieving the SDGs as well as putting a focus on gender equality in engineering professions.

The report formulates references in practice examples and possible solutions targeted at governments, engineering organisations, academia and educational institutions and industry to encourage cooperation and collaboration in engineering across the globe.

Current developments in engineering

For the purpose of finding a broad spectrum of viewpoints from the ECEC's member organisations, one person per member chamber was interviewed in a personal interview.

An overview of the results of these interviews will be presented in the following points and summarize various perspectives of professional engineers:

Ten out of the sixteen participating interviewees remarked that the role of engineers is gaining more and more importance, and that this relevance will considerably increase in the next years, particularly in the field of sustainable development, the climate change and it's consequences.

This is in accordance with the definition in the UNESCO report on "Engineering for sustainable development: Delivering on the Sustainable Development Goals" of 2021. It is stated there that engineering "is crucial for the advancement of each of the 17 [Sustainable Development] Goals".[31] The report stresses the crucial role of the engineering professions for solving critical problems such as climate change, urbanisation and the preservation of nature.

The topic of sustainable changes and developments in engineering was a focus in 9 out of 11 individual interviews with the claim that all individual sectors of engineering need to integrate sustainability reflections in order to achieve the Sustainable Development Goals. Elements such as energy efficiency, sustainable alternatives and data-driven strategies need to be automatically considered starting with the design of a project. Engineers are main drivers in implementing the UN defined SDGs by designing sustainable infrastructure, developing clean energy solutions, addressing climate change and managing natural resources. For sustainable changes, there is an emerging importance of realising a circular economy as opposed to one-time-use., especially in the building sector. Circular economy also

[31] United Nations Educational, Scientific and Cultural Organization 2021, P. 18

provides for new and alternative techniques and especially new materials to be used and reused in engineering.

The development of engineering also shows a fast and important process of digitalisation and computerisation, as stressed by fourteen individual and group interviewees. Digitalisation is said to fundamentally change the way engineers work and make it possible to apply completely new technologies such as Internet of Things, Artificial Intelligence in data-analytics as well as automation and robotics. Representatives of civil engineers also stressed the developments stemming from the use of Building Information Modelling (BIM) as opposed to AutoCad Drawings or other systems.

Two interview partners also addressed the process of internationalisation of engineering work based on the development of the internal market of the European Union but also going beyond and the important and fast evolving interdisciplinary practice of engineers.

Overall, the speed of the mentioned developments seems to be depending on geographical und institutional structures.

One national interview partner especially stressed that engineers' contribution to sustainable development on national level is rapidly increasing through implementation of renewable energy systems, transportation infrastructure and the application of innovative technologies. This statement was supported by another national interview partner, who reported on a positive national development towards a circular economy and the use of new materials, particularly the use of fly ashes in the building sector, though problems continuously appear on a political level.

In other regions and sectors, sustainability of processes is still in its early stages. One national representative reported about a disregard for proper construction waste management in its proper handling, disposal and recycling, leading to environmental pollution and other negative impacts on local communities.

Seismic engineering is regarded as an important aspect of sustainable and ethical engineering practice and was brought up in five of the interviews. Three interviewees mentioned the engineering disaster as an aftermath of the several earthquakes in Turkey and connected it to political sluggishness. On national representative reported rather positive developments with regard to quick responsiveness to earthquakes and a general awareness of the needs of the vulnerable population, while also observing a lack of legislative framework and lazy decision-making. Also here, the situation differs in different countries, as another national interviewee reported predominantly bad examples in seismic engineering, but a generally productive increase of good-quality construction in the country.

As for digitalisation in engineering, many of the interview partners observe a partly slow but very steady development, though full computerisation of processes is partly also considered from a critical perspective. Interviewees strongly stress that controlling the digital / AI tools will still have to be based on professional knowledge and skills in order ensure adequate input information, to define the right circumstances and to control and analyse the outputs. Three interviewees even called for a need to slower this process and put a stronger focus on practical skills and a scientific base of knowledge.

Opportunities and challenges for the profession

Digitalization and AI

The rapid advance in robotics, AI and multiple other technologies is regarded as a threshold to manifold opportunities for engineers.

Artificial Intelligence technologies can improve operation and lead decision-making for engineers on the basis of various data collections and are regarded as the basis for the implementation of new technologies in engineering. Some mentioned examples were the use for big data and digitalisation to improve sustainable management of agricultural land and resources, electricity usage modelling and multi-spatial climate data. All this is seen as a crucial basis for the further development of sustainable alternatives in all branches of engineering, included energy efficiency in the building sector. Therefore, several interviewees also expressed the importance of catching up in areas that have been poorly digitalized so far.

The interviewees also mentioned the chance – and necessity - for improved cybersecurity in connection with the implementation of new technologies. In one of the interviews, this was also connected to the emergence of telemedicine tools and e-Health as well as for the integration of smart manufacturing systems, attributed to sustainable factories.

The view that engineers will play a crucial role in the creation of innovations and technologies that are sustainable, cost-effective, righteous and ethical was explicitly stressed by seven interviewees.

Beside the fact that the significant changes due to the development of artificial intelligence that will fundamentally change the work of engineering professions in the coming years are seen as an important opportunity for the development of the engineering profession and the manifestation of the role of engineers in society, it was mentioned that they might also alleviate the problem of lack of engineering personnel.

Beside the numerous opportunities of digitalization there are a number of concerns, as was stated by ten of the interviewees. These challenges arise from the rapidity in which this computerisation and digitalisation is being carried out, which is difficult especially for engineers with an education that dates back to before this transition was ongoing. The development seems to be less challenging for young engineers, for older ones additional support measures could be important.

Similar problems also arise from the quick development of AI, which redefine the roles of engineers in the production process with new ways of working, new relationships with equipment and automation which requires different skills in data analysis and computer science.

(Multi-stakeholder) partnerships

The interviewees defined a number of opportunities coming from working in multi-stakeholder cooperation. It has to be noted, though, that the scope, definition and regulatory basis of such multi-stakeholder partnerships is different in different countries.

The view that multi-stakeholder partnerships directly tie into close collaboration of engineering stakeholders and improve an open dialogue between engineers, was supported by eight interviewees.

Such cooperation is also regarded as a possibility to ensure market freedom and give way to benchmarking. Eight of the interviewees expressed the possibility of the enhancement of a more levelled and balanced field of engineering.

It was also stressed that multi-stakeholder partnerships can establish and enhance the much-needed interdisciplinary approach that is a basis for excellent sustainable solutions. It can bring in various perspectives from engineers but also scientists, politicians, jurists etc. Another benefit of multi-stakeholder cooperation that was mentioned is the possibility of sharing experiences and knowledge in a confidential environment, which is otherwise difficult to encounter in a competitive engineering environment.

Some interviewees also elaborated that these types of partnerships can be an effective tool against corruption and monopoly systems and for ensuring market freedom.

Overall, there is agreement that interdisciplinary approaches – in or out of multi-stakeholder partnerships – are a crucial basis of sustainable development.

Several interviewees stress that unleashing the benefits of multi-stakeholder partnerships requires adequate regulatory frameworks that can avoid negative impacts.

For any form of collaboration of multiple stakeholders, interviewees see the need for diverse and inclusive decision-making processes. Five interviewees also expressed the need for a framework to ensure open dialogue, transparency and clear communication.

Four out of eleven individual interviewees stated that the regulatory framework of multi-stakeholder partnerships needs to ensure market freedom but also transparency for consumers and the public. An important prerequisite for this is the professional independence of engineers in their work. This independence, whether it be politically or economically, makes it possible to represent public interests and actively work against problems like greenwashing and corruption of the market. It is the also the basis for the implementation of the best engineering solutions that are not compromised by political or economical dependencies and for the highest level of consumer protection. Ensuring the professional independence of engineers requires adequate share-holding regulations that restricts the possibility of compromising the independent work of engineers.

Some interviewees stress that for such partnerships clear incentives for investment in natural resources, circular economy measures and research and development for sustainable practices need to be formulated and realised in order to get financing stakeholders to comply to these principles.

"Consciousness" in engineering

The interviewees regard a sound ethical basis for the work of engineers as a public interest concerning our society as a whole.

They see the execution and observance of the compliance mostly in the responsibility of chambers and other professional associations.

Regarding professional responsibilities, nine out of fifteen participants have stressed the importance of lifelong learning / CPD measures in view to engineering developments. Ensuring up-to-date skills and adapting to engineering developments is regarded as a basis for conscious conduct of the profession. Interviewees also expect the support of professional chambers in fulfilling such requirements. Some of them stress the fact that an unwillingness of some engineers to participate in CPDs due to a lack of time, lack of resources or a lack of incentives can lead to serious problems and see it in the responsibility of the chambers to provide such incentives and or / easily accessible CPD measures and / or other adequate support measures.

Beyond pure technical developments some interviewees have also expressed the importance of training programs and workshops on ethical decision-making, inclusion and sustainable design.

The Interviewees regard it as essential that chambers and other professional organisations establish enforceable codes of conduct and guidelines that emphasize ethical and sustainable practices and organize and conduct effective systems of compliance. This is regarded as a particular concern and safety risk for countries without obligatory membership to engineers chambers in which disciplinary sanctions can be easily avoided.

Several interviewees regard is as essential to ensure the professional independence of engineers not only on a regulatory basis (e.g. shareholding requirements) but also by raising the awareness already during the different steps of engineering education. Additionally, it is considered as a responsibility of the chambers to concern themselves with the factual independence and governance of this autonomy. Six out of ten interview results state that engineers are continuously struggling for this factual independence.

Engineers need to be able to consider multiple perspectives when designing a project or bringing it to life, particularly from a social viewpoint. It needs to be assessed whether the social implications are profitable to the end users and whether equity and other social principles are met.

Four interviewees stated that in view to sustainability and other ethical responsibilities, awareness raising needs to start long before university studies are pursued and encourage chamber activities to develop child-friendly ethical awareness methods such as books or games, which convey ethical consciousness, particularly responsibilities in protecting the environment, even to young children.

Interviewees regard chambers as the main factor in the adequate conveyance and organisation of ethical and sustainable responsibilities within the profession and in raising the awareness in society. With crises like the climate change, the safety and living quality of our society worldwide is more and more depending on adequate sustainable engineering solutions. Consciousness in engineering combined with professional independence are constantly gaining importance. Interviewees regard it as a priority of chambers' work to raise the awareness of all participants in the field of construction and of all levels of society about the role of engineers, their professional independence and ethical basis. This also extends to securing adequate Continuous Professional Development (CPDs) courses available to professional engineers as an important task for Chambers.

Engineering qualification and market needs

Based on the fast developments in digitalization and sustainability, interviewees regard the cooperation between universities and actors of the engineering profession as an important

opportunity to regularly modernize curricula and practical education. Seven interviewees stressed the positive impacts of such cooperation for enhancing curricula and applied study programmes that are and actors of the profession to achieve more applied study programmes and adapt curricula that are in compliance with market needs.

Most interview partners stressed that educational requirements are getting more and more complex. Skills are divided into hard skills (technical knowledge) and soft skills (personal skills). In engineering education there is a strong focus on hard skills and the conveyance of facts and scientific knowledge that are the necessary basis for engineering work. Eleven of sixteen participants stated that in practise there is an equal importance of hard and soft skills, whereby four interviewees believed that there needs to be an increased focus on soft skills in engineering education. Nevertheless, all interviewees stress the crucial importance of a sound theoretical basis for practising as an authorized engineer.

Among nine interviewees, there was also a call for more applied and practical skills in addition to the theoretical knowledge obtained at a university level or in other engineering learning institutions.

Six interviewees regard the ability to operate new technologies as a crucial skill for aspiring engineers nowadays. They are expected to know or acquire knowledge on automation and robotics, IoT, AR and VR, 3d printing and Ai data analytics for identifying and analysing complex technical challenges and developing innovative solutions.

Five interviewees especially stressed the importance of practical skills not based on computers or other technological aids. This includes basic abilities to think critically and extends to more practical appliance by controlling computer results and not trusting digital processes blindly. One interviewee called this the "engineering way of thinking" and also proclaimed a lack thereof in today's engineers.

Due to the internationalisation of engineering, engineers also need to acquire a "global view" as explicitly stressed by one interviewee, meaning to act locally but think globally. Engineers must be able to gather information of other realities and consider how local solutions may be applied elsewhere.

Several interview results also tie this to the need for the ability to think and act multidimensional and interdisciplinary. Engineers must be enabled to consider all the dimensions of a problem, meaning economic, political, ethical, sustainable, equitable in terms of gender imbalances and other dimensions. As many technical challenges today require cooperation between several disciplines, enhancing interdisciplinary thinking is of great importance. Engineers should be able to think outside the box of their own field and collaborate with experts from other fields. The ability to plan, organise, monitor and complete projects on time is crucial for success in the engineering profession.

There is agreement, that sustainable development can only be based on ethical engineering, which requires "conscious" engineers.

This means that overall, interviewees agree that engineers require theoretical knowledge, practical experience and the comprehensive understanding of the impacts of the engineering work supported by competences in all aspects of sustainability in a very broad sense. Apart from technical and engineering knowledge in sustainability, a holistic understanding for its dimension is necessary.

Finally, it is stressed they need to develop openness and "learning ability" – meaning the competence to be ready to gather learnings from each new project and experience and be willing to receive further education. This also provides for a strong scientific and theoretical base to which to add new knowledge which can be quickly interconnected with other knowledge.

In regard to the climate crisis one participant also remarked that it will become increasingly important to focus engineering expertise not only on avoiding the climate change but already on the preparation for negative impacts in worst case scenarios. A climate change adaptation skill is therefore of vital importance, meaning to develop strategies and adapt to the everchanging developments of climate change.

The current challenges and fast developments in engineering can lead to a lack of certain skills needed in order to effectively pursue goals of sustainability and digitisation.

It was also stressed that engineers are nowadays expected to bring forth communicative and personal skills which are usually developed with experience. One interviewee particularly expressed a need of knowledge on entrepreneurship principles as well as training on engineering responsibilities stemming from the independent position of engineers. Engineers also need confidence in their decision-making, which comes from a strong foundation in knowledge.

Meeting these complex requirements can only be based on a close cooperation between all stakeholders in engineering education and conduct in order to provide educational measures that complement each other and are able to fulfil all the different needs.

Approaches to bridge the gaps between education, profession and industry such as that of the E4E Skills Council are thus regarded as extremely important for unleashing the potential of future engineering opportunities.

Changes of the political and regulatory framework

While it has already been established that the engineering profession is developing in a more sustainable and digital direction, **the interview participants have stressed the necessity of fundamental changes in the political and regulatory frameworks in order to fully realise these positive developments.**

Especially in relation to sustainable developments, eight interviewees have expressed the need for political and regularity measures for achieving circular economy. They stress for example the importance of investment incentives and effective rehabilitation and reconstruction, the provision of broader possibilities to apply new and alternative techniques and especially new materials to be used and reused in engineering etc. One interviewee stresses that the implementation of the Sustainable Development Goals is not possible from an idealistic viewpoint that is still being applied today and but that the engineering profession needs to be fundamentally changed to provide for more sustainable use of constructions and designs.

Several interviewees have criticised the ability of the legal framework to ensure high quality engineering solutions in their countries or on the EU level. The Public Procurement Directive is regarded as an important tool to enhance quality in engineering. It is essential that engineering services - that are complex intellectual services - are **mandatorily** procured on the basis of quality competition and not price competition. The Directive therefore needs to be changed accordingly

Two interviewees also stated that they would like to see a more harmonised and unambiguous regulation of engineering professions on the EU level. As a first step the importance of the implementation of a Common Training Framework for civil engineers is stressed in order to agree on a common European qualification level as this would automatically lead to better mobility and more transparency for clients and consumers.

Three interviewees also showed concern for legislative approaches to sustainability issues, as they fear a general approach in overregulation of the profession making for ineffective engineering. This also relates to over boarding standardization activities that can even hinder innovative sustainable developments and practices.

In general, it was expressed several times that there is a need for the direct involvement of engineers in legislative processes and that more engineers should be represented on a state-level.

Shortage of engineers

Interview participants, particularly those active in pedagogic roles, have reported a general lack of engineers and of new engineering students particularly in specialised positions. In the interviews, the three participants expressing this concern tied this to a lower prestige of technical study programmes compared to humanitarian studies. This directly ties into the need for more visibility of engineering professions and better working conditions with an increase of salaries.

Additionally, this relates to the topic of equality / diversity in the profession and the potential that lie in attracting underrepresented groups of persons for the engineering professions.

Three interview results also bring forth difficulties in sustainable developments through the rapid energy and ecological transitions, meaning from traditional to sustainable energies and from a linear to a circular economy.

Conclusions

- In view to the topic of **Equality / Diversity in Engineering** there is an obvious conclusion. Implementing measures to enhance equality in the profession has a number of positive effects ranging from combating the lack of qualified engineers to providing more divers approaches to reach sustainable engineering solutions.
- The YesWePlan! project already provides an excellent set of recommendations that are openly accessible and can be used as a toolbox for measures on the level of Universities, of chambers and professional organizations and of employers which the **ECEC would recommend to use on all three levels and regards it as important to cover the topic of diversity/equality as a cross-sectional matter also in CPD measures. https://yesweplan.eu/intellectual-outputs/recommendations/**

- The continuously increasing **requirements in regard to engineering education and qualification call for an enforced cooperation of Universities, professions and industry**. Due to the fast and ongoing technical developments in engineering it is not possible anymore to gather all the required skills and competences for a professional lifetime during University education. Life-long learning combined with professional experience becomes increasingly important. Therefore, in order to meet the market needs, the different forms of education need to complement each other. This can only be reached by a close cooperation of all stakeholders in the engineering education and profession. **The ECEC therefore regards the enforcement of cooperation between Universities, professions and industry on national and European level as a necessity and sees the European Skills Council as an important tool.**

- Educational and professional requirements and circumstances in engineering considerably differ in Europe which can provide practical hindrances for professional mobility while **increased mobility is important for combatting the lack of engineers and enhancing know-how exchange and internationalisation of engineering solutions.** Measures such as the implementation of Common Training Frameworks foreseen in the Professional Recognition Directive (Article 49a) can help overcoming such hindrances, provide automatic recognition and thus enforce engineering mobility. **In any case, making use of such possibilities will also require the availability of adequate CPD measures supporting engineering internationalisation and cross border activities also for smaller engineering entities.**

- **Professional independence of authorized engineers is the basis to ensure the implementation of the best available sustainable planning solutions that are not compromised by political or economic interest.** Ensuring this independence therefore is a public interest and a pre-requisite for successfully meeting the manifold societal challenges. The ECEC thus regards it es extremely important to ensure this independence by adequate regulatory frameworks – including shareholding requirements – and further supporting measures on the level of professional chambers / organisations / educational institutions. **This includes adequate ethic-related CPD measures, also covering the topic of different forms of multi-stakeholder cooperation, as interdisciplinary approaches are rapidly growing in importance.**

- High quality engineering services will play a crucial role in reaching the aims of the European Commissions Green Deal. **The Public Procurement Directive is regarded as an important tool to enhance quality and innovation in engineering.** In other to enhance the required engineering excellence **it is essential that engineering services - that are complex intellectual services - are mandatorily procured on the basis of quality competition and not price competition**. The Directive therefore needs to be adapted accordingly**.** **Knowledge in procurement legislation and adequate procurement procedure is an important engineering competence, used either in the role of engineering service provider or as representative of the procuring authorities. Adequate CPD measures are therefore highly relevant.**

- **Engineering innovation and excellent engineering solutions depend to a certain degree on the regulatory surroundings, including standardization**. It is a fact, that overregulation can be a considerable hindrance to sustainable innovation (e.g. use of alternative building material etc).
  It is therefore important to – legally and also in regard to professional competences - enable engineering experts to provide alternative solutions to existing standards and thus remain important drivers of innovation.

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Annex

Individual Guided Interviews

Personal Information	
1.1 Age:	❍30 or less ❍ 31-40 ❍ 41-50 ❍ 51-60 ❍ 61 or more
1.2 Gender:	❍ female ❍ male ❍ diverse
1.3 What is your current job title?	
1.4 Which industry or sector do you work in?	
1.5 Which country do you work in?	
1.6 How many years of working experience do you have in this field?	❍ 5 or less ❍ 6-10 ❍ 11-20 ❍ 21 or more
Key Research Questions	
2.1 How will the engineering profession evolve over the next 5 and 10 years?	
2.2 And based on this, what are the emerging technical and transversal skills and competencies required in the engineering profession?	
2.3 How do hard (e.g. technical) and soft (e.g. personal) skills differ in terms of their importance for	

success in the engineering profession?	
2.4 What is the role of the engineering profession in the implementation of Sustainable Development Goals?	
2.5 Which new skills and competencies might be needed in order to achieve the Sustainable Development Goals?	
2.6 How can engineers be trained to become “conscious engineers” who prioritize ethical and sustainable practices in their work? 2.7 What role does professional independence play for Engineers in their working life and how important is it for the clients / society? How can University curricula and/or CPD measures enhance awareness of the	

different aspects of professional independence?	
2.8 Which factors might challenge the developments of new skills and competencies?	
2.9 How can multi-stakeholder partnerships address skills shortages/mismatches in the engineering profession and what are their dangers?	
2.10 How should policies correctly be addressed and which initiatives are needed for a more digital, green and resilient practice of the engineering profession?	
2.11 Are you aware of any case studies and best practice example which showcase the positive/negative development of current engineers?	
2.12 In general: What engineering education and training programs are needed for aspiring engineers?	

Further Questions/Notes:	

Thank you for your participation!

2. COUNTRY-LEVEL ANALYSIS

2.1 Portugal

2.1.1 Analysis by Faculdade de Engenharia da Universidade do Porto (FEUP)

1. Introduction

This report concerns UPorto-FEUPs' snapshot of the implementation of E4E common methodology and the conclusions drawn from the data gathered.

FEUP focused mainly on collecting data regarding 'What are the emerging transversal skills and competencies required in the engineering profession' and 'Is there a skills mismatch between what engineering curricula are delivering and what the job market is demanding'.

2. The Emerging transferable skills for Engineers

The number of higher education students enrolled in engineering programs has increased during the past few decades. This presents significant difficulties for Higher Education Institutions (HEIs), which have a social responsibility to advance the employability prospects of their graduates by empowering them to succeed in the workplace while also addressing the demands and expectations of the labor market in terms of skills.

Engineers in the post-industrial world are expected to have much more than just technical skills in their professions, despite the fact that they are typically seen as individual technical contributors. Additionally, the engineering job market anticipates that candidates will have a set of transversal skills, such as teamwork, time-management, management[32], and the ability to adjust to the difficulties of the twenty-first century, which include the frequent, unforeseen changes that are now the standard in many industries and companies.

These competencies are not related to specific fields of engineering and can be applied across various contexts, labor organizations, and roles. They enhance technical-scientifical skills, and contribute to professional success and adaptability.

Engineering programs all across the world are starting to encourage the development of transversal and transferable skills to address these issues. Despite this norm, engineering programs continue to place too much emphasis on technical abilities while giving nontechnical skills insufficient attention[33],[34]. In fact, HEIs frequently struggle to strike a balance between various curriculum requirements and job market needs.

In Portugal, transversal skills are already considered important, however, their development was for quite some time infused into the curriculum or left in the hands of Student Bodies/Associations. With the constant 'downsizing' of the curricular programs and insufficient preparation of the teaching staff to approach such competencies, transversal skills were often (to say the least) neglected. It was just assumed that by practicing 'some' oral presentations of their reports, students would eventually get

[32] Itani, M. and I. Srour. "Engineering Students' Perceptions of Soft Skills, Industry Expectations, and Career Aspirations." Journal of Professional Issues in Engineering Education and Practice 142 (2016): 04015005.
[33]J. Gilleard and J.D. Gilleard, "Developing cross cultural communications skills" JPI 128(4): 187-200. 2002
[34]T.J. Siller. A. Rosales and J. Haines, "Development of undergraduate students' professional skills," journal of professional issues in engineering education and practice, vol.135, no 3, pp. 102-108, 2009.

better at their communication skills and science communication. This isn't always true because in the presentations there is no reflection of these competencies nor are they assessed - the focus remains on the technical skills. This approach (infusing) proved to be ineffective and insufficient to prepare students for their new roles and responsibilities required by the labor market nowadays.

E4E research revealed that engineers in Portugal (and their employers) recognize the need to use transversal skills in their roles and daily tasks and request that more importance be given to such competencies in academic engineering curricula.

It also uncovered that there are two main approaches to developing transversal skills: promoting hands-on approaches to learning and focusing on integrating or bolting-on formal opportunities to develop and test these competencies.

3. Methodology

E4E common methodology is structured on 3 pillars:

1. Assess current situation: the methodology defines the tools, data, research models and assumptions to assess the "state of play" concerning demand and supply of skills and competencies for the profession, with a specific focus on the "non-technical" aspects such as:
    - Digital skills needed for a more integrated, dynamic and multidisciplinary profession.
    - Green skills: how the profession requires skills linked to a circular and greener economy.
    - Resilience skills: also referred to as "transversal", "soft" and "entrepreneurial" skills, i.e., adaptability, change management and care for each other as a community.
2. Anticipate future needs: based on realistic scenarios and the results of the analysis of the current situation, the methodology will allow to anticipate future needs for skills and competencies of the profession.
3. Monitor progress on a yearly basis to gauge the evolutions of the demand and supply of skills for the engineering profession to adjust the Skills Strategy.

The E4E research methodology combines primary and secondary research methods to gather relevant data from various stakeholders in the profession.

Primary research involves the organization of focus groups, and/or interviews, and/or questionnaire-based surveys with representatives of the engineering profession along the whole cycle of education, training, the world of work, employers and industry. This approach enables the E4E project to involve at least 200 stakeholders relevant to the profession in each round of monitoring. This primary research method provides in-depth insights into the challenges, opportunities and skills required in the engineering profession.

In this primary research, FEUP analyzed the data of SURVEY 1 - a survey conducted online, in 2022 to 1st cycle graduates in engineering. SURVEY 1 collected 473 validated responses (53% of all FEUPs 1st cycle graduates in engineering). Another survey (SURVEY 2) was launched by Engineers Europe, in 2023, to graduates (professionals and interns), academics and students in engineering.

Secondary research is based on desk research that captures specific trends for the engineering profession. This approach involves a review of relevant literature, reports, and statistics related to the profession, including the identification of trends and the development of at least 10 Fiches. Each Fiche depicts examples of concrete action, capturing not only good practices but also lessons learned about what works and what does not work in the acquisition of digital, green, resilience and entrepreneurial skills among engineers. HEI - Higher Education Institutions will focus on the current state of engineering education, including curriculum, teaching methodologies, and pedagogical practices, as well as the challenges and opportunities associated with the evolution of the profession in the next 5 to 10 years.

For the secondary research, FEUP analysed reports from U.Porto's Employment Observatory[35], the General Directorate of Higher Education[36] , the National Statistics Institute[37] and other relevant sources of information.

4. Needs

SURVEY 1 revealed that 92% of FEUPs engineering graduates/alumni consider that their roles and tasks are 'totally related' or ''partially related'' to what they've learned during their formal education.

92% of the respondents considered that personal and interpersonal skills are ''important'' or ''very important'' for the functions they currently perform, while 56% declared that these skills should be increased in the program they attended.

U.Porto's Employment Observatory , based on surveys to its graduates, aims to contribute to a better knowledge of the processes of transition to work, of the weight and influence of training not only in the lives of its graduates but also in society, in the economy and in the culture of the country and should serve as an instrument for the definition of strategic lines of development and quality of the training provided in the various programs. The surveys are applied annually.

The last available report[38], published in April 2022, surveyed alumni who graduated in the academic year 2018/2019, two years after graduation. 5884 alumni of U.Porto answered the survey, of which 1018 had graduated in a integrated master or master programme of the Faculty of Engineering (FEUP). Among the questions asked in the survey some relate to the perception of the skills acquired during the master programme and the skills professionally required in the current job. Graph 1 shows the comparison between the skills acquired during training and those needed professionally. The presented data corresponds to the average points of the FEUP respondents for each item in a scale from 1 (never) to 5 (always). Overall, there is a good overlap between the skills acquired and skills needed in the job. Yet, a detailed analysis highlights shortcomings and mismatches. Graph 2 shows the deviation between skills required professionally and skills acquired during the master programme. The values are normalized by the scale highest value. A positive value means that the skill is required professionally more intensely that what was acquired during the master programme. The largest positive deviations refer to the use of ICT skills and those skills that involve interactions with the working colleagues. On the other extreme are skills related with leadership, ethics and self-learning.

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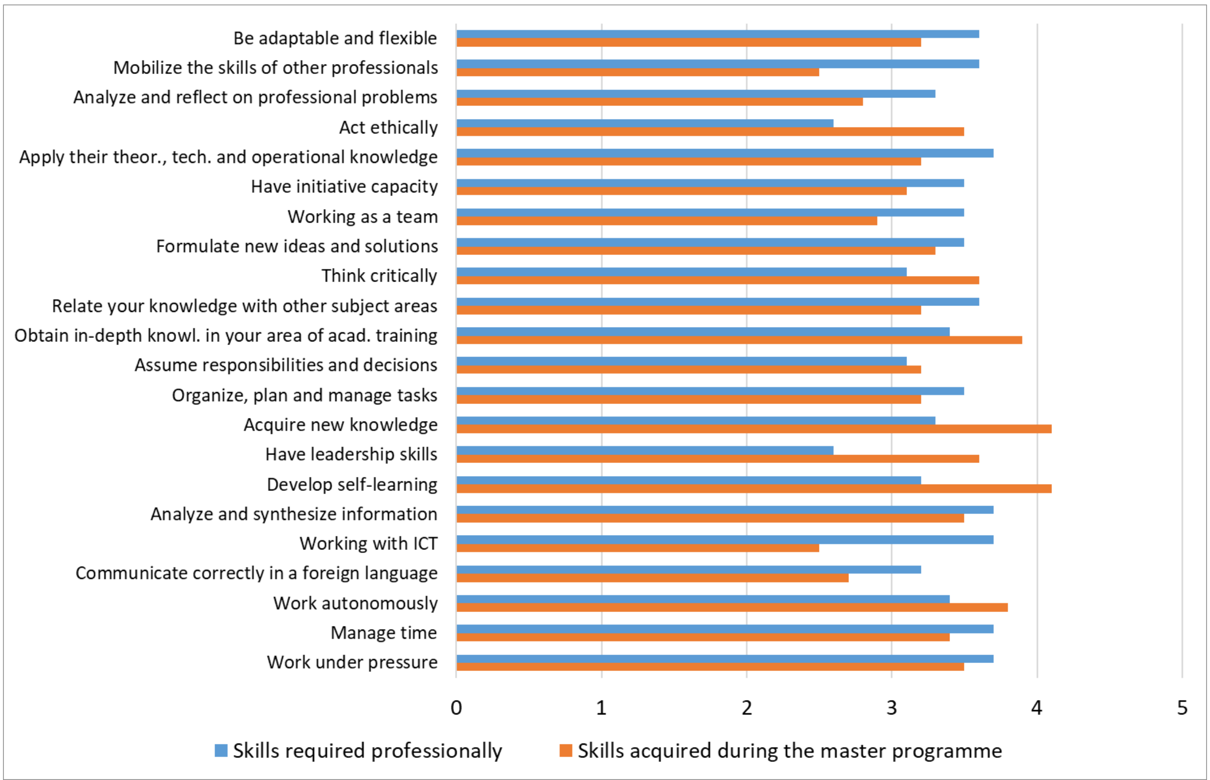
35 https://sigarra.up.pt/up/en/WEB_BASE.GERA_PAGINA?p_pagina=observat%c3%b3rio%20do%20emprego%20e%20da%20trajet%c3%b3ria%20dos%20diplomados%20da%20u.porto

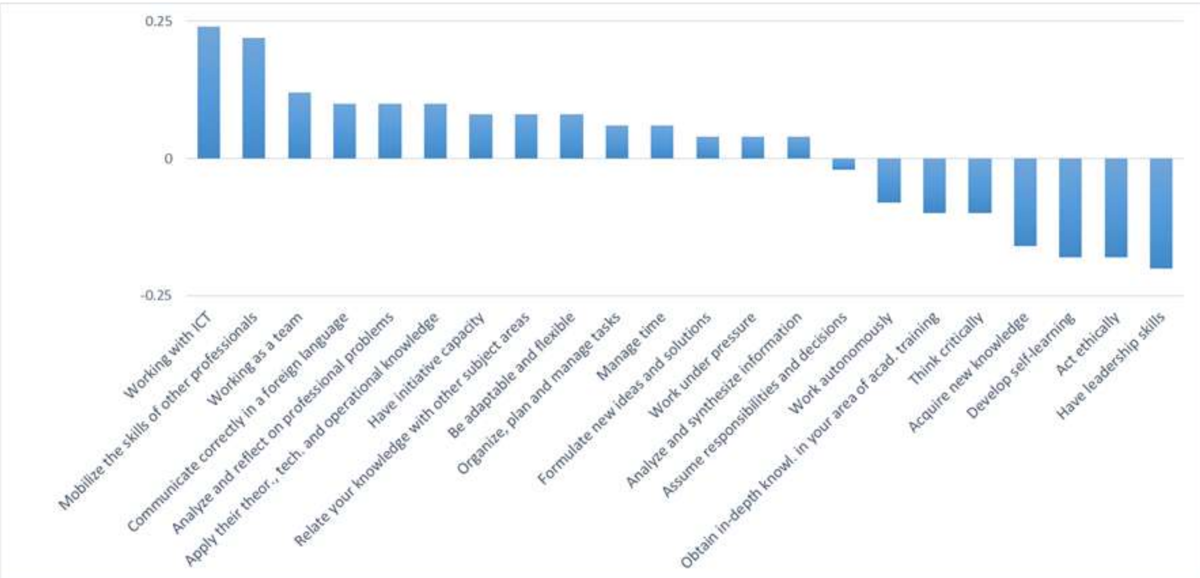
36 https://dges.gov.pt/

37 https://www.ine.pt/

38 Carlos Manuel Gonçalves (2022), Situação ocupacional dos diplomados da Universidade do Porto, https://sigarra.up.pt/up/pt/conteudos_service.conteudos_cont?pct_id=35070&pv_cod=13caaSkaEarE



Graph 1 - Skills acquired during FEUP's MSc programme and required professionally. Source: Gonçalves (2022)



Graph 2 - Skills acquired during FEUP's MSc programme and required professionally. Source: Gonçalves (2022)

4.1 Which types of competencies are not being sufficiently addressed in engineering programs?

When questioned about which type of competencies contributed to the functions (daily activities/tasks) they perform, 52% mentioned that the 'Personal and interpersonal skills' were 'very important' whilst 44% replied 'Basic technical-scientific skills in Engineering' were very important'.

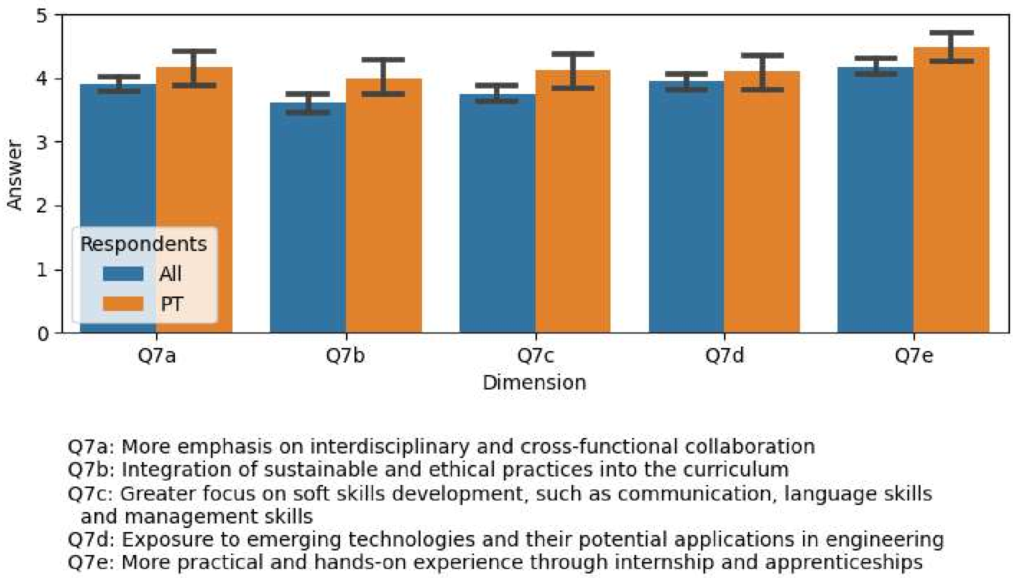
This indicates that the job market is, currently, with a high demand for engineering professionals, and in a context of volatility, uncertainty and rapid changes in technology-specific; context-related hard skills can become obsolete in a relatively short period of time. Thus, the transversal nature of soft skills remains relevant in different disciplines and work scenarios, but also in personal and social contexts[39].

Agreeing on the importance of developing such competencies in the engineering programs, the next step was to figure out how to do it.

4.2 How to develop transferable skills in undergraduate programs?

SURVEY 2 results (see Graph 3) revealed that to better prepare students for the evolving nature of the profession, the main aspect – for Portugal – was the creation of more practical and hands-on activities. Considering this aspect, several engineering HEIs in Portugal are actively working to implement active learning approaches that favor the development of transversal and transferable skills. HEIs are also proactive in contacting industry and companies and collaborating to make learning more meaningful and engaging, for example, through MSc thesis done in company environment.

SURVEY 2 results (see Graph 3) also revealed that engineering programs needed a greater focus on soft skills development.



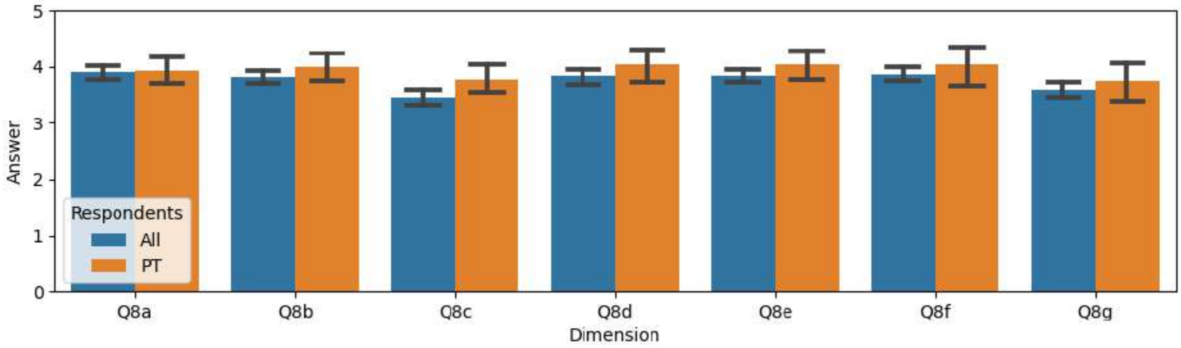
Graph 3 – What changes should be made to the engineering education and training programs to better prepare students to the evolving nature of the profession

Despite their significance and urgency, soft skills are insufficiently addressed in higher education programs. They may be described in the curricula explicitly, yet their delivery and development have

[39] Rao, M. S.: Soft skills enhancing employability. New Delhi, I. K. International Publishing House, 2010.

been overlooked for many decades. Nowadays, infusing transversal skills in the engineering curricula is being put aside to consider the bolting-on or the embedded approaches to their development.

When questioned about which approaches to develop the necessary skills for the engineering profession in formal education (Graph 4), the choices fall mainly on 'integration of hands-on and experiential learning opportunities' and 'emphasis on communication and collaboration skills'.



Q8a: Emphasis on interdisciplinary and systems thinking
Q8b: Incorporation of sustainability principles in engineering courses
Q8c: Greater focus on social and ethical issues related to engineering
Q8d: Integration of hands-on and experiential learning opportunities
Q8e: Emphasis on communication and collaboration skills in engineering
Q8f: Integration of emerging technologies and practices into the engineering curriculum
Q8g: Development of flexible, customized and short training programs

Graph 4 – What new approaches to formal engineering education and training are necessary to prepare engineers for the challenges of the 21st century?

4.3 How are HEIs in Portugal developing transferable skills?

4.3.1 Integrating hands-on approaches and experiential learning

Several HEIs in Portugal are trying to set up new approaches to develop transversal skills by integrating hands-on approaches and experiential learning.

FEUP (Porto), ULisboa (Lisboa), FEUC (Coimbra) have a course named 'Projeto Integrador' (Integrating Project). Through a real-life project scenario, the students will be able to apply and consolidate all the intended practices and techniques that a project encompasses. From its inception to its final product delivery, the students will go through all the phases of development, working in teams and collaborating to achieve a common goal. This "learn by doing" pedagogical philosophy allows for a deeper understanding of the practices and exposes the students to the hurdles and difficulties a real project might present. This methodology focuses on "product delivery", forcing the students to define a viable process to enable a fully functional, ready-to-use, final product release.).

FEUP created several courses on 'Students Competitions'. These competitions are voluntary, free of tuition and extracurricular. They group in teams, have soft skills formal training (teamwork, leadership, conflict resolution, time management and stress, etc) and then students, in a 2-day immersive environment and challenge-based learning, solve real-world cases provided by companies. Each course had a dedicated professor who coordinated all activities and was responsible for the quality of the process. By creating a transversal skills program 'outside' the engineering programs, FEUP adopted a bolting-on approach to the development of transversal competencies[40].

The students who enrolled were given 1,5 ECTS to credit in their academic paths. In the first two years of this program's implementation, there were around 500-600 participations per year[41] .

UAveiro is bridging all stakeholders to create a meaningful teaching and learning process and promote societal impact. Challenge-based learning takes place through the identification, analysis and design of a solution to a socio-technical problem. The learning experience is typically multidisciplinary, involves different stakeholder perspectives, and aims to find a collaboratively developed solution, which is environmentally, socially and economically sustainable. The students' participation is free of tuition, voluntary but not credited in the academic path.

EEng-UMinho is implementing project-based learning in some of its engineering programs. All courses contribute to the project and students learn the contents and work with an interdisciplinary mindset. The student's participation is mandatory and credited.

4.3.2 Integrating in the curricula, courses on Transversal Skills

With the opportunity of the DL n.º 65/2018[42] that stated the end of the national 5-year Integrated Masters programs and creation of 3-year 1st cycle graduate programs and 2-year 2nd cycle master programs, FEUP-UPorto and other national HEIs in engineering (such as UBI, UAveiro and IST) have created in all their 1st cycle and 2nd cycle programs, transferable skills courses.

This case is referred to in literature[43] as an integrating approach to the development of transversal competencies. One of the advantages of this approach is that it encourages the development of interrelated skills that complement and reinforce each other which allows learners to see the interconnectedness and interdependence of skills, leading to a more comprehensive skill set. It also gives visibility to this set of competencies conferring them relevance in the engineering skill set.

4.4 What transversal skills are being developed?

FEUPs transferable skills program is grouped into 4 types: 'soft skills', 'sustainability', 'digitalization' and 'entrepreneurship'. This taxonomy is in accordance with the project E4E framework.

Table 1 – Transversal Skills taxonomy and correspondence to project E4E

E4E project type	FEUP type	Skills
Resilience	soft skills	Communication, Conflict Management and Negotiation, Lifelong Employability, Leadership, Ethics, Philosophy

[40] Chadha, D; Nicholls, G (2006) Teaching transferable skills to undergraduate engineering students: Recognising the value of embedded and bolt-on approaches. International Journal of Engineering Education Vol: 22 Ed: 1 Pág: 116-122 ISSN: 0949-149X

[41] Vasques, F. (2023). Relatório do Programa de CTs da FEUP 2022/2023

[42] Decreto-Lei n.º 65/2018, de 16 de agosto , Diário da República n.º 157/2018, Série I de 2018-08-16, páginas 4147 - 4182

[43] Chadha, D; Nicholls, G (2006) Teaching transferable skills to undergraduate engineering students: Recognising the value of embedded and bolt-on approaches. International Journalof Engineering Education Vol: 22 Ed: 1 Pág: 116-122 ISSN: 0949-149X.

Green Skills	**sustainability**	Decarbonize the Building Sector to achieve Energy Sustainability, Engineering for sustainability, Challenges of sustainable development
Digital Transformation Skills	**digitalizalization**	Excel, Python, Optimization, MATLAB
Entrepreneurship Skills	**entrepreneurshi p**	Opportunities for innovation, Strategic management of innovation

Students can thus, choose for each slot, the course/transferable skill they'd like to attend.

The aim of the transferable skills courses is to align the program's contents with the new competencies (non-related to the scientific area of engineering) required by the job market and allow each student to develop the transferable skills they're less proficient in, to better prepare them to assume their functions in engineering.

UAveiro transversal skills program for engineering consists of soft skills, programming, sustainable development and technical drawing.

FE-UBI transversal skills program for engineering consists of soft skills (including ethics), entrepreneurship, sustainability, social responsibility.

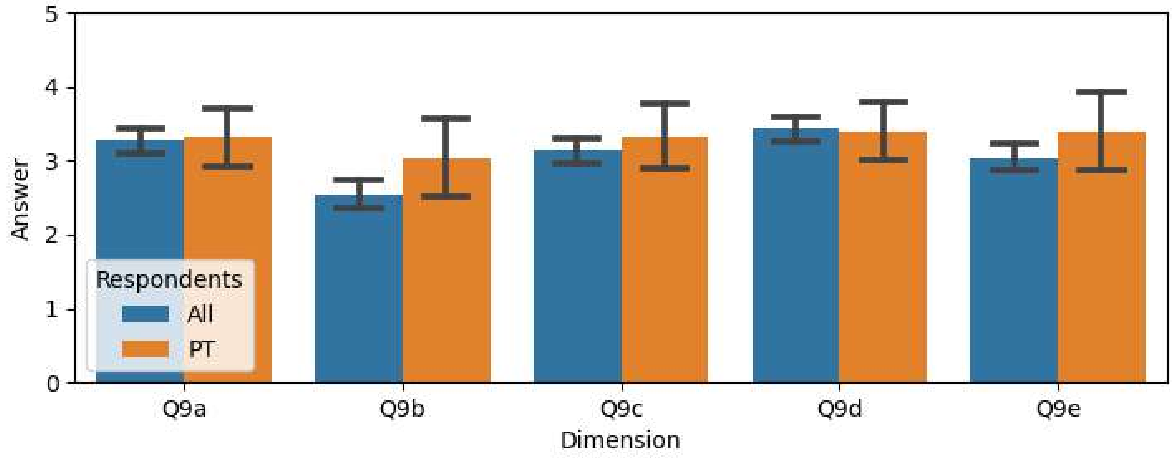
IST-ULisboa has a mix-model to develop transversal skills. Its infusing soft skills formal training seminars into several courses of its engineering programs and also has courses on transversal skills credited in the engineering programs.

FCT-NOVA - has several courses on transversal skills focused on soft skills and ethics on the 1st year of the engineering programs. In the 2nd year the transversal competencies focus on sustainability and digital transformation and on the 3rd year it focuses on research skills. On the masters level they focus on entrepreneurship skills.

EEng-UMinho- has the 'Opção UMinho': a set of electives that all students regardless of its program can choose to enroll. The offer is categorized into areas (Arts, Design, Sciences, Law, Economics and Management, Human Sciences, Psychology, Ethics and Firts Aid, Social Sciences, Sports, Global Citizenship)

FEUC has several courses on Transversal Skills in their engineering programs such as 'Ética, Comunicação e Liderança' , 'Empreendedorismo, Inovação e Transferência de Tecnologia'.

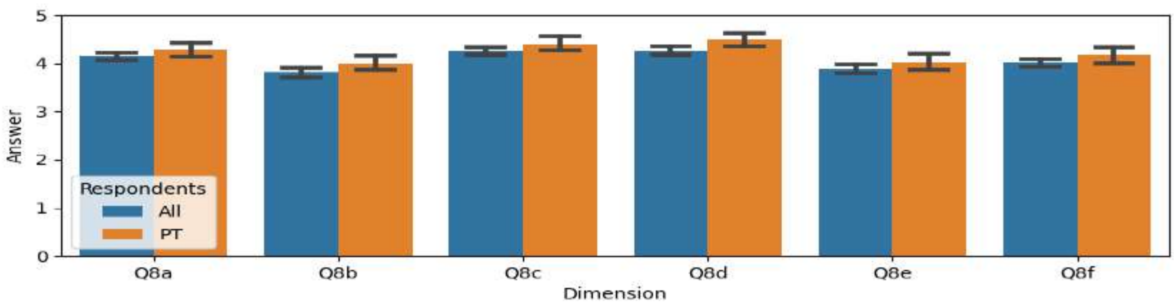
When questioned regarding several types of competencies (Graph 5), Portuguese engineers still feel (more than in other countries) the need to develop more technical skills specific to the field of engineering but also soft skills. However, Portuguese graduates feel that they already have sustainability skills sufficiently developed.



Q9a: Entrepreneurship and leadership (management skills)
Q9b: Technical skills development in your specific field of engineering
Q9c: Soft skills development (language skills, writing skills and overall communication skills)
Q9d: Ethics in engineering
Q9e: Innovation and sustainability (SDGs)

Graph 5 – Rank the following CPD courses in order of priority

When we look at the answers regarding soft skills needed to work successfully in the engineering profession (Graph 6), Portuguese graduates are aligned with the rest of Europe. The need is higher for collaboration skills/teamwork and critical thinking.

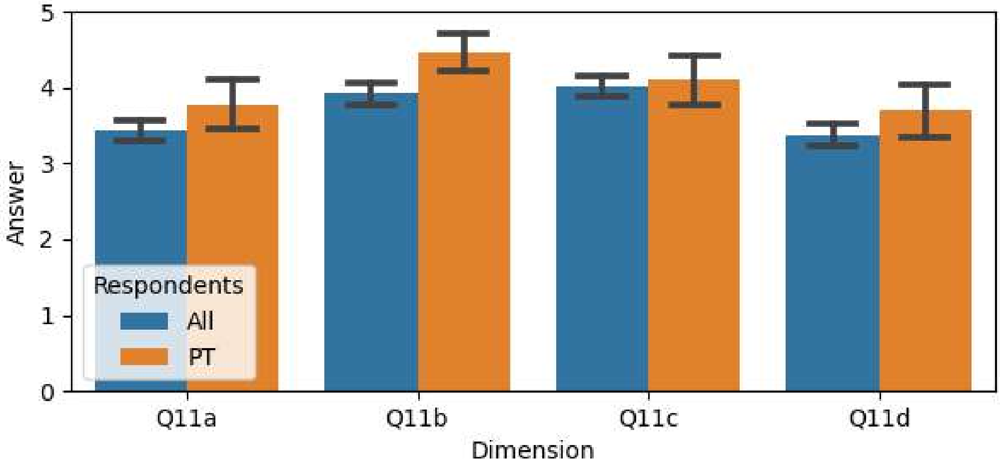


Q8a: Communication skills
Q8b: Leadership skills
Q8c: Collaboration skills
Q8d: Critical thinking skills
Q8e: Time management skills
Q8f: Adaptability skills

Graph 6 – Soft skills needed to work successfully in the engineering profession

4.5 What needs to be done in order to change this mismatch between academic programs in engineering and employment needs?

Graph 7 clearly shows that most respondents believe that Academia needs to establish partnerships with Industry in order to better understand the labor market needs and also to develop a framework with groups of transversal skills that are priority to develop.



Q11a: Provide financial incentives for training and development programs
Q11b: Establish partnerships between industry and educational institutions
Q11c: Invest in research and development
Q11d: Implement regulations and standards

Graph 7 – Policies and initiatives at regional and national levels that can effectively address digital, green, resilience and entrepreneurship skills shortages/mismatches in the engineering profession

5. Opportunities

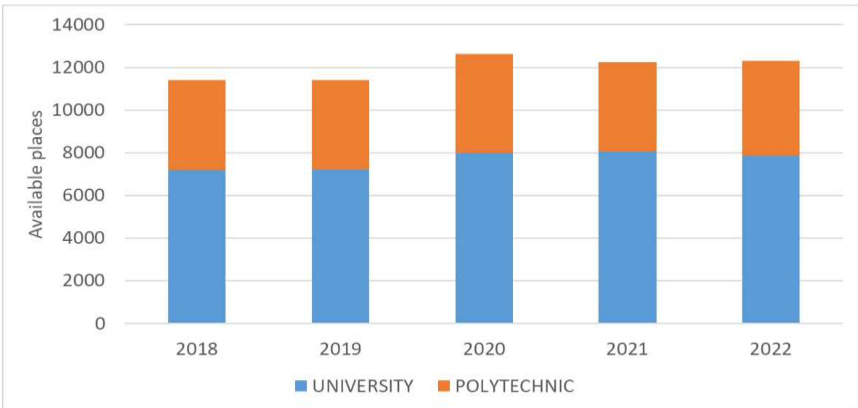
In Portugal, higher education is structured into two main components: university education and polytechnic education, which are offered by both public and private institutions. Private higher education institutions must obtain prior recognition from the Ministry responsible for Higher Education.

University education encompasses universities, university institutes, and other institutions that provide university-level instruction. Its primary focus is on promoting research and knowledge creation, while also ensuring a strong foundation in scientific and cultural education. It aims to provide technical training necessary for professional and cultural activities, as well as foster the development of design skills, innovation, and critical analysis.

Polytechnic education comprises polytechnic institutes and other institutions that offer polytechnic-level instruction. It emphasizes applied research and development to address practical problems. The main objectives of polytechnic education are to provide comprehensive cultural and technical training at an advanced level, foster innovation and critical analysis, and impart both theoretical and practical scientific knowledge applicable to professional activities.

In former times, the university education would lead to an engineer professional, while the polytechnic education would lead to a technical engineer professional. The recent legislation has made the difference between university and polytechnic education not so obvious since both systems provide the bachelor and master degree. The privilege of doctoral degree is still a prerrogative of the universities, though recent legislation opened the possibility for some polytechnic schools to award the doctoral degree if having excelent research capacities.

Access to higher education in Portugal is regulated by a central admission process, where students are assessed by the results of three national exams. Each programme as a limited number of places for enrollment, called *numerus clausus*. Graph 8 shows the number of available places in engineering programmes of Portuguese higher education institutions, in the past 5 years. About two thirds of the available places originate from the university subsystem. The number of available places grew from 2018 till 2020 and has stabilized in the last two years. The growth is explained by the strategy of the Portuguese government of increasing the numerus clausus of the engineering areas where the admission grade was higher than 17 (in 20)[44][45], which were seen as areas where the demand was higher. Graph 9 shows the occupation rate of the higher education institutions, that is the ratio of occupied to available places. In general, the university subsystem is able to occupy almost all available positions, with an average occupation rate above 90%. This demonstrates the high attractivity of the engineering programmes in Portugal. Yet, the polytechnic subsystem struggles to fill all the places, with an occupation rate below 80%. In the present, the social recognition of the university degrees surparses the one from polytechnic degrees, which is explained by the larger demand for university places in the admission process. The overall occupation rate of the Portuguese HE system shows that there is still available capacity to train more engineering professionals. It is thus fundamental to promote the profession to high school students through direct contact with schools and open days like the "Semana Profissão: Engenheiro"[46] from FEUP or the "Mostra UP"[47] organized the University of Porto.



Graph 8 – Number of available places in engineering programmes of the Portuguese higher education system. Source: Higher Education General Directorate[48]

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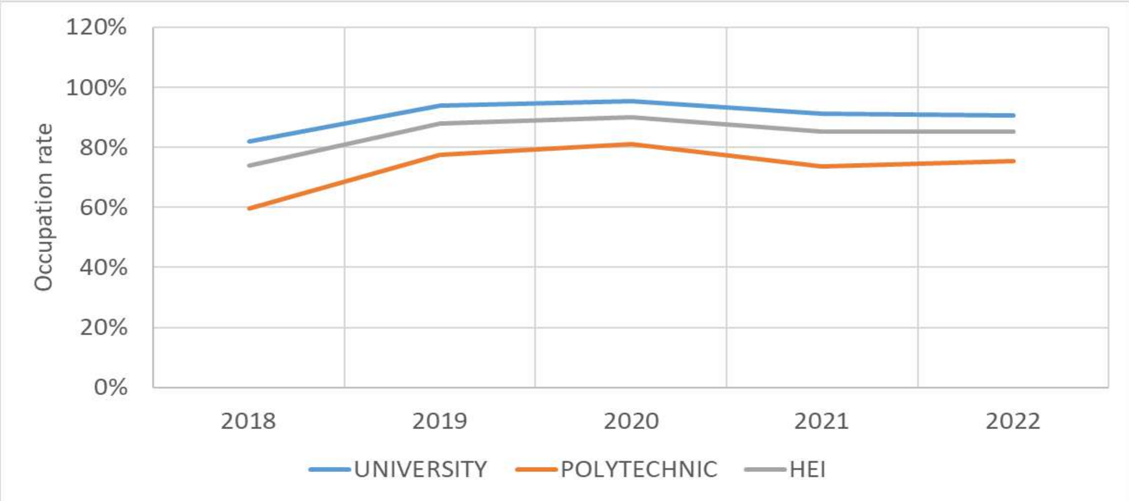
[44] https://www.publico.pt/2019/09/08/sociedade/noticia/cursos-subiram-vagas-esgotaram-aumentaram-medias-1885828
[45] https://www.jpn.up.pt/2019/06/07/poder-aumentar-vagas-e-uma-boa-noticia-para-a-feup/
[46] https://paginas.fe.up.pt/~escolas/
[47] https://mostra.up.pt/
[48] https://dges.gov.pt/coloc/2018/, https://dges.gov.pt/coloc/2019/, https://dges.gov.pt/coloc/2020/, https://dges.gov.pt/coloc/2021/, https://dges.gov.pt/coloc/2022/



Graph 9 – Occupation rate of the available places in engineering programmes. Source: Higher Education General Directorate

6. Challenges

By large, the biggest challenge to the higher education system, in general, and the engineering profession in particular is the demographic winter[49] which is expected to hit the universities and polytechnics by the end of the 2030 decade. Portugal is the third country in the European Union with the least number of births and places fourth in the number of residents aged 65 or more[50]. The diminishing number of students not only threatens the HEIs but endangers the economic competitive capacity of Portuguese companies. To tackle this challenge FEUP joined a project lead by Business Roundtable Portugal Association (BRP Association) and the Portuguese Investment and Foreign Trade Agency (AICEP) which will allow Portuguese companies to offer internships in Portugal to young foreigners who complete their master's degree in Portugal[51].

A recent challenge to academia in general and engineering education in particular derives from the emergence of artificial intelligence solutions which will automate many of the tasks currently done by humans. The most famous tool, is openai's chatGPT[52]. Even though large language models are not (yet) able to substitute the work of an engineer, several solutions are being developed to automate some of the more repetitive tasks currently performed by humans. At FEUP, artificial intelligence is being developed for the automation of high level tasks such as structural design[53], among other examples. Artificial intelligence will not only have an impact on the profession, but also on the teaching-learning process. Most of the discussion around chatGPT in the academic focus the ethical aspect of the use of such tools. Yet, the question might be better framed wether the HE and VET systems should adapt to this new reality and embrace it in the training of future generations[54].

[49] https://www.ffms.pt/pt-pt/infografia/infografia-portugal-um-pais-num-inverno-demografico
[50] https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_publicacoes&PUBLICACOESpub_boui=13932532&PUBLICACOESmodo=2
[51] https://noticias.up.pt/feup-integra-projeto-piloto-do-inov-contact-reverse/
[52] https://openai.com/blog/chatgpt
[53] https://repositorio-aberto.up.pt/handle/10216/144224
[54] https://hbsp.harvard.edu/inspiring-minds/chatgpt-and-ai-text-generators-should-academia-adapt-or-resist?cid=email%7Cmarketo%7C2023-02-09-inspiring-minds-digest-new%7C4729709%7Cinspiring-minds%7Ceducator%7Cinspiring-minds-

2.1.2 Analysis by Ordem dos Engenheiros (OE)

1. INTRODUCTION

1.1 The Green Deal and the SDGs

The Green Deal is a package of iniciatives that aims to transform European Union (EU) in a just and prosperous society, with a modern and competitive economy, establishing an ecologic transition with the ultimate goal of achieving carbon neutrality by 2050. For that, the Green Deal ensures:

- No net greenhouse gas emissions by 2050;
- Economic growth independent of resource use;
- No person and no place left behind.

