A holistic and Scalable Solution for research, innovation and Education in Energy Transition

D2.3 Learning goals catalogue for the energy sector

Work Package	WP2 Energy transition skills identification and societal challenges
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Executive Summary

This deliverable provides four major results to define the conceptual framework and deliver the means to facilitate the development of new learning offers and to replicate the ASSET concepts. These results are:

- The definition of the learning graph model for the Energy Transition;
- The derivation of the ASSET vocabulary;
- The identification of the learning graph model for all the ASSET learning offers;
- The mapping of ASSET learning offers to the Knowledge-Skills-Competences (KSCs) in demand for the Energy Transition.

The definition of the learning graph model provides the template for describing learning offers (ASSET and beyond), which is the basis for implementing the learning graph tool in WP3 ("Energy Transition Programme Preparation"). The model consists of the fields learning topic, learning outcomes and learning material, each organized in specific attributes.

The ASSET vocabulary defines the set of learning outcomes, and the related terminology, based on existing taxonomies. This step is the key to: 1) identify the learning graph model for the ASSET courses, 2) integrate future learning offers from the ASSET Community in a consistent way, and 3) support replicability in other topic areas. In particular, the replicability potential of ASSET for technical topic areas other than Energy Transition is exemplified in Section 5 of this report. The ASSET vocabulary will be finalized in D2.6 "Learning goals catalogue for the energy sector", final version of D2.3.

The instantiation of the ASSET courses in terms of Learning Graph model and Vocabulary defined in this deliverable is being implemented in the Learning Graph tool in WP3.

The mapping of the Learning Outcomes, and hence of the ASSET courses, onto the KSC for the Energy Transition laid out in D2.2 titled "Report on RIE needs related to energy transition" provides an easy way to determine the coverage of such needs that the ASSET courses realize. And besides, it provides a guide to new course planning & development, which supports the sustainability efforts of WP5 "Dissemination, communication and sustainability". The indications of this mapping will also be used towards the planning of new interdisciplinary courses in WP4 "Programs delivery and piloting", to support the users of the Course-on-Demand activity in WP4, and to identify relevant internship opportunities, thus supporting mobility as in WP1 "ASSET ecosystem and networking".

The mapping of learning outcomes onto KSC demonstrates the sizeable impact of ASSET on Energy Transition education. The mapping of learning outcomes onto the SET Plan areas demonstrates the support of ASSET to the strategy and innovation path of the EU. The mapping of learning outcomes per disciplinary area (of the Frascati manual) shows the penetration of ASSET in education, pointing at the areas that are strong or should be strengthened.

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List of Acronyms

Abbreviation / acronym	Description
AI	Artificial Intelligence
BD	Big Data
DoA	Description of Action
EQF	European Qualifications Framework
FORD	Fields of Research and Development
KPI	Key Performance Indicator
KSC	Knowledge, Skills and Competences
LG	Learning Graph
PV	Photovoltaic
RES	Renewable Energy Systems
SET	Strategic Energy Technology
TOC	Table of Content
Tx.x	Task number
WPx	Work package number

1. Introduction

1.1 Purpose & Scope

This deliverable is part of WP2 “Energy transition skills identification and societal challenges”. WP2 deals with the identification of needed skills and societal challenges in the energy transition and as a consequence on the definition of the ASSET learning model that ensures replicability. In this context, the objectives of this deliverable are explained below.

First, this deliverable aims to detail the learning graph concept and show how it is applied to the ASSET programmes. Using the learning graph concept, the ASSET programmes are defined in terms of learning topics and learning outcomes. The learning graph concept allows universities and training actors to accelerate the process of programme design and delivery, while pursuing the reuse of learning materials and programme structures.

Second, this deliverable aims to provide a vocabulary, which lists and explains the learning topics and outcomes in ASSET. Keywords are provided for each learning topic, while more detailed explanations are provided for each learning outcome. The ASSET programmes are also further classified according to the European Strategic Energy Technology (SET) Plan Areas that they address. This classification shows how the ASSET programmes address the needed actions for research and innovation for the transition towards a climate neutral energy system. In addition, the ASSET programmes are classified based on the fields of research and development (FORD) of the Frascati Manual. The mapping shows how the *ASSET programmes address fields in engineering, social science and humanities*.

Third, this deliverable aims to show the mapping between the learning outcomes of the ASSET programmes and the different knowledge, skills and competencies (KSC) needs in the energy transition. These KSC needs are identified in a previous task in the project and serve as inputs to this deliverable.

Finally, this deliverable aims to give some indications on the replicability of the ASSET methodology of defining programmes for other themes. This is achieved by identifying common learning challenges, interdisciplinary and interdependent features. Examples are provided for the themes of artificial intelligence, data-driven economy and industry 4.0.

1.2 Structure of the Deliverable

The deliverable is structured as follows:

- Section 1 provides the introduction to the document.
- Section 2 introduces the learning graph concept and describes its application to the ASSET programmes.
- Section 3 provides the classification of the ASSET topics, the learning outcomes per topic, and specific details about each learning outcome.
- Section 4 provides the mapping of learning outcomes to the KSC needs.
- Section 5 provides the ground for replicating the ASSET methodology in the other fields.
- Annex I provides the mapping of each learning outcome to the KSC needs identified in D2.2 “Report on RIE needs related to energy transition”.

1.3 Relation to other WPs & tasks

This deliverable reports the outcomes of Task 2.3. This task is tightly linked with the following tasks:

- Input from Task 2.2: Task 2.2 provides the KSC needs in the energy transition were identified and defined.
- Output to Task 3.1: Task 3.1 builds on the outputs of task 2.3 in creating instances of the learning graphs of the ASSET courses using an online graph tool. The tool will give universities

and trainers the means to look for programmes, learning materials, and related detailed information.
- Output to Task 3.2: Task 3.2 builds on the outputs of Task 2.3 and Task 3.1 to creating learning materials for the different learning topics and outcomes in ASSET.

D2.6, which will be an updated version of D2.3, will be submitted by the end of the project. D2.6 will contain the updated version and list of the learning topics and outcomes covered in the ASSET project. The updates are expected to include the following:

- Updates in the formulation of learning outcomes and topics, based on the lessons learned during the deployment of the courses.
- Modification on the formulation of learning outcomes to improve reusability.
- Consideration of the case-based modules in formulating the learning outcomes.

2. The learning graph concept and structure and its adoption in ASSET

2.1 Introduction

ASSET defines the conceptual framework to facilitate and significantly accelerate the creation of new and update of current programmes as well as their replication from the universities and training actors so that these match the continuously evolving energy market needs. ASSET considers that to accelerate educational programme design and delivery, we have to pursue the reuse of learning materials and programme structures. Although ASSET will also deliver digital tools to support this sharing, in this chapter we focus on the concept of the learning graph. ASSET conceptual framework is inspired from the learning graph model [1] that was used and piloted in highly diverse use cases in H2020 MaTHiSiS project[1]. In this chapter, we outline the learning graph concept as adopted by the ASSET consortium.

2.2 Learning structures and the learning graph concept in ASSET

For the definition of any programme / course, according to the literature, the following elements are defined:

- **Learning topics** express our main learning goal and as such they are broad, general statements of what we want our students to learn and provide: Direction, Focus, and Cohesion.
- **Learning objectives:** are measurable sub-goals of a lesson and inform particular learning outcomes.
- **Learning outcomes**: A learning outcome is the specification of what a student should learn as the result of a period of specified and supported study. Learning outcomes are concerned with the achievements of the learner rather than the intentions of the teacher (expressed in the aims of a module or course).

For each programme/course, different learning materials are prepared and used to achieve the set of defined learning outcomes. This situation is depicted in Figure 1.

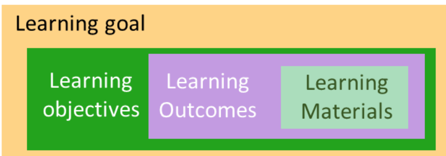

Figure 1: The organisation/structure of an educational programme today

In ASSET, we consider that any short programme can be modelled through tree structure(s) where each learning topic is sub-divided in multiple learning objectives and each learning objective in multiple learning outcomes and each learning outcome can be achieved through multiple learning materials, (as shown in Figure 2) without significant loss of generality or flexibility. While (as pointed out in [1]) any learning experience can be modelled through a learning graph which consists of four types of elements (learning goal, learning atom, Learning action and learning material), in ASSET, we consider that this structure can be simplified to a tree structure which can serve our goals of re-use of structures and materials because: the connection between different topics is a high level decision taken by the programme creator and there is no need and very little probability of two programme creators to target the same combination of topics. Thus, leaving any learning goal/topic to be organised on its own tree of learning objectives and outcomes is not limiting ASSET's vision.

