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Guidance document for the uptake of green skills and best practices by VET Systems

Work Package 3

Skills for the Green transition (development of Competence Units/Curriculum)

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1.SECTION A

1.1 Introduction

This document provides guidance on integrating essential green skills into education and training systems. It aims to support the development of competencies that foster sustainability across various sectors. By incorporating these skills into existing curricula, educators can play a pivotal role in preparing learners for the evolving demands of a greener economy.

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The methods and approaches outlined here include recommendations for teaching practices that emphasize practical, problem-solving techniques, the use of innovative technologies, and collaboration with industry. This ensures that learners not only gain theoretical knowledge but also acquire the skills needed to apply sustainable solutions in real-world scenarios.

The guidance encourages the development of educational materials that promote the autonomy of institutions while involving key stakeholders such as businesses, industry associations, and policymakers. By fostering collaboration and innovation, educators can help shape a workforce that is equipped to address environmental challenges and drive the transition toward a more sustainable future.

2 Method used for the guidance document.

To ensure that learners from all sectors (additive manufacturing, batteries, automotive, energy, defence and maritime) are prepared to meet the demands of a more sustainable economy. We have used the template developed for the GREEN project to collect and highlight the information needed to provide the recommendation needed to implement the set of key green skills in each sector involved in the project.

The purpose of this guide is to link D3.1 and D3.2 and use these to provide recommendations for implementing the green skills in the work on the development of the training material in WP4.

Each sector – **additive manufacturing, batteries, automotive, energy, defence and maritime** – has each identified 2 sector-specific occupations validated by the Sector Focus Groups and linked them to the green skills validated by the cross-sectoral focus group to provide recommendations for implementing the green skills to have a broad roadmap for the implementation and reproduction of similar activities in the EU.

By focusing on critical areas such as energy efficiency, resource management, and environmental impact, educators can equip students with the competencies needed to implement sustainable practices in their future careers. The focus is on fostering an understanding of how green technologies, regulations, and practices can be applied across industries.

Based on the curriculum for the two identified sectoral occupations, each sector has worked with the green skills found in D3.1 in relation to the transversal skills found in D3.2 and provided some recommendations on how to implement them in the curriculum and how to teach them in practice.

Fostering an understanding of how green technologies, regulations, and practices can be applied across industries. This includes promoting the use of innovative tools, such as digital platforms and workplace-based learning, to create a dynamic educational experience that reflects the evolving landscape of the global job market. By aligning curricula with sustainability goals, educational institutions can support both the personal and professional growth of learners, while also fostering long-term innovation and adaptability.

The final curricula are drawn up in WP 4, as well as incorporated into D3.4

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2. THE ADDITIVE MANUFACTURING SECTOR

2.1 The Additive Manufacturing sector represented by EWF, Belgium, has identified 2 occupations:

2.1.1 AM Designer

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Additive Manufacturing Designer

Design Metal AM solutions for AM Processes ensuring and validating that parts can be made cost-effective and efficiently. They also close design projects by verifying requirements for production with engineers as well as process requirements, ensuring liaison with other technical areas to sign of drawings, contributing to projects in a teaming environment cooperation with AM Team.

Metal AM Designers are the professionals with the specific knowledge, skills, autonomy and responsibility to design metal AM solutions specific processes. Manage complex processes design projects, taking responsibility for decision-making in unpredictable processes design applications.

Training programs are targeted for Engineers willing to specialise and pursue a career in AM, with focus on designing metal AM parts for different processes: PFB (Power Bed Fusion) and DED (Directed Energy Deposition). This training program is equivalent to EQF postgraduate training level 6 and EWF Advanced proficiency Level

Requirements: Engineering degree in Mechanical, Materials, Aeronautic or similar.

Training Program:

Competence Units	E/I D-PBF	
	Recommend Contact hours *	Expected Workload **
CU 00: Additive manufacturing Process overview	3.5	7
CU 25: Post processing	14	28
CU 59: Relevant principles of PBF Processes for Design	21	42
CU 60: Design Metal AM parts for PBF Processes	28	56
CU 61: Simulation Analysis	21	42
Subtotal	91	182
Optional : CU 62: Simulation Execution	14	28
	105	210

Competence Units	I MAM D-DED	
	Recommend Contact hours	Expected Workload
CU 00: Additive manufacturing Process overview	3.5	7

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CU 25: Post processing	14	28
CU 57: Relevant principles of DED Processes for Design	21	42
CU 58: Design Metal AM parts for DED Processes	28	56
CU 61: Simulation Analysis	21	42
Subtotal	91	182
Optional: CU 62: Simulation Execution	14	28
	105	210

* Recommended Contact Hours are the minimum recommended teaching hours for the Standard Routes. A contact hour shall contain at least 50 minutes of direct teaching time.

** Workload is calculated in hours, corresponds to an estimation of the time students typically need to complete all learning activities required to achieve the defined learning outcomes in formal learning environments plus the necessary time for individual study.

Within EWF´s qualifications, there are two types of Competence Units: Cross-cutting Competence Unit - A competence unit whose learning outcomes are not directly linked with one job function since the knowledge and skills achieved will be mobilized in several job functions and activities. Functional Competence Unit - A competence unit whose learning outcomes are directly linked with at least one job function and in which the knowledge and skills achieved will be mobilized in specific job functions and related activities.

2.1.2 Green Skills for the AM Designer

As a transversal technology present in diverse industrial sectors, Green Skills are deeply dependent on the chosen materials and process, so its fundamental the integration of transversal GREEN Skills into the learning programs**.** Nevertheless, there some skills addressed on the program that were considered as green:

- Simulation analysis
- Simulation Execution

2.2.1 Metal AM Process Engineer

Process Engineers are the professionals with the specific knowledge, skills, autonomy and responsibility to implement at least one of the following processes: power bed fusion- laser beam (PBF-LB) PBF-LB; direct energy deposition – laser beam (DED – LB); direct energy deposition – arc (DED-ARC) into the manufacturing chain assuring the efficient production and post-processing of additively manufactured parts. Manage metal additive manufacturing processes activities in a highly complex context. Take responsibility indecision n making and definition of process procedures and applications.

This training program is equivalent to EQF postgraduate training level 6 and EWF Advanced proficiency Level.

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Requirements: Engineering degree in Mechanical, Materials, Aeronautic or equivalent.

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The following programmes are specific for each technology within the Process Engineer Qualification:

- Metal Additive Manufacturing Process Engineer for Powder Bed Fusion

Competence Units	**I MAM PE PBF-LB**	
	Recommend Contact hours *	**Expected Workload ****
CU 00: Additive manufacturing Process overview	3.5	7
CU 15: PBF-LB Process	35	70
CU 25: Post Processing	14	28
CU 43: Production of PBF-LB parts	21	42
CU 44: Conformity of PBF-LB parts	35	70
CU 45: Conformity of facilities featuring PBF-LB	14	28
Subtotal	123	245
Optional : CU 26: Introduction to materials	14	28
Optional : CU 35: Metal AM integration	21	42
Optional : CU 36: Coordination activities	7	14
	165	329
Materials CUs ***		
CU 27: AM with steels feedstock (excluding Stainless Steel)	21	42
CU 28: AM with Stainless Steel feedstock	14	28
CU 29: AM with Aluminium feedstock	7	14
CU 30: AM with Nickel feedstock	7	14
CU 31: AM with Titanium feedstock	14	28
CU 32: AM with Tungsten feedstock	3.5	7
CU 33: Biomedical metallic materials	7	14

- Metal Additive Manufacturing Process Engineer for Directed Energy Deposition – Laser beam

Competence Units	**I MAM PE DED-LB**	
	Recommend Contact hours *	**Expected Workload ****
CU 00: Additive manufacturing Process overview	3.5	7
CU 08: DED-LB Process	35	70
CU 25: Post Processing	14	28

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CU 40: Production of DED-LB part	21	42
CU 41: Conformity of DED-LB parts	35	70
CU 42: Conformity of facilities featuring DED-LB	14	28
Subtotal	123	245
Optional : CU 26: Introduction to materials	14	28
Optional : CU 35: Metal AM integration	21	42
Optional : CU 36: Coordination activities	7	14
	165	329
Materials CUs ***		
CU 27: AM with steels feedstock (excluding Stainless Steel)	21	42
CU 28: AM with Stainless Steel feedstock	14	28
CU 29: AM with Aluminium feedstock	7	14
CU 30: AM with Nickel feedstock	7	14
CU 31: AM with Titanium feedstock	14	28
CU 32: AM with Tungsten feedstock	3.5	7
CU 33: Biomedical metallic materials	7	14

- Metal Additive Manufacturing Process Engineer for Directed Energy Deposition – Arc

Competence Units	I MAM PE DED-Arc	
	Recommend Contact hours *	Expected Workload **
CU 00: Additive manufacturing Process Overview	3.5	7
CU 01: DED-Arc Process	42	84
CU 25: Post Processing	14	28
CU 37: Production of DED-Arc parts	28	56
CU 38: Conformity of DED-Arc parts	42	84
CU 39: Conformity of facilities featuring DED-Arc	7	28
Subtotal	137	287
Optional : CU 26: Introduction to materials	14	28
Optional : CU 35: Metal AM integration	21	42
Optional : CU 36: Coordination activities	7	14
	165	329
Materials CUs ***		
CU 27: AM with steels feedstock (excluding Stainless Steel)	21	42

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CU 28: AM with Stainless Steel feedstock	14	28
CU 29: AM with Aluminium feedstock	7	14
CU 30: AM with Nickel feedstock	7	14
CU 31: AM with Titanium feedstock	14	28
CU 32: AM with Tungsten feedstock	3.5	7
CU 33: Biomedical metallic materials	7	14

* Contact Hours are the minimum recommended teaching hours for the Standard Routes. A contact hour shall contain at least 50 minutes of direct teaching time.

** Workload is calculated in hours, corresponds to an estimation of the time students typically need to complete all learning activities required to achieve the defined learning outcomes in formal learning environments plus the necessary time for individual study.

***A minimum of 2 CUs shall be selected from the list Materials CUs in order to successfully complete the qualification

Within EWF´s qualifications, there are two types of Competence Units:

Cross-cutting Competence Unit - A competence unit whose learning outcomes are not directly linked with one job function since the knowledge and skills achieved will be mobilized in several job functions and activities.

Functional Competence Unit - A competence unit whose learning outcomes are directly linked with at least one job function and in which the knowledge and skills achieved will be mobilized in specific job functions and related activities.

2.2.2 Green Skills for the Metal AM Process Engineer

As a transversal technology present in diverse industrial sectors, Green Skills are deeply dependent on the chosen materials and process, so its fundamental the integration of transversal GREEN Skills into the learning programs. In the following program were not identified specific GREEN Skills. However, the existing Skills and Knowledge can be put into practice following GREEN principles by chosen materials and processes more sustainable.

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3. THE AUTOMOTIVE SECTOR

3.1 The Automotive sector represented by VSB-Technical University of Ostrava (VSB-TUO), Czech Republic, has identified 2 occupations:

3.1.1 E-Powertrain Engineers

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<u>E-Powertrain Engineers</u>

The massive open online course on Electric Powertrain Engineer was created within project ECEPE co-funded by the Erasmus+ Call 2019 Round 1 KA203 Programme of the European Union under the agreement 2019-1-CZ01-KA203-061430 and partially supported by Grants of SGS No. SP2021/87 and SP2021/49, VSB - Technical University of Ostrava, Czech Republic. The MOOC is focused on the new job role of E-Powertrain Engineer which is instrumental in the green transition. The course deals with designing and optimizing e-powertrains for reduced emissions, improved energy efficiency, and the integration of renewable energy sources. The course is designed so that the work of E-Powertrain Engineer supports the development of sustainable mobility solutions, helps meet regulatory standards, and promotes innovation in the automotive industry.

Admission requirements for **MOOC E-Powertrain Engineer**

- Free of charge
- Available after registration at platform Academy Eurospi, https://academy.eurospi.net/enrol

MOOC on E-Powertrain Engineers		
1st chapter	**ECEPE. U1 Introduction**	**The unit introduces the e-powertrain domain. It investigates the main challenges and drivers-of-change in the automotive sector and the rationale behind electric powertrains. Different solutions such as the full electric vehicle, plug-in hybrid and hybrid are being described. The unit introduces also the product lifecycle phases from raw materials, via the development processes of embedded automotive systems (including the V-Cycle), production to the disposal.**
2nd chapter	**ECEPE.U2 System Engineering**	**The unit introduces system architecture thinking in context of an e-powertrain with an understanding of system functional design, system-wide feature thinking for functional safety, and cyber-security related development. It highlights the main components of an e-powertrain, the approaches and rationales behind dependable (safety & security) engineering concepts for electric powertrains. Different concepts, such as signal flow concepts, effect chain between components, and risk management in complex system design are being described.**

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3rd chapter	**ECEPE.U3 Propulsion Systems**	**This unit gives an overview about the division of electric motors, their principles, behaviour and control methods as well as overview about the division of car/vehicle inverters and Power electronics (PE) components. The motor control to manage the phase currents of the electric motor is done by a special Software called Field Oriented Controller (FOC) Software. Defined Software tool setups are used to explain the motor control software. An overview of block structures, properties, control methods and strategies of hybrid control systems is presented.**
4th chapter	**ECEPE.U4 Energy Storage Systems**	**Unit 4 "Energy Storage Systems" gives an overview of battery systems, battery management systems and fuel cells systems. Differences between the traction battery in a car with electric drive (EV) and traction battery for hybrid vehicle (EHV) as well as the differences in the properties of both on-board power supply networks are being discussed. Issues, solutions of systems, circuit solutions for measuring and evaluating the isolation condition, BMS hardware and software components and fuels cell systems principles are the main topics covered.**
5th chapter	**ECEPE.U5 Life Cycle Management**	**Unit 5 "Life Cycle Management" gives an overview about Life Cycle related topics like the Product Life Cycle or Life Cycle Management. Students gain insight into different topics as the different phases of Life Cycle Mangement and how to apply them on practical topics. Furthermore, business models are also involved in the taught subjects.**

3.1.2 Green Skills for the E-Powertrain Engineer

Green Skills	E-Powertrain Engineer: • Anticipate changes in car technology. • Apply health and safety standards. • Approve engineering design. • Assess powertrain. • Collaborate with designers. • Conduct performance tests. • Define technical requirements. • Manage engineering projects. • Compare alternative vehicles.