For this objectives to be attained, the EU has pledged to reduce the net greenhouse gas (GHG) emissions by at least 55 % by 2030, compared to 1990 levels. It's also possible to see the alignment of the green deal with the Sustainable Development Goals (SDGs) of the United Nations (UN), included in the 2030 agenda, since the green deal will provide (Conselho da União Europeia, n.d.) (European Commission, n.d.) (European Commission, n.d.) (European Comission, n.d.) (ENGINEERS EUROPE (former FEANI), 2021):

- Fresh air, clean water, healthy soil and biodiversity;
- Renovated, energy efficient buildings;
- Healthy and affordable food;
- More public transport;
- Cleaner energy and cutting-edge clean technological innovation;
- Longer lasting products that can be repaired, recycled and reused;
- Future proof jobs and skills training for the transition;
- Globally competitive and resilient industry.

The EU is committed to the refered SDGs and placed the Green Deal at the center of its recovery efforts.

There are 17 SDGs, all intertwined, adopted by all the state-members of UN in 2015, in order to define priorities and aspirations of global sustainable development to be achieved by 2030. ((Business Council for Sustainable Development - Portugal), BCSD, n.d.), (Department of Economic and Social Affairs, UN, n.d.).

The main goal of the SDGs is to assemble global efforts around a set of targets and common goals, mobilizing both developed and developing countries ((Business Council for Sustainable Development - Portugal), BCSD, n.d.), (Department of Economic and Social Affairs, UN, n.d.).

The point of the SDGs is to complete what the previous goals, the Millenium Development Goals (MDG), did not complete, and stimulate action in the following areas:

- People: it refers to ending poverty and hunger, promoting dignity and equality;
- Planet: it's about sustainable consumption and production, combating climate change and natural resources management;

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article%7Cfeb2023&acctID=none&mkt_tok=ODU1LUFUWi0yOTQAAAGJ1QX11J8Ctx6BVx0YPgd6cc6ZM6p5RinI_XZN5oEF0dChaqK40_Rj-cnZzsQ4-L4QBAjOOS7ILOrfB0X35Y_hUOTznk_z6t036ylDmCZIEw

- Prosperity: it concerns personal realization, economic, technological and social progress;
- Peace: to promote a peacefull, just and inclusive society, free from fear and violence;
- Partnership: is related to transversal integration, interconnection and joint mobilization for the most vulnerable. (Department of Economic and Social Affairs, UN, n.d.) ((Business Council for Sustainable Development - Portugal), BCSD, n.d.) (Iberdrola, n.d.)

The 17 SDGs are:

1. No poverty: end poverty in all its forms everywhere;
2. Zero hunger: end hunger, achieve food security and improved nutrition and promote sustainable agriculture;
3. Good health and well-being: ensure healthy lives and promote well-being for all at all ages;
4. Quality education: ensure inclusive and equitable quality education and promote lifelong learning opportunities for all;
5. Gender equality: achieve gender equality and empower all women and girls;
6. Clean water and sanitation: ensure availability and sustainable management of water and sanitation for all;
7. Affordable and clean energy: ensure access to affordable, reliable, sustainable and modern energy for all;
8. Decent work and economic growth: promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all;
9. Industry, innovation and infrastructure: build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation;
10. Reduced inequalities: reduce inequalities within and amongst countries;
11. Sustainable cities and communities: make cities and human settlements inclusive, safe, resilient and sustainable;
12. Responsible consumption and production: ensure sustainable consumption and production patterns;
13. Climate action: take urgent action to combat climate change and its impacts;
14. Life below water: conserve and sustainably use the oceans, seas and marine resources for sustainable development;
15. Life on land: protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification and halt and reverse land degradation and halt biodiversity loss;
16. Peace, justice and strong institutions: promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels;
17. Partnerships for the goals: strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development. (Department of Economic and Social Affairs, UN, n.d.) (República Portuguesa, 2023) (Instituto Nacional de Estatística, I.P., 2023) (Iberdrola, n.d.)

Associated with these 17 SDGs are 170 targets and 248 global indicators. In Portugal, comparing the recent year with 2015, we can see that most of the global indicators analyzed (101) had a positive evolution, from which 20 have already reached the target; 28 global indicators have shown a negative evolution; 3 global indicators didn’t show evolution; 38 can’t be evaluated (78 indicators from the UN list aren’t part of the Portuguese list, since they don’t apply to our national context, don’t have a stabilized methodology and/or there isn’t available data), as shown in figure 1. (Instituto Nacional de Estatística, I.P., 2023).

Figure 3: Available indicators in our country to measure progress of SDG implementation.

In figure 2 a summary of the SDGs implementation landscape is presented (Instituto Nacional de Estatística, I.P., 2023):

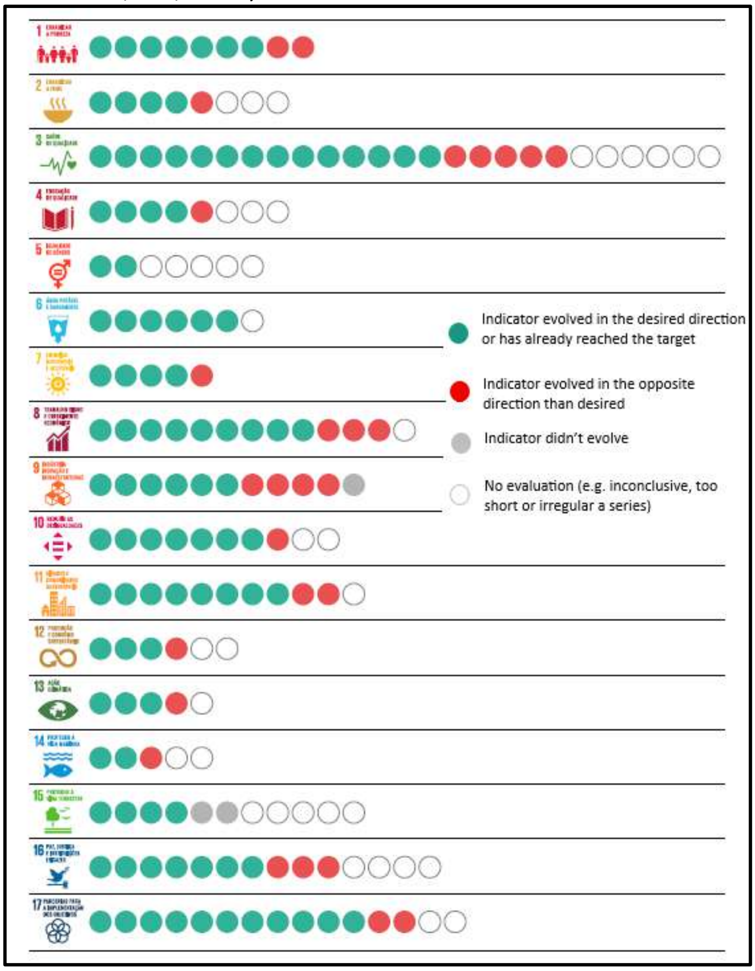

Figure 4: Progress in implementing SDGs in our country.

In Portugal we have already achieved some targets related to SDGs 1, 3, 6, 7, 10, 11, 13, 15, 16 and 17, despite the impact of the COVID-19 pandemic and the war in Ukraine.

SDG 1 – No Poverty

In regard to SDG 1, there has been some favorable progress since 2015, although the data available so far doesn't fully reflect the complete impact of COVID-19 pandemic. The poverty rate has decreased from 19,0% in 2015 to 16,4% in 2021 and in the area of social protection there's an upward trend in the series for the proportion of the unemployed population (looking for a new job) receiving unemployment benefits since 2017, in particular a substantial increase that was ensured in the first two years of the COVID-19 pandemic. However, between 2015 and 2021, the ratio of "social security old-age pensioners per 1 000 residents aged 65 and over" reduced by almost 10%, and the evolution of the ratio of the number of social security disability pensioners to the working population was just below 30%. The total proportion of public spending on education, health and social protection also increased between 2015 and 2021. It should be noted that between 2019 and 2020 there was a one-off decrease, justified by the growth in total public expenditure (driven by support for businesses in the confinement period) which implied the loss of relative weight of expenditure on essential services, despite its increase, in response to the health crisis. In Official Development Assistance (ODA), there was also an increase in total donations for poverty reduction, compared to the 2015 numbers. On the other hand, the number of deaths attributed to disasters rose significantly in 2020, due to the COVID-19 pandemic (Instituto Nacional de Estatística, I.P., 2023) (República Portuguesa, 2023) (United Nations, n.d.).

SDG 2 – Zero Hunger

Portugal's situation regarding SDG 2 is mostly characterized by improvements since 2015. In monitoring SDG 2 in the national context, it's observed that the trends are advantageous in terms of food insecurity (the proportion of the adult population suffering from moderate or severe food insecurity has decreased from 14.7% in 2015 to 11.6% in 2020), but in terms of obesity we don't have the same results. The proportion of agricultural areas under organic farming has increased slightly. The ODA and other official flows to the agricultural sector have increased since 2015, peaking in 2017. On a less positive note, the indicator of food price anomalies deteriorated in 2020 (from 0,36 in 2015 to 1,37 in 2020) (Instituto Nacional de Estatística, I.P., 2023) (República Portuguesa, 2023) (United Nations, n.d.).

SDG 3 – Good Health and Well-being

About Portugal's situation regarding SDG 3, this is mostly characterized by improvements since 2015. Similar to SDG 1, the assessment of SDG 3 does not yet fully reflect the full impact of the pandemic COVID-19 due to the time lag in the availability of the respective indicators. Improvements were verified in almost all health-related areas monitored under the SDGs compared to 2015. The reduction in mortality rates in several areas (infant and neonatal, circulatory system diseases, malignant tumors, diabetes mellitus and chronic respiratory diseases, suicide and road accidents), as well as in teenage fertility rates and incidence of reported cases of HIV and malaria, stand out favorably. Equally positive are the increases in vaccination coverage and in the number of doctors, nurses, dentists, and pharmacy professionals. On the other hand, there are increases in maternal mortality rates (although within the target range) and in mortality attributed to unsafe water sources or sanitation, lack of hygiene, and accidental poisoning. There is also a decrease in health ODA, despite a counter-cyclical increase in 2020 due to international aid during the COVID-19 pandemic (Instituto Nacional de Estatística, I.P., 2023) (República Portuguesa, 2023) (United Nations, n.d.).

SDG 4 – Quality Education

The fourth SDG presents a favorable evolution in most indicators. Comparing with 2015, the conclusion rate of middle school and high school education has increased, along with the enrolment rate at 5 years old, meaning that Portugal is close to achieve the target by registering 99,2 % in the school year 2020/2021. These indicators will not have been affected by the pandemic in 2020 and 2021, since they continue to increase. However, the trends have been less favorable for educational outcomes and competencies in some areas, which lack more up-to-date data. Still, the proportion of students with reading proficiency, as measured in the OECD's PISA (Program for International Student Assessment) study, decreased between 2015 and 2018, showing a withdrawal from the target prior to the health crisis. On a more positive note, proficiency in mathematics, measured by the same study, increased. In terms of gender parity, the trend was favorable in reading and math. Also, it was registered favorable progress in digital skills, with Portugal slightly ahead of the EU27 in the dissemination of digital skills amongst adults. This indicator also shows that there is parity between men and women, with the discrepancies previously recorded having been reduced. In 2018, the proportion of schools with access to computers for pedagogical purposes, basic drinking water, electricity, Internet, single-sex basic sanitation and with basic handwashing facilities was 100% (Instituto Nacional de Estatística, I.P., 2023) (República Portuguesa, 2023) (United Nations, n.d.).

SDG 5 – Gender Equality

In regard to SDG 5, there has been mostly favorable developments in the monitored areas. In spite these improvements, gender equality remains far from being totally achieved. It's important to highlight that it exists legal frameworks that promote, enforce and monitor gender equality, as well as the relative parity in the use of Information and Communication Technologies (ICT). However, considering the respective relevance, the good national performance at legal level and in use of ICT may show that progress in gender equality would benefit from a more comprehensive assessment. Therefore, it's suggested that the reading of this SDG should be complemented by additional information included in the analysis of other indicators contained within other SDGs. However, it's in full participation and equal opportunities at civil and economic level (e.g., political office and leadership positions, respectively) that the greatest disparities are registered. There has been some progress registered in these dimensions: the increase of women in leadership positions when compared to 2015, and in particular, the proportion of women in public administration. This proportion has been over 50% since 2015, even though disparities persist in different levels of responsibility (fewer women in senior management positions compared with management positions) (Instituto Nacional de Estatística, I.P., 2023) (República Portuguesa, 2023) (United Nations, n.d.).

SDG 6 – Clean Water and Sanitation

Related to SDG 6 there has been generally favorable progress. Several areas approached or reached the target, with particular focus on the level of excellence in the quality of water for human consumption, with 99 % of safe water. Similarly favorable, it was registered a decrease in the percentage of people without adequate sanitary facilities in their homes, as well as the increase in proportion of households served by water supply. It's noteworthy that, within the framework of international cooperation, 100% of transboundary river and lake basins are covered by an operational cooperation agreement, as well as ODA in the areas of water and sanitation, which increased in 2021 compared to 2015 (Instituto Nacional de Estatística, I.P., 2023) (República Portuguesa, 2023) (United Nations, n.d.).

SDG 7 – Affordable and Clean Energy

The evaluation of SDG 7 indicators is mostly positive. We draw special attention to the goals already achieved or practically achieved in terms of energy matters such as: 100 % of the population has access to electricity and over 95% with primary access to clean fuels and technologies. Equally favourable is the evolution of renewable energy in final energy consumption which by 2021 was higher than the observed in 2015. Our country is also more energy efficient, as it's reflected in the decrease of the energy intensity of the economy compared to 2015 (ratio between total primary energy consumption and Gross Domestic Product - GDP). On a less positive note, the financial flow to developing countries to support research and development of clean and renewable energy production has decreased, compared to 2015 (Instituto Nacional de Estatística, I.P., 2023) (República Portuguesa, 2023) (United Nations, n.d.).

SDG 8 – Decent Work and Economic Growth

About Portugal's situation regarding SDG 8, this is mostly characterized by improvements in the economic and employment situation compared to 2015, which were interrupted in 2020, but resumed since 2021. Some illustrative indicators are: the annual rate of change in GPD per capita (6,9% in 2022), the unemployment rate (6,0% in 2022) and the rate of young people not employed and who are not in education or training (9,4 % in 2022). It's important to highlight that in 2020 public measures to protect employment during confinement, such as simplified layoff, helped to mitigate the negative impact of the pandemic on the labor market, as it's reflected in the performance of the respective indicators. Tourism was particularly affected by the pandemic context, but has since begin its recovery process in 2021, with a 27,3 % increase in its Gross Value Added (GVA). In contrast, the numbers of non-fatal and fatal accidents at work have increased in the period in question in comparison with numbers of the EU27 (in spite of the favourable progress since 2015). Likewise, in the accessibility of financial services, there was a reduction in the number of other monetary intermediation establishments, which mainly reflects an increase in the relative importance of home banking payments, in detriment of physical access to these services. In international cooperation, there was also a decrease in ODA and Other Public Flows (OPF) for trade support between 2015 and 2021 (83,7%) (Instituto Nacional de Estatística, I.P., 2023) (República Portuguesa, 2023) (United Nations, n.d.).

SDG 9 – Industry, Innovation and Infrastructure

In regard of SDG 9, most of its indicators show a positive evolution compared to 2015. The increase in the proportion of the GVA of high and medium technology industries in the GVA of the manufacturing industry and of expenditure on research and development in GDP, which is still far from the 3% set in the national target for 2030 is a good progress for this SDG. Likewise, in the area of Research & Development (R&D) and Innovation, the steady increase in the proportion of researchers per 1 000 inhabitants is positive. The intensity of atmospheric emissions of the economy (measured by CO_2 emissions in relation to GVA) also improved, compared to 2015, as did the number of micro and small debtor companies, that decreased in relation to the total number of companies. Finally, the goal achieved in the proportion of population covered by mobile network, which achieved 99,9 % in 2021, should be noted. On a less positive note, other dimensions, like the area of transport and passengers and cargo (by various modes of transport), after a favourable progress until 2019, changed in 2020 in the sequence of the pandemic situation, moving away from the desired target (for instance, the decrease to less than a third in air transport between 2019 and 2020). In manufacturing, the decline in employment and in proportion of value added of micro industrial enterprises isn't favourable. Still, in 2022, manufacturing maintained its importance in our economy (Instituto Nacional de Estatística, I.P., 2023) (República Portuguesa, 2023) (United Nations, n.d.).

SDG 10 – Reduced Inequalities

The development related to SDG 10 show a positive picture. In 2021 it's possible to observe a trend of growth in median income since 2015, either for general population and for the 40% of population with fewer resources, in spite of the drop registered in 2020 for the latter group. The share of people in households with an income below 50% of median income decreased between 2015 and 2021, once again, despite the increase registered in the first year of the COVID-19 pandemic. The share of GDP also showed favourable progress, increasing in 2020 compared to 2015. The evolution of financial soundness was also positive, specifically with a decrease in non-performing loans. In the international dimension, our country's assessment improved regarding migration policies that facilitate orderly, safe, regular and responsible migration and mobility of people. ODA, OPF and private support also increased between 2015 and 2021. On the other hand, the evolution of foreign investment is unfavourable, going from a positive balance between 2015 and 2019 to a negative balance in 2020, which became worse in 2021. In 2021, economic inequality was reduced, but the redistributive impact of taxes on income and wealth and social contributions maintained the unfavourable trend (Instituto Nacional de Estatística, I.P., 2023) (República Portuguesa, 2023) (United Nations, n.d.).

SDG 11 – Sustainable Cities and Communities

Indicators available to SDG 11 still don't reflect the full impact of the COVID-19 pandemic. Nonetheless, its evolution since 2015 was positive. The rate of expenses in housing, the evolution of artificial territories *per capita*, the public expense in cultural patrimony and the air quality (in regard of medium content of particles $PM_{2,5}$ and PM_{10}) were favorable. On the other hand, the pandemic situation increased the number of deaths attributed to catastrophes, registering a significant rise in 2020 and 2021 (from 59 people in 2015 to 12 056 people in 2021). The urban waste collected had an unfavorable evolution in 2020, comparing to 2015. Private expenditure on heritage (e.g., libraries, archives, museums, and other cultural services) interrupted its growth in 2020, going on to display a pronounced decrease (Instituto Nacional de Estatística, I.P., 2023) (República Portuguesa, 2023) (United Nations, n.d.).

SDG 12 – Responsible Consumption and Production

The trends related to SDG 12 don't reflect the full impact of the COVID-19 pandemic. Since 2015 there has been an overall positive evolution, but this SDG has a relatively low availability of indicators, some of which with inconclusive tendencies. The progress made in domestic material consumption per unit of GDP, as well as in the material footprint is noteworthy and favorable, since it decreased in 2021 when compared to 2015. There's also a favorable trend in the proportion of municipal waste prepared for reuse and recycling (which remains above the values of 2015, in spite of its decrease in 2020 compared to 2019). On a less positive note, there has been an increase in internal consumption of materials and internal consumption of materials *per capita* between 2015 and 2021. The area of hazardous waste also shows an increase, for instance in sectoral hazardous waste *per capita* or the general trend in various sectors of activity, in which there were increases of varying intensity in the generation of this waste, in 2021 (Instituto Nacional de Estatística, I.P., 2023) (República Portuguesa, 2023).

SDG 13 – Climate Action

The general evaluation of progress related to SDG 13 is mostly positive. Although according with provisory estimates for 2020, our country has reduced their GHG emissions by 1,5% since 1990 and 32,9 % since 2005, there's a need for further progress to meet the target of a 55% reduction (compared to 2005 data) by 2030. In 2020, the decrease in GHG emissions was accentuated due to the COVID-19 pandemic that began in that year and that determined a decrease in economic activity and circulation in the various modes of transport. This assessment is based on the past progress and doesn't take into account developments after 2020. The pandemic situation conditioned the number of deaths attributed to catastrophes, which rose significantly in 2020. The score attributed to Portugal regarding the adoption and implementation of the national strategy for Disaster Risk Reduction (DRR) in line with the Sendai Framework has increased since 2015 (Instituto Nacional de Estatística, I.P., 2023) (República Portuguesa, 2023).

SDG 14 – Life Below Water

The available data for SDS 14 is still limited in scope, which limits the overall assessment. Portugal has a maximum rating regarding the degree of implementation of international instruments aimed at combating illegal, unreported and unregulated fishing. Correspondingly, the indicator for the degree of implementation of a legal/regulatory/policy/institutional framework that recognizes and protects the right of access of small-scale fishing registered an increase. Regarding fisheries management, in 2022, for the third consecutive year, all stocks subject to assessments were considered sustainable. In the Autonomous Regions of Madeira, in 2022, in the stocks subject to national analytical assessment, persisted the unsustainable exploitation of horse mackerel. On the other hand, the black scabbardfish is being exploited in a sustainable exploitation. On a less positive note, it should be noted that the proportion of R&D investment in marine technology as a proportion of total investment in intellectual property has decreased (Instituto Nacional de Estatística, I.P., 2023) (República Portuguesa, 2023).

SDG 15 – Life on Land

The available data for SDG 15 is of limited actuality, which limits the overall assessment. However, the information for the indicators that can be used to assess progress since 2015 is mostly favorable. Our country is amongst the countries that have adopted legislative, administrative and policy frameworks to ensure the fair and equitable sharing of benefits, having relevant national legislation and allocating adequate resources for the prevention or control of exotic invasive species. Portugal has a National Biodiversity Strategy and Action Plan (NBSAP) and has set national targets in accordance with the Aichi Biodiversity Target 2 of the Strategic Plan for Biodiversity 2011-2020. Biodiversity values are integrated into the national accounts systems, defined with the implementation of the System of Environmental Economic Accounts (SCEA). The ODA allocated to biodiversity recorded a favorable trend (Instituto Nacional de Estatística, I.P., 2023) (República Portuguesa, 2023).

SDG 16 – Peace, Justice and Strong Institutions

Most SDG 16 indicators have showed favourable trends when compared to 2015. Deaths caused by homicide have decreased, as well as the corruption perception index, which decreased slightly. The number of women leaders in the Public Administration sector and women elected to the National Assembly increased, compared to 2015, but there was a decrease of 4,5 % between the 2022 and 2019 elections. There was also an increase in the number of firearms seized, surrendered/recovered by the police, more than doubling between 2015 and 2021. Against the desirable evolution, there is an increase in the proportion of preventive prisoners (significantly in 2020). Likewise, between 2015 and 2021, the number of human trafficking crimes increased. However, it's to be noted that in 2020, in the context of a pandemic, this number fell by almost half, compared to the previous year. A direct consequence is that the proportion of people who feel safe walking around alone after dark has decreased (Instituto Nacional de Estatística, I.P., 2023) (República Portuguesa, 2023).

SDG 17 – Partnerships for the Goals

The developments regarding SDG 17 are mostly positive. The tax burden and the percentage of the State Budget financed by taxes have registered favorable trends (in the context of target 17.1 - strengthen domestic resource mobilization - the upward trend is favorable as it aims to improve the national capacity to collect taxes and other sources of revenue). Digitalization-related indicators also show a favorable trend, with an increase in broadband Internet access at a fixed location and in the percentage of adults using the Internet.

The total ODA and the proportion of ODA to Gross National Income (GNI) increased. ODA for statistical capacity building in developing countries decreased slightly, conditioned by the suspension of in-site activities during the COVID-19 pandemic. With a less positive evolution, it should be noted that the Foreign Direct Investment (FDI) and the weight of remittances from emigrants and immigrants in GDP decreased (Instituto Nacional de Estatística, I.P., 2023) (República Portuguesa, 2023) (United Nations, n.d.).

Quantitative indicators on the evolving nature of the engineering profession

In our country, presently, we have a total of 61 422 engineers registered in "Ordem dos Engenheiros" (OE), distributed by 12 specialties as shown in table 1 (Ordem dos Engenheiros, 2023):

Table 1: Engineers registered in OE by specialty.

Specialty	Total
Agronomic Engineering	2610
Environmental Engineering	2192
Civil Engineering	29231
Electrotechnical Engineering	11439
Forest Engineering	637
Geographical Engineering	477
Geological and Mining Engineering	1184
Computer Engineering	1030
Materials Engineering	463
Mechanical Engineering	9067
Marine Engineering	142
Chemical and Biological Engineering	2950
Total	61422

Facing the evolution of the specificity in engineering programs, OE created 5 more specialties: biomedical engineering, food engineering, industrial management and engineering, aeronautic and spacial engineering and quality and security engineering, hoping to attract more engineers, especially more young engineers.

2. Qualitative descriptors of the evolving nature of the engineering profession

For the primary research, we conducted a series of interviews (template used for the interviews in Annex 1 and a resume table in Annex 2), two round table discussions, one of which with a dean and one president of an engineering school, and a dinner-debate (there are some photographs of all the events in Annex 3 and a resume of information gathered at these events in Annex 4). For the secondary research we proceeded, as requested, with desk research (resume table in Annex 5).

2.1 Evolution of the engineering profession

According to the research, the engineering profession is increasingly becoming more and more dynamic, expedited by the manufacturing sector, as well as government and services enterprises, accompanying the evolution of the economy and society. The future of the engineering profession is dependent not only, on the ability of the engineers to meet the economic and industrial demands, but also depends on the ability to innovate, diversify and drive the economic and industrial operational trends. The future of the engineering profession is ever more aligned with environmental sustainability and the green transition, demographic changes, advances in technology and the globalization of value chains.

Engineers will be fundamental to attain the SDGs goals, so that a just, sustainable, efficient and competitive transition can be achieved. Engineers will be responsible for design, develop and implement several solutions in several areas, such as energy, water, air, agriculture, mobility, infrastructure, transportation, construction, technology and AI.

There are all the time more and more new engineering disciplines, leading to new engineering roles, each time more specific, that didn't exist before, which conducts to a change in the nature of engineering and where engineers work – less site and more office. So, as more engineers join the field and the industry evolves, so does the job opportunities, the needs of employers and the challenges faced by engineers. Nowadays, to stay competitive in the job market, both aspiring engineers and engineers who want to advance in their careers need to build a strong and diverse set of skills, so they can be set apart in a highly competitive job market.

3. Opportunities

As opportunities for the engineering profession, the research done show that, since there are some challenges, there are also several opportunities.

Since engineers have abilities fundamental to decision making processes and to induce political decisions, there's an opportunity for engineers to enroll in that route, which leads to the engineering perspective to be more accounted for by political decision-making bodies, promoting a better coordination.

In the meantime, there's an opportunity to promote CPD (Continuous Professional Development), through microcredentials, couching and other forms of acquiring soft skills in order to complement hard skills, already developed. For that, industry itself can help by training and upskilling their own engineers, which in turn gives them more confidence to perform their duties and decreasing the probability of those same engineers leaving that company (for not being able to progress in their careers).

For engineers that are still not formed, HEIs have an opportunity to reform the engineering programs in order to achieve a better balance between soft and hard skills, between theoretic and practical knowledge, as well as to respond more promptly to the industry needs. For this goal to be achieved its suggested to promote a closer cooperation between HEI's and Industry, for instance by encouraging more students to be more involved in their areas of engineering, cooperating with companies of their field of engineering, which, in that process, might recruit an engineer. This student is, by then, embedded in the company's policies, or the company gains new skills and perspectives brought by the young training engineer, even though he ends up working for another company. Either way, it's a win-win situation.

Another opportunity for the engineering profession is to recruit more engineering students by promoting the engineering profession at an earlier age stage. For that, it's suggested that children should begin to be exposed to the engineering profession at a tender age, since the role of an engineer in everyday life is not as visible as, for example, that of a doctor.
To promote an increase in the numbers of female engineers, it is suggested that role-models are very important. It's also imperative to dissolve the pay gap between men and women engineers as well as to improve workplace policies and practices that strengthen women's careers in engineering, in order to give them more support to develop their careers.

4. Needs

According to the research made, it was possible to identify several needs related to the engineering profession. One of the main needs identified was to have a stronger bridge of sharing and communication between higher education and industry, so that higher education can better respond to the evolution of industry and its needs. One of the most pointed out flaws was the need to incorporate and balance hard and soft skills in the programs of higher education, such as research and critical thinking, computer sciences, artificial intelligence (AI), internet of things (IoT), sustainability, circular economy, renewable energies, risks and project management, data analysis and synthesis, design thinking, communication, leadership, entrepreneurship, teamwork, social responsibility, problem-solving, planning and organization, innovation/creativity, emotional intelligence, passion transmission, stress management, adaptability, humanistic and social values, since they complement each other, in order to achieve a more well-adjusted engineer.
Each engineer should be able to choose, according to his needs, the soft skills, microcredentials, post-graduations, coaching programs and masters that are most appropriate to develop in his work field.
Since there is a severe shortage of engineers, there's also a need for senior engineers to reskill, through the programs referred above, so that they can respond to the future needs of industry.

5. Challenges

With AI development, there will be some negative impact in terms of decrease in tasks of engineering competencies. In face of the increase in virtual professional practice (digital nomads), there is a risk that humans will unlearn to interact physically and emotionally with their peers and with society in general. It's also a risk that professionals will come to believe in the truths provided by channels/platforms, such as chat-GTP and others to come, and be driven by algorithms that may be misleading, which in turn leads to them to stop reasoning for themselves.
Considering these potential risks, in addition to the need of formation in soft skills, one of the most common challenges faced by engineers today is to expand their spectrum of competencies beyond the field of engineering towards a more holistic view and approach, complementing what they learned in their engineering courses. Another angle is to adapt the engineering programs to the new demands of industry, in order for the engineers of the future to leave HEIs better equipped to face the job market. This means that in one case or the other, there needs to be a perfect balance between soft skills and hard skills, theory and practice of engineering in the field. Some references suggest that for that goal to be achieved, maybe could implemented 6-years engineering programs, of which it would result a 4-year bachelor's degree plus a 2-year master's degree, giving HEIs more room to embed soft skills engineering programs, since they consider that an engineering program of 3 years doesn't give enough competencies to a complete professional engineer. They also suggest that there should be a correspondence between a given number of theorical hours and practice hours in a professional/entrepreneurial environment, which justifies the increment of engineering programs in 1 year at the 3-year post-Bologna degree.

An additional challenge faced by the engineering profession is the low number of students of engineering. To tackle this challenge, its suggested that children should be exposed to professional engineers and their role in society from an early age, for instance by coloring engineering themed books, visiting schools and companies. The key concept is that young people who know more about what engineers do are more likely to considerer a career in engineering.
There's also a lack of engineers in the decision-making process at the political level, mostly in feminine gender. Engineers possess a great ability to design, analyze, manage and gauge different options and put them into perspective, which makes them perfectly equipped to have an active role in inducing political decisions and participate in public political discussions.
Also, a greater representation of women in engineering and in decision-making positions would bring benefits in terms of innovation, balance, common sense, peace, safety and accessibility of new inventions. For this to become a reality, it's very important the existence of role-models, even to attract more young girls to a career in engineering. Less than two in ten engineering students are women, and women make up for only 15% of the university-qualified engineering force. To make matters worse, there is a difference of up to 24% between payments made to men and women engineers in comparison with 13% across all industries, a situation to be corrected in the future.
To close this section, there's also report of a high turnover, low salaries and an increased attractiveness for engineers to change to management positions and better paying industries.

6. Conclusions and recommendations

The engineering profession is going through a phase of rapid evolution, with the development of the virtual world and AI, which causes the disappearance of old concepts and the appearance of new ones related to the engineering profession.
Considering this, it's essential to adapt the teaching programs of engineering to the new demands of the job market.
It's increasingly more necessary to find balance between hard and soft skills. Leadership, entrepreneurship, communication, teamwork, problem-solving, research and critical-thinking, planning and organization, innovation/creativity, computer sciences are considered the most important soft skills for an engineer.
Microcredentials and post-graduations are crucial for engineers to quickly get up to speed on the latest trends and developments, so they can accompany the evolution of their areas of expertise.
It was also possible to identify the opportunity to recruit more students for engineering programs by exposing them to the concept of the engineering profession and its contribution to everyday life from an early stage. It's as well very important to increase the number of female engineers, as suggested.

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Annexes

Annex 1: Template used for Interviews

Introduction

The Ordem dos Engenheiros, OE, is one of the 13 partners of the European Project Engineers 4 Europe (E4E), promoted by ENGINEERS EUROPE, EE, (former FEANI), whose goal is the implementation of a Council of Competences, which will create a channel for sharing and communication between Higher Education, Industry, Training and Professional Associations, so that the enhancement and competitiveness of the profession can be strengthened.

This council will identify trends, challenges and opportunities for the evolution of the engineering profession over the next 5 to 10 years, in accordance with global technological developments and the achievement of the 17 SDGs (Sustainable Development Goals - established by the UN) such as sustainability based on digital, green, resilience and entrepreneurship, among others, so that engineers have the necessary skills to continue providing their contribution to society.

Currently, the engineering profession faces many challenges, both in terms of strengthening skills, in order to eliminate existing gaps in transversal training, and in structural changes, which may improve the link between Higher Education and Industry, responding better to their needs.

There have been several international studies and surveys, including in the European Union, EU, that show that there is a shortage of the "socially motivated engineers" needed to implement the 17ODS as well as to achieve the EU's 2030 and 2050 targets.

In view of the above, we would like to ask you to express your opinion, anonymously, on the possible skills needed for the engineers of the future, considering the expected changes in engineering for the next 5 to 10 years.

Personal Information

Photograph (Optional)	Age:	❍30 or less ❍ 31-40 ❍ 41-50 ❍ 51-60 ❍ 61 or more
	Gender:	❍ feminine ❍ masculine ❍ Other
	What's your current job?	
	Indicate in which area/sector you work in:	
	Indicate the country you work in:	
	Years of professional experience:	❍ 5 or less ❍ 6-10 ❍ 11-20 ❍ 21 or more

Key Questions

1. How will the profession of engineer evolve over the next 5 and 10 years?	
2. In face of the expectation of evolution of engineering, indicate how the Higher Education will contribute to the competencies of the future engineer.	
3. What's the role of engineers in implementing the Sustainable Development Goals (SDGs)?	
4. Whats the difference and contribute of hard and soft skills in the success of the profession of engineer?	
5. What's the role of short-term training (microcredentials) in training future engineers? Which ones do you suggest?	
Suggestions:	

Annex 2: Key sentences of the interview responses

Enterview	Question 1	Question 2	Question 3	Question 4	Question 5
1	"(...) it will be at the level of IT technologies, but also in the Agricultural area (...) Example: Developments in the Genetic/ Varietal area more adapted to the climate or vertical agrocultures with all production factors controlled."	"Higher education provides the basis for the engineer to easily adapt to any position within an organization."	"(...) it is fundamental for the application of sustainable practices, whether at the agricultural level or even in an office."	"Hard skills are the foundation of the boat without them any boat will sink. Soft skills are competences that can be acquired through training."	"Any training is fundamental for development. However, practical work develops all skills. On-the-job trainings will be important regardless of the training area."
2	"(...) In summary, history shows that engineering will continue to play an essential role in responding to the problems facing society, which requires a permanent updating of content in course plans and complementary training in lifelong learning formats."	"(...) it should be complemented by areas of specialization and which, in turn, should be permanently updated with postgraduate and/or micro-credential formats (...) it also requires engineering training to be more flexible, to provide the course plan with subjects that confer multidisciplinary skills and to think about teaching formats in a real context, namely in a company context (...)"	"(...) Engineering assumes a relevant role in the decarbonization of industry and other economic activities, in the use of renewable energies, in the management of water resources, in the circular economy, in food production, as well as in other areas involved in a carbon neutrality strategy. (...) must take into account the transversal SDGs, namely the fight against hunger and poverty, gender equality, among others (...)"	"(...) Engineering should continue to maintain a solid and consistent component of hard skills, which should be complemented with soft skills, which should be provided for in new formats of multidisciplinary study plans and of a flexible nature, sometimes in a scenario of optional subjects. (...) namely in the field of interpersonal communication, conflict resolution, working in groups and under pressure, leadership skills, among others."	"(...) this strategy will assume greater relevance, given that qualification deficits still persist in the active population (...) the new challenges are to respond to the digitization of economic activity, as well as to guarantee the desired carbon neutrality, constituting priority themes (...)"

3	"The engineering profession is always dynamic and based on the Principle of Continuous Improvement (...) it will continue to evolve as it has done so far, but at a faster pace."	"(...) Engineering education requires that a wide range of physical-mathematical knowledge be obtained, trained and perfected (and sedimented), the acquisition of which requires time. (...)"	"There is no Development, neither sustainable nor of any other kind without Engineers and Engineering (...) we see that engineering is present from turning on a switch, taking a shower, sleeping in a bed, riding in a car, turning on a cell phone, eating a loaf of bread.... Engineers are fundamental."	"Engineers are good at hard skills (...) they need to work on soft skills and these are fundamental to be well in the company, in society and in teamwork (...)"	"Very important. It depends on each area of knowledge. In horizontal terms, IT is fundamental and interpersonal issues are something you have to work on and improve throughout your life."
4	"The engineering profession will be influenced by a number of factors, including technological advances, social and environmental changes, industry demands and societal needs (...)"	"(...) higher education in engineering is essential for the skills of the engineer of the future. It provides a solid knowledge base, allows specialization in specific areas, develops critical thinking skills."	"Engineers play a key role in the implementation of the 17 Sustainable Development Goals (SDGs) (...)"	"Hard skills and soft skills play complementary and equally important roles in the success of the engineering profession (...)"	"(...) Short-term trainings, also known as micro-credentials, play a relevant role in the education of the engineer of the future, complementing traditional academic education. (...) suggestions for short-term trainings, they depend on the engineer's specific areas of interest and needs (...)"
5	"(...) the evolution of the engineering profession may vary according to the specialty and the technological evolution in the different areas (...)"	"University education plays a key role in developing the skills of an engineer, providing theoretical, technical and practical knowledge to meet future challenges (...)"	"Engineers have a significant impact on achieving the SDG targets (...)"	"(...) hardskills (...) are essential for an engineer to perform the technical tasks effectively (...) softskills (...) are important for an engineer (...)"	"(...) This training allows engineers to quickly update themselves on the latest trends and developments so that they are up-to-date in the areas of specialization (...)"
6	"(...) it will evolve in a very positive way, but this means that the Engineer	"(...) a higher and permanently updated training in the	"(...) the contribution of Engineering to the creation of a better, fairer	"(...) we need people who have activities and "sensibilities" beyond	"The continuous training of the Engineer is decisive in view of the speed of the

	must have a holistic and interdisciplinary approach, cooperating with other areas of Engineering with increasingly international links (...)"	competences of the Engineer is necessary. Leaving the "classroom", having training in companies, visits, critical spirit, is very important in the training of Engineers."	and more sustainable world in its different pillars: economic, social and environmental and perhaps add another which is governance (...)"	Engineering (...) I value group spirit, volunteering, concern for others, freedom to think and have critical spirit, willingness to learn and question."	challenges and their volatility, taking into account innovation, technology, development and research / experimentation (...) would address the CAP and the Farm to Fork Strategy, for example (...)"
7	"(...) it will undoubtedly evolve, with the new models of the evolution of artificial intelligence and based on current trends. It will depend on each professional, the commitment and direction they will give it (...) There will have to be an adaptation to new technologies (...) evolve towards a more integrated approach and work in a multidisciplinary way."	"Higher education will have to adapt to the development of these new skills and increasingly teaching has to be linked to the world of business and work (...) There are even teachers who are business professionals."	"In my opinion, engineers play a key role in this implementation, since the routine of engineers is to define these objectives and enforce them, setting targets to be achieved (...)"	"(...) both hard and soft skills play an important role in the success of the profession and even complement each other (...)"	"(...) they are fundamental since they are additional opportunities to all initial training, and a constant updating of all professionals. As a suggestion: - New technologies - Emotional intelligence - Leadership - Sustainability and social responsibility - Risk management - Other training more dedicated to each area."
8	"It will evolve by accumulation of other skills to the fundamental knowledge that an Engineer acquires in Universities (...)"	"Higher education should remain essential for the acquisition of foundational knowledge although it should be complemented (...) with other skills (...)"	"(...) ensuring the proper implementation of the same something that stems from the specialized technical knowledge they hold (...) contributing to the critical analysis of the same proposing updates whenever necessary."	"(...) I believe that complementing hard skills with soft skills is mandatory for the success of an engineer's activity (...)"	"Fundamental (...) Suggestions: cyber, project management, talent management, sustainability, artificial and cognitive intelligence."
9	"(...) A well-equipped engineer will seek to stay	"(...) HEIs may need to react more promptly to close the gap between the	"Undoubtedly, engineers have always had a major part and will continue to	"(...) Both play an important role but depending on the career stage and duties one	"(...) micro-accreditations will ensure that engineers stay relevant and up to

	relevant and up-to-date, even on the short term.”	needs of employers/society and the SDGs.”	be a key player in delivering a more sustainable future. (…)”	may be more important than the other (…)”	date with the best practices, methodologies and technological advances throughout their careers (…) on areas where engineers already have a major role delivering these goals, such as on sustainable energy, industrialization or cities (…) coaching and emotional intelligence.”
10	"Greater reliance on new technologies, greater environmental concern and greater demand from society."	"(...) updating the contents of the Curricular Units (...) changing the curricula of the courses of the various study cycles (...) training for teachers - new teaching methodologies and tools, new technologies."	"Essential. Engineering is one of the pillars of society's development (...) occupying coordination, development, implementation and creation roles in the labor market."	"(...) hard skills will increasingly have to be complemented with soft skills (...)"	"(...) can contribute to the acquisition of soft skills or to the reinforcement and updating of hard skills. Suggestions: - Science communication - Stress management - Adaptation to various situations - Interaction with others."
11	"(...) engineering projects will be increasingly demanding, as they will have to incorporate more and more environmental constraints, while having to be economically competitive and socially useful (...)"	"(...) Higher education is essential to provide engineers with the scientific knowledge, technological skills and human and psychological preparation to be able to decide, execute and optimize engineering projects and acts in scenarios of major scientific and technological changes, and sometimes also of	"(...) develop the most effective technological tools to achieve the Sustainable Development Goals that, in an optimal way, do not cause, at the same time, negative side effects, both in economic, social and even environmental terms (...)".	"(...) have to be properly balanced (...) so that projects involving new concepts and technologies are put at the service of the community in the most user-friendly way possible, in order to be socially inclusive."	"(...) are key to update engineers on key technological innovations (...) relevant short term training modules on the latest developments in IT- Information Technology and AI- Artificial Intelligence (...) soft skills for engineers, I also consider relevant modules on Industrial Management, Team

		great strategic vagueness on the part of some political and business decision-makers (...)."			Leadership as well as Technological Innovation Management in Business Environment (...)"
12	"(...) evolve in three directions (...) increasing specialization (...) specialization will tend to be short-term (...) specializations will tend to be multidisciplinary (...)"	"(...) increasingly contribute to teaching future professionals to learn new paradigms and to correlate different areas of knowledge."	"Engineers have a central role in implementing the SDGs (...)"	"(...) the value of the contribution of hard skills is unquestionable (...) Soft skills are essential for the success of the profession (...)"	"(...) will be permanently needed. Of particular relevance are trainings involving different areas of knowledge, such as medicine and electrotechnics, industrial management and informatics, civil and environmental engineering, etc. as well as all areas of data analysis and application of artificial intelligence to the most diverse areas."
13	"(…) we will see a growing interest in microtechnologies, sustainability and evolution in medical engineering."	"Higher education will not only develop the soft-skills, but increasingly provide specialized tools for the exercise of the profession in various narrow band areas"	"Engineers play a key role in achieving sustainability goals as they have all the skills in various engineering specialties to achieve those goals."	"(…) complement each other for good execution and leadership."	"Microcredenciações allow specialization and the practice of the profession in very specific areas that can complement the practice of engineering (…)"
14	"Engineering is constantly evolving and in the next 5-10 years this trend will intensify. I anticipate an increasingly multidisciplinary profession (...)"	"Higher education has a key role to play in preparing future engineers (...) will have to adapt to digital evolution (...)"	"Engineers play a crucial role in the implementation of the SDGs. They are responsible for planning, designing and executing projects that have a direct impact on many of the SDGs (...)"	"Both are fundamental to the success of the engineering profession (...) The combination of hard and soft skills enables engineers to be more effective in their roles and to contribute positively to society. "	"(...) allow the updating and acquisition of new knowledge and skills, following the rapid evolution of engineering and technology. (...) areas such as: IoT, Artificial Intelligence and Machine Learning,

					Project Management, Design Thinking, Big Data and Data Analysis, Programming and Software Development, Renewable Energies, and Sustainability and Energy Efficiency."
15	"There will be a greater diversity of specializations (...)"	"(...) will have to be versed in up-to-date technological skills in order to ensure competences in more specific areas of engineering."	"(...) engineers must adapt their way of thinking about solutions in order to implement the sustainability of each system."	"(...) basic training will give greater sustainability to niches of knowledge and skills, while an aggregate of soft skills may represent only immediate solutions."	"Create skills and application of new innovative techniques/methods in each of the engineering disciplines."
16	"(...) will require up-to-date knowledge to meet new challenges."	"(...) a basis that serves as a starting point for the beginning of their professional activity (...) support for new training and new knowledge."	"One of the main functions, because their knowledge will help in that implementation and in finding new processes."	"(...) they are both essential to the success of the profession."	"(...) fundamental in the consistent development of knowledge acquisition. Being short term they are more easily attended and not as demanding in terms of time invested."
17	"The "Engineering of the Future", will be based on the use of digital tools - Technologies 4.0 (...)"	"(...) will have to adapt to new realities and empower the "Engineer of the Future" for versatility and multidisciplinarity (...)"	"Most of the 17 SDGs are areas impossible to achieve without the leadership of the Engineer, so the role of Engineers will be of great relevance and indispensability."	"(...) there will be a tendency towards a balance between technical skills (hard skills) and behavioral skills (soft skills) (...)"	"(...) short-term training will have great relevance in the training of the "Engineer of the Future". (...) greater importance will be given to those aimed at the digitization of processes."
18	"(...) It is expected that their valorization and recognition will happen (...)."	"(...) needs a curriculum review, more appropriate to new technologies and trends of new generations (...) inclusion of soft skills (...)"	"Our engineering touches several SDGs, and engineers must be prepared to recognize those that may impact their role, and include new	"(...) If there is a balance between the two the engineer will be much more complete and efficient in the performance of his function."	"The training of a professional must be continuous (...) I always suggest in the technical component, legislation, normative references, and specializations within the

			approaches if necessary to meet the SDGs."		engineering area. As for soft skills, these are also trainings that should be done with some regularity."
19	"(...) there will be continuity in relation to what currently happens. (...) will allow Engineers to make their contribution in management and in other areas of economic and socially relevant activity."	"(...) availability of sound basic scientific knowledge, combined with contact with the evolution of practical solutions and with the freedom of individual development (...)"	"The SDGs are extremely demanding in core subjects that concentrate the knowledge and skills typical of Engineers (...)"	“("(...) Soft skills will be a necessary complement, some of which will be generally useful, others applicable in a specific way."	“(…) fundamental along a professional path (...)"
20	"(...) The accountability of engineering technicians will increasingly have to be an important fact for the dignification of projects, however it will be necessary to create well-defined systems that highlight their actions and their links to the various themes that represent them (...)"	"(...) heavily revised in many of the schools (...) as is the case with mathematics, these cannot be neglected (...)"	“It is essential that this is a key point for the various engineering areas (...) must ensure the sustainability of projects (...)"	"(...) These two aspects linked at an early stage of an engineer's career make these professionals easily stand out in the market given the ease they have in adapting to the situations that are proposed to them and the ease they have in solving problems."	"Any area certainly needs systematic and continuous updating (...) technicians to improve their areas of professional development as a method of standing out on the job market (...)"
21	"(...) the engineering profession will face challenges, but will also pave the way for significant opportunities. Engineers who are prepared to adapt to these changes, invest in relevant skills and keep pace with technological advances	"(...) is essential for the development of the competences required by the engineers of the future. It should provide technical expertise, stimulate critical thinking, offer hands-on experiences, promote collaboration and	"(...) the importance of engineers in promoting sustainability and pursuing the Sustainable Development Goals is undeniable, contributing to a more just, equitable and environmentally responsible future."	"(...) the success of the engineering profession depends on the harmonious combination of hard skills, which provide technical and specialized knowledge, and soft skills, which strengthen interpersonal skills (...)"	"(...) micro-credentials play an important role in the continuing education and skills development of the engineers of the future. They enable the acquisition of specialized knowledge, both in new technologies and in behavioural skills,

	will be well placed to thrive in this ever-changing landscape."	communication, and prepare engineers to adapt to technological change and stay up-to-date throughout their careers."			contributing to adaptation to the labour market and professional advancement in the field of engineering."
22	"Increased focus on process digitalization, use of artificial intelligence for process optimization and increasingly dedicated to the environmental and sustainability area, particularly in the energy sector."	"Training should have in the curricula (...) digitalization, AI, sustainability, energy, among others (...)"	"Engineers should have the ability to conceive, design and implement measures and projects that contribute to the SDGs (...)"	"(...) technical skills are fundamental for adequate and qualified performance; social skills are equally important (...)"	"They are important for closing specific gaps in any professional area. Trainings in the environmental and social field."
23	"(...) Engineering will play a key role in the necessary response that society needs. These 5 to 10 years will be the path for the evolution of the required response."	"(...) Upgrading is essential. We will not be able to fulfill our intended role if we cannot overcome chronic immobility in our system."	"Taking into account the 17 SDGs, we can only say that none of them will be achievable without the role of engineering being incorporated."	"Soft skills will be one of the most important aspects for hard skills to be able to have their dissemination leveraged. (...)"	"(...) they will be able to enhance the more integrative holistic reading that the present challenge requires (...) Digital will allow a very aggressive use of micro-credentials."
24	"The engineering profession will undergo significant evolutions due to technological advances and emerging needs for (land) space and climate transition (...) engineers must learn and adapt to new technologies and new challenges."	"Gain skills in: digitization and automation; Internet of Things (IoT); artificial intelligence (AI) and machine learning enabling real-time data collection and analysis; advanced modelling and simulation, and automation of technological processes. (...)"	"Engineers are key in the implementation of the Sustainable Development Goals (SDGs) because they have the technical knowledge and skills to design, develop and implement sustainable solutions in various areas (...)"	"Hard skills and soft skills play complementary roles in the success of the engineering profession and are crucial to the success of the engineer (...)"	"(...) play an important role in shaping the engineer of the future (...) should be complementary to traditional academic engineering education, to help engineers keep up to date (...)"
25	"(...) the engineering profession is the one with the most responsibility	"(...) Higher education is the basis of the engineer's training, and increasingly	"Engineers will play a crucial role, as engineering is a profession that cuts	"We are facing a technological change in which generations will have	"(...) Engineering is constantly changing and it is essential to have training

	and action in this context and in this increasingly digital "era". (...) sustainable engineering will have considerable growth in this time window (...)"	it will have to be demanding (...) the engineer will also have to be an analyst and manager (...)"	across all areas of the Sustainable Development Goals (...)"	to adapt, but with other soft skills (...)"	for professionals to be up to date. (...) training in the different areas and specialties of engineering and transversal, such as management, artificial intelligence, environment, legislation, ethics."
26	"(…) will lead to a path of growth, based on innovation and investment in technology in different specialties (…)"	"(…) will have to keep abreast of future trends (...) notably in areas of new energies - biofuels, hydrogen and solar energy, in the field of food and agriculture and agri-food services, and in scenario studies of developments."	"(…) the involvement of engineers with their respective expertise will be key to the implementation of the SDGs so that this transition is made in a fair, sustainable, efficient and competitive manner."	"In the educational and training context it seems to us that hard skills are privileged. However, for a productive work environment, both hard and soft skills are important for the success of the professional (...) A balance between their technical and social skills is fundamental and crucial. "	"(…) certify learning outcomes following experiences in various learning contexts, and highlighted common aspects ensuring their quality, transparency, cross-border comparability, recognition and portability (…)"
27	"(…) the engineer will have to integrate the following areas: - Data analytics - Artificial intelligence"	"(…) it is urgent that the programs of the various higher education entities be reviewed."	"The different areas of engineering can cover all the SDGs."	"Hard-skills need to be reviewed, as mentioned above. With regard to soft-skills, there is also an urgent need for engineers to have specific training e.g. in emotional intelligence (…)"	"Micro-accreditations bring much-needed flexibility to skills acquisition."
28	"Increased diversification and specialization of skills, blurring the boundaries between traditional specialties (...) Some negative impact in terms of reduction of tasks within their competence	"(…) will maintain its importance (...) the biggest challenge will be to reconcile the diversification and specialization of the skills of engineering graduates/masters with	"Most of these objectives can only be achieved through the development, dissemination and implementation of technologies that are part of the various branches of engineering. (...)"	"The so-called soft skills are increasingly important to the performance of an engineer's duties (...) they are thus indispensable for engineers, especially those who want to lead teams. "	"(…) must be framed within the concept of continuous training throughout the professional life of that engineer (...) from very specific technical aspects that are not framed within

	due to the development of Artificial Intelligence (...) Relative "proletarianization" of engineers in terms of dominant position in work teams and salaries (...) "	the need to maintain a solid training in the basic sciences (...) the so-called soft skills are essential in the professional life of an engineer and cannot be dispensed with (...)”			the branch of school training of the professional concerned, to training in issues outside the field of Engineering, (such as, e.g., management, finance, psychology, law, toxicology)".
29	“The increasing need for innovation associated with technologies and the development of societies will allow the engineering profession to evolve more and more”	“(...) higher education provides the foundation and mental resilience to develop the skills of an engineer."	"(...) contributes in several ways: economic, infrastructural, agricultural and environmental, innovation."	“Hard skills are very important in very technical professions. Soft skills are fundamental in the corporate context in which most companies find themselves.”	“Short-term trainings can respond to (…) increase or reinforce knowledge on certain topics (…)”

Annex 3: Photographs of the events organized for primary research

Figure 5: Round Table.

Figure 6: Round table.

Figure 7:Round table.

Figure 8: Dinner-debate.

Annex 4: Resume of information gathered in round tables and dinner-debate

Question 1: What's your expectation on the evolution of the engineering profession in the next 5 and 10 years?

- "An engineer has to learn the theory, but the most fundamental thing is to fall in love with practice and overcoming real problems and challenges"

- "The engineer should be creative, empathetic, resilient, able to solve complex problems, have critical thinking, in addition to technical knowledge. But as the technical knowledge requirement is being set aside, there will be fewer and fewer engineers."

- "Given the galloping progress of Artificial Intelligence, in the next five years engineers will be the first to benefit from these advances, but also to suffer the consequences of the errors produced by them. Engineers will need to be able to verify and validate the correctness and appropriateness of the solutions offered, have an unparalleled critical spirit and a strong belief in their skills. Without these, we risk the machines making us stagnate with the solutions of the past."

- "Engineers will have to adapt and respond to new technological demands, always using their main tools: creativity and rigor. But the greatest challenges of today, beyond the technological ones, are the social and political ones, in which the world is undergoing a profound and vertiginous change. I hope that Engineers never lose their grip on reality, because it is the solutions to people's real needs that make them so important to society"

Question 2: Indicate which hard skills, soft skills and microcredentials should be included in engineering training, that can contribute to the success of the future engineers.

- "In my opinion: Soft Skills: leadership, Co-Leaders, techniques for managing people; Hard skills: legal framework in the various areas. Practical cases"

- "Artificial intelligence linked to the simplification of processes/projects and motivated with emotional intelligence"

- "Leadership, cost-benefit analysis of solutions"

- “Proficiency in English and specific engineering tools, development of communication skills and teamwork and leadership, mandatory development of projects in a work context for university students”

- “Strong academic background, ability to work in a team, on-the-job training”

In summary: The world of work is and has always been evolving. Nowadays it is necessary to train students in the most diverse areas, such as flexibility, adaptability, ethical, social and humanistic values, critical thinking, differentiation, knowing how to accept and accompany changes, etc, trying that the engineers of the future think more and more autonomously and critically, since this will differentiate them from Artificial Intelligence. For this, HEIs are fundamental, since they act as a trigger for the evolution of society.

Annex 5: Key sentences of the secondary research

Reference (APA style)	Key ideas
(Lantada, 2020)	"(…) presents the concept of ''Engineering Education 5.0'', a future educational paradigm linked to a vision of engineering education characterized by a need for continuous evolution, as a consequence of a challenging quest for a more sustainable and caring future (…) transcends the development and application of technology and enters the realm of ethics and humanism, as key aspects of for a new generation of engineers." "(…) it is necessary to transform the structures and contents of engineering programmes and, almost certainly, the structures and processes of academic institutions (…) Summarizing, a whole 6-year programme, based on a 4-year bachelor's degree plus a 2-year master's degree, can very adequately provide students with fundamental scientific technological knowledge, specialized professional and transversal skills, necessary ethical values, and even give them important opportunities for personalization and professional planning (…)" "(…) in order to train a new generation of engineers, capable of leading and mentoring the next technological advances and their application towards a more equitable and sustainable world, a reformulation of engineering education is urgent. This reformulation should chorally integrate the views of the key societal stakeholders, including: professional associations, engineering institutions, representatives from the industry, policy makers, accreditation boards, organizations from the third sector, students, educators and their representatives."
(Piwai Chikasha, 2021)	"Just as industry is dynamic, constantly evolving according to the state of technology, economics, politics and so on, so must be, higher education (…)" "(…) This study develops a concept for industrial engineers of the future and demonstrates that is it possible to better prepare graduates for the uncertain future, by predicting some key skill requirements of industry ahead of time from information of yesterday and today (…)" "(…) it is therefore critical that higher education incorporates aspects of the futuristic profession, into the lessons of today, for the benefit of not only the students, but also the respective industry, and not only for today, but tomorrow as well (...)" "(…) to maintain relevance of higher education, it is important to adapt education to the prevailing industrial requirements. It is even more important to actually predict where the industry requirements' evolution is headed, and to then manipulate higher education accordingly (...)"

	"(...) innovation and entrepreneurship, sustainable development and finally, the digital technologies (...) as knowledge areas of high priority for the benefit of graduate industrial engineers (...)"
(OECD, 2023)	"(…) leading to an increase in demand for more highly educated and highly skilled workers in the sector (…)" "(…) Globally, there are four mega-trends that are driving changes in skill requirements at work over the past decades: 1) technological change, 2) climate change and the green transition, 3) demographic developments, and 4) the globalization of value chains (…)" "(…) Agriculture and the food sector, in particular, are substantially affected by the climate emergency and the "green" recovery measures in most countries (…)" "(…) amongst the skills needed in agriculture, forestry and fishing sector, the greatest skills shortages are related to social skills and teamwork, problem solving, learning, planning, and job specific skills. (…)" "(…) there are major challenges to addressing the low level of digital skills in agriculture, which can have an adverse effect on the adoption of new technologies and productivity (…)" "(…) general skills shortages are concentrated among content skills (reading comprehension, writing, speaking), process skills (critical thinking and active learning), and problem-solving and social skills (instructing, social perceptiveness) (…)" "(…) largest share of qualification mismatches is in the agricultural sector (…)"
(Olushola Akinshipe, 2022)	"(…) Productivity is impacted by skills shortage, especially in the field of engineering (…)" "(…) major effects of engineering skills shortage in the construction industry are difficulties in recruiting, poor decision making due to not having the right skilled people, lack of relevance of training received and low employment rate (…)" "(…) Communication, life-long learning, planning and organizing, problem-solving, teamwork, self-management, technology and initiative and enterprise skills are the most needed for graduate employees (…)" "(…) it is recommended that the academic curriculum of higher institutions be revised to cover the important knowledge engineering graduates need to possess for them to be relevant (…)" "(…) there is a need for reskilling of graduates who are redundant (…)"
(Business Europe, 2022)	"(…) skills shortages are a manifestation of persisting skills mismatches, a result of people's educational choices not sufficiently aligned with the labour market needs (…)" "(…) constitute a bottleneck to economic growth potential and a waste of human potential (…)" "(…) education and training curricula are lagging behind the changing jobs demands (…)" "(…) qualitative shortages may be induced by the discrepancy between the nature/profile of available jobs and jobseekers' preferences (…)"

	"(…) two main strategies to tackle labour force shortages: (re-) engaging people on the side-lines of the labour market and increasing labour force through migration (…)" "(…) it is important to continue to develop real-time labour market and skills intelligence, which will be a foundation for the successful functioning of improved skills matching (…)"
(ENGINEERS EUROPE, 2021)	"(…) future engineers will have to extend their spectrum of competences beyond expert knowledge in the field of technology and engineering towards a more holistic view and approach, e. g. they need to develop the ability to reflect upon their work before a wider international political and socio-economic context (…)" "(…) engineering community must fight to get more children and young people interested in science and technology (…)" "(…) many engineers have a hard time to explain to the average citizen with a non-engineering background what the role of the engineer is and how it affects their life and work (…)" "(…) Engineers regularly express the concern that they are underrepresented in political decision-making bodies. At the same time, they shy away from taking an active role in politics and public political discussions. This is especially regrettable, as engineers with their ability to analyze and gauge different options and put them into perspective are perfectly equipped for an active role in inducing political decisions on overarching challenges (…)"
(A4M-EUMAT, 2020)	"(…) machine learning - a tool which can guide researchers and engineers in an unbiased way (beyond their intuition) towards the best materials and the best synthetic strategies, hence saving time and money (e.g., in terms of computational costs, optimization of parameters controlling manufacturing etc) – requires not only new concepts and techniques to be learned but also new best practices (such as data and metadata sharing) need to be accepted (...)" "(...) Higher Education at both master and doctoral levels is crucial to develop a new generation of materials scientists able to use, for example, data-mining techniques and to build open databases (...)" "(...) Teaching methods should mainly rely on 'learning by doing', based on problems arising from dealing with practical applications (...)"
(Pereira, 2023)	"(…) I propose and describe the 5 essential characteristics of professionals and managers in organizations (...) Collaboration; Communication; Digital; Constant learning; Initiative (…)"
(Indeed Editorial Team, 2023)	"(…) The talents required to be a successful engineer include a combination of both hard and soft skills. They allow an engineer to perform the labor of the position and also work with coworkers to operate as a unit efficiently (…)" 12 top engineering skills employers look for: problem-solving; computer science; Industry skills; pressure management; teamwork; creativity; structural analysis; communication; attention to detail; education commitment; data modeling; leadership.

