ane ASSOCIATION OF NORDIC ENGINEERS

TOWARDS A CIRCULAR ECONOMY

Skills and competences for STEM professionals

Produced by Ethica
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FOREWORD

The concept of circular economy is high on the political agenda in the Nordic region, at the EU level and globally, as this new economic system provides solutions to the pressing problems caused by overproduction and overconsumption. The solutions used in traditional or linear economic systems are not viable, nor are they sustainable.

The benefits of transitioning to circularity outweigh the disadvantages. However, more efforts are needed to move from conceptualisation to implementation. This, of course, requires not only a political commitment and the right business mindset but also a prioritisation and investment in innovation, the utilisation of new technological solutions, and the right set of skills and competences.

Engineers and STEM professionals are the frontrunners of new technological development and innovation, and, therefore, it is assumed that the transition to a circular economy will increase the demand for new skills within engineering and the general STEM sector. However, there is very limited knowledge of what skills are needed for this transition and whether these skills are provided in the STEM education field.

The report, which we are proud to present, provides an overview of the future need for STEM and engineering skills during the transition and in a circular economy. It also introduces the Circular Economy Competence Framework for STEM specialists. This framework presents a set of essential technical and analytical skills for creating circular solutions. We suggest that technical universities use it and embed it in STEM educational programmes.

We also call for national governments in the Nordic Region to prioritise skills and competences in their national circular economy strategies. Today, the political compass of circular economy is missing its main component; its competence and development needle to successfully complete the navigation from linearity to circularity.

Moreover, we also invite politicians, in cooperation with business, academia, and social partners, to invest in research on the demand for green skills. Without solid arguments and sound information, we will continue to talk in hypotheticals.

We encourage you to read this report and engage with us in finding the best solutions for securing the skills and competences to match the circular economy.

We would like to express our gratitude to Ethica for producing this report and the ANE working group on circular economy for its coordination efforts.

Trond Markussen
President

Inese Podgaiska
Secretary General

ABOUT THIS REPORT

There is an assumption that a transition to a Circular Economy (CE) in the Nordic region will create demand for new skills within engineering and the general STEM sector. However, there is currently very limited shared knowledge of which STEM skills will be needed for the transition and if these skills are already taught in the current educational and professional STEM environments.

Assuming there will be a future skills gap in the STEM sector, the Association of Nordic Engineers (ANE) working group on circular economy (CEWG) requested an analysis highlighting the specific competences that the circular transition requires and describing the future need for STEM and engineering skills.

The analysis presented in this report enables the creation of knowledge-based recommendations on how to bridge this skill deficiency before it becomes an issue holding back the transition to circular economies in the Nordic region.

The analysis was conducted by Ethica, a circular economy consultancy based in Finland. The analysis is based on 11 expert interviews (interviewees listed at the end of this report), a brief literature review and Ethica's experience in the sector. The experts were selected from all Nordic countries to represent academia, industry and industry advocacy organisations, research and innovation organisations, and circular economy and sustainable development advocates.

ABOUT THE ANE CEWG

The working group on circular economy (CEWG) was created by ANE to better understand what the Nordic region's transition to a more circular economy (CE) will mean for Nordic engineers and other STEM professionals.

ANE is a cooperation platform for engineering organisations in Denmark, Finland, Iceland, Norway and Sweden –and enables the engineering trade unions to speak with a shared voice on a Nordic, European and international level. The cooperation focuses on securing sustainable working lives for engineers and on demonstrating the role of engineers in the sustainable transition of our societies. https://nordicengineers.org/.

The ANE Circular Economy Working Group (CEWG)

Sine Beuse Fauerby, IDA
Jussi-Pekka Teini, TEK
Robert Nyheim-Jomisko, NITO
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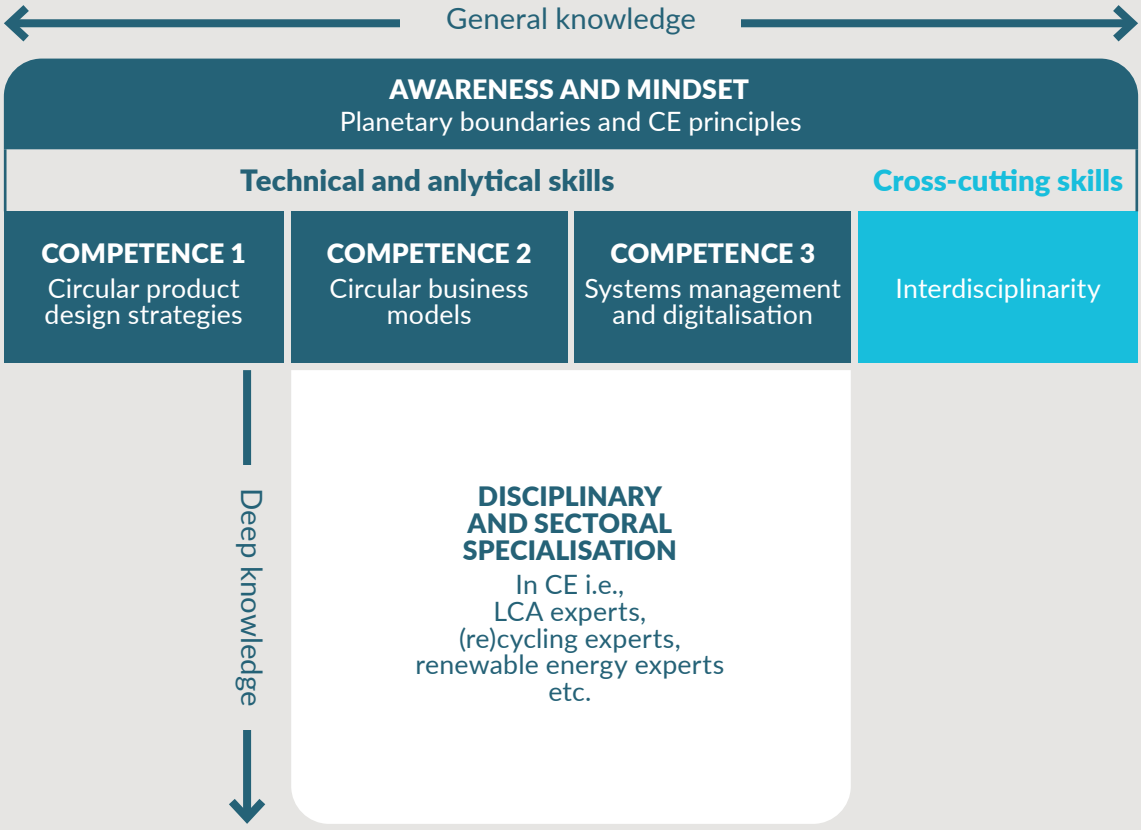
MAIN FINDINGS