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	• Describe electric drive system. • Design electromechanical systems. • Design hybrid operating strategies. • Evaluate vehicle ecological footprint. • Perform scientific research. • Product Lifecycle Management. • Knowledge on Energy Transformation Systems. • Knowledge on Energy Storage Systems. • Knowledge on Battery Systems. • Knowledge on Fuel Cells • Knowledge on Hybrid vehicle architecture • Knowledge on Electric motors • Knowledge on Biodiesel • Knowledge on Emission Standards • Knowledge on Energy saving potential

3.2.1 Life Cycle Assessment Manager`s

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<u>Life Cycle Assessment Manager's</u>

The massive open online course on Life Cycle assessment in Automotive was created within project aLIFEca co-funded by the Erasmus+ Call 2019 Round 1 KA203 Programme of the European Union under the agreement 2021-1-CZ01-KA220-HED-000032222 and coordinated by VSB - Technical University of Ostrava, Czech Republic. The MOOC is focused on comprehensive knowledge about the environmental impact of cutting-edge transport technologies which is significant across the whole automotive sector and accompanying services. The course is designed so that the work of Life Cycle Assessment Manager's expertise and assessment capabilities contribute to the green transition by driving sustainable decision-making, promoting innovation, and supporting the adoption of environmentally friendly practices throughout the entire life cycle of products and systems.

Admission requirements for **MOOC on Life Cycle Assessment in Automotive**

- Free of charge¨
- Available after registration at platform Learning Platform, https://learn.skills-framework.eu/

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MOOC on LCA in Automotive		
1st chapter	**Getting Started**	**This chapter includes basic information about the course and its certification framework.**
2nd chapter	**Introduction to Life Cycle Assessment and Sustainability**	**The chapter deals with essential terms of sustainability and the development of sustainable thinking. The essential terms of LCA methodology are explained. The students will learn what Life Cycle Assessment (LCA) is used for, what environmental footprint means, what LCA phases are there and why the LCA is important. It explains which LCA system boundaries are recognized and what approaches are there to carry out life cycle assessment, what functional unit means.**
3rd chapter	**LCA in Automotive: Conventional Fuel Vehicles**	**The chapter sums up theoretical information about internal combustion engines, currently applicable European emission regulations, and various methods of fuel consumption measuring. Moreover, general information about Life Cycle Assessment is then applied to the issue of conventional fuel vehicles. The theoretical knowledge is supported by examples of the results of specific measurements of consumption and production of greenhouse gases of a passenger car, a bus, and a train in real operation. The chapter also includes case studies on the topic of life cycle assessment of conventional fuel vehicles.**
4th chapter	**LCA in Automotive: Alternative Fuel Vehicles**	**Chapter 4 deals with life cycle assessment of alternative fuel vehicles. The chapter offers a comparison between environmental impacts of alternative fuel vehicles and internal combustion engine ones. It describes the main factors that have an impact on the environment. It also presents carbon footprint, water footprint and resource footprint of alternative fuel vehicles. Students will learn the determinants of environmental assessment of the life cycle of vehicles and alternative fuels. This chapter includes theory about battery electric vehicles, LCA model and case study on environmental impact of battery electric vehicles (BEVs), fuel cell electric vehicles (FCEVs).**

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5th chapter	**Tools for LCA and Environmental Impact Assessment**	**Chapter 5 deals with basic tools which can help to carry out life cycle assessment. It includes basis information about life cycle inventory databases and software tools. The chapter will help students in acquiring a systematic survey on LCA software tools which can be useful in their future professional work related to automotive and zero emission transport.**

3.2.2 Green Skills for the Life Cycle Assessment Manager`s

Green Skills	<u>Life Cycle Assessment Manager's</u> • Evaluate the environmental impact of raw material extraction for product. • Evaluate the environmental impact of product production. • Evaluate the environmental impact of product distribution. • Evaluate the environmental impact of product disposal. • Minimize the product's carbon footprint. • Ensure compliance with environmental regulations. • Develop business plans. • Develop communications strategies. • Develop new products. • Develop product design. • Develop promotional tools. • Draw conclusions from market research results. • Perform environmental research. • Carry out training in environmental matters. • Manage environmental management system. • Mitigate waste of resources. • Measure company's sustainability performance. • Manage recycling program budget • Knowledge on environmental policy, gloabal standards for sustainability and legislation

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	• Knowledge on circular economy • Knowledge on emission standards and energy efficiency • Knowledge on waste management and hazardous waste types

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4. THE BATTERIES SECTOR

4.1 The Battery sector represented by OliFe, Czech Republic, has identified 2 occupations:

4.1.1 Battery System Engineer

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<u>Battery System Engineer</u>

A massive open online course on battery system engineer was created within project ALBATTS: The Alliance for Batteries Technology, Training and Skills funded by the Erasmus+ Sector Skills Alliances Programme VSB - Technical University of Ostrava, Czech Republic. The MOOC is focused on the new job role of Battery System Engineers responsible for designing, developing, and testing battery systems for various applications. The course deals with efficient, safe and cost-effective energy storage solutions for electric vehicles, consumer electronics, grid storage and other applications. The battery system engineers need to have a strong understanding of electrical engineering, materials science, and manufacturing processes, as well as experience with battery management systems, safety protocols and regulations. They also need to be familiar with simulation and modeling tools to predict the performance of the battery systems under different conditions. They need to be able to work closely with other engineers and stakeholders to ensure that the battery system meets the requirements of the application and is compatible with the rest of the system.

Admission requirements for **MOOC Automotive Battery System Engineer**

- Free of charge¨
- Available after registration at Learning Platform https://learn.skills-framework.eu/

MOOC on Automotive Battery Systems Engineers		
1st chapter	**Introduction to Battery Concepts in Automotive**	**The chapter includes two units: U1.E1 Introduction to Battery Concepts in Automotive Architectures and U1.E2 Basic Batteries Markets**
2nd chapter	**Battery Engineering**	**The chapter includes: U2.E1 Battery Management System, U2.E2 High Voltage Relays, U2.E3 Functional Safety, U2.E4 Cybersecurity, U2.E5 Testing of electrically propelled road vehicles**

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3rd chapter	**Battery homologation**	**The chapter deals with automotive homologation process basics, specific norms applied to qualify and release a battery system in automotive.**

4.1.2 Green Skills for the System Battery Engineer

System Battery Engineer:

- Design battery system
- Design, develop battery system with low environmental impact
- Test battery system
- Create efficient, safe and cost-effective energy storage solutions
- Control performance of the battery system
- Control thermal management
- Control safety systems
- Understanding of electrical engineering
- Understanding of material science
- Understanding of manufacturing processes
- Experience with battery management systems
- Experience with safety protocols and regulations
- Experience with simulation and moodelling tools Anticipate changes in car technology.

4.2.1 Chemical Process Engineer

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Chemical Process Engineer

Chemical Process Engineers develop and implement chemical process designs of the proprietary lithium-ion battery recycling processes and primary resource extraction technologies. The Chemical Process Engineers are focused designing, implementing, and maintaining efficient chemical manufacturing processes, ensuring quality control of outputs, specifying equipment, crafting and deploying monitoring protocols. They scale processes proven at the bench scale up to pilot- or pre-commercial scales. They have a constant focus on evaluating current processing steps and proposing and developing next-generation solutions to continuously improve system performance and operability. At VSB-TU the bachelor programme in Process Engineering in Raw Materials is provided. The bachelor programme in Process Engineering in Raw Materials is a three years' full time study with a focus on optimizing of processes an interdisciplinary field focused on the transformation of substances (whether natural or artificially created by human activity) into other useful products that can be used in other areas of human activity. As an intermediary between science and production, it is the basis for all manufacturing sectors. The basis of the entire process engineering conceived in this way are mechanical processes dealing with the transformation and movement of loose materials (particulate materials), which are part of all industrial and agricultural processes (activities). As part of the Bachelor's degree in Process Engineering, the student is introduced to the basic processes of formation and transformation and characterization of bulk materials, especially of a natural nature. The study program is composed gradually of basic theoretical subjects, which are then followed by professional subjects and, at the end of the study, by specialized subjects, all closely linked to the technical basis in the form of the basics of design and the necessary knowledge in the field of electrical engineering and engineering.

Admission Requirements

Bachelor's study program

- Secondary education with a school-leaving examination obtained at a Czech secondary school or a document proving the fulfillment of the condition of obtaining secondary education with a school-leaving examination if education was obtained abroad.
- For study in English a school-leaving certificate with exams in the English language or a certificate proving their knowledge of English at B1 level (e.g. TOEFL or IELTS) plus a fee 50 000 CZK per semester

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Course of study for Bc in Process Engineering in Raw Materials				
1st semester	**Basics of Mathematics (2 ECTS)**	**Chemistry (8 ECTS)**	**Computer Practicum (2 ECTS)**	**Introduction into Process Engineering (5 ECTS)**
		Mineral Deposits (5 ECTS)	**Mineralogy and Petrography (5 ECTS)**	**Elective (3ECTS)**
2nd semester	**Current State and Development of Environment in Czech Republic** (3 ECTS)	**Descriptive Geometry** (5 ECTS)	**Fundamentals of Law** (2 ECTS)	**Mathematics I** (5 ECTS)
	Elective (3 ECTS)	**Raw materials and their Utilization** (4 ECTS)	**Technical support for designing process of** (2 ECTS) **(equipment** (2 ECTS)	**Treatment of raw materials and waste I** (6 ECTS)
3rd semester	**Elective** (3 ECTS)	**Bachelor Physics** (5 ECTS)	**Bulk Materials** (5 ECTS)	**Excursion** (2 ECTS)
	Mathematics II (5 ECTS)		**Mining** (5 ECTS)	**Physical Separation Processes I** (5 ECTS)

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4th semester	**Elective** (3 ECTS)	**Branch Work Experience** (8ECTS)	**Construction of machines and equipment** (5 ECTS)	**Numecrical Methods** (2 ECTS)
	Physical Separation Methods (4 ECTS)	**Process engineering of bulk materials** (5 ECTS)		**Technical mechanics** (5 ECTS)
5th semester	**Elective** (10 ECTS)	**Automation of technological processes** (3 ECTS)	**Design of process lines** (5 ECTS)	**Electrical Engineering** (5 ECTS)
	Laboratory of Bulk Solikds (2 ECTS)	**Transport and storage equipment** (5 ECTS)		
6th semester	**Bachelor thesis seminar** (10 ECTS)	**Laboratory of Bulk Solikds** (6 ECTS)	**Safety at Work and Fire Protection** (4 ECTS)	**Elective** (10 ECTS)

After the bachelor you can go on with Master's degree in Process Engineering in Raw Materials

Admission requirements

- A university bachelor's degree related to the field of study
- The course is in Czech (at least B1) and English (B1 at least). English Course is paid.

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Course of study for Master degree, Ing. in Process Engineering in Raw Materials				
1st semester	**Mechanics of bulk solids** (6 ECTS)	**Process equipment I** (5 ECTS)	**Sampling of powder and liquids** (5 ECTS)	**Selected chapters from general and inorganic chemistry** (5 ECTS)
		Special Topics in Mathematics (5 ECTS)	**Statistics** (4 ECTS)	**Optional** (0 ECTS)
2nd semester	**Laboratory Course** (3 ECTS)	**Mechanical Processes** (5 ECTS)	**Process equipment II** (5 ECTS)	**Selected Chapters of Physics** (5 ECTS)
	Elective (7 ECTS)	**Simulation of process systems** (5 ECTS)		
3rd semester	**Optional** (2 ECTS)	**Coal Treatment Technologies** (5 ECTS)	**Environmental Impact Assessment** (5 ECTS)	**Process Equipment III** (5 ECTS)
	Technology Designing (4 ECTS)		**Technology of Ores Treatment** (5 ECTS)	**Waste Management** (5 ECTS)

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4th semester	**Optional** (2 ECTS)	**Branch Work Experience** (6 ECTS)	**Engineering innovations in process engineering** (5 ECTS)	**Numecrical Methods** (2 ECTS)
	Design of Process Lines (5 ECTS)			**Diploma thesis seminar** (15 ECTS)

4.2.2 Green Skills for the Chemical Process Engineer

Chemical Process Engineer:

- Develop and implement chemical process designs.
- Develop and implement lithium-ion battery recycling processes
- Develop primary resource extraction technologies.
- Understanding of design, installation, commissioning, and operations of first-of-kind facilities
- Understanding of processes of quality control and monitoring protocols
- Understanding of chemical manufacturing processes
- Interest in scaling processes proven at the bench scale up to pilot- or pre-commercial scales
- Constant focus on evaluating current processing steps

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5. THE DEFENCE SECTOR

5.1 The Defence sector represented by Mercantec, Denmark, has identified 2 occupations:

5.1.1 Data Scientist

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Data Scientist:

The bachelor programme in Data Science is a three-year full-time study with a focus on mathematics and statistics, computer science, and applied social science. Through extensive project work, students are trained in applying these skills in realistic settings, including interacting with domain experts and decision makers in the industry to formulate relevant goals and to support data-driven decision-making processes.