(Design Solutions, 2022)	"(…) Advances in technology continue to expand possibilities and inspire future engineers (...)" "(…) From the innovation of advanced software to artificial intelligence and virtual reality, there are now lots of new engineering roles that didn't exist 10 years ago (...)"
(Knowhow, 2023)	"(…) The engineering and manufacturing industries are crucial sectors that contribute to economic growth and development. The skills shortage affects the global economy as these industries are essential (...)" "(...) more businesses mentioned labour shortages in their filings internationally in 2022 compared to 2021 (...) construction, technology, packaging, and consumer goods are the ones with the most labour shortage discussions (...)" "(…) Starting from downturn in innovation and technological advancement to increased labour costs and deepened skills gap (...)" "(...) To address the understaffing issue in engineering and manufacturing industries, several solutions need to be implemented (...)"
(IET - Institution of Engineering and Technology, 2021)	"(…) Less than half of new engineering recruits have either the necessary technical or soft skills needed for work within the industry (…)" "(…) The impact of missing skills means 45% of companies who see a skills shortage within young people provide additional training for apprentices/graduates who are new to the industry, whereas a quarter simply recruits fewer apprentices and graduates as a result (25%) (…)" "(…) Two-thirds (71%) of the UK engineering workforce who are experiencing internal skills gaps say it is down to missing engineering or technical skills (…)" "(…) only a third of businesses taking action to improve the diversity of their workforce across gender (33%) or ethnicity (30%) (…)" "(…) we are seeing a sustained skills gap that will continue to grow unless government and industry take action (…)" "(…) Engineering companies across the UK now have to look to improve profitability and productivity with fewer staff than before (…)" "(…) To solve this skills crisis there needs to be deeper engagement between government, employers, and the education system to produce a talent pipeline (…)" "(…) Design and manufacturing is recognised as a key area (…)" "(…) However, energy and environmental sustainability is the second most cited area (…)"
(CIHT - Chartered Institution of Highways & Transportation, 2022)	"(…) there is a recognized skills shortage within the engineering sector, skilled engineers are increasingly sought after and there just simply are not enough engineers to go around (…)" "(…) the need for multidisciplinary engineers working in fields such as renewable technology are also being impacted (...)"

	"(...) Almost half (48.7%) said an ageing workforce is one of the biggest challenges as experienced staff reach retirement age and take a wealth of expertise with them (...)" "(...) Others highlighted issues including high staff turnover, low salaries and the lure of better-paying industries or management positions (...)"
(Institution of Mechanical Engineers, 2022)	"(…) 49% of engineering businesses are experiencing difficulties recruiting workers with the skills they need (...)" "(…) subjects like science and math's are eagerly taught in schools, but connecting them to engineering – the link between these subjects, their purpose and application to the world in which we live – is not currently being made clear (...)" "(...) Teacher training could also boost understanding and confidence about talking about engineering in the classroom (...)" "(…) more than half of parents (55%) agree that without formal teaching in engineering and technology, their children will not be able to make informed career choices (...)"
(Tertiary Education Comission, 2020)	The jobs in demand in engineering in New Zeland are: Chemical Engineer, Civil Engineer; Civil Engineering Technician/Draughtsperson; Electrical Engineering Technician; Electrical Engineer; Electronics Engineer; Environmental Engineer; Mechanical Engineer and Engineering Technician.
(Mannan, 2021)	"(…) there simply aren't enough engineers required to complete large-scale investments of local, national and international importance (...)" "(...) it is not just the "traditional" jobs in civil, mechanical, electrical, and aeronautical engineering; there is a growing need for multidisciplinary engineers working in renewable technology, robotics, additive manufacturing, the digitization of industry and 6G networks to name but a few areas (...)" "(…) historically most engineers were produced from developed countries like the UK, Germany and USA, recent trends have demonstrated that a significant number of engineers are being produced from emerging countries like Russia, India and Iran (...)" "(...) identified civil, mechanical, electrical and software engineers as some of the occupations in which there are a significant shortfall of skilled professionals (...)" "(...) estimate that 203,000 roles are required annually, made up of 124,000 engineers and technicians with core engineering skills, plus 79,000 related roles requiring a mix of engineering knowledge and other skills sets like project management (...)" "(…) three areas worth noting when it comes to why young people are not entering the sector in enough numbers: an insufficient awareness of what engineers do, a misperception of what engineering is, and a lack of opportunity for all to be involved

	almost half of those between 11 and 19 years old say they know little or nothing about what engineers do (…)" "(...) new engineering disciplines has grown in the past few decades and as highlighted above, roles are needed now, and into the future, in software engineering, robotics and AI etc. This changes the nature of engineering and where engineers work – less site and more office. This also calls for a new set of skills and problem-solving knowledge (...)" "(…) engineering workforce was just 6% ethnic minority and 9% female to tackle the shortage of skills in engineering it is necessary to tackle the root causes: awareness, perception, and lack of opportunity for all (…)" "(…) The solution (...) coordinated set of actions undertaken by government, policymakers, educators, and engineering companies (…)"
(Randstad, 2019)	"(…) measures need to be taken to help the leaders of the engineering industry fill the jobs that are integral to the field (...)they would need around 186,000 skilled recruits each year until 2024 (...)" "(...) On a list of bottlenecks across all occupations within the EU, mechanical engineers are ranked seventh, electrical engineers 12th and civil engineers 14th.When it comes to newer and experimental engineering fields such as software system engineering or control and calibration engineering, highly skilled employees are even more in-demand (...)" "(…) IET revealed in a report that up to 62 per cent of engineering employers say that graduates cannot offer the right skills, which is a contributing factor, and also suggest not enough is being done by schools and universities to prepare future engineers for their debut in the workforce (...)"
(Australia, 2023)	"(...) Professionals Australia projects a skills shortage of 200,000 engineers by 2040 (...)" "(...) identifies failures in the education pipeline for engineers, the underutilization of qualified engineers in the workforce, and an extremely low participation rate of women in engineering as the main reasons for the predicted shortage (...)" "(…) Key Statistics: • Australia will be short 200,000 engineers by 2040 - Australia will experience an engineering workforce shortage of 200,000 by 2040 if new and additional measures are not put in place to grow the workforce • Underutilisation of engineering skills - Just 66% of Australian-born engineers and 49% of overseas-born engineers work in engineering roles. • Insufficient numbers of graduate engineers – Only 8.5 per cent of Australian university students graduate with engineering degrees, compared with over 12 per cent in

	Canada and over 23 per cent in Germany. Graduation numbers have also been stagnant since 2018 at around 25,000 per year. • Low engineering participation rate for women - Less than two in ten engineering students are women, and women make up only 15% of the university-qualified engineering workforce. • Engineering gender pay gap for women – The engineering gender pay gap is 24 per cent for women compared with 13 per cent across all industries.
(Schaefer, 2023)	"Engineers face plenty of challenges throughout their careers (…) Institute of Education Sciences lamented the lack of soft skills among engineers and engineering graduates (…)" "(…) soft or "people" skills are just as important as technical competence and, in some cases, even more so. (…) Understanding who we are as engineers and how to interact with other under a variety of circumstances can go long way in ensuring work gets done correctly and efficiently and is key in career advancement (…)" "(…) students should at least have some exposure to these concepts before entering the workforce (…) balancing their technical and leadership skills (…)" "(…) developing soft skills is an absolute necessity if an engineer wants to successfully navigate management and workplace culture to create an efficient and safe working environment (…)"
(Landry, 2023)	"(…) as more engineers enter the field and the industry evolves, so too will the job opportunities and needs of employers (...)" "(...) To stay competitive in the job market, aspiring engineers and those who want to advance need a strong, diverse set of skills (...)" "(...) in-demand skills in the engineering industry include: Technology and computer science skills; Communication; Management; Problem-solving; Business operations; Research and critical thinking; Leadership (…)" "(…) engineering has a business side as well (...)" "(…) acquiring essential business skills, engineers can better equip themselves to meet changing workforce demands and gain a competitive edge (...)"
(Glassdoor, 2021)	"(…) Possessing soft skills will facilitate better collaboration and ensure that engineers can perform their duties more effectively (...)" Most common engineering soft skills: Verbal and non-verbal communication; stress management and tolerance; public speaking and presentation; negotiation skills; strategic planning; time management; creativity and innovation; teamwork and people skills; research and analytical skills; organizational skills; adaptability; ethics; dedication and commitment.

	Tips to improve soft skills: practice communication; seek out training opportunities; create a plan for each day; remain committed to the job; practice active listening; be respectful of everyone.
(Michael Page, 2023)	"(…) Soft skills – when coupled with the right combination of technical skills – are in great demand, and can significantly set you apart in a highly competitive jobs market (...)" Top 5 engineering soft skills: strong communication skills; leadership skills; lateral thinking; the ability to influence others; problem-solving skills
(Michael Page, 2019)	"(…) there's demand for most engineering jobs in Australia (...)" "(...) greater demand for professionals with soft skills to complement their technical capabilities in the industry, in particular those who can interact comfortably with stakeholders and clients (...)"
(Indeed, 2023)	"(…) Engineers require both technical and soft skills to perform their duties effectively. Soft skills help engineers use their technical abilities and knowledge with fewer interpersonal issues (...)" Examples of soft skills for engineers: communication skills; emotional intelligence; leadership ability; problem solving skills; organization skills; teamwork; adaptability; creativity; listening skills; costumer service skills. How to improve soft skills: prioritize the skills to improve; request feedback; practice self-reflection; actively listen; develop writing skills.
(IET - Institution of Engineering & Technology, 2023)	"(…) companies are crying out for numerate people with data skills (…)" "(…) in sectors such as engineering, employers have been wary of spending money on training and upskilling for fear of losing those workers to higher-paying competitors (…)" "(…) Upskilling gives people more confidence and research has shown it is the people lacking the skills who are more likely to leave. (…)" "(…) technology continues to move increasingly quickly. To be competitive in today's environment, organizations must ensure their employees are not only up to speed but also have the tools they need to help the business succeed (…)" "(…) Employers often point out that the numbers simply are not there when it comes to finding older engineers and others who could conceivably reskill (…)" "(…) To get access to more scientists and engineers with computational-design skills, Pilkington is working more closely with universities (…)" "(…) The bigger step is to encourage schoolchildren to consider STEM for future careers (…)" "(…) remain questions as to how ready industry itself is to handle a greater influx in an environment where companies seem to want both fresh faces and experience (...)"

(ENGGPRO, 2019)	Six most common challenges faced by engineering and engineers: climate change, improve energy efficiency, skill and staff shortage, lack of female engineers, project management, technological advancements. "(…) Engineers are struggling hard to find ways to reduce potential climate crisis (...) and recruit more eco-conscious engineers to cut the risk on the environment (...)" "(…) need to reduce fossil fuels consumption and work on improving energy efficiency (...)" "(...) According to Deloitte there will be somewhere between 2 million and 3.5 million unfilled manufacturing jobs by 2025 (...)" "(...) female engineer numbers have hardly budged since the early nineties (...)" "(...) The project a skilled engineer might be working on, however, won't be successful unless there is an equally skilled project manager involved leading and managing the engineering project (...)" "(...) to resist the rapidly evolving world around us, we need to have a system in place to adapt with the changes (...)"
(Smith, 2022)	"(…) While the need to recruit fresh talent into the industry is a pressing concern, it isn't the only challenge that the sector is facing (…)" "(...) Jobs will become increasingly available in solar, wind power, the electricity grid and electric vehicles, but engineers are also working on innovations in how we travel, how we power our lives, sustainable food production and planet-friendly fashion (…)" "(...) in order to inspire young people into engineering, the sector as a whole needs to improve the quality, targeting, inclusivity and reach of activities designed to attract talent to the industry (…)" "(...) young people who know more about what engineers do are more likely to perceive the profession in a positive way and to consider a career in engineering (…)"
(Silva, 2019)	" Engineering is one of the fastest growing and most exciting fields today (...)" "(...) every successful professional is always looking for training and continuous improvement, not only in the technical skills called Hard Skills but also in the so-called Soft Skills (...)" Most important soft skills in any engineer's career: Creative thinking, effective communication, critical thinking, negotiation, people management and teamwork, emotional intelligence, time management.
(World Economic Forum, 2023)	"(…) Economic, health and geopolitical trends have created divergent outcomes for labour markets globally in 2023 (…)" "(…) Technology adoption will remain a key driver of business transformation in the next five years (…)"

	"(…) The fastest-growing roles relative to their size today are driven by technology, digitalization and sustainability. The majority of the fastest growing roles are technology related roles. AI and Machine Learning Specialists top the list of fast-growing jobs, followed by Sustainability Specialists, Business Intelligence Analysts and Information Security Analysts. Renewable Energy Engineers, and Solar Energy Installation and System Engineers are relatively fast-growing roles, as economies shift towards renewable energy (…)" "(…) Analytical thinking is considered a core skill by more companies than any other skill and constitutes, on average, 9% of the core skills reported by companies. Creative thinking, another cognitive skill, ranks second, ahead of three self-efficacy skills – resilience, flexibility and agility; motivation and self-awareness; and curiosity and lifelong learning – in recognition of the importance of workers ability to adapt to disrupted workplaces. Dependability and attention to detail, ranks sixth, behind technological literacy. The core skills top 10 is completed by two attitudes relating to working with others – empathy and active listening and leadership and social influence – as well as quality control (…)" "(…) The skills that companies report to be increasing in importance the fastest are not always reflected in corporate upskilling strategies (…)" "(…) Surveyed companies report that investing in learning and on-the-job training and automating processes are the most common workforce strategies which will be adopted to deliver their organizations' business goals (…)" "(…) Forty-five percent of businesses see funding for skills training as an effective intervention available to governments seeking to connect talent to employment (…)"
(Peña, Inteligência Artificial e desafios na formação avançada e na investigação, 2023)	"(…) AI can free up more time for transformative actions, lead to higher productivity, more well-being, better living standards. It all depends on measures to balance benefits and threats (...)" "(...) improve the quality and versatility of training, use AI to complement it, further train imagination, decision-making and critical thinking (...)" "(...) It is up to education to complement AI with causal models for verification and decision that are trained through experience, abstraction and the development of imagination. ChatGPT can be a teaser to develop this critical sense (...)"
(Peña, O ensino da Engenharia que existe e ainda não existe, 2021)	"(…) Science, engineering and technology have a huge impact on lifestyle and quality of life and are constantly evolving. Education must keep pace with this progress and make scientific and technological research fertile. Education teaches the science, engineering and technology that exists, and prepares for that which does not yet exist (...)" "(...) The success of education is measured both by the talent it generates and the talent it does not waste (...)"

	“(...) They require efficient, modular and diverse teaching and learning for adaptation and agility, initiative and innovation. In a difficult balance, without shaking the pillars of solid training in fundamental sciences (...)”
(Naves, 2023)	“(…) 2023 Top 10 includes innovations in environmental sustainability and decarbonization of transport (…)” “(…) There is a world of innovations waiting to change our societies (...)” “(...) Among the ten technologies of the future chosen this year by the World Economic Forum, brain implants will be the most controversial, alongside rapid developments in Artificial Intelligence (AI) (...)” “(...) the world may be close to an agricultural revolution that could change the way plants themselves are controlled (...)”

2.2 Ireland

2.2.1 Analysis by Technological University Dublin (TU Dublin)

1. Introduction

The future of engineering education, as argued by Lönngren (2019), might be considered a 'wicked problem', particularly when there is an emphasis on working for sustainability. Issues such as climate change and resource management are particularly important in engineering education since technological development has profound impacts on social and environmental welfare (Lönngren, 2019). Graham, in her global consideration of the state of the art in engineering education, provided an insight (through an initial snapshot and subsequent case studies) into the cutting edge of global engineering education and a horizon scan of how the state of the art is likely to develop in the future (Graham, 2018). The report highlighted the different educational themes that are increasingly pervasive internationally, including blended learning, increased diversification of choice and cross-disciplinary learning. The European University Association in its Trends 2018 report, also identified how institutions are in the process of establishing more systematic and strategic approaches to learning and teaching innovation and transformation, leading to exchange and collaboration with a wider range of external parties, including partner universities, as well as industries and schools.

However, and the issue at the heart of the E4E project, how these educational and curricula innovations can systematically, and pre-emptively synergize with the ever-changing needs in industry, is less well understood. It is a balance between education necessary to afford skills, values and attitudes required in society in general, and the provision of the necessities to meet the market's expectations (Aljohani et al., 2022). The industries of tomorrow need engineers, who as ambassadors of their technological areas can, through innovation and leadership, combine specialist expertise with an ability to operate creatively across boundaries in increasingly complex environments (Taylor, 2019). Moreover, non-standard progression through the engineering profession needs consideration. There is a growing interest globally in exploring such routes to help address engineering skills shortages both for young people and, increasingly, for reskilling older generations (Taylor, 2019). This is a narrative shared in Ireland, extending to the importance of lifelong learning as an instrument for problem solving and as a support to keep abreast with technological advancements (Beagon & Kyne, 2023).

This report, offers an antecedent insight into the state of engineering education, including curriculum, competence alignment, teaching methodologies, and pedagogical practices, and consideration of the challenges and opportunities associated with the evolution of the engineering profession in the short to medium term. The report considers issues pertinent to the Irish HEI - Higher Education Institutions –and VET - Vocational Education Providers. The discussion herein offers a backdrop for the subsequent examination of the outputs collated from the *Engineers Europe*[55] survey into the future of the engineering profession from which a more holistic appreciation of the state of the art will be established.

[55] https://www.linkedin.com/feed/update/urn:li:activity:7076914781307170816/

2. Literature Review

The literature review findings, as provided in section 3, start by considering competencies relevant to the engineering profession and moves on to how the Sustainable Development Goals (United Nations, 2015) are the essential barometer to ensure the adherence to societal imperatives for effective engineering education strategies. Irish policy requirements pertaining to engineering and vocational education requirements and their alignment with European requirements are subsequently considered, as are methodologies and strategies that synergise engineering curricula with industry needs.

3. Findings

3.1 Competencies

Defining generic competencies that can align to specific engineering disciplines is a significant challenge. In general, the top skills needed by engineers are broadly encompassed within effective problem solving, the ability to communicate, creativity and innovations skills and the ability to collaborate effectively through refined emotional intelligence (NewEngineer, 2020). However, with the increasing demand for engineers, increased consideration in terms of the specific fields and disciplines involved is necessary (Engineering UK, 2023a). Moreover, the quickening pace of technological advancement and its effect on our society, emphasises the need to be able to identify skills, and competencies that offer a future-proofing capability of the engineering profession (Royal Academy of Engineering, 2019). This includes nurturing practical skills and creativity, alongside the development of enabling skills such as complex problem solving and critical thinking and professional behaviours such as ethical consideration and environmental awareness, increasingly identified as critical by employers (Royal Academy of Engineering, 2019). It is not just a case of the pace of technological advancement, the priority of skills are also be affected and at pace. A comparison World Economic Forum reports 2020 (World Economic Forum, 2020), where the top 15 skills for 2025 was presented, and the 2023 report (World Economic Forum, 2023) presented in **Figure 9** and **Figure 10** respectively,demonstrate the changing priority and emphasis.

1	Analytical thinking and innovation	**9**	Resilience, stress tolerance and flexibility
2	Active learning and learning strategies	**10**	Reasoning, problem-solving and ideation
3	Complex problem-solving	**11**	Emotional intelligence
4	Critical thinking and analysis	**12**	Troubleshooting and user experience
5	Creativity, originality and initiative	**13**	Service orientation
6	Leadership and social influence	**14**	Systems analysis and evaluation
7	Technology use, monitoring and control	**15**	Persuasion and negotiation
8	Technology design and programming		

Figure 9: Top 15 skills for 2025 (World Economic Forum, 2020)

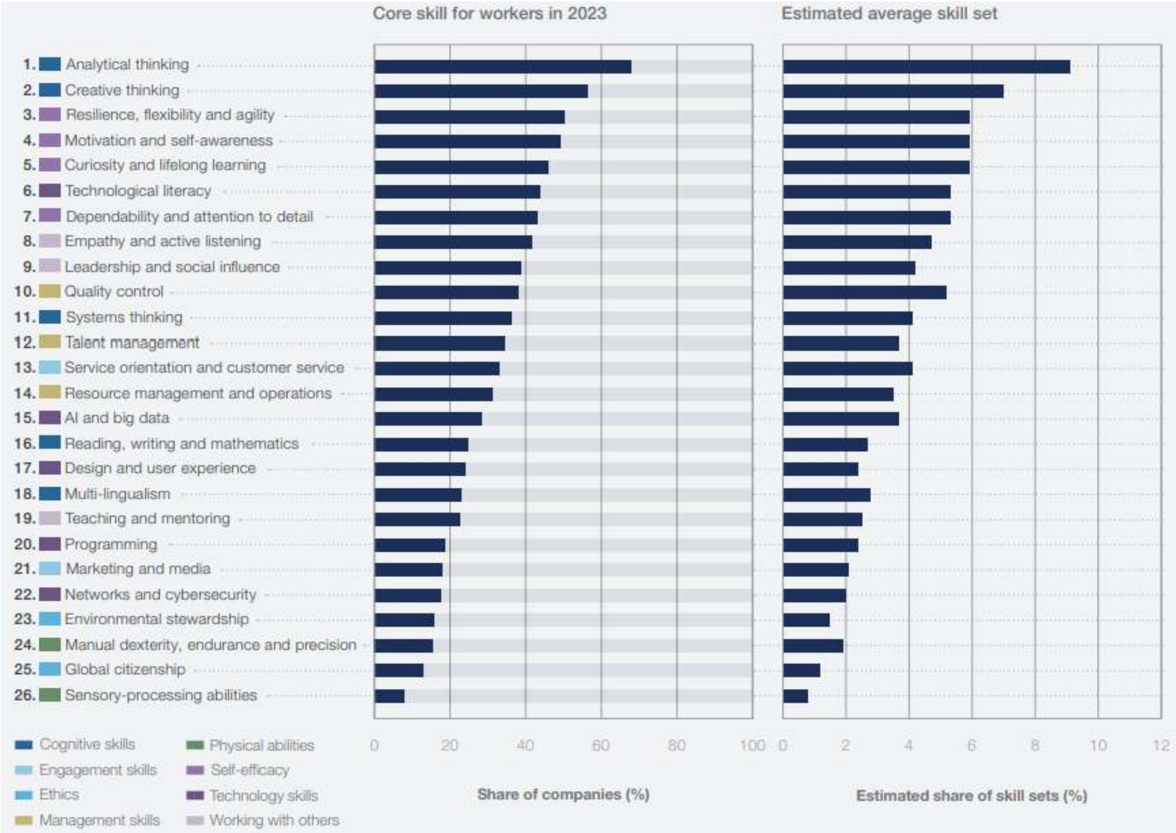

Figure 10: Core skills 2023 (World Economic Forum, 2023)

Professional bodies, such as ABET and ENAEE have a responsibility to define the competencies for engineering standards. Through the ENAEE EUR-ACE framework standards and guidelines, for instance, universities develop accredited programmes using programme outcomes frameworks for first and second cycle degrees. These frameworks also need to be adaptable. In the past 5 years postings for 'green' engineering jobs have increased by 55% and postings requiring 'green skills' by 48% (Engineering UK, 2023a). An example of adaptability in respect to evolving competency emphasis is how Engineers Ireland refined their engineering programme accreditation criteria (Engineers Ireland, 2021). These criteria, in programme area #7, provides for a focus on sustainability as a requirement within engineering degrees, recognizing that the engineering profession has a critical role to play in sustainability and climate change mitigation and adaptation through a prioritization of the UN Sustainable Development Goals (SDGs).

Passow and Passow (2017) integrated a quantitative synthesis inspired by meta-analytic techniques (27 studies, 14,429 participants) and a qualitative thematic analysis (25 studies, 2,174 participants plus 36,100 job postings) to establish a comprehensive list of generic engineering competencies, their relative importance, and rich descriptions highlighting interrelationships. **Figure 11** below presents a synopsis of what the study deemed to be the primary skills required in engineering in terms of importance and differentiation with an appreciation of the differentiation between ordinary and outstanding engineering performance (Passow & Passow, 2017).

Engineer within constraints

Take initiative [R2,D] – Influence project direction; take multiple perspectives; seek "big-picture" understanding of the client's problem, its context, *constraints*, and impacts; and take goal-directed initiative to exceed expectations.

Gather information [D] – Maintain a drive to understand; gather information as needed by searching literature and standards, initiating *coordinated efforts*, *measuring*, etc. Validate facts and assumptions.

Define constraints [D] – Define constraints imposed by technical and manufacturing feasibility, time, budget, business context, codes, regulation, ethics, culture, politics, and impacts on safety, health, the environment, local community, and global society.

Think creatively [R2,D] – Think creatively when *interpreting data*, *measuring*, *problem solving*, *designing solutions*, and *decision making*. Reframe problems, challenge constraints, conceive alternatives, envision impacts, and innovate.

Solve problems [R1] – Identify, formulate, and solve real-world, ill-defined, engineering problems within *defined constraints*. (Effective coordination of other competencies increases the quality and timeliness of solutions.)

Design solutions – Design a system, component, or process to meet desired needs within *defined constraints*.

Make decisions [R2,D] – Make sound decisions informed by context about *problem solving*, *designing solutions*, *measuring*, taking risks, and engineering *process* (including trade-offs between gaining certainty and time expended).

Collaborate with coworkers, clients, suppliers, and other stakeholders

Communicate effectively [R1,D] – Communicate effectively with people that have diverse goals and backgrounds – across disciplines, organizational levels, and organizational boundaries, through listening, oral, written, and graphical means.

Coordinate efforts [R1,D] – Create vision; build consensus; secure and offer willing and conscientious collaboration to achieve goals shared with coworkers, clients, and suppliers; coordinate efforts; lead effective meetings; negotiate; and assume joint responsibility. (Note: Coordination is distinct from formal project management that comes with authority. All engineers need to coordinate efforts, while only a subset formally manage projects.)

Apply technical foundations

Interpret data [R1] – Organize, analyze, and interpret data. Question the validity and reliability of measures. Explore trends and anomalies.

Apply knowledge – Apply knowledge of mathematics, science, and engineering in interpreting data, modeling, analysis, estimation, and prediction for problem solving, design solutions, and measurement.

Apply skills – Apply engineering tools, techniques, and information technology skills that are currently necessary for engineering practice for problem solving, design solutions, and measurement.

Measure accurately – Measure accurately and quantify errors. Determine when testing is adequate versus when true experimentation is required. Design and conduct experiments.

Manage own performance

Devise process [R1,D] – Devise and manage one's own engineering process to accomplish a goal. Choose what to do, when to use a competency, when to stop using it, and how to coordinate competencies, e.g., when to *gather information* and *coordinate efforts*. Estimate time and cost; plan; set and adjust priorities; schedule and monitor tasks; maintain standards; regulate own work commitments; and meet deadlines and budget.

Take responsibility – Take professional and ethical responsibility for *decisions* and behavior; envision and manage impacts and *constraints* from multiple perspectives.

Expand skills – Expand skills by maintaining curiosity, admitting ignorance and error, seeking advice, learning from successes and failures, and engaging in formal training.

R1 Rated top importance for engineering practice; **R2** Rated just below top; **D** Differentiates between outstanding and ordinary engineering performance

Figure 11: Important skills in engineering work (Passow & Passow, 2017)

3.1.1 The Sustainable Development Goals (SDGs)

The 2030 Agenda for Sustainable Development, adopted by the United Nations General Assembly in September 2015, is a plan of action for people, planet, prosperity and peace (United Nations, 2015). The Agenda incorporates seventeen Sustainable Development Goals with 169 targets, to be achieved by the year 2030. The 17 Goals are integrated and indivisible and balance the three dimensions of sustainable development: the economic, social and environmental. The Goals are universal; all countries and all people have a responsibility to act to realise the Goals.

The Higher Education Sustainability Initiative (HESI) is an open partnership between several United Nations entities and the higher education community launched in the lead-up to the Rio+20 Conference in 2012. It is currently chaired by the United Nations Department of Economic and Social Affairs (UN DESA) and the Sulitest Association (Sulitest, 2023) - a non-profit organization and online platform aimed at improving sustainability literacy for all. Other UN partners include UNESCO, UN Environment Programme, UN Global Compact's Principles for Responsible Management Education initiative, UN University, UN-HABITAT, UNCTAD, UNITAR, UN Office for Partnerships, and UN Academic Impact. Through its strong association with the United Nations, HESI aims to provide higher education with an interface between higher education, science, and policy making by raising the profile of higher education's sector in supporting sustainable development, convening multi-stakeholder discussions and action, and sharing best practices.

Each year, HESI designates Action Groups to tackle topics related to higher education for sustainable development. Action Groups draw upon the full HESI community to carry out its work and is often composed of several organizations and contributors. Results are published on the HESI website and promoted by the network. The aim of the HESI Partner Programme is to connect higher education institutions, networks, and student organizations to create a community of shared learning in support of SDG integration into curricula, research, programmes and campus practices and facilitate transfer of knowledge. The programme will draw from the diverse knowledge and experience of those working in different circumstances. A fundamental principle of the group is that everyone has something to offer, regardless of their stage in integrating the SDGs into their curricula, research, programmes or campus practices (United Nations, n.d.).

3.2 Policy considerations

The United Nations Educational, Scientific and Cultural Organisation report (2021) highlights the crucial role of engineering in achieving each of the 17 SDGs. It shows how equal opportunities for all is key to ensuring an inclusive and gender balanced profession that can better respond to the shortage of engineers for implementing the SDGs. In this report, the educational approaches that have proven effective are discussed (International Centre for Engineering Education, 2021). The report highlights the crucial role of engineering in achieving each of the 17 SDGs. It shows how equal opportunities for all is key to ensuring an inclusive and gender balanced profession that can better respond to the shortage of engineers for implementing the SDGs. The report highlights the educational approaches have proven effective where educational institutions have moved from a teacher-driven system towards a student-driven learning environment, including

- Active learning in the classroom (the 'flipped classroom') and problem and project-based learning (PBL),
- Practice-related learning with the inclusion in the curriculum of elements devoted to later work situations, such as internships, industry projects, entrepreneurship and innovation hubs, and learning professional competencies,
- An increased number of institutions have moved to a more system-oriented approach where entire institutions change their curriculum instead of single courses (Graham, 2018).

The report also highlights how with the advent of new technologies, automation, demographic changes and employment mobility, continuous reskilling and the importance of life-long-learning (LLL), particularly in the context of vocational education and learning and especially for achieving the SDGs (International Centre for Engineering Education, 2021).

In the review of Education for Sustainable Development and Global Citizenship Education in Teacher Education (2018), a review into whether learners will acquire the knowledge and skills needed to promote sustainable development through education for sustainable development. The report also informed UNESCO in its preparation for the 2017 Global Education Monitoring Report (GEM) Report, the purpose was to examine the current preparation of teachers in Education for Sustainable Development (ESD) and Global Citizenship Education (GCED) (National Council for Curriculum & Assessment, 2018). In the context of ESD, the report focused on the preparation of teachers for the compulsory school cycle in consideration of ESD and the best methodology to monitor the ESD-related training of teachers, particularly at the level of initial teacher education. The report also considered international comparisons to appreciate the best mechanisms to improve ESD-related teacher education

In a European context, there are strategies seeking to develop key competencies through the development of skills (European Commission, 2022a), including a vision for vocational education and training (European Commission, 2023). European agencies that support cooperation in vocational training, and more spectficially, Cedefop, the European Centre for the Development of Vocational Training, support cooperation on VET and contribute to the evolving policy agenda with the European Commission, EU Member States and social partners to help develop, promote and implement VET, skills and qualifications policies. Cedefop promotes knowledge sharing and policy learning. It plays a key role in monitoring the implementation of the priorities and actions defined in the Council Recommendation on VET and the Osnabrück Declaration (Council of the European Union, 2022).

UNESCO International Centre for Technical and Vocational Education and Training advocate how technical and vocational education and training (TVET) is critical in addressing knowledge and skills challenges to achieving the SDGs . More importantly, TVET can transmit the right mindset and attitude among trainees and the future workforce through well-designed education and training programmes.

However, the right policies and skills strategies need to be strengthened to maximize its impact (UNESCO-UNEVOC, 2022). UNESCO-UNEVOC recognizes several challenges to reaching the SDGs and climate-related plans of action:

- Lack of awareness about sustainability
- Low capacity at the levels of decision making, teaching and implementation in practice
- Shortages in skills resulting in unmet labour market demands
- Unsustainable patterns of consumption and production
- Outdated competencies and qualifications
- Lack of recognition and assessment mechanisms for skills acquired through non-formal and informal learning
- Lack of targeted engagement of key actors including youth, community and enterprises

In an Irish context, a national strategy on Education for Sustainable Development was developed to ensure that the Irish education system contributed effectively to sustainable development (National Council for Curriculum & Assessment, 2018). The strategy prioritized the equipping of learners with the relevant knowledge (the 'what'), the key dispositions and skills (the 'how') and the values (the 'why') that will motivate and empower them throughout their lives to become informed active citizens who take action for a more sustainable future (Department of Education and Skills (DES), 2014).

The Second National Strategy on Education for Sustainable Development: ESD to 2030 (Government of Ireland, 2023), provides a framework to steer and support the contribution that the education sector is making and will continue to make towards a sustainable future by 2030. ESD to 2030 spans the continuum of education in Ireland, from early learning and care to third level education and research, and extends beyond to engage with local communities, and youth groups through lifelong learning. Building on the progress achieved under the first National Strategy on Education for Sustainable Development (Department of Education and Skills (DES), 2014), ESD to 2030 sets out five key priority areas for action over the coming years. Vocational education in Ireland is going through a significant change. In the Action Plan for Apprenticeship (2021), a key deliverable identified in the context of vocational education is the need for an agile system, responsive to workplace change and evolving skills needs. This deliverable acknowledges the rapid pace of workplace and broader economic change arising from increased digital adoption, deployment of artificial intelligence solutions and the need to become sustainable and energy efficient as priorities in Ireland (Department of Further and Higher Education, 2021).

Professional bodies have a significant responsibility in ensuring the future readiness of the engineering profession in support of national economic imperatives. Engineers Ireland have developed a Sustainability Plan (Engineers Ireland, 2022) where under the headline *learn*, *live*, *lead* and *link* actions, a series of priorities are emphasized to signpost the engineering profession in Ireland.

3.3 Curriculum considerations and Industry requirements

In recent years, there has been an increased emphasis on research and focus on preparing engineers for life-long-learning and competence awareness. Projects such as 'TRAINengPDP'[56] (Training engineers for lifelong learning through a personal development process) and 'REFL³ECT'[57], examines how to enhance LLL competencies among engineering students. Another project, PREFER (Professional Roles and Employability of Future Engineers) investigated the need for the development of a framework of professional roles for future engineers and the implementation of dedicated skills education in engineering curricula to train students for engineering roles (Gaughan et al., 2017).

Other work considering SDG competences and engineering education Beagon et al. (2023) focused on the a lack of agreement on which competences should be prioritised to prepare engineering students to resolve future sustainability challenges (Mulder, 2017; Shephard et al., 2019). The work examined and compared the views of key stakeholders of engineering education (Academics, Employers and Students) using (twelve) focus groups in Denmark, Finland, France and Ireland. Table 1 below presents the Focus Group outcomes of competences needed for engineers to support the SDGs.

Table 2: Focus Group outcomes of competences needed for engineers to support the SDGs

Technical		Non-technical		Attitudes	
Fundamental Technical Skills	Application Skills	Outward Facing – People Orientated Skills	Inward Facing – Ways of Thinking	World view	Character and Ethical Orientation
Mathematics Skills	Multidisciplinary Skills	Inter Cultural Skills	Critical Thinking	Global Awareness	Respect for others
Digital Skills	Problem Solving	Collaboration	Life cycle thinking	Social Responsibility	Open mindedness
Economic Skills	Design Skills	Leadership	Holistic Thinking	Challenging the status quo	Agility
Research Skills	Interpretation Skills	Conflict Management	Systems thinking	Sustainability Awareness	Adaptability
Technical Skills	Conceptual understanding	Negotiation	Creativity	Environmental Awareness	Curiosity
	Resources optimisation	Communication[a]	Analytical Thinking	General Knowledge	Empathy
	Innovation	Foreign Languages	Stress Management	Lifelong Learning	Emotional Intelligence
	Entrepreneurship	Listening	Time Management		Perseverance/Grit
	Decision Making Skills	Respecting Diversity	Self-Reflection		Ethical Conscience
	Learning to Learn	Teamwork	Multi-perspective thinking		Personal engagement/agency
	Project Management	Inter Cultural Skills			
	Organisation Skills				
	Problematisation				

[a]Communication was identified as a competence which included communication, foreign languages and listening skills.

The findings, mapped against competences identified in previous studies, confirmed the strong emphasis on normative, strategic and systems thinking competences in engineering. However, the outcomes also lack acknowledgement of anticipatory competence, contradicting the future oriented perspective required to achieve sustainable development (Beagon et al., 2023).

Souto-Otero (2023) reviewed the concept of sustainability in education and its incarnation in SDG4. Against the present challenging environment, it reflected on sustainable development's role, practice and approaches in VET, discussing its environmental, economic and social dimensions. He presents six guiding principles to consider in the path towards ensuring sustainability in VET: 1) the adoption of a

[56] https://iiw.kuleuven.be/english/trainengpdp
[57] https://set.kuleuven.be/LESEC/groups/study-career-guidance-of-steam-students/reflect

holistic conceptualisation, 2) inclusion, 3) responsiveness, 4) permeability, 5) human centredness in the use of technology and 6) appropriate provision of resources (Souto-Otero, 2023).

3.3.1 Pedagogical Practices and Teaching Methodologies

Thakore et al. (2022) in their paper give examples and strategies of how to integrate sustainability into engineering programmes under different themes, namely 1) environmental education with practical projects, 2)critical pedagogy with systems-thinking and design thinking, 3) transnational education, 4) synergies and trade-offs in reaching the SDGs, and 5)developing whole school pedagogical values. The primary objective of the article was to collect and highlight the latest innovative case studies or advances across disciplines to identify systemic transformative and resilient interventional drivers for education for sustainability to provide answers to a meta-question. The rationale for collecting case studies was that before delving into these systems and thinking about how we can change them, we need to do a reality check, i.e., understand the stock of our education delivery (Thakore et al., 2022)

In another study the outcomes of focus groups held in Ireland, France, Denmark and Finland as part of A-Step 2030 Project France, Denmark and Finland. The aim of the Focus Groups, which were held with Engineering Academics, Engineering Students and Engineering Employers was to provide insights into research questions under three different themes (Beagon et al., 2019). The first theme was to determine the extent of knowledge (of Academics, Students and Employers) about Sustainable Development (SD) in general and the Sustainable Development Goals (SDGs) in particular. The second set of questions related to current Sustainable Development related activities within engineering programmes and the third was to identify skills requirements for the future.

The key findings show that Energy and Environment are the words most associated with Sustainable Development, reflecting the pillar of Environment. There is evidence of the influence of national policies and initiatives in each country which raised awareness of particular issues such as Carbon Tax (Ireland),Circular Economy (Finland), Climate and Transport (Denmark) and Innovation (France). There was a range of views on how SD was included within engineering programmes, ranging from not covered at all to isolated standalone modules, integrated modules or specific projects, which dealt with SD. Several barriers were highlighted which prevents the integration of SD in engineering programmes including; lack of academic staff knowledge on SD and other broad topics and the difficulties in changing the curriculum or finding space in the curriculum. Opportunities presented included the use of new optional modules or the implementation of industry based or multidisciplinary projects. Regarding the skills needed from engineers to solve the SDGs, many of the focus group outcomes presented both technical and non-technical skills and highlighted the importance of a balance between the two. “Communication” as a skill topped the list with followed by “Technical Skills”, “Critical thinking” and being “Ethical”. In the main, the consensus was that technical skills are still deemed important and students, academics and employers all agreed that the Universities are doing a good job of producing good technical engineering graduates.

There are some significant examples of SDG Integration into teaching and learning in Ireland. The University College Cork (UCC) Sustainable Development Goals Toolkit project aims to foster the development of globally-minded and action-oriented citizens who are empowered to help create solutions for a sustainable future. With this in mind, the SDG Toolkit project has developed and curated resources to support staff in integrating sustainability into learning and teaching using the lens of the U.N. Sustainable Development Goals (SDGs). Resources in the SDG Toolkit were informed by student and staff consultations emphasizing active learning pedagogies, including project-based learning, problem-based learning, and case studies. A Community of Interest emerged during the development and piloting of the toolkit which makes it more dynamic and can be built on to encourage further knowledge exchange and transdisciplinary collaboration.

The REEdI - Rethinking Engineering Education in Ireland - project has developed an agile and innovative framework for the design, development and delivery of engineering education in Ireland. The project has built on the success of world-leading cutting-edge models of engineering pedagogy to deliver a transformative programme of self-directed and self-scheduled learning for the next generation of engineers (Walsh et al., 2022). One of the key outputs of the project was a Bachelor of Engineering (Hons) in Mechanical and Manufacturing Engineering- the "REEdI Engineering degree". This programme is the embodiment of an agile and innovative blended 4-year degree where student engineers get to learn using immersive technologies, such as virtual and augmented reality, and cutting-edge models of engineering education. The student engineers time is equally divided between on-campus activities and industry (enterprise) placement. Students spend the first two years on campus and the final two years at a host industry partner gaining the essential industry skills and personal attributes an employer looks for in a graduate engineer. The three-way relationship between student, university and industry is core to the approach on which the programme is designed. The industry partners committed to hosting REEdI student engineers on placement range across a variety of manufacturing sectors- MedTech, Pharma, Automotive, General Manufacturing and AgriTech. The REEdI project will provide an alternative framework for engineering education and indeed, other undergraduate and post graduate programmes across higher education in Ireland, with an ultimate aim being for any HEI to be able to adopt the approach utilizing the roadmap's and framework's developed and tested.

3.3.2 Microcredentials

Micro-credentials are certified documents that provide recognised proofs of the achievement of learning outcomes from shorter, less duration, educational or training activities (McGreal & Olcott, 2022). Focusing on the validation of competency-based skills, outcomes and/or knowledge using transparent standards and reliable assessments, which can enhance graduates' employability prospects, a micro-credential can be accepted for credit by an institution or organization or be an attestation for employers. A micro-credential attests to specific knowledge or skills competencies with defined learning outcomes and may or may not be stacked towards larger units of accreditation (Brown et al., 2023; Cirlan & Loukkola, 2020; Debiais-Sainton, 2020). The term Alternative Digital Credentials (ADCs) has also been used to define these credentials (ICDE & OECD) by recognizing that not all micro-credentials are digital (McGreal & Olcott, 2022). The micro-credentials landscape can be a means of accentuating assessment and validation processes. With micro-credentials existing – for the most part - outside the formal qualifications frameworks of traditional universities and colleges, these frameworks provide formal guidance. Learners will want micro-credentials to be transparent and applicable to formal credentials even if they may or may not be stackable or combinable towards higher qualifications, and in some cases may be accepted into formal certificate and/or degree credit programmes (McGreal & Olcott, 2022).

As observed by McGreal (2022), the global workforce and economy are at a crossroads and organisations in the public and private sector are increasingly faced with new economic and workforce imperatives for the future (Georgetown University Center on Education and Workforce, 2020). Recent trends in the high cost of higher education, employer concerns about graduate skills and competencies, and student frustrations about the lack of job opportunities have all been catalysts for universities, independent credentialing agencies, and leaders of national qualification reference frameworks to rethink the broader credentials continuum (Matkin et al., 2020; Selvaratnam & Sankey, 2020). The trend towards micro-credentials and skill-competency based training is growing globally. The onset of the global COVID-19 pandemic has been a catalyst for expansion of micro-credentials as unemployment and devastating economic crises during the pandemic have crippled many industries and sectors.

Skillnet Ireland launch Ireland's first micro-credential programmes for climate action (Skillnet, 2022). In partnership with the University of Limerick (UL) Skillnet launched the first enterprise-led micro-credential programmes dedicated to climate action in Ireland. The stackable micro-credentials, developed by Skillnet Ireland's Climate Ready Academy, will enable participants to develop tailored sustainability charters and action plans for their organisation across the areas of energy, sustainability and waste and circularity while also achieving recognised third-level certification on the National Framework of Qualifications. The micro-credentials may be stacked, over time, leading to a full Level 7 award accredited by the University of Limerick.

The programmes launched were the 'Energy Leaders', the 'Waste and Circular Economy Leaders' and the 'Sustainability Leaders' programmes which are designed to incentivise and support employees in developing practical environmental improvements for their businesses. In 2022, Skillnet Ireland, in partnership with the Economic and Social Research Institute (ESRI), published research on talent requirements for the green economy (Siedschlag et al., 2022). The report found specific skills gaps which are holding back businesses when it comes to developing and implementing sustainability strategies. The new programmes are one of Skillnet Ireland's new initiatives designed for removing these identified barriers.

Micro-credentials may not be a panacea for resolving (education) institutional challenges, but they may provide strategic value in their integration with other major institutional initiatives (McGreal & Olcott, 2022).

4. Discussion

The review presented herein is primarily to establish a snapshot of issues at the heart of the challenges that the E4E project aims to address. Indeed, the first survey collated by the E4E partners will instead offer a perspective into the state of the art as perceived by engineering stakeholders, there are a number of points that can be drawn as reference points against which the survey outputs can be critiqued and considered.

1. Irrespective of whether future engineering curricula are formal, or through instruments that can be 'stacked' into a formal qualification structure, a significant challenge is how learning is organized to be synergized with industry requirements – or even pre-emptive of industry challenges
2. The skills and competences required by engineers are well established, but they need refinement to facilitate (Beagon et al., 2023; Engineering UK, 2023b; World Economic Forum, 2023)
3. The Sustainable Development Goals need to be adopted by higher education providers as the primary framework steering engineering education (Government of Ireland, 2023; Thakore et al., 2022), with policy supporting this strategy for enducation
4. Education strategy and the embracement of the SDGS needs to be adopted for VETs as well as HEIs (European Commission, 2022b, 2023; International Centre for Engineering Education, 2021)
5. Notwithstanding some of the established (and funded) projects/research looking to align curricula considerations with industry requirements (Beagon et al., 2019; Bourn et al., 2018; Thakore et al., 2022; Walsh et al., 2022), more exemplar – and wider-reaching – example are needed to represent the wider European educational diversity to facilitate a unified European priority
6. Micro credentials, while offering flexibility, agility and choice for broader education that might be integrated into specific discipline requirements (McGreal & Olcott, 2022; Siedschlag et al., 2022; Skillnet, 2022). They don't facilitate a panacea for the bigger engineering education and future needs challenges (McGreal & Olcott, 2022).

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2.2.2 Analysis by Engineers Ireland (EI)

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, and 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 8,000 new engineering jobs being expected by 2023. However, the number of engineering graduates remains consistent at around 6,000 students (HEA, 2023), which has led to a significant gap between the supply and demand of engineers in the country. This has become one of the biggest challenges facing the engineering profession in Ireland, with finding experienced engineers to support existing projects becoming increasingly difficult.

Despite this challenge, Engineers Ireland has been working hard to promote engineering as a career choice, and this has led to an increase in the number of students choosing to study engineering. The Engineering Barometer Report also highlights 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.

Quantitative indicators and qualitative descriptions on the evolving nature of the engineering profession

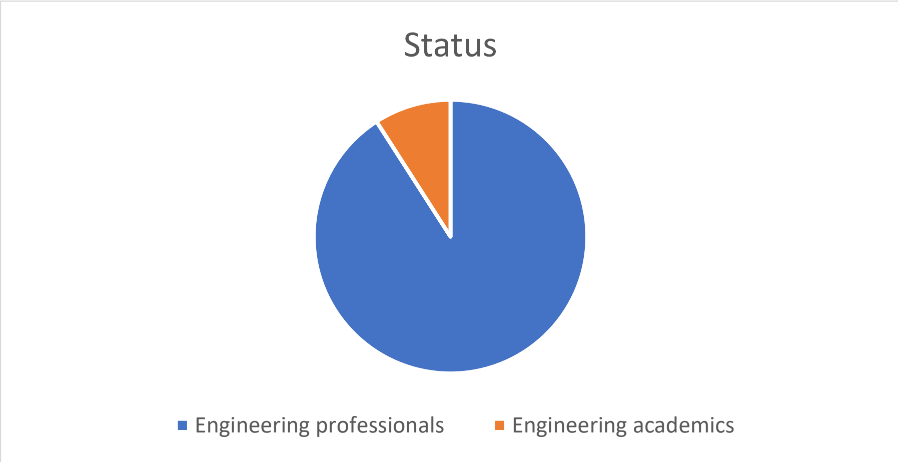
The following quantitative indicators and qualitative descriptions were developed through primary research conducted using two online surveys launched on 9 June 2023 to a targeted group of stakeholders within the Engineers Ireland community.

The findings below reflect the results of the survey on 23 June 2023.

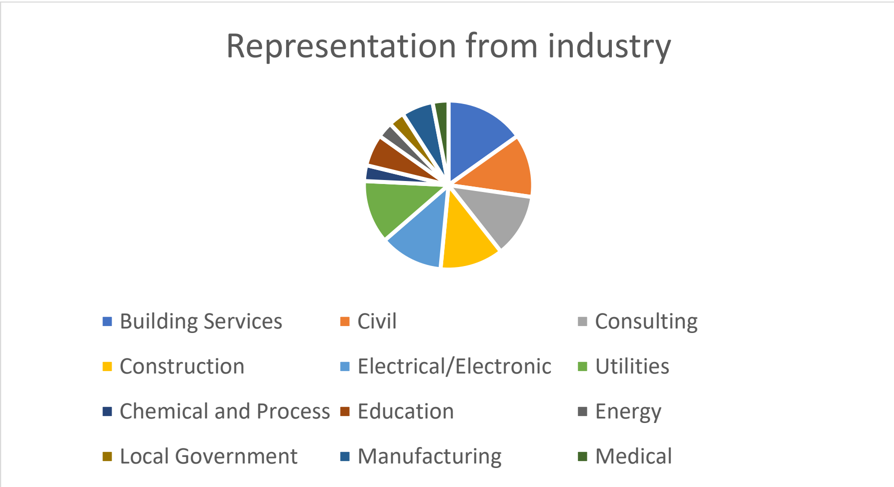
These findings are complemented by an online survey (The Engineers Ireland 2023 Salary Survey) with a dedicated section comprising questions regarding digital, green, entrepreneurial and resilience skills, which was conducted in February 2023.

Primary research survey 1 (June 2023):

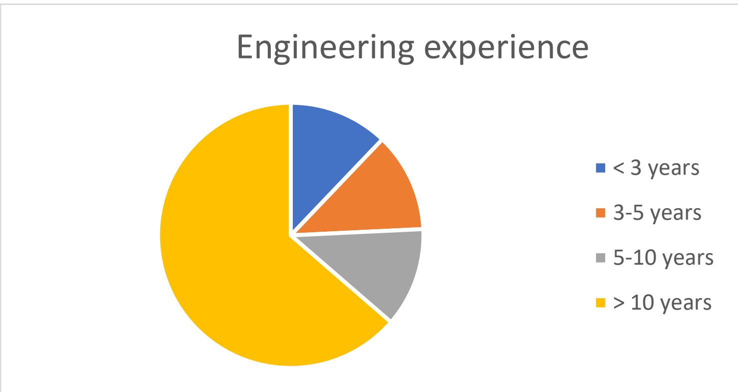
Of the total respondents indicating Ireland as the country where they are professionally active, 91% were engineering professionals and 9% engineering academics.



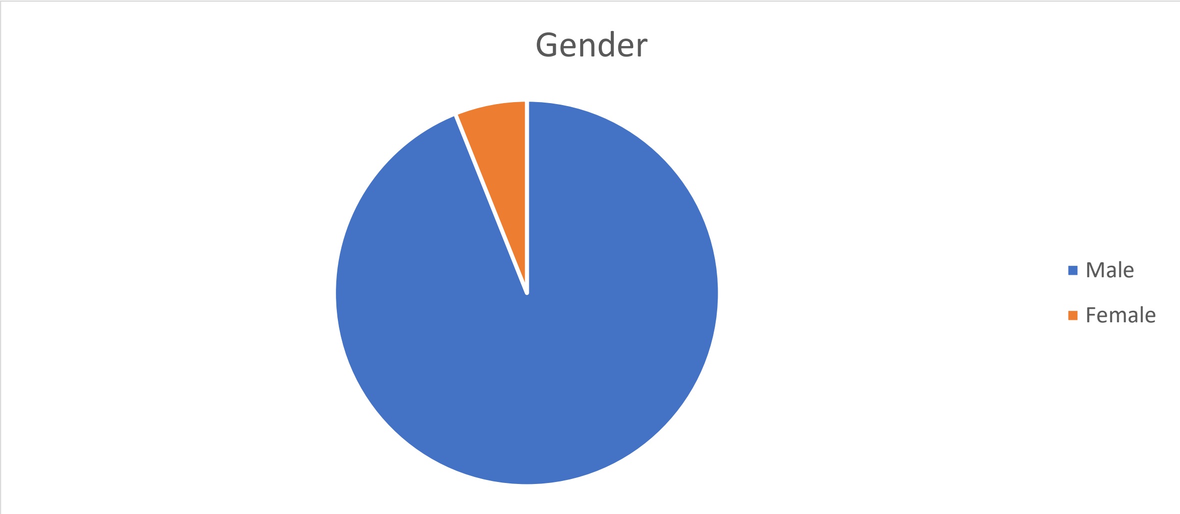
Representation was spread across industries with Civil, Consulting, Construction, Electrical/Electronic and Utilities best represented.



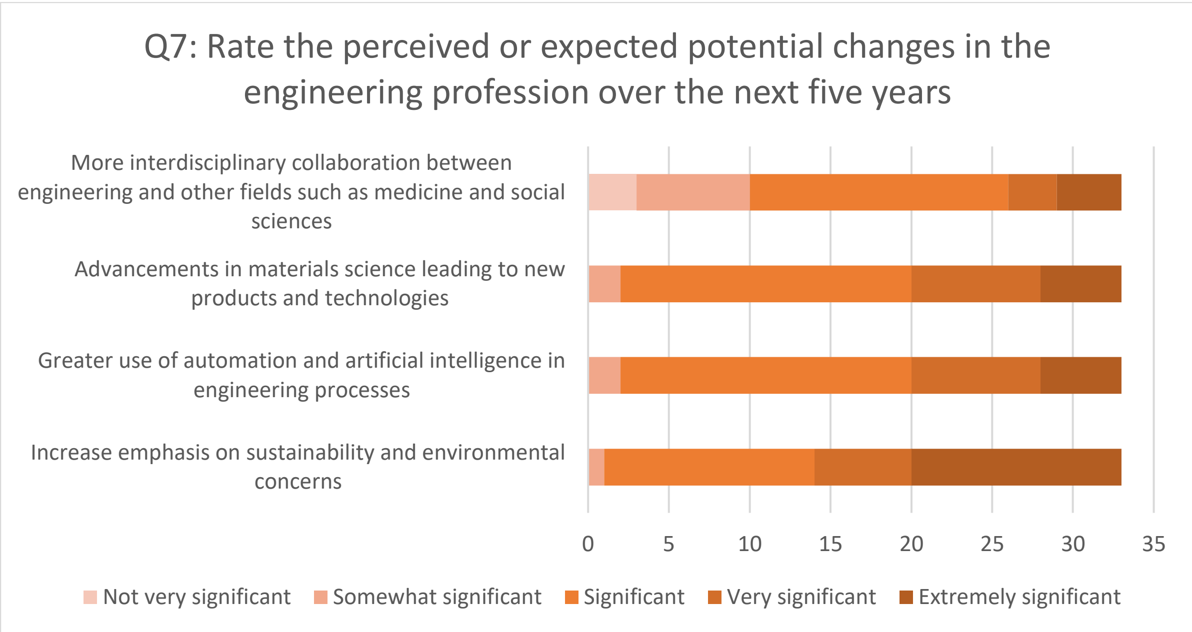
In terms of engineering experience, respondents were mainly engineering professionals with more than 10 years' experience.



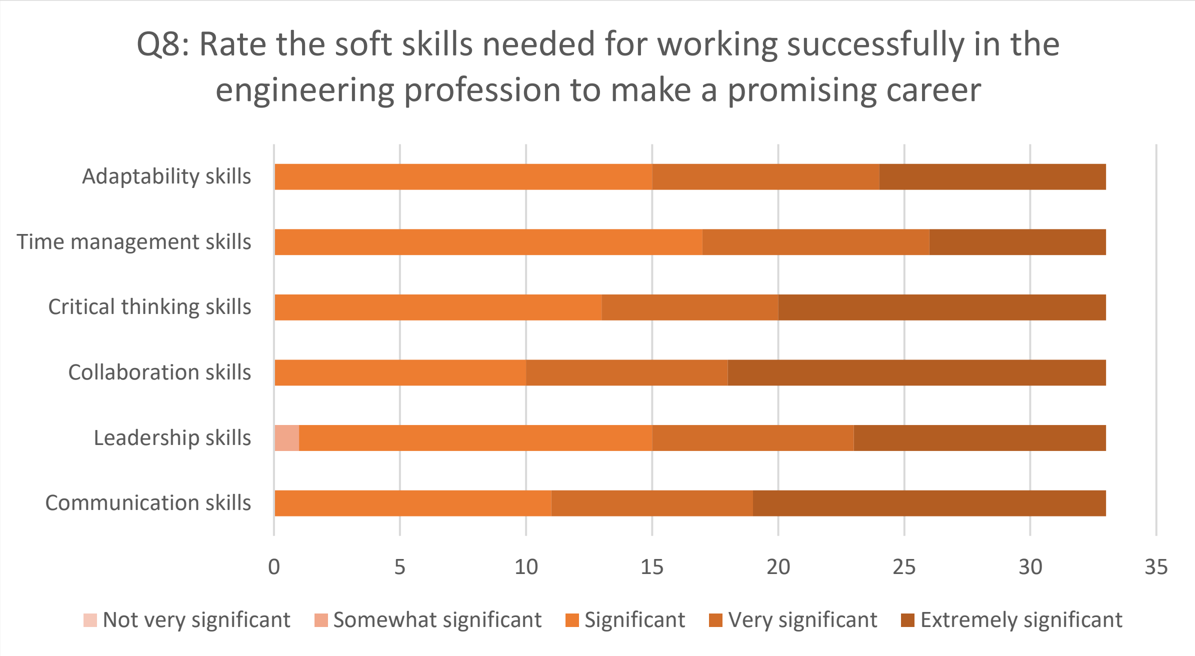
94% of respondents were male, with only 6% female.