- STEM professionals are a key stakeholder group in CE because of their central role in design and technology development.
- Skills and competences need to be developed across the STEM disciplines to leverage the full potential of circular economy in the Nordic societies and beyond. A circular economy competence framework (CEC) is developed in this study to structure the future skills need regarding CE.
- The reasoning behind the framework is that the circular economy principles should guide how the STEM professionals and engineers approach, analyse and solve problems. These principles fundamentally differ from the ones driving the hitherto dominant linear economy. A paradigm shift in problem-solving and design practices is required.
- Awareness of the planetary boundaries and understanding of circular economy principles form a foundation for further implementing technical and analytical tools for circular problem-solving.
- Circular thinking should be embedded in mainstream design and engineering practices. All STEM professionals should have at least knowledge of the core technical and analytical frameworks related to circular design and business models, systems management and digitalisation that support the creation of circular solutions.
- Interdisciplinary and cross-disciplinary collaboration is fundamental for the circular transition.
- A snapshot analysis conducted into five renowned Nordic universities indicates that CE competences are not yet universally embedded in Nordic STEM education.

Model of the Circular Economy CEC framework



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BACKGROUND

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Circular Economy – restorative and regenerative by design

In the past decade, the concept of a circular economy (CE) has been climbing up on the political agenda in the EU. Progressive business leaders, policymakers, academics and NGOs argue that a move towards a more circular economy is necessary to solve global environmental, climate and economic challenges.

The European Commission sees circular strategies and material use as a principal way to accelerate the transition towards a regenerative growth model that gives back to the planet more than it takes and advances the EU towards keeping its resource consumption within the planetary boundaries.[1]

The aim of the CE is to close the resource loops and keep the resources in the system for as long as possible at the highest utility level. One of the global CE advocates, the Ellen McArthur Foundation, describes the circular economy as a system that is regenerative by intention and design. A circular economy can be achieved by

1. **eliminating waste and pollution through the superior design of materials, products and systems**
2. **keeping products and materials in use with new business models and**
3. **focusing on the regeneration of natural systems.**

1 European Commission - Circular Economy Action Plan

The European transition to a regenerative growth model, which is operationalised by circular thinking and business models, is a fundamental systemic change that challenges the way products, services, systems and infrastructures are designed. The concept of CE is well embraced by business as it provides a concrete set of tools to implement the much-discussed concept of sustainable development.

Circular economy strategies at the EU and Nordic countries

The new Circular Economy Action Plan[2] proposed by the European Commission in 2020 aims to further the realisation of the CE. The Action plan focuses on strengthening the existing sustainable product policy framework and widening the scope of the Ecodesign Directive. Also, the Action Plan recognises the importance to support the critical product value chains in comprehensive and coordinated actions towards circular solutions. In addition, an enhanced waste policy will be developed to support waste prevention and circularity. Though, these documents do not explicitly include competence and skills development.

However, the European Green Deal foresees to set up a European competence framework, and the European Commission has promised to propose a recommendation before the end of 2021 on education for environmental sustainability.[3] The public consultation was closed end September 2021.

Many EU member states, including the Nordic countries, have adopted a variety of implementation strategies that are in line with the European Union ambition to transform into a circular economy and a zero-emission continent by 2050. Table 1 on page 13 highlights the different targets in Nordic countries.

2 European Commission - Circular Economy Action Plan
3 European Commission – Education for at greener, more sustainable Europe: Share your Ideas!

The role of skills and competence development in the Nordic strategies and programs

The importance of new skills and competences is recognised by the Finnish government and Sitra, the Finnish Innovation Fund, who have worked together with other parties to accelerate the inclusion of the circular economy competence as part of the education programs. The Finnish program regarding competence development is the most elaborated of all when compared to other Nordic countries. Efforts are being put, for example, to educate teachers and lecturers in the circular economy.

In the Danish, Norwegian and Swedish strategies and action plans, the role of working life competences in circular transition are less pronounced. The knowledge development is addressed mainly through directing funding to research, technology development and demonstrations activities. The Danish Advisory Board for Circular economy recommended that a circular economy be embedded in the entire educational system (one of 27 recommendations).[4] Yet, the current Danish action plan for CE does not suggest any concrete action regarding this. Iceland has not compiled a comprehensive national strategy.

It is not explicitly elaborated in any of the strategies what the circular economy competences contain. Yet, the underlying assumption in all strategies is that the Nordic societies and businesses need to rethink how to design and use products and services and re-evaluate how value is created in economic activities. This requires changes in prevailing thinking patterns of current and future professionals.

4 The advisory Board for Circular Economy – recommendation for the Danish Government

Table 1: **Nordic Strategies towards Circular Economy**

COUNTRY	STRATEGY PUBLISHED	TARGETS
Denmark	Denmark Strategy for Circular Economy was launched in 2018 and an action plan in 2021.[5,6]	• The aim is to increase the competitiveness and productivity of Danish Businesses while decreasing virgin material use. • By 2030 Denmark aims to increase its resource productivity by 40% from the 2014 level, achieve a recycling rate of 80%, and obtain a 70% decrease in GHG emissions from the 1990 level.
Finland	The first roadmap was published in 2016.[7] The Finnish Strategic Circular Economy program was published in 2021.[8]	• Finland aims to be a carbon-neutral country by 2035, and a circular economy is seen as key leverage in reaching the goal. • Target is that the total consumption of domestic primary raw materials in 2035 will not exceed the level in 2015 and that the productivity of resources is doubled by 2035 from the situation in 2015, and circular material use rate (CMU) is doubled by 2035.
Norway	National strategy for a green and circular economy 2021.[9]	• Norway's target is to become a zero-emission country by 2050 and have a 50% emission reduction by 2030.
Sweden	Strategy for the transition in Sweden 2020.[10]	• The strategy draws a vision of a society where resources are used efficiently in toxic-free circular flows, thus replacing new materials. • Sweden aims to achieve net-zero emissions by 2045.
Iceland	Has not compiled a comprehensive national circular economy strategy, but programs to advance the sustainable resources use and recycling of materials do exist.	• Iceland has set a target to have a maximum of 5% of waste being landfilled by 2025. • Compared to other Nordic countries, Iceland has a strong emphasis on the well-being of its citizens and is committed to measuring the prosperity and quality of life beyond GDP.