[1] http://www.mathisis-project.eu/

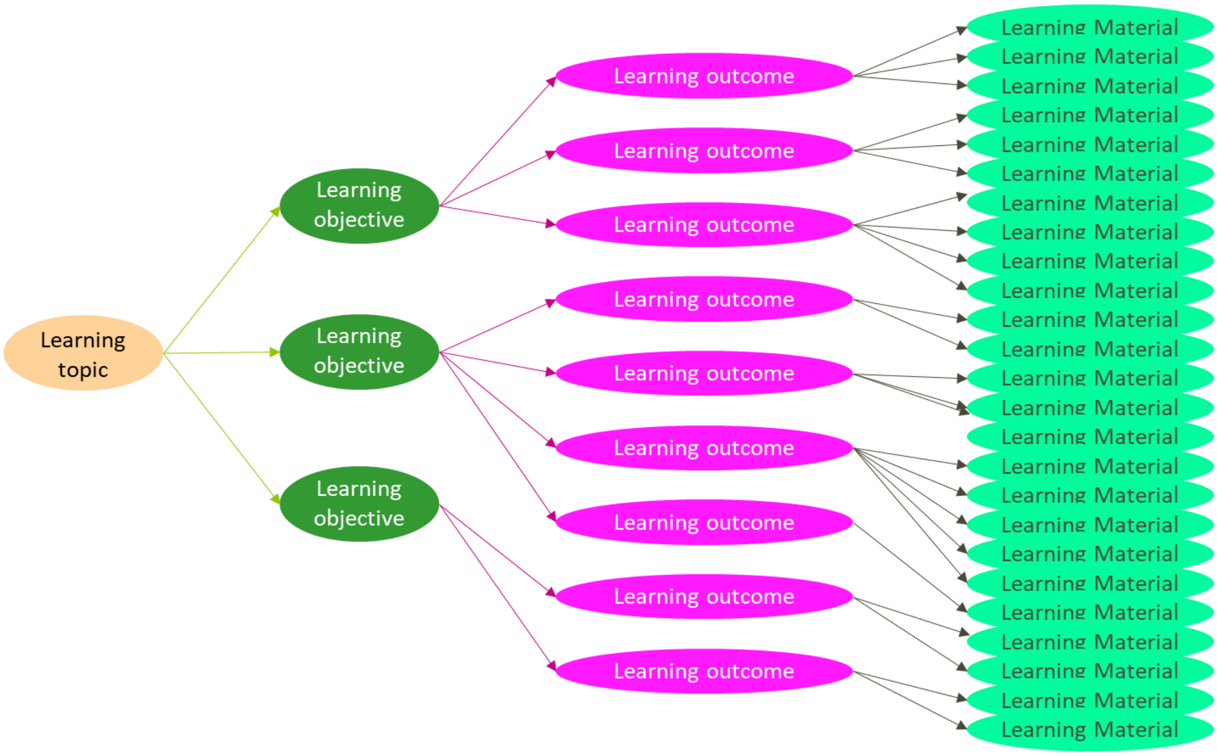

Figure 2: Tree structure of an educational programme

To simplify the situation and focus on sharing of learning materials and structures, ASSET removes the learning objective component and associates the learning outcomes directly with learning topics since there is a one-to-one relation between learning objectives and topics and between learning outcomes and objectives. The simplified situation is now shown in Figure 3. This simplification will be internally evaluated during the construction of the learning model of each of the ASSET short programmes.

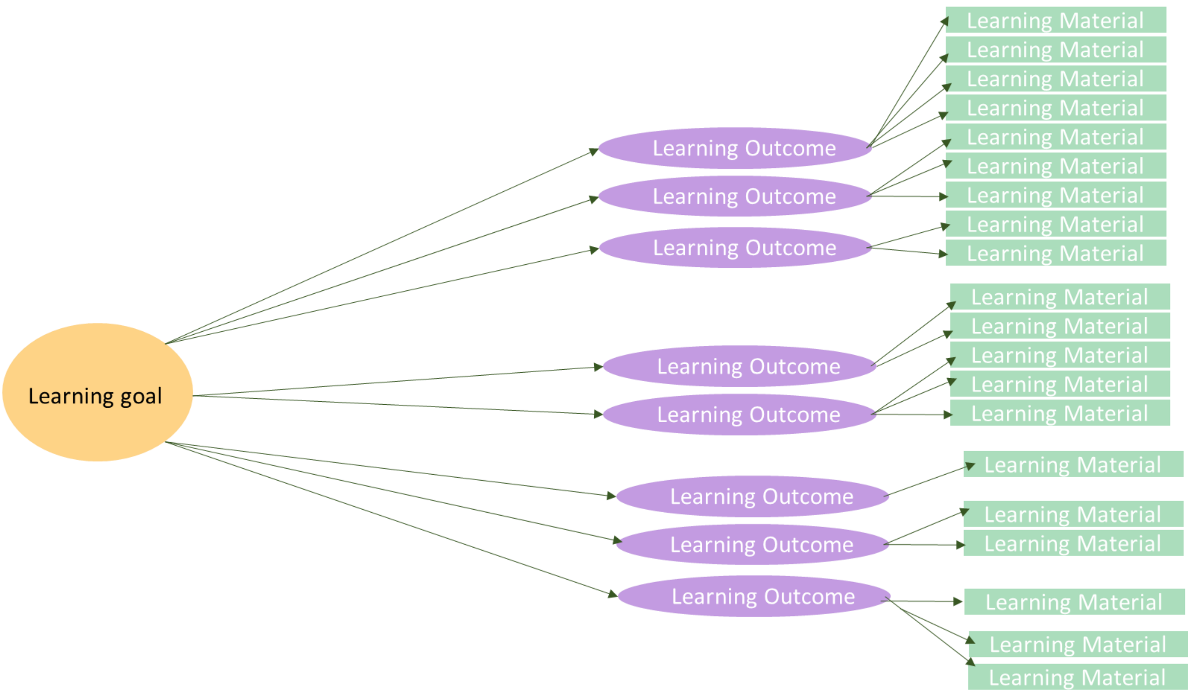

Figure 3: ASSET Learning Graph

Although in the proposal text, the learning objective and learning outcome were merged to "learning atom", we decided to keep the same (three) levels of detail but rename "learning atom" to "learning outcome". The rationale for this decision is to enable sharing of learning resources since it is mandatory to establish a widely accepted and recognised vocabulary for their description. In this perspective:

a) "Learning outcome" is a term widely used and recognised and allows for easy association between learning materials and learning outcomes and
b) attempts to create a common vocabulary have been witnessed. So, ASSET aims to contribute to these efforts and not to replace them in order to have higher potential for sustainability.

ASSET consortium partners consider that the learning graph concept enables sharing of learning resources because:

- learning **programmes targeting different EQF levels** may share common structures, such as learning topics and outcomes;
- learning programmes targeting **different teaching models** (face-to-face, MOOCs, blended or other) may have common components, such as online test, or case-based modules or presentation or educational apps;
- learning programmes targeting **different subjects** may share subsets of the learning graph structures, such as learning outcomes.

In all those cases, the tutors can re-use the whole learning topic (organised in outcomes and associated with materials) obviating the need to design and develop everything from scratch.

2.3 The elements of the ASSET Learning Graphs and the "Energy Transition Educational Vocabulary"

The ASSET learning graph comprises:

- Learning topic
- Learning outcomes
- Learning materials

For the first two, namely learning topics and learning outcomes, ASSET seeks to define and propose to the international research community a vocabulary, the "Energy Transition Educational vocabulary", to boost the re-use of the learning resources. In the follow up work in ASSET we will fully develop few tens of short programmes, each described by a learning graph/tree model.