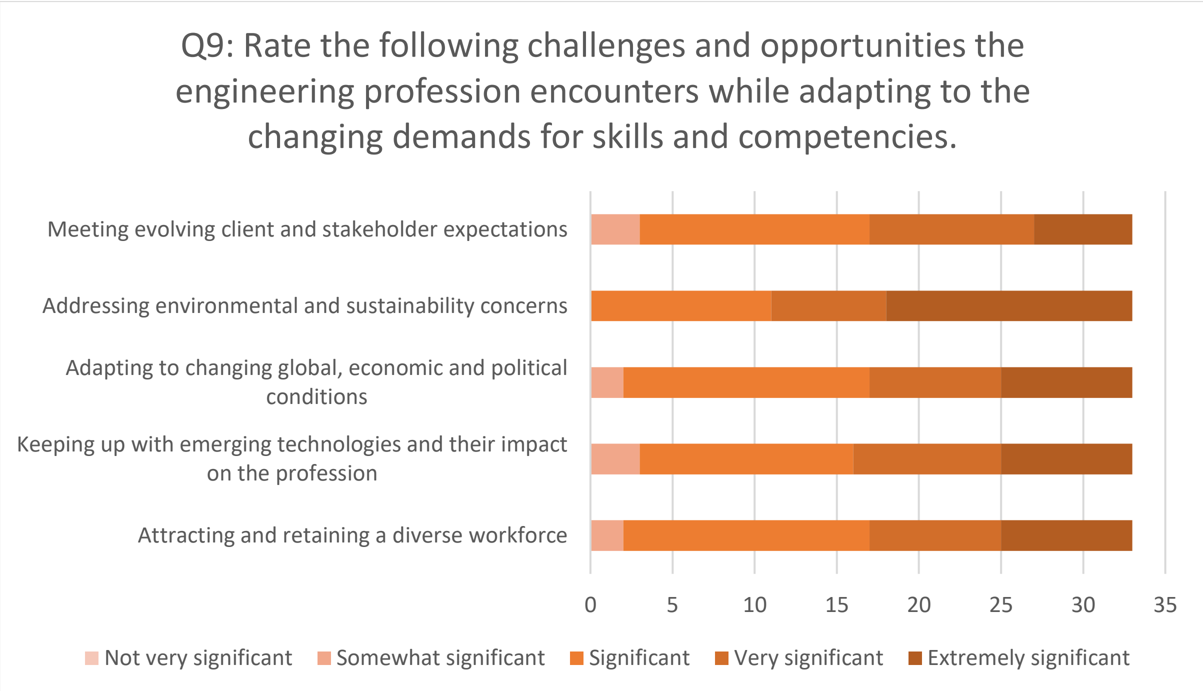
On the question of perceived or expected potential changes in the engineering profession over the next five years, greatest significance was given to increased emphasis on sustainability and environmental concerns.



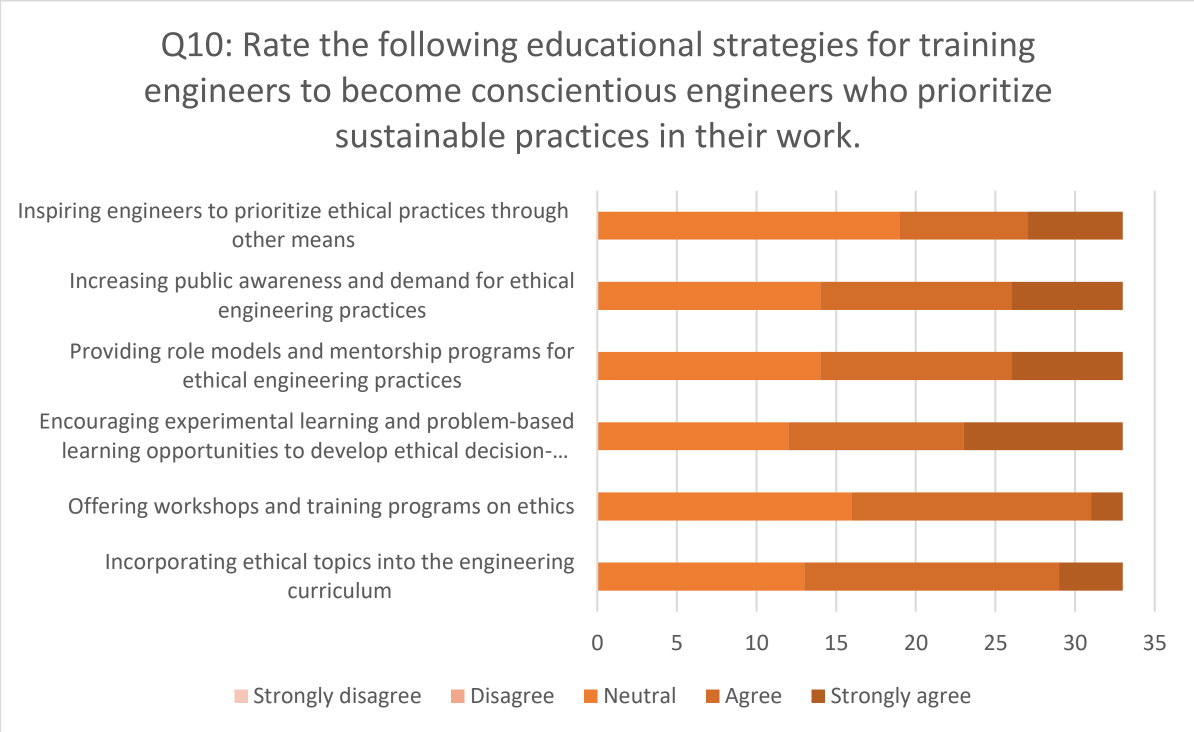
In terms of the soft skills needed for working successfully in the engineering profession to make a promising career, collaboration and communication skills rated highest.



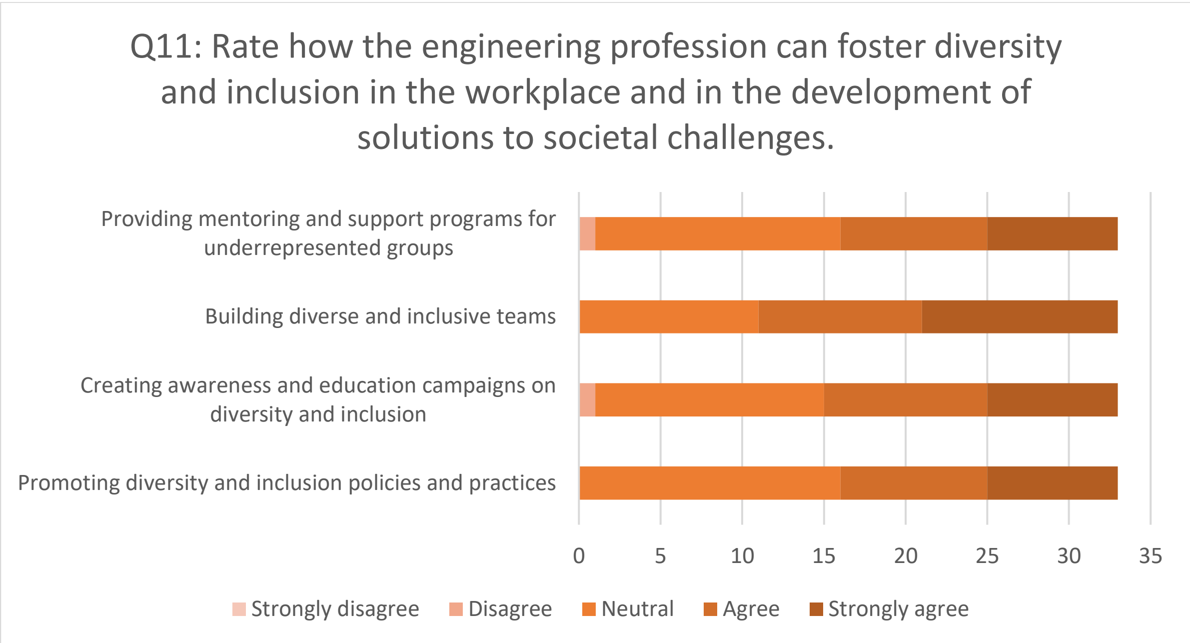
In terms of the challenges and opportunities the engineering profession encounters while adapting to the changing demands for skills and competencies, addressing environmental and sustainability concerns was ranked most significant.



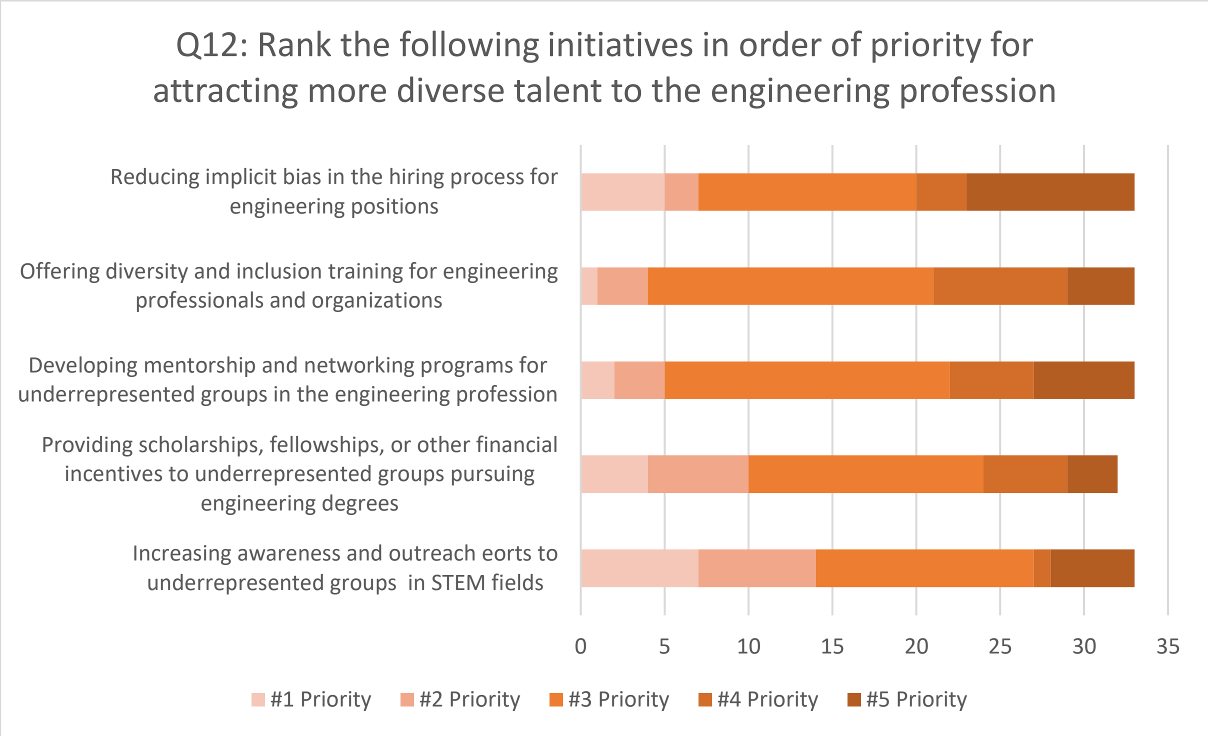
When addressing educational strategies for training engineers to become conscientious engineers who prioritize sustainable practices in their work, encouraging experimental learning and problem-based learning opportunities to develop ethical decision-making skills was rated highest.



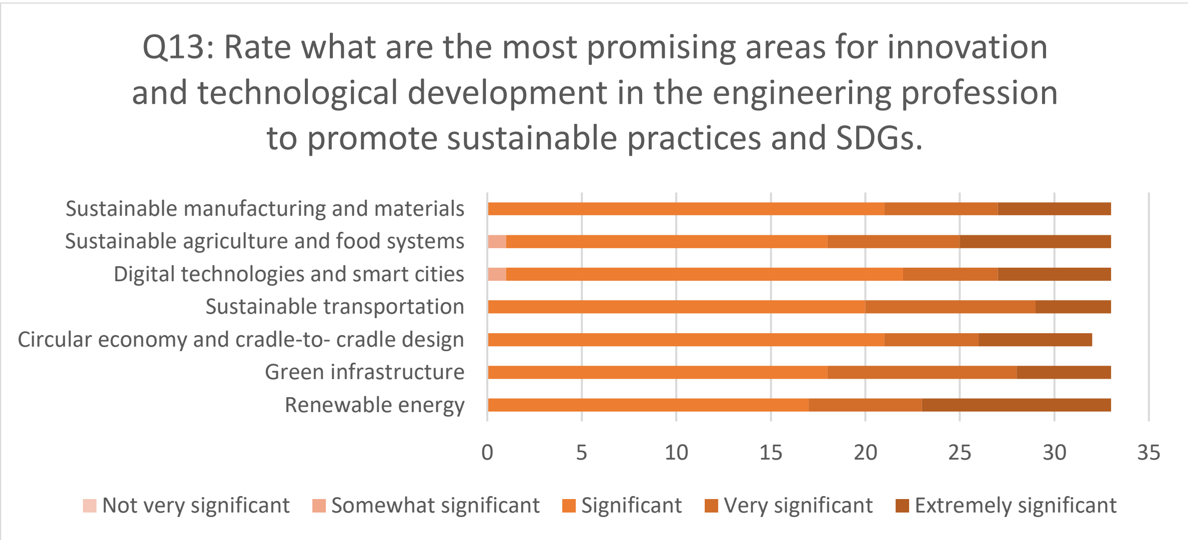
When asked how the engineering profession can foster diversity and inclusion in the workplace and in the development of solutions to societal challenges, building diverse and inclusive teams rated highest.



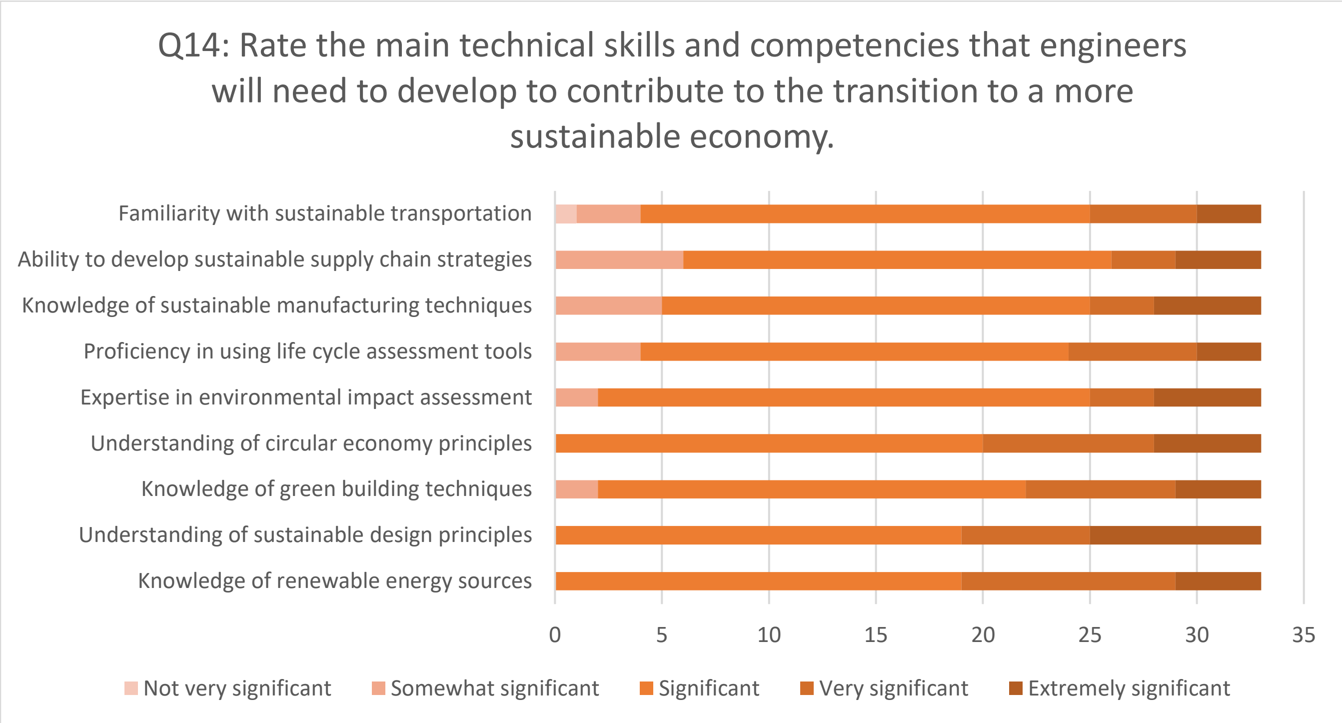
In terms of initiatives in order of priority for attracting more diverse talent to the engineering profession, reducing implicit bias in the hiring process for engineering positions, and offering diversity and inclusion training for engineering professionals and organisations rated highest:



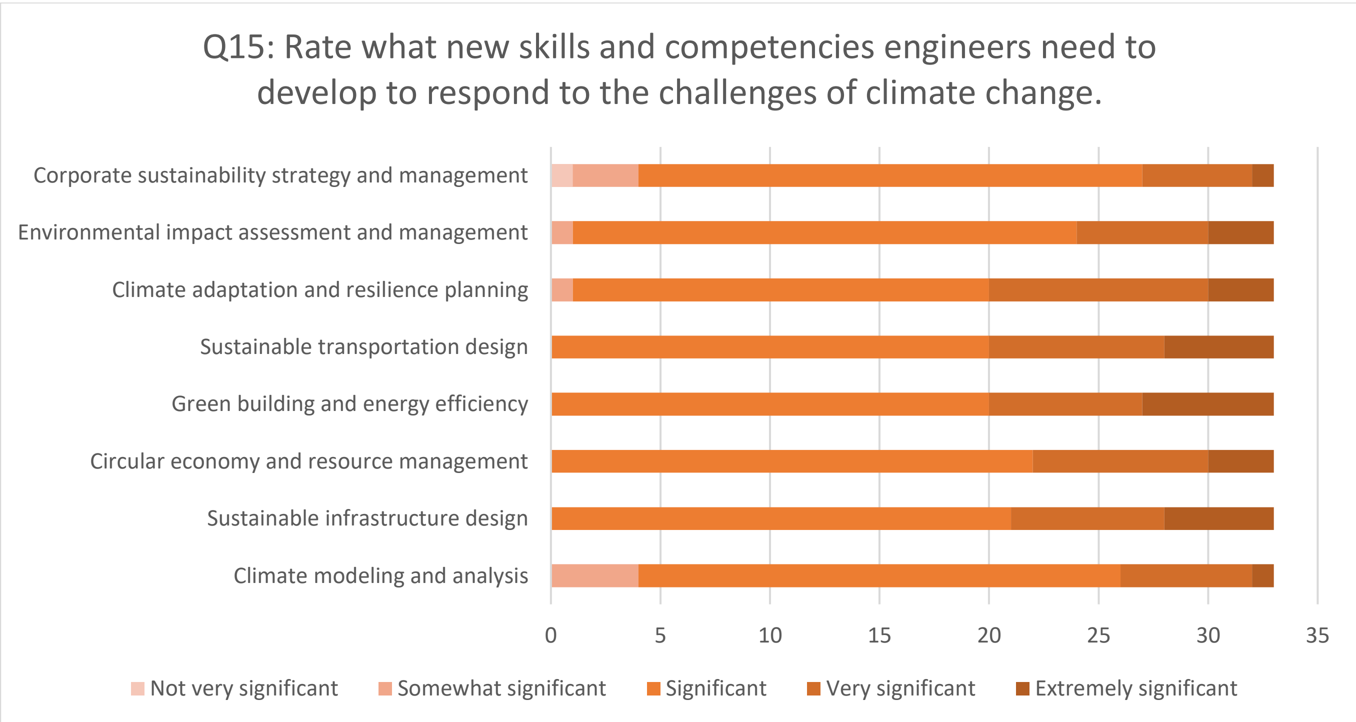
The most promising areas for innovation and technological development in the engineering profession to promote sustainable practices and SDGs were renewable energy, green infrastructure and sustainable agriculture and food systems rated highest.



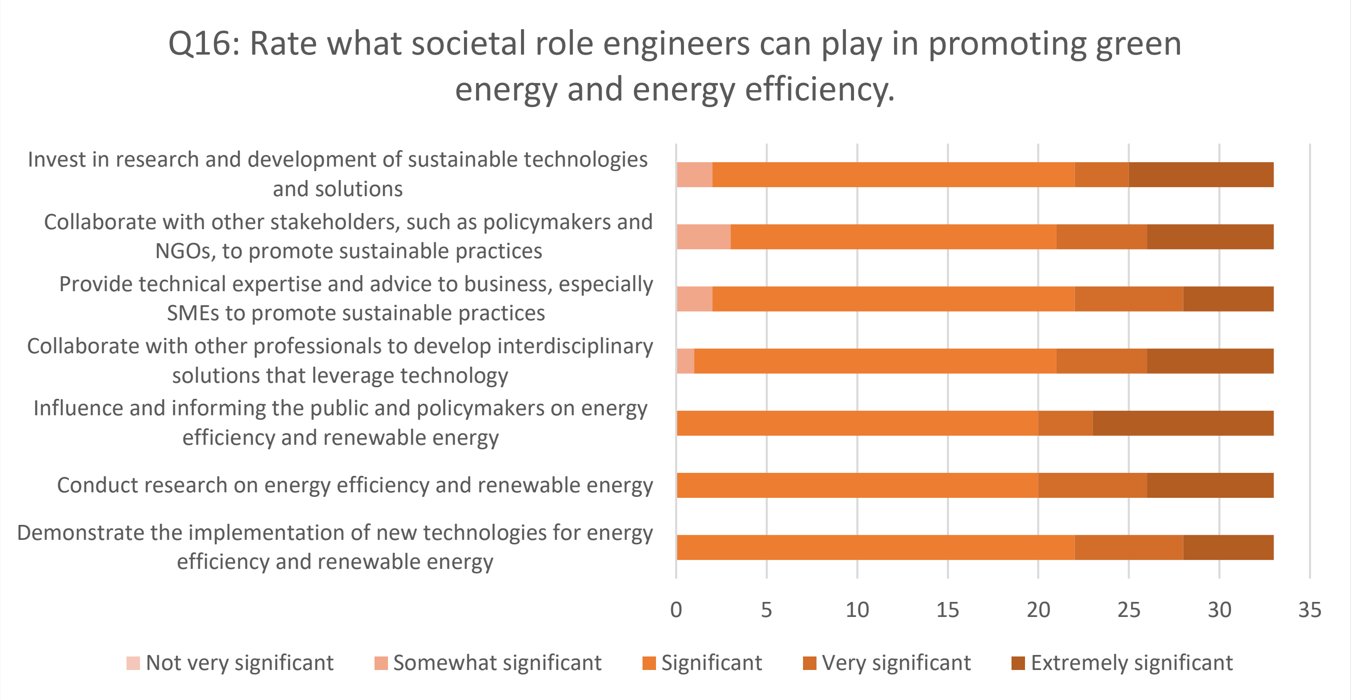
When asked what are the main technical skills and competencies that engineers will need to develop to contribute to the transition to a more sustainable economy, understanding of sustainable design principles, understanding of circular economy principles and knowledge of renewable energy sources ranked highest.



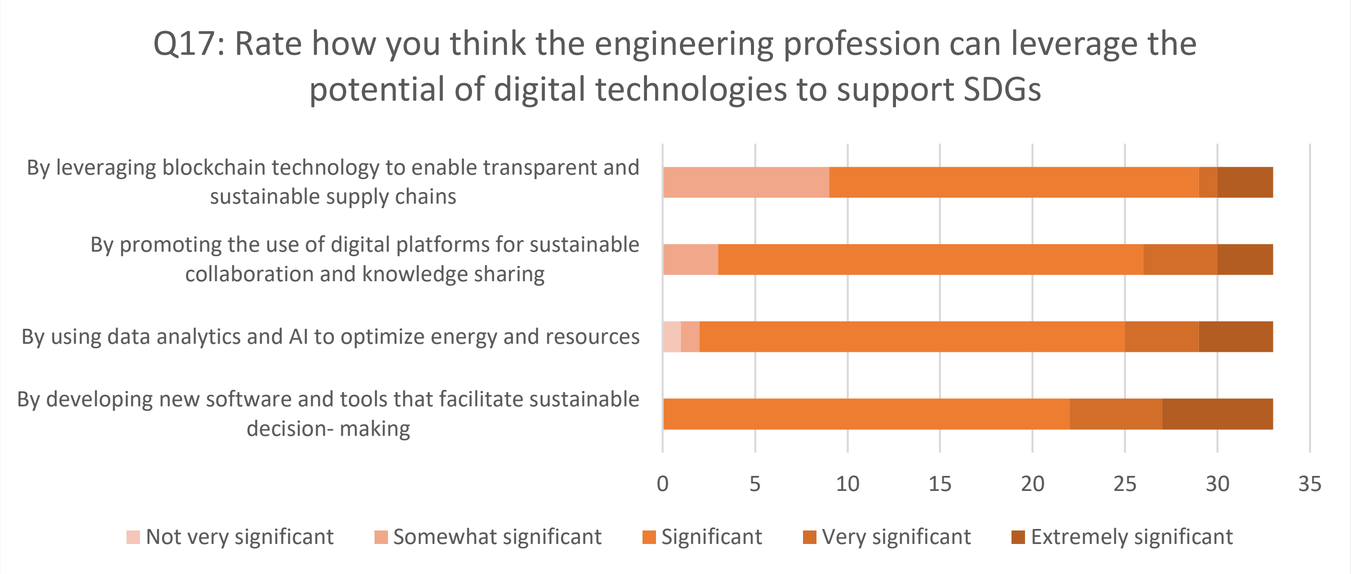
Which new skills and competencies engineers need to develop to respond to the challenges of climate change according to respondents were above all green building and energy efficiency as well as climate adaptation and resilience planning.



Influence and informing the public and policymakers on energy efficiency and renewable energy was rated highest when asked what societal role engineers can play in promoting green energy and energy efficiency.

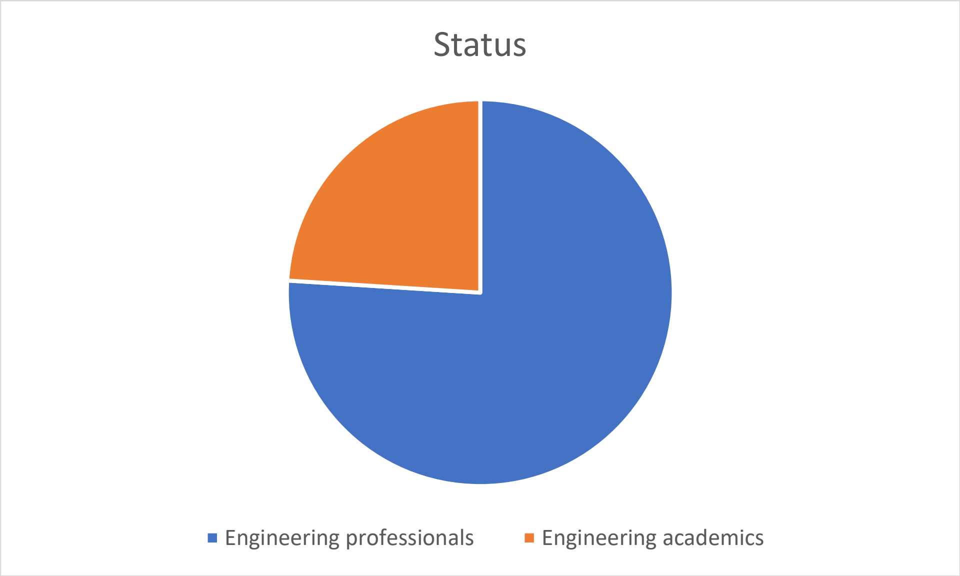


When asked how the engineering profession can leverage the potential of digital technologies to support SDGs and promote sustainable practices, developing new software and tools that facilitate sustainable decision-making rated highest.

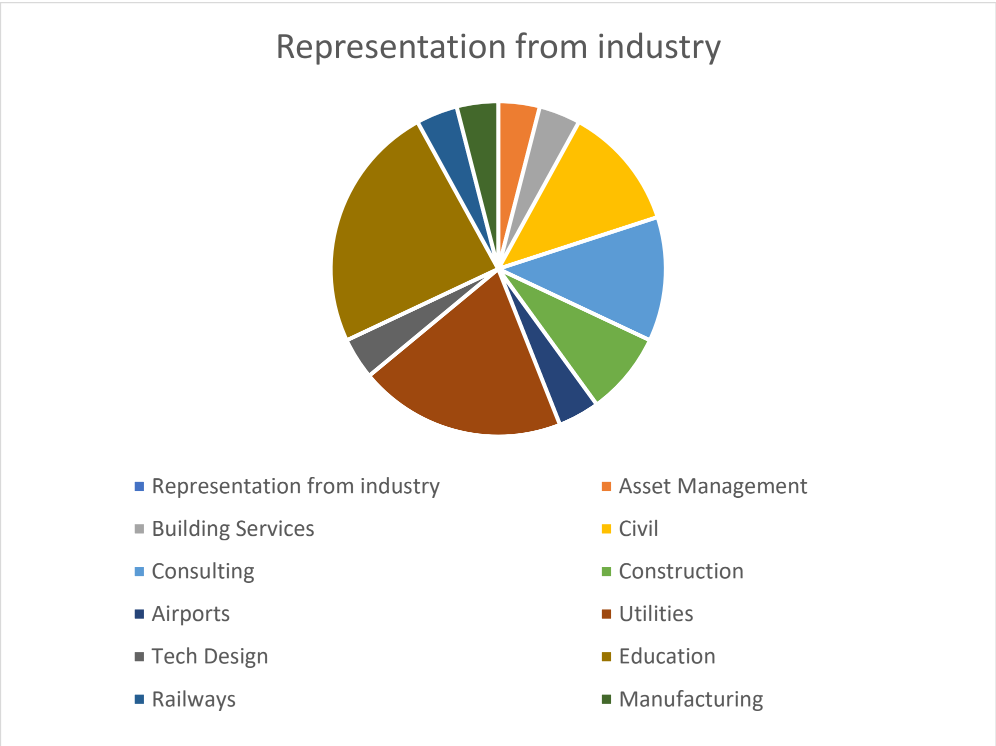


SURVEY 2

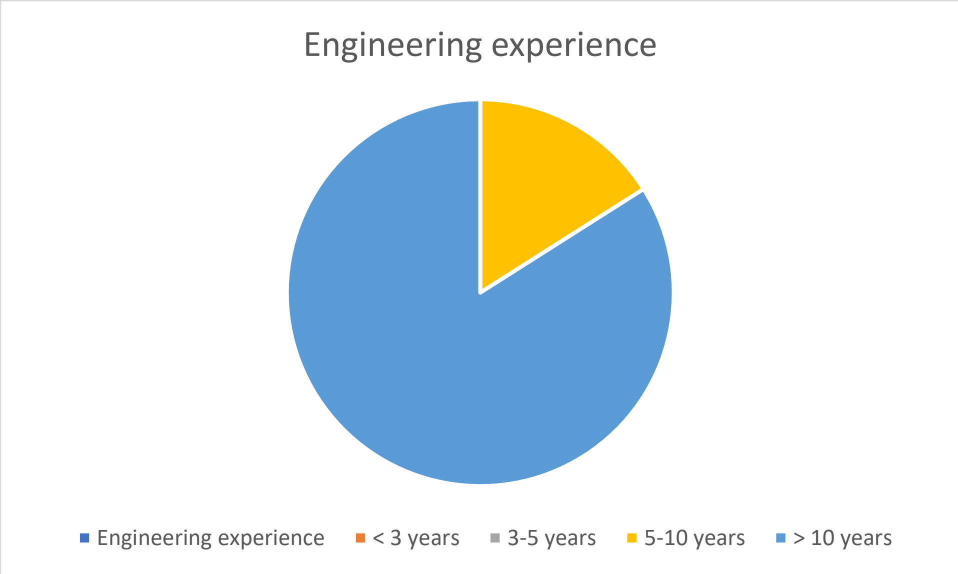
Of those surveyed indicating Ireland as the country where they are professionally active, 76% were engineering professionals and 24% engineering academics.



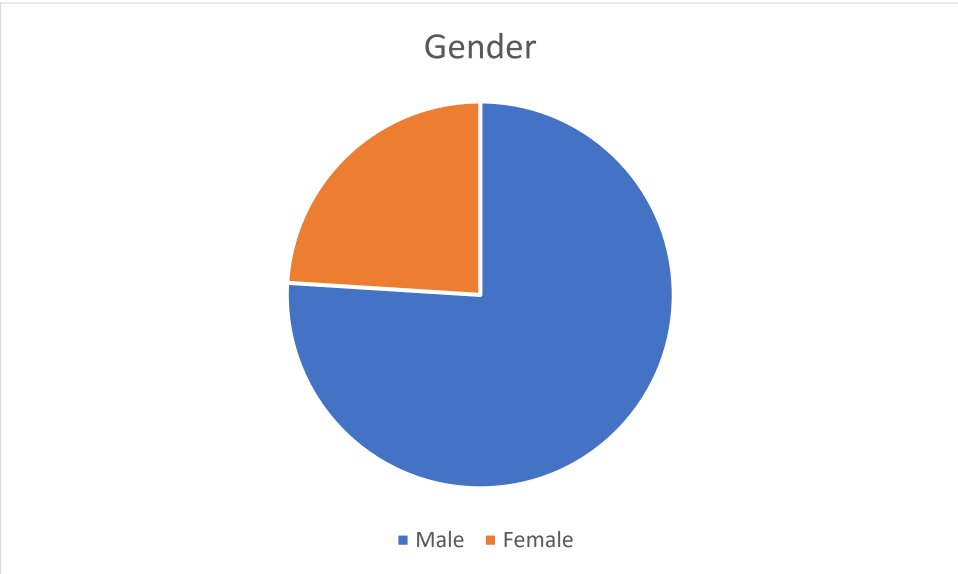
Representation was from across industry with Utilities, Civil, Consulting, and Education most represented.



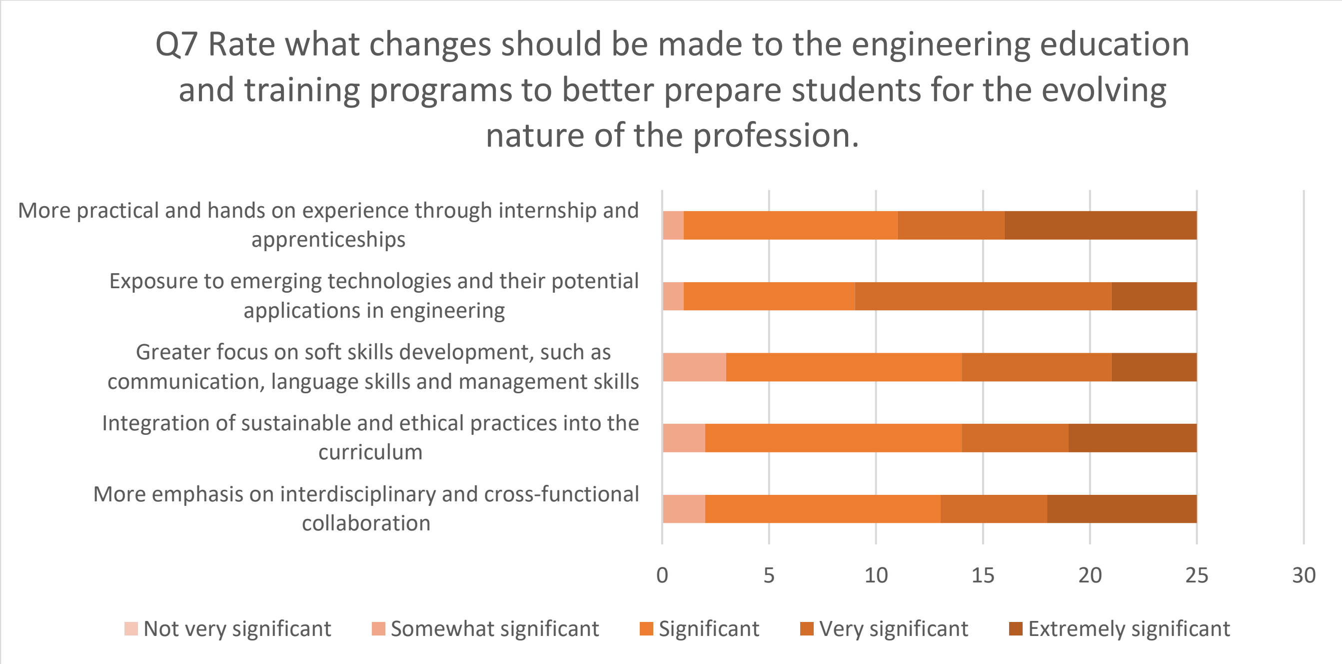
In terms of engineering experience, 16% had between 5-10 years' experience with the remainder having more than 10 years' experience.



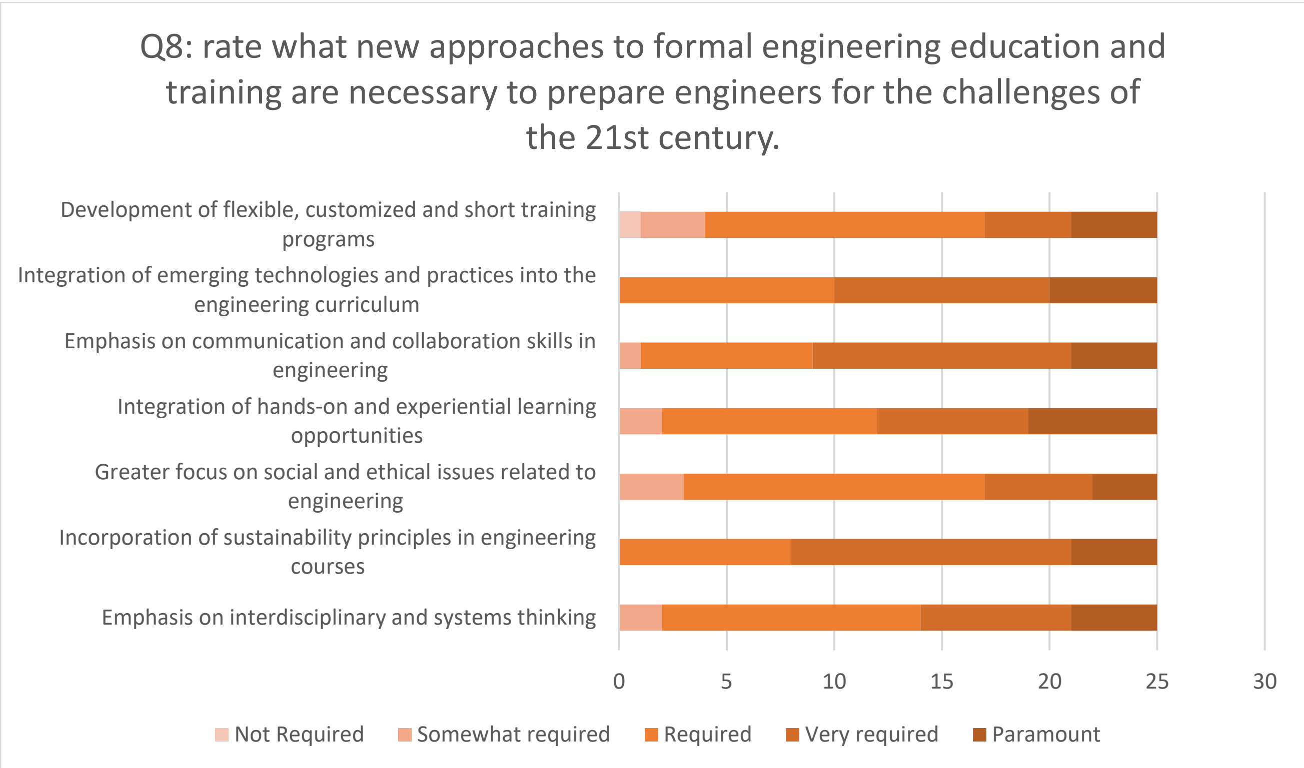
76% respondents were male and 24% were female.



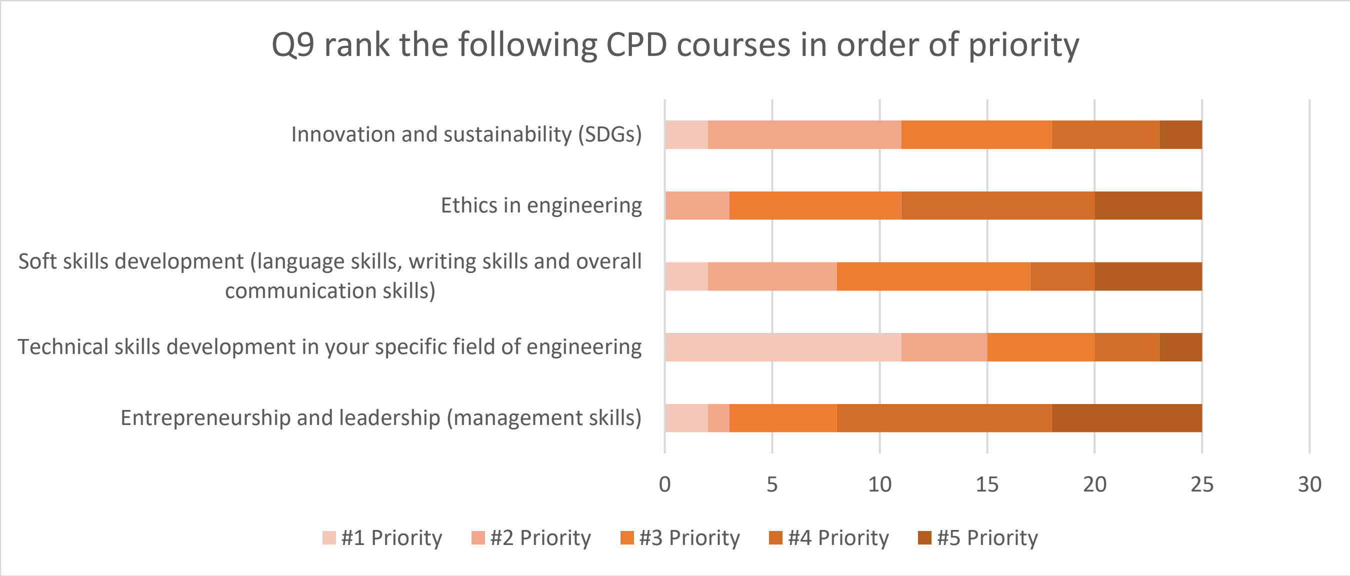
When asked what changes should be made to the engineering education and training programs to better prepare students for the evolving nature of the profession, more practical and hands on experience through internship and apprenticeships and exposure to emerging technologies and their potential applications in engineering rated highest.



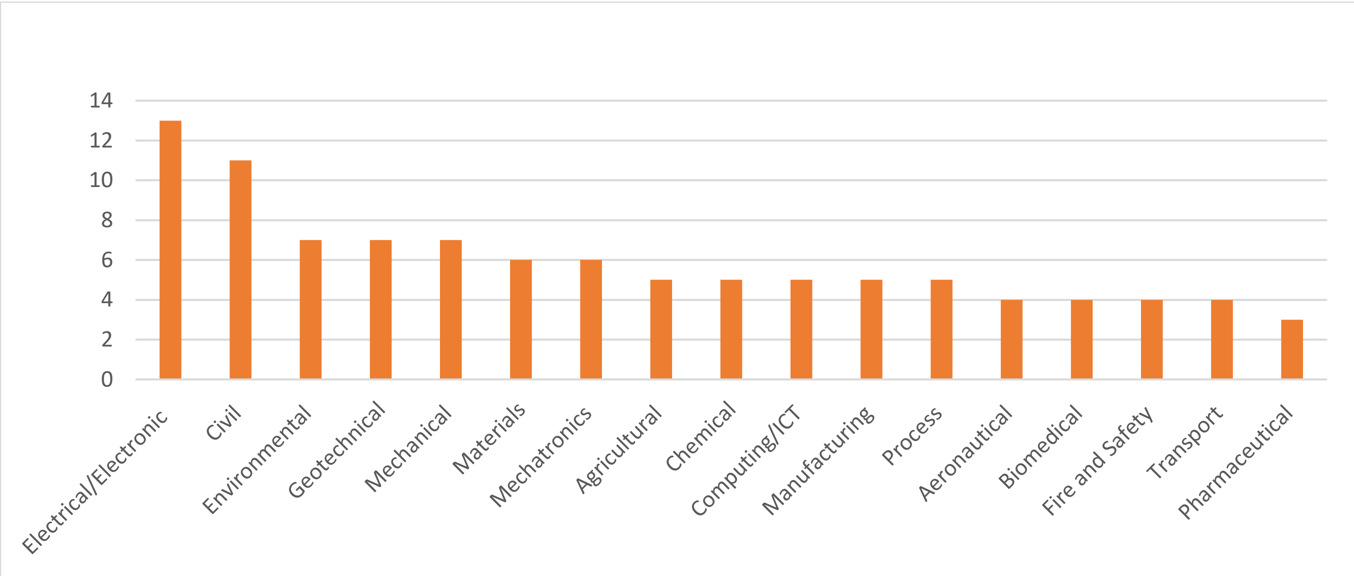
When rating what new approaches to formal engineering education and training are necessary to prepare engineers for the challenges of the 21st century, integration of emerging technologies and practices into the engineering curriculum, integration of hands-on and experiential learning opportunities and emphasis on communication and collaboration skills in engineering were rated highest.



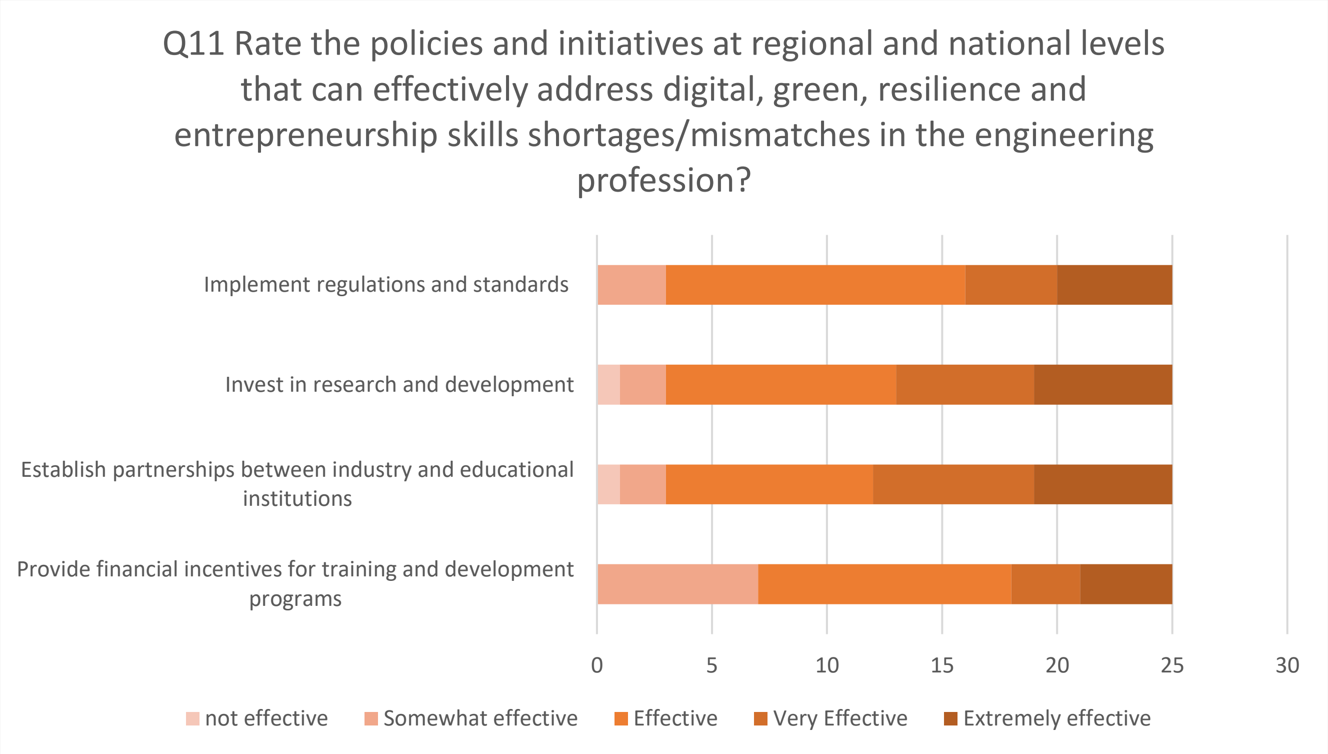
When ranking CPD courses in order of priority, entrepreneurship and leadership (management skills) and ethics in engineering came out highest.



When asked which engineering discipline will have a serious concern due to the future shortages of skilled engineers electrical/electronic and civil came out highest.

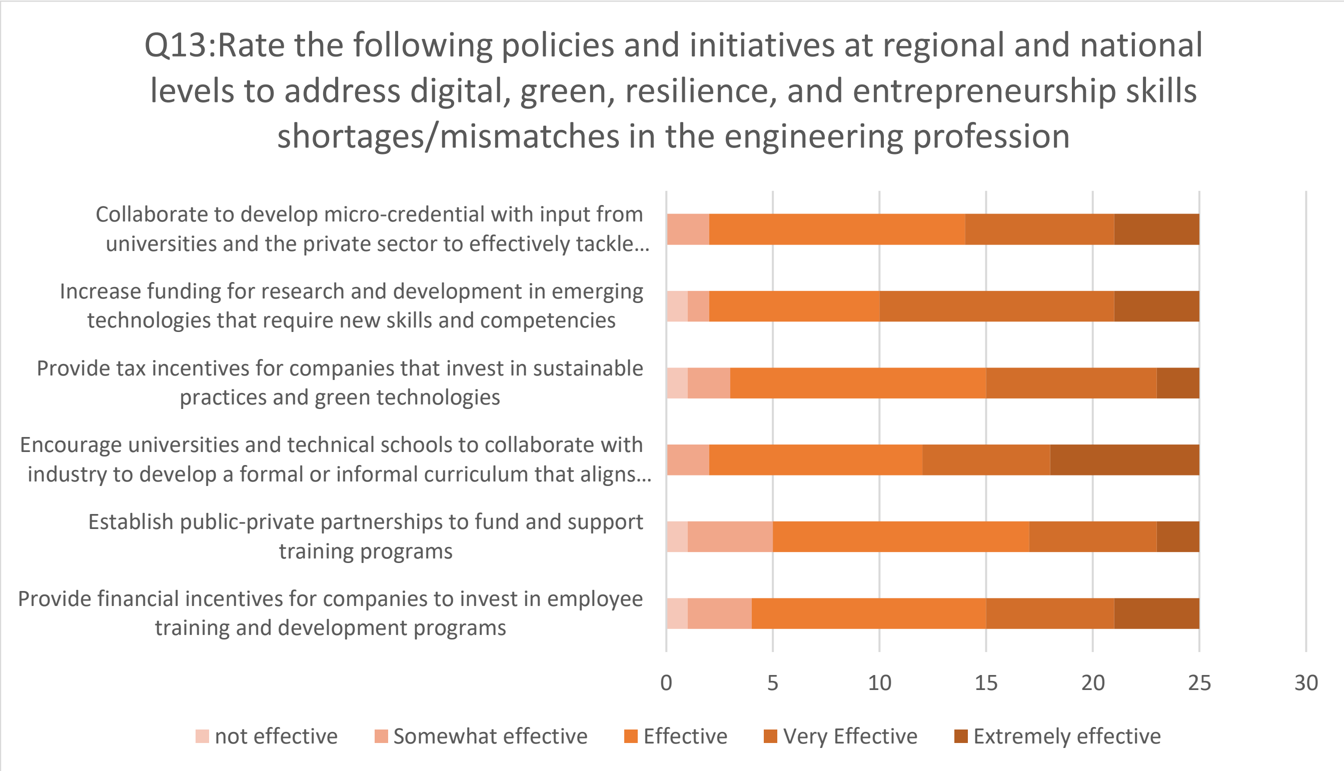


When rating the policies and initiatives at regional and national levels that can effectively address digital, green, resilience and entrepreneurship skills shortages/mismatches in the engineering profession, most options ranked similarly with provide financial incentives for training and development programs deemed the least effective.

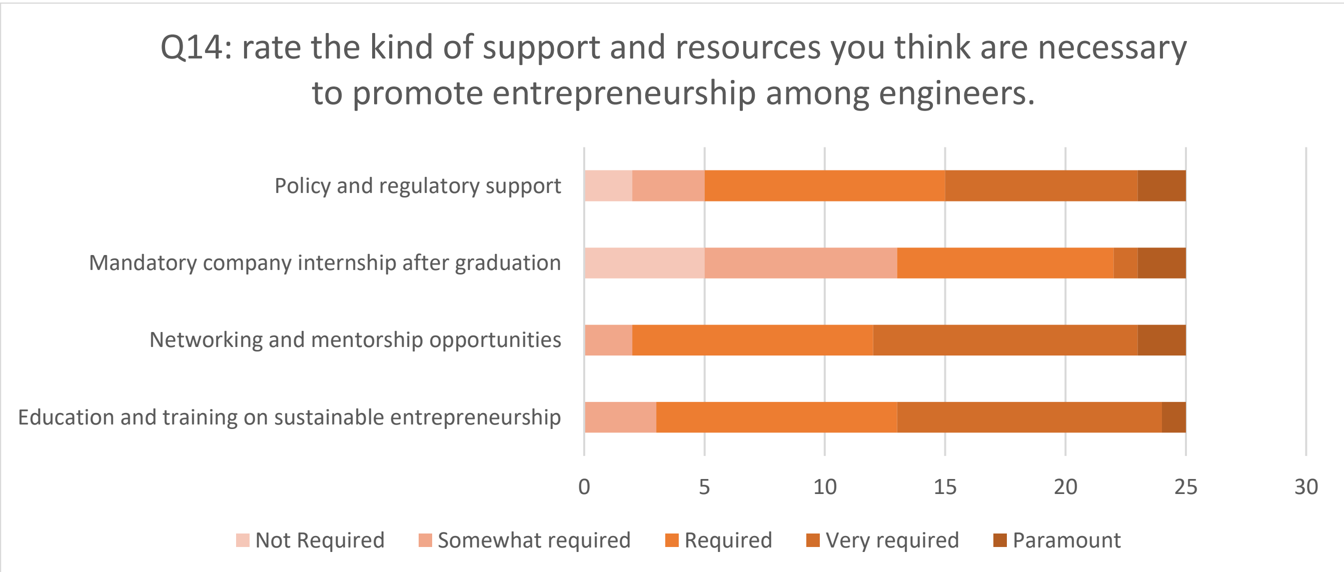


When asked how can engineering professionals better collaborate with other stakeholders, such as policymakers, NGOs, and civil society organisations, to achieve SDGs, participation in policymaking and decision-making processes rated highest.

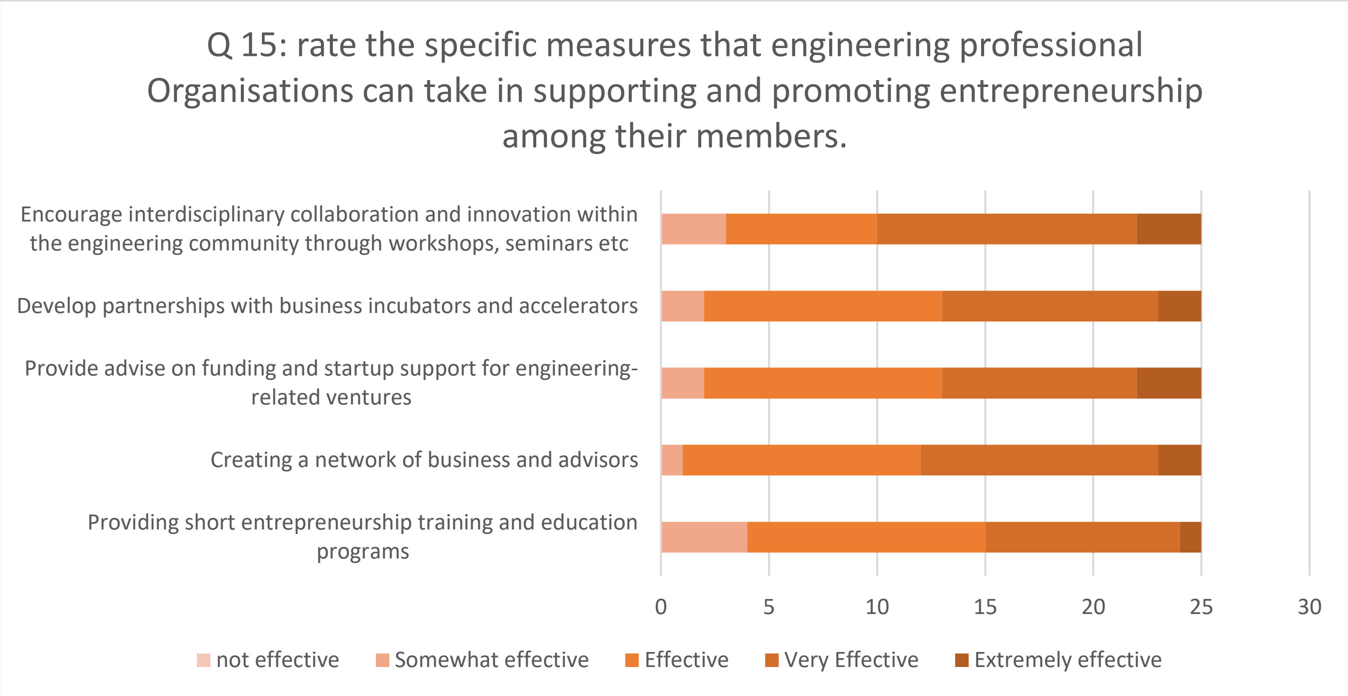
When rating policies and initiatives at regional and national levels to address digital, green, resilience, and entrepreneurship skills shortages/mismatches in the engineering profession, encourage universities and technical schools to collaborate with industry to develop a formal or informal curriculum that aligns with the needs of the job market and increase funding for research and development in emerging technologies that require new skills and competencies came out on top.



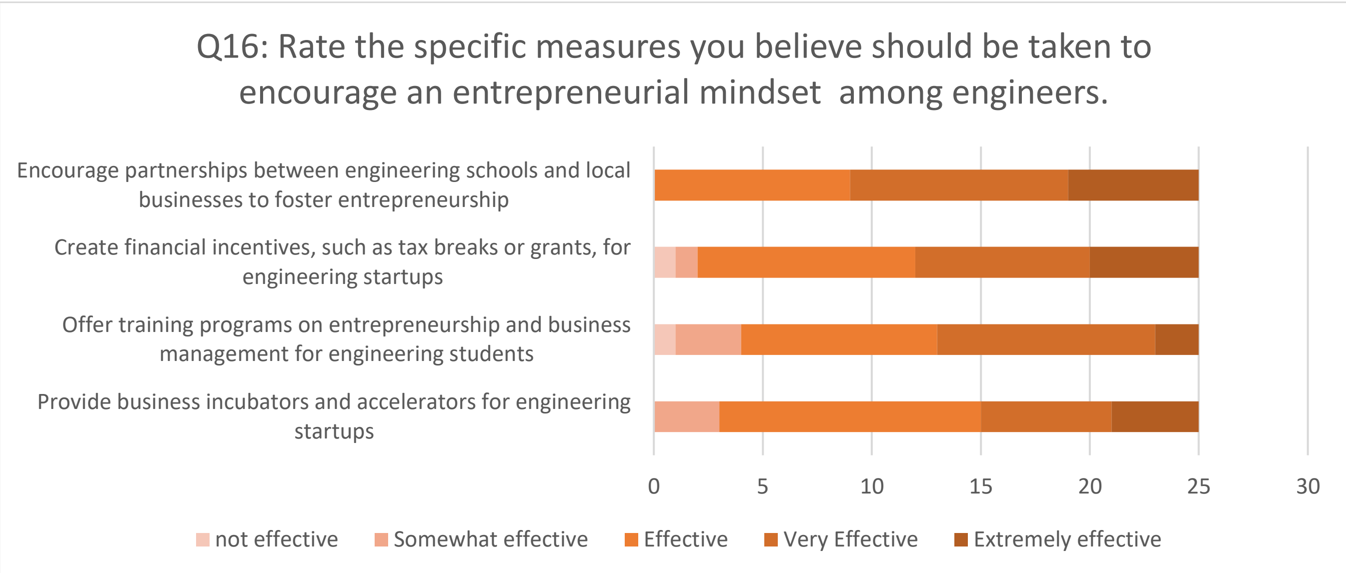
When asked to rate the kind of support and resources you think are necessary to promote entrepreneurship among engineers, networking and mentorship opportunities came out on top.



When rating the specific measures that engineering professional organisations can take in supporting and promoting entrepreneurship among their members, encourage interdisciplinary collaboration and innovation within the engineering community through workshops, seminars etc. came out on top.