5 Miljø- og Fødevareministeriet og Erhvervsministeriet - Strategi for cirkulær økonomi - Mere værdi og bedre miljø gennem design, forbrug og genanvendelse
6 Miljøministeriet – Handlingsplan for cirkulær økonomi
7 Sitra - Leading the cycle: Finnish road map to a circular economy 2016-2025
8 Ministery of the Environment: Government Resolution on the Strategic Programme for Circular Economy
9 The Norwegian Government: Norway's strategy for developing a green, circular economy
10 Government Offices of Sweden:Circular Economy – Strategy for the transition in Sweden

The STEM sector's role in the CE transition

Transition to a CE implies significant changes in current industrial systems and business models. Transitions are defined as shifts from one socio-technical system to another, and they require multiple changes in technologies, markets, legislation, and common practices.[11] Technological innovations are at the core of such transitions where systems change come about through the interplay between technology and society.[12] STEM professionals and engineers, therefore, have a crucial role in developing necessary innovations and driving the transition to a CE.

Transitions at a systems level translate to the adoption of new practices and knowledge on an individual level. Studies and the feedback from the expert interviews underline that in the future, every professional should be able to apply circular thinking in their work and have some circular competences, regardless of what they do.[13] The transition in societal (or company level) cannot rely on the shoulders of a few sustainability professionals and managers. Neither it is enough to have a school of "green" designers and architects with a speciality in sustainability matters.[14]

The interviewees shared the opinion that there is a need for universal and basic CE competences in the STEM sector to lead the transition. Many of the interviews identified a skills mismatch, especially in the SMEs, to address the topic of CE and overall sustainability and saw it as an obstacle for growth and, in more general terms, greening the economy. International Labour Organisation (ILO) made similar findings in its survey.[15]

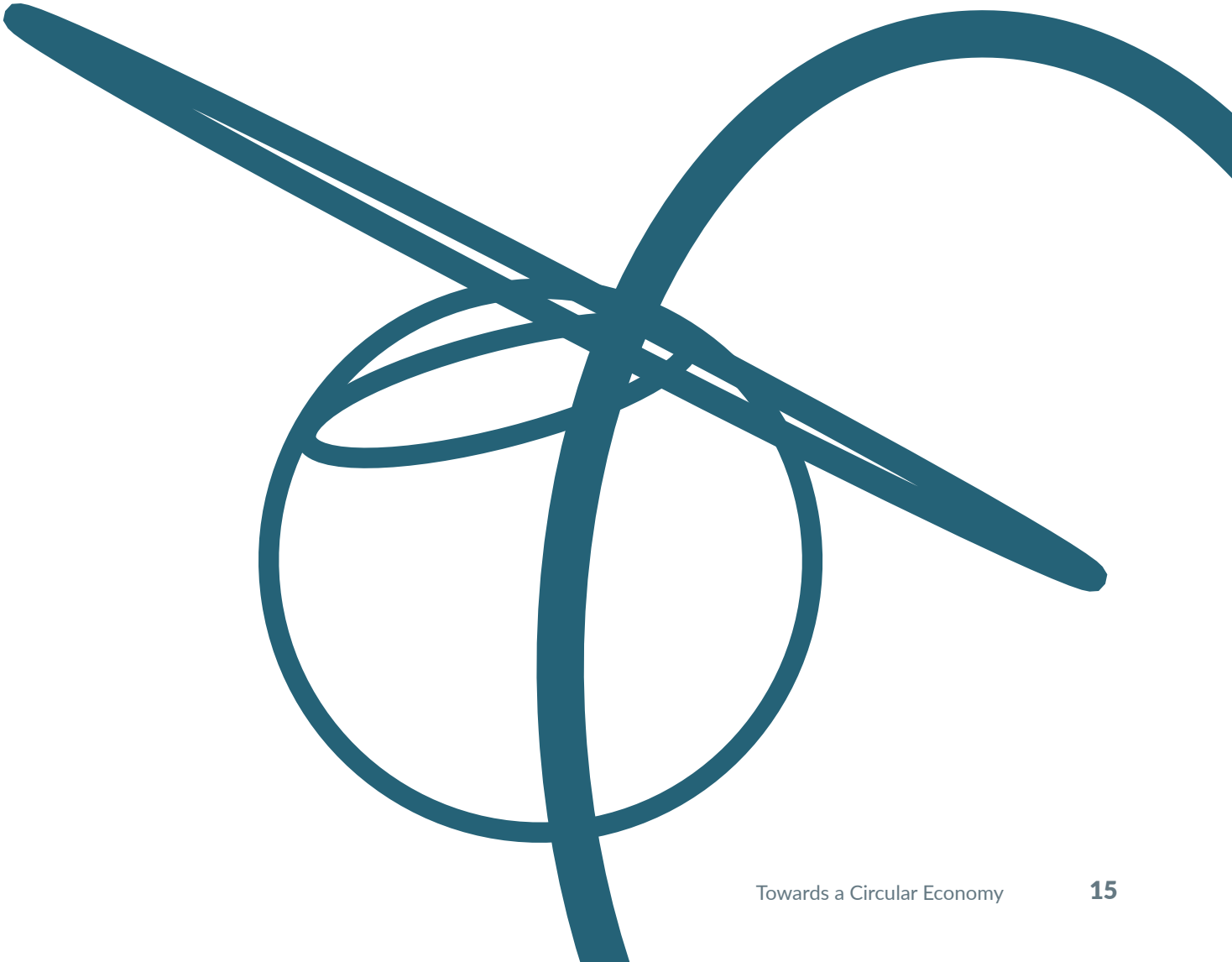
Also, it was noted that the CE initiatives in the EU have typically centred around recycling strategies, i.e., looping materials back into the system.[16] For more radical changes to happen in the world's natural resources use, the CE competence development should be done systematically across all disciplines, resulting in a paradigm shift in the way things and whole systems are being designed.