Admission requirements

- A qualifying examination certificate equal to a Danish upper secondary school leaving certificate.
- Mathematics corresponding to the Danish A-level with an average mark of at least 6 on the Danish 7-point marking scale of the marks included in the subject on your certificate.
- English corresponding to the Danish B-level with an average mark of at least 6 on the Danish 7-point marking scale of the marks included in the subject on your certificate (there is no grade requirement if you have passed English corresponding to the Danish A-level).

<table>
<tr><th colspan="4">Course of study for BSc in Data Science</th><th></th></tr>
<tr><td>1st semester</td><td colspan="2">Introduction to Data Science and Programming
(15 ECTS)</td><td>Linear Algebra and Optimisation
(7.5 ECTS)</td><td>Foundations of Probability
(7.5 ECTS)</td></tr>
<tr><td>2nd semester</td><td colspan="2">Applied Statistics
(15 ECTS)</td><td>Algorithms and Data Structures
(7.5 ECTS)</td><td>Projects in Data Science
(7.5 ECTS)</td></tr>
<tr><td>3rd semester</td><td colspan="2">Machine Learning
(15 ECTS)</td><td>Introduction to Database Systems
(7.5 ECTS)</td><td>Network Analysis
(7.5 ECTS)</td></tr>
<tr><td>4th semester</td><td colspan="2">Natural Language Processing and Deep Learning
(15 ECTS)</td><td>Data Visualisation and Data-driven Decision-making
(7.5 ECTS)</td><td>Large-Scale Data Analysis
(7.5 ECTS)</td></tr>
<tr><td>5th semester</td><td>Technical Communication
(7.5 ECTS)</td><td>Security and Privacy
(7.5 ECTS)</td><td>Software Development and Software Engineering
(7.5 ECTS)</td><td>Elective
(7.5 ECTS)</td></tr>
<tr><td>6th semester</td><td colspan="2">Bachelor Project
(15 ECTS)</td><td>Reflections on Data Science
(7.5 ECTS)</td><td>Elective
(7.5 ECTS)</td></tr>
</table>

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After the bachelor you can get an MSc In Data Science:

Admission requirements

- A university bachelor's degree or a professional bachelor's degree.
- English corresponding to the Danish B-level with a minimum of 3 in grade point average.
- A qualifying (bachelor) degree related to data science covering some specific topics.

Course of study for MSc in Data Science				
1st semester	**Algorithm Design** (7.5 ECTS)	**Advanced Applied Statistics** (7.5 ECTS)	**Data in the Wild: Wrangling and visualizing data** (7,5 ECTS)	**Seminars in Data science** (7,5 ECTS)
2nd semester	**Elective** (7.5 ECTS)	**Advanced Machine Learning** (7,5 ECTS)	**Data Science in Production** (7,5 ECTS)	**Algorithmic Fairness, Accountability a Ethics** (7,5 ECTS)
3rd semester	**Elective** (7,5 ECTS)	**Elective** (7,5 ECTS)	**Elective** (7,5 ECTS)	**Research Project** (7,5 ECTS)
	-OR- Elective (15 ECTS)			
4th semester	**Master thesis** (30 ECTS)			

5.1.2 Green Skills for the Data Scientist

Data Scientist:

- Apply research ethics and scientific integrity principles in research activities.
- Build recommender systems.
- Conduct research across disciplines.
- Deliver visual presentation af data.
- Develop professional network with researchers and scientists.
- Draft scientific or academic papers and technical documentation.
- Implement data quality processes.
- Manage intellectual property rights.
- Manage research data.
- Mentor individuals.
- Preform scientific research.
- Promote open innovation in research.
- Promote the participation of citizens in scientific and research activities.

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5.2.1 Aerospace Engineer

Aerospace Engineer (180 EC, 36 Months):

There is no opportunity to study Aerospace Engineering in Denmark. But here we have taken an example from Delft University of Technology in the Netherlands. BSc Aerospace Engineering - TU Delft

The bachelor programme Aerospace Engineering takes three years. Each year consists of four quarters of ten weeks each, finalised with an exam period. The programme comprises a variety of education forms, such as classical lectures, work lectures, projects and self-study. During classes, you will be taught the usual engineering foundation of physics and mathematics, augmented by aerospace courses on, for example, aerodynamics and orbital mechanics, as well as soft-skills courses on presenting, scientific writing and reporting.

Course of study for BSc in Aerospace Engineering (180 ECTS)			
1st semester	**Exploring Aerospace Engineering**	**Engineering Drawing**	**Introduction to Aerospace Engineering I**
1st semester	**Introduction to Aerospace Engineering II**	**Statics**	**Aerospace Materials**
1st semester	**Calculus I a**	**Calculus I b**	**Dynamics**
2nd semester	**Design and Construction**	**Technical Writing**	**Aerospace Design and Systems Engineering**
2nd semester	**Aerospace Mechanics of Materials**	**Linear Algebra**	**Physics, Thermodynamics, Wavers and Electromagnetism**
2nd semester	**Calculus II**	**Programming & Scientific Computing in Python**	
3rd semester	**Systems Design**	**Oral Presentations**	**Aerospace Design and Systems Engineering II**
3rd semester	**Low Speed Wind Tunnel Test**	**Aerodynamics I**	**Aerodynamics II**
3rd semester	**Differential Equations**	**Structural Analysis and Design**	**Probability and Statistics**

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Course of study for BSc in Aerospace Engineering (180 ECTS)			
3rd semester	**Vibrations**		
4th semester	**Test, Analysis and Simulation**	**Scientific Writing**	**Flight and Orbital Mechanics**
4th semester	**Aerospace Systems and Control Theory**	**Propulsion and Power**	**Signal Analysis and Telecommunication**
4th semester	**Artificial Intelligence for Aerospace Engineering**	**Computational Modeling**	
5th semester	**Minor Programme**		
6th semester	**Simulation, Verification and Validation**	**Design Synthesis Exercise**	**Production of Aerospace Materials**
6th semester	**Systems Engineering & Aerospace Design**	**Aerospace Flight Dynamics & Simulations**	

5.2.2 Green Skills for the Aerospace Engineer

Aerospace Engineer:

- Adjust engineering designs
- Approve engineering design
- Ensure aircraft compliance with regulation
- Perform scientific research
- Aerospace engineering
- Aircraft mechanics
- Engineering principles
- Engineering processes
- Industrial engineering
- Manufacturing processes
- Production processes

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6. THE ENERGY SECTOR

6.1 The Energy sector represented by University of Cyprus (UCY), Cyprus, has identified 2 occupations:

6.1.1 Energy Systems Engineer

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Energy Systems Engineer

No bachelor program specifically focuses on Energy systems engineers. However, students can choose to follow different engineering sectors such as Chemical, Electrical, and Mechanical to get a fundamental background of systems in general. On the other hand, there is a 2-year MSc program on Energy Technologies and Sustainable Design that focuses on sustainable energy technologies and energy-efficient technologies for buildings. The students, through the completion of various theoretical courses, team, and individual, obtain the necessary background for applying the basic principles of sustainable energy systems and sustainable design in real-world applications.

Admission requirements:

- Bachelor’s degree from a recognized university
- Previous university education in a suitable background and grades in relevant courses
- Recommendation Letters

The course is taught in Greek.

Energy Technologies and Sustainable Design (M.Sc.)					
1st semester	Technologies of Renewable Energy (8 ECTS)	Basic Principles of Interdisciplinary Engineering (1 ECTS)	Research Methodology (8 ECTS)	Energy Efficiency of Buildings (8 ECTS)	Capstone Design and Research Project I (8 ECTS)
2nd semester	Environmental Building Design (8 ECTS)	Building Integration of Photovoltaic (8 ECTS)	Graduate Seminar (1 ECTS)	Engagement with Practice and Industry (1 ECTS)	Capstone Design and Research Project II (8 ECTS)
3rd semester	Master Thesis Research I (8 ECTS)	Master Thesis Research II (8 ECTS)	Capstone Design and Research Project III (8 ECTS)	Elective (8 ECTS)	
4th semester	Master Thesis Research III (8 ECTS)	Master Thesis Research IV (8 ECTS)	Master Thesis Research V (8 ECTS)		

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6.1.2 Green Skills for the Energy Systems Engineer

- Promote sustainable energy,
- Environmental engineering,
- Renewable energy technologies,
- Energy performance of buildings,
- Solar energy,
- Smart grid systems,
- Perform energy simulations,
- Determine appropriate heating and cooling system,
- Adapt energy distribution,
- Design passive energy measures,
- Use data processing techniques,
- Energy Market Analysis,
- Energy storage,
- Hydrogen Technologies,
- Power electronics.

6.2.1 Solar Energy Technician

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Solar energy technician

For this occupation, there is no bachelor's or master's degree being offered. These degrees will focus primarily on the theoretical aspect of the occupation, whereas a technician is requires both theoretical and practical aspects to be included. There is a relative course being offered by a research institute of UCY, called FOSS. The VET program name is “Design and Installer” and refers to photovoltaic (PV) systems. The participants, through the completion of hybrid lectures learn about the basic theory of photovoltaic systems, the potential in Cyprus, the various technologies, and their specifications following European and National legislation for the design of these systems. Towards the end of the course, maintenance, fault detection, and installation procedures are explained. The program duration is 40 teaching hours and is taught in Greek. Various laboratory demonstrations, simulations, and online lectures equip the student with the appropriate knowledge for the design, installation and maintenance of PV systems. In addition to this, related to this occupation, another VET course related to energy storage systems is given by the same institution. It is called “Energy Storage: Diverse role in the modern Electricity Network “and similar teaching techniques are followed with the previous course. The course equips the participants with theoretical and practical knowledge of the procedure for dimensioning energy storage systems, identifying potential risks, and the different smart devices that could be used for monitoring. The course duration is 30 hours, where 2/3 are theoretical and 1/3 involve practical experience. For both courses, workers in the engineering-related fields and/or directly related to the electrical installations field can participate. However, anyone interested can participate.

6.2.2 Green Skills for the Solar Energy Technician

- Install concentrated solar power systems,
- Install electrical and electronic equipment,
- Install photovoltaic systems,
- Mount photovoltaic panels work ergonomically,
- Solar energy,
- Types of photovoltaic panels,
- Provide information on solar panels,
- Follow health and safety procedures in construction,
- Use measurement instruments,
- Determine the suitability of materials,
- Install automation components,
- Maintain solar energy systems,
- Analyse big data.

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7. THE MARITIME TECHNOLOGIES SECTOR

7.1 The Maritime Technologies sector represented by CETMAR, Spain, has identified 2 occupations:

7.1.1 Offshore Renewable Energy Engineer

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- **ORE engineer**

Offshore renewable Energy is an emerging sector, and most of the education and training offer are provided as a specialisation either in EQF level 6 and 7. Furthermore, very few training offers are specifically addressed to the offshore renewables, being this content a specific section of the renewable energies training, or the offshore engineering training. We have selected for this analysis a Master programme specifically addressed at renewable energies in the marine environment.

The aim of the **Renewable Energies in the Marine Environment (REM PLUS) Erasmus Mundus Master's degree** is to train specialists with the necessary skills to achieve this technological challenge and, specifically, to respond to the industry's demand for skilled professionals. The REM PLUS master is a 2 years joint Erasmus Mundus Master (EMJMD) offered by four universities: the University of the Basque Country, the National University of Ireland-Cork, the Norwegian University of Science and Technology and the Central School of Nantes. It is co-financed by the European Union's Erasmus + programme and provides access to doctoral studies[1].