When asked what specific measures you believe should be taken to encourage an entrepreneurial mindset among engineers, encourage partnerships between engineering schools and local businesses to foster entrepreneurship ranked highest.



In the 2023 Salary Survey, Engineers Ireland members were asked to rank the most important skills in the coming 10 years under the headings of Green Skills, Digital Skills, Resilience Skills, Entrepreneurial Skills and Other Skills. The results were as follows:

Engineers Ireland

Green Skills

Ranking	Topic	% of 420 responses
1	Sustainability	7%
2	Carbon Accounting	5%
3	Life Cycle Analysis	4%
4	Decarbonatisation	4%
5	Sustainable Design	3%
6	Renewables	3%
6	Recycle Materials	2%
6	Circular Economy	2%
6	Environment	2%
6	Green Procurement	2%
6	SUDs	2%
6	Sustainable Materials	2%
12	Active Travel	1%
12	Design	1%
12	EIA	1%
12	Energy Efficiency	1%
12	ESG	1%
12	Green Design	1%
12	Hydrogen	1%
12	Green Materials	1%
12	Lean	1%
12	LEED	1%
12	Nature-based solutions	1%
12	Net Zero	1%
12	Solar	1%
12	Wind	1%
27	Biodiversity	0.5%
27	Retrofitting	0.5%
27	Nuclear	0.5%

Engineers Ireland

Digital Skills

Ranking	Topic	% of 371 responses
1	BIM	22%
2	AI	17%
3	Data	11%
4	Coding	6%
5	Software	4%
6	AR/VR	3%
7	Automation	3%
8	Microsoft Suite	3%
8	Remote Working	3%
9	Programming	2%
10	Modelling	2%
11	Revit	2%
12	3D	2%
13	Communications	1%
14	IoT	1%
15	Cloud	1%
15	Digital Twin	1%
16	Collaboration	1%
16	CAD	1%
16	GIS	1%
16	I 4.0	1%
16	Parametric Design	1%

ENGINEERS IRELAND

Resilience Skills

Ranking	Topic
1	Adaptability
2	Mental Wellness
2	Remote Working
4	Communications
5	Stress Management
5	Work Life Balance
7	Workload
7	Influencing/Negotiating
7	Change Management
10	Time Management
11	Crisis Management

ENGINEERS IRELAND

Entrepreneurial Skills

Ranking	Topic
1	Financial Acumen
2	Creativity
3	Innovation
4	Start up
5	Technology
5	Management

ENGINEERS 4 EUROPE

ENGINEERS IRELAND

Other Skills

Ranking	Topic
1	Communications Skills
2	Management Skills
3	Interpersonal Skills
4	Influencing Skills
5	Leadership Skills
6	Problem Solving Skills
7	Financial Acumen
8	Diversity & Inclusion
8	Presentation Skills
10	Commercial Skills

Trends in the Engineering Profession in Ireland

The engineering profession in Ireland is broad and encompasses all major disciplines of engineering. According to the Industrial Development Authority (IDA), the engineering sector attracts renowned companies like Liebherr, Henkel, Element Six, Sulzer and Thermoking. The sector contributes more than €5.6 billion annually to Irish exports, with the top eight industrial automation companies with a presence in Ireland and four of the top 10 global engineering design firms here. (IDA Ireland, 2023).

Ireland is the European location of choice for growing numbers of industrial engineering and technology companies in manufacturing, research and innovation. Remaining ninth in the European league table of the most attractive investment opportunities for Foreign Direct Investment (FDI) according to the European Attractiveness survey in 2021 (RTE, 2023) this is largely due to the "Brexit bounce" effect that occurred in 2018. Many international engineering firms have recently expanded their operations in Ireland to serve European, Middle East and African markets.

In the coming years, Ireland will experience global trends that can either provide opportunities or pose challenges similar to Atlantic storms. These "megatrends" have been identified by the Irish Academy of Engineers (IAE) as having a global impact, and they will greatly influence employment and society in Ireland beyond 2040. (The Irish Academy of Engineering, 2023). Key areas that see significant activity in engineering in Ireland are:

- Technological Advancements
- Sustainability and Renewable Energy
- Pharmaceutical manufacture
- Digitalisation and Data Analytics
- Remote Working

Technological Advancements: Rapid advancements in technologies such as artificial intelligence, the Internet of Things (IoT), robotics, and automation are transforming the engineering landscape in Ireland. Engineers are leveraging these technologies to enhance productivity, improve efficiency, and develop innovative solutions across various sectors.

Sustainability and Renewable Energy: Ireland increasingly emphasises sustainability and renewable energy sources. Engineers are at the forefront of developing and implementing green technologies, including wind farms, solar energy systems, and energy-efficient infrastructure. The focus on sustainability presents significant opportunities for engineers to contribute to Ireland's climate goals. This can be seen in the government's plan to have 5GW of offshore wind energy by 2030 (Dept. of the Environment, Climate and Communications, 2023) and also by Engineers Ireland's new "Chartered Environmentalist" title (Engineers Ireland, 2023).

Pharmaceutical manufacture: The pharmaceutical sector in Ireland significantly contributes to the country's economy, employment, and innovation. Ireland has emerged as a global hub for pharmaceutical manufacturing, research and development. With chemicals and related products being one of the largest exported products Ireland produces with Exports of Organic Chemicals at €156 million in April 2023 (Central Statistics Office, 2023).

Digitalisation and Data Analytics: The digitalisation of engineering processes and the utilisation of data analytics are becoming increasingly important. Engineers are leveraging advanced software tools, simulation models, and data analytics to optimise designs, analyse complex systems, and improve decision-making processes. Building Information Modelling (BIM) is a good example of this. BIM s a process for creating and managing information on a construction project across the lifecycle of the project, which adheres to I.S. EN ISO 19650-2:2018. The Irish government have stated it will require BIM on complex projects from 2019 (National Standards Authority of Ireland, 2023)

Remote working: Remote and hybrid working has changed the competitive landscape for cities, regions, and countries. To attract top talent, Ireland needs to prioritise enhancing its overall quality of life. Modern amenities, strong community engagement, and well-developed infrastructure can differentiate Ireland. Personal taxation and affordable housing are also important factors. By embracing a holistic approach and addressing practical issues, Ireland can position itself as an alluring destination for talented individuals who can work and live in different locations.

Opportunities in the Engineering Profession in Ireland

Infrastructure Development: Ireland's growing economy and expanding population create opportunities for engineers involved in infrastructure development projects which include transportation, housing, water management, and renewable energy. The government's unwavering commitment towards investing in critical infrastructure creates a conducive environment for engineering professionals. Especially in terms of information development, Ireland's high level of communication infrastructure, thanks to the national broadband plan (NBP), is noteworthy. The NBP is an initiative by the government to provide high-speed broadband services to all premises in Ireland. It will be accomplished through investment by commercial enterprises along with the State's intervention in those regions where private companies have no investment plans. The NBP will reach 560,000 premises and over 1.1 million people. (Dept. of the Environment Climate and Communications, 2020)

Research and Development: Ireland has a strong focus on research and development (R&D), with various initiatives and funding programs supporting innovation (Dept. of Further and Higher Education, Research, innovation and Science, 2022). Engineers have opportunities to work on cutting-edge R&D projects, collaborate with academic institutions, and contribute to technological advancements in diverse fields. This research and development is important in attracting foreign direct investment (FDI), aided by Ireland's growing reputation as a global centre for innovation and development (O'Connell, 2023). Irish companies are also involved in space research as part of the European Space Agency (ESA) with 94 companies being involved in developing components for active space missions in 2021 (Enterprise Ireland, 2021).

Foreign Direct Investment: Ireland's favourable business environment, skilled workforce, and strong engineering capabilities have attracted significant FDI from multinational companies. This influx of FDI presents opportunities for engineers to work on innovative projects and contribute to Ireland's position as a global hub for technology and engineering.

FDI plays a significant role in the Irish economy, and it will remain important in the future. IDA Ireland has developed a strategy, called "Driving Recovery and Sustainable Growth, for 2021-2024" (IDA Ireland, 2021). The strategy focuses on Growth, Transformation, Regions, Sustainability, and Impact. It outlines key targets that the Agency is working towards to encourage and expand investment by international companies in the coming years.

Another opportunity for the engineering profession in Ireland is its focus on renewable energy. The government has set ambitious targets for renewable energy usage, and greenhouse gas reductions by 2030 in various sectors. (Dept. of the Taoiseach, 2021)

- Electricity: 62-81%
- Transport: 42-50%
- Buildings: 44-56%
- Industry/Enterprise: 29-41%
- Agriculture: 22-30% reduction
- Land Use, Land Use Change and Forestry (LULUCF): 37-58%

These targets are admirable, but engineers will play a crucial role in achieving them. The sector is also expected to benefit from the increasing demand for electric vehicles and smart cities.

Challenges in the Engineering Profession in Ireland

Skills Shortage: One of the primary challenges in the engineering profession in Ireland is the shortage of skilled professionals. The demand for engineers exceeds the available talent pool, particularly in specialised areas such as data analytics, cybersecurity, and renewable energy. Addressing this shortage requires a focus on education and training initiatives to develop a pipeline of skilled engineers. Ireland already ranks third in the rate of third-level education attainment globally, at 54%, as compared with an average of 41% (OECD , 2022). However, even with such a high take-up of third-level education, there are insufficient numbers of graduating engineers, which remains consistent at around 6,000 students graduates (HEA, 2023) per year.

One of the key challenges facing the engineering profession in Ireland is the shortage of skilled professionals with five years or more experience. Although there has been an increase in the number of students pursuing engineering degrees, there is still a significant gap between the demand and supply of engineers. This is illustrated on the government "Critical Skills Occupation List" which lists 24 disciplines of engineering professionals as a shortage (Gov.ie, 2021)

Despite the shortage of skilled professionals, the engineering sector in Ireland has numerous opportunities. With almost 8,000 jobs expected in 2023 according to the Engineers Ireland barometer report 2023 (Engineers Ireland, 2023). The country's strong focus on innovation and technology makes it an ideal location for engineering firms to set up shop. Ireland's membership of the EU and its favourable business environment also makes it an attractive destination for engineering companies. Gender diversity has been a historical issue in engineering in Ireland and internationally. Women remain an untapped resource within the engineering profession.

Brexit Implications: Brexit has introduced uncertainties for the engineering profession in Ireland, particularly in terms of trade, regulatory standards, and collaboration with the United Kingdom. Engineers need to adapt to changing regulations and explore new opportunities in the European Union and global markets.

Conclusions from Primary Research

Sustainability

From our primary research group we learned that in terms of potential changes in the engineering profession over the next five years, greatest significance is given to increased emphasis on sustainability and environmental concerns and that addressing skills and competencies in this space is most significant. As far as technical skills and competencies that engineers will need to develop to contribute to the transition to a more sustainable economy, understanding of sustainable design principles, understanding of circular economy principles and knowledge of renewable energy sources ranked highest. The skills and competencies engineers need to develop to respond to the challenges of climate change according to respondents were above all green building and energy efficiency as well as climate adaptation and resilience planning.

In terms of specific skills development, topics such as sustainability, sustainable design and sustainable materials ranked high among Engineers Ireland members as well as carbon accounting, life-cycle analysis, decarbonisation and renewables.

Innovation and Technological Development

Looking at innovation and technological development, the most promising areas ranked by respondents for innovation and technological development in the engineering profession to promote sustainable practices and SDGs were renewable energy, green infrastructure and sustainable agriculture and food systems.

When asked how the engineering profession can leverage the potential of digital technologies to support SDGs and promote sustainable practices, developing new software and tools that facilitate sustainable decision-making rated highest.

Building Information Modelling was the leading skill requirement for Engineers Ireland members under the heading of Digital Skills, followed by AI, Data, Coding and Software.

Soft Skills and CPD Courses

Looking at soft skills needed for working successfully in the engineering profession to make a promising career, collaboration and communication skills come out on top. And when ranking CPD courses in order of priority, entrepreneurship and leadership (management skills) and ethics in engineering came out highest.

Engineers Ireland members ranked communication skills, management skills and interpersonal skills highest as well as adaptability, mental wellness, and remote working.

Diversity and Inclusion

When asked how the engineering profession can foster diversity and inclusion in the workplace and in the development of solutions to societal challenges, building diverse and inclusive teams rated highest. In terms of initiatives in order of priority for attracting more diverse talent to the engineering profession, reducing implicit bias in the hiring process for engineering positions, and offering diversity and inclusion training for engineering professionals and organisations rated highest.

Education

When addressing educational strategies for training engineers to become conscientious engineers who prioritise sustainable practices in their work, encouraging experimental learning and problem-based learning opportunities to develop ethical decision-making skills was rated highest. Similarly, when asked what changes should be made to the engineering education and training programs to better prepare students for the evolving nature of the profession, more practical and hands-on experience through internship and apprenticeships and exposure to emerging technologies and their potential applications in engineering rated highest.

Of the new approaches to formal engineering education and training necessary to prepare engineers for the challenges of the 21st century, integration of emerging technologies and practices into the engineering curriculum, integration of hands-on and experiential learning opportunities and emphasis on communication and collaboration skills in engineering were rated highest.

Influence and Public Policy

Influence and informing the public and policymakers on energy efficiency and renewable energy was rated highest when asked what societal role engineers can play in promoting green energy and energy efficiency.

When asked how can engineering professionals better collaborate with other stakeholders, such as policymakers, NGOs, and civil society organisations, to achieve SDGs, participation in policymaking and decision-making processes rated highest.

When rating the policies and initiatives at regional and national levels that can effectively address digital, green, resilience and entrepreneurship skills shortages/mismatches in the engineering profession, most options ranked similarly with provide financial incentives for training and development programs deemed the least effective.

When rating policies and initiatives at regional and national levels to address digital, green, resilience, and entrepreneurship skills shortages/mismatches in the engineering profession, encourage universities and technical schools to collaborate with industry to develop a formal or informal curriculum that aligns with the needs of the job market and increase funding for research and development in emerging technologies that require new skills and competencies came out on top.

Entrepreneurship

When asked to rate the kind of support and resources necessary to promote entrepreneurship among engineers, networking and mentorship opportunities came out on top.

When rating the specific measures that engineering professional organisations can take in supporting and promoting entrepreneurship among their members, encourage interdisciplinary collaboration and innovation within the engineering community through workshops, seminars etc. are deemed most effective. When asked what specific measures you believe should be taken to encourage an entrepreneurial mindset among engineers, encourage partnerships between engineering schools and local businesses to foster entrepreneurship ranked highest.

Developing financial acumen, creativity and innovation were ranked highest by Engineers Ireland members under the heading of Entrepreneurial Skills.

Conclusion and Recommendations

The field of engineering in Ireland is experiencing exciting transformations driven by technological advancements, sustainable goals, and the move towards digitisation. Despite facing challenges such as skills shortages and uncertainties arising from Brexit, there are numerous opportunities emerging in areas such as infrastructure development, research, and foreign direct investment. By embracing these trends and overcoming obstacles, engineers in Ireland can shape a promising future and contribute to the country's sustainable growth.

Key recommendations for the engineering profession based on the above research are:

1. Ireland must continue to foster and encourage collaboration between engineering professionals, academia, and industry through networking events, conferences, and knowledge-sharing platforms.
2. The transition to reducing greenhouse emissions requires a skilled workforce capable of implementing innovative solutions. Investment in education and skills development, particularly in STEM, should be prioritised to ensure a sustainable talent pool going into the future. This ranges from increased apprenticeships and technician education to degree-level engineering qualifications.
3. Create a favourable environment for engineering entrepreneurship and startup ventures. Provide financial support, mentoring programs, and access to networks and resources for aspiring engineering entrepreneurs, particularly with endeavours focused on sustainability.

4. Fostering closer collaboration between industry and government agencies will ensure policies and regulations are conducive to growth in Ireland and that industry focuses on the correct priorities for Ireland.
5. Encourage diversity and inclusion in the engineering profession by supporting initiatives that promote gender balance, ethnic diversity, and equal opportunities.

In conclusion, 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, and the future looks bright for this promising field.

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2.3 Belgium

2.3.1 Analysis by Katholieke Universiteit Leuven (KU Leuven)

Introduction

"Engineers are building, shaping, crafting the future – but they are already 'a different breed of people than the engineers we educated in the 20th century'
(James Plummer, former dean of Stanford University)

Engineering courses should train the future engineers, engineers who are prepared for the unpredictable careers the future will offer them. Therefore, more and more Higher Education Institutions (HEIs) are experimenting with **new approaches to the way engineering is taught. Trendsetters such as Olin College and MIT set the stage.**
Ruth Graham (2018) has performed a benchmarking study to provide an overview of the **cutting edge of engineering education** globally and a horizon scan of how the state-of-the-art is likely to develop in the future. In summary it comes down to this: best practice worldwide is associated with some educational features, including user-centred design, hands-on experiential learning and opportunities for entrepreneurial development within and beyond the curriculum. Some emerging leaders in engineering education incorporate education themes such as (i) the blending of resource-intensive, on-campus, active learning experiences with off-campus online learning, (ii) an increased flexibility, choice and diversification offered to students, and (iii) curricula that bring together cross-disciplinary learning, human-centred engineering and global experiences. These educational features are trending not only in engineering education but also in Higher Education as a whole (EUA, 2018). Blended learning, collaborative learning, active learning, interdisciplinary learning, etc. are well-researched teaching & learning methodologies broadly implemented in HEIs.
These new learning environments provide opportunities to train **the 21st century competencies.** In the past years, a considerable number of research studies addressed the question of which competencies may become important in engineering education in the context of the future challenges, such as digitisation, sustainable development, etc. (National Academy of Engineering, 2004; American Society for Engineering Education, 2015; Royal Academy of Engineering, 2019). Passow and Passow (2017) have performed a systematic literature review to establish a comprehensive list of generic engineering competencies and their relative importance. They have defined 16 generic competencies important for engineering practice and the most crucial one is 'coordinating multiple competencies to accomplish a goal'. The United Nations (2015) have developed 17 Sustainable Development Goals (SDGs). This offers an opportunity to consider the competencies needed of tomorrow's engineers. The SDGs include 169 targets related to sustainability challenges in various domains. The Engineering for Europe (E4E) project has a strong focus on four SDGs, more specifically

- **SDG 4. Quality education**, which sounds as *"Ensure inclusive and equitable quality education and promote life-long learning opportunities for all"*;
- **SDG 8. Decent jobs and economic growth.** "Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all";
- **SDG 9. Industry, innovations and infrastructure.** "Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation";
- **SDG 17. Partnerships for the goals.** "Strengthen the means of implementation and revitalize the global partnership for sustainable development".

The 'engineer 2020' study (2015), conducted among 1948 professional engineers in Flanders (Belgium), shows that engineers are strongly convinced that the technological changes will quickly succeed each other and that engineers will have to acquire and apply new knowledge under increasing time pressure. More than 60% of the academics in this study indicate that more attention should be given to lifelong learning (LLL) and only half of them agreed that currently graduating engineers master LLL competencies. AGORIA speaks of a training paradox (AGORIA, 2020): companies are investing in LLL opportunities, but the 'active learning attitude' in Belgium scores below the European average (OECD 2021a). Students should be aware that learning will remain a core value during their entire professional career and HEI should support students in the development of these lifelong learning competencies. KU Leuven is, like all other HEIs in Europe, committed to lifelong learning, especially for engineers since the half-life of an engineer's specialized technical knowledge is limited to only two to five years (Charette, 2013). Thanks to two approved research projects 'TRAINengPDP' and 'REFL³ECT', the Faculty of Engineering Technology at KU Leuven examines how to improve the training of LLL competencies among engineering students.
In this snapshot, the dynamics, challenges and opportunities for skills development within the engineering profession are described based on two types of indicators: quantitative indicators (chapter 2) and qualitative indicators (chapter 3). These indicators are obtained using qualitative (thematic analysis) and quantitative (statistical analysis) research methodologies. The quantitative indicators are a result of four studies (ordered from more general to more specific): (1) the quantitative part of the systematic literature review of the generic competencies needed in the engineering practice, made by Passow and Passow (2017), (2) the online survey 'engineer 2020' organized by all Flemish universities in 2015 and administered to 534 employers, 1948 professional engineers and 363 academics and (3) the survey 'professional skills of civil engineers' organised by the discipline 'civil engineering' within the Faculty of Engineering Technology (KU Leuven) in 2021 among 25 employers. The qualitative indicators are obtained thanks to three studies: (1) The qualitative results within the systematic literature review of Passow and Passow (2017), (2) the E4E-literature review made by KU Leuven in 2023, and (3) the E4E-interviews organized in 2023 by KU Leuven with academics who have educational responsibilities at Campus De Nayer (KU Leuven).
Based on these findings, we have made an overview of possible opportunities (chapter 3), needs (chapter 4) and challenges (chapter 5). The snapshot is concluded with an overview of some final conclusions and recommendations (chapter 6).

1. Quantitative indicators

This chapter starts with the quantitative part of the systematic literature review of Passow and Passow (2017), summarizing 27 studies. The two following parts are the result of surveys organized in Flanders. This chapter closes with some conclusions based on the three parts.

1.1 Systematic literature review of Passow and Passow (2017)

The goal of the systematic literature review of Passow and Passow (2017) is to establish a comprehensive list of professional competencies important for professional engineers across disciplines and work contexts. It comprises 8232 reports. In the quantitative synthesis 27 studies are included (60 samples, composed of 14429 participants). These respondents were 6,063 practicing engineers, 7,934 alumni of undergraduate engineering programs, and 432 engineering faculty. The statistical results appear in Figure 1. Each competency's mean importance across all 60 samples is shown. A white diamond is the mean for all 60 samples, while a black diamond is the mean in which each sample is weighted by its number of respondents.

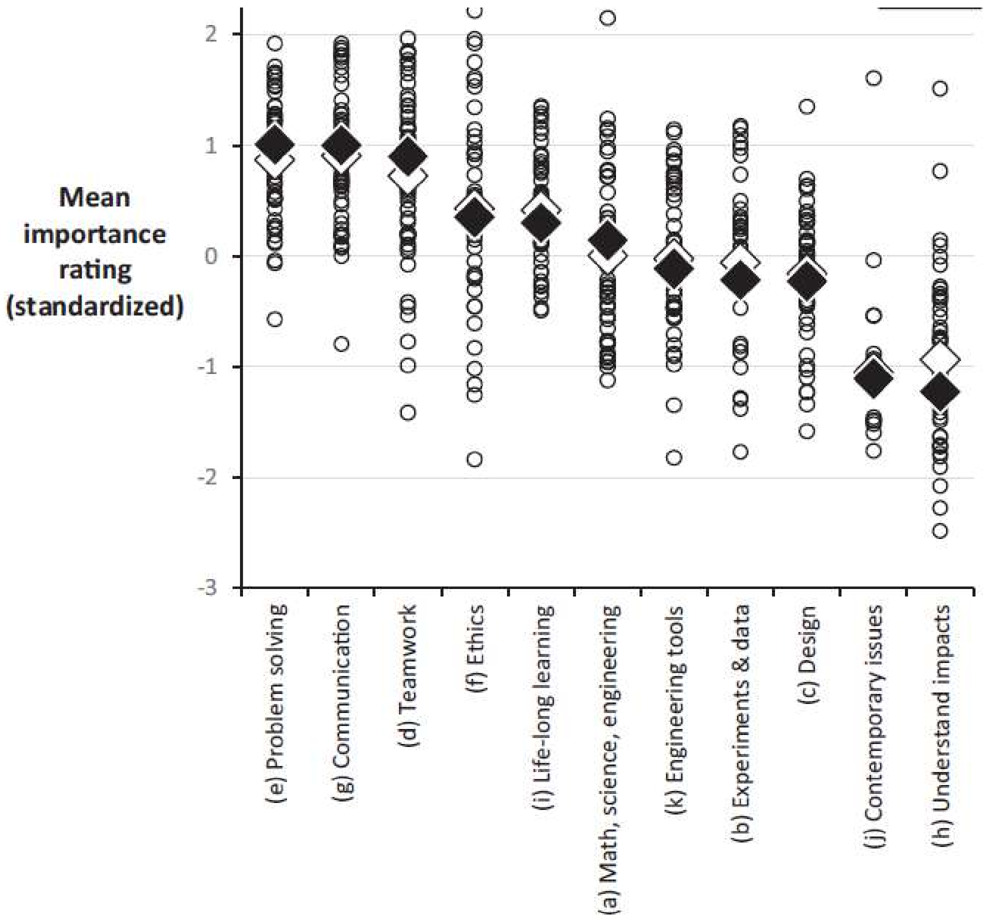

Figure 1. Mean importance of different professional competencies (Passow and Passow, 2017)

As can be seen, the top competencies are problem solving, communication, and teamwork. In the intermediate cluster, the following competencies can be found: ethics, lifelong learning, math, science, and engineering knowledge, engineering tools, experiments & data analysis and design.

1.2 Survey 'engineer 2020' organized by all Flemish universities (2015)

The Flemish universities (KU Leuven, University of Antwerp, University of Ghent, Hasselt University, Free University of Brussels) have organised in 2015 a survey among 533 employers to collect information about their perceptions regarding the competencies of recently graduated engineers (Flemish universities, 2015). The survey was provided in the context of 'The engineer 2020 project' which aimed to map the expected and present competences of engineers graduated in Flanders. The distribution of the 533 respondents as a function of their job function is given in Table 1.

Function	Total
Management function	58,91
HR manager	18,20
Operational management	10,88
Team leader	2,44
Other	9,57
Total	100,00
N	533

Table 1. Distribution (%) of the job function of the respondents
(Flemish universities, 2015)

The companies were asked to select the five most important actual and future competencies from the list in Appendix 7.1.

Table 2 provides an overview of the current importance of the various competencies according to the companies. The competencies are ranked by descending mean expressed as a percentage. Technical knowledge scores highest at 67%, followed by problem-solving skills at 66%. Overall, much less important are project management (26%), managing complexity (23%) and working in teams (21%). Specific sector and business knowledge, practical skills, team leadership and technical-commercial skills are situated between 12 and 17%. The seven remaining competencies remain below 10%.

Competence	Total		
	Total score	Avg. pp	Gem. in %
Technical knowledge	1421	3,36	67,19
Problem-solving ability	1406	3,32	66,48
Project-based working	547	1,29	25,86
Managing complexity	481	1,14	22,74
Working in teams	433	1,02	20,47
Specific sector and business knowledge	358	0,85	16,93
Practical skills	299	0,71	14,14
Team leadership	266	0,63	12,58
Technical-commercial skills	266	0,63	12,58
Business and economic acumen	206	0,49	9,74
Lifelong learning	191	0,45	9,03
Oral communication	182	0,43	8,61
Skill in other languages	154	0,36	7,28
Written communication	57	0,13	2,70
Acting ethically	21	0,05	0,99
Social knowledge	14	0,03	0,66

Table 2. Actual importance of the competencies according to the companies
(Flemish universities, 2015)

Table 3 shows the future importance of these competencies according to the companies. In the future, technical knowledge (59%) and problem-solving skills (59%) will remain most important. But they lose some importance compared to the current situation. Mastering complexity (30%), working in projects (24%) and working in teams (21%) score between 20 and 30% on average. Five competences have an average between 12 and 17%. These are business and economic acumen, team leadership, specific sector and business knowledge, technical-commercial skills and lifelong learning.

Competence	Total		
	Total score	Avg. pp	Avg. in %
Technical knowledge	1221	2,94	58,70
Problem-solving ability	1216	2,92	58,46
Managing complexity	630	1,51	30,29
Project-based working	490	1,18	23,56
Working in teams	429	1,03	20,63
Business and economic acumen	338	0,81	16,25
Team leadership	320	0,77	15,38
Specific sector and business knowledge	313	0,75	15,05
Technical-comm. skills	269	0,65	12,93
Lifelong learning	256	0,62	12,31
Practical skills	205	0,49	9,86
Skill in other languages	198	0,48	9,52
Oral communication	164	0,39	7,88
Written communication	55	0,13	2,64
Social knowledge	46	0,11	2,21
Acting ethically	29	0,07	1,39

Table 3. Future importance of the competencies according to the companies
(Flemish universities, 2015)

Chart 1 visualizes the differences between the current and future importance of the competencies, expressed in percentages. The competences are ordered according to their current importance. The respondents believe that technical knowledge, problem-solving skills, project-based work and specific sector and business knowledge and practical skills will become relatively less important in future. The other competences remain about the same or gain in importance.

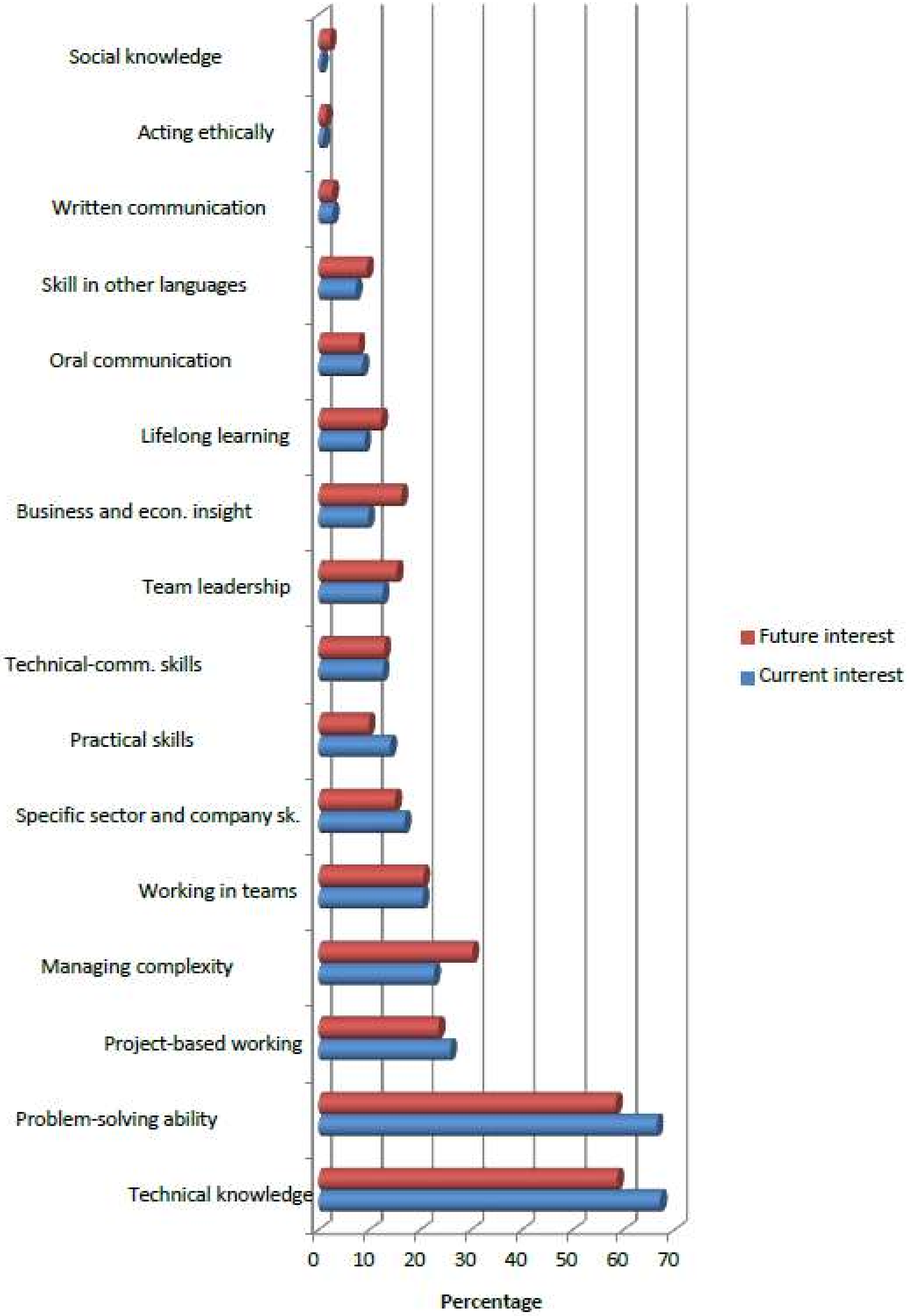

Chart 1. Current and future importance of the competencies
(Flemish universities, 2015)

Another objective of this study was to determine the extent to which employers are satisfied with the competencies of the current graduated engineers. The summarised results are presented in Chart 2. Employers are the most satisfied with technical knowledge, working in teams, acting ethically, lifelong learning, problem-solving ability and project-based work. There is also a high level of satisfaction with basic and IT knowledge.

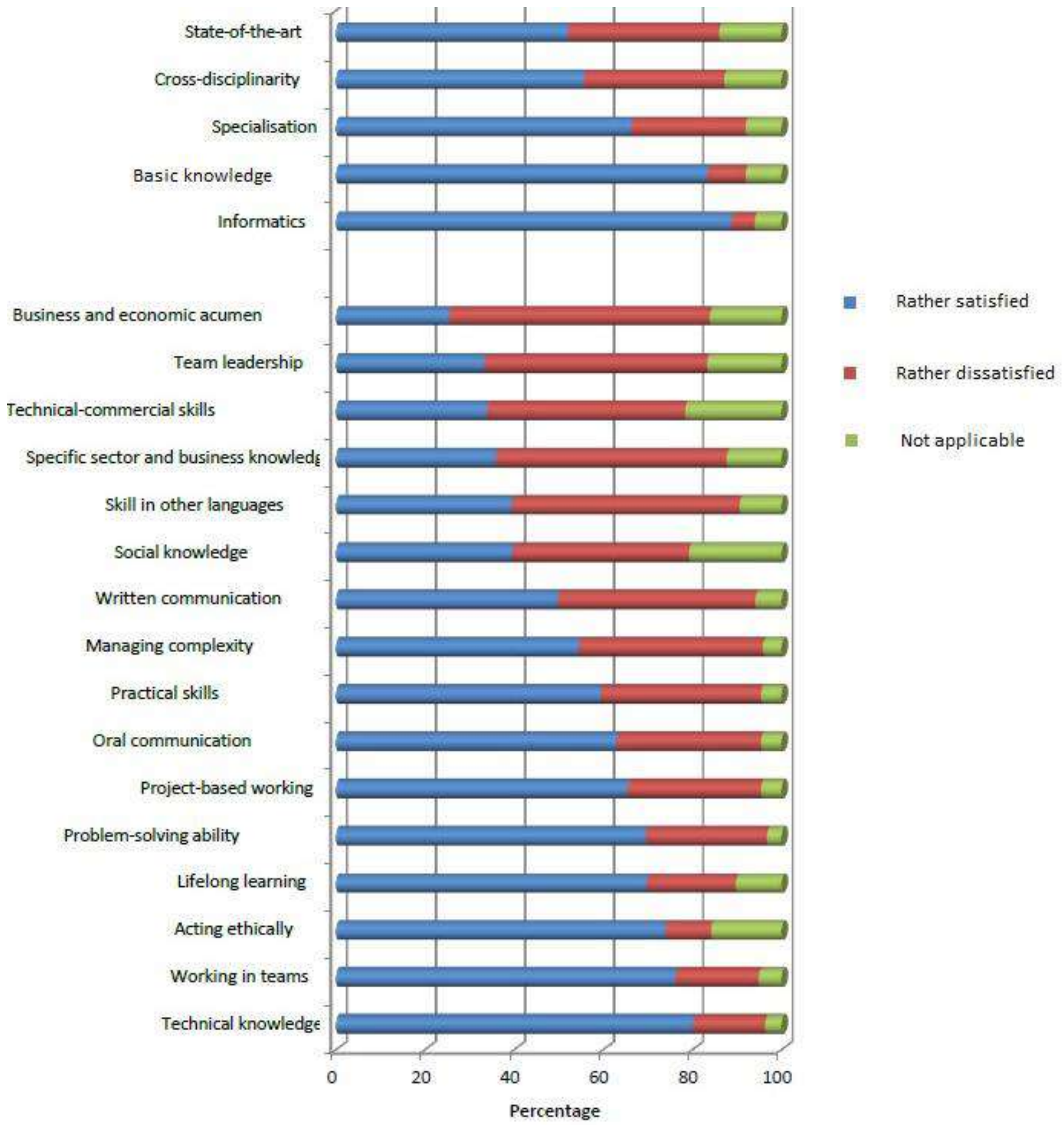

Chart 2. Extent to which employers are satisfied with the competencies of the current graduated engineers (Flemish universities, 2015)

1.3 Survey ‘professional skills of civil engineers’ organized (2023)

To improve the quality of the study programmes KU Leuven regularly contacts companies and questions them about their needs and experiences. In 2023 colleagues involved in civil engineering-programmes contacted 25 representatives of companies who were the supervisors of recent internships. They organised a survey focusing on the representatives’ perceptions of the professional competencies of the almost graduated engineering students. The assessment is based on the SAM scale (Scale for Attitude Measurement), which was adapted and supplemented (KU Leuven, 2021). The skills are divided into 4 groups (Table 4): personal attitudes and skills (A skills), organizational attitudes and skills (B skills), social attitudes and skills (C skills) and cognitive attitudes and skills (D skills).

The group of professional skills	The name of the professional skill
A. PERSONAL ATTITUDES AND SKILLS	A.1 Initiative
	A.2 Commitment and perseverance
	A.3 Discipline and punctuality
	A.4 Flexibility
B. ORGANIZATIONAL ATTITUDES AND SKILLS	B.1 Care for people, resources and the environment
	B.2 Personal planning and work organization
	B.3 Quality assurance and result orientation
C. SOCIAL ATTITUDES AND SKILLS	C.1 Social attitude
	C.2 Leadership
	C.3 Persuasion – assertiveness
	C.4 Communicating
D. COGNITIVE ATTITUDES AND SKILLS	D.1. Basic knowledge
	D.2 Inquisitiveness and interest

Table 4. Adapted Scale for Attitude Measurement (KU Leuven, 2021)

In appendix 7.2 an overview of the collected data during the academic year 2022-2023 is visualized. 25 respondents took part in the survey. All of them were representatives of Belgian engineering companies and played the role of internship supervisors. The representatives are especially satisfied with the achieved level of the professional skills from groups A, B and D. However, group C scores poorly. More specifically, more attention should be paid during the curriculum to ‘leadership’ (see chart 11 in appendix 7.2) and ‘persuasion & assertiveness’ (see chart 12 in appendix 7.2).

1.4. Conclusions quantitative indicators

Although the first two studies (1.1 and 1.2) included in this snapshot are done in a different context, the conclusions are very similar: the employers consider ‘problem solving’, ‘communication’ and ‘teamwork’ as the most important professional competencies. Interesting to notice is that all professional competencies mentioned in the list (see Appendix 3.1) were selected in some way by the companies.

The current level of the professional competencies among engineering graduates in Flanders is, according to the ‘engineer 2020’-study excellent for ‘working in teams’, ‘acting ethically’, ‘aptitude for

lifelong learning' and 'problem-solving ability'. This means that most graduated engineers correspond to the main needs of the actual labour market.
However, some of the graduates' professional competencies were not rated high by the employers in Flanders. In particular, 'business and economic acumen', 'leadership', 'technical-commercial skills', 'specific sector and business knowledge', 'other languages' and 'written communication' score low. This is in line with the study in paragraph 1.3, also conducted in Flandres but only within the discipline of 'civil engineering'. The internship supervisors confirmed that too many civil engineering students have problems with leadership.
One should be aware that the definitions of professional competencies in the different studies are not necessarily the same. And this is unfortunately also the case in the literature in general.

2. Qualitative indicators

This chapter starts with the qualitative part of the systematic literature review of Passow and Passow (2017), which provides an overview of the interrelationships among professional competencies. The two following parts are the result of a literature review conducted by Repka P. She also organized interviews with some programme directors and made an overview of these results in the last part. This chapter closes with some conclusions based on the four parts.

2.1 Systematic literature review of Passow and Passow (2017)

The qualitative study within the systematic literature review of Passow and Passow (2017) explores interrelationships among competencies. Thanks to 25 studies, in which 2174 participants took part, seven major findings emerged:

1. Engineering competencies are tied to the life cycle of a product, process, or system.
2. Technical competency is inseparably intertwined with effective collaboration.
3. Engineers spend more than half their workday (55%–60%) communicating.
4. Engineering practice requires coordinating multiple competencies to accomplish a goal.
5. Competencies important for engineering practice differ from required learning outcomes and graduate attributes.
6. Solving problems is the core of engineering practice, and eight competencies differentiate between outstanding and ordinary performance.
7. Engineering education could better coordinate competencies as in engineering practice.

The seventh finding revealed three simple principles for curriculum design, based on the qualitative research done by Passow and Passow (2017):

- In engineering education, engineers are trained to do and not the rest of their jobs. However engineering work extends far beyond science-based tasks.
- Non-technical skills cannot be taught in isolation from the technical context in which they will be used, and integrated projects are a crucial tool for achieving such ends.
- Engineering education needs a greater connection to practice from the first day, including hands-on problem solving of authentic, ill-structured problems within constraints, iteration, working toward a big picture goal, and realistic social elements, such as working with clients, gathering information, coordinating technical work, work-like writing and speaking, and demonstrating professional behaviour.

2.2 E4E-literature review - main trends in engineering profession (2023)

This chapter's focus is the identification of the main trends, challenges and opportunities in the engineering profession in the context of the implementation of the SDGs. The search for relevant literature is conducted through the library of KU Leuven and the UNESCO digital library based on the snowball method.

In the UNESCO report 'Engineering for sustainable development' (UNESCO, 2021), "science, technology and engineering lie at the heart of sustainable development". The Secretary-General of the United Nations, António Guterres (2018), pointed out the following in his congratulatory letter to the Global Engineering Congress: "We strive to achieve the 17 Sustainable Development Goals – the world's blueprint for building a future of peace and prosperity for all, on a healthy planet. Every Goal requires solutions rooted in science, technology and engineering".

Engineering plays a critical role in sustainable development by supporting the creation of infrastructure. This includes both economic infrastructure such as energy, transport and telecommunications as well as social infrastructure such as irrigation, sanitation and housing (UNESCO, 2021). Increasing investment in infrastructure, especially in communications infrastructure, has become a major global trend over the past decade. The link between infrastructure and development is well established: improved infrastructure contributes to both overall productivity growth and a more even distribution of growth gains, while imperfect infrastructure stifles both growth and equity (Cigu et al., 2019; UNOSAA, 2015).

The science of sustainable development has grown considerably in the twenty-first century in response to global challenges (Bettencourt, L. and Kaur, J., 2011). More specifically, four enabling trends are especially important for sustainability science and engineering (UNESCO, 2021):

- Inter, cross and transdisciplinary knowledge is breaking down conventional boundaries to create a more holistic approach.
- Entrepreneurship, which mainly takes the form of techno-entrepreneurship, is defined as the ability to add value by generating polyvalent knowledge that integrates and synthesizes theoretical, practical and policy-oriented elements.
- The notion of diversity is expanding to mean inclusivity for all, involving not only traditionally disadvantaged groups, such as those categorized by their gender and/or social economic background, but also personal characteristics such as physical condition, and ethnic and cultural identities.
- Human and ecological well-being are two sides of the same coin. Engineering is adopting a more sensitive, holistic and cautious approach to human-made changes to the Earth's natural environment in order to avoid a harmful and irreversible 'state shift' in ecosystems.

These trends are stimulating the development of sustainable engineering to broaden the scope and scale of its disciplines, while fostering greater interaction between engineering and other sciences to promote sustainable development (UNESCO, 2021).

Unfortunately, the number of professional engineers does not meet the needs of the labour market. As can be seen in Figure 1, the labour market is extensively growing in both scale and scope in industry and service sectors. But at the same time "despite the continuous expansion of higher education in most parts of the world, the attractiveness of engineering as a career option for youth has declined in many countries" (UNESCO, 2021).

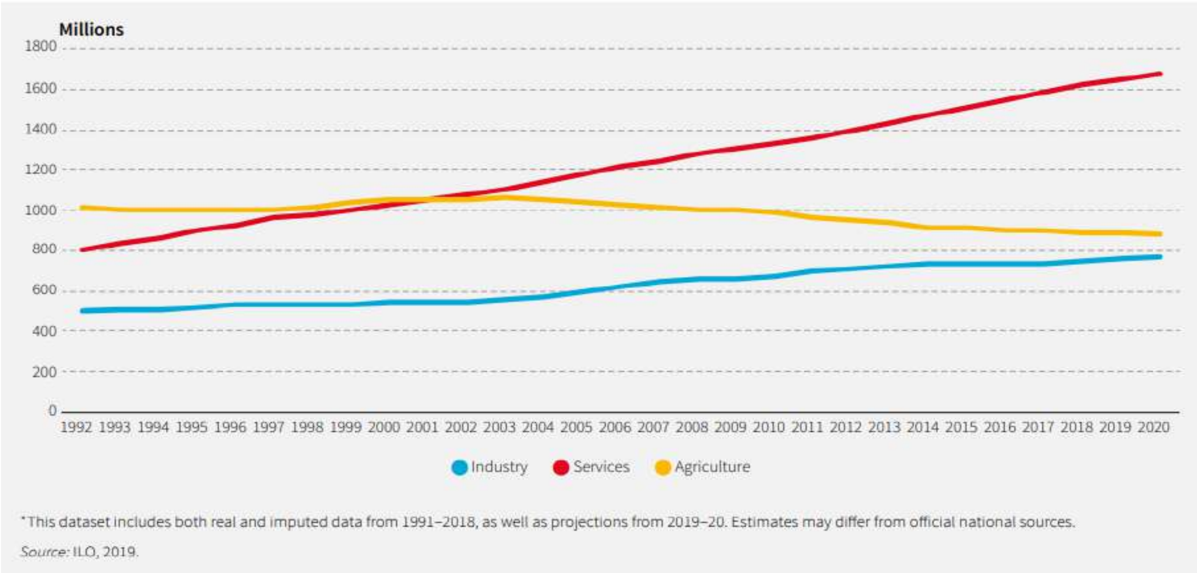

Figure 1. Employment by sector from 1991 to 2020 (UNESCO, 2021).

According to the European Commission, the move to a resource-efficient, circular, digitalized and low-carbon economy could create more than one million new jobs in Europe by 2030 (European Commission, 2020).

Several authors are trying to assess the impact of digitalization on employment and predict different ratios between new jobs being created and jobs that will be replaced by new technologies. This clearly indicates that science and technology professionals may be undergoing one of the biggest changes in the labour market. For example, in energy transition these professionals are expected to have the highest rates both of jobs destroyed rather than reallocated, and new jobs absorbing laid-off workers, as illustrated in Figure 2 (UNESCO, 2021).

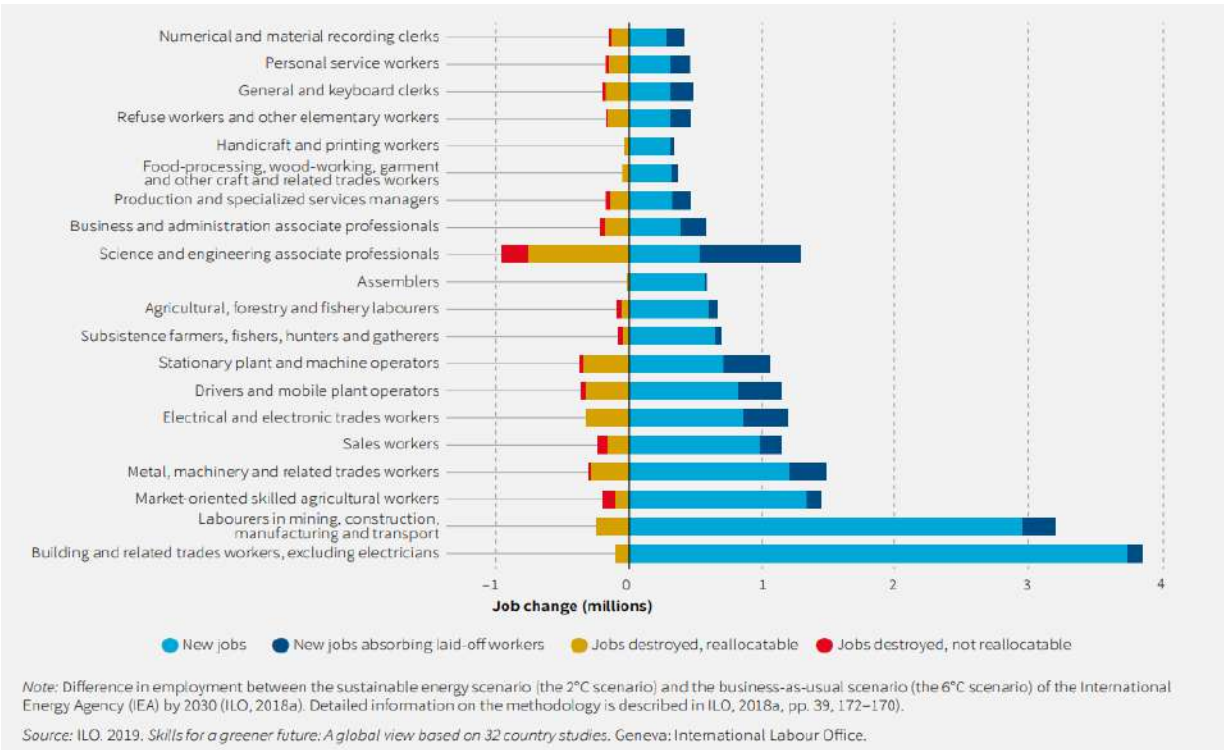

Figure 2. Occupations most in demand across industries in a global energy sustainability scenario (UNESCO, 2021)

Fortunately, there are also positive dynamics to observe in Europe. For example, scientists and engineers aged 25–64 in the European Union have increased by 10% from 2016 to 2019 (UNESCO, 2021). Their total number was estimated to be 17.2 million in 2018, representing 23% of all workers employed in science and technology occupations in the EU. Many of the jobs that employers may need to fill by 2030 will require a higher level of skills. The largest number (four million) are predicted to include jobs that do not yet exist, often because of new technologies. 2.6 million projected new jobs are for science and engineering professionals (McKinsey Global Institute, 2020).

Education is key to accelerating the implementation of the SDGs. General megatrends such as green and digital transition are also changing the engineering landscape and educational requirements. Green and digital transitions will require the upskilling of new technologies and processes, including building information modelling (BIM), cloud computing, artificial intelligence, 3D printing, virtual reality, IoT and blockchain technology (EFCA, 2018).

In Europe and North America, there is a growing need and recognition for future-oriented engineers with interdisciplinary competencies. Although engineers continue to be "technological problem solvers", they are increasingly seen as communicators and facilitators. They support decision-making processes and interact with a wide range of stakeholders, from local communities to politicians. Engineers are expected to work in multidisciplinary teams and be able to listen to all stakeholders and integrate their views into proposed solutions. Professional skills such as the ability to adapt to change, creativity and flexibility are in high demand and the employers across Europe have a similar view on this lack of skills, as shown in Figure 3 (UNESCO, 2021).

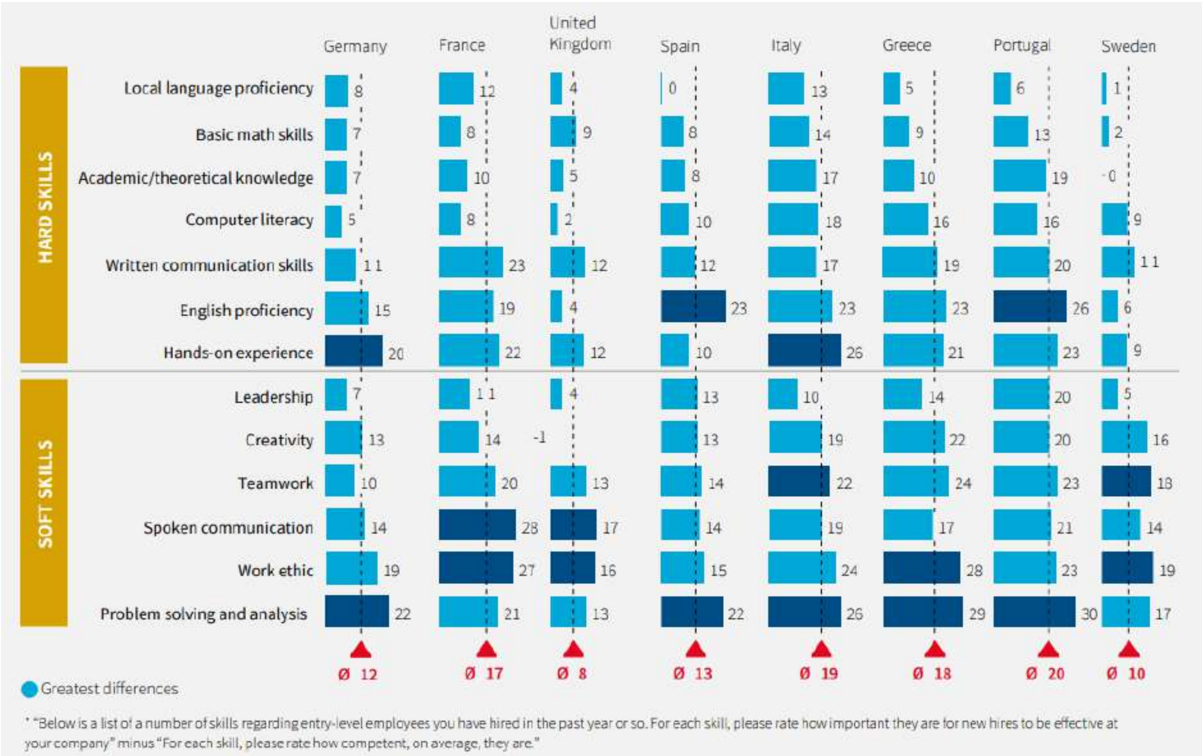

Figure 3. Difference between importance of competencies as rated by employers and the average competency level of new hires (UNESCO, 2021).

2.3 E4E-literature review - Professional competencies required for engineers (2023)

The focus of this literature review is on the professional competencies needed by future engineers in the context of their employability and more specifically in the context of sustainable development. The search for relevant literature was made through the web-library of the KU Leuven and the UNESCO digital library based on the snowball method.

HEIs renew their curricula regularly such that they can implement attention to new trends, such as sustainable development. According to Barlett et al. (2020), an effective sustainability curriculum is deliberately constructed with the aim to graduate students with the capacities to be effective systemic change agents. Debra Rowe, president of the U.S. Partnership for Education for Sustainable Development mentioned the necessity to go beyond a focus on conceptual knowledge in education and shift our attention to develop student capacities to become agents for systemic change, which means integrating values, attitudes, behaviour, and ethics with other education reform pedagogical strategies in the classroom (Barlett et al., 2020; National Research Council, 2012). Wiek et al. (2015) and Rieckmann (2012) have identified various competencies that they have consolidated into five key categories of systems thinking, futures thinking, values thinking, and strategic thinking which converge in practice and pedagogy as collaborative (teamwork) problem-solving competence necessary to become effective change agents (Barlett et al., 2020; Wiek et al., 2011; Wiek et al., 2015; Rieckmann, 2012). Later Penn State University and the Sustainability Institute made their own research to identify core sustainability learning meta-competencies (Barlett et al., 2020; Engle et al., 2017; Engle et al., 2016; Buckland & Engle, 2018): system thinking, temporal thinking, interpersonal literacy, ethical literacy, and creativity/imagination and the strategic thinking competency. Afterwards, Rieckmann has extended and integrated sustainability competencies into learning objectives for a resource: Education for sustainable development goals: Learning objectives (Rieckmann, 2017; UNESCO 2017).

Already for years, most national and cross-national engineering accreditation bodies have included professional competencies in their requirements for accrediting engineering programmes (Picard et al., 2021; Winberg et al., 2020). There seems to be an overall agreement that engineering education should not only address science and engineering but also social, ethical, and organisational aspects of engineers' practices and responsibilities. Despite this importance, there is no clear consensus yet on the exact set of skills under the term professional competencies (Picard et al., 2021; Winberg et al., 2020; Kolmos & Holgaard, 2019) Communication, teamwork, and organisational abilities are featured prominently in sources looking at labour-market needs (Carter, 2011; Itani & Srour, 2016; Craps, 2017) or in occupational databases such as O*NET (Picard et al., 2021; O*NET), which provide information on the skills considered important for current engineering positions. In the Future of Jobs report 2023 (World Economic Forum, 2023) the most demanded competencies are: (1) Analytical thinking, (2) Creative thinking, (3) Resilience, flexibility and agility, (4) Motivation and self-awareness, (5) Curiosity and lifelong learning, (6) Technological literacy, (7) Dependability and attention to detail, (8) Empathy and active listening, (9) Leadership and social influence and (10) Quality control (see Figure 1). Today there are a lot of different opinions about which communication and interpersonal skills are needed by the employers. Theses opinions are mostly based on the personal vision of different researchers without deep analysis of job market trends. That is why we decided to concentrate on the studies which highlighted this topic more in depth.

Some of the considered papers conducted empirical studies in which job ads in the different European countries were analysed (Herrmann, 2013; Daneva et al., 2017; Caggiano et al., 2020). Daneva et al. (2017) noticed that the most frequently mentioned professional competency in job ads in The Netherlands is proficiency in English and Dutch. (Figure 4).

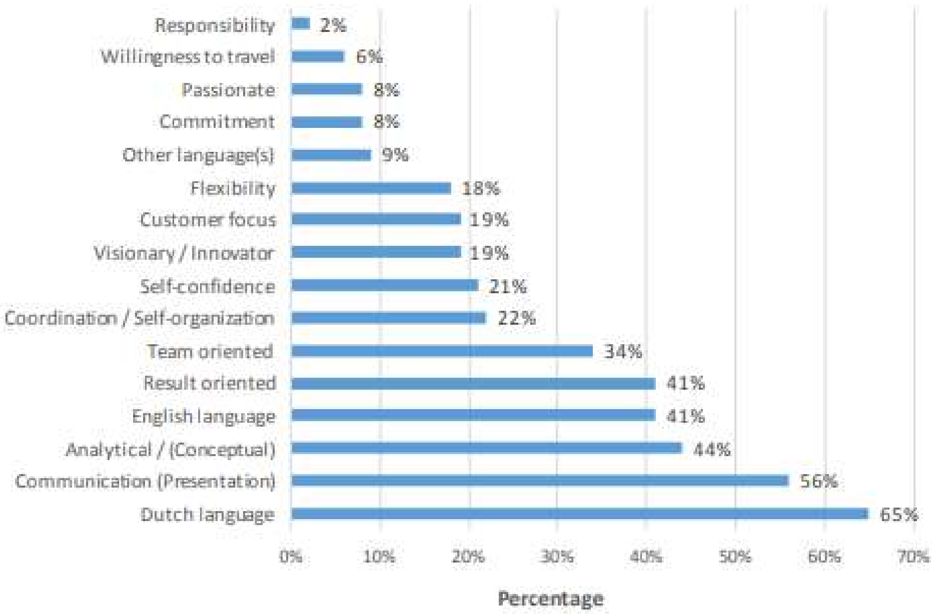

Figure 4. Distribution of sought professional competencies in The Netherlands (Daneva et al, 2017).

In addition to the papers mentioned above, we also analysed the results of the article in which authors provided focus groups (FG), during which representatives of employers discussed professional competencies. One can conclude that in contrast to technical skills, professional competencies (1) form a much longer list, (2) do not always have the same meaning, and (3) seem to be country-specific (Daneva et al, 2019). The researchers also collected statements for and against the importance of professional competencies (see Table 5).

Professional skill	Arguments for the importance of the skill	Arguments against the importance of a skill
Communication skills	Communication skills are important for any job There is a lot of teamwork in RE, hence communication is a must	
Teamwork skills	Teamwork skills are important for everyone, not only in RE Teamwork includes leading a group with respect to context, and to keep to rules and templates RE as a whole means working with others, thus teamwork is key	
Analytical skills	A requirements engineer must be able to switch between abstraction and details He/she must be able to decompose problems and to abstract, but also to work in a structured way	• Too much of it is bad because of risks to over-analyze and over-engineer seemingly trivial requirements • There is a danger of “analysis-paralysis”.
Flexibility		

Professional skill	Arguments for the importance of the skill	Arguments against the importance of a skill
	This is important because of working in different time zones	• Being too flexible signals reluctance to make decisions • Flexibility may signal a lack of ability to say "No" and push back, which is detrimental to requirements negotiation.
Customer orientation / Empathy with users	A business analyst needs to see the work from other peoples' perspective	
Self-confidence	You need it if you need to work with stakeholders who are much older than you It can happen that a specification is thrown away, when a new requirements engineer writes his first specification; this demands self-confidence, i.e. to be sure that one can learn it, to be sure of one's own working style, but also to be flexible and to adapt, to cope with week-wise planning, dynamic context or unknown application domain, or with masses of information In software requirements for car manufacturing, the work climate is harsh; what does not work there is speaking in term of understatements "I don't get respect". This attitude slows down the work to be done. When you know that you'll get negative responses, you get reluctant.	• Too much self-confidence can be detrimental, too. Such a person ignores advices from clients, stakeholders and peers. • Whether it is needed, depend on the role.
Self-organization	It is important because a requirements engineer works mostly alone.	The requirement engineer does not need to organize anything, when a project manager makes the plans
Language proficiency in English	It is needed for communication in general It is needed to specify requirements if working with international vendors.	• It is best to use the local language for requirements. • In government projects, English is not needed.
Willingness to travel		Too much of it is detrimental as you detach yourself from your clients.