11 J Grin, J Rotmans, J Schot: Transitions to sustainable development: new directions in the study of long term transformative change
12 F.W. Geels: Processes and patterns in transitions and system innovations: Refining the co-evolutionary multi-level perspective
13 Sitra: How does the circular economy change jobs in Europe: Upskilling and reskilling for a just transition.
14 Expert interviews, Torben Lenau, Elin, Piian Nurmi etc.
15 International Labor Organization: World Employment and Social Outlook 2018: Greening with jobs.
16 Purva Mhatre, Rohit Panchal, Anju Singh, Shyam Bibyan: A systematic literature review on the circular economy initiatives in the European Union

The STEM professionals and engineers have a strong T-shape knowledge profile. That is deep expertise in a single field combined with general knowledge and abilities across disciplines. Sustainability and circular economy should be incorporated more strongly in the horizontal line together with basic competence related to digitalisation and other future cross-cutting skills.

Leena Pöntynen

Director, Skills and Competence, Technology Industries of Finland



2

THE CIRCULAR ECONOMY COMPETENCE FRAMEWORK

The following chapter elaborates on what CE competence means for engineering and other STEM professionals and suggests a framework for a universal CE competence for the STEM sector. The framework is a synthesis based on the expert interviews (for a complete list of interviewees, see p. 37) from the education and business sector, non-governmental organisations, as well as existing literature.

This study proposes a universal Circular Economy Competence (CEC) framework for all engineers and STEM professionals. We will go through each framework element (Figure 1) in more detail in the following chapters.

The reasoning behind the structure of the framework is the following. Engineers and other STEM professionals have problem-solving and design routines that direct their everyday work. These are formed by the technical and analytical skills the professionals possess. The framework introduces a set of technical and analytical skills that are important in the creation of circular solutions. These skills should be embedded in the basic engineering and design education as new knowledge and competence areas.

In addition, to fully support the adoption of circular skills, it is not sufficient to focus only on skills and competences. It is generally accepted that our actions and intentions are affected by our beliefs and

attitudes, and together they form our view of the world. To create a fundamental paradigm shift, there is a need to re-evaluate whether this worldview is based on linear thinking and introduce the circular mindset that creates fertile soil for adopting and implementing CE skills.

Figure 1: **The Circular Economy Competence (CEC) framework**

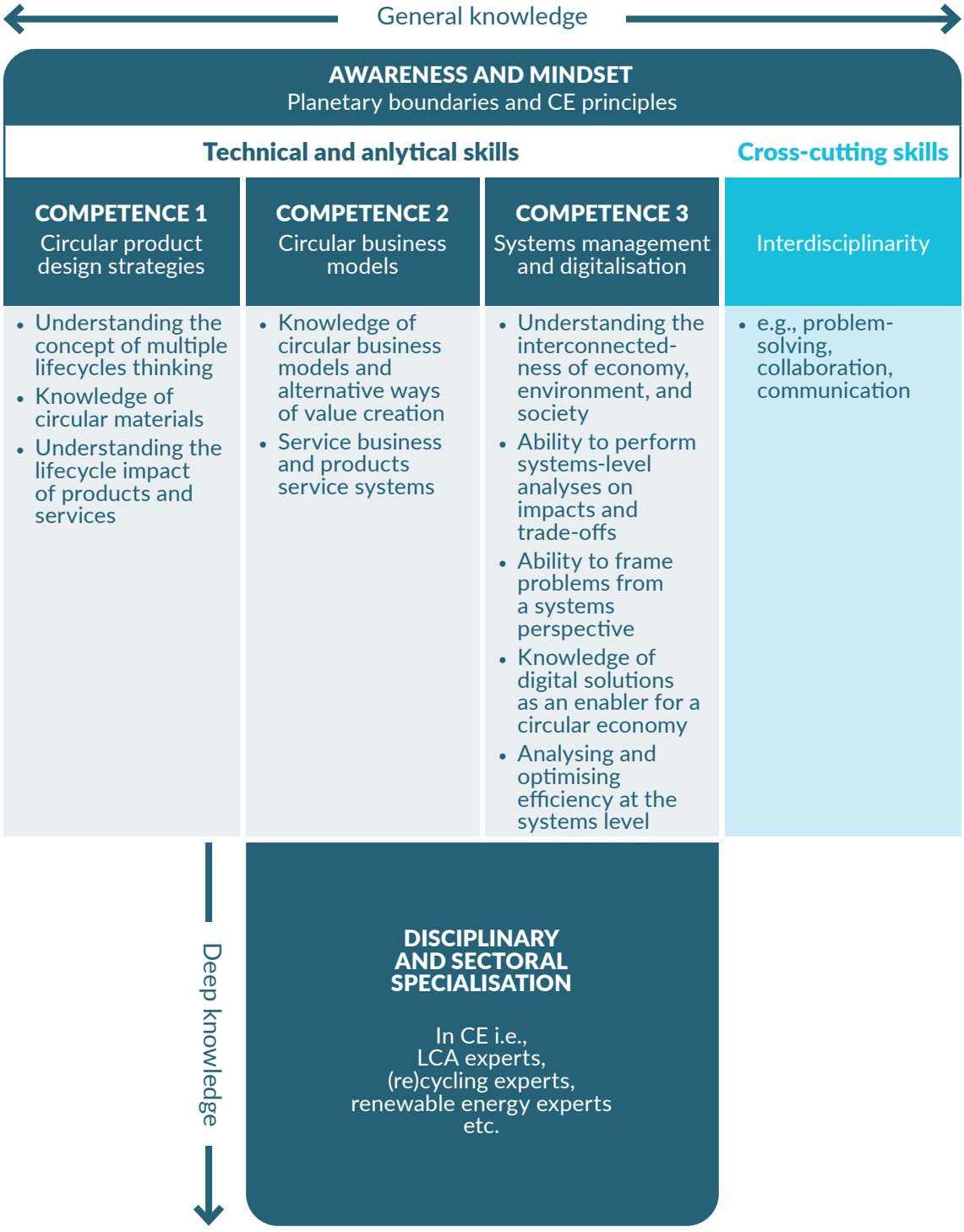


Figure 1: Illustration of the Circular Economy Competence (CEC) framework.
The circular economy knowledge and skills are placed in a T-shape knowledge profile. The horizontal bar represents the cross-disciplinary competences and knowledge that is of a more general type. The vertical bar represents the disciplinary and sectoral specialisation.