Syllabus – Erasmus Mundus Master in Renewable Energy in the Marine Environment[2]

Common Contents of the Syllabus in ECTS	
Basque language and culture	3
Civil Engineering Systems	5
Environmental conditions for marine renewable concepts	3
Integration of renewable energy into the electricity system	3
Ocean Energy	5
Ocean wave energy and offshore wind energy assessment	4.5
Operation of transmission and distribution networks	3
Operations and maintenance of marine energy arrays	3
Sustainable Energy	5
Optional Contents of the Syllabus in ECTS	
Advanced fluid dynamics modeling for marine engineering applications	4.5
Computational fluid dynamics for turbulent flows	3
Data Analytics for Engineering	5
Environmental Hydrodynamics	5
Experimental hydrodynamics	4
French language and culture	4
General concepts of hydrodynamics	4
Hydraulics	5
Marine renewable energy	5
Numerical hydrodynamics	5
Theoretical and numerical aspects in fluid dynamics and turbulent flow	3
Water waves and sea states modelling	4
Wave-structure interactions and moorings	4

[1] https://www.ehu.eus/en/web/master/master-renewable-energy-marine-environment/syllabus
[2] https://www.ehu.eus/documents/d/master/master-rem-plus-pdf?download=true

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7.1.2 Green Skills for the Offshore Renewable Energy Engineer

Blue: Skills and competences labelled as GREEN by ESCO.
Green: proposed by the experts to be included in this occupation (already labelled as GREEN by ESCO)
Orange: not yet classified as GREEN by ESCO, but might be proposed to be green-labelled
SKILLS

- *advise on offshore renewable energies subjects*
- *coordinate electricity generation*
- *design offshore energy systems*
- *ensure compliance with environmental legislation in food production*
- *inspect offshore constructions*
- *perform project management*
- *prevent marine pollution*
- *promote sustainable energy*
- *research locations for offshore farms*
- *research ocean energy projects*

KNOWLEDGE:

- *marine technology*
- *oceanography*
- *offshore constructions and facilities*
- *offshore renewable energy technologies*
- *renewable energy technologies*
- *marine technology*
- *oceanography*
- *offshore constructions and facilities*
- *offshore renewable energy technologies*
- *renewable energy technologies*
- *types of photovoltaic panels*
- *types of tidal stream generators*
- *types of wave energy converters*
- *types of wind turbines*
- *maritime law*
- energy storage (* in ESCO is ”energy storage systems”)
- new materials (not found in ESCO)
- offshore maintenance (* in ESCO is ”Maintenance operations”)

7.2.1 Marine Engineer

The studies of **Marine Engineering** have technological character and give access to perform the position of Marine Engineer and Chief Engineer (Master of Marine Engineering also required) onboard of ships.

The study plan is focused on training of students facing to activities of operation, maintenance and management of all installations on-board of a ship. Courses of the study plan ensure learning the skills of operation, maintenance, design, redesign and management of the facilities of the ship.

Graduates acquire a very wide scientific and technological training, which also allows apply the methodology and techniques of engineering in a wide range of activities in the energy field, technical office, production equipment, management and administration.

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We present the syllabus followed in the Universidade de A Coruña (UDC).

Syllabus degree in marine engineering in ECTS		
1st Year	Mathematics I	6
	Chemistry	6
	Physics I	6
	Informatics	6
	Maritime Business and Law	6
	Mathematics II	6
	Technical Draw	6
	Physics II	6
	Science and Engineering of Materials	6
	Sanitary and Maritime Training	6
2nd year	Numerical and Statistical Methods	6
	Maritime Technical English	6
	Mechanics and Strength of Materials	6
	Thermodynamics and Engineering Thermodynamics	6
	Electrotechnology and Ship Electrical Machines	6
	Electronics and Control Systems	6
	Fluid Mechanics	6
	Naval Construction and Ship Stability	6
	Maritime Safety and Pollution	6
	Tanker and Passenger Ships	6
3rd Year	Internal Combustion Engines	9
	Mechanical Technology	9
	Electrical Ship Maintenance and Instrumentation	9
	Automatisms and Control Systems	9
	Steam and Gas Turbines	6
	Heat Transfer and Steam Generators	6
	Auxiliary Equipment for Ships	6
	Cooling Techniques Applied to Ship	6
	Thermal Marine Machinery	6
	Analogue Electronics	6
	Digital Electronics	6
	Electrical Machinery for Ships	6
	Hydraulic and Neumatic Systems	6
	Maintenance Management for Ships	6
	Auxiliary Systems for Ships	6
	Auxiliary Services for Ships	6
	Power Electronics	6
	High Voltage and Electrical Power Distribution on Board	6

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7.2.2 Green Skills for the Marine Engineer

SKILLS

- *analyse energy consumption*
- *assess environmental impact*
- *conduct energy audit*
- *develop energy saving concepts*
- *develop waste management processes*
- *ensure compliance with environmental legislation*
- *identify energy needs*
- *prevent sea pollution*
- *promote innovative infrastructure design*

KNOWLEDGE:

- *International Convention for the Prevention of Pollution from Ships*
- *energy efficiency*
- *environmental legislation*
- *renewable energy technologies*
- *ship related legislative requirements*
- *solar energy*

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8. SYLLABUS FOR ALL SECTORS

Partner	Sector	Country	Occupation
UCY	Energy	Cyprus	Energy Systems Engineer
UCY	Energy	Cyprus	Solar energy technician
VSB-TUO	Automotive	Czech Republic	E-Powertrain Engineer
VSB-TUO	Automotive	Czech Republic	Live Cycle Assessment Manager
OLIFE	Batteries	Czech Republic	Battery System Engineer
OLIFE	Batteries	Czech Republic	Chemical Process Engineer
CETMAR	Maritime	Spain	Offshore renewable Energy Engineer
CETMAR	Maritime	Spain	Marine Engineer
MERCANTEC	Defence	Denmark	Data Scientist
MERCANTEC	Defence	Denmark	Aerospace Engineer
EWF	Additive Manufacturing	Belgium	AM Designer
EWF	Additive Manufacturing	Belgium	Metal AM Process Engineer

In order to cover all sectors and occupations, we suggest concentrating on “Systems thinking”, “Critical thinking” and “Problem framing” in order to embracing complexity in sustainability.

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Proposals for syllabus

Embracing complexity in sustainability (GreenComp).

The competence area ‘Embracing complexity in sustainability’ is about:

- empowering learners with systemic and critical thinking, and encouraging them to reflect on how to better assess information and challenge and sustainability.
- scanning systems by identifying interconnections and feedback; and
- framing challenges as sustainability problems which helps us learn about the scale of a situation while identifying everyone involved.

Systems thinking:

Descriptor (2.1): To approach a sustainability problem from all sides; to consider time, space and context in order to understand how elements interact within and between systems.

Knowledge: knows that every human action has environmental, social, cultural and economic impacts.

Skills: can describe sustainability as a holistic concept that includes environmental, economic, social, and cultural issues.

Attitudes: is concerned about the short- and longterm impacts of personal actions on others and the planet.

Here is a brief description of the theory behind systems thinking:

1. **System definition:**
   - A system is considered a collection of elements or components that are interconnected and interact to fulfill a common purpose or achieve a goal.
2. **Interaction and Connections:**
   - Focus on the relationships and interactions between the elements of the system, rather than isolated analysis of each element individually.
3. **Overall perspective:**
   - Emphasis on understanding the system as a whole, where the sum of the components creates a unique dynamic that cannot be understood by simply studying the sub-elements in isolation.
4. **Causation:**
   - Identification of cause-and-effect relationships within the system to understand how changes in one part can affect other parts.
5. **Feedback mechanisms:**

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- Recognition of feedback mechanisms in which the consequences of an action can influence future decisions and actions within the system.

6. **Dynamics over time:**

   - Consideration of how the system evolves over time and how changes can have long-lasting effects.

7. **Targeted intervention:**

   - Opportunity to identify strategic points for intervention in order to positively influence the system and work towards desired goals.

8. **Complexity and Uncertainty:**

   - Recognition of complexity and uncertainty as natural features of systems, and the ability to deal with this complexity through systemic thinking.

Systemic thinking has wide application, from organizations and business to community development and environmental issues. It serves as a powerful method for navigating complex situations and finding sustainable solutions.

Critical thinking:

Descriptor (2.2): To assess information and arguments, identify assumptions, challenge the status quo, and reflect on how personal, social and cultural backgrounds influence thinking and conclusions.

Knowledge: knows sustainability claims without robust evidence are often mere communication strategies, also known as greenwashing.

Skills: can analyze and assess arguments, ideas, actions and scenarios to determine whether they are in line with evidence and values in terms of sustainability.

Attitudes: trusts science even when lacking some of the knowledge required to fully understand scientific claims.

Here is a brief description of critical thinking:

1. **Analysis:**

   - The ability to closely examine and understand information by breaking complex ideas into smaller parts to identify patterns and contexts.

2. **Evaluation:**

   - To assess the accuracy, relevance and reliability of information and arguments, including identifying any bias or omissions.

3. **Logisk Reasoning:**

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- Use of logic and deductive/relevant arguments to draw conclusions and formulate well-founded views.

4. **Identification of Assumptions:**

- Consciously recognizing and challenging assumptions that support information or arguments, and assessing their validity.

5. **Problem solving:**

- The ability to apply critical thinking in solving complex problems by considering alternative solutions and their consequences.

6. **Reflection:**

- Reflecting on one's own thinking, acknowledging one's own prejudices, and being open to revising views based on new information or considerations.

7. **Evidence-based decision-making:**

- Making decisions based on solid evidence and valid information and avoiding being guided by emotions or unfounded claims.

8. **Self-awareness:**

- Being aware of one's own cognitive processes and thinking about how one's background and experiences can influence one's thinking.

Critical thinking is a fundamental skill that is important in education, business, and daily life. It helps a person make informed decisions and navigate complex situations.

Problem framing:

Descriptor (2.3): To formulate current or potential challenges as a sustainability problem in terms of difficulty, people involved, time and geographical scope, in order to identify suitable approaches to anticipating and preventing problems, and to mitigating and adapting to already existing problems.

Knowledge: knows that to identify fair and inclusive actions, it is necessary to look at sustainability problems from different stakeholder perspectives.

Skills: can establish a transdisciplinary approach to framing current and potential sustainability challenges.

Attitudes: listens actively and shows empathy when collaborating with others to frame current and potential sustainability challenges.'

Here is a brief description of problem framing:

1. **Identifying the Problem:**

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- Begin by identifying and understanding the specific problem that needs to be tackled. This often involves a careful analysis of the causes and effects of the problem.

2. **Definition of the extent of the problem:**

- Clearly define the scope of the problem by establishing its boundaries in time, place and relevant stakeholders or affected parties.

3. **Inclusion of Stakeholder Perspectives:**

- Take into account different perspectives by including the views of stakeholders affected by or interested in the problem.

4. **Transdisciplinary approach:**

- Consider the problem from a multidisciplinary point of view in order to create a more comprehensive understanding and promote diverse approaches to solutions.

5. **Focus on Fairness and Inclusivity:**

- Pay attention to fairness and inclusivity by ensuring that solutions take into account the needs and concerns of different groups in society.

6. **Time and Geographical Dimensions:**

- Take into account time perspectives (short-term and long-term consequences) and geographical dimensions to understand the evolution and spread of the problem.

7. **Acknowledging Ambiguity and Uncertainty:**

- Realize that problems are often complex and characterized by uncertainty. Be open to dealing with ambiguities and include flexibility in solution strategies.

8. **Formulation of Solution Options:**

- Once the problem has been formulated, appropriate response strategies can be examined and evaluated in order to address the core of the problem and bring about positive change.

Problem framing is an important stage in solution-oriented thinking, as a clear formulation of the problem creates the necessary foundation for developing effective and sustainable solutions.

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9. HOW DO I GET ALL 3 ASPECTS INTO MY TEACHING

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How do I get all 3 aspects into my teaching

Including systems thinking, critical thinking, and problem framing in your teaching can create a holistic and in-depth learning experience. Here are some ways these aspects can be integrated into teaching:

1. **Project-based learning:**
    - Design projects in which students must analyze complex problems or systems. This may involve different phases, such as identifying the problem (problem framing), examining system interactions (systemic thinking), and critically assessing solution options (critical thinking).
2. **Case Studies and Practice Examples:**
    - Integrate case studies and practice examples that demonstrate the application of systemic thinking, critical thinking, and problem framing in real-world situations. This helps students connect theory with practice.
3. **Discussions and Debate:**
    - Provoke discussions and debates on complex topics where students can apply systemic thinking to understand the whole, critical thinking to evaluate different points of view, and problem framing to formulate relevant questions.
4. **Multidisciplinary approach:**
    - Promote a multidisciplinary approach by involving different disciplines. This helps students develop transdisciplinary skills and understand the complexity of problems from different perspectives.
5. **Hands-On Activities:**
    - Use hands-on activities, simulations, or role-playing games that require students to apply systemic thinking, critical thinking, and problem framing to solve tasks or explore concrete scenarios.
6. **Reflection tasks:**
    - Include regular reflection assignments where students can reflect on their application of systemic thinking, critical thinking, and problem framing in their learning process and project work.
7. **Guest Lectures and Expert Involvement:**
    - Invite guest lecturers or experts in relevant fields to give students insight into how these approaches are applied in practice.
8. **Forms of assessment:**
    - Design assessment assignments require students to demonstrate their abilities in systemic thinking, critical thinking, and problem framing, such as project reports, presentations, or debate participation.

Integrating these approaches creates a dynamic learning environment that encourages students to develop key skills in understanding, evaluating, and solving complex problems.

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10. WHEN THE SUSTAINABLE ELEMENT IS ADDED

When the sustainable element is added

Combining systems thinking, critical thinking, problem framing and sustainability in teaching creates a strong link between intellectual skills and an ethical approach to complex challenges. Here are some ways it can be done:

1. **Sustainability projects:**
   - Design projects in which students examine sustainability challenges by applying systems thinking to understand system interactions, critical thinking to evaluate sustainability initiatives, and problem framing to identify equitable and inclusive solutions.
2. **Sustainability discussions:**
   - Provoke discussions on sustainability issues and have students apply their critical thinking skills to evaluate different perspectives and proposed solutions. Use problem framing to formulate key questions in sustainability.
3. **Sustainability case studies:**
   - Include case studies on successful and challenging sustainability initiatives. Students can use systems thinking to analyze the systems involved, critical thinking to evaluate the effectiveness of initiatives, and problem framing to identify further opportunities or improvements.
4. **Sustainability activities:**
   - Implement hands-on activities, such as sustainable building projects or ecological experiments, where students apply their systems thinking to understand the processes involved, critical thinking to evaluate consequences, and problem framing to create innovative solutions.
5. **Sustainability challenges:**
   - Introduce students to real sustainability challenges by involving guest lecturers from business or local organizations. Use problem framing to identify key areas and systems thinking to explore solutions.
6. **Sustainability reflection:**
   - Integrate regular reflection tasks where students think about how to integrate systems and critical thinking as well as problem framing into their understanding and commitment to sustainability.
7. **Interdisciplinary approach:**

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- Collaborate with teachers from different subject areas to create an interdisciplinary approach where students can apply systems and critical thinking across different disciplines to solve sustainability issues.