An overall aim is to liaise the learning resources with specific KSCs. For this purpose, research on the needed KSC and on the association of KSCs with Learning Outcomes will be carried out in the framework of WP2.

2.3.1 Learning topic

As already stated above, learning topics are broad, general statements of what we want our students to learn. In ASSET, for each short programme we will define a learning topic, which will be categorised under a specific field in the energy transition sector.

This way for example, for the short programme "DC Microgrids", the learning topic is DC microgrids which is classified under the field "smart and flexible energy systems". The fields under which all ASSET learning topic will be classified are those defined by European recommendations.

With each learning topic uniquely pointing to a learning programme, in ASSET, we consider that each learning topic is associated with:

- thematic field under which it is classified (e.g. Smart and flexible energy systems, Energy storage, Renewable energy, etc.)
- title: this is the name of the learning graph/topic
- relevant keywords: to facilitate search from tutors looking for similar topics
- author
- organisation

2.3.2 Learning outcomes

ASSET adopts the definition of the learning outcomes widely used. As such, before organizing the learning graphs of the ASSET educational programmes, ASSET partners will survey:

a) rules for the definition of learning outcomes and
b) existing proposals for learning outcomes description in the energy sector. Where possible, the learning outcomes of programmes addressing similar topics will be surveyed towards defining a mature vocabulary for the sector.

In ASSET, we consider that each learning outcome is associated with:

- a specific learning topic
- title: this is the name of the learning outcome
- relevant keywords: to facilitate search from tutors looking for similar topics
- author
- organisation

2.3.3 Learning materials

Learning materials are whatever can be used by a learner to achieve a learning outcome. It can be a lecture offered by a professor, a slide-set, a serious game, video-based lessons, documents and presentations, problem-based projects (described in any format), web-based materials like quizzes, 3D objects, native mobile applications that can be executed anywhere, robot-based activities or HoloLens-based materials or any other. In ASSET, any type is of interest; however, we focus on those that can be shared and reused and thus "a lecture offered by a professor" remains out of scope of our digital tools supporting the learning graph concept.

Each learning material is associated with the following information:

- target learning outcome
- targeted EQF level
- the targeted learning/delivery mode (e.g. face to face, online, blended etc.
- the targeted audiences
- format
- content; either the file format of the learning material or a link to it (outside ASSET Learning Graph Tool).
- author
- organisation

2.4 List of ASSET Programs

In ASSET, all partners contributing to educational programmes are aware of the above concept and contribute in its refinement. We should all keep in mind that we need to include case-based modules per programme. The list of the ASSET educational programmes (copied from the DoA) is as follows:

Table 1: List of ASSET Programmes

Field	Programme	EQF	ASSET partner
Smart and flexible energy systems	Multi-terminal DC grids (Form: Seminar for Industry and PhD/MSc students)	7-8	RWTH
	AC Microgrids	7-8	AAU
	Power Quality in Microgrids		AAU

Field	Programme	EQF	ASSET partner
	DC Microgrids		AAU
	Challenges and solutions in Future Power Networks (Form: MOOC for Industry and PhD/MSc students)		RWTH
	Monitoring and distributed control for power systems (Form: course for Industry and PhD/MSc students)		RWTH
	Implementation of automation functions for monitoring and control (Form: course for Industry and PhD/MSc students)		RWTH
	Maritime Microgrids		AAU
	Power Systems Dynamics (Form: course for Industry and PhD/MSc students)		RWTH
	Case study on distribution grid operation (Form: seminar for Industry and PhD/MSc students, can be integrated as module in other courses)		RWTH
	Optimization Strategies and Energy Management Systems		AAU /LS
Energy storage	Hydrogen as energy vector	7	UPV
Renewable Energy	New Materials for solar cells applications	6- 8	UWA
	Renewable Energy Technologies[2]	6-7	UNINA
	Energy and environment	6-7	UWA
	Electrical heat pumps in the energy transition framework (CBL Module)[2]	6-7	UNINA
SSH and other cross cutting themes:	Corporate and institutional communication and Social Responsibility	6-7	UNINA
	Innovation and Diversity in engineering (MOOC)	6-7	RWTH
	Understanding Responsibility in research and Innovation (Seminar for Industry and PhD students, Postdocs, Research Group Coordinators and Science Managers)	7-8	RWTH
	Green professionalization and ethics	6-7	UNINA
	Participatory planning tools and social network analysis[3]	6-7	UNINA
	Innovation processes in the energy sector	6	OTEA

[2] Previously titled "Heat pump technology for smart production of heating and cooling using renewable sources" in the DoA.
[3] Previously titled " Socio-technical analysis" in the DoA.

Field	Programme	EQF	ASSET partner
	Energy Efficient and Ecological Design of Products and Equipment	6-7	UWA
	Economics of energy sources and the optimal integration of renewable energies and energy conservation measures	6	LS
	Behavioural change as a powerful drive to minimize the energy consumption while providing the same level of energy service	6	LS

3. ASSET Learning Outcomes

3.1 Introduction

ASSET has decided to define the so-called ASSET vocabulary in order to maximise the potential of reusability of learning resources. The ASSET vocabulary is the set of words, phrases, and terminologies that is used in ASSET to describe learning resources. Learning resources that are suitable to be re-used are:

- The learning materials (slide presentations, video lectures, web-based quiz, serious games, assessment materials and forms, Real life cases to drive project-based learning and others).
- The learning graph/ tree consisting of the learning topic and the learning outcomes; the graph for a certain topic of interest, facilitates and accelerates the job of a tutor in setting up a new educational programme.

Given that currently the ASSET learning graph consists of learning topics, learning objectives and learning materials, we need to define a vocabulary of learning topics and learning objectives. As also mentioned in the DoA, in this first deliverable, the vocabulary will include all the words/phrases that describe the educational programmes that are being built in the framework of ASSET. *It will be enriched to include more terms in the 2nd version of this deliverable.* Furthermore, to facilitate search in the ASSET Learning Graph tool, the learning topics that ASSET will address will be classified based on widely adopted taxonomies.

In the rest of this chapter we:

1. Present the most widely accepted scientific fields' taxonomies, we select the one to be adopted and supported in the ASSET learning graph and classify the ASSET topics according to it.
2. Present the learning outcomes per learning topic for each of the educational programmes that is built in ASSET. In this course, we have conducted short surveys per topic so as to check for relevant available materials and terminology in order *to maximise acceptance potential*.

For the description of the educational programmes in terms of level, we adopt the EQF while we will examine using two-digit description adopting the UNESCO's ISCET-2011[2].

Alternative wording and synonyms for keywords are taken from the EU ESCO[3], which represents a direct link to skills and jobs. Whereas this is not intended to overload D2.2, it may instead broaden it with terminology that is common to our learning objectives. Furthermore, notice that some of the key terms in our courses are not listed in this ESCO database (e.g. DC for direct current). Hence, we also used the following resources for finding relevant keywords and terminologies:

- 2019 IEEE Taxonomy [4] (for scientific use, unlike ESCO which is for linking to professional skills)
- Definition of terminology in the IEEE standards (e.g., to define items like "microgrid") [5]

3.2 Scientific Field Taxonomy

The European Universities Association in its Energy and Environment platform[6] has adopted two ways of classification of the educational programmes: the SET plan areas and the more generic "Field of education and training". Here we adopt the SET plan areas, as an impact of learning in the innovation areas which represent the foundation of EU competitiveness, and the Frascati Manual [7] as a commonly adopted basis for collecting and classifying information on scientific, research and innovation areas.

3.2.1 Supporting the SET plans through the ASSET learning topics

ASSET has decided to map its programmes to the ten key action areas identified in the European Strategic Energy Technology (SET) plan[7]. The plan coordinates national research efforts to promote cooperation among EU countries, companies and research institutions. The ten key action areas identified in the plan are the following:

1. integrating renewable technologies in the energy systems;
2. reducing costs of technologies;
3. new technologies and services for consumers;
4. resilience and security of energy systems;
5. new materials and technologies for buildings;
6. energy efficiency for industry;
7. competitiveness in global battery sector and e-mobility;
8. renewable fuels and bioenergy;
9. carbon capture and storage;
10. nuclear safety.

Error! Reference source not found. shows how each ASSET programme maps to the different SET Key Action Areas listed above.