I don't think STEM professionals need new skills. They need new questions. If you give them the right problem statement, they will do the job.

Hrund Gunnsteinsdóttir
Managing Director, Festa

Awareness and mindset as a foundation

At the heart of the CEC Framework are awareness and the mindset, which can be called 'circular economy understanding'.[17] These form the basis for more technical and analytical skills discussed later in the text.

The awareness and the mindset are grounded on the following two concepts:

1. Planetary Boundaries: Planetary boundaries concept was introduced in 2009 by a group of Earth system and environmental scientists led by Johan Rockström, aiming to define the environmental limits within which humanity can safely operate.[18] Planetary boundaries are the following nine processes that regulate the stability and resilience of the Earth system:

- **Climate change**
- **Ocean acidification**
- **Stratospheric ozone depletion**
- **Interference with the global phosphorus and nitrogen cycles**
- **Rate of biodiversity loss**
- **Global freshwater use**
- **Land-system change**
- **Aerosol loading**
- **Chemical pollution**

According to the interviewees, there is still very limited understanding in the private sector of the nine planetary boundaries. SMEs, in particular, are struggling to internalise the circular ideas and sustainability work because of limited knowledge resources.

17 TUDelft: Design competencies for a circular economy
18 Stockholm Resilience Centre: Planetary boundaries

2. Circular Economy Principles: Awareness and the mindset is also about having a clear understanding of the holistic CE concept as well as mastering the vocabulary to be able to clearly communicate with others.[19] This competence was seen as foundational to many interviewees as it forms the basis for further actions.

TECHNICAL AND ANALYTICAL SKILLS: COMPETENCE AREA 1:

Circular product design strategies

The role of design plays a crucial role in the transition towards a circular economy. It has been stated, for example, that 80% of the environmental impact of products is determined at the design phase.[20]

STEM professionals and engineers are pivotal in any design process, be it machines, structures, and other items such as industrial processes or logistics systems. Thus, the competence to harness a circular design approach applies to all STEM professionals.

Circular product design strategies refer to a set of approaches that aim to keep the right (safe & non-toxic for living beings and the environment) materials in circulation through various product features. The big goal is to support the idea of decoupling; that is, decoupling the creation of growth and well-being from the increasing use of virgin raw materials and natural resources (see Figure 2). For example, 'design for disassembly' should enable disassembly and reassembly of the product without damaging it.

The world is finite and has a finite carrying capacity. It is crucial to understand how natural systems work and what the planetary boundaries are. I don't think we emphasise these yet enough in any level of education.

Elin Larsson

Program manager, RISE

19 Stockholm Resilience Centre: Planetary boundaries
20 Stockholm Resilience Centre: Planetary boundaries

Figure 2: **Illustration of the idea of decoupling**

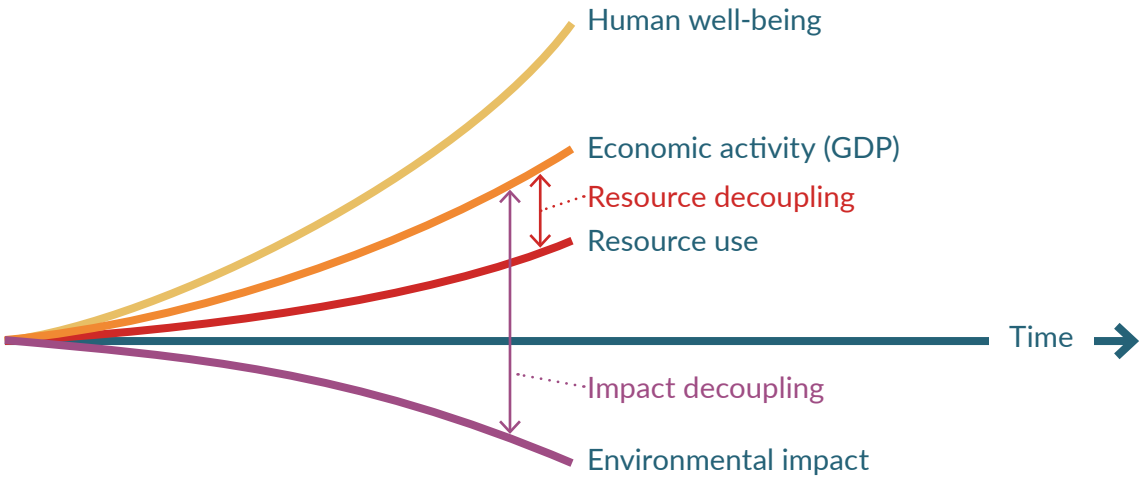


Figure 2: Illustration of the idea of decoupling. Ultimate decoupling is achieved in a society when the environmental impact of economic activities decreases while human well-being increases and the growth in economic prosperity is not dependant on the increase in resource consumption.

Both academia and private organisations have developed sound circular design frameworks that guide embedding circularity in design processes. Some of the most recent literature also addresses the implications of circular design practices to prevailing designers' skills and competences.[21, 22]

Based on literature and the expert interviews, we identify the following analytical and technical skills in the circular product design competence area.

Understanding the concept of multiple lifecycles thinking

Multiple lifecycles thinking challenges the current mindset of STEM professionals. It requires them to look further ahead and predict how the product will be used after its first use cycle, extend the lifetime of the product or its components, and which value recovery strategy to apply. Multiple lifecycles thinking entails considerations of modularity, durability, and safety as well as maintainability, repairability, updatability, reusability and recyclability of products and materials.

21 TUDelft: Design competencies for a circular economy
22 Giliam Dokter, Liane Thuvander, Ulrike Rahe: How circular is current design practice? Investigating perspectives across industrial design and architecture in the transition towards a circular economy

Knowledge of circular materials

A basic level understanding of what makes material fit for a circular economy is needed to be able to search for better alternatives and make educated choices between different materials. A starting point is considering all materials as nutrients (elimination of waste).