8. **Sustainability ethics:**

- Include ethical discussion on sustainability to advance students' understanding of fair and ethically responsible solutions. Use problem framing to explore issues of equity and inclusion in sustainable action.

This combination creates a learning experience that not only develops intellectual skills but also cultivates a deeper understanding of sustainable and ethical dimensions of complex challenges.

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11. THE PRACTICAL WORKFLOW EXAMPLE

Sustainability in Product Development:

- **Systems Thinking:** Students can analyze the life cycle of a product, identifying resource use, production, distribution, use, and waste management as a coherent process.
- **Critical Thinking:** Students can critically evaluate existing products and production methods in terms of their environmental impact, social responsibility, and economic viability.
- **Problem Framing:** Students can articulate sustainability issues in product development, such as waste issues, resource depletion, or environmental impacts, and work to develop sustainable alternatives.

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11.1 The Additive Manufacturing Sector

11.1.1 AM Designer

Implementation in the AM designer qualification

In the Additive Manufacturing qualifications framework, the necessity for dedicated competence units emerged from the SAM Project, as detailed in Report 3.1 - Report on skills needs for the green transition, referenced within this document. Concerning GREEN and Sustainable topics, there is a single Competence unit applicable to all Additive Manufacturing (AM) profiles is Sustainability in AM. This unit emphasizes Green skills such as the ability to discern more sustainable and straight forward solutions for daily AM activities, understanding their advantages and disadvantages, and proactively suggesting more sustainable choices throughout the AM product life cycle. Additionally, there are two other competence units pertaining to the materials used in AM Technology, one for metal materials and another for polymers.

For the Additive Manufacturing Designers specializing in metals, the competence unit Metal AM Sustainability and Circularity equips designers to:

- identify the various ways in which sustainability affects our lives;
- compare sustainable tools, considering their advantages and limitations in Metal AM production;
- explain the impact of metal AM process chains on sustainability; and
- evaluate the metal AM process chain to optimize sustainability in each segment.

While not yet incorporated into the qualification guidelines for the Designer profile, it should be included as an option, contextualizing the environmental impact relative to the industry where AM is applied.

Both simulation competence units are already integrating to the Designer qualification Program, facilitating compliance verification, topology optimization, and the proposal of production strategies aligned with simulation analysis. By simulating the execution itself, it enables the design of parts reflecting a Green Thinking approach.

Although, in this profile, there are competence units where the identification of Green Skills is evident, **Green thinking** should be embedded in all competence units of the qualification program, promoting a mindset shift among Designers. While maintaining the existing topics, we can integrate Green thinking through educational approaches and methodologies, incorporating exercises, case studies, and examples addressing Green thinking principles.

The suggestion of embed sustainable principles within this program could be done by the following examples in the addressing competence units:

Competence Unit 00: Additive manufacturing Process Overview

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Identification of the applicability of different AM processes, according to the characteristics of each process – activity suggestion:

- **Systems Thinking:** group discussion about the impact of each process into the environment and understanding the interconnection within different systems and the cause-and-effect and identifying different possibilities in order the reduce the negative impact of the designer decisions.

  Encourage trainees to delve into the systemic implications of various AM processes, considering factors such as material compatibility, part complexity and production volume.
- **Critical thinking** could be added by fostering critical analysis of each process's strengths and limitations towards the environment.
- **Problem Framing** could be integrated creating different possible scenarios that highlight the importance of selecting AM processes that align with sustainability goals, promoting a holistic approach to process selection.

Competence Unit 25: Post Processing

- **Systems Thinking** By including the analyses of environmental implications in the different post-processing options, factors such as recyclability and biodegradability can be considered.

  Promote group discussions or case studies where students will learn collaboratively when facing a problem day need to solve.
- **Critical thinking**: Trainers can Emphasize the sustainability benefits such as minimizing material waste and energy consumption during post-processing. Foster critical evaluation of post-processing methods in terms of their environmental impact, encouraging learners to prioritize techniques that minimize resource usage and emissions.
- **Problem Framing**: Frame discussions around problem-solving exercises that challenge learners to explore innovative, sustainable approaches to distortion mitigation, promoting a mindset of eco-conscious problem- solving.

  When discussing post-processing requirements, trainers should encourage learners to consider sustainability such as the use of eco-friendly materials and energy-efficient processing techniques.

Competence Unit 57: Relevant principles of DED Processes for Design

- **Systems Thinking**: Integrate sustainability criteria into the design thinking process, prompting learners to consider how eco-friendly design solutions can contribute to the overall project success.
- **Critical thinking**: Presenting learners scenarios where they need to identify opportunities for reducing environmental impact through innovative design approach.
- **Problem Framing:** Frame discussions around problem solving that emphasizes the importance of sustainable goals in shaping design solution, encouraging learners to prioritize eco-conscious design strategies.

Competence Unit 58: Design Metal AM parts for DED Processes

- **Systems Thinking** Prompting learners to question the sustainability implications of proposed production solutions considering factors such as resource usage and emissions. Motivate learners to consider long-term environmental costs and benefits of different design and production choices. Promoting exercises where learners can assess the true cost of sustainability including factors as lifecycle analysis and social responsibility.

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- **Critical thinking:** Foster critical thinking also by prompting learners to evaluate environmental impact of Metal AM possible alternative design approaches, considering factors such as material efficiency and end-of- life recyclability.
- **Problem Framing:** Challenge learners to identify opportunities for improving product sustainability through design iteration. Integrate sustainability metrics into cost analysis.

Transversal to all Competence unit trainers must promote interdisciplinary collaboration with focus on sustainability, this involves integrating eco-conscious (GREEN) principles into every stage of the design process and promoting discussions that prioritize sustainability goals in cross-functional communication and decision-making, especially regarding problem framing.

What are the benefits of implement

By embedding green skills into the Additive Manufacturing (AM) designer curricula and promoting systemic thinking, critical thinking, and problem framing, we pave the way for a more sustainable future in manufacturing. The integration of green principles not only equips designers with the knowledge and tools to minimize environmental impact but also fosters a mindset of innovation and efficiency.

Through systemic thinking, designers can consider the interrelationship of design choices, production processes, and environmental outcomes, leading to more holistic and sustainable solutions.

Critical thinking encourages designers to question assumptions, evaluate trade-offs, and explore alternative approaches, ensuring that sustainability remains a central focus throughout the design process.

Furthermore, problem framing empowers designers to redefine challenges within the context of sustainability, enabling them to identify opportunities for eco-conscious innovation and improvement.

By instilling these skills in AM designers, we not only address current environmental challenges from the early stages of the AM value chain but also nurture a generation of professionals capable of driving sustainable innovation and progress in the manufacturing industry.

11.1.2 Metal AM Process Engineer

Implementation in the Metal Process Engineer

In the Additive Manufacturing qualifications framework, the necessity for dedicated competence units emerged from the SAM Project, as detailed in Report 3.1 - Report on skills needs for the green transition, referenced within this document. Concerning GREEN and Sustainable topics, there is a single Competence unit applicable to all Additive Manufacturing (AM) profiles is Sustainability in AM. This unit emphasizes Green skills such as the ability to discern more sustainable and straight forward solutions for daily AM activities, understanding their advantages and disadvantages, and proactively suggesting more sustainable choices throughout the AM product life cycle. Additionally, there are two other competence units pertaining to the materials used in AM Technology, one for metal materials and another for polymers.

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For the Additive Manufacturing Process Engineers specializing in metals, the competence unit Metal AM Sustainability and Circularity equips Engineers to:

- identify the various ways in which sustainability affects our lives;
- compare sustainable tools, considering their advantages and limitations in Metal AM production;
- explain the impact of metal AM process chains on sustainability; and
- evaluate the metal AM process chain to optimize sustainability in each segment.

While not yet incorporated into the qualification guidelines for the Process Engineer profile, it should be included as an option, contextualizing the environmental impact relative to the industry where AM is applied.

Although the qualification programme for process engineers does not directly include the acquisition of green skills, these skills can be acquired and promoted throughout the qualification process. This is achieved through a methodological approach that encourages a change in attitude towards environmental issues.
It is therefore suggested that activities that promote critical, systemic and problem-framed thinking be prioritised throughout training.

The suggestion to embed green skills in this programme will be common to the technologies initially identified and not presented in a process specific approach.

Competence Unit 00: Additive manufacturing Process Overview

Identification of the applicability of different AM processes, according to the characteristics of each process – activity suggestion:

- **Systems Thinking:** Group discussion about the impact of each process into the environment and understanding the interconnection within different systems and the cause-and-effect and identifying different possibilities in order the reduce the negative impact of the decisions. Encourage trainees to delve into the systemic implications of various AM processes, considering factors such as material compatibility, part complexity and production volume.
- **Critical thinking:** could be added by fostering critical analysis of each process's strengths and limitations towards the environment.
- **Problem Framing:** could be integrated creating different possible scenarios that highlight the importance of selecting AM processes that align with sustainability goals, promoting a holistic approach to process selection.

Our proposal for incorporating the GREENComp approach into the qualification program for the Metal Additive Manufacturing Process Engineer encompasses optional competence units that are shared across both technologies, Directed Energy Deposition – Arc & Directed Energy deposition – LB and Powder Bed Fusion-LB. These optional units include Introduction to Materials, Metal AM Integration, and Coordination Activities, as they are applicable to and benefit both technological approaches.

Optional: CU 26: Introduction to materials

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Trainers can approach the structure and properties of metals in a GREEN way by integrating on their session planning the following actions:

- **Systems Thinking:** Encourage future engineers to approach the study of metal structures and properties from a systemic perspective, considering how material choices impact both performance and sustainability.
- **Critical thinking:** Foster critical analysis of the metal properties, prompting learners to evaluate the environmental implications of different alloys and manufacturing methods.
- **Problem Framing:** Organise group debates and brainstorming sessions with your students around the framing of problems related to the selection of materials with ecological characteristics, such as recyclability and energy efficiency.

Optional: CU 35: Metal AM integration

The topic related to the business model of an industry company and the adoption of AM processes can be target by trainers with a GREEN approach following the bellow activities:

- **Systems Thinking:** Integrate sustainability considerations into process analysis, prompting learners to evaluate the environmental impact of different manufacturing methods, including AM.
- **Critical thinking:** Promote critical thinking by challenging learners to question assumptions about the sustainability of conventional manufacturing processes and compare and explore alternative approaches enabled by AM.
- **Problem Framing:** Use case studies to promote learning through problem solving where learners need identify alternatives for integrating AM into existing processes/procedures to improve sustainability outcomes, such as reducing material waste and energy consumption. Engage students in analysing additive manufacturing (AM) processes from a sustainability perspective and identifying opportunities for green initiatives within the manufacturing process.

In order to prepare engineers to be able to design AM cells including selection of AM machine and methods to manipulate, fixturing and sensing of the part, equipment for loading and unloading, and include into their and analysis the GREEN thinking trainers can use the following activities:

- Challenge your students to consider the impact on the environment when designing AM cells considering the entire process chain.
- Use case studies where students must assess the environmental implications of equipment selection.

Frame discussions and allow your students to redefine design challenges with the context of sustainability development goals, guiding them to eco-conscious solutions that minimize resource usage and environmental impact

Optional: CU 36: Coordination activities

This Competence unit gives the students the ability to manage communications across all actors involved in the AM manufacturing chain, and the integration of green skills can be done by trainer's trough a proactive and interactive approach:

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- **Systems Thinking:** Engage students in discussions about the interconnectedness of various stakeholders in the AM process, emphasizing the importance of clear and transparent communication. Use real-world examples or case studies to illustrate how effective communication can lead to improve sustainability outcomes in AM.
- **Critical thinking:** Encourage students to critically evaluate the importance of collaboration on the AM value chain in promoting eco-friendly practices and sharing best practices.
- **Problem Framing:** Facilitate brainstorming sessions where students identify and discuss challenges within the AM manufacturing chain communication barriers and its impact on sustainability decisions.

Process AM engineers need to have the ability to established procedures for information control and traceability, trainers can promote the acquisition of this skill taking green thinking into account by applying these methods:

- Promote the integration of sustainability principles into information control and traceability procedures, prompting students to consider how data management practices can support environmental goals, such as tracking material origins and monitoring energy usage in order to establish measures to reduce carbon footprint.

Foster critical evaluation of information control and traceability systems challenging learners to assess their effectiveness in ensuring compliance with sustainability standards and regulations.

What are the benefits of implement

By incorporating systemic thinking, critical thinking, and problem framing into the training approach for additive manufacturing (AM) process engineers, we enhance their ability to drive sustainable practices and innovation within the manufacturing industry. Systemic thinking encourages engineers to consider the broader implications of their decisions, taking into account the interconnectedness of materials, processes, and environmental impacts. This approach enables engineers to make decisions that optimize resource usage, minimize waste, and reduce energy consumption, contributing to overall sustainability goals.