Table 2: Mapping of ASSET learning topics to the SET Key Action Areas

ASSET Learning Topic	**SET Key Action Area Addressed**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Multi-terminal DC grids	✓									
AC Microgrids	✓		✓	✓						
Power Quality in Microgrids	✓			✓		✓				
DC Microgrids	✓		✓	✓	✓					
Challenges and solutions in Future Power Networks	✓									
Monitoring and distributed control for power systems	✓									
Implementation of automation functions for monitoring and control	✓									
Maritime Microgrids	✓	✓						✓		
Power Systems Dynamics	✓									
Case study on distribution grid operation	✓									
Optimization Strategies and Energy Management Systems	✓	✓				✓				
Hydrogen as energy vector	✓							✓		
New Materials for solar cells applications	✓									
Energy Integration of Renewable Sources to District Heating, Cooling and Power Systems										
Energy and environment	✓					✓		✓		
Electrical heat pumps in the energy transition framework			✓		✓					
Corporate and institutional communication and Social Responsibility			✓							
Innovation and Diversity in engineering/Scientific Integrity	✓									
Understanding Responsibility in research and Innovation	✓									
Green professionalization and ethics			✓							
Participatory planning tools and Social network analysis			✓							
Innovation processes in the energy sector			✓							
Energy Efficient and Ecological Design of Products and Equipment	✓	✓	✓			✓		✓		
Economics of energy sources and the optimal integration of renewable energies and energy conservation measures	✓									
Behavioural change as a powerful drive to minimize the energy consumption while providing the same level of energy service			✓	✓						

3.2.2 Classification of the ASSET Learning Topics

The Frascati Manual[8] has been used for more than 50 years as a worldwide standard for collecting and reporting data and statistics for research and development. It is published by the Organisation for Economic Co-operation and Development (OECD). The manual provides a common language for discussing R&D and its outcomes. The manual also has a classification of R&D units according to their knowledge domain. ASSET has decided to use this classification to assess the distribution of its learning topics among engineering and SSH domains.

Below is the list of the fields of research and development (FORD) covered by the ASSET programmes, as well as the subcategories covered:

2. Engineering and technology
    - 2.2. Electrical engineering, electronic engineering, information engineering
    - 2.3. Mechanical Engineering
    - 2.5. Materials Engineering
    - 2.7. Environmental Engineering
    - 2.11. Other engineering and technologies
5. Social Sciences
    - 5.3. Education
    - 5.4. Sociology
    - 5.9. Other social sciences
6. Humanities and arts
    - 6.3. Philosophy, ethics and religion
    - 6.5. Other humanities

The numbers for each field are identical to those used in the Frascati Manual 2015. Furthermore, **Error! Reference source not found.** shows the different fields covered by each ASSET programme.

Table 3: Fields of R&D covered by the ASSET learning topics

ASSET Programme	Engineering and Technology					Social Sciences			Huma-nities and arts	
	2.2	**2.3**	**2.5**	**2.7**	**2.11**	**5.3**	**5.4**	**5.9**	**6.3**	**6.5**
Multi-terminal DC grids	✓									
AC Microgrids	✓									
Power Quality in Microgrids	✓									
DC Microgrids	✓									
Challenges and solutions in Future Power Networks	✓									
Monitoring and distributed control for power systems	✓									
Implementation of automation functions for monitoring and control	✓									
Maritime Microgrids	✓									
Power Systems Dynamics	✓									
Case study on distribution grid operation	✓									
Optimization Strategies and Energy Management Systems	✓									
Hydrogen as energy vector	✓				✓					
New Materials for solar cells applications			✓							

ASSET Programme	Engineering and Technology					Social Sciences			Huma-nities and arts	
	2.2	**2.3**	**2.5**	**2.7**	**2.11**	**5.3**	**5.4**	**5.9**	**6.3**	**6.5**
Energy Integration of Renewable Sources to District Heating, Cooling and Power Systems										
Energy and environment	✓	✓		✓						
Electrical heat pumps in the energy transition framework		✓								
Corporate and institutional communication and Social Responsibility							✓			
Innovation and Diversity in engineering/Scientific Integrity						✓	✓		✓	
Understanding Responsibility in research and Innovation								✓		✓
Green professionalization and ethics							✓			
Participatory planning tools and Social network analysis							✓			
Innovation processes in the energy sector						✓				
Energy Efficient and Ecological Design of Products and Equipment	✓		✓	✓	✓					
Economics of energy sources and the optimal integration of renewable energies and energy conservation measures					✓					
Behavioural change as a powerful drive to minimize the energy consumption while providing the same level of energy service					✓					

If somebody decides to go with other taxonomies, then there are:

- the NSF taxonomy of the fields of study[4], where energy engineering and environmental engineering are distinct categories in the engineering class and sociology is under social sciences;
- the OECD Revised Field of Science and Technology (FOS) classification in the Frascati Manual 2015[5].

As SET Plan areas are more elaborated than any other taxonomy of fields, we consider that ASSET educational resources will be organized at a first level adopting OECD revised Frascati manual [7] and at a second level adopting SET-plan areas. Then, towards more elaborate categories, ASSET defines its own sub-categories as no standardized approach seems to exist today.

3.3 ASSET Learning Graphs and Vocabulary

In this section, we provide the initial learning graphs and vocabulary for the programs in ASSET. The vocabulary consists of words, phrases, and terminologies that give more detail about the learning outcomes and the learning topics. Recall that in ASSET, each programme has one learning topic, and this learning topic is the title of the programme itself. Therefore, the keywords provided for a programme are also the keywords provided for the learning topic.

[4] https://www.nsfgrfp.org/applicants/application_components/choosing_primary_field

[5] https://read.oecd-ilibrary.org/science-and-technology/frascati-manual-2015_9789264239012-en#page61), where energy falls under class 2 (engineering and technology) and more specifically category 2.2 (electrical engineering) and 2.7 environmental engineering

3.3.1 Multi-terminal DC grids

Table 4: Program Overview: Multi-terminal DC grids

Educational Programme Title	Multi-terminal DC grids
SET Area	Integrating renewable technologies in the energy systems
EQF level	7-8
Learning outcomes	• Explain the application areas of multi-terminal DC (MTDC) grids • Identify and describe the differences in operation and control between AC and DC systems • Recognise and discuss the main challenges for control of MTDC grids • Determine and establish the control objectives of converter-level control • Clarify the main features of advanced control methods applied to converter-level control • Determine and establish the control and energy management objectives of system-level control for MTDC grids • List and describe different control strategies for system-level control of MTDC grids • Explain and analyse the main challenges for monitoring and measurements in MTDC grids • Explain and formulate state estimation methods for MTDC grids • Describe the challenges for fault detection in MTDC grids • Clarify the main features of methods for fault detection in MTDC grids
Other relevant keywords	Control engineering, Control architectures, Power system stability, Control system analysis, Converters, Power electronics, Advanced control methods, Estimation, State estimation, Fault detection, Monitoring, Measurements
Notes	This single module of 2 academic hours is intended to be stand alone, easy to integrate in traditional power systems courses to give a perspective on DC and to be core for developing a full new course on the topic after verifying the relevance for the ASSET stakeholders.