The next step is the recognition of biological (renewable) and technical (non-renewable) material flows and their separate cycles, either in industrial or biological processes. The third step is knowledge of non-toxic chemicals, as chemicals can have a massive impact on human health and the environment and interfere with biological and technical cycles. For example, an acoustic panel could be made of renewable material, thus belonging to a biological cycle. At the end of the lifecycle, it could be used as a soil conditioner (nutrient), but only if chemicals used in the product are non-toxic. If the panel is coated with a chemical cocktail, it can no longer cycle in a biological nutrient flow and becomes waste.

Understanding the lifecycle impact of products and services

Design for circular economy further accentuates the need for a holistic view of resource consumption and related environmental and social impacts of products and services from cradle to cradle instead of cradle to grave.

Not everybody needs to be an expert in the life cycle impact assessments. Still, everybody should be able to ask the right questions, understand the analytical basis of such assessments and have the ability to apply such information.

Lifecycle and cross-generational thinking, as one interviewee noted, fits quite poorly in the culture of quarterly reports but is imperative for future STEM professionals.

TECHNICAL AND ANALYTICAL SKILLS: COMPETENCE AREA 2:

Circular Business models

The circular economy is an economic model, and accordingly, we need to understand the economic aspect. Many interviewees agreed that a CE requires science and technology professionals to increase the focus on business-related topics in the future. This observation is affirmed by the experience of industrial designers and architects that have adopted circular design practices.[23]

Shortly, a linear business model is based on "sell more, sell faster" business logic and demands an ever-increasing amount of virgin raw materials and natural resources to do business and create growth. Circular business models (CBM), instead, aim to break this bond (decoupling) between the growth creation and the increasing use of virgin raw materials and minimise all negative environmental impacts from the operations. Put differently, the means of value capture, creation and delivery are different from the linear model.

Broadly, CBMs can be categorised in the following way (in practice, they overlap, creating hybrid models):

- **Product-as-a-service & product life extension:** performance or function-based service, enabling the company to retain product ownership and harness reuse/remanufacture strategies. There are multiple sub-categories, such as leasing, renting, providing care service, monthly subscription etc.
- **Sharing platform:** increasing use rate through collaborative models and digital solutions, e.g. car/bike sharing
- **Recovery and recycling:** recovering usable resources or by-products through innovations and technological solutions, e.g. using post-consumer t-shirts as feedstock to a technological process to produce fabric and new t-shirts. Industrial symbiosis is another example: companies within proximity use residual outputs from one process as feedstock for another process.

We identify the following analytical and technical skills in the circular business competence area:

Knowledge of circular business models and alternative ways of value creation

The basic logic in a circular economy is that the value of things should be kept as high as possible for as long as possible. The challenge is that the economic

23 Giliam Dokter, Liane Thuvander, Ulrike Rahe: How circular is current design practice? Investigating perspectives across industrial design and architecture in the transition towards a circular economy

incentives for circular solutions might not be in place yet as the circular value propositions and the financial benefits are usually only apparent when considering multiple lifecycles of products and buildings over a long time. Analytical tools such as life cycle costing can make the circular alternatives more lucrative in economic terms.

Some of the interviewees also noted that whilst we need new technologies, there are already plenty of good technical solutions available. The challenge is not so much in technology development but in implementing and scaling up these solutions. Here again, the barriers might be economical, and it is beneficial if more people can challenge the economic discourse and find alternative business models, where environmental costs are included, and the creation of value is somewhat decoupled from resources consumption.

Service business and products service systems

In product design, the circular solution relies upon combining the physical design and the business model, both aspects being simultaneously discussed and developed. Creating such product service systems requires a basic understanding of business models also from the engineers' and designers' sides.

TECHNICAL AND ANALYTICAL SKILLS: COMPETENCE AREA 3:

Circular systems management and digitalisation

A circular economy requires a fundamental shift instead of incremental twisting of the current system. To develop insights into a real-world system which are typically interconnected, complex, and dynamic, we need capabilities in systems thinking. Circular economy amplifies the need to better understand systems change and how systems function and interact all-around human activities, most importantly, natural ecosystems.

The interviewees noted that there are many inefficiencies in our current systems, for example, logistics solutions, materials management in the supply chain etc., that can be addressed only if the problems are framed from a systems perspective.

The big question and challenge in a circular economy is how do we (re)organise our systems.

Arne Remmen

Professor, Aalborg University

As the systemic picture gets clear, it is also easier for individual actors to see their part. "If you understand the big picture and have a holistic view on things, then you will design things differently." as one of the interviewees, Elin Bergman, Cradlenet and Nordic Circular Hotspot, framed it.

Ability to harness systems thinking consists of the following analytical skills:

- **Understanding the interconnectedness of economy, environment, and society**
- **Ability to perform systems-level analyses on impacts and trade-offs**
- **Ability to frame problems from a systems perspective**

In addition, this competence area consists of the following skills:

- **Knowledge of digital solutions as an enabler for a circular economy**
- **Analysing and optimising efficiency at the systems level** (e.g., supply chain, materials use chain, logistics etc.)

As digitalisation is seen as a primary enabler for the circular economy, it is discussed more in detail below.

The Role of digitalisation in Circular Economy

In addition to CE, another major transition, digitalisation, is accelerating in every sector. Digitalisation should be seen as an integral part and a key enabler for a circular economy. The many possibilities of digital technologies are acknowledged in various EU and national level circular economy research papers.

Digital technologies provide vital tools for the life cycle and systems management in a circular economy. The solutions typically fall into the three categories:

1. **Product and service life cycle management**
2. **Supply chain optimisation**
3. **Analysing and optimising efficiency in the product and the systems level**

All of the three depends on data collection and management technologies, which in many cases are decided at the design phase of a process, product or service. IT professionals should be involved in an early phase of the design process to successfully integrate such technologies into the product and service systems and process optimisation. Other engineers and designers should have the ability to co-design with them the digital dimension of the system at hand. This requires basic knowledge of digital technologies (see Table 2) from STEM professionals and engineers.

There is significant potential in rendering the existing processes more efficient as most of the data collected by the companies are not being used effectively. Sharing data across companies would enable streamlining whole supply chains and logistics systems, but companies need to find the business case for information sharing. On the legislative side, the European Commission's Sustainable products initiative proposes the disclosure of product's sustainability information along value chains in the form of a digital product passport.[24]

Digitalisation enables companies to move up in the value chain by producing more sophisticated services

Riikka Heikinheimo

Director, Confederation of Finnish Industries

The possibility to collect and share data is an important enabler for new circular business models such as in predictive maintenance of machinery or car-sharing platforms (some examples of key technologies can be found in Table 2). Data itself does not provide value unless it is of good quality, processed efficiently and used for something meaningful, which requires understanding in data management and analytics from a broad range of professionals, especially STEM professionals and engineers.