Table 5. Citations from participants in FG for and against some professional competencies (Daneva et.al., 2019).

Beagon et al. (2022) have organized focus groups in Denmark, Finland, France and Ireland. They collected the views of three key stakeholders, academics, employers and students, on professional competencies for sustainable development. The outcomes of the FGs are mapped against competencies identified in previous studies to highlight gaps and opportunities for development. To be more precise, their research question is "How do the competences identified in this study context compare to the "Key competencies for sustainability" published in UNESCO (2017) and more recent literature?". Table 6 outlines the stakeholders' view on the competencies identified by UNESCO (2017) and in Table 7, the same is done for some additional competencies. They conclude their paper with four statements: "The first and most surprising issue is the relative absence of the anticipatory competence, which was not directly perceived by the participants of this study. It should be marked, that the anticipatory competence is one of the key competences identified by UNESCO (2017). Future thinking competences, such as anticipating and estimating consequences, dealing with uncertainty and future changes or envisioning possible futures are considered by numerous authors as critical sustainability competences (Heiskanen et al., 2016; Rieckmann 2018; Quelhas et al. 2019; Brundiers et al. 2021; Redman et al. 2021). … However, the findings of this study suggest that none of the key stakeholders in engineering education acknowledged that this competence is necessary and hence, there is work to do both in extending the awareness of and teaching methods to expose students to opportunities to develop anticipatory competence. The second issue is the importance of normative competence for graduate engineers with the unanimity of all stakeholders confirming the results of Quendler and Lamb (2016). As stated by academic and employer stakeholders, recent engineering graduates have stronger environmental and social motivations to contribute to society (Haase 2014; Fitzpatrick et al. 2021) whilst simultaneously considering economic, environmental and social dimensions of sustainability. ... It is important, therefore, that engineering educators are sufficiently trained and that they also acknowledge and integrate normative competence, within technical modules, to avoid additional pressure on the already overcrowded curriculum. The third issue is the strong acknowledgement of interpersonal competence, indicating that these competences are highly relevant in the context of advancing a sustainable future (Konrad et al. 2020). Interpersonal competences such as communication, teamwork, resilience and agility are viewed as critical competences and will be valued and recognised in engineering (UNESCO 2021). … This finding makes the case that there needs to be more emphasis and explicit assessment of interpersonal competences in order to reduce this gap, rather than relying on gaining these competences implicitly through project work. Finally, the fourth interesting issue is that continuous learning was identified as a highly relevant sustainability competence by academics and employers alone, not by students. … The concept of lifelong learning and professional development for students is, therefore, yet another crucial aspect which needs to be better integrated in the engineering curriculum. Personal development planning and regular review of progress, such as keeping an e-portfolio may be a solution to this issue, which focuses the student on the future without adding yet another module to a curriculum.”

		Students	Academics	Employers
Key competencies for Sustainability relevant to all SDGs (UNESCO, 2017)				
Systems thinking competency				
	Analytical Thinking	√	√	√
	Holistic Thinking	√	√	√
	Global Awareness	√	√	
	General Knowledge	√		√
	Systems Thinking		√	√
	Life cycle Thinking	√		
Anticipatory competency				
			None identified in this study	
Normative competency				
	Ethical Conscience	√	√	√
	Social Responsibility	√	√	√
	Sustainability Awareness	√	√	√
	Environmental Awareness	√		√
Strategic competency				
	Innovation	√	√	√
	Creativity	√	√	√
	Project Management	√	√	√
	Decision Making Skills	√	√	
	Design Skills	√		√
	Organisation Skills	√		
	Entrepreneurship		√	
	Resources optimisation		√	
	Conceptual understanding		√	

Collaboration Competency				
	Communication	√	√	√
	Collaboration	√	√	√
	Teamwork	√	√	√
	Personal engagement & agency	√	√	√
	Listening Skills	√	√	
	Emotional Intelligence	√	√	
	Respect for others	√		√
	Inter-Cultural Skills		√	√
	Foreign Languages		√	√
	Respecting Diversity		√	√
	Leadership	√		
	Conflict Management		√	
	Negotiation		√	
	Empathy		√	
Critical thinking Competency				
	Critical Thinking	√	√	√
	Open mindedness	√	√	√
	Curiosity		√	√
	Self-Reflection		√	
	Challenging the status quo			√
Self Awareness Competency				
	Perseverance/Grit	√	√	
	Adaptability	√		√
	Agility	√		√
	Time Management	√		
	Stress Management	√		
Integrated Problem Solving Competency				
	Problem Solving	√	√	√
	Research Skills	√	√	
	Problematisation		√	
	Interpretation Skills			√

Table 6. Focus group outcomes of competencies needed for engineers mapped to UNESCO 2017-competencies (green = identified by all 3 stakeholder groups; yellow: raised by 2 stakeholder groups and blue = mentioned by 1 stakeholder) (Beagon et al., 2022)

		Students	Academics	Employers
Interdisciplinary work				
	Multidisciplinary Skills[1]	√	√	√
Continuous Learning				
	Learning to Learn		√	√
	Lifelong Learning		√	√
Implementation competence				
		None identified in this study		
Transdisciplinarity				
		None identified in this study		
Fundamental Disciplinary competences				
	Technical Skills	√	√	√
	Economic Skills	√	√	√
	Digital Skills	√		√
	Mathematics Skills			√

Table 7. Focus group outcomes of competencies needed for engineers, mapped against additional competencies (Beagon et al., 2022)

2.4 E4E-interviews (2023)

The purpose of this study was to provide in-depth insights into the challenges, opportunities and skills required in the engineering profession. KU Leuven has organized four face-to-face structured interviews with programme directors of different disciplines within engineering education. The interview questions were selected from the Key Research Questions supplied by E4E. These questions were not supplied a priori to the interview so that the respondents would be more extemporaneous. Each of the participants was questioned on their own perceptions and they were not permitted to stop at broad or vague answers but were questioned until the answers were very specific. The interviews were recorded throughout the interview and transcribed with Microsoft 365 online transcriber. The transcriptions were imported into NVivo and thematically analysed. After all data was coded, the most important findings were identified as those with the greatest frequency of occurrence.

The results of the E4E-interviews are the following:

1. How will the engineering profession evolve over the next 5 or 10 years?
    - According to the interviewees, one of the main trends in the engineering profession evolution nowadays is **interdisciplinarity.** "Engineers will have to collaborate interdisciplinary. Interdisciplinarity means that they do not only have to know some elementary knowledge about other disciplines, but also they should be able to communicate with professionals in other fields of knowledge."
    - Another key trend which was identified by the respondents is the need for **lifelong learning,** the reason for which lies in the speed of new technology development. "Things are changing very quickly, so they will have to learn for a lifetime. The lifelong learning will be important in the in the profession."
    - Also, interviewees mentioned that the engineering profession is already very international, but it will become even more international in the nearest future. "So, modern engineers should be able to **communicate interculturally**. "
    - One of the respondents expressed an idea that there is a high possibility that in near future Europe will **go back in the direction of production** again. "Earlier we went from production into services, bringing every production to China, Vietnam, Cambodia. I think that there's a high possibility that the timeline will be reversed somehow in the following years."
    - Additionally, interviewees identified the need for engineers. "In the current moment, there is a big request for professional engineers on the labor market. There is also a decreasing number of students in engineering. So, there is a risk that there will be a **lack of engineers in the nearest future.**"
2. What are the emerging technical and transversal skills and competencies required in the engineering profession?
    - All the respondents marked **the importance of teamwork skills** for modern engineers, because "an engineer doesn't work alone anymore, but an engineer is a team player." In particular, as a lot of teams nowadays include people from different countries, nationalities and cultural backgrounds, special attention should be paid to **intercultural communication** and **ethics.**
    - Also, respondents marked the importance of **digital literacy,** in particular working with big data, AI (for example, ChatGPT). "Today everything is done with and by computer, so you need enough digital skills to be able to cope with it. This is a very important one."

- Three respondents mentioned **communication skills** as important. Two respondents made a special accent on the necessity to learn future engineers to communicate not only with other engineers, but also with representatives of other specialties.
- Among **other professional skills** which were mentioned: management skills, identifying your personal role in the team, critical thinking, self-reflection and reflection on their environment's awareness ("...but that's a difficult one, because it's close to pushing your own political agenda."), quality management and safety measures.

3. How do technical and other professional skills differ in terms of their importance for success in the engineering profession?
   - All the respondents marked that both technical and professional competencies are important for a successful future career in engineering. However, as one of the respondents noted "the basis for everything is a good technical expertise, for an engineer, this is the starting point."
4. What is the role of the engineering profession in the implementation of Sustainable Development Goals (SDGs)?
   - All the interviewees noted the **importance of SDGs** and the **crucial role of engineering in their implementation.** "Sustainable goals are crucial, and engineers will have to find new ways to make a product more sustainable". "Engineering is also a driving force towards those goals".
   - It should be noted that all participants mentioned the importance of **including the SDGs in the study process** of the future engineers. "We have a new generation of students which are more sensitive to these goals, I think. 10 years ago, only technical aspects interested the students. Fortunately, it has changed." Another participant said: "I know many European projects focusing on sustainable development implemented in engineering education. And to give you an example of what we are doing in our faculty: already in the first year all our engineering students have a project which is focusing on one of the SDG's. We talk about the SDG's during courses and explain why it's so important to know them."
   - One of the respondents also marked that it's important that society accepts the SDGs. "Now, it's the other way around. Engineers do what the public wants, or what the media tells the public that they need.
5. How can the engineering profession contribute to the achievement of SDGs through the development of new skills and competencies?
   - According to the interviewees, the role of engineering in the context of SDGs implementation is **to give the relevant tools and to find technical solutions** which will give opportunity to solve existing problems. So, engineering education should teach students not only "how to do things in the optimal way from the engineering point of view, but also from the sustainable development point of view. For instance, recyclability. If you make a design, can it be reused? Can it be recycled in an easy way? Or we are producing future waste? It's something which is very important to think about, so this can be implemented."
   - Another important issue which was mentioned by the respondents is "to teach students always **to think about consequences of their professional activities**."
   - The interviewees also marked that it is better **to include some parts of sustainability knowledge into the already existed courses** than to create separate workshops on this topic. "Making a separate course with those skills would be challenging and probably inefficient. A few years ago, there was a researcher who was working here, and she wrote a PhD about the different ways people take information. She told me that there was research that if you want

for example a student to improve the learning strategies, then you really should try to put it into your courses to make it more authentic, for instance, into a mathematics course."

- The respondents also identify **the problem of assessing** professional skills. "They should be included in the curriculum, but the problem is how you can make an exam around critical thinking or self-reflection?"

6. How can engineers be trained to become "conscious engineers" who prioritize ethical and sustainable practices in their work?
   - According to the interviewees there are already several **courses on sustainability** in KU Leuven, which goal is to increase consciousness and awareness of students about existing ecological, social and other problems related to sustainable development.
   - However, they also identified the weak side of these courses. In particular, despite increasing awareness about existing problems, they **don't give clear technical solutions** for solving them.
   - One of the respondents marked that "increasing consciousness should be also the priority for companies, because it is much easier for them to influence their employees by including relevant policies in their practices".
7. What are the challenges and opportunities for the engineering profession in adapting to the changing nature of skills and competencies required?
   - The first challenge, which was noted by respondents, was **money.** "Because an engineer in industry is expensive. And if you want to give him the opportunity to learn, then he or she should have time to learn. And at that moment the engineer is not doing work which results in money. So, the company should have money to guarantee that this is possible".
   - The second challenge from the respondents' point of view is to form **the right composition of the engineers' team.** "If you have a young group of engineers, with dynamic, fixed mindsets and they're convinced that what they are doing is the right thing, it's very difficult to change".
   - Another problem which was indicated by the interviewees was "**problem of companies' growth**". "A company needs to be successful and being successful means increasing your output every year. The planet cannot take care of all those growing companies and growing number of people, so we should be aware that growing can also mean something different. Growing can mean a better quality of life, better services, more inclusive services and things like that".
   - As for the opportunities, respondents named **the high consciousness of young generations.** "Young people nowadays come to the street and say the planet is in danger and we have to take care of our planet. So, I'm sure they love to change their skills and competencies to reach sustainable development."
   - Also, respondents mentioned **high level of digitalization**, which increases efficiency of a lot of processes significantly. For example, "ChatGPT tools that help programmers write codes. And I think similar ideas will be emerging in other engineering contexts as well."
   - Another idea about the possible development of the engineering profession in Europe in nearest times was the possible **offset from only providing services in production,** resulting in a different skill set for engineers. "I think there is a high possibility that we will come back a little bit from focusing on only services towards more production. And then the fun thing is that everything that we have done in recent years about professional skills, will change and will become maybe not less important, but important in a different way. I think that the skillset might be going back a little bit more to team leadership and those kinds of professional skills."

8. How can engineering education and training programs better prepare students for the evolving nature of the profession?
   - The respondents supported the idea that the evolution of the engineering profession should be included in engineering education as well. In particular, **all relevant technical and professional skills** should be included in study programs.
   - Also according to the interviewees, the important feature of modern education is **interdisciplinarity**, because "students need broad knowledge, not only very specialized in one discipline. They should know the basis of many disciplines and in one of them they can go deep, but not too deep because within 10 years everything they have learned when they go too deep is old."
   - Another important aspect which should be taken into account is teaching students **to work in groups.** "From day one, they have to collaborate. They have to learn that it's not always easy to work with other people. So, they have to learn how to adapt, to be flexible, to talk to people from other cultures."
9. What are the key factors that contribute to successful multistakeholder partnerships in addressing skills shortages/mismatches in the engineering profession?
   - The main factors which contribute to the successful partnership are **trust between stakeholders** and **feeling of confidence between them.** "Among all the projects I have done already, projects were only successful, when there was trust among the partners".
   - Another important factor which was mentioned by the respondents was **complementarity of stakeholders' skills.** "When you have skill A and he has skill B, you can collaborate and then you are not just A+B. Now it's more than that. You can grow."
   - The last, but not least factor which was mentioned by respondents is "**efficient and effective communication**".
   - In the context of university-industry partnership, one of the respondents expressed the idea that it could be useful to **invite representatives of industry to the university** for them to share their experience of achieving SDGs with students. Also the discussion between students and industry representatives can be initiated about key problems of greening, ecology and sustainable development, which can increase the awareness of both sides about existing problems and maybe even will help to find possible solutions.
10. How can policies and initiatives at regional and national levels effectively address the digital, green, resilience and entrepreneurship skills shortages/mismatches in the engineering profession?
   - One of the possible methods of improving the quality of the engineers' skills which was proposed by interviewees is implementation of **obligatory refresher courses** and **periodic certification for compliance with the position held.**
   - Another idea which was expressed is **to organize some seminars with politicians** to share their vision of sustainable development and to open the discussion with students. Such seminars can increase awareness of both sides about existing problems and give opportunity for better understanding by youth of future sustainable development perspectives.
   - Also **moving up to a "3 + 2" study program instead of "3 + 1"** was mentioned as an initiative that can improve the educational program, because in the current moment "there is just lack of time for highlighting all important aspects."

2.5 Conclusions qualitative indicators

Nowadays, it is obvious that engineering plays a crucial role in achieving the SDGs, especially those related to the development and implementation of the modern technologies. In this regard a question arises how engineering education should be transformed to prepare professionals that are able to deal with challenges which are related to this issue. For answering this question, the main trends in engineering profession were analysed.

One of the notable trends is the increase of investments in infrastructure development. And according to the UNESCO report "Engineering for sustainable development 2021", there are four favourable trends: a more holistic approach to engineering, need for techno-entrepreneurship, attention to diversity and a more sensitive, holistic and cautious approach to human-made changes to the Earth's natural environment. However, there are also some negative trends in engineering. Due to an extensive growth of the labour market in the field of engineering, the number of professional engineers does not meet the needs of the labour market, and this situation is redoubled by demographic changes.

Another important tendency, which should be mentioned, is the change of requirements to engineers. A modern engineer should not only have technical skills, but also other professional skills, which give him or her the opportunity to work in multidisciplinary teams, be able to listen to all stakeholders and to integrate their views into proposed solutions and, at the same time, make his or her own independent decisions. Professional skills nowadays are included in requirements for accrediting engineering programs of most national and cross-national engineering accreditation bodies. However, ambiguity still exists about the list of professional skills that should be included in the study curriculum of HEIs. In the current moment there are different opinions about this issue. In the Future of Jobs report 2023 (World Economic Forum, 2023) the most demanded employees' competencies are the following: (1) Analytical thinking, (2) Creative thinking, (3) Resilience, flexibility and agility, (4) Motivation and self-awareness, (5) Curiosity and lifelong learning, (6) Technological literacy, (7) Dependability and attention to detail, (8) Empathy and active listening, (9) Leadership and social influence and (10) Quality control. On the other hand, in the academic resources investigated in the frame of this research, the professional competencies most needed are: (i) Language proficiency in English, (ii) Teamwork skills, (iii) Communication skills, (iv) Analytical skills, (v) Self-confidence, (vi) Flexibility, (vii) Customer orientation/ Empathy with users, (viii) Willingness to travel, (ix) Self-organization. Beagon et al. (2022) made a comprehensive overview of the needs of the different stakeholders and found a large diversity.

Despite the difference in opinions, one thing is clear: professional competencies play a significant role for employers. In this regard, HEIs in cooperation with VET, Professional Bodies and Industry Associations need to find a solution for the current issue and help engineers to meet the high requirements of modern labour market.

Based on these findings, we have made an overview of possible opportunities (chapter 3), needs (chapter 4) and challenges (chapter 5). The snapshot is concluded with an overview of some final conclusions and recommendations (chapter 6).

3. Opportunities

As Bettencourt and Kaur (2011) marked, "the science of sustainable development has grown considerably in the twenty-first century in response to global challenges." According to UNESCO (2021), this is stimulating the development of sustainable engineering to broaden the scope and scale

of its disciplines, fields and practices, while fostering greater interaction between engineering and other sciences and arts to promote sustainable development.
Another important trend, which influences our modern life is digitalisation. Engineering certainly is not an exception. The use of digital technologies can speed up a lot of processes in industry and also minimize "the human factor". For engineers, the results of big data analytics will be particularly relevant in various fields such as predictive and preventive maintenance, product and structural design, among others, leading to more efficient project management and cost effectiveness in a sustainable development environment (UNESCO, 2021).
Since the sustainable development needs are interdisciplinary, it's great to see how engineering teams become more and more diverse. This will support the rapid development of new, creative solutions.

4. Needs

Such megatrends as green and digital transition are changing the engineering landscape and education requirements. Education is key to accelerating the implementation of the SDGs. The system of engineering education needs continuous re-evaluation to support the engineering students in solving technological problems with a holistic approach that takes into account the impact of engineering innovations and activities on the environment and society as a whole. According to EFCA (2018), "green and digital transitions will require the upskilling of new technologies and processes, including building information modeling (BIM), cloud computing, artificial intelligence, 3D printing, virtual reality, IoT and blockchain technology."
Interdisciplinary approaches to technology development are also needed to ensure socially responsible communication networks and urban governance systems (UNESCO, 2021). According to interviewees, who took part in KU Leuven interviews for Primary research for this report, interdisciplinarity is one of the main trends of engineering profession nowadays. "Future engineers will have to collaborate interdisciplinary. Interdisciplinarity means that they do not only have to know some elementary knowledge about other disciplines, but also they should be able to communicate with professionals in other fields of knowledge." UNESCO (2021) states that "in Europe and North America, there is a growing need and recognition for future-oriented engineers with interdisciplinary competencies. Although engineers continue to be "technological problem solvers", they are increasingly seen as communicators and facilitators. They support decision-making processes and interact with a wide range of stakeholders, from local communities to politicians. Engineers are expected to work in multidisciplinary teams and be able to listen to all stakeholders and integrate their views into proposed solutions."
Most national and cross-national engineering accreditation bodies have included professional competencies in their requirements for accrediting engineering programmes. However, the debate about the list of comptencies needed by engineers is still ongoing.

5. Challenges

According to UNESCO (2021), "a key indicator of engineering capacity-building is research and development (R&D), which is defined as efforts to develop new or improve existing products or services". There are notable differences in R&D across regions of the world in terms of costs and human resources and these disparities have widened over the last decade (UIS, 2019).
Moreover, today the number of professional engineers does not meet the needs of the labour market. It happens because the labour market nowadays is extensively growing in both scale and scope, but at the same time "despite the continuous expansion of higher education in most parts of the world, the

attractiveness of engineering as a career option for youth has declined in many countries" (UNESCO, 2021).

Several authors try to estimate the impact of digitalisation on employment and predict different ratios between the new jobs created and the jobs that will be replaced by new technologies. This clearly indicates that Science & Technology professionals may undergo some of the biggest changes in the labour market. In the energy transition, for example, these professionals are expected to see the highest rates of both job destruction, rather than job redistribution, and the emergence of new jobs absorbing laid-off workers (UNESCO, 2021).

As mentioned in several of the previous studies, the professional competencies need more attention in Higher Education. However, the curriculum is already fully packed. So the question arises how they can be implemented and assessed in HEI without overloading the programmes. A possible answer is integration into the existing technical courses, highlighting simultaneously the importance of interdisciplinarity, diversity and the holistic approach.

6. Final conclusions and recommendations

Institutions have to find the mix of factual knowledge and tools to be open and rigorous at the same time. Finding the right balance when the slope is changing, is the great challenge for institutions.

(Nina Waaler, vice-rector for education at Akershus University of Applied Sciences)

Engineering education plays a central role in overcoming the challenges faced in achieving the SDGs. Therefore, it is important for engineering education to find ways to educate engineers that can incorporate sustainable values into technology development. Fortunately, as the Primary research revealed, students have a high level of consciousness and understanding of ecological problems and SDGs. Such trend gives us hopes that future engineers will actively join the SDGs implementation and development of new sustainable and ecology-friendly technologies.

Moreover, engineering HEIs need to keep up with the societal evolutions and monitor modern engineering trends because technologies nowadays are changing very quickly, and it is important to give students knowledge that will be relevant not only in the short term, but also in the more distant future. According to interviewees, who took part in KU Leuven research, it is important not only to increase students' awareness about existing problems, but also inspire them to look for possible technical solutions. Fortunately, the market of relevant technologies is growing extensively thanks to R&D.

Another crucial issue which was highlighted in this report is the wider set of requirements a modern engineer must meet. Despite the main role of an engineer is still finding technical solutions, employers expect that engineers will also take part in communication with different (often international) stakeholders, become active team members, show high level of critical-thinking, independency in solving problems and a lot of other professional competenicies. Requirements differ from employer to employer, however, the main trend remains unchanged: modern employers demand engineers who show a set of high level professional competencies. This trend gives a great responsibility to engineering HEIs, who need to develop the demanded skills.

The last but not least important tendency is the necessity of lifelong learning. Nowadays this tendency is universal for the majority of professions. However, due to the speed with which modern technologies are developing, the engineering profession is at the top of the list of important professional and technical skills. As was marked by one of KU Leuven interviewees, obligatory courses for professional engineers are critically important for maintaining the high level of our engineers.

7. Appendices

7.1. Description of competences

Competence	Description
Knowledge	
Technical knowledge	**Basic knowledge**: basic scientific-disciplinary knowledge (including mathematics) with a focus on practice.
	Informatics
	Specialisation: scientific-disciplinary advanced knowledge with focus on practice.
	State-of-the art: scientific-disciplinary in-depth knowledge with focus on practice.
	Cross-disciplinarity: cross-disciplinary knowledge, specific and general (energy, environment, safety, ...).
Specific sector and business knowledge	**Sector knowledge**, knowledge of the sector ecosystem: stakeholders (companies, regulatory framework governments, society, ...) and interactions.
	Business knowledge: knowledge of internal organisation, operations and processes.
Business and economic understanding	Knowledge of financial economics in business or social sector.
Social knowledge	Knowledge of the general social context.
Professional skills (hard skills) and attitudes	
Problem-solving ability	(Recognise) problems and be able to come to a plan of action to solve them: (a) **analytical thinking**: solution-oriented formulation and analysis of complex problems within the specialism, reduce complex problems to manageable sub-problems. Testing functionality upon integration.
	(b) **Design implementation-oriented solutions**: be able to select, adapt or develop techniques and methods as appropriate and be able to apply it adequately (=implementation).
	(c) **Attitudes**: creativity, outside-the-box thinking, innovative thinking, accuracy, critical evaluation and reflection, perseverance.
Controlling complexity	Be able to keep an overview of the entire problem / system / project (coherence, factors, dynamics).

Practical skills	Be able to apply knowledge in different situations (insight), assimilation ability, hands-on skill (lab-skills, experiments set up), practical thinking
Project-based working	Independently (a) conceive an engineering project (determine phases and steps), (b) plan (determine time duration of phases and steps), (c) execute (implement) and (d) follow up (monitor development trajectory keeping) taking into account available time and resources.
Skill in other languages	Fluent use of languages other than Dutch
Written communication	Written reporting
Interpersonal skills and attitudes	
Working in teams	Function as a member of an (inter- and multidisciplinary) team, operate in an international or intercultural environment.
Team leadership	**Leadership**: leading meetings, playing a bridging role to the shop floor, persuasion, decision making.
	People management: observing (being able to see what is happening, grasping and understanding feelings, listening), giving direction (creating clarity), asking questions (gathering information about progress), reassuring (removing uncertainties), creating cooperation (helping people trust each other so that they exchange information) and clarifying information (being able to tell a story in such a way that people understand it).
Oral communication	Spoken communication and presentation to peers and lay people
Technical-commercial skills	Consulting, advice, customer orientation, negotiation, commercial
Lifelong learning	Alertness to new evolutions (agility), agility (resilience)
Acting ethically	Values-based approach: respectful, correct, sense of responsibility, attention to sustainability (ecological, social, etc.), safety, compliance

7.2. Evaluation of the students' professional skills by the internship supervisors. Statistics for the internship 2022-2023

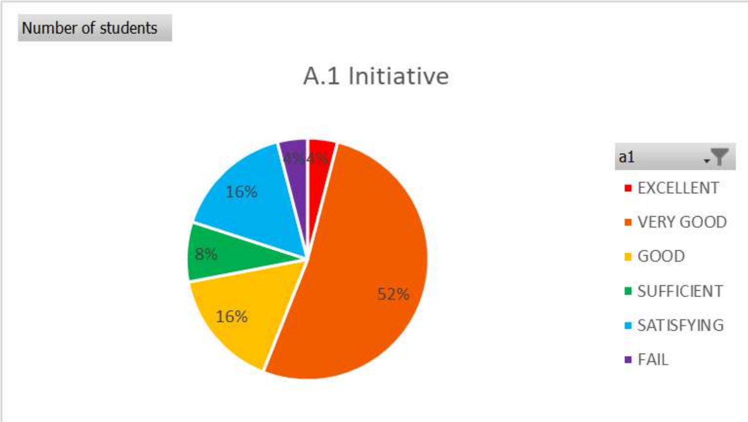

Chart 3. Evaluation of 'Initiative' by the internship supervisors.

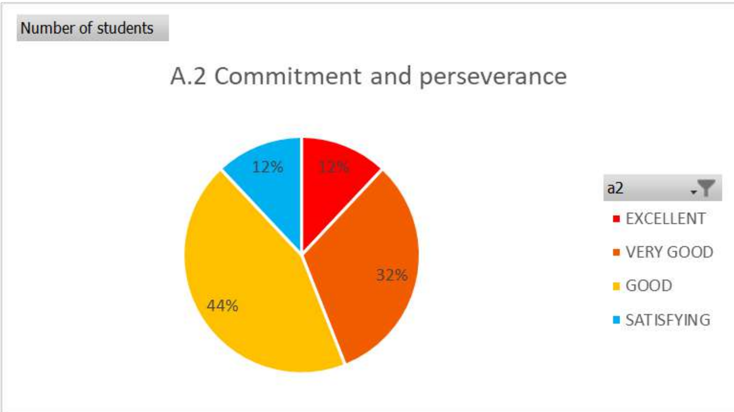

Chart 4. Evaluation of 'Commitment and perseverance' by the internship supervisors.

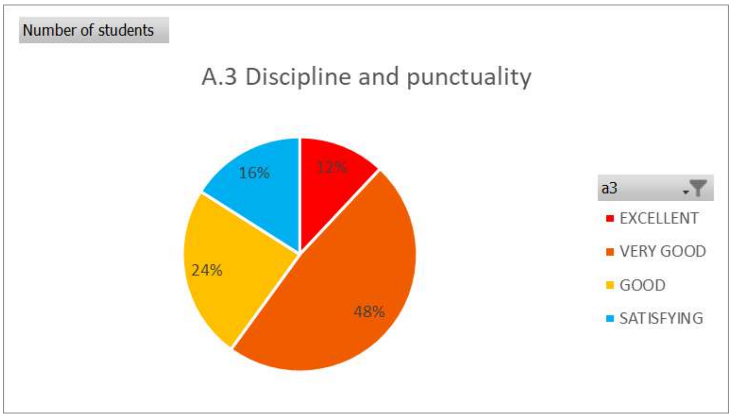

Chart 5. Evaluation of 'Discipline and punctuality' by the internship supervisors.

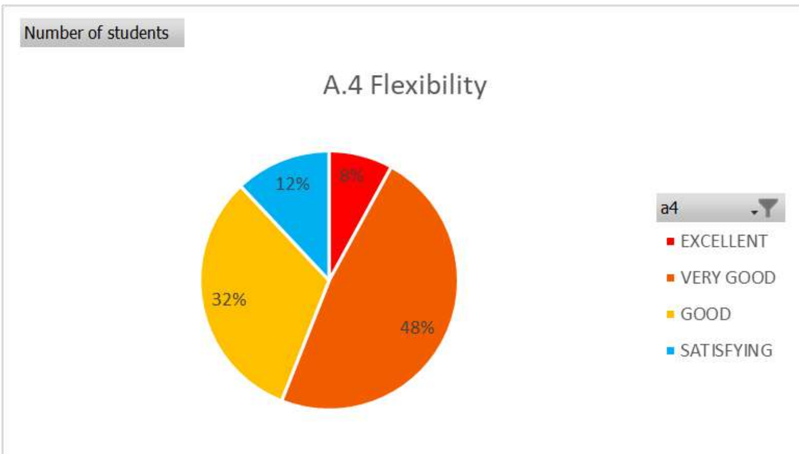

Chart 6. Evaluation of ‘Flexibility’ by the internship supervisors.

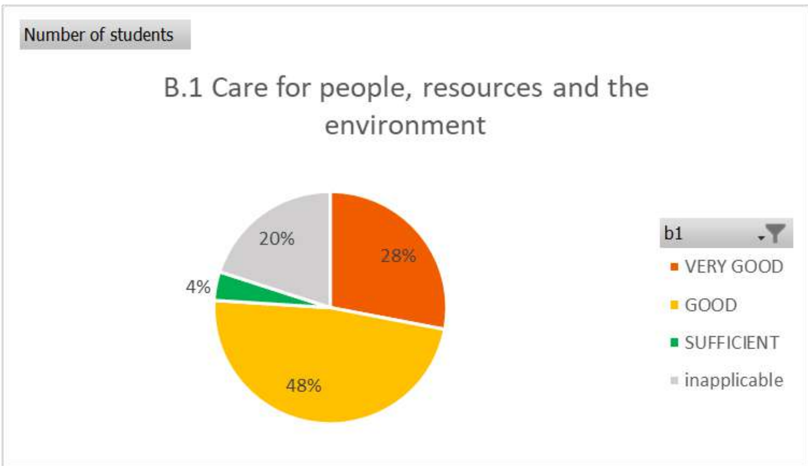

Chart 7. Evaluation of ‘Care for people, resources and the environment’ by the internship supervisors.

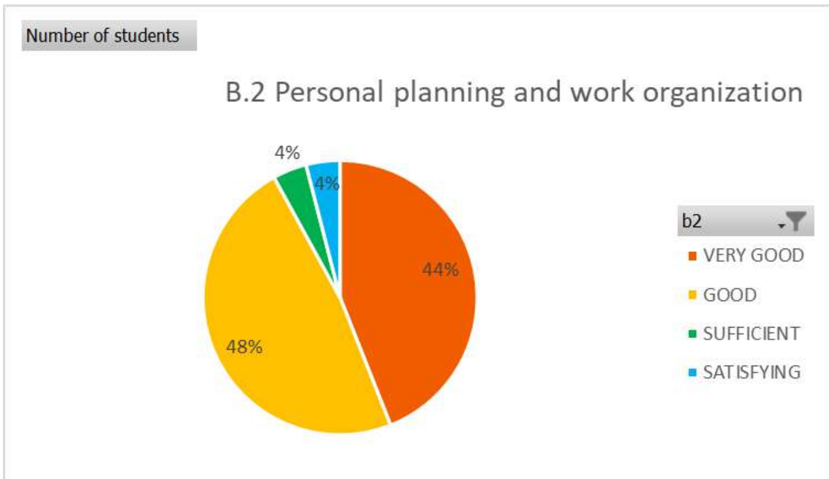

Chart 8. Evaluation of ‘Personal planning and work organization’ by the internship supervisors.

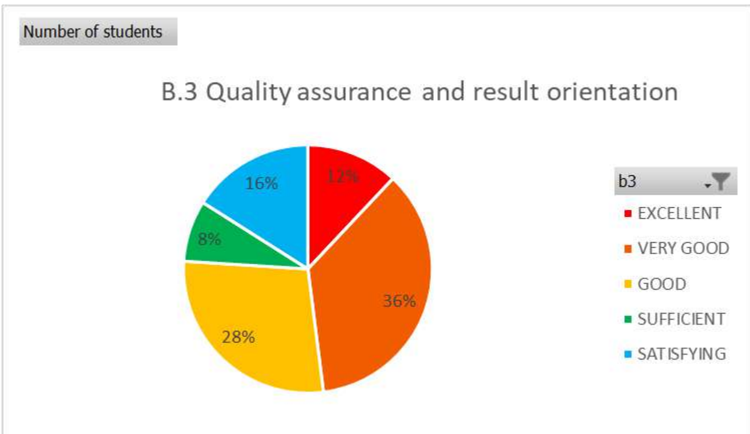

Chart 9. Evaluation of 'Quality assurance and result orientation' by the internship supervisors.

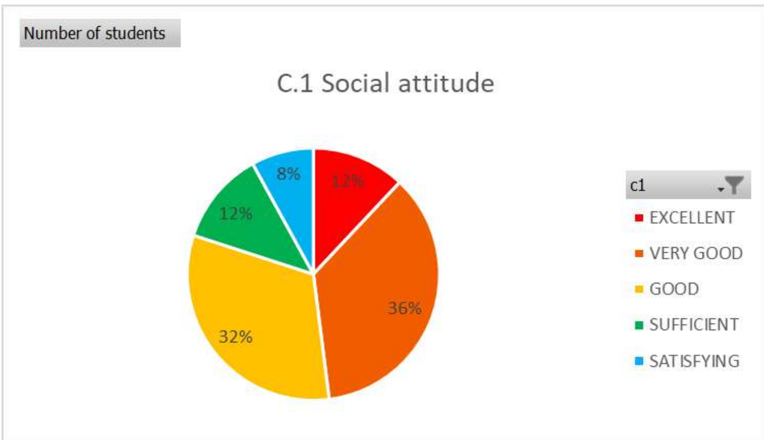

Chart 10. Evaluation of 'Social attitude' by the internship supervisors.

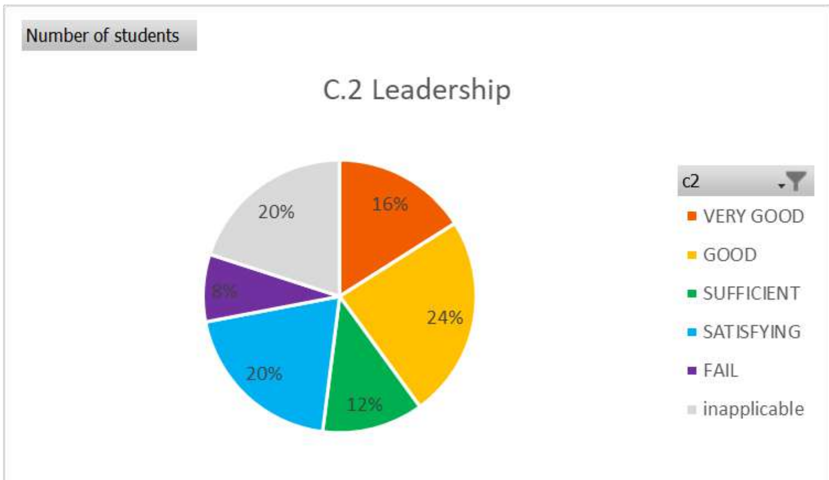

Chart 11. Evaluation of ‘Leadership’ by the internship supervisors.

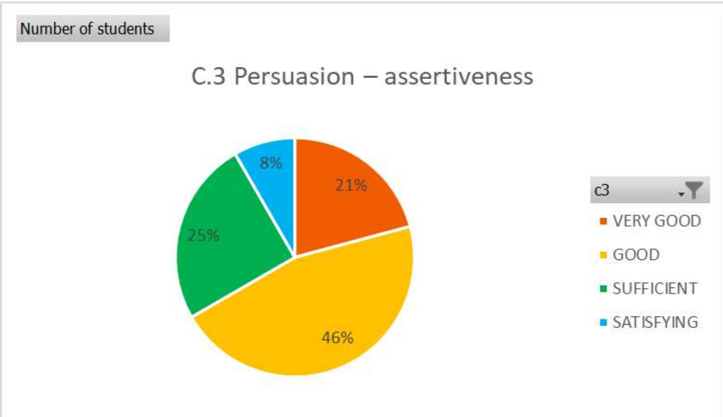

Chart 12. Evaluation of ‘Persuasion - assertiveness’ by the internship supervisors.

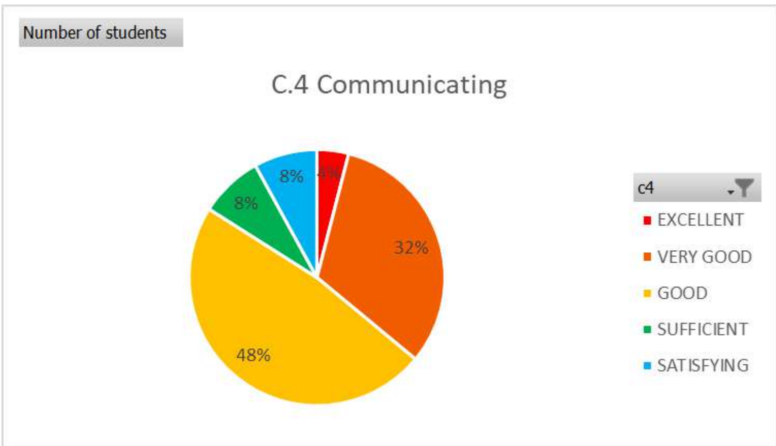

Chart 13. Evaluation of ‘Communication’ by the internship supervisors.

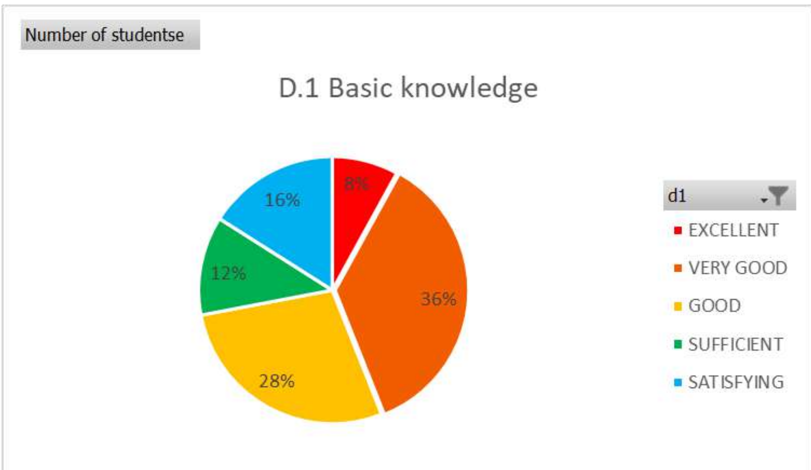

Chart 14. Evaluation of ‘Basic knowledge’ by the internship supervisors.

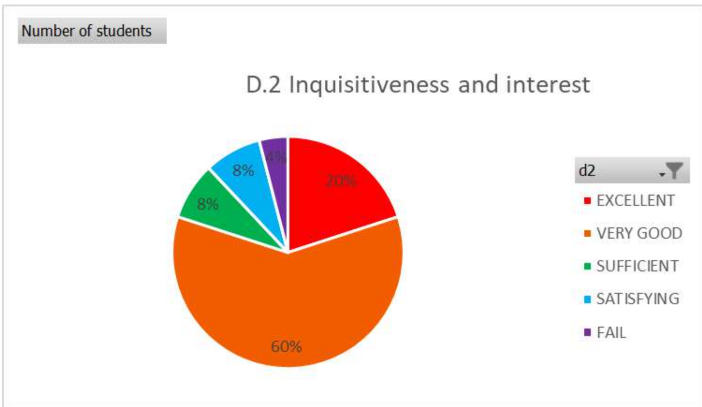

Chart 15. Evaluation of ‘Inquisitiveness and interest’ by the internship supervisors.

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2.4 Slovakia

2.4.1 Analysis by Newport Group S.A. (NG)

Introduction

1.1 The Executive Summary

Engineers are at the forefront of technological advancements, infrastructure development, and sustainable solutions. Their expertise is critical for addressing pressing challenges such as digital transformation, climate change, and economic competitiveness. But at the same time, given the importance of engineering in sustainable development we can observe how the profession meet a skills mismatch, communication gap, shortage of the manpower and insufficient curriculum.

By comprehensively studying the evolving nature of the engineering profession, the project aims to address the challenges faced by engineers and ensure their continued success in an increasingly complex and rapidly changing world.

Additionally, the engineering sector was considered in the Slovak republic. Slovakia has strong machine and industrial engineering industry with a historical background. Well-tuned supply and transportation chains allows the country to get permanent provision. Meanwhile, some gaps such as 'brain drain', small market size and competitive landscape were discovered.

One more thing that will affect Slovakia is digitalization strategy plan that adopted up to 2030 year. This plan aims to provide digital competences among all possible individuals, including engineers. First of all, for them it be regarded automatization and robotization in the industry. So, it will be crucial for Slovakia to upskill its workers.

There become obvious that the world and, within it, technologies involve extremely fast. Trends rapidly appear and disappear. And without proper upskilling depending on needs of the time, it is impossible to stay on track. Meanwhile the engineering profession met two polar problems with it. The first one is that engineers who are already have been long in the profession cannot catch what brought the digitalization era. It is not surprising because their preparation for the profession was not close to what we call engineering now. On the other hand, there are newly graduated engineers that were studying during COVID-19 when education find itself in the most ineffective times. That means when they come into the industry, employers can see a lot of training needed to make newly graduated engineers qualified professionals.

Despite all challenges, the engineering profession has also opportunities. There is predicted a big growth of the new workplaces and an increase of interest in the profession. Engineering is also highly required in SDGs and in the developing innovations.

It is important already now to actively lure individuals to pursue professional development opportunities, participate in industry conferences, and stay updated on the latest trends and advancements in engineering. VET and multidisciplinary trainings could be extremely useful. It is also needed to add more practical, teamworking, problem-solving, and life-learning aspects in the learning process, but in that way to avoid pressure on the already overcrowded curriculum.

1.2 Research Description, Goals, and Methods

The objective is to develop a robust methodology that captures the multifaceted nature of the engineering profession, taking into account the acquisition of essential skills such as digital literacy, green technologies, resilience, and entrepreneurship.

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.

By combining primary and secondary research methods, this report is going to gather relevant data. The following methods were employed to ensure a comprehensive and rigorous approach to data collection and analysis:

- Literature research: national reports, position papers, analyses, policy briefs, agendas, and university studies, as well as the private sector and consulting companies' researches. Overall, 54 sources are utilized.
- Inclusion/Exclusion Criteria: 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).
- Stakeholder Interviews and Surveys: In addition to secondary research, primary research methods were employed to gather insights directly from stakeholders within the engineering profession. This has included conducting interviews with engineering teachers, industry leaders, and representatives from VET-industry institutions. Surveys also have been distributed to stakeholders.

The combination of primary and secondary research methods ensures a multidimensional understanding of the engineering profession. The secondary research phase provided a solid foundation by reviewing existing literature, reports, and statistics, while the primary research methods offer direct insights and perspectives from key stakeholders.

Qualitative descriptions of the evolving nature of the engineering profession

2.1 Overview of the evolving nature of the engineering profession and its implications for the Slovak Republic

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 labor 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 digitization, 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 Sustainable Development Goals (SDGs) adopted in 2015 by the UN are another significant trend of our time. Achieving these goals requires a comprehensive approach, and engineers face the challenge of overcoming the inefficiencies in education following the pandemic, the lack of skills training, and the need to reskill and upskill themselves (Cunha et al., 2021). 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 specific technical knowledge relevant to their field of specialization. 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 globalization, engineering problems are not problems of only one specific country or region anymore.

2.2 Skills mismatch in the engineering profession

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 digitalization.

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 a comprehensive 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 3 Comparison of Current Skills and Future Skills for Engineers (EC, 2023; 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, organization, 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
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.

The national context: Slovak Republic

3.1 Country-specific industry features

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 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, internationalization, 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 neighboring countries. However, the challenge that that companies met is exactly because collaboration the best workers are being poached by those neighboring companies, which causes the 'brain drain'.

The following SWOT analysis (Figure 1) provides an assessment of the engineering market in Slovakia.

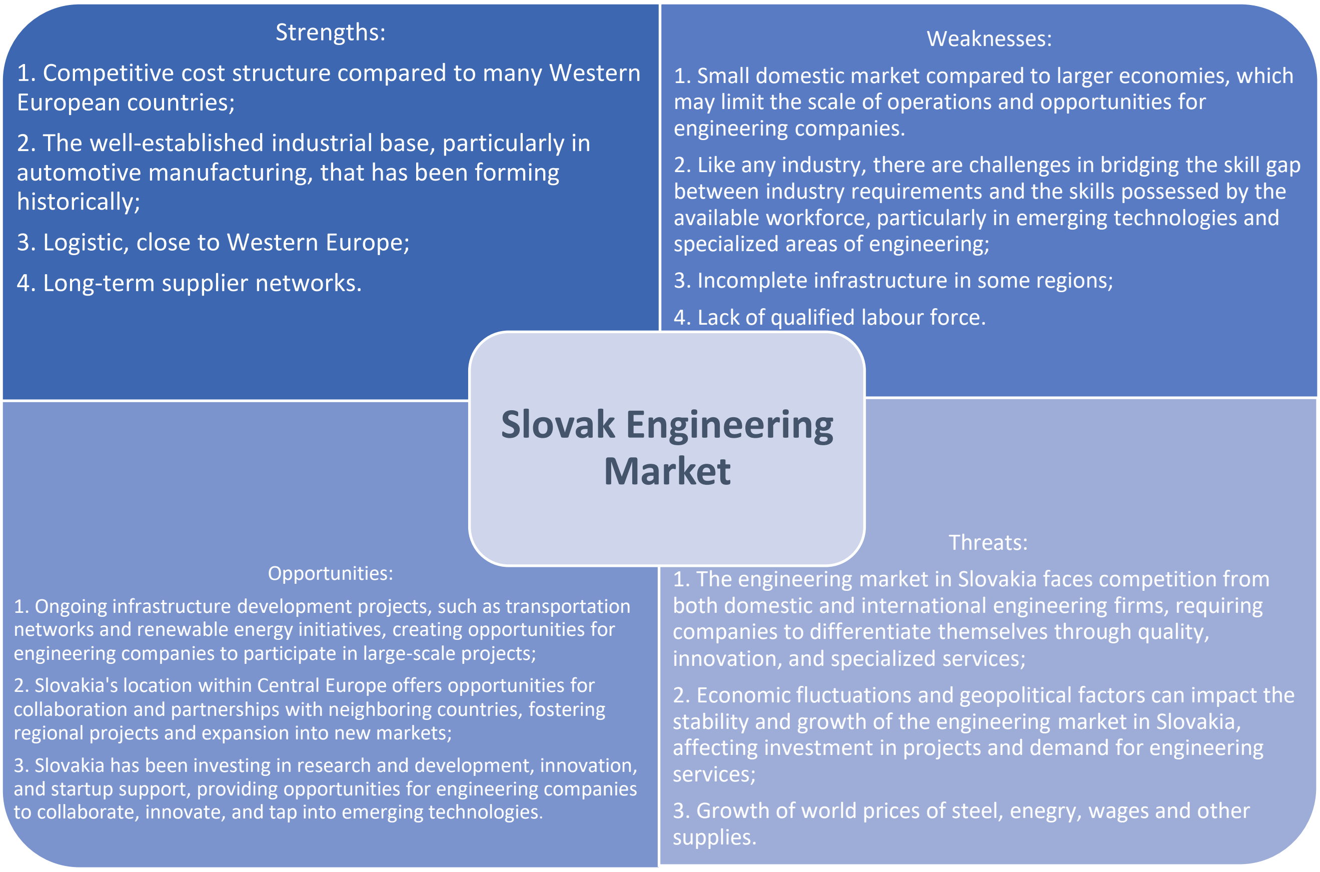

Figure 12 SWOT-analysis of the engineering Slovak market (SARIO, 2020; International Trade Administration, 2022)

3.2 Digital Transformation Strategy for Slovakia: how it will affect the engineering profession?

The 2030 Strategy for Digital Transformation of Slovakia is a comprehensive government framework that outlines the policy priorities for the country's ongoing digital transformation. This strategy aims to adapt the economy and society of Slovakia to the influence of innovative technologies and global megatrends of the digital era. (Slovakia - 2030 Digital Transformation Strategy, 2022). The primary objective of the 2030 Strategy is to modernize the Slovakian economy by leveraging innovative and environmentally-friendly industrial solutions.

Chapter 3.2 of the Strategy, titled "Society and Education," specifically addresses the crucial topic of digital skills (Ministerstvo investícií, regionálneho rozvoja a informatizácie, 2023). It emphasizes the importance of equipping individuals with the necessary digital competencies to participate actively in the digital economy and society. By prioritizing digital skills, Slovakia aims to ensure that its citizens are well-prepared to embrace the opportunities and navigate the challenges of the digital landscape.

Digital transformation plays a crucial role in Slovakia's Recovery and Resilience Plan, with measures aimed at facilitating the country's transition to a digital society. These measures account for 21% (EUR 1.33 billion), surpassing the targeted goal of 20% (Ministerstvo investícií, regionálneho rozvoja a informatizácie, 2023). The main driving force behind achieving the digital objectives is Digitálne Slovensko, which focuses on enhancing mobile services, cybersecurity, providing fast internet access for all, and fostering the digital economy. Additionally, the plan emphasizes digital investments in education, research, innovation, and sustainable transportation.

The plan encompasses various reforms to promote eGovernment, improve connectivity, facilitate the digital transformation of the economy and society, enhance education, and strengthen IT cyber and information security in public administration (Ministerstvo investícií, regionálneho rozvoja a informatizácie, 2023). It also adopts a strategic approach to digital skills education in collaboration with key stakeholders. To foster the growth of the digital economy, the plan supports Slovakia's participation in cross-border European projects and encourages the development and application of cutting-edge digital technologies. Furthermore, hackathons are promoted as a means to drive innovation and collaboration in the digital realm.

For the period 2021 – 2026 most of the activities in digital transformation are financed through Recovery and Resilience facility but also as activities in Horizon, Erasmus+, ESIF, and EEA grant schemes (Ministerstvo investícií, regionálneho rozvoja a informatizácie, 2023).

As the country focuses on digitalization, engineers will need to adapt to emerging technologies and develop digital skills to stay competitive. One of the key changes will be an increased emphasis on digital skills in engineering areas such as automation software for engineers, cloud computing, 5G technology data analytics, artificial intelligence, the Internet of Things (IoT), cybersecurity, etc.

Furthermore, digital transformation often involves the automation of processes and the integration of smart technologies. Routine and repetitive tasks will be automated, allowing engineers to focus on complex problem-solving, innovation, and strategic decision-making (Deloitte, 2021). Proficiency in data analytics, predictive modeling, machine learning, and other data-driven techniques will be essential to derive meaningful insights from the abundance of available data.

From this, it is understandable that engineers will work closely with professionals from other disciplines such as data scientists, software developers, and user experience designers, which will also require them to develop effective communication and collaboration skills for working in cross-functional teams.

It is important already now to actively pursue professional development opportunities, participate in industry conferences, and stay updated on the latest trends and advancements in engineering.

Continuous learning will be crucial to keep pace with the evolving technological landscape and remain relevant in the field.

3.3 The support system and institutional framework for Engineers in the Slovak Republic

In Slovakia, engineers benefit from a comprehensive support framework that fosters their professional development and provides assistance in their work. This framework includes various key components, which are described below.

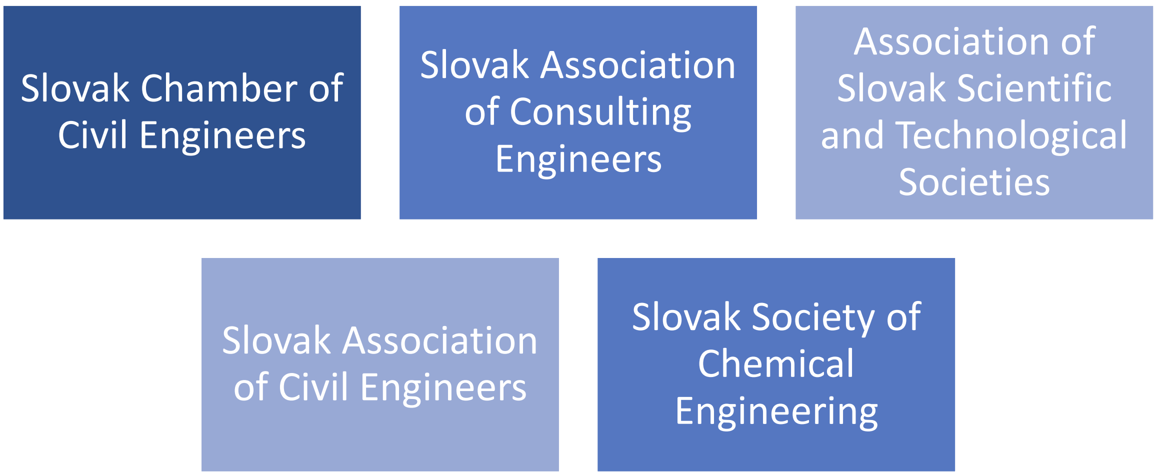

Figure 13 Professional associations for engineers in Slovakia

Professional associations play a vital role in supporting engineers in Slovakia. In Figure 2 prominent examples are shown. These associations provide networking opportunities, facilitate knowledge sharing, and organize professional development activities such as seminars, conferences, workshops, and certifications. In Annex A elements of this supporting system are described in more detail way.

Engineering education in Slovakia is provided by reputable universities and technical institutions. These educational institutions offer programs that equip aspiring engineers with a solid foundation (see Figure 3).

These universities in Slovakia offer engineering programs at the undergraduate (Bachelor's), postgraduate (Master's), and doctoral (Ph.D.) levels. The specific programs are available across institutions but commonly include disciplines such as Mechanical Engineering, Electrical Engineering, Civil Engineering, Chemical Engineering, Computer Science, and Information Technology. While two last one faculties are in the high-demand between enrollees, we can see how graduators of this faculties usually leaving Slovakia causing the ‘brain drain’.

The Slovak Government implemented the new dual education framework facilitating shared theoretical education in schools and practical training in companies (CVTI, 2022; Cedefop, 2020). The companies joining the new scheme have the advantage of not only benefiting from a prepared and qualified labor force but also from the possibility to utilize related incentives. By SARIO, more than 1,000 companies & 8,400 students joined dual education in 2020.

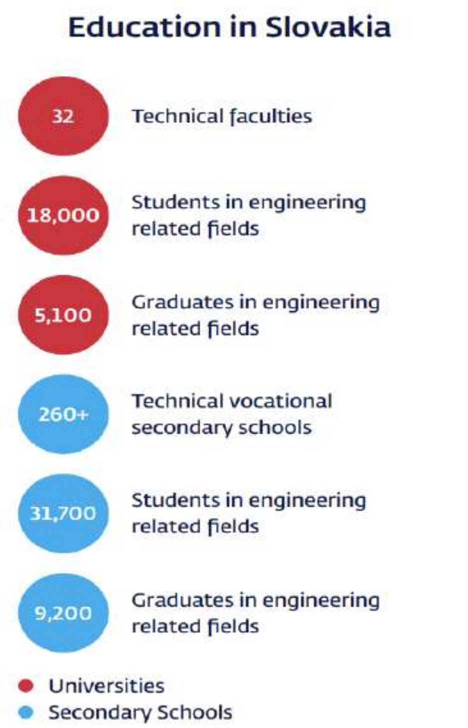

Figure 14 Statistics of education in engineering related fields in Slovakia (SARIO, 2022)

Continuing education and training programs are available to engineers in Slovakia (workshops, seminars, and specialized courses).

However, the COVID-19 shift has made its mark (European Commission, 2020). A lot of students that used to lazy online lections with low involvement are not ready for actual learning and upskilling process. It is important as future generations will not only be catalysts of technical innovation but will also play a leading role in addressing social issues (Deasha & Hargoves, 2021, as cited in Beagon & et al., 2022).

At the same time, engineering education in Slovakia faces several challenges that warrant attention for further improvement. One area of concern is the potential for outdated curricula that do not always align with rapidly evolving technologies and industry needs. This lag results in a mismatch between graduates' skills and the demands of the job market.

Insufficient industry collaboration also hinders students' exposure to real-world challenges and opportunities for internships. While efforts are being made, the integration of interdisciplinary approaches in engineering education and collaboration with other fields require further emphasis. However, Slovakia supports research and development (R&D) through grants and subsidies (SARIO, 2020). Engineers can access these funding opportunities to pursue research initiatives, technological advancements, and collaborations with industry partners. Technology transfer centers in Slovakia bridge the gap between research institutions and industries (SARIO, 2021). Both young and old-school engineers can pursue specialized training programs, certifications, and workshops to enhance their skills and knowledge and develop themselves as professionals. But as it was mentioned, usually that who actually attend all of those activities sooner or later leaves Slovakia seeking for better opportunities.

3.4 VET sector in Slovakia

3.4.1 The national VET system

Vocational Education and Training in the Slovak republic is defined and legislatively regulated by the Law No. 61 of 2015. Under this law the vocational education is understood as an educational process, in which knowledge, skills and competences are necessary for a specific vocation, group of vocations or execution of vocational activities. It is divided into theoretical and practical education.

The system of Vocational education and Training in Slovakia is based on the model established in the 1970s, which focus was to provide all students with at least upper secondary education, primarily through vocational schools. The reform of the vocational education system introduced with Law No. 61 of 2015 introduced additional elements of the dual vocational education, which is based on practical learning in the work environment provided by partner employers, which have contracts with individual students (Cedefop, 2016).

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. However, the number of private and church schools has gradually increased since 1990. In the school year 2021/2022 85,4% of students studied at public schools, 11,4% at private schools and only 3,2 at church-affiliated schools. The total number of students at vocational schools in Slovakia in 2021 was 121 470 students, which is continuously decreasing from 202 621 students in 2000 (CVTI, 2021).

VET in Slovakia is strictly regulated by the state. Wide variety of secondary VET programs ensures a high level of vocational education among youth as well as reduces the dropout rate in the sector. In 2019 91,3% of population between 20 – 24 years of age finished at least upper-secondary education (in comparison to 82,7% in EU-28) and in that same year only 6,9% of 18 to 24 years old left the educational system before graduating (in comparison to 11,0% in EU-28) (Cedefop, 2020).