Table 5: Learning Outcomes and Learning Materials: Multi-terminal DC grids

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
Explain the application areas of multi-terminal DC (MTDC) grids	● Explain the technical benefits and challenges of using MTDC grids as: - local distribution grids, like DC city quarters, and DC microgrids, like university/industrial campi - connection of separate areas of DC systems (e.g. feeders connected to different secondary substations of the distribution network) - connection between DC microgrids and microgrids with the AC power grid - collectors of renewable resources, e.g. DC collector of wind farms - DC e-vehicle charging infrastructures - shipboard or aircraft DC power systems - power systems for railway applications - energy routing networks	● Seminar slides
Identify and describe the differences in operation and control between AC and DC systems	● Key differences in the nature of AC and DC systems in terms of: - System integration - operation objectives (according to the application) - controllable electrical quantities and their characteristics - time scales of control and operation - monitoring and type of measurements - safety of network, equipment and human beings ● Existence or lack of standards for operation, control and automation	● Seminar slides
Recognise and discuss the main challenges for control of MTDC grids	● Recognise the control challenges related to: - System dynamics and time scales of control Interoperability and variety of converter vendors - Plug-and-play capability of converter-interfaced units System-level control and power flow control - Different types of distributed energy resources in MTDC microgrids (different	● Seminar slides

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
	operational characteristics, different ownership) - Emerging structures and topologies of MTDC grids ● Protections and HVDC breaker ● Economic aspects ● MTDC grid ownership and management ● Standardization	
Determine and establish the control objectives of converter-level control	● Determine and establish the control objectives for: - Fast control - Control design independent from converter model and system model - Robustness and stability	● Seminar slides
Clarify the main features of advanced control methods applied to converter-level control	● Clarify the features related to: - Virtual disturbance concept: estimation and rejection - Disturbance decoupling for converters interactions in MTDC grids	● Seminar slides ● Demo: Hardware-in-the-Loop test for validation of converter-level controller
Determine and establish the control and energy management objectives of system-level control for MTDC grids	● Determine and establish the control objectives related to: - DC voltage restoration - Power sharing among converters in MTDC microgrid - Coordination of converter-interfaced distributed energy resources in MTDC microgrid - Power flow control in DC distribution networks - Reliability, scalability and modularity of control architectures – Data privacy - Resilience to changes in control structures	● Seminar slides
List and describe different control strategies for	● List and describe the control strategies for:	● Seminar slides

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
system-level control of MTDC grids	- Primary control level in MTDC microgrids (decentralised): ▪ Droop-based control ▪ Non-droop-based control - Secondary control level in MTDC microgrids: ▪ Distributed control strategies – Consensus algorithms - Power flow control between DC microgrids - Approaches for system-level control in MTDC distribution grids - Distributed optimal power flow algorithms • Describe aspects of communication network of distributed control structures	
Explain and analyse the main challenges for monitoring and measurements in MTDC grids	• Design considerations for converter data models for grid operation • Extended IEC 61850 data model for converters	• Seminar slides
Explain and formulate state estimation methods for MTDC grids	• State estimation • Estimators in MTDC grids • State Estimation Model for AC/MTDC Distribution System	• Seminar slides
Describe the challenges for fault detection in MTDC grids	• The fault characteristics in MTDC grids • The fault impact on the operation of MTDC grids • Challenges of fault detection and isolation in MTDC grids	• Seminar slides
Clarify the main features of methods for fault detection in MTDC grids	• Methods for fault detection and location identification	• Seminar slides • Demo: Hardware-in-the-Loop test for validation of fault detection algorithm

3.3.2 AC Microgrids

Table 6: Program Overview: AC Microgrids

Educational Programme Title	AC Microgrids
SET Area	• Integrating renewable technologies in the energy system • New technologies and services for consumers • Resilience and security of energy systems
EQF level	Level 7-8
Learning outcomes	• Illustrate the concepts and Modelling of distributed AC power systems and AC microgrids • Design various control schemes for power electronic converters including voltage source inverter (VSC) • Integrate power electronics converters to form AC pico, nano and smart Microgrids in grid connected and islanded modes • Design the control schemes for the parallel operation of power converters including master slave and droop control. • Design the converter control for soft starting, harmonic current sharing and low voltage ride through capability. • Apply hierarchical control on AC microgrids with primary, secondary and tertiary layers. • Illustrate the operation of an AC microgrids cluster and interconnections of multiple AC microgrids clusters • Apply consensus and cooperation strategies for microgrids using networked multi-agent systems.
Other relevant keywords	Smart Grids, Distributed AC Power Systems, Uninterruptable Power Supply (UPS) Systems, Virtual Impedance, Droop Control, Hierarchical Control, Voltage Source Converters, Grid connected and Islanded Power Systems.

Table 7: Learning Outcomes and Learning Materials: AC Microgrids

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
Illustrate the concepts and Modelling of distributed AC power systems and AC microgrids.	• Distributed power systems • Microgrid definition • Microgrid configurations • Examples of Microgrid projects • Uninterruptible Power Systems (UPS)	(1 set of slides, 5 readings)

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
Design various control schemes for power electronic converters including voltage source inverter (VSC)	• Control principles for Voltage Source Inverter • Voltage and frequency control • Active and reactive power control	(1 set of slides, 3 readings, 2 Lab handouts and 2 simulation exercises)
Design the control schemes for the parallel operation of power converters including master slave and droop control.	• Control for parallel power converters • Master-slave control • Droop control in AC systems • Virtual impedance	(1 set of slides, 4 readings, 1 Lab handout and 1 simulation exercise)
Design the converter control for soft starting, harmonic current sharing and low voltage ride through capability.	• Soft starting mechanism • Harmonic current sharing control strategies • Low voltage ride through capability scheme design	1 set of slides, and 5 readings)
Apply hierarchical control on AC microgrids with primary, secondary and tertiary layers.	• Hierarchical control principle • Secondary control: Frequency and amplitude deviations • Secondary control for Microgrids • Microgrid synchronization with the main grid • Tertiary control for AC microgrids	(1 set of slides, 3 readings, 1 Lab handout and 1 simulation exercises)
To be able to understand the operation of an AC microgrids cluster and interconnection of multiple AC microgrids clusters	• Distributed Vs. Centralized control • Smart-grids • Interconnection of Microgrids • Clusters of AC Microgrids • Control and stability challenges of the Microgrid Cluster	(1 set of slides, and 5 readings)
To be able to understand and Implement Consensus and Cooperation in Networked Multi	• Small Signal Analysis for Primary and Secondary Control • Consensus in Multi-Agent systems applied to Microgrids	(1 set of slides, 3 readings)

3.3.3 Power Quality in Microgrids

Table 8: Program Overview: Power Quality in Microgrids

Educational Programme Title	Power Quality in Microgrids
SET Area	• Integrating renewable technologies in the energy system • Resilience and security of energy systems • Energy efficiency for industry
EQF level	Level 7-8
Learning outcomes	• Illustrate the power quality problems including harmonics, power-frequency deviations, voltage fluctuations, voltage dips, swells, interruptions and voltage unbalance • Apply various techniques for power quality improvement in microgrids including active power Injection, reactive power sharing, harmonic current sharing and voltage regulation via smart loads • Design microgrid hierarchical architecture for voltage regulation and reactive power sharing • Design virtual impedance loops for load sharing and power quality Improvement • Apply Secondary Control for Compensation of Voltage Unbalance and Harmonics in Microgrids • Employ Current-/Voltage-Controlled Inverters for Power Quality Improvement in Microgrids • Design synchronization techniques for power converters including open loop, Phase-locked loops (PLLs) and Frequency-locked loops (FLLs) based synchronization techniques
Other relevant keywords	Power Quality, Total Harmonic Distortion (THD), Unbalanced Supply and loading, Voltage Dips, Harmonic resonance

Table 9: Learning Outcomes and Learning Materials: Power Quality in Microgrids

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
Illustrate the power quality problems including harmonics, power-frequency deviations, voltage fluctuations, voltage dips, swells, interruptions and voltage unbalance	• Introduction to Power Quality Issues • Harmonics • Power-Frequency Deviations • Voltage Fluctuations • Voltage Dips, Swells and Interruptions • Voltage Unbalance	(1 set of slides, 5readings)

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
Apply various techniques for power quality improvement in microgrids including active power Injection, reactive power sharing, harmonic current sharing and voltage regulation via smart loads	• Active Power Injection • Voltage Regulation • Reactive Power Sharing Problem & Voltage Regulation • Active Power Curtailment (APC)	(1 set of slides, 3 readings, 1 lab handout and 1 simulation exercise)
Design microgrid hierarchical architecture for voltage regulation and reactive power sharing	• Microgrid Hierarchical Architecture for Voltage Regulation and Reactive Power Sharing • Voltage Regulation via Smart Loads	(1 set of slides, 4 readings)
Design virtual impedance loops for load sharing and power quality Improvement	• Islanded Harmonic Current Sharing Problem • Primary Harmonic Sharing via Inner Control Loops • Virtual Impedance Concept • Resistive, inductive, and inductive-resistive virtual impedances • Capacitive virtual impedances • Resistive-capacitive virtual impedances • Performance comparison of virtual impedance techniques • Three-phase adaptive virtual impedance • Grid-Connected Current Harmonic Injection Problem • Virtual admittances to reduce harmonic injection	(1 set of slides, 3 readings, 1 lab handout and 1 simulation exercise)
Apply Primary and Secondary Control for Compensation of Voltage Unbalance and Harmonics in Microgrids	• Primary Control for Microgrids Power Quality • Secondary Control for Microgrids Power Quality	(1 set of slides, 2 readings, 1 lab handout and 1 simulation exercise)
Employ Current-/Voltage-Controlled Inverters for	• Coordinated Control of CCM Inverters	(1 set of slides, 3 readings,1 Lab handout