Critical thinking empowers process engineers to analyse complex challenges, question assumptions, and explore alternative solutions. By critically evaluating AM processes and technologies, engineers can identify opportunities for improvement and innovation, ensuring that sustainability considerations are integrated into every aspect of the manufacturing process. Moreover, critical thinking fosters a culture of continuous improvement, where engineers actively seek out opportunities to enhance sustainability performance and efficiency.

Problem framing provides process engineers with the framework to define and approach sustainability challenges systematically. By framing problems within the context of sustainability goals, engineers can develop targeted solutions that address key environmental concerns, such as material recyclability, energy efficiency, and emissions reduction. This approach encourages engineers to consider the long-term implications of their decisions, fostering a proactive approach to sustainability within the manufacturing industry.

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By incorporating systemic thinking, critical thinking, and problem framing into the training approach for AM process engineers, trainers equip them with the skills and mindset needed to drive sustainable innovation and progress. With a focus on sustainability, engineers can play a pivotal role in shaping the future of manufacturing, creating processes and technologies that not only meet the needs of today but also safeguard the environment for future generations.

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11.2 The Automotive Sector

11.2.1 E-Powertrain Engineer

Implementation in the E-Powertrain Engineering study program

Here are three practical examples of how sustainability can be integrated into E-Power Engineering teaching by combining systems thinking, critical thinking and problem framing:

Sustainable Electronic Systems Development:

- **Systems Thinking:** Analyze the electronic system development as a system that involves planning, coding, testing, safety aspects and maintenance. Identify interactions and dependencies between development phases and consider their sustainability.
- **Critical Thinking:** Critically evaluate existing electronic system development methods and technologies in terms of their energy consumption, resource efficiency, and electronic footprint impact. Consiter the feedback loops and recognize the interconnected nature of electronic systems with other ones such as energy sources and data networks.
- **Problem Framing:** Articulate sustainability challenges in electronic system development, clearly define objectives related to it, considering environmental, social, and economic dimensions.

Green Vehicle Design:

- **Systems Thinking:** Consider vehicle design as part of a larger system that includes e.g. eMotor, Power electronics, inverters, Motor control unit, Hybrid control systems, Energy transformation systems, and Transmission systems. Identify the complex interactions between vehicle components and the potential environmental impacts. Implement monitoring and feedback mechanisms to continuous assessment.
- **Critical Thinking:** Critically evaluate vehicle design and automotive electronic systems in terms of their energy efficiency, the need for vehicle components, fuel, and the social and environmental impacts of vehicle use. Evaluate also other phases of vehicle life cycle such as its components recycling or disposal. Assess different design options, technologies and strategies to determine their feasibility, effectiveness, and sustainability.
- **Problem Framing:** Formulate sustainability issues in vehicle design, such as fuel consumption during vehicle usage, issues of electricity production and storage, and the need for ethical vehicle design, and identify potential solutions.

Green Energy Storage Systems:

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- **Systems Thinking:** Consider the entire energy storage system, including the type of storage technology, charging/discharging mechanisms, and integration with renewable energy sources, to ensure sustainable energy management.
- **Critical Thinking:** Critically evaluate energy storage systemsin view of technological limitations, resource availability, and regulatory requirements. Assess different energy storage technologies (e.g. batteries, fuel cells) to determine their feasibility, effectiveness and sustainability. Identify technological risks, market risks and environmental risks. Incorporate new technologies such as energy storage in hydrogen and its efficiency.
- **Problem Framing:** Formulate challenges in energy storage and engage with relevant stakeholders such as researchers, engineers, policymakers to understand their perspectives, needs and concerns.

These examples illustrate how sustainability can be integrated into E-powertrain Engineering education by combining systems thinking, critical thinking, and problem framing to explore and solve sustainability challenges in E-powertrain Engineering.

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< What are the benefits of implement >

The electrification of the automotive sector is rapidly expanding. The E-powertrain Engineer will play a crucial role in addressing sustainability challenges by providing valuable insights, informing decision-making processes, and facilitating evidence-based solutions. Powertrain engineers, with their focus on developing eco-friendly and energy-efficient propulsion systems, are instrumental in advancing sustainable transportation. The ESCO label attests to their green skills, affirming their capacity to innovate and implement environmentally conscious solutions that contribute to reduced carbon footprints and enhanced energy efficiency.

Here are three examples in which E-powertrain Engineering is important for sustainability:

Reduced Greenhouse Gas Emissions:

- Electric powertrains, when compared to traditional internal combustion engines, produce fewer or zero emissions at the point of use. E-powertrain engineers work on designing and optimizing electric vehicles (EVs) to reduce greenhouse gas emissions, contributing to the fight against climate change.

Energy Efficiency:

- E-powertrain engineers focus on enhancing the efficiency of electric powertrains, ensuring that a higher percentage of the energy from the power source is converted into vehicle movement. Improved efficiency reduces overall energy consumption, making electric vehicles a more sustainable transportation option.

Battery Technology Development:

- E-powertrain engineers are instrumental in the advancement of battery technologies. Developing batteries with higher energy density, faster charging capabilities, and longer lifespan contributes to the sustainability of electric vehicles by increasing their overall performance and reducing environmental impact.

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11.2.2 Life Cycle Assessment Manager`s

Implementation in the LCA Manager study program

Here are three practical examples of how sustainability can be integrated into LCA Manager teaching by combining systems thinking, critical thinking and problem framing:

Sustainable Automotive:

- **Systems Thinking:** Analyze the vehicle development as a system that involves raw material extraction, distribution, vehicle production, vehicle operation, vehicle recycling, vehicle disposal with other input elements. Identify interactions and dependencies between phases and environmental impacts.
- **Critical Thinking:** Critically evaluate existing vehicle development methods and technologies in terms of their energy consumption, resource efficiency, and environmental footprint.
- **Problem Framing:** Articulate sustainability challenges in vehicle development, such as overuse of material resources, electronic waste, and security issues, and work to identify solutions.

Mobility Infrastructure Design:

- **Systems Thinking:** Apply a holistic approach that considers environmental, social, and economic aspects of a vehicle production process, usage or disposal. Consider vehicle design, energy production, energy storage systems, and charging infrastructure. Identify the complex interactions between vehicle components and the potential environmental impacts.
- **Critical Thinking:** Critically evaluate vehicle design, charging systems and infrastructure in terms of their energy efficiency, the needs for the components, fuel/energy sources, and the social and environmental impacts. Critically evaluate sources of energy for green vehicle usage. Software tools are recommended for the objective assessment of formulated sustainability issues in vehicle design.
- **Problem Framing:** Adopt a multidisciplinary approach to problem-solving, integrating expertise and insights from various fields, such as transportation engineering, urban planning, environmental science, sociology, and economics, to develop innovative and sustainable solutions.

Waste Reduction and Recycling:

- **Systems Thinking:** Consider vehicle development as part of an ecosystem that includes raw materials extraction, transport, processing, vehicle production, phase of vehicle operation and its recycling or disposal. Describe the picture of the whole system, identify its boundaries, system unit and select the approach for the assessment. Use circualr economy principles.
- **Critical Thinking:** Critically evaluate the phase of life cycle of the vehicle and fuel, assess the selected approach.
- **Problem Framing:** Formulate sustainability challenges according to the life cycle of a vehicle. Focus on its recycling development, identify industry where the components can be used, identify sustainable processing methods.

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These examples illustrate how sustainability can be integrated into LCA Manager education by combining systems thinking, critical thinking, and problem framing to explore and solve sustainability challenges in LCA Manager.

< What are the benefits of implement >

A Life Cycle Assessment (LCA) Manager plays a crucial role in promoting sustainability by conducting comprehensive assessments of products, processes, or services throughout their entire life cycle. By providing a systematic and data-driven approach to evaluating environmental impacts, an LCA Manager helps organizations make more sustainable decisions, reduce their ecological footprint, and contribute to the overall transition toward a more sustainable and responsible economy.

Here are three examples in which Life Cycle Assessment (LCA) Manager is important for sustainability:

Holistic Analysis:

- LCA Managers conduct holistic analyses that consider environmental, social, and economic aspects of a vehicle or production process. This comprehensive approach helps identify potential environmental impacts and allows for a more informed decision-making process.

Identifying Hotspots:

- LCA Managers can identify environmental "hotspots" or areas with the highest environmental impact throughout the vehicle life cycle. This information is valuable to see sustainability challenges.

Optimizing Design and Manufacturing:

- By analyzing the entire vehicle life cycle, LCA Managers can provide insights into opportunities for optimizing vehicle design and manufacturing processes. This optimization can lead to resource efficiency, waste reduction, and lower environmental impact during the production phase.

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11.3 The Batteries Sector

11.3.1 Battery Systems Engineering

Implementation in the Battery Systems Engineering study program.

Here are three practical examples of how sustainability can be integrated into Battery Systems Engineering teaching by combining systems thinking, critical thinking and problem framing:

Sustainable Battery Systems Development:

- **Systems Thinking:** Analyze the battery system development as a system that involves several phases: extraction and distribution of raw materials, battery production, operation, recycling. There are also included activities such as planning, coding, testing, safety and cyber security aspects and maintenance. Identify interactions and dependencies between development phases and environmental impacts.
- **Critical Thinking:** Critically evaluate existing battery systems and development methods and technologies in terms of their energy efficiency, resource efficiency, infrastructure for battery system application and environmental impact.
- **Problem Framing:** Articulate sustainability challenges in battery systems development, such as overuse of resources, battery waste and recycling, security issues, and work to identify solutions.

Battery Design:

- **Systems Thinking:** Consider battery design as part of a larger system that includes power electronics, inverters, control unit, energy transformation systems, and transmission systems. Identify the complex interactions between vehicle components, battery and the potential environmental impacts. Consider infrastructure for battery charging.
- **Critical Thinking:** Critically evaluate raw materials and their availability. Consider possibilities of raw materials upcycling. Consider safety issue of battery systems.
- **Problem Framing:** Formulate sustainability issues in battery design, such as raw materials availability, energy storage and battery efficiency and identify potential solutions.

Energy Storage Systems:

- **Systems Thinking:** Consider battery development as part of an ecosystem that involves circuit models, executive circuits, and drive of electronic circuits, battery systems, battery management systems and fuel cells. Identify interactions between these components and the impact on resource usage.
- **Critical Thinking:** Critically evaluate electronic circuit development practices in terms of their impact on users' energy consumption, data usage, and overall environmental impacts.

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- **Problem Framing:** Formulate sustainability challenges in electronic circuit and battery development, such as material and energy consumption, optimizing of circuits, and work to identify sustainable development methods and designs.

These examples illustrate how sustainability can be integrated into E-powertrain Engineering education by combining systems thinking, critical thinking, and problem framing to explore and solve sustainability challenges in Battery System Engineering.

< What are the benefits of implement >

Battery System Engineers are instrumental in advancing technologies that enhance the integration of renewable energy, improve energy storage efficiency, and contribute to the overall sustainability of the energy systems and transportation networks.

Here are three examples in which Battery System Engineering is important for sustainability:

Integrate Renewable Energy:

- Battery System Engineers design and optimize energy storage solutions that facilitate the integration of renewable energy sources such as solar and wind into the power grid.
- They help balance the intermittent nature of renewable energy by storing excess energy during peak production times and releasing it when demand is high.

Important for Electric Vehicles (EVs) development:

- Battery System Engineers are essential in the development of advanced and efficient battery technologies for electric vehicles.
- They contribute to increasing the range of electric vehicles, improving charging infrastructure, and enhancing the overall performance of EVs, thus reducing reliance on fossil fuels and lowering greenhouse gas emissions.

Contribute to Grid Stability:

- Battery System Engineers work on creating smart grid solutions, using batteries to store excess energy during off-peak times and releasing it during peak demand, reducing the need for conventional power plants that may use non-renewable resources.

11.3.2 Chemical Process Engineer

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Implementation in the Chemical Process Engineering study program

Here are 2 practical examples of how sustainability can be integrated into Battery Systems Engineering teaching by combining systems thinking, critical thinking and problem framing:

Sustainable Chemical Practice:

- **Systems Thinking:** Analyze the chemical processes in relation to battery system development as a system that involves several phases: extraction and distribution of raw materials, battery production, operation, recycling. There are also included processes of water management, energy management and compliance with regulations.
- **Critical Thinking:** Critically evaluate existing chemical processes in terms of their energy efficiency, resource efficiency, waste management, safety measures and environmental impact.
- **Problem Framing:** Articulate sustainability challenges in chemical processes development, such as overuse of resources, waste management, water management, materials recycling, security issues, and work to identify solutions.

Processess Optimization:

- **Systems Thinking:** Consider raw materials processing as part of an ecosystem that starts with raw material extraction, distribution, processing and extraction and application for battery production.
- **Critical Thinking:** Critically evaluate extraction and processing methods in view of their environmental impact and sustainability.
- **Problem Framing:** Formulate sustainability challenges in raw material processing such as energy consumption, materials recycling and optimizing of processing methods.

These examples illustrate how sustainability can be integrated into Chemical Process Engineering education by combining systems thinking, critical thinking, and problem framing to explore and solve sustainability challenge.

< What are the benefits of implement >

Chemical Process Engineers are instrumental in advancing sustainability within the chemical industry by implementing green practices, optimizing processes, minimizing waste, controlling emissions, and ensuring compliance with environmental regulations. Their expertise is essential for developing and maintaining sustainable practices that balance economic, environmental, and social considerations.