3.4.2 Secondary Education

The VET in Slovakia generally starts at 15 years of age, and can be categorized into following ISCED levels (Figure 4).

ISCED 2 level

- 2-3 years programs mainly for students who were not able to finish the elementary school education. In some cases, these programs finish with vocational certificates, but are largely finished with proof of apprenticeships.

ISCED 3 level

- 4 years programs with various shares of practical education, which are finished with maturita (graduation exam) allowing students to continue their studies in tertiary level at universities. Students may also receive a vocational certificate. (ISCED 354). Additionally, there are 3-year programs, which are finished only with vocational certificate, but without maturita and do not allow students to continue in tertiary level. (ISCED 353)

Figure 4 ISCES levels in Slovakia (Cedefop, 2016)

There is an interesting trend within the secondary VET sector, where the interest in the upper secondary programs at ISCED 3 level, with maturita graduation exam, which allows students to continue in tertiary level education, remains strong (ISCED 354). However, the 3-year study programs with only vocational certificates (ISCED 353) not allowing tertiary level education are continuously falling out of interest of the students (CVTI, 2022).

In the school year 2021/2022 there were in total 416 vocational secondary schools in Slovakia, which accounted for the total number of 121 470 students. In this school there were more enrolled students 40 803 in comparison to the graduates at 30 098 (CVTI, 2022).

3.4.3. Dual Education System

Historically, in former Czechoslovakia there were strong ties between the vocational education sector and the industrial sectors. Every big company had established its own company school, which offered education in what would today be called dual education system. However, the ties between the vocational schools and companies were loosened in the early 1990s during the years of the economic transformation, when many of the companies went bankrupt, were overtaken by foreign investors, or lost interest in systematic development of VET due to shifting interests.

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 specializing in engineering or a related field.

3.4.4. VET at higher (tertiary) education

In Slovakia at tertiary education level there are at the moment no universities of applied sciences and no practically oriented bachelor's programs. The planned National Programme for the Development of Education and Training plans to carry out substantial reforms to address this problem in the next ten years.

Currently there are 35 higher education institutions (including 12 private) in Slovakia offering Vocational education at tertiary level. These offer bachelor, master and PhD studies and basic and applied research in various fields. Slovak technical university is the second largest university in the country based on the number of students (MŠVVaŠ SR, 2021).

3.4.5. VET Governance

The system of Vocational education and training in Slovakia is strictly regulated. The highest authority is the Ministry of Education, Science, Research and Sport of the Slovak Republic (Ministerstvo školstva vedy výskumu a športu SR). In the sector of secondary vocational schools, the authorities of Self-governing regions play an important role as founders of secondary vocational schools, thus the ministry oversees the whole system, but the secondary schools are subordinated directly to the Self-governing regions. The VET sector is specific also by the involvement of employer´s interest organizations, who are represented in the Government council for VET (Rada vlády SR pre OVP) and 8 Regional councils for VET.

The system of the adult education is simultaneously regulated by the Ministry of Social affairs and Family of the Slovak republic (Ministerstvo práce sociálnych vecí a rodiny SR), which regulates and appropriates the funding for continuous education measures as labour market policy.

3.5 Skills anticipation framework in Slovakia

The development of skills anticipation in Slovakia is currently in progress (Cedefop, 2020). Various actors are responsible for different aspects of skills anticipation, but their cooperation is not always effective. As a result, the labor market intelligence produced is fragmented and does not fully meet the needs of different end-users.

In 2017, the government approved the National Programme for the Development of Education (NDPE), which was designed by the Ministry of Education. This 10-year plan consists of policy measures that directly relate to skills anticipation. Although there are several measures in place for skills anticipation, such as collecting and analyzing administrative and survey data, as well as skills forecasting, it is believed that the connections between these different sources have not been fully utilized.

The regulation of skills anticipation activities is governed by laws on public employment services, general and VET, and higher education. Additionally, the recently developed National System of Occupations (Národná Sústava Povolani) and National Qualifications System (Národnej sústavy kvalifikáci), along with inter-institutional sectoral VET councils, are relevant in this context. All of these national-level regulations are guided by the National Employment Strategy of the Slovak Republic (2014-2020), which establishes the link between national and European policies.

Most of the existing skills anticipation initiatives have been developed under the Ministry of Labour, Social Affairs, and Family (MPSVR), with the Central Office of Labour, Social Affairs, and Family (COLSAF) taking the lead. COLSAF is the main entity responsible for gathering and providing data and information about the labor market situation, including skills assessment and its developments, to relevant institutions. The key tasks related to skills anticipation are assigned to COLSAF and regional labor offices. The Ministry of Education, Science, Research, and Sport is also a key player in coordinating policymaking, particularly in relation to VET and higher education. At the sub-national level, self-governing regional authorities lead the dialogue with other stakeholders.

Currently, there is no specific budget allocated for skills anticipation in Slovakia, and a significant portion of the resources for generating skills intelligence comes from the European Social Fund (ESF) (Cedefop, 2020). Despite the existence of anticipation activities, the lack of a coordinated approach has hindered the effective link between the gathered skills intelligence and policymaking. As a result, the impact of skills anticipation-oriented research on policies remains weak.

The Primary research: Slovak stakeholders focus groups

During our research, we held several meetings with stakeholders. They included one focus group meeting, face-to-face interviews, and informal interviews with partners, who are relevant stakeholders in the field. A total of 25 participants from the industry, educational sector, entrepreneurs and research and development fields took part in the primary research activities. In addition, the project partnership conducted an online survey. In specific relation to the research questions addressed in this paper, participants were asked to brainstorm on the evolving nature of the engineering profession and its' future.

The data collection took place in June and July 2023. Focus group meeting lasted an hour and a half and was undertaken in the native language of the participants in order to facilitate a deep discussion. The standardised questions as defined in the Methodology were followed to the extent possible in order to induce the discussion.

The data was then summarized and synthesized according to a standardized template and data treatment procedures including.

The portrait of the focus group participants is shown in **Annex B**. The interview results are obtained and the issues discussed are shown in **Annex C** of this paper.

The main outcome of the research was definition of several key points formulated by the respondents.

The engineering profession is expected to undergo rapid development in the next 5 and 10 years, driven by technological advancements, digitalization, interdisciplinary collaboration, and the rise of artificial intelligence. Despite the decline of some professions, engineers will continue to be in high demand, contributing to mechanical, industrial, agricultural, scientific, and green progress.

The engineering profession requires a combination of technical and transversal skills. Technical skills encompass proficiency in digital technologies, information and data literacy, communication and collaboration, problem-solving, and interdisciplinary competence. Transversal skills, such as adaptability, teamwork, leadership, and emotional intelligence, are increasingly important for effective communication and collaboration, given the growing interdisciplinary nature of the engineering profession.

Hard skills in engineering pertain to technical expertise and knowledge specific to the field, while soft skills refer to non-technical interpersonal and communication abilities. Both hard and soft skills are crucial for success in the engineering profession. Hard skills provide the technical foundation for problem-solving and innovation, enabling engineers to analyse complex problems and implement effective solutions. Soft skills, on the other hand, are vital for effective communication, collaboration, leadership, and adaptability, enabling engineers to work well with clients, colleagues, and stakeholders, and contribute to a positive work environment and project management.

The engineering profession plays a significant role in implementing the Sustainable Development Goals (SDGs) set by the United Nations. Engineers contribute to infrastructure development, renewable energy and climate action, water and sanitation initiatives, sustainable urbanization, sustainable industrial practices, innovation and technology, among others. Through their expertise, engineers design and construct sustainable infrastructure, develop renewable energy technologies, ensure access to safe water and sanitation, promote sustainable urban planning, and drive innovation for sustainable solutions.

The engineering profession can contribute to achieving the SDGs by developing new skills and competencies. This includes integrating sustainability principles into design, acquiring expertise in renewable energy technologies, designing sustainable water and sanitation systems, incorporating smart technologies into urban planning, acquiring circular economy and waste management skills, and fostering interdisciplinary collaboration to develop holistic solutions.

Engineers can become "conscious engineers" who prioritize ethical and sustainable practices through various strategies. These strategies include incorporating ethics and sustainability into engineering curricula, providing experiential learning opportunities, fostering a culture of continuous learning, implementing mentorship programs, encouraging interdisciplinary collaboration, and adhering to industry standards and certifications.

The engineering profession faces challenges and opportunities in adapting to the changing nature of required skills and competencies. Challenges include keeping up with rapid technological advancements, meeting interdisciplinary demands, evolving sustainability expectations, and embracing globalization and cultural awareness. Opportunities arise from innovation and entrepreneurship, emerging technologies, lifelong learning and professional development, collaborative approaches, and global connectivity.

Engineering education and training programs can better prepare students for the evolving nature of the profession by emphasizing interdisciplinary learning, providing hands-on experience, incorporating emerging technologies, integrating ethics and sustainability throughout the curriculum, fostering entrepreneurship and innovation, and promoting a culture of continuous learning.

Successful multistakeholder partnerships in addressing skills shortages/mismatches in the engineering profession require clear objectives and alignment, engagement of diverse stakeholders, collaboration and coordination, targeted training and education programs, continuous industry engagement, leveraging technology and innovation, recognition of prior learning and experience, sustainable funding and resources, and evaluation and monitoring.

Policies and initiatives at regional and national levels can effectively address skills shortages/mismatches in the engineering profession by crafting comprehensive skills strategies, promoting interdisciplinary collaboration, providing hands-on learning experiences, incorporating emerging technologies, fostering entrepreneurship, recognizing and celebrating achievements, and facilitating public-private partnerships for shared knowledge and resources.

Identification and exploration of emerging opportunities within the profession

5.1 The Growth of Job Places

What we expect in the profession? 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.

5.2 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 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.

5.3 Robotics and Automation in Construction

Engineers can leverage robotics and automation to automate repetitive and labor-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 labor 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.

Identification and exploration of needs within the profession

6.1 What are the emerging needs of the engineering profession?

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 vocational training (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 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).

Addressing these needs through comprehensive trainings, curriculum updates, and support systems can empower engineers to navigate the future successfully.

6.2 Prognosed necessary skills pack for engineers

To ensure the preparedness and effectiveness of engineers in meeting the challenges of the future, it is crucial to understand the required skills for this profession. This review explores the evolving nature of the engineering profession and provides a prognosis of the required skills for engineers. A summary of them is shown below in Figure 5.

Figure 15: Prognose of required skills for the engineering profession (World Economic Forum, 2023; European Commission, 2023; Beagon & et al., 2023; Cedefop 202; OECD, 2018; Cedefop, 2018)

Fundamental Disciplinary Skills

- Technical skills
- Ability in mathematics
- Economic skills
- Working with field programs (e.g.)
- Analytical thinking
- General knowledge

Skills Required by Digital Word

- Using IT-tools
- Ability to analize data
- Basic skills in programming, robotics
- Internet of Things understanding
- AI compentence

Strategic Competence

- Critical thinking, holistic thinking
- Innovation, creativity
- Decision making
- Conceptual understanding
- Resource optimisation
- Personal management
- Project management
- Entrepreneurship
- Challenging the status quo
- Research skills
- Life cycle thinking

Interpersonal Skills

- Communication, collaboration, and teamwork
- Listening skills
- Respecting individuals, respecting diversity, empathy
- Emotional intelligence
- Inter-cultural skills
- Foreign languages
- Conflict management
- Negotiation
- Leadership

Normative Competence

- Social responsibility
- Ethical conscience, understanding of the social responsibility
- Sustainability awareness

Interdisciplinary Work

- Multidisciplinary skills

Continuous Learning

- Learning to learn
- Lifelong learning

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 (Conde et al., 2021).

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).

The skills profiles engineers adjust to the needs and developments of the sectors/industries they work for. Cross-sectoral trends are also expected to further shape the demand for skills. So, Figure 6 is shown key drivers that affect the engineering profession and will be affecting in the nearest future.

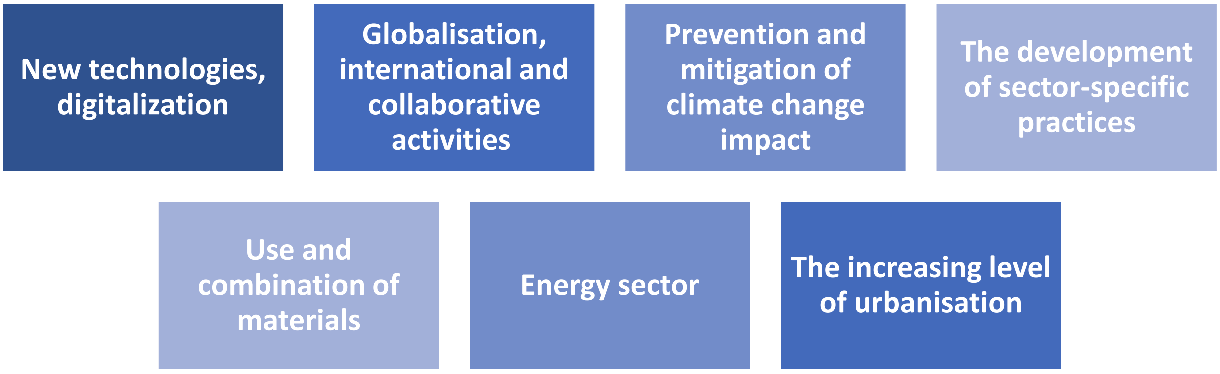

***Figure 16** Drivers of change that affect the engineering profession (Cedefop, 2019)*

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, 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).

6.3 How these skill needs can be met?

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 emphasizing 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).

Challenges

7.1 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 (4IR) 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 (AI), robotics, Internet of Things (IoT), 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 labor, 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 societal impacts. Collaborative efforts between industry, academia, and policymakers are necessary to establish flexible, adaptive, and inclusive regulatory frameworks (OECD, 2021).

7.2 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, minimizing 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.

7.3 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, 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 minimizing 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 modernization 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.

7.4 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 utilizing materials that are renewable, biodegradable, or recyclable, aiming to minimize waste generation, energy consumption, and environmental pollution.

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.

Conclusions and Recommendations

This report examined the main trends and weaknesses of the engineering profession in the future, and also suggested ways to strengthen the profession. The main thing that became obvious is that future generations of engineers will not only be catalysts of technical innovation but will also play a leading role in addressing various social issues.

These sustainability challenges call for future engineers who are able to deal with these ill-defined, open-ended, cross-disciplinary, complex socio-technical problems. Thus, in order to deal with these complex and global societal challenges, future engineers need to be equipped with a new set of competences and upskill themselves all the time. This is what means life-long learning. Adapting to emerging technologies and interdisciplinary demands will be crucial for professionals in this occupation to thrive. The summarization of future required skills and modification of existing skills for engineers was presented in this report. The main of them are technical, industrial competences, holistic, critical thinking, problem-solving, effective communication and teamwork, ethic competences, life-learn skills, involving new technologies in the work process, and data analysis.

In Slovakia, there are a lot of opportunities for engineers such as trainings, exchanges, practice during the education process, well-equipped classrooms, research and development support, but the main problem is the low interest of individuals who are left and the human capital flight of that who actually participated those activities. Meanwhile, the Slovak VET system is orienteered for the future labour market as it contains a lot of practice lessons. And this is its advantage.

There was considered solutions such as continuous professional development programs, industry-academia partnerships, and regular skill assessments to identify emerging skill needs. They are essential. Additionally, promoting interdisciplinary education, providing relevant internships and apprenticeships, and encouraging lifelong learning can help bridge the gap between required skills and available talent. By actively addressing skill mismatch, the engineering profession can better align the skills of engineers with industry demands.

There was also a conclusion that communication and other soft skills are essential for engineers as they are expected to be proficient in presentation, organization, leadership, conflict or culture resolution, etc. The engineering institutes should include soft skills development programs and courses in their curricula. This should be made in a way to combine it with technical skills avoiding an overcrowded curriculum.

Overall, the future of engineers looks promising, with significant job growth expected in various sectors. As technology continues to advance and industries become more complex, the demand for skilled engineers is set to rise. Consequently, there will be a pressing need to expand and enhance educational programs to equip aspiring engineers with the necessary knowledge and skills to meet the evolving demands of the workforce.

One of the primary needs that arise from the projected job growth is the requirement for comprehensive and specialized educational programs. Traditional engineering disciplines such as mechanical, civil, electrical, and chemical engineering will continue to be vital, but emerging fields like renewable energy, artificial intelligence, data science, and robotics will also become increasingly important. To meet these evolving needs, educational institutions and training centers must develop and offer programs that cover these emerging areas of engineering, ensuring that graduates are well-prepared for the challenges and opportunities that lie ahead.

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Annex A

Table A: Supporting organizations for engineers in Slovakia

Name of the organization	Short description	Goals and tasks	Web-site
Slovak Chamber of Civil Engineers (SCCE)	Slovenská komora stavebných inžinierov - SKSI) is a self-governing professional organization established by the Act of the Slovak National Council No. 138/1992 Coll. on Authorised Architects and Authorised Civil Engineers as amended by subsequent regulations.	The SCCE is responsible for regulating the professional practice of civil engineering in Slovakia. It grants licenses and certifications, promotes continuing professional development, ensuring that civil engineers practice their profession in a professional manner, supporting the international exchange and facilitates networking among civil engineers. The chamber also advocates for the interests of the profession and raises public awareness about the importance of civil engineering. The Slovak Chamber of Civil Engineers is also the authority for the recognition of professional qualifications of civil engineers who want to perform their professional activities in Slovakia.	http://www.sksi.sk/
Slovak Association of Consulting Engineers (SACE)	It is a grouping of corporate entities established in 2003, in accordance to §20f et seq. of the Civil Code as amended.	support consulting engineering activities and mutual coordination of consulting companies in the Slovak Republic.	https://sace.sk/
Association of Slovak Scientific and Technological Societies (ZSVTS)	ASSTS is a voluntary, non-profit, democratic and non-political association of public interest, gathering expert scientific and technological societies,	to foster and promote scientific and technological advancements in Slovakia. It serves as a platform for collaboration, communication, and coordination among various scientific and technological societies in the country. The	https://www.zsvts.sk/

	associations, committees and regional coordination centres.	association aims to facilitate the exchange of knowledge, encourage research and innovation, organize scientific events and conferences, and contribute to the development and dissemination of scientific and technological information.	
The Slovak Society of Chemical Engineering (SSCHI)	SSCHI is a professional organization in Slovakia dedicated to promoting and advancing the field of chemical engineering. The society plays a crucial role in fostering the development and growth of chemical engineering in Slovakia.	SSCHI aims to facilitate knowledge sharing, networking, and collaboration among professionals, researchers, educators, and students in the field. By organizing conferences, seminars, and workshops, the society creates opportunities for members to stay updated on the latest developments, exchange ideas, and contribute to the growth of chemical engineering in Slovakia.	https://www.sschi.sk/

Annex B

Table B-1: *The portrait of the focus group participants*

Focus group organized at the Private Vocational School DSA in Nitra, Slovakia at 19.07.2023

No.	Participants' field	Gender	Engineering field	Years in the industry	Position
SK-FGD-01	Industry stakeholder	F	Machinery production	8	HR manager
SK-FGD-02	Education field stakeholders	M	Machinery production	10	Engineer - company trainer
SK-FGD-03	Education provider	M	Secondary VET school	12	VET Teacher
SK-FGD-04	Education provider	M	Secondary VET school	7	VET Teacher
SK-FGD-05	Education field stakeholder	F	Machinery production	23	Engineer - company trainer
SK-FGD-06	Company education	M	Electrotechnics	15	HR manager
SK-FGD-07	VET oversight authority	F	Regional public administration	21	Head of Department of regional VET-network
SK-FGD-08	VET oversight authority	F	Regional public administration	5	Consultant in Department of regional VET-network

Table B-2: *The portrait of the individual Respondents in Primary research in Slovakia*

No.	Participants' field	Gender	Engineering field	Years in the industry	Position
SK-I-09	Industry	M	Machinery and Logistics	23	Plant manager
SK-I-10	Industry Association	M	Machinery, Construction, Electrotechnics and Logistics	9	General Secretary
SK-I-11	National VET authority	M	Public administration - Ministry	18	Head of Department

SK-I-12	National VET authority	F	Public administration – Ministry subsidiary organization	13	Section director
SK-I-13	Employer´s Association	M	Machinery Sector	7	Chairman of the oversight Board
SK-I-14	Employer´s Association	F	Machinery, Construction, Electrotechnics and Logistics	12	Analytic and Research expert
SK-I-15	VET provider	F	Construction and IT	18	Executive Director
SK-I-16	Public authority	M	Regional Public authority	18	Head of Department of regional VET network
SK-I-17	Technical University	M	Faculty of Natural Sciences	22	Professor
SK-I-18	Technical University	F	Faculty of Natural Sciences	7	Research fellow
SK-I-19	Company RnD	M	Machinery - Mechatronics	15	Development engineering
SK-I-20	Company RnD	F	Machinery - Mechatronics	8	Development engineering
SK-I-21	Employer´s Association	F	Mining and Metal processing	19	Chairman
SK-I-22	Technical University	M	IT	12	Research fellow
SK-I-23	Secondary school education	F	Mechatronics	7	Teacher
SK-I-24	VET-Provider	M	VET	8	Executive Director
SK-I-25	Industry	F	Construction	15	Executive Director

Annex C

Table C: The interview overview

Questions	Generalization of answers
1) How will the engineering profession evolve over the next 5 and 10 years?	Most interviewees believe that, first of all, the engineering profession, like most others, will develop very quickly. Such development will be associated with the rapid development of technologies, digitalization, a change in the scientific paradigm, and the emergence and further development of artificial intelligence. They believe that the engineering profession will still be in high demand, despite the fact that some professions are already gradually "dying out", engineers will be needed for mechanical, industrial, agricultural, scientific, and green progress. +interdisciplinary +Complex + socialized
2) What are the emerging technical and transversal skills and competencies required in the engineering profession?	Considering the above, we also learned about the necessary skills that will be in demand in connection with future changes. First, technical progress and digitalization will require engineers to have appropriate skills, such as the use of newly developed equipment and programs, the confident, critical, and responsible use of, and engagement with, digital technologies for learning, at work, and for participation in society. It includes information and data literacy, communication and collaboration, media literacy, digital content creation (including programming), safety (including digital well-being and competencies related to cybersecurity), intellectual property-related questions, problem-solving, and the use of artificial intelligence and the Internet of Things. Second, as the engineering profession will be involved in interdisciplinary collaboration, the industry will need to move beyond just STEM skills and acquire greater competence in communications (adaptability, teamwork, leadership, problem-solving, interpersonal skills, and emotional intelligence, + EXAMPLES FROM THE UNESCO TABLE) These skills will be needed for effective and non-conflicting communication between employees, superiors, colleagues, customers, etc., as the amount of communication required will increase.
3) How do hard and soft skills differ in terms of their importance for success in the engineering profession?	Hard and soft skills play distinctive roles in the success of engineers in the profession. Here's how they differ in terms of their importance: **Hard Skills:** Hard skills in engineering refer to the technical expertise, knowledge, and abilities that are specific to the field. These skills are typically acquired through education, training, and experience. Examples of hard skills in engineering include proficiency in programming languages, an understanding of mathematical and scientific principles, proficiency in CAD software, and knowledge of engineering principles and practices. Hard skills are essential for engineers as they form the foundation of their technical competence. They enable engineers to analyze complex problems, design innovative solutions, and implement engineering projects effectively. Hard skills are particularly important in areas such as structural design, computer programming, electrical circuit analysis, and

	mechanical engineering, where specific technical knowledge and expertise are required. **Soft Skills:** Soft skills, on the other hand, are non-technical skills that relate to how individuals interact, communicate, and collaborate with others. These skills are often transferable and can be applied across different contexts and professions. Examples of soft skills include communication, teamwork, problem-solving, leadership, adaptability, critical thinking, and time management. Soft skills are increasingly recognized as essential for success in the engineering profession. Engineers not only need to possess technical expertise but also must effectively communicate their ideas, collaborate with multidisciplinary teams, present their work, and adapt to changing circumstances. Soft skills enable engineers to work effectively with clients, colleagues, and stakeholders, and they contribute to a positive work environment, effective project management, and strong leadership within engineering teams. ***Both hard and soft skills are crucial for success in the engineering profession***, but their relative importance may vary depending on the specific context and requirements of the role. Hard skills provide the technical foundation and expertise necessary to perform engineering tasks and solve complex problems. They are often the entry point for securing engineering positions and meeting the technical demands of the job. However, soft skills are equally important for engineers to thrive in their careers. Engineers need to effectively communicate their ideas, collaborate with diverse teams, lead projects, and adapt to changing circumstances. Soft skills contribute to effective teamwork, client relationships, project management, and the ability to navigate complex social and professional environments. In today's dynamic and interconnected world, the importance of soft skills is increasingly recognized. Employers and clients value engineers who not only possess strong technical skills but also demonstrate excellent communication, teamwork, and problem-solving abilities. The ability to effectively apply technical expertise in a collaborative and adaptable manner is what sets successful engineers apart in their professional journey.
4) What is the role of the engineering profession in the implementation of Sustainable Development Goals (SDGs)?	The engineering profession plays a decisive role in the implementation of SDGs and participates in the implementation of each of the 17 UN goals. Here are some key aspects of the engineering profession's role in SDG implementation that participants have highlighted. **Infrastructure Development**: Engineers are essential in designing and constructing sustainable infrastructure, such as transportation systems, buildings, energy systems, water and sanitation networks, and waste management facilities. **Renewable Energy and Climate Action**: Engineers contribute to the development and implementation of renewable energy technologies,

	such as solar, wind, hydro, and geothermal power. They design efficient energy systems, promote energy conservation measures, and help transition from fossil fuel-dependent systems to low-carbon alternatives. By enabling climate action, engineers support SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action). **Water and Sanitation**: Ensuring universal access to safe water and adequate sanitation facilities is a key aspect of SDG 6 (Clean Water and Sanitation). Engineers play a vital role in designing and implementing water treatment plants, wastewater management systems, irrigation systems, and sustainable water resource management practices to address water scarcity, pollution, and hygiene challenges. **Sustainable Urbanization**: Engineers contribute to sustainable urban planning and development, considering aspects like efficient land use, public transportation, smart infrastructure, green building design, and resilience against natural disasters. By incorporating sustainable practices, engineers help achieve SDG 11 (Sustainable Cities and Communities). **Sustainable Industrialization**: Engineers play a critical role in promoting sustainable industrial practices that reduce resource consumption, minimize waste generation, and mitigate environmental impacts. They develop and implement technologies for cleaner production processes, eco-friendly materials, and efficient resource management, contributing to SDG 9 (Industry, Innovation, and Infrastructure). **Innovation and Technology**: Engineers drive innovation by developing sustainable technologies, materials, and solutions to address pressing challenges. They contribute to research and development, technological advancements, and knowledge sharing, supporting various SDGs, including SDG 9 (Industry, Innovation, and Infrastructure) and SDG 17 (Partnerships for the Goals).
5) How can the engineering profession contribute to the achievement of SDGs through the development of new skills and competencies?	Based on the answers, the engineering profession can contribute to the achievement of the SDGs through the development of new skills and competencies in the following ways: ○ Integrating sustainability principles into design, considering life-cycle assessments, energy efficiency, and waste reduction. ○ Developing expertise in renewable energy technologies to accelerate the transition to clean energy. ○ Designing sustainable water and sanitation systems to address water scarcity and inadequate sanitation. ○ Incorporating smart technologies into urban planning and infrastructure development for sustainable cities. ○ Acquiring skills in circular economy practices and waste management to promote responsible consumption and production. ○ Designing resilient infrastructure to withstand climate change-related events. ○ Fostering collaboration and interdisciplinary approaches to develop holistic solutions.

6) How can engineers be trained to become "conscious engineers" who prioritize ethical and sustainable practices in their work?	***Firstly***, it is essential to incorporate ethics and sustainability into engineering curricula. This includes dedicated courses or modules that emphasize the ethical implications of engineering decisions and the principles of sustainable development. By integrating these topics into their education, engineers can develop a strong foundation in ethical and sustainable practices from the outset. ***Secondly***, experiential learning opportunities can play a significant role. Engaging engineers in real-world projects that require ethical decision-making and sustainable solutions allows them to apply their knowledge in practical scenarios. This hands-on experience enhances their understanding of the complexities and challenges involved in balancing ethical considerations and sustainable outcomes. ***Furthermore***, fostering a culture of continuous learning is crucial. Providing access to professional development programs, workshops, and seminars on ethics and sustainability allows engineers to stay updated on the latest practices and techniques. This enables them to continuously enhance their skills and knowledge in these areas. Mentorship programs can also be valuable in nurturing ethical and sustainable practices. Pairing early-career engineers with experienced professionals who demonstrate a strong commitment to ethics and sustainability can help instill these values in the next generation. Mentors can provide guidance, share real-world experiences, and serve as role models for ethical decision-making. Collaboration and interdisciplinary engagement should also be encouraged. Engineers should have opportunities to work alongside professionals from other disciplines, such as environmental scientists, social scientists, and policymakers. This interdisciplinary collaboration promotes a broader perspective and encourages engineers to consider the social, environmental, and economic impacts of their work. ***Lastly***, industry standards and certifications play a significant role in promoting ethical and sustainable practices. Encouraging engineers to pursue certifications related to ethics, sustainability, or specific sustainability frameworks provides them with a recognized benchmark for their knowledge and commitment to these principles. It also helps align the engineering profession with global sustainability goals and expectations. ***In summary***, by implementing these strategies, engineers can develop the necessary skills and mindset to make informed decisions that consider the ethical and sustainable dimensions of their work.
7) What are the challenges and opportunities for the engineering profession in adapting to the changing nature of skills	The engineering profession faces both challenges and opportunities in adapting to the changing nature of the skills and competencies required. Some key points include: **Challenges:** ○ Rapid Technological Advancements: Keeping up with the pace of technological advancements requires continuous learning and upskilling to remain relevant and competitive.

and competencies required?	○ Interdisciplinary Demands: Addressing complex global challenges often requires collaboration with professionals from other disciplines, necessitating the development of interdisciplinary skills. ○ Evolving Sustainability Expectations: Meeting the growing emphasis on sustainability requires engineers to acquire knowledge of eco-friendly practices and integrate them into their designs. ○ Globalization and Cultural Awareness: Working in diverse international contexts demands cross-cultural competencies and an understanding of local regulations and standards. **Opportunities:** ○ Innovation and Entrepreneurship: The changing landscape provides opportunities for engineers to explore entrepreneurial ventures and drive innovation by applying new skills to develop sustainable solutions. ○ Emerging Technologies: Embracing emerging technologies like artificial intelligence, machine learning, and robotics allows engineers to enhance their problem-solving abilities and create cutting-edge solutions. ○ Lifelong Learning and Professional Development: The need for continuous learning presents opportunities for engineers to expand their skill sets, pursue advanced degrees or certifications, and stay updated with the latest industry trends. ○ Collaborative Approaches: The demand for interdisciplinary collaboration offers opportunities to work with professionals from diverse backgrounds, fostering creativity and generating innovative solutions. ○ Global Connectivity: Engineers can leverage digital platforms and global connectivity to collaborate on projects, access knowledge resources, and engage in cross-border initiatives. In summary, while the engineering profession faces challenges in adapting to changing skill requirements, there are also ample opportunities for innovation, entrepreneurship, lifelong learning, collaboration, and leveraging global connectivity. By embracing these opportunities, engineers can navigate the evolving landscape and contribute effectively to sustainable development.
8) How can engineering education and training programs better prepare students for the evolving nature of the profession?	Engineering education and training programs can better prepare students for the evolving nature of the profession by implementing several strategies. Firstly, there should be an emphasis on interdisciplinary learning, where students are exposed to diverse fields such as computer science, environmental science, social sciences, and business. This prepares them to collaborate with professionals from different backgrounds and solve complex, multifaceted problems. In addition, hands-on experience is crucial. Programs should provide opportunities for practical learning through internships, co-op programs, or industry partnerships. This allows students to apply their theoretical knowledge in real-world settings, develop problem-solving skills, and gain industry insights.

	To keep pace with the evolving profession, engineering education should incorporate emerging technologies. Introducing students to topics like artificial intelligence, robotics, and data analytics equips them with the skills needed to leverage advancements and address future challenges. Ethics and sustainability should be integrated throughout the curriculum. Dedicated courses on these topics help students understand the ethical responsibilities of their profession and the importance of incorporating sustainability principles into their work. Case studies, discussions, and projects can enable students to explore real-world ethical and sustainable dilemmas, fostering critical thinking skills. Furthermore, engineering programs should encourage entrepreneurship and innovation. Providing opportunities for students to develop entrepreneurial skills, explore innovation-driven projects, and engage with industry experts promotes a mindset of adaptability and problem-solving. Lastly, fostering a culture of continuous learning is essential. Engineering education should encourage lifelong learning by providing access to professional development programs, workshops, and seminars. This allows students and professionals to stay updated on emerging trends, technologies, and best practices. By implementing these strategies, engineering education and training programs can better equip students for the evolving nature of the profession, ensuring they possess the skills, knowledge, and mindset required to tackle the challenges of the future. +VET + EXCHANGES + TEAMWORK ON LESSONS + WORK-BASED LEARNING
9) What are the key factors that contribute to successful multistakeholder partnerships in addressing skills shortages/mismatches in the engineering profession?	Successful multistakeholder partnerships in addressing skills shortages/mismatches in the engineering profession are influenced by several key factors: ○ Clear Objectives and Alignment: A shared understanding of the objectives and a clear alignment of goals among all stakeholders are essential. This ensures that everyone is working towards a common purpose, facilitating effective collaboration and decision-making. ○ Engagement of Diverse Stakeholders: Inclusive partnerships that involve a wide range of stakeholders, including educational institutions, industry associations, government bodies, professional organizations, and community representatives, are crucial. Each stakeholder brings unique perspectives, expertise, and resources to address the skills shortages/mismatches comprehensively. ○ Collaboration and Coordination: Strong collaboration and coordination mechanisms are vital for successful partnerships. Establishing effective communication channels, regular meetings, and joint planning processes allow stakeholders to work together, share information, and pool resources efficiently. ○ Targeted Training and Education Programs: Developing targeted training and education programs that address specific skill shortages

	and mismatches is crucial. By identifying the specific needs of the engineering profession, partnerships can design and deliver educational initiatives that align with industry requirements and equip individuals with the necessary skills. ○ Continuous Industry Engagement: Continuous engagement with industry stakeholders is vital to ensure that training programs remain relevant and up to date with evolving industry needs. Regular feedback loops, industry advisory boards, and participation in curriculum development enable ongoing alignment between educational institutions and industry requirements. ○ Leveraging Technology and Innovation: Embracing technology and innovation can play a significant role in addressing skills shortages/mismatches. Partnerships can leverage e-learning platforms, virtual training tools, and emerging technologies to deliver training programs more efficiently and reach a wider audience. ○ Recognition of Prior Learning and Experience: Acknowledging and valuing prior learning and experience of individuals can help address skills shortages/mismatches. By recognizing and providing pathways for individuals with relevant experience, partnerships can bridge the gap between existing skills and industry demands. ○ Sustainable Funding and Resources: Adequate funding and resources are essential to sustain partnership efforts. Identifying and securing financial support from various sources, such as government funding, private sector investments, and philanthropic contributions, ensures the continuity and scalability of initiatives. ○ Evaluation and Monitoring: Regular evaluation and monitoring of partnership activities are crucial to assess the effectiveness and impact of interventions. By tracking progress, collecting feedback, and analyzing data, partnerships can identify areas for improvement and make informed decisions to optimize outcomes.
10) How can policies and initiatives at regional and national levels effectively address the digital, green, resilience and entrepreneurship skills shortages/mismatches in the engineering profession?	Policies and initiatives at regional and national levels hold great potential in effectively addressing the skills shortages and mismatches in the engineering profession, particularly in the domains of digital, green, resilience, and entrepreneurship. Here's a creative take on how these policies can make a difference: Governments can embark on a transformative journey by crafting comprehensive skills strategies that encompass the digital, green, resilience, and entrepreneurship dimensions. These strategies, co-created with academia, industry leaders, and policymakers, would chart a clear roadmap for bridging the gaps in engineering skills. To strengthen education and training programs, governments can unleash their creative prowess. They can empower engineering institutions to reshape curricula, infusing them with interactive learning experiences and cutting-edge technologies. Picture futuristic labs where students collaborate on green engineering projects or immerse themselves in virtual simulations of resilient infrastructure design.

	The stage is set for a harmonious duet between academia and industry. Governments can orchestrate symphonies of collaboration, bringing together universities and companies in a grand performance of shared knowledge and resources. Together, they can compose internship programs that harmoniously blend theoretical foundations with real-world challenges, giving students a chance to fine-tune their skills in digital transformation, sustainability, and entrepreneurship. In their role as impresarios, governments can entice engineers with financial incentives that rival the fortunes of a treasure hunt. Scholarships, grants, and tax breaks await those who dare to embark on the quest for mastery in digital skills, sustainable engineering practices, resilient infrastructure design, and entrepreneurial endeavors. The promise of a brighter future beckons, drawing talent into the transformative currents of the engineering profession. To sustain the virtuosity of engineers, governments can create a symphony of support for their lifelong learning endeavors. A vast library of resources, from online courses to state-of-the-art training centers, would be readily accessible, inviting engineers to compose their own melodies of growth and evolution. Governments would take pride in recognizing and celebrating their achievements, with prestigious awards and accolades serving as standing ovations to honor their dedication. Amidst this symphony of progress, public-private partnerships would be the secret ingredient that elevates the performance to new heights. Governments, industry leaders, and academia would dance in harmonious synchronization, jointly curating training programs, sponsoring research projects, and fostering innovation ecosystems. The collective energy and resources would fuel a virtuous cycle of skill development, propelling the engineering profession forward. Through captivating storytelling and captivating visuals, governments would cast a spotlight on the captivating engineers who have mastered the art of digital transformation, green engineering, resilience, and entrepreneurship. These role models would inspire future generations, igniting a passion for engineering and creating a virtuous circle of talent and innovation that propels society toward a sustainable and prosperous future. In this captivating narrative, regional and national policies would shape a symphony of transformation, weaving together the threads of digital, green, resilience, and entrepreneurship skills. The engineering profession would stand center stage, celebrated for its unwavering commitment to pushing the boundaries of human achievement and crafting a better world for all.

2.5 Greece

2.5.1 Analysis by Institute of Industrial and Business Education & Training (IVEPE-SEV)

Introduction

1.1 Executive Summary

The engineering profession plays a pivotal role in shaping the modern world by leading the design, development, and implementation of innovative solutions to complex problems and streamline or optimize existing engineering solutions to better address the problem they solve.

Engineering is a diverse and multidisciplinary field with various branches such as civil, mechanical, electrical, chemical, computer, and aerospace engineering, among others. Engineers are often the driving force behind technological advancements, infrastructure development, and industrial progress. The engineering mindset is set to balance creativity with theoretical concepts allowing advancements in various industries and research sectors such as biomechanics, nanotechnology, genetic engineering, space exploration etc.

As this diverse and multidisciplinary application of the engineering principles meets real life application and commercialization, the question of addressing sustainability through the engineering profession arises. In this extremely fast growing environment where innovation and new technology advancement is extremely fast, it is extremely important meet the sustainability requirements for the profession allowing to mitigate all risks linked with the SDG goals and put into practice concepts such as reduction of carbon footprint, optimization in energy consumption and energy efficiency, utilization of renewable energy resources and also counterweight the impact on the environment by minimizing production and prototyping waste, sustainable design solutions and circular economy principles. The above are a few of the pillars on which the engineering future could be laid on for a sustainable and responsible future.

The social impact of engineering is profound and far-reaching, touching every aspect of human life and reshaping societies across the globe. Engineering has fostered social inclusion by designing products and services that cater to the needs of diverse communities, ensuring accessibility and equal opportunities for all. From cutting-edge medical devices that save lives to digital platforms that connect people worldwide, engineering's transformative influence continues to forge a path toward a more interconnected, equitable, and prosperous future for humanity. However, as engineers wield considerable power in shaping society, they must also be mindful of the ethical implications of their creations, ensuring that technology is deployed responsibly, preserving privacy, and safeguarding against unintended consequences. Thus, it is crucial that the engineering profession maintains a balance between innovation and responsibility as well as having a solid ethical core in the development of solutions that touch millions of individuals worldwide.

It is extremely important that we as a consortium of partners, help in shaping the engineering profession by considering the above and taking into consideration the research results.

1.2 Objective and Research Methodology

Objective of this report is to capture the national context and state of play for the engineering profession.

Moreover, this report aims into a deeper look into the engineering profession in sense of future needs and development of skills and competences for the future of the profession at national and EU level.

Our contribution of the insights provided in this report will be consolidated in the projects report summarizing the current state of play of the engineering profession at EU level allowing a deeper understanding of the evolution of the profession and setting the cornerstone in developing a roadmap and development of training opportunities for engineers to develop skills crucial for the future of the profession.

Finally, this report aims into gathering all relevant data and sources to allow this deeper look into the profession on a national level. The following methods have been utilized to meet the above said requirements.

1. Literature research: This includes relevant national reports, studies, position papers and all relevant documents that are publicly accessible for both public and private sector.
2. Interviews and Surveys: Additionally to the desk research, engineers from diverse backgrounds have been

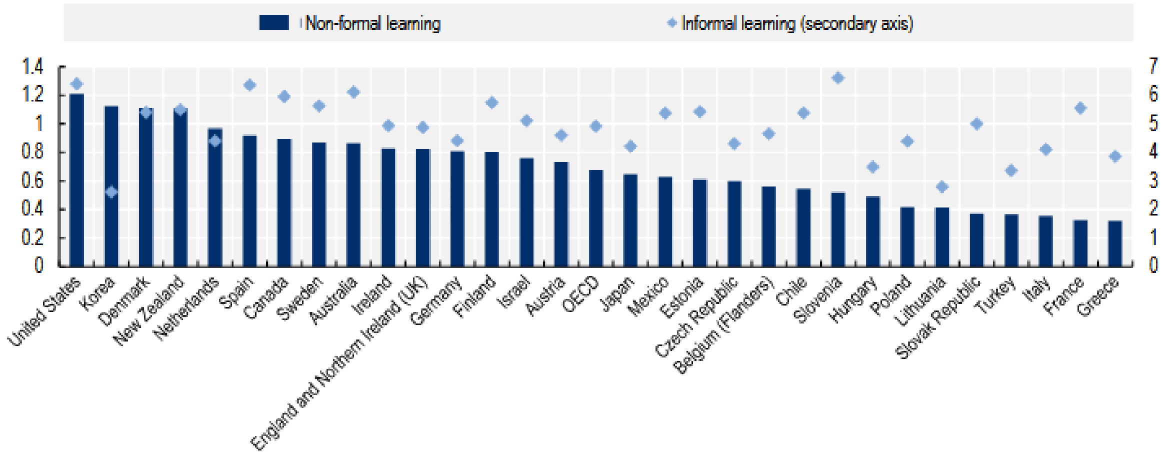
Qualitative descriptions of the evolving nature of the engineering profession

2.1 Overview of the evolving nature of the engineering profession and its implications for Greece

The disruption in everyday life that was introduced by Covid 19 pandemic demonstrated the need to change way of thinking and approach on what it was considered a linear development of skills. Because of the pandemic, skills that we considered as granted became obvious that were not as developed as we though they were.

In fact, on a relevant paper OECD denotes that on-the-job training and development of skills was significantly disrupted. Although the estimated learning loss is vastly heterogeneous based on sector and country, informal learning that typically relies on interaction among colleagues and peers was disrupted and created a gap during the social distancing measures. (Adult Learning and COVID-19: How much informal and non-formal learning are workers missing?, OCED, 2021)

Figure 4 Hours of non-formal and informal learning by country



Source: OECD (2015[3]), OECD Survey of Adult Skills (PIAAC), (Database 2012, 2015).

Subsequently, the engineering profession that in many cases relies on the exchange of ideas between peers and team members suffered from the same loss of non-formal and informal learning.

Further into the paper, the operational re-design from businesses to adjust their operations with a remote and mixed mode employment scheme suggests that “the intensity of sectoral shutdowns and the ability of firms in particular sector to transfer their operations online are two key determinants of the ability for workers in that sector to access learning provision.”

Table 5 Sectoral Shutdown(%)

Sector (ISIC, 1-digit)	Assumed % of the activity shutdown	
	***Widespread* scenario**	***Limited* scenario**
Mining and quarrying (VB)	100%	63%
Manufacturing (VC)	50%	35%
Construction (VF)	50%	47%
Wholesale and retail trade (VG)	75%	35%
Accommodation and food services (VI)	75%	75%
Real estate services (VL)	40%	40%
Professional service activities (VM)	50%	29%
Administrative and support service activities (VN)	100%	64%
Arts, entertainment and recreation (VR)	100%	100%
Other service activities (VS)	100%	86%

Source: OECD (2021), AdultLearning and COVID-19

The above table puts into perspective the shutdown of Sectors that heavily depend on engineers, among other workers, such as Mining and quarrying, Manufacturing and Construction.

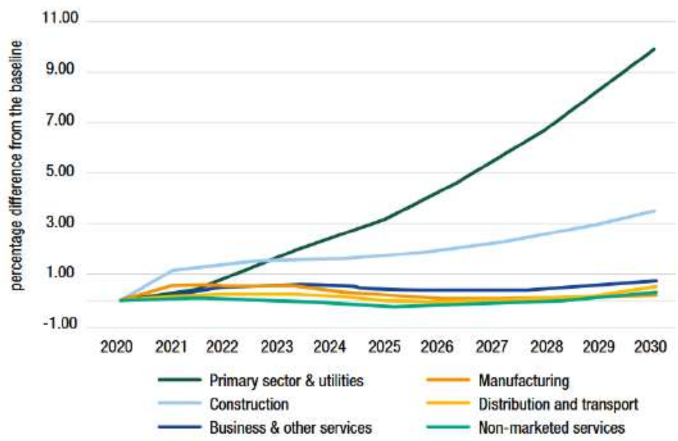
Following the rational of the paper it is apparent that engineers employed in those sectors had the opportunity to explore new training options and develop both personal and professional skills. Though what are the future skills required on an engineer and how could an engineer define the learning development path in the vast offering of training opportunities?

CEDEFOP in a recent publication (Cedefop (2021). The green employment and skills transformation: insights from a European Green Deal skills forecast scenario. Luxembourg: Publications Office) denotes the shift towards greener and more sustainable economies as a “game changer in EU labour market”. It also places this shift alongside digitalisation and automation trends. This publication further explores the skills forecast framework to meet the sectoral and occupational shifts at EU level that would likely occur if the EGD 2030 50-55% emission reduction target were fully met.

The publication points out the exponential raise in percentage difference from 2020 to 2030 from the base line based on sector and an interesting point is that the Construction sector almost triples in this projection (Figure 2).

It is worth mentioning that traditionally in the Greek economy construction sector had been of significant importance with many Civil engineers, Architects and Constructions engineers primarily working in the sector. It is also worth mentioning that based on the data available at Technical Chamber of Greece out of 108.242 Engineers registered 53.130 (49%) are Civil, Architect and Survey Engineers that are directly related to the construction industry (Table 2).

Figure 2: Forecast employment impact of the EGD (% difference between EGD skills forecast scenario and baseline) by broad sector, EU-27



Source: Cedefop skills forecast, 2020 baseline and EGD scenario estimates

Table 2: Engineers per discipline. Members of the Technical Chamber of Greece.

Discipline	Count	%
Civil Engineer	28,916	26.71
Architects	17,257	15.94
Mechanical Engineer	15,502	14.32
Electrical Engineer	18,279	16.89
Mechanical & Electrical Engineer	618	0.57
Survey Engineer	6,040	5.58
Chemical Engineer	9,266	8.56
Mining Enineer	1,933	1.79
Naval Engineer	46	0.04
Naval Mechanical Engineer	1,720	1.59
Electronics Engineer	4,169	3.85
Planning & Urban Planning Engineer	917	0.85
Enviromental Engineer	1,024	0.95
Mineral Engineer	543	0.50
Production Engineer	2,012	1.86
TOTAL	***108,242***	***100***

Source: Technical Chamber of Greece (https://web.tee.gr/tmima-mitroon/meli-tee/)

The numbers in table 2 are of extreme significance as they denote the number of active engineers in Greece. By Greek legislation, to exercise the engineering profession in Greece, an engineer needs to be registered in the Technical Chamber of Greece. Technical Chamber of Greece provides the signatory right to engineers to exercise their profession. Of course, the actual number of engineering degree holders in Greece is higher and engineers that are not actively exercising their profession are not obligated to be members of the Technical Chamber.

The engineering profession in Greece is linked to Higher Education with Polytechnic Schools and Universities (and some formerly Technological Educational Institutes that have been merged recently with universities), that offer degrees in engineering disciplines.

A graduate of those Polytechnic School and University that offers Engineering degrees, needs to pass an exam from the Technical Chamber of Greece and to also submit the relevant degree from either a Greek institute or an institute abroad. Upon successful examination, the engineer will get registered in the Technical Chambers database and will be provided with a registration number that allows the engineer to exercise the profession.

A shift in this trend of engineers related to the construction sector with engineers related to IT and software development is expected over the next years following Greece's plan on digital transformation (Bible on Digital Transformation, Hellenic Ministry of Digital Governance).

This Bible or Plan on Digital Transformation demonstrates the road map on digital transformation of Greece both in public and private sector and ultimately setting the goal of attracting investments allowing companies that operate in the IT sector and Online services to set up infrastructure and subsidiaries in Greece.

It has been publicly announced that Microsoft has already come to an agreement with the Greek government to establish a data center in Greece with a total investment of 1 billion USD that will further accelerate the digital transformation and potentially increase the demand for engineers. It is also expected that this move will attract other companies in similar manner to invest in infrastructure in Greece.

If the above projections are true, the need of trained engineers in those sectors that also have skills in Sustainability will raise drastically over the next years and the Greek engineering scene will potentially drastically shift from a construction-based sector to IT / Online services sector.

2.2 Skills Mismatch in the engineering profession

As the engineering profession in Greece is heavily depended on the University training and Polytechnic school training (described in section 2.1), it is apparent that sector specific skills and industry needed skills are in most of the cases trained in a non-formal way in the workplace.

Engineers have the engineering principles after their graduation as well as advanced knowledge in their discipline (in example mathematics, programming principles, design principles etc) but are often not linked with a real-life application or workplace application but remain only as theoretical approaches.

This is also how IVEPE SEV was created. Founded by SEV (Hellenic Federation of Enterprises), IVEPE SEV (Institute of Industrial and Business Education & Training, Hellenic Federation of Enterprises) was established as the training branch of SEV to offer the Greek industries applied knowledge in technical skills that are required in the workplace.

This skill mismatch has been apparent for a long time and until this point it has been tackled by companies willing to offer their employees specific knowledge, skills and competencies beyond their theoretical knowledge allowing them to perform their duties in an effective and reliable way.

For years companies focused on offering “hard” skills to their employees in the form of certifications or specific application training such as coding, electrical installation certifications etc, with the pandemic it was apparent globally that there was a huge gap in soft skills such as communication, working in teams etc that only came to light with the remote work scenario where multiple companies reported communication gaps in the work force. The IT sector produces some interesting results on this gap. (Yang, L., Holtz, D., Jaffe, S. *et al.* The effects of remote work on collaboration among information workers. *Nat Hum Behav* **6**, 43–54 (2022). https://doi.org/10.1038/s41562-021-01196-4).

Employment and Social Developments in Europe (ESDE) report 2023, shows that the skill gap identified with the Skill Shortages and gaps in European Enterprises report by Cedefop 2015, is still present.

In the ESDE report, the plan for 2023 European Year of Skill aims to provide a 5-year plan to support businesses and individuals to develop and apply skills for sustainable competitiveness, social fairness and resilience. 12 actions are in place to support this plan.

Table 3: European Skills Agenda: Actions

1. **Pact for Skills**	***2.*** **Skills Intelligence**	***3.*** **EU support for strategic national upskilling action**
4. **Council Recommendation on vocational education and training**	*5.* European universities initiative and upskilling scientists	*6.* Skills to support the green and digital transitions
7. Increasing STEM graduates and fostering entrepreneurial and transversal skills	*8.* Skills for Life	*9.* Initiative on individual learning accounts
10. A European approach to micro-credentials	*11.* New Europa Platform	*12.* Improving the enabling framework for Member States' and private investment in skills

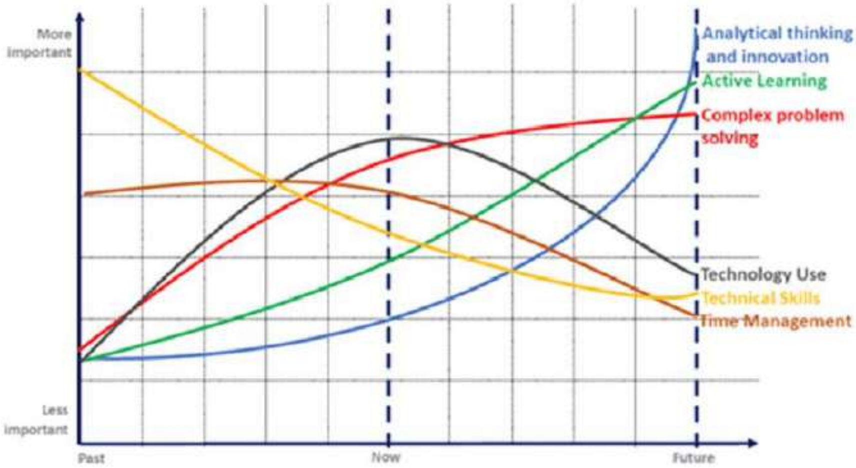
Source: European Skills Agenda - Employment, Social Affairs & Inclusion - European Commission (europa.eu)

As stated in the report the above table *"presents the analysis of the overall impact of improved skills matching, followed by an assessment of some specific policies contributing to better matching: vocational training and lifelong learning, and access to PES. This is complemented by the presentation of the Pact for Skills in key sectors experiencing shortages, skills intelligence, and skills governance arrangements across the EU, together covering four key actions of the European Skills Agenda."*

From the above statement it is apparent that micro-credentials and individual learning accounts will be in the centre of attention trying to create flexible training paths to individuals.

A study from 2019 on the past present and future of engineering skills, demonstrates some interesting findings in a comprehensive diagram. (Fussenecker, Claudia & Ahrens, Tim & Niemann, Jörg & Schlösser, Martin. (2019). ELIC-Teacher as a Medium to Build a New Generation of Skilled Engineers.)

Figure 3: Engineering Skills in the past, present and the future



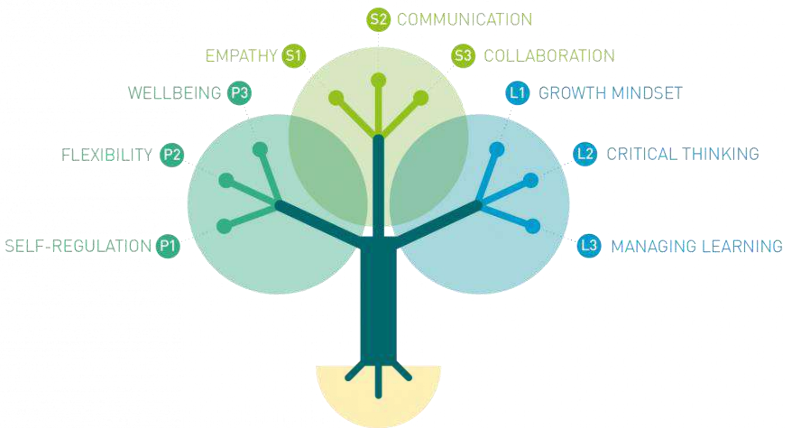
Source: Fussenecker, Claudia & Ahrens, Tim & Niemann, Jörg & Schlösser, Martin. (2019). ELIC-Teacher as a Medium to Build a New Generation of Skilled Engineers.)

From the paper and figure 3, it is apparent that Active Learning, complex problem solving and Analytical thinking and innovation are the skills that will be more important in the future.

This is inline with the EU research papers that have produced various frameworks for adaptation within the EU countries. Active learning and the development of "learning to learn" as well as critical thinking, are key concepts in the Lifecomp Framework were 9 competencies are described and can be learned by everyone in formal, informal and non-formal education. (European Commission, Joint Research Centre, Sala, A., Punie, Y., Garkov, V., et al., *LifeComp : the European Framework for personal, social and learning to learn key competence*, Publications Office of the European Union, 2020)

This conceptual framework aims in developing lifelong learners that can cope with complexity and can also socially responsible individuals.

Figure 4: The 9 competencies of LifeComp



Source: European Commission, Joint Research Centre, Sala, A., Punie, Y., Garkov, V., et al., LifeComp : the European Framework for personal, social and learning to learn key competence, Publications Office of the European Union, 2020)

It is interesting that all the published competencies frameworks published by the European Union intertwine with each other creating a holistic approach to a developmental path with competences and skills required by each individual in their professional development but also linked with wellbeing, continues improvement while also respecting the non-working life and access to personal time. The frameworks take a turn to the 1980's 1990's and early 2000's approach of skills that were all about "applied knowledge" and are going into a more "human-centric" approach remind us that we should create our own path to knowledge, and we are responsible for our personal professional development.

Figure 5: DigiComp Skills

Figure 5 demonstrates the intertwined skills concept between the frameworks as Problem solving is also present in this framework and communication and collaboration is also one of the shared competences between DigiComp and Lifecomp.

Source: European Commission, Joint Research Centre, Sala, A., Punie, Y., Garkov, V., et al., LifeComp : the European Framework for personal, social and learning to learn key competence, Publications Office of the European Union, 2020)

How are the above-mentioned skills and identified skill gaps related to the engineering profession?

To respond to that we must take into account the core principles in the centre of the engineering profession.

An engineer is linked to the engineering mindset that is structures in such a way to find solutions on complex matters while applying theoretical principles and design a solution. It is often not apparent that a continuous path of improvement and the "learning to learn" approach needs to be in place for an engineer to explore knowledge besides the specific discipline that was educated with.

Future engineers will require:

- Advanced knowledge of tools such as proficiency with AI tools and machine learning tools rather the theoretical principles in traditional engineering training.
- Green technologies and sustainability skills as well as circular economy applications rather than knowledge and understanding on engineering impact to environment.
- Finding solutions to complex problems in a team environment and effective communication in both technical and non-technical involved parties rather than solve problems as part of team detached from non-technical stakeholders.
- Ability to work in interdisciplinary teams with different technical background and diverse groups rather than working on a singular section of a problem solution.
- High level of ethical training employing ethical tests to solutions before commercialization or release to the public rather than just be conscious of social responsibility concepts.
- Self-motivation, learning to learn culture and work life balance rather than self-completion through complex problem solution.

Greek National Context

3.1 Industry characteristics

As mentioned earlier in this report most engineers (close to 49%) are related to the construction sector. Following the economic crisis, the construction sector in Greece has embarked on a path of adaptation and evolution. The challenges presented during the crisis prompted construction companies to reevaluate their strategies, become more resource-efficient, and embrace innovative construction techniques. As the economy slowly rebounds, foreign investments and collaborations have also increased, injecting fresh capital and expertise into the industry.

One significant area of growth for the construction sector in Greece lies in the realm of infrastructure projects. The government's commitment to boosting economic development has led to an emphasis on public infrastructure initiatives, such as road expansions, airport modernizations, and urban redevelopment projects. These initiatives not only stimulate economic growth but also improve the overall quality of life for citizens and attract tourists, further supporting the country's tourism sector.

Moreover, sustainability has emerged as a key driver for the construction industry in Greece. In response to environmental concerns and EU regulations, there is a growing focus on green building practices, energy-efficient designs, and the use of eco-friendly materials. Sustainable construction not only aligns with global trends but also positions Greece as a responsible player in the European construction market.

Despite these positive trends, the construction sector still faces challenges. One ongoing concern is the need to address labour shortages and skill gaps. The crisis prompted many skilled workers to seek opportunities abroad, leaving a shortage of experienced personnel within the sector. As the industry grows, efforts to attract and retain talent are developed.

To ensure the construction sector's long-term success, it is crucial for the Greek government to maintain stable economic policies and provide a conducive business environment. This includes streamlining bureaucratic procedures and offering incentives for private investments in construction projects. The construction sector in Greece has demonstrated resilience and adaptability in the aftermath of the economic crisis. The industry's gradual recovery is driven by increased investments, a focus on infrastructure development, and a commitment to sustainability. As the Greek economy continues to stabilize and expand, the construction sector is expected to play an integral role in driving growth, creating jobs, and shaping a more modern and sustainable built environment for the nation.