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
Power Quality Improvement in Microgrids	• Coordinated Control of VCM and CCM inverters	and 1 simulation exercise)
Design synchronization techniques for power converters including open loop, Phase-locked loops (PLLs) and Frequency-locked loops (FLLs) based synchronization techniques	• Phase-locked loops (PLLs) • Frequency-locked loops (FLLs) • Open-loop synchronization techniques • Dynamic interaction between power converter and PLL	(1 set of slides,5 readings, 2 Lab handouts and 2 simulation exercise)

3.3.4 DC Microgrids

Table 10: Program Overview: DC Microgrids

Educational Programme Title	DC Microgrids
SET Area	• Integrating renewable technologies in the energy system • New technologies and services for consumers • Resilience and security of energy systems • New materials and technologies for buildings
EQF level	Level 7-8
Learning outcomes	• Recognize the importance of DC Microgrids as a reliable, resilient and efficient technology for the integration, distribution, and utilization of renewable / non-renewable based generation and storage resources • Illustrate various architectures, configurations and applications of DC Microgrids at the residential, commercial and industrial level • Design various control schemes on the individual power electronic converters for DC microgrids • Design various control schemes on the parallel converters for DC microgrids • Design and apply various layers of hierarchical control including primary, secondary and tertiary control for DC microgrids
Other relevant keywords	Integration of DC Distributed Generation, DC Distribution, HVDC for Transmission

Table 11: Learning Outcomes and Learning Materials: DC Microgrids

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
Recognize the importance of DC Microgrids as a reliable, resilient and efficient technology for the integration, distribution, and utilization of renewable / non-renewable based generation and storage resources	• Distributed Renewable/Non-renewable Energy Resources • Overview of Microgrid Technology • Microgrid Configurations and Examples	(1 set of slides, 2readings)
Illustrate various architectures, configurations and applications of DC Microgrids at the residential, commercial and industrial level	• Current war • DC Microgrids configurations • DC Microgrids at home • DC Microgrids facilities	(1 set of slides, 3 readings)
Design various control schemes on the individual power electronic converters for DC microgrids	• Feedback linearization control • One cycle control • Buck converter • Half-bridge with synchronous rectifiers • Half-bridge current doubler rectifier	(1 set of slides, 3 readings, 2Lab handouts and 2 simulation exercises)
Design various control schemes on the parallel converters for DC microgrids	• Parallel control schemes • Centralized control • Master-slave control • Averaged control • Droop control • Virtual impedance • Adaptive voltage positioning (AVP)	(1 set of slides, 4 readings, 1 Lab handouts and 1 simulation exercise)
Design and apply various layers of hierarchical control including primary, secondary and tertiary control for DC microgrids	• Voltage droop: Primary control • Secondary control • Secondary control for DC Microgrids	(1 set of slides, 3 readings, 3 Lab handout and 3 simulation exercises)

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
	• Tertiary control for DC Microgrids • Clusters of DC Microgrids	

3.3.5 Challenges and solutions in Future Power Networks

Table 12: Program Overview: Challenges and solutions in Future Power Networks

Educational Programme Title	Challenges and solutions in Future Power Networks
SET Area	Integrating renewable technologies in the energy systems
EQF level	7-8
Learning outcomes	• List and explain the challenges in future power systems • Explain and analyse how new control techniques can be used for addressing the challenges • Explain how real time simulations help in testing new solutions for future power systems • Explain how monitoring systems enable key functions in future power systems
Other relevant keywords	Control engineering, Frequency control, Automatic frequency control, Voltage control, Automatic voltage control, Power system stability, Power system dynamics, Power system monitoring, Real-time systems, Monitoring, Measurements, ICT

Table 13: Learning Outcomes and Learning Materials: Challenges and solutions in Future Power Networks

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
List and explain the challenges in future power systems	• Technical issues in power systems caused by distributed generation, power-electronic based grids, low-inertia systems, and other new technologies.	• Lecture Slides and Video: Today's and Tomorrow's Networks
Explain and analyse how new control techniques can be used for addressing the challenges	• Methods for stabilizing low-inertia systems using RoCoF control • Maintaining stability using the concept Linear Swing Dynamics	• Lecture Slides and Video: Linear Swing Dynamic: a new approach to frequency control • Lecture Slides and Video: New voltage control techniques • Lecture Slides and Video: Frequency Control & Stability in Future Power Electronics Networks (Workshop)

		• Lecture Slides and Video: Dynamic Voltage Stability (Workshop)
Explain how real time simulations help in testing new solutions for future power systems	• Commercial and customized simulation tools • Simulation tools for developing new control techniques for future power systems	• Lecture Slides and Video: Introduction to real time simulation tools
Explain how monitoring systems enable key functions in future power systems	• Classical state-estimation • State-estimation as applied to distribution systems • Multi-area state estimation approaches	• Lecture Slides and Video: Monitoring of Power Systems

3.3.6 Monitoring and distributed control for power systems

Table 14: Program Overview: Monitoring and distributed control for power systems

Educational Programme Title	Monitoring and distributed control for power systems
SET Area	Integrating renewable technologies in the energy systems
EQF level	7-8
Learning outcomes	• To investigate and apply the basics of uncertainty propagation in measurements • To assess the applications of measurements in power systems • To examine and appraise the application of distributed measurements in power systems • To investigate and apply the fundamentals of distributed intelligence in power system
Other relevant keywords	• State Estimation Measurement uncertainty, Measurement errors, Substation automation architecture, Phasor Measurement Unit, Synchrophasor

Table 15: Learning Outcomes and Learning Materials: Monitoring and distributed control for power systems

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
To investigate and apply the basics of uncertainty	• Identify the basic principles of measurement and its uncertainty. • Recognise the challenges in measurement in power systems	• Lecture slides: Introduction and features of the evolving power system • Lecture slides: Fundamentals of metrology and

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
propagation in measurements	• Analyse how uncertainties propagate in power system measurements • Arrange simple statistical evaluation of measurements • Evaluate measurement compatibilities.	measurement Uncertainty, GUM standard • Exercise: Uncertainty calculation and propagation
To assess the applications of measurements in power systems	• Describe how transducers (voltmeter, ammeter) are used for measurements • Investigate how to perform power measurements in multi-phase systems • Examine the synchrophasor concept and how it is implemented via PMU • Examine the function of the different parts of the PMU	• Lecture slides: transducers for power systems • Lecture slides: digitization of monitoring chain • Lecture slides: Synchrophasor measurement, PMUs • Exercise: Calculation of synchrophasors
To examine and appraise the application of distributed measurements in power systems	• Analyse how state-estimation works • Apply distributed measurements for state-estimation • Employ quantities measured by the PMU to improve the performance of state-estimation	• Lecture slides: State Estimation -- Static, centralized state estimation • Lecture slides: Integration of PMU data in state estimation (extension of classical state estimation, new linear problem form, post-processing) • Exercise: Computation of state estimation
To investigate and apply the fundamentals of distributed intelligence in power system	• Identify the advantage and need of using agents in power system. • Examine the use and significance of the FIPA standard	• Lecture slides: Agents in power systems: an introduction. • Demo: Agents sample application

3.3.7 Implementation of automation functions for monitoring and control

Table 16: Program Overview: Implementation of automation functions for monitoring and control

Educational Programme Title	Implementation of automation functions for monitoring and control
SET Area	Integrating renewable technologies in the energy systems
EQF level	7-8
Learning outcomes	• to explain and apply the basics of IEC61850

	• to employ Intelligent Electronic Devices for monitoring, distribution and protection functions • to examine and criticise the IED and substation configuration recognize and define the main features of advanced control methods applied in converter-level control
Other relevant keywords	Automation, Hands-on, Automation standards
Notes	This is a laboratory