This fundamental shift to service business, for example, in the manufacturing industry, needs to be backed up with skills in customer-centric thinking and service design to provide a relevant value proposition to the customers and the users. Once again, we find interdisciplinary skills essential in the new, more complex value networks.

24 European Commission: Sustainable products initiative

One thing to be noted is that research underlines the need to pay attention to, e.g., energy consumption and the short life span of digital devices containing critical raw materials.[25] Digitalisation is an enabler for CE, but digitalisation is also dependent on CE solutions on the hardware side.

Table 2: **Examples of technologies used in circular economy solutions**

TECHNOLOGY	POSSIBLE USE CASES	EXAMPLES
Artificial Intelligence (AI)	Optimising material use, material recovery, optimising logistics	Alchemite™ finds relationships in high-dimensional data and can optimise against multiple target properties. Generate innovative solutions that you might otherwise miss. https://intellegens.ai/products-services/alchemite-analytics/
		Zen Robotics AI-powered waste recycling solutions https://zenrobotics.com/
Augmented Reality (AR)	Better serviceability, supporting design & training	TeamViewer Assist AR real-time support for customers or service technicians https://www.teamviewer.com/en/augmented-reality
Blockchain	Traceability of materials, material "pass"	Circularise facilitates a shift to a circular economy by digitising and tracing materials across complex supply chains on a public blockchain. https://www.circularise.com/
Internet of Things (IoT)	Collecting data and optimising use, predictive maintenance, product as a service model, assessing the value of used products	Konecranes TRUCONNECT remote monitoring https://www.konecranes.com/service/predictive-maintenance-and-remote-monitoring/predictive-maintenance
Big Data, Advanced analytics		Green mobility car sharing https://www.greenmobility.com/fi/en/

25 European Commission: 2020 Strategic Foresight Report -Charting the course towards a more resilient Europe

CORE CROSS-CUTTING COMPETENCE:

Interdisciplinary skills

A circular economy amplifies some future skills demand that are cross-cutting competences such as problem-solving, collaboration and communication. Nearly all interviewees emphasised the importance of interdisciplinarity as a future circular economy skill.

Sustainable development problems, in general, are problems that do not fit into one discipline. Therefore, it implies that sustainable development learning should be interdisciplinary.[26] This is the case in circular economy learning, too. When building circular solutions, new connections are established between clients, suppliers, manufacturers, and other players in the value chain and across value chains to find opportunities for circularity.

Also, relationships in supply chains may need to transform to enable new ways of collaboration and dialogue. Understanding partnerships and how to co-develop things is also equally crucial when changing whole systems.

Disciplinary and sectoral specialisation

The CEC framework intends to address the question, "What do all STEM professionals need to learn about CE?" However, even if the STEM sector adopts a circular mindset in the future and the engineering practices result in circular solutions, it does not remove the need for more specialised programs in CE to drive innovation.

Specialised CE talent includes, for example, specialisation modules and degree programs in life cycle analyses, recycling of materials, bio- and circular economy etc. Several of these programs are already available in the Nordic higher education institutions, but more will likely be needed when more production has transitioned to circular business models.

Setting up CE specific modules and degree programmes also requires hiring qualified and specialised academic staff to teach them. They will have an essential role as change agents within the academic community.

26 Mulder, Karel & Segalas, Jordi & Ferrer-Balas, Didac: How to educate engineers for/in sustainable development: Ten years of discussion, remaining challenges

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BRIDGING THE GAP IN CURRENT ENGINEERING EDUCATION

To understand better the state of the arts regarding engineering studies and how broadly the topic of circular economy is addressed in the basic study programs, we conducted a simple snapshot analysis on five Nordic universities and six bachelor-level programs.

We selected some of the largest engineering disciplines, mechanical and civil engineering, and investigated (1.) if there is an emphasis in the program to build up the necessary awareness and mindset for a circular economy to start with, and (2.) to which extent the three circular competence areas are covered within the basic studies.

We studied the course descriptions of all the selected programs listed in Table 3 and looked if the subjects concerning the awareness and mindset, technical and analytical skills listed as central circular economy competence, and interdisciplinarity as cross-cutting competence occurred in the program and course descriptions. The results of the study are presented in Table 3.

None of the programs had all the circular economy competence areas fully covered. Many programs encompassed some of the identified key analytical skills, such as life cycle management and systems thinking. Yet, for example, regarding circular design competence, the technical skill of design for multiple lifecycles was barely addressed by any of the programs.

Table 3: **Case study on example programs about CE skills currently taught in Nordic countries**

INSTITUTION / DEPARTMENT	PROGRAM	AWARENESS & MINDSET	CIRCULAR DESIGN	CIRCULAR BUSINESS MODELS	SYSTEMS MANAGEMENT	INTERDISCIPLINARY SKILLS	REMARKS
Aalto University / School of Engineering	BSc in Engineering / mechanical and construction engineering				X	X	
Metropolia / University of Applied Sciences	BSc in Civil Engineering	(X)				X	Sustainable development is mentioned as one of the subjects in the Chemistry of Building Materials and Communication course.
KTH (Kungliga Tekniska Högskola) / Mechanical Engineering	BSc in Mechanical Engineering	X	(X)		(X)	X	Only interpreting the results of a life cycle analysis. Possibility to focus on Industrial Ecology as an elective.
Högskolan i Borås	BSc in Civil engineering	(X)				X	Extensive course on Sustainable development, circular economy not mentioned.
NTNU (Norges teknisk-naturvitenskaplige universitet) / Mechanical Engineering	BSc in Mechanical Engineering, specialisation in product and system design	X	X	(X)		X	Life Cycle Costing.
Western Norway University of Applied Sciences / Civil Engineering	Civil engineer, Environment, plan and infrastructure		(X)		X	X	Considers only life cycle perspective.
DTU (Technical University of Denmark) / Mechanical Engineering	BSc in Mechanical Engineering	X	X			X	
Aarhus University / Civil Engineering	Civil Engineer, Graduate engineer, Diplomingeniör	(X)	(X)			X	General emphasis on sustainability (CE or planetary boundaries not explicitly mentioned).
University of Iceland / Faculty of Industrial Engineering, Mechanical Engineering and Computer Science	BSc in Mechanical Engineering	(X)			(X)	(X)	Elective courses within programme.
University of Iceland / School of Engineering and Natural Sciences	BSc in Civil Engineering	X				(X)	Elective courses within the programme.