Here are three examples in which Battery System Engineering is important for sustainability:

Implement Green Chemistry Practice

- Chemical Process Engineers implement green chemistry principles, which focus on designing processes that minimize the use of hazardous materials, reduce waste generation, and promote safer and more sustainable chemical reactions.

Contribute to Energy Efficiency:

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- Chemical Process Engineers implement energy-efficient processes, utilize renewable energy sources, and incorporate heat recovery systems to reduce overall energy consumption.

Select Raw Materials:

- Chemical Process Engineers explore alternative feedstocks, consider renewable resources, and assess the environmental impact of raw material extraction and processing.

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11.4 The Defence Sector

11.4.1 Data Scientist

Implementation in the Data Science study program

Here are three practical examples of how sustainability can be integrated into Data science teaching by combining systems thinking, critical thinking and problem framing:

Sustainable Software Development:

- **Systems Thinking:** Analyze the software development lifecycle as a system that involves planning, coding, testing, and maintenance. Identify interactions and dependencies between development phases and environmental impacts.
- **Critical Thinking:** Critically evaluate existing software development methods and technologies in terms of their energy consumption, resource efficiency, and impact on users' digital footprint.
- **Problem Framing:** Articulate sustainability challenges in software development, such as overuse of server resources, electronic waste, and security issues, and work to identify solutions.

Green Data Management:

- **Systems Thinking:** Consider data management as part of a larger system that includes collecting, storing, analyzing, and sharing data. Identify the complex interactions between data components and the potential environmental impacts.
- **Critical Thinking:** Critically evaluate computing methods and algorithms in terms of their energy efficiency, the need for large data warehouses, and the social and environmental impacts of data use.
- **Problem Framing:** Formulate sustainability issues in data management, such as energy consumption at large data warehouses, data security issues, and the need for ethical computing, and identify potential solutions.

Eco-friendly App Development:

- **Systems Thinking:** Consider mobile app development as part of an ecosystem that involves user interaction, data transfer, and server infrastructure. Identify interactions between these components and the impact on resource usage.
- **Critical Thinking:** Critically evaluate app development practices in terms of their impact on users' energy consumption, data usage, and overall environmental impacts.
- **Problem Framing:** Formulate sustainability challenges in app development, such as battery consumption, transfer of large amounts of data, and digital traces, and work to identify sustainable development methods and designs.

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These examples illustrate how sustainability can be integrated into Data science education by combining systems thinking, critical thinking, and problem framing to explore and solve sustainability challenges in software development and data management.

< What are the benefits of implement >

Data science plays a crucial role in addressing sustainability challenges by providing valuable insights, informing decision-making processes, and facilitating evidence-based solutions. Here are three examples in which data science is important for sustainability:

Data-Driven Decision Making:

- Data science allows organizations and policymakers to make informed decisions based on empirical evidence and analysis rather than relying solely on intuition or traditional methods.
- By analyzing large datasets, patterns, and trends, decision-makers can identify areas of improvement and allocate resources more efficiently to achieve sustainability goals.

Environmental Monitoring and Management:

- Data science enables the collection and analysis of environmental data, such as air and water quality, deforestation rates, and climate change indicators.
- Monitoring and analyzing environmental data helps identify issues, track changes over time, and develop effective strategies for conservation and sustainable resource management.

Predictive Modeling for Climate Change:

- Data science techniques, including machine learning and predictive modeling, can be used to forecast and simulate the potential impacts of climate change.
- Predictive models help in developing strategies to mitigate the effects of climate change, adapt to changing conditions, and plan for sustainable development.

11.4.2 Aerospace Engineer

Implementation in the Aerospace Engineering study program

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Here are three examples of how sustainability can be integrated into aerospace engineering teaching through the lens of systems thinking, critical thinking, and problem framing:

Fuel Efficiency Optimization Project:

- Systems Thinking: Students analyze the aerospace system as a whole, considering the interconnectedness of components such as propulsion systems, airframe design, and operational procedures.
- Critical Thinking: They critically evaluate existing propulsion technologies, aerodynamic principles, and flight management systems to identify areas for improvement in fuel efficiency.
- Problem Framing: The project could involve framing the problem of reducing fuel consumption not just as a technical challenge but also as a socio-economic one, considering factors like environmental impact and cost-effectiveness.

Materials Selection for Sustainable Manufacturing:

- Systems Thinking: Students examine the lifecycle of aerospace materials from extraction and processing to manufacturing, usage, and disposal/recycling.
- Critical Thinking: They critically assess the environmental impact, energy consumption, and recyclability of different materials commonly used in aerospace engineering.
- Problem Framing: The project involves framing the challenge of material selection not just based on technical performance but also on sustainability criteria such as carbon footprint, resource depletion, and end-of-life disposal.

Designing Eco-Friendly Aircraft Concepts:

- Systems Thinking: Students consider the broader aviation ecosystem including airports, air traffic management, and passenger behavior alongside aircraft design.
- Critical Thinking: They critically evaluate traditional aircraft design parameters and explore innovative concepts such as electric propulsion, alternative fuels, and lightweight materials.
- Problem Framing: The project involves framing the design challenge not just in terms of performance metrics like speed and range but also in terms of environmental impact metrics like carbon emissions per passenger-mile, noise pollution, and habitat disruption.

In each of these examples, students are encouraged to approach sustainability challenges in aerospace engineering holistically, thinking critically about the trade-offs and synergies between technical, environmental, and socio-economic factors, and framing problems in a way that fosters innovative and sustainable solutions.

< What are the benefits of implement >

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Implementing sustainability into aerospace engineering education offers several benefits, her are three examples:

Holistic Understanding:

- By integrating sustainability principles, students develop a holistic understanding of aerospace systems, considering not only technical aspects but also environmental and socio-economic factors. This broad perspective enhances their ability to address complex challenges in the field.

Innovation and Creativity:

- Sustainability challenges often require innovative solutions. Teaching sustainability encourages students to think creatively and develop novel approaches to design, manufacturing, and operations that minimize environmental impact while maintaining performance and safety standards.

Real-world Relevance:

- Incorporating sustainability into aerospace engineering education ensures that students are prepared to address real-world sustainability issues facing the aerospace industry. This makes their education more relevant and practical, increasing their employability and readiness to contribute meaningfully to the field.

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11.5 The Energy Sector

11.5.1 Energy Systems Engineer

Implementation in the Energy Technologies and Sustainable Design study program

Here are three practical examples of how sustainability can be integrated into Energy Technologies and Sustainable Design teaching by combining systems thinking, critical thinking, and problem framing:

Sustainable Energy Supply System:

- **Systems Thinking:** Students can analyze the potential sustainable technologies that could be used in their region and analyze their capacity, reliability, and efficiency as an energy supply method.
- **Critical Thinking:** Students can critically evaluate existing energy technologies in terms of their levelized cost of energy, energy supply given local meteorological conditions and internal rate of return.
- **Problem Framing:** Students can formulate different issues in sustainable energy production, such as the periodic supply of energy, recyclability of materials, materials availability, and methods of production issues. Using their knowledge, they should propose different solutions for each problem.

Energy Efficient Buildings

- **Systems Thinking:** Students should be able to analyze the devices that are commonly used for different types of buildings and their more significant energy demands.
- **Critical Thinking:** Identify sustainable solutions that will decrease the energy demand at peak times and increase the supply of energy using the appropriate energy technology. This could also include energy storage technologies and thermal insulation measures to be taken. For sustainable energy sources, the technologies should evaluate using the daily energy produced, the area required, and the cost of implementation. Furthermore, for increasing the energy efficiency of buildings, the methods should be assessed using the cost of implementation and energy reduction abilities.
- **Problem Framing:** Formulate sustainability issues in the reliability and energy capacity of sustainable energy sources and energy storage devices. They should also assess the environmental impact of the different devices inside a building and propose methods to reduce it.

Smart Energy Grid Integration:

- **Systems Thinking:** Considers the grid and its connection to various energy technologies. Identify interactions and connections between the energy transfer from the grid to the various buildings.

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- **Critical Thinking:** Critically assess the smart technologies and devices that could be used to make the grid more sustainable and prepared for the green transition in terms of ease of implementation, material costs, and environmental impact of technologies.
- **Problem Framing:** Understand the various issues imposed by the current grid technologies such as lack of energy storage devices, data security issues, and ways to deal with forecasting energy production of renewable energy systems. Then use their knowledge to formulate different solutions that could enable a more efficient and sustainable grid.

These examples illustrate how sustainability can be integrated into Energy Technologies and Sustainable Design education by combining systems thinking, critical thinking, and problem framing to explore and solve sustainability challenges in software development and data management.

< What are the benefits of implementation>

Energy Systems would play a significant role in driving the green transition by offering advice to consumers willing to install sustainable energy systems and performing market analysis that will provide insightful information about current market trends. Here are three examples where energy systems could drive a sustainable future:

Energy Efficient Buildings

- Energy systems engineers could propose different technologies and devices that will enable an increase in the energy efficiency of buildings. These solutions will significantly decrease both the energy demands and the negative environmental impact of a building.

Smart Grid Integration

- The grid needs to be digitalized and additional security measures to be added to enable the integration of sustainable energy sources into the grid.
- Energy system engineers should be available to identify the potential issues of the current grid and various smart technologies that could be utilized to resolve the current problems.

Energy Storage Devices

- Energy storage devices are a necessity for the green transition as the energy demand and supply of a building do not always match. Energy storage devices would enable the usage of extra electricity produced at times when energy production is low.
- Energy systems engineers will know different energy storage technologies and consult the individual or the company about the most suitable technology to be used in terms of its sizing and ease of implementation.

11.5.2 Solar Energy Technician

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Implementation in the Design and Installer and the energy storage devices VET Courses

Here are three practical examples of how sustainability can be integrated into Energy Technologies and Sustainable Design teaching by combining systems thinking, critical thinking, and problem framing:

Photovoltaic system design:

- **Systems Thinking:** Students can analyze the potential photovoltaic technologies, their power capacity, and their lifetime. The students can also include a techno-economic analysis of the designed PV system.
- **Critical Thinking:** Students can critically evaluate existing energy technologies in terms of their levelized cost of energy, energy supply given local meteorological conditions and internal rate of return. In addition, they can assess each photovoltaic technology's efficiency and the appropriate components required to complete the system.
- **Problem Framing:** Students can formulate different issues in photovoltaic energy systems such as availability, recyclability of materials, risks associated with the installation of PV systems, and how to resolve them. It can also include difficulty in data monitoring information at all sites.

Battery system design:

- **Systems Thinking:** Students should be able to analyze the system in terms of self-consumption, self-sufficiency and sizing of the battery system.
- **Critical Thinking:** Identify the appropriate sizing of the battery system and enable its monitoring through smart energy devices that will optimize the flow of energy from the photovoltaic system to the battery. The student should also identify how to install the energy storage and photovoltaic system effectively, following the required health and safety procedures.
- **Problem Framing:** Formulate sustainability issues in the reliability and the problems of current materials of battery systems. Formulate safety issues and potential risks of installing such a system at the desired location.

Smart Energy Grid Integration:

- **Systems Thinking:** Considers the grid and its connection to various energy technologies. Identify interactions and connections between the energy transfer from the grid to the various buildings.
- **Critical Thinking:** Critically assess the smart technologies and devices that could be used to make the grid more sustainable and prepared for the green transition in terms of ease of implementation, material costs, and environmental impact of technologies.
- **Problem Framing:** Formulate potential issues of the current grid technologies and how to enable a safe transition to a smart energy grid. Identify potential issues of installing renewable energy sources instead of finite fossil fuels such as unpredictability and lack of storage options. Then use their practical knowledge to formulate different solutions that could enable a more efficient and sustainable grid.

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11.6 The Maritime Technologies Sector

11.6.1 Offshore Renewable Energy Engineer

Implementation in the Renewable Energy in the Marine Environment study program

Here are three practical examples of how sustainability can be integrated into Renewable Energy in the Marine Environment teaching by combining systems thinking, critical thinking, and problem framing:

Environmental conditions for marine renewable concepts

- **Systems Thinking:** Students analyse both the necessary environmental conditions that a marine renewable project has to consider and the impacts that the installation can produce in the environment.
- **Critical Thinking:** Students can critically evaluate different locations for offshore renewable energy projects in terms of their conditions for the renewable energy production and environmental loads considering also the environmental impact of the installation, social responsibility, and economic viability.
- **Problem Framing**: Students can articulate sustainability issues in an offshore renewable energy installation, such as those related to the construction materials, adequate design or environmental impacts, and work to develop sustainable alternatives. They formulate proposals to minimise impacts, and maximise the profits, including not only the energy generation, but also the services (as gathering oceanographic data) and ease the measurement of the impacts.

Operations and maintenance of marine energy arrays

- **Systems Thinking:** Students can analyse the life cycle of an offshore renewable energy array, identifying the different operations and maintenance activities required throughout the lifecycle of the project.
- **Critical Thinking**: Students can critically evaluate different maintenance strategies for offshore renewable energy projects in terms of their environmental impact of the installation, social responsibility, and economic viability.
- **Problem Framing:** Students can articulate sustainability issues in the operations and maintenance of an offshore renewable energy installation, such as those related to the use of fossil fuel energy in the process, the safety, and the cost. They formulate proposals to minimise impacts, and increase sustainability.

Integration of renewable energy into the electricity system

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- **Systems Thinking:** Considers the grid and identifies interactions and connections with the offshore energy production. Students should be able to analyse the system in terms of the impacts caused by the integration of renewable generation in the power system.