Table 17: Learning Outcomes and Learning Materials: Implementation of automation functions for monitoring and control

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
to explain and apply the basics of IEC61850	• Apply IEC61850 in order to implement a substation architecture	• Laboratory Module: IEC 61850 Substation Architecture • Lecture slides, quiz, lab assignment descriptions
to employ Intelligent Electronic Devices for monitoring, distribution and protection functions	• Implement automation functions using a range of monitoring and intelligent-end devices. • Configure the devices with the appropriate settings.	• Lecture slides: System Specification description • Laboratory Module: Network Topologies for automation system • Laboratory Module: Automation using PMU in ac grid • Laboratory Module: Automation and Protection • Lecture slides, quiz, lab assignment descriptions
to examine and criticise the IED and substation configuration recognize and define the main features of advanced control methods applied in converter-level control	• Configure the IEDs, PMUs, and substation devices with the appropriate settings.	• lecture slides: Substation configuration description • Laboratory Module: Communication protocols in IEC 61850 substation automation • Lecture slides, quiz, lab assignment descriptions

3.3.8 Maritime Microgrids

Table 18: Program Overview: Maritime Microgrids

Educational Programme Title	Maritime Microgrids
SET Area	1) integrating renewable technologies in the energy system 2) energy efficiency for industries 3) reducing the cost of technologies
EQF level	Level 7-8
Learning outcomes	• Illustrate the shipboard power system and integrated electric applications in ships. • Analyse maritime microgrid characteristics and identify power quality challenges in shipboard microgrid power systems • Apply signal processing techniques to analyse power quality disturbances in maritime microgrids • Categorise the ship power systems evolution and identify the directions for future research challenges • Analyse the stability of Multi-converter shipboard MVDC power system.
Other relevant keywords	Electric Ships, Shipboard Microgrids, Shipboards power systems. Islanded Mobile Microgrids, Electric Ferries

Table 19: Learning Outcomes and Learning Materials: Maritime Microgrids

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
Illustrate the shipboard power system and integrated electric applications in ships.	• Ships power system evolution. • Shipboard electrical applications (Integrated Power Systems). • MVDC power systems on ships. • Integrated Electrical/Electronics ships Power Systems design. • Integrated Power & Energy Systems Dependability on ships	(1 set of slides, 2readings)
Analyse maritime microgrid characteristics and identify power quality challenges in shipboard microgrid power systems	• Introduction to power quality in maritime microgrids • Maritime microgrids characteristics • Standard framework • Power quality assessment in • Marine microgrids	(1 set of slides, 3 readings)
Apply signal processing techniques to analyse power quality	• Basic standards related to PQ • Phenomena measurement	(1 set of slides, 3 readings, 2Lab hand-outs

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
disturbances in maritime microgrids	• Overview of measuring • Instruments hardware • Standard methods of signal • Processing of PQ disturbances • Recommendations for • Measurement of PQ • Disturbances in maritime • Microgrids	and 2 simulation exercises)
Categorise the ship power systems evolution and identify the directions for future research challenges	• Shipboard DC microgrids • Model parameters estimation • Options for the DC interface	(1 set of slides, 3 readings)
Analyse the stability of Multi-converter shipboard MVDC power system.	• Multi-converter shipboard MVDC power system • Voltage control solutions in the multi-converter case • Constant Power Load issue • CPL modelling • Control techniques to face the CPL instability	(1 set of slides, and 3 readings, 1 lab hand-out and 1 simulation exercise)

3.3.9 Power Systems Dynamics

Table 20: Program Overview: Power Systems Dynamics

Educational Programme Title	Power Systems Dynamics
SET Area	Integrating renewable technologies in the energy systems
EQF level	7-8
Learning outcomes	• To explain and apply the principles of power system dynamics • To describe and show the fundamentals of the associated network components • To classify the division of power system dynamics • To explain and apply stability control
Other relevant keywords	Stability, Frequency Stability, Voltage Stability, Power System Modelling, Classification of power System Dynamics, Multi-Machine Systems

Table 21: Learning Outcomes and Learning Materials: Power Systems Dynamics

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
To explain and apply the principles of power system dynamics	• Explain the basic principles, different disturbances that cause dynamics in the power system • Explain the analytical and graphical methods to study electromechanical dynamics of power systems • Explain the concept of stability in the context of power systems • Identify the challenges in power system stability arising from the new trends in power systems	• Lecture slides: Trends in power system structure and services • Lecture slides: Fundamentals on PSD: present and future • Lecture slides: Stability problems and methods • Lecture slides: Swing equations (analytical method) • Lecture slides: Equal area criterion (graphic method) • Exercise: Equal area criterion • Lecture slides: Static stability problems
To describe and show the fundamentals of the associated network components	• Illustrate and apply line and machine models in order to determine the system response to disturbances. • Explain the steady-state behaviour of power system components • Describe the electromagnetic concepts governing the response of the synchronous machine	• Lecture slides: Transmission lines model • Lecture slides: Synchronous machine model • Exercise: transmission line modelling • Exercise: electromagnetic phenomena
To classify the division of power system dynamics	• Identify the different issues and areas of study under power system dynamics • Identify the main causes of power system dynamics, its spectrum, and the nature of the system response to these dynamics	• Lecture slide: Classification of Power System Dynamics • Exercise: Classification of Power System Dynamics
To explain and apply stability control	• Define and apply control theory and methods to maintain voltage and frequency stability in the power system	• Lecture slides: Steady-State Stability of Multi-Machine System • Lecture slides: Voltage Stability • Exercise: Voltage Stability • Lecture slides: Frequency Stability • Exercise: Frequency Stability

3.3.10 Case study on distribution grid operation

Table 22: Program Overview: Case study on distribution grid operation

Educational Programme Title	Case study on distribution grid operation
SET Area	Integrating renewable technologies in the energy systems
EQF level	7-8
Learning outcomes	• Explain the new measurement and monitoring needs in distribution systems • Explain the automation requirements in distribution systems for measurement and monitoring • Explain the problems and automation solutions for monitoring based on an actual implementation on a distribution grid
Other relevant keywords	State Estimation, Substation automation architecture, Phasor Measurement Unit, Automation, Automation standards

Table 23: Learning Outcomes and Learning Materials: Case study on distribution grid operation

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
Explain the new measurement and monitoring needs in distribution systems	• Understanding why there is a need to integrate monitoring devices in distribution grids • Understanding the specification of the state of art monitoring devices (SM, PMU, …) utilized in distribution grids • The application of state estimation as a monitoring solution in distribution systems	• Lecture slides: problem definition in operation of active distribution grid • Lecture slides: Monitoring devices (SM, PMU, …) • Lecture slides: distribution system state estimation
Explain the automation requirements in distribution systems for measurement and monitoring	• Design of automation system architecture (e.g. SGAM framework) • Standards for the automation system (IEC 61850, DLMS/COSEM, IEEE C37.118, …) • Data acquisition and the interfaces between the monitoring system and the peripheral devices	• Lecture Slides: Distribution Automation Concept, Architecture Design and Implementation • Readings: Deliverable 3.1 and 3.2 of the IDE4L project
Explain the problems and automation solutions for monitoring based on an actual implementation on a distribution grid	• Introducing the test site (LV+MV grids) • Measuring different electrical variables via SM, PMU and VIED • To send measured values and store them in the database (PostgreSQL, MySQL, etc.)	• Lecture slides: The grid topology from Unareti • Lecture slides: the automation architecture for monitoring the grid

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
		• Video: a demo shows sending and storing the measurements

3.3.11 Optimization Strategies and Energy Management Systems

Table 24: Program Overview: Optimization Strategies and Energy Management Systems

Educational Programme Title	Optimization Strategies and Energy Management Systems
SET Area	• Integrating renewable technologies in the energy system • Energy efficiency for industries • Reducing the cost of technologies
EQF level	Level 7-8
Learning outcomes	• Relate process system engineering with modelling and optimization techniques used in power systems. • Apply different optimization tools for solving continuous, semi continuous and discrete optimization problems in energy systems. • Employ EXCEL, MATLAB, and GAMS for solving continuous, semi continuous and discrete optimization problems. • Employ various optimization and planning tools including heuristic optimization, and population-based optimization. • Design the schemes for supply side management including optimal power dispatch and unit commitment. • Design the schemes for demand/load side management including peak shaving and load control/ load shifting programs
Other relevant keywords	Power System Optimization, Energy Management Systems (SMS), Demand Side Management, Supply Side Management, Economic Dispatch, Unit Commitment