The biggest gap between the programs and the suggested CEC framework was related to the circular business competence area. We witnessed that even though many programs incorporated economics as part of basic studies, the circular value creation models were not introduced according to the course descriptions. The only exception here was the Mechanical engineering bachelor program in NTNU (Norges Teknisk-Naturvitenskaplige Universitet) that had incorporated life cycle costing (LCC) as one analytical tool for the students.

Though the study was delimited, it suggests that political ambitions to become circular societies in Nordic Countries do not yet demonstrate in the basic engineering studies, and work needs to be done to incorporate the topic in higher-level education. More comprehensive analyses should be conducted to achieve a tenable picture of the state of the arts of CE education in Nordic Universities. The basis for circular economy competence cannot be left only for elective courses or special programs.

RECOMMENDATIONS

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A successful transition to a circular economy depends on the willingness to take responsibility across all sectors of society and the essential knowledge to enable the change. If the public sector is to focus on, e.g. green public procurement, the sector must understand the climate and environmental impact of spending. Equally, businesses transforming their business models will need support and guidance based on the circular economy principles. Employees with both a specialised and a general understanding of the circular economy are likely to be in strong demand across all sectors.

In this report, Ethica and the ANE CEWG have focused on understanding which STEM competences are needed for the challenges of a transition to a circular economy. Furthermore, the report analyses whether engineers and STEM professionals' education, knowledge and upskilling possibilities are suited to match their central role in the transition to greener societies based on a circular economy.

From the findings of this research, the ANE working group offers recommendations on how to prevent a skills gap in the transition to CE. The recommendations are provided at three levels: Policymakers, higher education institutions, and employers.

For the policymakers both at the EU and the Nordic levels

- **Include a strong focus on skills and competences in national circular economy policies.** The national policies on CE must encompass the development of CE education and competences, as well as upskilling and reskilling within the lifelong learning framework. The knowledge development associated with the transition towards a circular economy is not explicitly addressed in the national strategies in the Nordic Region apart from in Finland.
- **Conduct more research on the demand for skills for a green transition.** Researching which green skills and competences are needed in the future can help prevent a skills mismatch and provide a clear picture of the demand side.
- **Provide funding for higher education institutions to enable the transition to a circular mindset**. The transition into circular societies is dependent on a mindset change and the continued education of future circular economy professionals. Funding should be made available to enable existing academic staff to acquire circular competences. Public funding for higher education institutions' research, development and innovation activities could be focused on circularity, and building networks and ecosystems focused on sustainability with businesses and the public sector.
- **Broaden current strategies at the Nordic level.** The spectre of the circular economy initiatives should be broadened. There must be a focus on recycling strategies, but even more so, there must be a focus on preventing the need for recycling for as long as possible. As 80 % of the environmental impact is determined in the design phase, engineers and STEM professionals have a vital role in the transition to a circular economy. More encompassing Nordic strategies will clarify the importance of expanding circular business models and help guide the development of circular competences across the STEM higher education institutions.

For the universities and higher education institutions

- **Establish a universal Circular Economy Competency framework for all engineers & STEM professionals.** While it is crucial to educate specialists in, for example, life cycle assessment and materials recycling, it is even more important to have a greater CE focus on the basic STEM and engineering programmes. This report suggests a foundation for a framework.
- **Integrate the Circular Economy Competency framework in all degree programmes and as learning goals of courses.** It is essential that a circular mindset is introduced to create fertile soil for adopting and implementing CE skills and a fundamental paradigm shift. The current engineering practices and analytical frameworks drive a linear economy and should be replaced by a circular approach. In the first instance, it is recommended for all educational programs to cover the concepts of planetary boundaries and circular economy principles. This does not require drastic changes in any curricula, seeing the topic of sustainability is already addressed widely. This incremental improvement alone can be highly effective.
- **Educate the educators.** There should be opportunities for educators at all levels to acquire competences in teaching circularity, such as circular design and mindset. Circular economy amplifies the necessity to better understand systems change and how systems function and interact with all-around human activities, most notably natural ecosystems. The transition to a CE cannot be led by the next generation of STEM professionals if there are no professors and teachers to educate them.

For the employers

- **Create spaces for upskilling.** A rapid change of mindset in the STEM sector is necessary to achieve a truly circular economy. Due to the formal constraints that higher education institutions operate within, they may not change education and re-education quickly enough. By creating spaces for up-skilling, employers could increase shared understanding of current ecological constraints, circular economy principles, and business models amongst specialists in various domains involved in innovation development.
- **Create agile ways to train graduate engineers and STEM professionals.** It is recommended to build new and expand existing collaborations between the private sector, CE STEM professionals, and universities to harness the state-of-the-art knowledge on circular economy practices. Established programmes should be further supported to offer flexible re-education through more short courses and study modules explicitly developed for lifelong learning opportunities on CE.
- **Promote STEM professionals as leaders in the circular economy.** There is a need to step up the awareness-raising of the opportunities for young people to make an impact towards a more sustainable future through STEM professions. Along with an increased focus on the interdisciplinary elements of a circular economy, this could increase the attraction of the engineering and STEM professions.

ABOUT ETHICA

This report was developed by Ethica on behalf of ANE. Ethica is an internationally awarded pioneer and consultant in circular economy since 2013. Ethica has played a key role in guiding companies and entire sectors in Finland towards circular practices and has gained a good insight into the knowledge barriers related to the dissemination of circular economy thinking and practices. https://www.ethica.fi/en/

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The Association of Nordic Engineers, ANE,
consists of engineering trade union associations
from the five largest Nordic countries:

The Swedish Association of Graduate Engineers
The Danish Society of Engineers (IDA)
The Norwegian Society of Engineers and Technologists (NITO)
The Association of Chartered Engineers in Iceland (VFÍ)
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