- **Critical Thinking:** Critically assess the smart technologies and devices that could be used to make the grid more sustainable and prepared for the green transition in terms of ease of implementation, material costs, and environmental impact of technologies. Identify the appropriate types of energy storage for the different points of the system assessing their benefits and weaknesses.

- **Problem Framing:** Understand the technical and economic impacts of distributed renewable generation, and ways to deal with forecasting energy production of renewable energy systems. Then use their knowledge to formulate different solutions that could enable a more efficient and sustainable grid. Formulate sustainability issues in the reliability and the problems of current materials of energy-storage systems. Formulate safety issues and potential risks of installing such a system at the desired location.

What are the benefits of implementation

Offshore Renewable Energy Engineers are expected to a crucial role in driving the green transition by contributing increase the deployment of offshore energy installations, increasing the share of renewable energy. They design and supervise the installation of offshore energy farms and equipment. They research and test locations to find the most productive location, ensure the successful execution of the design plan and make any necessary modifications or provide targeted advice.

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Environmental conditions

- A comprehensive understanding of all the environmental conditions that should be taken into account for the installation of marine renewable energy arrays is necessary to identify the most suited locations. This should involve not only the necessary conditions to produce energy and avoid damage of the structure, but also an assessment of the environmental impacts that the structure would have in the location, considering its social and economic impact.

- An extended awareness of the needs for sustainability in terms of environment, society and economy will contribute to the social acceptance of the installation of marine energy arrays.

Operations and maintenance

- Reduction in the use of fossil fuels for the operations and maintenance, increasing the efficiency of the operations and decreasing their environmental impact.

- Increased awareness of the social and economic impacts of the operation and maintenance activities.

Smart Grid Integration

- The grid needs to be digitalized and additional security measures to be added to enable the

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integration of sustainable energy sources into the grid.

- ORE engineers should be available to identify the potential issues of the current grid and various smart technologies that could be utilized to resolve the current problems.

Energy Storage Devices

- Energy storage devices are a necessity for the green transition as the energy demand and production do not always match. Energy storage devices would enable the storage of energy when the low demand matches with a high energy production.

- Energy systems engineers will know different energy storage technologies and identify the most suited solutions to install such a system at the desired location.

11.6.2 Marine Engineer

Implementation in the Marine Engineering program

Here are three practical examples of how sustainability can be integrated into Marine Engineering teaching by combining systems thinking, critical thinking, and problem framing; these examples are inspired in the activities developed in the Universidade da Coruña (UDC), as part of the Green Campus Program Multidisciplinary approach[3]. The proposed activities would be addressed jointly by several modules, following a transversal approach:

Heating Monitoring and Control

- **Systems Thinking:** Students evaluate the influence of heating parameters in the energy consumption of the buildings. They receive information of the Centralized heating system, and also of the real consumption of energy.

- **Critical Thinking:** Students can critically evaluate different parameters that can be selected to provide an optimal temperature with the lowest consumption in each area. They analyse the impact of decisions as opening doors and windows, adjusting temperature at different ranges, etc…

- **Problem Framing**: Students can articulate sustainability issues in the heating system, which may be due either to technical aspects (as matreials, isolation, or devices) or due to the uses of the facilities (temperature adjustment, opening doors, etc). They formulate proposals to minimise consumption and evaluate the benefits and constraints.

Water Audit

- **Systems Thinking:** Students evaluate the influence of tap adjustments and cisterns

[3] https://campusindustrial.udc.es/en/green-campus/

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maintenance in the water consumption. They participate in the measure of water consumption before and after the revision of cisterns, tap adjustment and installation of diffusers.

- **Critical Thinking:** Students can critically evaluate the impact of maintenance in water consumption. They analyse the impact of design in the use of water (as in the capacity of cisterns), the impact of parameters as the time programmed when a tap is open.

- **Problem Framing**: Students can articulate sustainability issues in the water management of the University buildings, which may be due either to technical aspects (as the use of diffusors, reduction of the volume of cisterns) or due to the uses of the facilities (time adjustment in the taps…). They formulate proposals to minimise consumption and evaluate the benefits and constraints.

Recycling Audit

- **Systems Thinking:** Students conduct an analysis of the recycling processes and their needs, in terms of the different types of waste produced in their training center and their classification for recycling. By groups, they develop a qualitative and quantitative analysis of the different recycling points of the center.
- **Critical Thinking:** Students can critically evaluate the accuracy in the use of recycling points, and the reasons for not classifying waste or for not doing it properly. They can evaluate the sustainability of different products in terms of the waste generated, considering their average shelf life, the possibility of re-use and recycling, and the cost for management of their waste.
- **Problem Framing**: Students can articulate sustainability issues in the selection of products in terms of their sustainability and recycling possibilities. They formulate proposals to improve the organisation of the recycling points.

What are the benefits of implementation

Marine engineers will play a crucial role in the green transition due to their responsibility in the design, building, maintenance and reparation of vessels. Marine chief engineers are responsible for the entire technical operations of the vessel. They are the head of the entire engine department aboard the ship and have overall responsibility for all technical operations and equipment on-board the ship. Integrating the green perspective from their education and training will facilitate their contribution in the design of greener vessels, but also in the better performance of technical operations.

Heating monitoring and control

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- Marine engineers will be responsible for the design of auxiliary systems in the ships, such as engines, heating, and ventilation, and also electronic equipment such as the energy and heating monitoring system. They will be responsible for developing optimised designs.
- Marine chief engineers will adapt the operations and provide instructions for a better management of the energy on board.
- Monitoring and analyzing heating data helps identify issues, track changes over time, and develop effective strategies for sustainable energy management.

Water Audit

- Marine engineers will be responsible for the design of auxiliary systems in the ships, such as pumps, and fresh water tanks and devices, and also electronic equipment such as the water monitoring system. They will be responsible for developing optimised designs for a sustainable use of water on board.
- Marine chief engineers will adapt the operations and provide instructions for a better management of fresh water on board.
- Monitoring and analyzing water consumption data helps identify issues, track changes over time, and develop effective strategies for sustainable water management.

Recycling Audit

- Marine engineers will be responsible for the design of the internal spaces of vessels, including the spaces to store or treat waste. They will be responsible for developing optimised designs for a sustainable management of waste on board in conditions of limited space.
- Marine chief engineers will be the head of the entire engine department aboard the ship having overall responsibility for maintaining vessel engine room and vessel inventory. They will be in position to optimise the waste management system at the engine room, promoting the proper recycling of waste materials.

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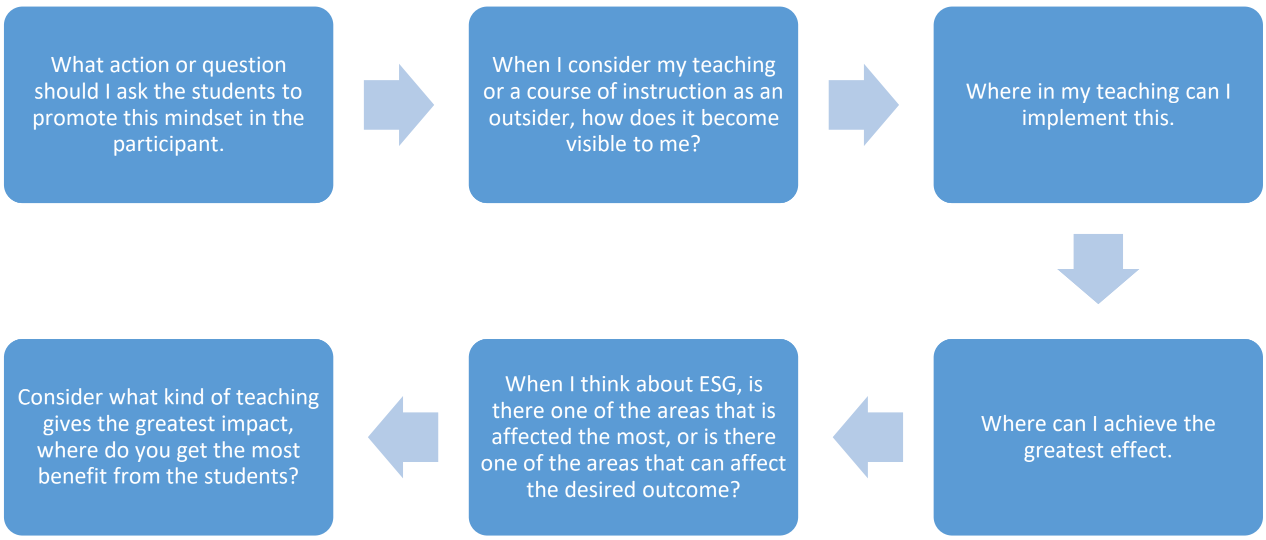
12. General recommendation

How do I implement Sustainability via Systemic Thinking, Critical Thinking and Problem Framing.

Questions you can ask yourself:



Form for implementation of the 3 aspects in teaching.

Explanation

The form is intended as a template for reflection on one's own practice in teaching. Imagine that topics 1 to 4 are questions to be answered in relation to Critical Thinking, System Thinking and Problem Framing.

The answer also includes ideas and examples of how to bring sustainable thinking into teaching.

1. What action or question should I ask the students to promote this mindset in the participant.

1.1 Examples of action

2.1. When I consider my teaching or a course of instruction as an outsider, how does it become visible to me?

3. Where in my teaching can I implement this. Where can I achieve the greatest effect. When I think about

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ESG, is there one of the areas that is affected the most, or is there one of the areas that can affect the desired outcome?

4. Consider what kind of teaching gives the greatest impact, where do you get the most benefit from the students?

Template form

	Occupation/Sector			
	Questions:	Critical thinking	Systems thinking	Problem Framing
1	How do I get this into my teaching?			
2	How do I see it in my teaching			
3	In which part of my teaching can I implement this?			
4	Can I influence the environment, socially or organizationally?			
5	Which tool should I use (Project/Case/discussion/Hands On/ Reflection….?)			

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Form filled out with some examples from different sectors

	Occupation/Sector			
	Questions:	Critical thinking	Systems thinking	Problem Framing
1	How do I get this into my teaching?	Defence/Data Students can critically evaluate existing products and production methods in terms of their environmental impact, social responsibility, and economic viability.	Battery Formulate sustainability issues in battery design, such as raw materials availability, energy storage and battery efficiency and identify potential solutions.	Energy Students can formulate different issues in sustainable energy production, such as the periodic supply of energy, recyclability of materials, materials availability, and methods of production issues. Using their knowledge, they should propose different solutions for each problem.
2	How do I see it in my teaching	Energy Students can critically evaluate existing energy technologies in terms of their levelized cost of energy, energy supply given local meteorological conditions and internal rate of return.	Auto Analyse the electronic system development as a system that involves planning, coding, testing, safety aspects and maintenance. Identify interactions and dependencies between development phases and consider their sustainability	Defence/Data Formulate sustainability challenges in app development, such as battery consumption, transfer of large amounts of data, and digital traces, and work to identify sustainable development methods and designs.
3	In which part of my teaching can I implement this?	Think ESG Which of the 3 E, S or G is relevant in this subject. Where is the biggest effect?	Think ESG Which of the 3 E, S or G is relevant in this subject Where is the biggest effect?	Think ESG Which of the 3 E, S or G is relevant in this subject. Where is the biggest effect?
4	Can I influence the environment, socially or organizationally?			
5	Which tool should I use (Project/Case/discussion/Hands On/ Reflection….?)			

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The form is a working document that can be specialized for each sector, occupation or be used in generally as it is.

Combining systems thinking, critical thinking, problem framing and sustainability in teaching creates a strong link between intellectual skills and an ethical approach to complex challenges.

We also recommend best practices as:

Sustainability projects:

- Design projects in which students examine sustainability challenges by applying systems thinking to understand system interactions, critical thinking to evaluate sustainability initiatives, and problem framing to identify equitable and inclusive solutions.

Sustainability discussions:

- Provoke discussions on sustainability issues and have students apply their critical thinking skills to evaluate different perspectives and proposed solutions. Use problem framing to formulate key questions in sustainability.

Sustainability case studies:

- Include case studies on successful and challenging sustainability initiatives. Students can use systems thinking to analyse the systems involved, critical thinking to evaluate the effectiveness of initiatives, and problem framing to identify further opportunities or improvements.

Sustainability activities:

- Implement hands-on activities, such as sustainable building projects or ecological experiments, where students apply their systems thinking to understand the processes involved, critical thinking to evaluate consequences, and problem framing to create innovative solutions.

Sustainability challenges:

- Introduce students to real sustainability challenges by involving guest lecturers from business or local organizations. Use problem framing to identify key areas and systems thinking to explore solutions.

Sustainability reflection:

- Integrate regular reflection tasks where students think about how to integrate systems and critical thinking as well as problem framing into their understanding and commitment to sustainability.

Interdisciplinary approach:

- Collaborate with teachers from different subject areas to create an interdisciplinary approach where students can apply systems and critical thinking across different disciplines to solve sustainability issues.

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Sustainability ethics:

- Include ethical discussion on sustainability to advance students' understanding of fair and ethically responsible solutions. Use problem framing to explore issues of equity and inclusion in sustainable action.

This combination creates a learning experience that not only develops intellectual skills but also cultivates a deeper understanding of sustainable and ethical dimensions of complex challenges.

We recommend going to WP 4.1 for best practices you can use in your teaching. There are several approaches to pick from.

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