Further to the construction industry, Greece's heavy industry comprises of major players in different sectors such as heavy manufacturing and infrastructure development.

We can cluster the major industries in Greece in the following sectors:

Refineries: Hellenic Petroleum and Motor Oil both operate in that sector and primarily are involved in refining, distribution, and marketing of petroleum products.

Cement: Titan Cement Company and AGET Heracles are major players in the production of construction materials including cement, aggregates and other related materials. Titan Cement has global presence with operations in Greece and other countries and AGET Heracles is part of Holcim Group.

Mytillineos Holdings is a diversified industrial group with operations in various sectors, including **metallurgy**, energy, and engineering. It is involved in the production of aluminum and operates power plants contributing to both **heavy industry** and **energy sector**.

ELVALHALCOR is one of the leading companies in **aluminum** rolled products in Europe. The company is the result of a merger between ELVAL a leading aluminum rolling company and HALCOR a copper products industry.

GEK TERNA Group operates also in several sectors including construction and **energy** and is involved in large-scale **infrastructure** projects and energy production.

Finally, Public Power Corporations is Greece's largest power generation company that is involved in the production, distribution, and supply of electricity in the sector of **energy**.

The above-mentioned companies are only mentioned to better describe the industrial landscape in Greece and to pinpoint the key industries that are of interest for this report.

As a summary the industrial sectors are

Construction: With big industrial companies that facilitate infrastructure and public construction projects while many SMEs are also involved in the construction sector deeming it one of the largest sectors of the Greek industry.

Building Materials: Mainly involved in the production of Cement, aggregates and building materials.

Energy: With a wide range of players from oil refineries to energy distribution

Metallurgy: With major industries operating in the production of aluminum.

The predominant sector in the Greek economy is Tourism and Services but has not been mentioned in the report as it is outside of the report's scope related to the engineering profession. The above is only mentioned to accurately depict the industry segments and a rough contribution to GDP per sector for 2022 would be 68% Services, 15.5% Industry and 3.8% Agriculture while the rest spans over different sectors.

3.2 Digital Transformation

Greece is undergoing a vast digital transformation following the Bible for Digital Transformation 2020-2025.

OCED has also published a analysis on the BDT for Greece. (Digital Transformation Projects in Greece's Public Sector, Governance, Procurement, and Implementation, 2022)

The pivotal points in this Digital Transformation are:

Planning and funding digital investments

- Adopt an ICT portfolio management system for digital/ICT investments, including project approval processes' redesign, and the establishment of clear, transparent prioritisation criteria.

- Integrate ICT portfolio system into the governance of digital government, through existing bodies, which oversee DTB implementation (i.e., Steering Committee and Executive Network).
- Secure coherent funding management of digital projects – to ensure investment decisions remain independent of funding mechanisms.

Strengthening public sector capabilities

- Strengthen line ministries' capabilities (via digital standards) – to support coherent and aligned implementation of ITC/digital projects: (1) data sharing; (2) agile project management; (3) digital identity; (4) notification systems.
- Promote a user-driven culture throughout the public sector to guide digital transformation projects.
- Encourage training and capacity-building (via agile project management, user research, and user satisfaction measurements).
- Increase capacities to target advanced procurement practices and digital skills (e.g., gap-assessment indicators, pilot promotion) to test specific, scalable approaches.
- Examine the scope for ICT procurement centralisation to benefit from efficiency gains, greater specialisation, and related capacity improvements.

Although the Bible for Digital Transformation is a roadmap for transforming public sector and simplifying bureaucratic procedures it is also aimed as a means of attracting foreign investments by the simplified procedures of the government as well as the infrastructure developed to facilitate this transformation. Following this commitment and the clear path of Greece in playing a pivotal role in the European Union regarding Digital Transformation, an agreement between Microsoft and the government has been made for the creation of a Microsoft datacentre in Greece. The total investment from this agreement alone is 1 billion USD.

Early in 2022, it was also announced that Digital Realty will implement a 4th data centre in Greece under the name "ATH4" that will serve the needs of Amazon Web Services (AWS) in the greater region of East Mediterranean with an estimated investment of 400 million USD. Within 2021 the same company also finished the construction of their data centre "ATH3" that brought around 100 million USD as an investment.
The above digital transformation plan has indeed demonstrated the ability to attract foreign investments from major players in the sector and demonstrates the capabilities of Greece to become a technology hub in the region.

The future projection in that domain is to create opportunities for start-ups and technology companies and attracting them by offering access to the infrastructure that is generated. If the rate of foreign investments does not decrease until 2025 it might signify the entrance of Greece in the sector of online services and thus having the need for trained engineers in the relative disciplines.

Primary Research

4.1 Summary

As part of the primary research, we have reached out to engineers requesting to respond to the centralised online survey related to the engineering profession. For the scope of this National report, we do not include any data that derive from the centralised survey.

Moreover, for the scope of the National report, and by utilizing the structured 10-point questionnaire (as developed within the work package 2 tasks), we have reached out to engineers that were open to participate in the primary research and provide their insights and responses to the 10 points defined.

The responses have been extracted from the participants in the most convenient way for them as we propose either a face-to-face meeting or a remote session.

We encouraged participants to develop their point of view in the matter and the data was summarized according to the methodology to the standardized template.

4.2 Responses and analysis

<u>How will the engineering profession evolve over the next 5 and 10 years?</u>

Among the interviewees it was apparent that the Fourth Industrial Revolution with all the new technologies employed such as digitalization of production process, integration of cyber physical systems (CPS) in production and Internet of Things (IoT) applications as well as Industrial Internet of Things (IIoT) would drive the demand for the evolution of the profession.

Beyond the initial approach on the Fourth Industrial Revolution, the use of advanced tools such as Artificial Intelligence (AI), Machine Learning (ML) would also shape and direct the engineering profession towards a direction where engineers would need to employee such methods in their daily working routines.

The sustainability constrains as set by the Sustainable Development Goals and more specifically the environmental sustainability sub goals will challenge the profession over the next few years in the energy production, clean water and sanitation, clean energy, and climate change domains.

It was apparent during the interview process that the innovation challenge to meet this goal and at the same time utilize highly energy requiring solutions would be in the centre of attention over the next 5 to 10 years.

In example the use of computational power of AI in large clusters allowing it to be readily available to the public would directly impact the consumption of energy goal and the transition to clean energy or better higher energy efficiency would need to swiftly be adopted to allow large scale implementation of the above-mentioned tools.

<u>What are the emerging technical and transversal skills and competencies required in the engineering profession?</u>

Interviewees linked this question with the previous one and their response to that overlapped in some sense.

The driver for transversal skills and competencies will be new technologies. Skills and competences will directly derive from new technologies. Though, there is a pivotal point that came as a conclusion. Technology can drive the skills and competencies only when said technology passes the early adaptation phase. At this stage technologies such as AI have been utilized by some companies and some industry sectors but the “life span” of such technologies is uncertain. As AI is fairly new, a new technology might spin off from this before AI gets to general access to the public and in a more commercial way.

In the above sense there is a general consensus that competences will need to satisfy the new demands of the market and engineers will need to operate such tools and also have the skills to develop applications, skills to use new equipment and use of new software. That indirectly dictates the development of a learning to learn mindset as well as being open to new challenges and facilitate change. Interviewees also responded that skills such as project management, communication, critical thinking and problem-solving will be very important for the engineering profession.

How do hard and soft skills differ in terms of their importance for success in the engineering profession?

Following a more open conversation with the interviewees, it is a common belief that both a combination of hard and soft skills leads to success in the engineering profession.

Hard skills and theoretical knowledge along with the acquisition of know-how are the fundamental tools that will solve the problems that an engineer faces. Soft skills on the other hand are acquired through either specialized training and also come with experience in the field and by practicing the profession.

With the rapid development in AI, automations, and optimization algorithms skills such as creativity, critical thinking, emotional intelligence, adaptability, persuasion, collaboration might be more important than hard skills in the future. The reason for that is that machines cannot substitute such task and in this regard engineers as the end users of such machines and tools would need to employee all those soft skills.

What is the role of the engineering profession in the implementation of Sustainable Development Goals (SDGs)?

The role of engineers in SDGs has a dual nature. Engineers will be called to work on a solution of an existing problem such as renewable energy, clean energy and might be even called to optimize existing solutions such as photovoltaic systems, wind turbines to harness solar and wind energy. At the same time, they will also be called to reduce their carbon footprint in the process, to create less waste in the production process, to potentially recycle and reuse resources etc.
The above process will also require engineers to design and construct sustainable infrastructure which involves roads, buildings, bridges, energy, and water systems with due consideration to economic, social, and environmental implications.

Engineers will also be called to provide solutions in the restructuring of existing technologies to comply with the SDG requirements such as converting existing buildings to become energy efficient, retrofit infrastructure with optimized equipment meeting energy requirements etc.

The biggest challenge for the role of engineers at this moment is to adjust all the existing technologies to meet the requirements and make sure that they will employee SDGs while designing new solutions.

The interviewees also mentioned the ethical extensions of SDGs where solutions to the problems should be distributed to all the society lowering the inequalities that exist today as well as ensuring that the use case can be utilized by other cultures, and countries with less opportunities currently. Finally, the issue of addressing waste of resources that are used as raw materials and preservation of resources such as clean water was also a key point during the interview.

How can the engineering profession contribute to the achievement of SDGs through the development of new skills and competencies?

The response on this lead that the engineering profession can contribute in achieving the SDGs through the development of new skills and competencies regarding the renewable energy sources technologies, the new eco-friendly materials, cleaner manufacturing processes, waste management, water management, smart technologies and to practice and put into work principles for sustainability (both industrial and urban),

Critical thinking will also be important along with teamwork to achieve SDGs.

How can engineers be trained to become "conscious engineers" who prioritize ethical and sustainable practices in their work?

The interviewees believe that this is mainly the responsibility of the educational institutions like technical universities, polytechnic schools, and universities to organize the education of students and adjust the syllabus by integrating into their curricula relative courses that include modules for ethical and sustainable principles and practices in their work and decision-making process. The impact of engineering in the society and the environment needs to also be addressed in those courses. It is very crucial that the young engineers start their professional life by having a positive mentality in sustainability and a solid core of ethical principles. Other social institutions and professional organizations such as the technical and professional chambers should also contribute by fostering a culture of continuous learning and organizing workshops, discussions and seminars on ethical and sustainable practices and principles.

That would result in engineers being always updated on the latest practices and trends.

In addition, on the job training like working on projects can play a significant role, because the engineer will implement those principles in a practical way resulting in a learn by doing approach.

Case studies and real examples of unethical engineering practices can also help in understanding the implications of their decisions in society and the environment.

What are the challenges and opportunities for the engineering profession in adapting to the changing nature of skills and competencies required?

The answers denote that key challenges are the rapid development of technology which requires the engineers to keep up with these advancements, the nature of projects which requires the development of interdisciplinary skills allowing engineers to cooperate and communicate with professionals from other disciplines.

The fourth industrial revolution, automation and the artificial intelligence that affect the engineering profession are creating new demands on the level of knowledge, skills, competences, and job descriptions. The engineers must learn how to work effectively together with those new technologies soon. On the other hand, several opportunities are emerging like the new technologies which enables engineers to provide advanced solutions to technical problems, the access to continuous learning and opportunities to expand their skills and competences via global connectivity tools, through digital platforms and remote collaboration applications.

How can engineering education and training programs better prepare students for the evolving nature of the profession?

Education and training programs should be organized by universities with the cooperation of professional chambers and technical chambers where experienced professionals can train students on issues related to the emerging technical and transversal skills. Engineering education must encourage lifelong learning for engineers to be updated on new technologies and trends throughout their working life. Training courses must include the learning of emerging technologies like digitalization of production processes, the integration of cyber physical systems in production processes, the application of Internet of Things and Industrial Internet of Things, the artificial intelligence, the machine learning, advanced manufacturing methods, data analysis, programming, and digital tools relevant to the engineering profession. Training courses must also include interdisciplinary learning, to prepare and teach the students to work together with professionals from different sectors (business, financial, computer science) and provide solutions to multilevel problems.

The programs must provide participation of students in internships and co-op programs through direct cooperation with the industry. This good practice will help the students to apply their theoretical knowledge in practice. Another good suggestion is the use of experienced professionals as mentors to students to provide their professional experiences to students.

What are the key factors that contribute to successful multistakeholder partnerships in addressing skills shortages/mismatches in the engineering profession?

According to answers of interviewees, stakeholders like industry and construction organizations, engineering organizations, technical universities, educational institutions, government authorities, non-governmental organizations, professional associations, and technical and professional chambers can play significant role in addressing skills shortages/mismatches in the engineering profession under the condition of their successful cooperation. Key factors which can contribute to this can be the financial and decision-making support from the government authorities of the partnerships between the interested parties, the direct communication between government authorities and stakeholders for sharing opinions, experiences and decisions-making, the long-term partnerships between stakeholders which can help the achievement of sustainable results, the common approach of the stakeholders regarding the setting of quality goals for the addressing skills shortages/mismatches, the renewal of the educational and training material of the engineering education and training programs, the interconnection with the industry and construction sector for the identification of emerging market needs, trends and skills in the engineering profession and the enrichment of engineering curricula according to this feedback, the participation of students in internships, cooperation programs, and piloting them into real jobs to bridge the gap between academia and the professional world.

How can policies and initiatives at regional and national levels effectively address the digital, green, resilience and entrepreneurship skills shortages/mismatches in the engineering profession?

According to answers of questionnaires, comprehensive policies, and initiatives at regional and national levels can effectively address those skills shortages/mismatches in the engineering profession. Such policies and initiatives should be based on research and studies related to the needs of the market considering experience in applying successful policies and initiatives in other countries. The participation of key stakeholders is very important for the success of such policies and initiatives. Several policies can be effective like the integrate into engineering curricula of topics regarding digital literacy and coding, green technologies, resilience engineering and entrepreneurship, for strong understanding of students for the emerging technologies and their familiarization with the culture of enterprises and the handling of difficult cases in work, the provision of scholarships to students who will choose the expertise on the fields of digital, green, resilience, and entrepreneurship skills, the continuing training and education for the upskilling of professionals, the collaboration between educational institutions and the industry and construction sector in order to identify market needs and design training programs accordingly, the direct communication between government authorities and stakeholders for sharing opinions, experiences and decisions-making, the financial support and incentives like tax breaks, from government authorities in order engineering sector to invest at new digital and green technologies, the financial support from government authorities for young engineers to establish startups, the financial support in research and development in digital and green technologies.

Conclusion and Recommendations

Interviews demonstrate that participants have an intermediate level of understanding for SDGs and the development of new technologies.

They appear to monitor the development of technology, new tools and methods that are developing related to the engineering profession.

Interviewees also expect formal education to set the base line on matters of ethics and sustainability for the new engineers as well as for professional bodies and technical chambers and associations to provide follow-up sessions on the matter.

It is also a common belief that the skills required in the engineering profession will shift to skills related with the use of tools such as machine learning and AI as well as IoT applications.

Moreover, skills such as empathy, critical thinking and social awareness are on the map, and they need to be developed in the short future by engineers.

The expectation of solid policies to identify the context in which engineers operate is also one of the key findings along with incentives to implement such policies for companies and employees.

Finally, an important finding is that interviewees appear to know some skills may require specialized training and their expectation is clustered as follows:

- University provides the fundamentals and key principles.
- Technical associations and professional bodies provide keep the engineers updated.
- Other providers such as VET schools provide specialized courses for specific skills.

To conclude the fact that this clustering is apparent, denotes that the “learning to learn” process somehow is in place within the engineering profession as well as a clear point of view on the expectation of “who” delivers “what” at least in the matter of training, reskilling, and upskilling.

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Annex A

Questions	Generalization of answers
1) How will the engineering profession evolve over the next 5 and 10 years?	The common belief of the interviewees is that the engineering profession will be grown as the needs for technical knowledge is always increasing due to rapid development of new technologies. The engineering profession will be evolved adapting to the already running challenges of the Fourth Industrial Revolution (4IR) which include the digitalization of production processes, the integration of cyber physical systems (CPS) in production processes, the application of Internet of Things (IoT), of Industrial Internet of Things (IIoT), of artificial intelligence (AI), of machine learning, etc. and challenges regarding the energy production changes and the sustainable development targets regarding clean water and sanitation, clean energy, innovation, sustainability, climate change.
2) What are the emerging technical and transversal skills and competencies required in the engineering profession?	New technologies impact what engineers need to learn, as well as what skills and competences they should have to satisfy the new demands of the market. Most of the questionees answered that there is need for technical skills like the programming and development of applications, use of new equipment software and engagement and familiarization with digital technologies. Other skills like project management, communication, teamwork, critical and innovative thinking, problem-solving and negotiating. are also very important in the engineering profession.
3) How do hard and soft skills differ in terms of their importance for success in the engineering profession?	All interviewees believe that both hard and soft skills have an important role for success in the engineering profession. Hard skills provide to engineers the necessary technical know-how and expertise to perform specific projects and can be acquired through university education, training, and experience, while soft skills which are not technical skills are acquired through specialized training and of course from experience while performing the engineering profession. Due to rapid development of new technologies as artificial intelligence (AI), automation and algorithms, several soft skills like creativity, critical thinking, emotional intelligence, adaptability, persuasion, collaboration, time management, in the future may be more important than hard skills, because machines can't yet easily replicate them.
4) What is the role of the engineering profession in the implementation of Sustainable	Based on the interviewee's answers, the role of engineers is very important in the implementation of some of the UN Sustainable Development Goals. For example, the engineers can design and implement renewable energy producing systems (photovoltaic systems, wind generators, etc.) to harness solar energy, wind energy, water

Development Goals (SDGs)?	energy and geothermal energy, engineers can redesign existing processes to reduce carbon footprint and energy consumption, engineers can design and construct sustainable infrastructure which involves roads, buildings, bridges, energy, and water systems with due consideration to economic, social, and environmental implications, engineers can contribute to the sustainable cities design through clean energy, energy efficiency, high performance buildings, green buildings, sustainable transportation, engineers can contribute to the sustainable industrialization by promoting energy-efficient technology, energy management systems, renewable energy sources, energy-saving practices, cleaner manufacturing processes, use of eco-friendly materials, in order to reduce resource consumption, waste generation, and environmental impacts, engineers can design water management systems (irrigation, water treatment plants, water reservoirs, etc.) for safe water, hygiene and address water shortage and water wastage.
5) How can the engineering profession contribute to the achievement of SDGs through the development of new skills and competencies?	Based on the answers, the engineering profession can contribute to the achievement of the SDGs through the development of new skills and competencies regarding the renewable energy sources technologies, the new eco-friendly materials, the cleaner manufacturing processes, the waste management, the water management, the smart technologies, the practices and principles for sustainability (industry and urban). In addition, teamwork, innovative thinking and project management competencies and skills are considered also as critical to the achievement of SDGs.
6) How can engineers be trained to become "conscious engineers" who prioritize ethical and sustainable practices in their work?	It is a main responsibility of the educational institutions like technical universities, to organize the education of their students by integrating into their curricula relative courses which must include modules for ethical and sustainable principles and practices in their work and decision-making and the impacts of engineering in the society and the environment. It is very crucial the young engineers to start their professional life by having the right mentality in ethics and sustainability. Other social institutions like the technical and professional chambers can also contribute by fostering a culture of continuous learning and organizing workshops, discussions, and seminars on ethical and sustainable practices and principles, resulting the engineers to stay updated on the latest practices. In addition, on the job training like working on projects can play a significant role, because the engineer will implement those principles in a practical way. Case studies and real examples of unethical engineering practices can help engineers to understand the implications of their decisions in the society and the environment.
7) What are the challenges and opportunities for the engineering profession in adapting to the changing nature of skills	Based on the answers some key challenges are the rapid development of technology which requires the engineers to keep up with these advancements, the nature of projects which requires the development of interdisciplinary skills in order engineers to cooperate and communicate with professionals from other scientific sectors, the fourth industrial revolution, automation and the artificial intelligence which

and competencies required?	affect the engineering profession by creating new demands on the level of knowledge, skills and jobs descriptions. The engineers must learn how to work effectively together with those new technologies soon. On the other hand, a number of opportunities are emerging like the new technologies which enables engineers to provide advanced solutions to technical problems, the access to continuous learning and expand their skills and competences, the global connectivity through digital platforms and remote collaboration.
8) How can engineering education and training programs better prepare students for the evolving nature of the profession?	Education and training programs should be organized by universities with the cooperation of professional chambers and technical chambers where experienced professionals can train students on issues related to the emerging technical and transversal skills. Engineering education must encourage the lifelong learning in order engineers to be updated on new technologies and trends throughout their working life. Training courses must include the learning of emerging technologies like digitalization of production processes, the integration of cyber physical systems in production processes, the application of Internet of Things and Industrial Internet of Things, the artificial intelligence, the machine learning, advanced manufacturing methods, data analysis, programming, and digital tools relevant to the engineering profession. Training courses must also include interdisciplinary learning, to prepare and learn the students to work together with professionals from different sectors (business, financial, computer science) and provide solutions in multilevel problems. The programs must provide participation of students in internships and co-op programs through the direct cooperation with the industry. This good practice will help the students to apply their theoretical knowledge in practice. Another good suggestion is the use of experienced professional as mentors to students to provide their professional experiences to students.
9) What are the key factors that contribute to successful multistakeholder partnerships in addressing skills shortages/mismatches in the engineering profession?	According to answers of questionnaires, stakeholders like industry and construction organizations, engineering organizations, technical universities, educational institutions, government authorities, non-governmental organizations, professional associations, and technical and professional chambers can play significant role in addressing skills shortages/mismatches in the engineering profession under the condition of their successful cooperation. Key factors which can contribute to this can be the financial and decision-making support from the government authorities of the partnerships between the interested parties, the direct communication between government authorities and stakeholders for sharing opinions, experiences and decisions-making, the long-term partnerships between stakeholders which can help the achievement of sustainable results, the common approach of the stakeholders regarding the setting of quality goals for the addressing skills shortages/mismatches, the renewal of the educational and training material of the engineering education and training programs, the interconnection with the industry and construction sector for the identification of emerging market needs, trends and skills in the

	engineering profession and the enrichment of engineering curricula according to this feedback, the participation of students in internships, cooperation programs, and piloting them into real jobs to bridge the gap between academia and the professional world.
10) How can policies and initiatives at regional and national levels effectively address the digital, green, resilience and entrepreneurship skills shortages/mismatches in the engineering profession?	According to answers of questionnaires, comprehensive policies, and initiatives at regional and national levels can effectively address those skills shortages/mismatches in the engineering profession. Such policies and initiatives should be based on research and studies related to the needs of market considering experience in applying successful policies and initiatives in other countries. The participation of key stakeholders is very important for the success of such policies and initiatives. Several policies can be effective like the integrate into engineering curricula of topics regarding digital literacy and coding, green technologies, resilience engineering and entrepreneurship, for strong understanding of students for the emerging technologies and their familiarization with the culture of enterprises and the handling of difficult cases in work, the provision of scholarships to students who will choose the expertise on the fields of digital, green, resilience, and entrepreneurship skills, the continuing training and education for the upskilling of professionals, the collaboration between educational institutions and the industry and construction sector in order to identify market needs and design training programs accordingly, the direct communication between government authorities and stakeholders for sharing opinions, experiences and decisions-making, the financial support and incentives like tax breaks, from government authorities in order engineering sector to invest at new digital and green technologies, the financial support from government authorities for young engineers to establish startups, the financial support in research and development in digital and green technologies.

2.6 Spain

2.6.1 Analysis by National Agency for Quality Assessment and Accreditation of Spain (ANECA)

Introduction

The job of an industrial engineer is changing as the pace of innovation accelerates in many industries. Now more than ever, companies need engineers who can adapt to changing conditions and lead teams. The engineer is present in all these productive sectors and associated services such as energy, industry (mechanical, electrical, electronic and chemical), logistics, environmental, food, hospital, transport, naval, infrastructure, construction and building, engineering, services, as well as in administration, government and even consultancy.

The level of employment of engineers is expected to increase by 15% by 2030. During this period, more than one million new jobs for researchers and engineers will be created. All 27 EU Member States are expected to create new jobs for engineers. Given this projected growth and the 3.3 million workers expected to leave the profession for one reason or another, around 4.3 million vacancies will need to be filled.

According to a report by the World Economic Forum, over the next five to 10 years, around half of the world's workers will have to reskill and adapt to new jobs that do not exist today.

As the work of engineers involves the use of many new technologies, demand for engineers is expected to be high in most sectors. Key sectors where this demand is expected to increase include services, manufacturing, education and healthcare.

The importance of the development of the engineering sector in recent years towards a more sustainable future has led to the evolution of the most sought-after professional profiles in this area.

All production processes are tending to become increasingly sustainable. Spain is one of the countries where most engineers are trained and develop professionally in the field of sustainability. The job of an industrial engineer is changing as the pace of innovation accelerates in many industries.

Factors likely to change the professional profile of engineers in the coming years include the following:

- New technologies, such as those linked to renewable energy, will create unique skill sets.
- Biotechnology is also the driver of innovation for researchers and engineers in several sectors, including healthcare.
- Electronic components such as those used in building automation and smart homes are playing an increasingly prominent role, particularly in the construction sector.
- Consumer demand for more specialised products is contributing to more technology-intensive production processes, which challenge the capabilities of engineers.
- Climate change will increase the demand for engineers and life scientists to support related research and development.

- Globalisation means that strong interdisciplinary and communication skills are becoming increasingly important for researchers and engineers.

- Sector specific trends will also play a role: for example the integration of ICT in the pharmaceutical sector will affect the need for skills in this sector.

While skills challenges are conditioned by sector-specific developments, training plays an important role throughout the process. It is essential for the development of sector-specific skills, but also of transferable skills, such as business, operational and leadership expertise.

Partnerships and joint initiatives between government authorities, social partners and others can provide solutions to address skills shortages and accelerate the adoption of appropriate training approaches in new sectors requiring specific skill sets.

Climate change, the drive towards sustainability and the pandemic crisis are proving that STEM (science, technology, engineering and mathematics) careers are increasingly important. Teacher training and effective career guidance can also help to make STEM subjects more attractive to students in primary, secondary and higher education. The European Commission and Member States are also joining forces to make these professions more attractive to women.

In recent years, the professional competences taken into account by companies have been changing. This is due to the fact that both the professions themselves and the models of work and business organisation are undergoing major changes.

Basically, a professional competence is an attitude. If you complement your training with these kinds of behaviours, your chances of becoming a great professional will increase. Thus, we can divide these skills into two main groups:

- Hard skills: these are the technical and job-specific skills you have. These skills are obtained through training and experience. For example, if you are a programmer, you should have programming skills.

- Soft skills: these are skills related to personality. These skills can also be acquired with a little effort and some training. For example, team work, good emotional management, organisation, etc.

Although they may seem less specific, soft skills are becoming increasingly important. Many companies are looking for people with these skills. Social relations and the business world are changing. Beyond specific knowledge in one area (which would be the hard skills), today and in the future, it will be necessary to have a series of transversal skills that make it possible to meet the needs of companies. These are some of the most important for the future:

Engagement

Now that almost all sectors are moving towards more sustainable business models and people are realising the need to do their part to save the environment, engagement is one of the key skills you will need to develop. The ability to understand the needs of the business and the environment, to be able to see different points of view and to make a decision that takes all aspects into account is essential.

Communication

To be successful you need to communicate your views and ideas. You must do this with enthusiasm, conviction, honesty and emotion; this is something that machines cannot do. Communication is increasingly taking place via video, as recorded or live talks, so presentation skills are becoming a necessity. With this you need to be flexible in your communication so that you can adapt to different audiences.

Curiosity and creativity

The labour market is changing because of people's creativity, i.e. robots were a human idea. Creativity requires a certain intuitive unpredictability that cannot currently be imitated by machines, like the design of a building by an architect, for example. To work on curiosity, you will have to observe the world and find ideas and opportunities that you think will be important. You will have to see possibilities that others cannot see. You must let go of your judgements of practicality and possibility, and focus more on seeing potential.

Problem solving

It is necessary to be able to make decisions and act with confidence when faced with a difficult situation. Management experience can be an asset, because it brings security.

However, it is not just about experience: generally, being able to think analytically and having the creativity to find other perspectives can help you solve the problems companies face.

The environment is changing, so there are always new cases of conflict. It is advisable to remain calm and apply critical thinking to analyse the situation. Initiative is one of the most valued professional skills.

Organisation

Nowadays, a worker has to be prepared to deal with multiple tasks (there is a trend towards polyvalence). He/she can sometimes be affected by stressful situations if he/she is not able to self-manage work and time.

Today's world is moving faster and faster, production processes are becoming shorter and delivery of tasks may be subject to tight deadlines. In this respect, the employee must be able to plan ahead, manage timing, withstand pressure and be able to adapt to any situation and task.

A flexible mind and a positive character help a lot in developing these skills. You can also devise specific self-management strategies.

Teamwork

Another paradigm that exists today and is expected to increase in the future concerns the complexity of work processes.

In the past, a single person could perform all or almost all actions in a field of action. However, due to an increased demand for added value, the quality of the final work requires teamwork.

Diversity of viewpoints (in a multidisciplinary team) has become an imperative. Working alone cannot achieve the quality and speed that a team can achieve. This requires perfect co-ordination, which means communicating fluently and listening to each other's needs.

In this context, aspects such as respect and tolerance for the ideas of others, negotiation skills to reach agreements in the team, good communication, leadership and influence and other social skills play an important role.

Take the initiative

Businesses suffer when risks are not taken. It is important to think outside the box and come up with new ideas and designs.

Use of technological tools

Information and Communication Technologies (ICTs) are penetrating all sectors. These types of solutions are necessary for a company to remain competitive.

Therefore, any professional has the obligation (no longer the need) to learn how to use them in an impeccable way.

Digitalisation is a fact, all companies in the future will have to have an online presence. Moreover, companies use various types of software to keep internal communications active, analyse data, monitor costs, etc.

In short, technology is a resource of prime necessity in business. Not having professional skills in this field means being left far behind in a recruitment process.

For our work for having sources of information for skills and competencies in the engineering world, several sources of information are very important, and we can focus on three parts:

a) The work done or promoted by institutions, in the Spanish case, by ANECA
b) The research done for the engineering professors distributed and published in conferences internationally well renowned
c) The Society in general and the managers of the companies, in particular that they know very well the needs of the companies for developing the work in production and in management, work to be done by engineers.

In the next pages we develop a bit more every one of this three parts.

Institutional studies

ANECA develops a great work with Spanish universities and in particular, with the Schools of engineering for improving the teaching and learning process, as well the skills and competencies that the engineers must have for their future work. In such a way promoted by ANECA, several white books have been written.

The white books are the result of a work carried out by a network of Spanish universities, supported by ANECA, with the aim of carrying out studies and practical assumptions useful in the design of engineering degrees adapted to the EHEA.

The books presented here include numerous fundamental aspects in the design of a engineering bachelor's or master´s degree model: analysis of the corresponding or related studies in Europe, characteristics of the selected European degree, studies of labour insertion of graduates during the last five years, and profiles and professional skills, among other aspects.

In its development, the participating universities have carried out an exhaustive work, debating and evaluating different options, with the aim of reaching a final consensual model that includes all the relevant aspects of the degree under study.

In the web page of ANECA it is possible to find the next white books:

- White book of nautical and maritime engineering degree https://www.aneca.es/documents/20123/63950/libroblanco_nautica_def.pdf/94fecb88-9f9c-5cdf-8008-39c7e70c8bea?t=1654601641580
- White book of naval and oceanic engineering degree https://www.aneca.es/documents/20123/63950/libroblanco_naval_def.pdf/1e5a0323-1794-c525-7cd0-27561e0c8d25?t=1654601686376
- White book of the industrial engineering degree. In this book there are the studies of:
    - Chapter I. Industrial design and product development
    - Chapter II. Electrical engineering
    - Chapter III. Electronics and Automatics engineering
    - Chapter IV. Mechanical engineering
    - Chapter V. Industrial management
    - Chapter VI. Chemical engineering
    - Chapter VII. Materials engineering
    - Chapter VIII. Textile engineering

  https://www.aneca.es/documents/20123/63950/libroblanco_industrialessup_def.pdf/cbbcca6a-77aa-65db-dd71-4bee114b3ce1?t=1654601644613
- White book of aeronautical engineering degree https://www.aneca.es/documents/20123/63950/libroblanco_aeronautica_def.pdf/71e9d121-d79f-9b7b-cf3e-9886a2becc62?t=1654601686963
- White book in materials engineering degree https://www.aneca.es/documents/20123/63950/libroblanco_materiales_def.pdf/9c484bc6-d933-56de-2a44-42021e015315?t=1654601687750
- White book in Chemical engineering degree https://www.aneca.es/documents/20123/63950/libroblanco_ingquimica_def.pdf/c03fea54-7b9a-dcfa-2633-bce49a27284f?t=1654601692381
- White book in Telecommunications engineering degree https://www.aneca.es/documents/20123/63950/libroblanco_telecomunicaciones.pdf/e8fbaa75-bdd4-c289-fbb4-c4fa0509e24e?t=1654601707122
- White book in Civil engineering degree https://www.aneca.es/documents/20123/63950/libroblanco_ingcivil_def.pdf/28f7585c-7986-63ba-1eb5-2cf6c9c11b6f?t=1654601731634
- White book in Agricultural and forestry engineering degree https://www.aneca.es/documents/20123/63950/libroblanco_agrarias_forestales_def.pdf/ce8f1b9d-8f9e-c3cc-1267-5ff12c2a1a0b?t=1654601751220

- White book in Mines and Energy engineering degree https://www.aneca.es/documents/20123/63950/libroblanco_minas_def.pdf/e9c06e7b-8684-18a5-6243-3e5eb5ecaba4?t=1654601768501
- White book in Building engineering degree https://www.aneca.es/documents/20123/63950/libroblanco_jun05_edificacion.pdf/c7a27074-cb27-d316-b9a0-15b50a00562c?t=1654601777930
- White book in Informatics engineering degree https://www.aneca.es/documents/20123/63950/libroblanco_jun05_informatica.pdf/133da07c-df6a-b56b-b536-bc1b4d3180a8?t=1654601783672
- White book in Geomatics and topography engineering degree https://www.aneca.es/documents/20123/63950/libroblanco_jun05_topografia.pdf/0d3a07be-8d40-053c-a72b-048e17249c2c?t=1654601812195
- White book in Materials engineering degree

Universities or Regional government agencies work for improving the engineering education and some other documents or information can be obtained by the web, like the report of UNED, National Distance University, that has prepared a very important report about the methods used for teaching and his impact in some skills in function of the taught technology (The Engineering Education Report (uned.es))

Initiatives in Spain and other countries

The schools of Engineering in Spain have constituted a consortium for promoting the improvement in teaching engineering. For so 30 years ago they organized a conference (CUIEET, University Conference in Innovation in the Technical Education) about education in engineering [1]. Most books of papers are available on Internet.

In such a conference it is possible to find a lot of papers about competences and skills and the way to teach for integrate the skills in the curricula of students. Each year more than one hundred of papers about innovation in engineering education are presented and discussed

Another big society that performs research in Engineering education is the Institute of Electrical and Electronics Engineers (IEEE) that groups more than 200,000 engineers all over the world. In the IEEE there are several societies, one of them is Engineering Education Society that groups engineers interested in education in universities and in companies. This Education Society IEEE EdSoc) organises several conferences annually.

One of them is for all world, Frontiers in Education, FiE [2] and there are other regional conferences covering a large part of regions. Most of the papers send to these conferences are published in the journal IEEE Transactions on Education [3] and accessible for subscribers or members of the IEEE through https://ieeexplore.ieee.org. Some of the conferences are:

- **EDUCON**. Annual Global Engineering Education Conference for Europe The IEEE Global Engineering Education Conference (EDUCON) is one of the flagship conferences of the IEEE Education Society. EDUCON 2023 is the 14th in a series of conferences that rotate among central locations in IEEE Region 8 (Europe, Middle East, and Africa).

Held annually since 2010, EDUCON provides an opportunity to scientists, professional engineers, and students to present their work, publish their results, exchange ideas, and network for future scientific and industrial collaborations. [4]

- **TALE**, an international conference on engineering, technology, and education is the IEEE Education Society's premier conference series in the Asia-Pacific region. It aims to provide a forum for scholars and practitioners to share their knowledge and experience in engineering and technology education, as well as in technology-enabled educational innovation across a variety of academic and professional disciplines. The target audience of the conference is diverse and includes those working in the higher education, vocational education and training (VET), K-12, corporate, government and healthcare sectors [5]
- **EDUNINE** [6] IEEE World Engineering Education Conference is a unique and innovative international conference that favours the exchange of knowledge, experiences and is a meeting point for academics, professionals, researchers and students of education in Engineering, Computing and related topics from Latin America and the rest of the world. The program of the conference covers the main issues that are presented in education today, among which stand out: the design and development of new learning environments, the use of new technologies and experiences, the motivation of students, the evaluation of learning and competences, intervention in the face of learning difficulties, etc.

Other engineering sectorial associations organise technical conferences but always there is a section devoted to education in such kind of engineering. The list of conferences is very large but some of them can be indicated below:

- **AEIM** [7] The National Conference of Mechanical Engineering is held biannually and is the main meeting place for the exchange of scientific and technical knowledge, professional experiences and competitive projects in the field of Mechanical Engineering at a national level.
- **TAEE** [8] The objective of the TAEE Conference is to improve teaching in the field of Electronics through joint reflection on the problems faced, the generation of didactic resources, mainly with a technological base, the promotion of reuse and the cooperative generation of knowledge. and, especially, its link to research and professional activity.
- **SAAEI** [9] The SAAEI is an annual conference and is aimed at national researchers and companies so that they can share the results of their research, exchange ideas and form consortia with which to undertake future projects with greater efficiency and impact. The congress seeks papers describing original work in the fields of automation, electronics, instrumentation and education.
- **CISTI** [10] The CISTI is an annual technical-scientific event, which aims to present and discuss knowledge, new perspectives, experiences and innovations in the field of information systems and technologies.
- **ICREPQ** [11] The intention of the organisers of the 22th International Conference on Renewable Energy and Power Quality (ICREPQ'24) is to give an opportunity to academics, scientists, engineers, manufacturers and users from all over the world to come together in a pleasant location to discuss physically recent development in the areas of Renewable Energies and Power Quality.
- **MECCE** [12] This conference is presented as a great opportunity to implement the entire 2030 Agenda from science and its power of transfer.

In addition, the special times in which we are involved mean that society, companies, and professionals need to obtain more real answers to the challenges we face in terms of digitalization, energy, decarbonization, circularity, new materials, and new surfaces. Considering, of course, all Chemical Engineering topics like Unit Operations and Separation Processes, Chemical Reaction Engineering, Process Systems Engineering, Product Engineering, Applied Biotechnology, Safety, Health and Environment, or Chemical Engineering Solutions to Global Societal Challenges. An edition where the scientific community will dress up to offer and to share its knowledge in essential and critical industrial sectors.

The great differential value of this conference is that it unites science and industry, being a unique bridge for the scientific and business communities to come together in an incomparable setting.

Apart from these conferences it is possible to find lots of studies about competences and skills for engineers and the needs for new skill for the future. This is possible to find lots of papers published in international technical journals and in the Internet.

Sources of information of the Society

The information from the Society can be obtained from our research with the surveys done last months, but some other sources can be the European Union with several organizations working for the labour market like CEDEFOP (https://www.cedefop.europa.eu/es/publications/research-papers)

Cedefop's skills forecast allows us to imagine what the world of work might look like ten years from now by forecasting future trends in employment. In our new series of articles, we examine the potential challenges and changes that certain professions will face between now and 2030 https://eures.ec.europa.eu/future-work-researchers-and-engineers-2021-05-12_es

https://www.cedefop.europa.eu/es/projects/skills-forecast

https://www.cedefop.europa.eu/en/themes/skills-labour-market

The 2023 Skills forecast of CEDEFOP is the latest round of the forecast and covers the period up to 2035. The forecast takes account of global economic developments up to Spring 2022. The short-term GDP projections are in line with Ameco's Spring 2022 Economic Forecast, while the long-term projections are in line with the GDP projections used in the Europop 2019 population projections, as detailed in the 2021 Ageing Report. Since the 2021 Ageing Report does not contain assumptions about the European Green Deal, the long-term GDP projections have been adjusted to reflect the implementation of parts of the Green Deal, based on information from the European Commission Fit-For-55 Impact Assessment. For full details please see our Technical Report (https://www.cedefop.europa.eu/en/publications-and-resources/data-visualisations/skills-forecast) .

At the European level, there is the initiative led by Cedefop (European Centre for Development of Vocational Training) [14]. More specifically, Cedefop Skills Forecast. Cedefop Skills Forecast provides comprehensive information on future labour market trends in Europe. The forecast acts as an early warning mechanism to help alleviating potential labour market imbalances and support different labour market actors in making informed decisions. The Skills Forecast does not intend to replace skills anticipation and forecasting initiatives taking place at national level, which are often built around more sophisticated methodologies and may offer a greater level of detail. The strength of the Cedefop Skills Forecast is that it uses harmonised data and a single methodology to make results comparable across countries which can be aggregated to provide an overall picture of labour market trends and skill development in the EU. The results cover all EU Member States plus a few more countries.

The following links provide relevant information on this initiative, which aims to complement the work carried out in other projects, such as the E4E:

https://www.cedefop.europa.eu/en/tools/european-skills-index

https://www.cedefop.europa.eu/en/tools/european-skills-index/country/spain

https://www.cedefop.europa.eu/en/themes/new-forms-work

https://www.cedefop.europa.eu/en/themes/skills-changing-societies

https://www.cedefop.europa.eu/en/themes/skills-and-jobs-demand

https://www.cedefop.europa.eu/en/themes/digitalisation

https://www.cedefop.europa.eu/en/themes/utilising-skills

https://www.cedefop.europa.eu/en/themes/matching-skills-and-jobs

https://www.cedefop.europa.eu/en/themes/learning-anticipate-and-match-skills

https://www.cedefop.europa.eu/en/themes/skills-labour-market

https://www.cedefop.europa.eu/en/themes/supporting-stakeholders-skills-intelligence-and-matching

https://www.cedefop.europa.eu/en/themes/new-forms-work

In addition, the special times in which we are involved mean that society, companies, and professionals need to obtain more real answers to the challenges we face in terms of digitalization, energy, decarbonization, circularity, new materials, and new surfaces. Considering, of course, all Chemical Engineering topics like Unit Operations and Separation Processes, Chemical Reaction Engineering, Process Systems Engineering, Product Engineering, Applied Biotechnology, Safety, Health and Environment, or Chemical Engineering Solutions to Global Societal Challenges. An edition where the scientific community will dress up to offer and to share its knowledge in essential and critical industrial sectors.

The great differential value of this conference is that it unites science and industry, being a unique bridge for the scientific and business communities to come together in an incomparable setting.

Other associations sectorial or generals that can send some information about skills and competencies for the future engineer are:

- the associations of engineers in different countries in general (Colegio de ingenieros industriales (https://ingenierosindustriales.es/) , colegio de ingenieros técnicos (https://cogiti.es/))
- The Federation of Chemical Industries FEIQUE (https://www.feique.org/)
- AFMEC (https://www.afmec.es/) the Spanish Association of Machining and Metalworking Transformation, is a new association designed to group and serve companies of machining, boilermaking, deformation and everything related to metalworking transformation
- ANFAC (https://anfac.com/) association of automobile manufacturers
- ANMOPYC (https://www.anmopyc.es/es) association of manufacturers of construction and mining equipment
- AELEC (https://aelec.es/) Association of Companies of Electrical Energy is the organization that brings together the large electricity companies in Spain, an organization that aims to represent, promote, manage and defend the general and common interests of its members and the electricity sector

These are only a short number of examples of company associations that will allow to have more information about the skills needed in a future for the new engineers, but more specialised the group of companies more particulars will be the skills needed.

References

[1] Book of papers of the 29 CUIEET https://riunet.upv.es/bitstream/handle/10251/185329/Libro-de-Actas_CUIEET_29.pdf?sequence=8&isAllowed=y (last access 18/07/2023)

[2] Frontiers in Education Conference, https://2023.fie-conference.org, (last access 18/07/2023)

[3] IEEE Trans on Education, https://ieee-edusociety.org/publication/ieee-toe. (last access 18/07/2023)

[4] Annual Global Engineering Education Conference, https://educon-conference.org/ (last access 18/07/2023)

[5] TALE https://tale2023.org/, (last access 18/07/2023)

[6] EDUNINE, https://edunine.eu/, (last access 18/07/2023)

[7] AEIM, www.asoc-aeim.es/congresos.html,

[8] TAEE, https://congresotaee.es/,

[9] SAAEI, https://www.saaei.org/ediciones/edicion2023/,

[10] CISTI, http://cisti.eu/index.php?lang=es,

[11] ICREPQ, https://www.icrepq.com/,

[12] MECCE, https://www.mecce.org/

2.7 Germany

2.7.1 Analysis by Verein Deutscher Ingenieure (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):

- ***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 2019) - around half of them in traditional engineering professions (See Figure 1).

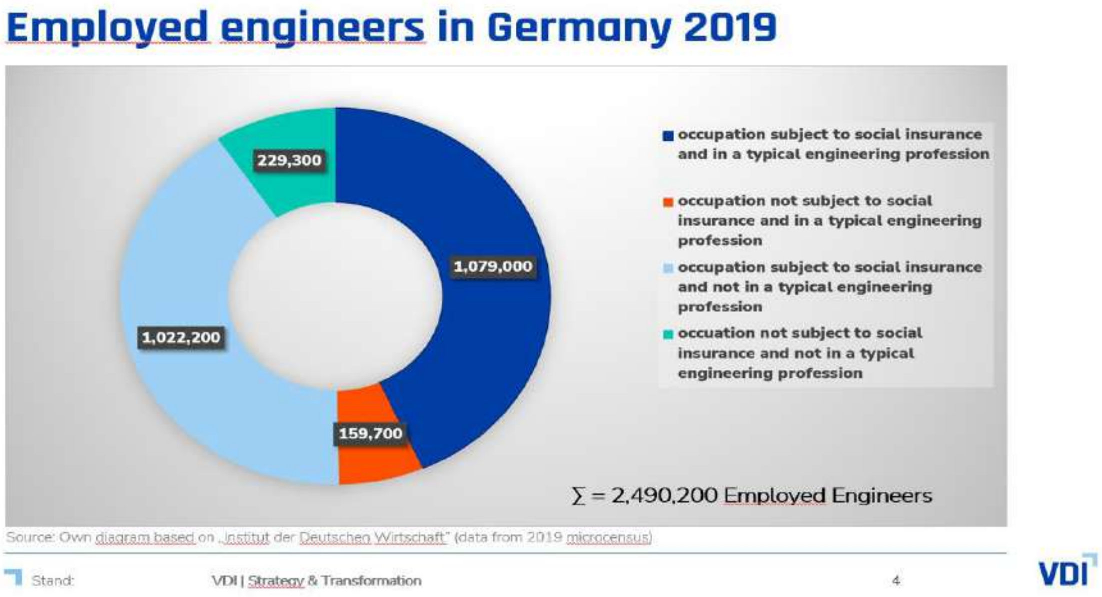

Figure 1: Employed engineers in Germany 2019

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.[58]

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 2022 (IW/VDI 2023).

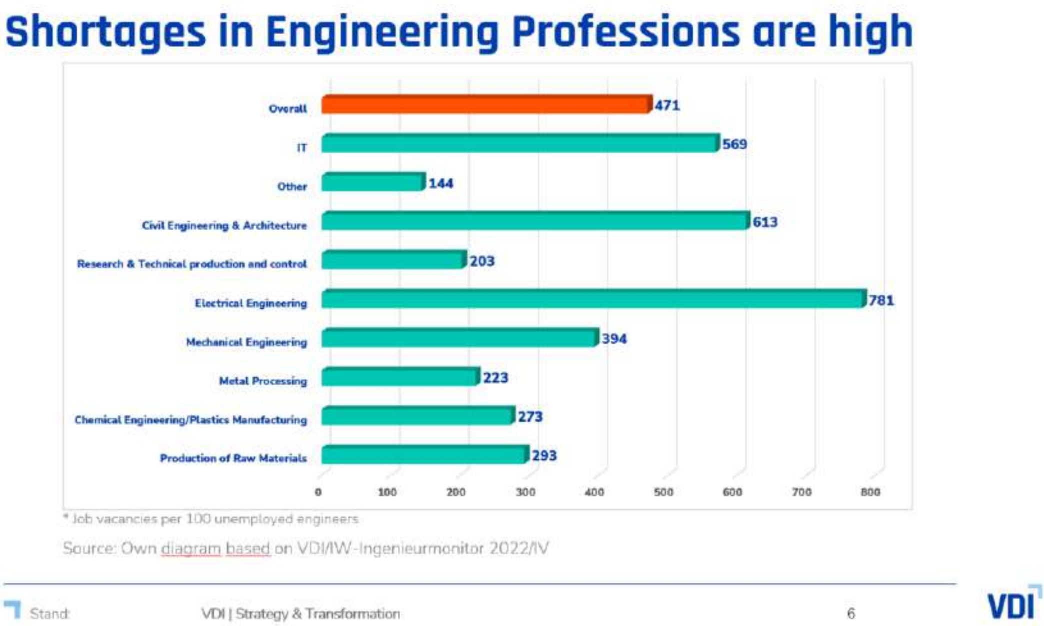

Table 1: Shortages in Engineering Professions in Germany Q4/2022

After a new record level of 492 vacancies per 100 unemployed engineers was achieved in the second quarter of 2022, a slight decline in the shortage ratio was observed in the third and fourth quarters of 2022 (IW/VDI 2023). The total number of vacancies initially rose slightly from 171,300 in the second quarter of 2022 to 173,300 in the third quarter and then fell to 170,300 in the fourth quarter of 2022. The number of people unemployed in engineering and IT occupations rose from 34,821 in the second quarter of 2022 to 36,480 in the third quarter of 2022 and fell slightly to 36,120 in the fourth quarter of 2022. The shortage ratio thus fell slightly to 471 vacancies per 100 unemployed.

[58] It should be noted here, that informational scientists have only been systematically counted as engineers since 2015.

In a year-on-year comparison to fourth quarter of 2021, the number of vacancies in the fourth quarter of 2022 increased by 21.6 percent to 170,300 - a new record value for the fourth quarter. In civil engineering, the number of vacancies increased by only 5.0 per cent year-on-year and has fallen in recent quarters. Rising energy costs associated with the economic slowdown due to the Ukraine war, rising inflation and rising interest rates are having an impact here.

Compared to the previous year, the number of unemployed in engineering and IT remained at almost the same level in the fourth quarter of 2022. At 36,120, unemployment was almost exactly at the previous year's level of 36,128. Unemployment fell particularly sharply in the engineering occupations of technical research and production control as well as mechanical engineering. In contrast, there was a slight increase in unemployment compared to the previous year in civil engineering, in the IT and in the metal technology engineering.

If one relates the number of vacancies to the number of unemployed, the result is the shortage ratio in engineering and IT. In the fourth quarter of 2021, there were still 387 vacancies for every 100 unemployed persons. In the fourth quarter of 2022, this shortage ratio rose to 471 - a significant increase, but a shortage ratio below the record value of the second quarter of 2022 with 492. The shortages differ significantly between the occupations: the greatest shortages exist in electrical engineering, ahead of civil engineering. IT follows in third place. There are also shortages in all other engineering occupations in the fourth quarter of 2022. The shortages in technical research and production control as well as mechanical engineering and electrical engineering have risen particularly strong over the years. Compared to the previous year, however, the shortages in the civil engineering occupations are decreasing.

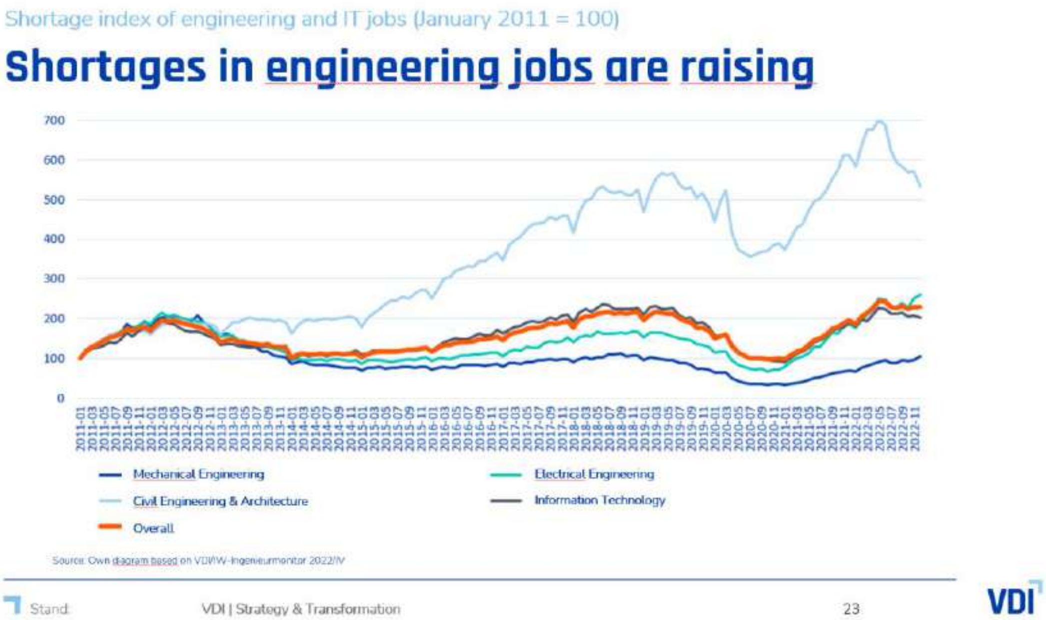

Figure 2: Shortage index of engineering and IT jobs in Germany

In the coming years, digitisation and climate protection will significantly increase the need for employees 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 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 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. 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.

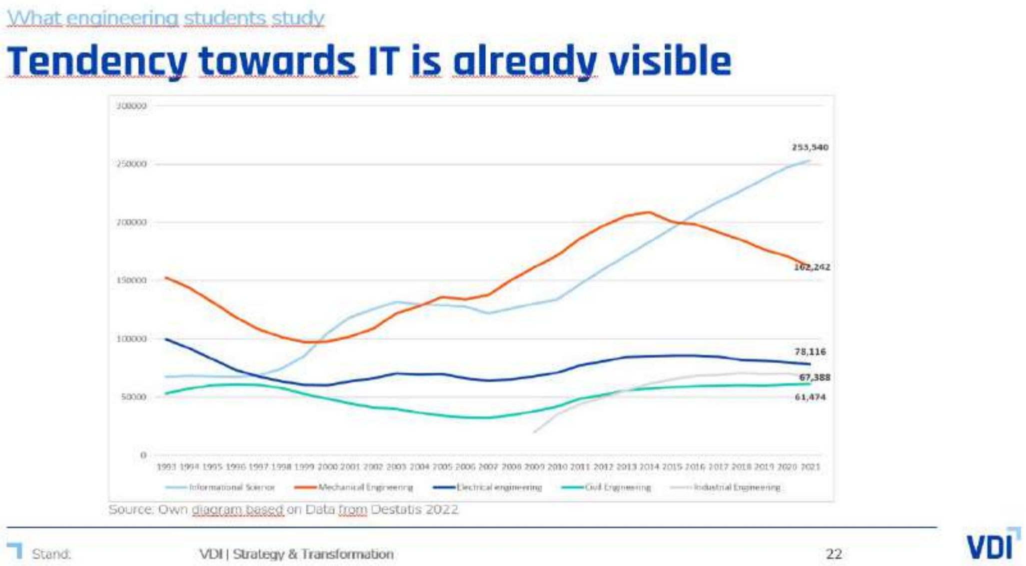

Figure 3: Students in engineering and IT in Germany

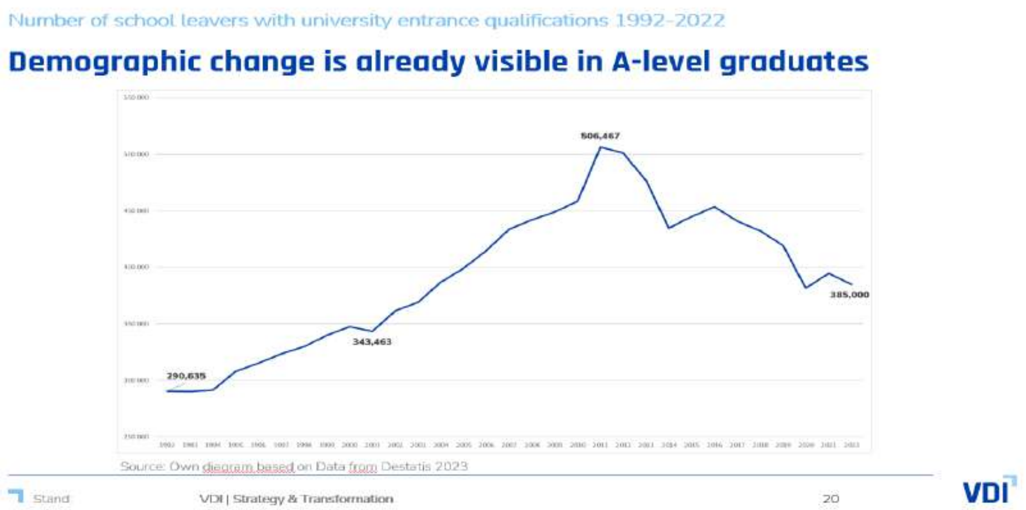

Figure 4: Number of school leavers with university entrance qualifications in Germany 1992-2022

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

3.1 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.

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.

3.2 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.[59]

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 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

[59] It was not possible to generate answers to all of the questions in the interview guide, as the group of engineers to be interviewed are predominantly outside the higher education sector in their professional lives and are also only able to provide information where they have or have had points of contact with the German education system.

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.

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.[60]

[60] Here, the so-called rigidities in the labour market must be taken into account, which make it difficult to change jobs (local ties, family environment, financial obligations, etc.).

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 acitivity, 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.

4. 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.

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.

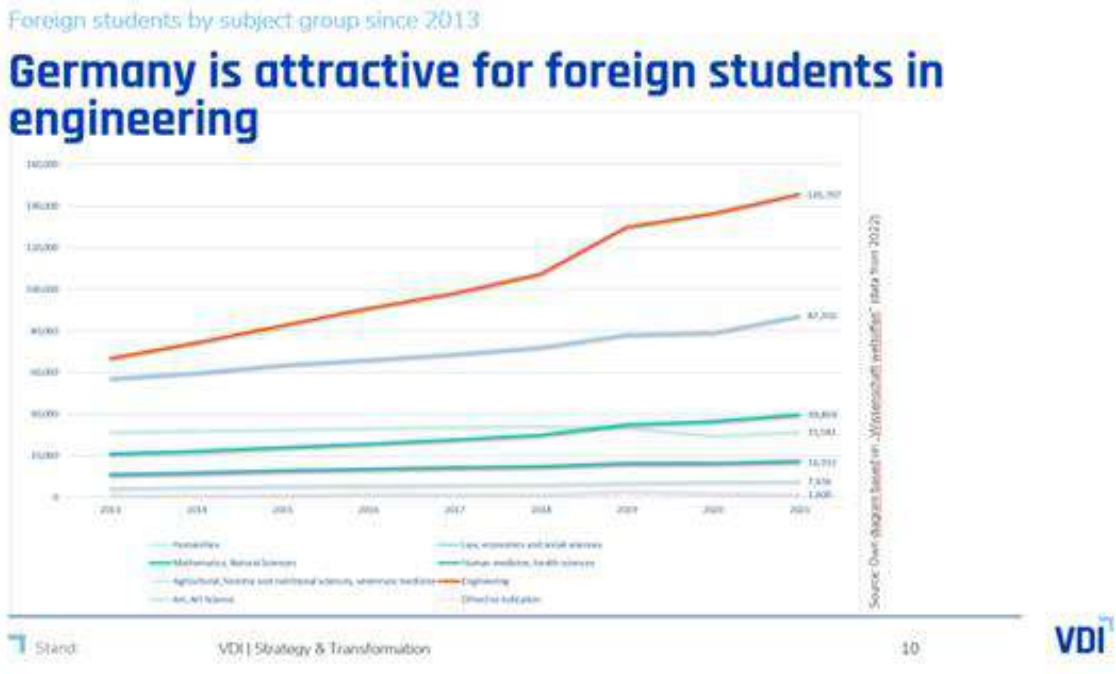

Figure 5: Foreign Students by subject group 2013-2021

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).

5. 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 skills.

6. 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.
- 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.

7. 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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