Table 25: Learning Outcomes and Learning Materials: Optimization Strategies and Energy Management Systems

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
Relate process system engineering with modelling and optimization techniques used in power systems.	• Interlink between PSE and energy management systems (EMS) • Energy Management in Microgrids and smart grids	(1 set of slides, 3 readings)
Apply different optimization tools for solving continuous, semi continuous and discrete	• Linear Programming • Quadratic Programming	(1 set of slides, 3 readings, 1 lab hand-

optimization problems in energy systems.	• Mixed Integer Linear Programming (MILP)	out and 1 simulation exercise)
Employ EXCEL, MATLAB, and GAMS for solving continuous, semi continuous and discrete optimization problems	Implementation on • Excel • Matlab • GAMS	(1 set of slides, 3 readings, 1 lab hand-out and 1 simulation exercise)
Employ various optimization and planning tools including heuristic optimization, and population-based optimization.	• Limits of classical optimization methods • Heuristic Optimization methods • Population-based Optimization and Swarm Intelligence	(1 set of slides, 5 readings, 1 lab hand-out and 1 simulation exercise)
Design the schemes for supply and demand side management including unit commitment, economic power dispatch, peak shaving, and load shifting.	• Peak shaving • Generation/Supply Side Management • Demand/Load Side Management	(1 set of slides, 4 readings, 1 lab hand-out and 1 simulation exercise)

3.3.12 Hydrogen as energy vector

Table 26: Program Overview: Hydrogen as energy vector

Educational Programme Title	Hydrogen as energy vector
SET Area	Integrating renewable technologies in the energy systems by means of energy storage, using hydrogen as a renewable fuel.
EQF level	7
Learning outcomes	• Identify hydrogen properties and applications • Recognise industrial hydrogen production processes • Explain electrolysis technology working • Describe hydrogen storage technology • Explain electricity generation through the use of fuel cells • Calculate a hydrogen energy storage system
Other relevant keywords	Energy storage, Hydrogen storage, Fuel Cells, Energy conversion, Fuel economy, Renewable energy sources
Notes	The programme provides the fundaments of the hydrogen technology, using it as a way to store energy. Hydrogen production methods (using different energy sources) are presented, among which more special attention is paid to electrolysis as a mean for producing hydrogen from renewable energies. Hydrogen storage methods are described and process of electrical energy generation from hydrogen by using fuel cell technology is explained.

Table 27: Learning Outcomes and Learning Materials: Hydrogen as energy vector

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
Identify hydrogen properties and applications.	The properties of the hydrogen, as energy content, compression factor, etc., should be known as introduction to the use of this gas as energy vector. Moreover, is useful to know current applications of hydrogen.	• Seminar slides
Recognise industrial hydrogen production processes.	Hydrogen is the most abundant element in the universe, however it is always combined with other elements forming compounds. Knowing the industrial processes for obtaining hydrogen is a key element when it comes to its use as an energy storage. Production methods from fossil fuels, from biological sources and by means of thermolysis are presented.	• Seminar slides
Explain electrolysis technology working.	When hydrogen is used as energy storage from renewable sources, electrolysis of water is done. It is important to know the basic principles of electrolysis and the two main technologies used currently to do it: alkaline electrolysers and Polymer Electrolyte Membrane (PEM) electrolysers.	• Seminar slides • Electrolyser demonstration video (Laboratory session).
Describe hydrogen storage technology.	Produced hydrogen should be stored. There are different methods to store hydrogen. Knowing the technology and the advantages and disadvantages of each method is important, as well as all the elements involved in a hydrogen storage system.	• Seminar slides
Explain electricity generation through the use of fuel cells.	In order to complete the hydrogen energy store cycle, production of electrical energy from hydrogen is done. Fuel cells are used to do it. There are six types of fuel cells: Alkaline fuel cells (AFC), Molten Carbonate Fuel Cells (MCFC), Solid Oxide Fuel Cells (SOFC), Phosphoric Acid Fuel Cells (PAFC), Polymer Electrolyte Fuel Cells (PEMFC) and Direct Methanol Fuel Cells (DMFC). Knowing each technology and the scope of their working is important to decide how to use them in each case.	• Seminar slides • PEMFC demonstration video (Laboratory session)
Calculate a hydrogen energy storage system.	For a particular renewable energy production system, the methodology to select the components and size the hydrogen energy storage system is presented.	• Seminar slides • Case study

3.3.13 New Materials for solar cells applications

Table 28: Program Overview: New Materials for solar cells applications

Educational Programme Title	New Materials for solar cells applications
SET Area	Integrating renewable technologies in the energy systems
EQF level	Level 7
Learning outcomes	• Recall the history of Solar Cells • Identify the importance of Solar Energy • Define the Power generation from solar cells • Recall the operation of solar cells • Describe the Production of solar cells • List thin films solar cells • Describe the polymer solar cells • Define Methodology and Importance of materials characterization • Describe Solar cells technology • List the Characterization techniques • Describe the optical measurements • Identify materials properties and characterization • Define implement Solar Energy Spectrum and the Necessity of Band Gap Tuning
Other relevant keywords	Solar Energy, Energy resources, Energy conversion, Solar cells materials, Polymer films, thin films, nanostructured materials

Table 29: Learning Outcomes and Learning Materials: New Materials for solar cells applications

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
Recall the history of Solar Cells	Be aware of the History of solar cell using slides, videos and practice exercises	• Slides & videos • 5 readings • 5 practice exercises
Identify the importance of Solar Energy	Understand the important of solar energy using slides, videos and practice exercises	• Slides & videos • 5 readings • 4 practice exercises
Define the power generation from solar cells	Study power generation from solar cells using slides, videos and practice exercises	• Slides & videos • 4 readings • 4 practice exercises
Recall the operation of solar cells	Acquire knowledge on the operation of solar cells, using slides, videos and practice exercises	• Slides & videos • 5 readings

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
		• 4 practice exercises
Describe the Production of solar cells	Acquire knowledge on the use of silicon for the production of solar cell, using slides, videos and practice exercises	• Slides & videos • 7 readings • 4 practice exercises
List thin films solar cells	Acquire knowledge on the use Thin film solar cells, using slides, videos and practice exercises	• Sides & videos • 5 readings • 5 practice exercises
Describe the Polymer solar cells	Acquire knowledge on the use Polymer solar cells, using slides, videos and practice exercises	• Slides & videos • 7 readings • 5 practice exercises
Define the methodology and Importance of materials characterization	Understand the concept, importance and methodologies for materials characterization, using slides, videos and practice exercises	• Slides & videos • 5 readings • 2 practice exercises
Describe the Solar cells technology	Understand solar cell technologies, using slides, videos and practice exercises	• Slides & videos • 5 readings • 2 practice exercises
List the characterization techniques	Be able to apply techniques for characterization, using slides, videos and practice exercises	• Slides & videos • 5 readings • 2 practice exercises
Describe the Optical measurements	Be able to design and perform optical measurement, using slides, videos and practice exercises	• Slides & videos • 5 readings • 2 practice exercises
Identify materials properties and characterization	Be able to design and perform band gap measurements. Understand material properties. Be able to model a solar cell. Acquire knowledge of solar energy conversion by semiconductors	• Slides & videos • 5 readings • 2 practice exercises
Describe the Implement Solar Energy Spectrum and the Necessity of Band Gap Tuning	a. Perform experiments to measure Band Gap of ZnO Films Using UV-Vis Absorption Spectra (CBL) b. Preparation of Zn1-xMxO Films c. Analysis of Results	• Slides & videos • 5 readings • 2 practice exercises

3.3.14 Renewable Energy Technologies

Table 30: Program Overview: Renewable Energy Technologies

Educational Programme Title	Renewable Energy Technologies
SET Area	Integrating renewable technologies in the energy systems
EQF level	Level 3/Level 4
Learning outcomes	At the end of the course, students will be able to: • describe fundamentals and main characteristics of renewable energy sources and technologies and their differences compared to fossil fuels; • evaluate the effects that current energy systems based on fossil fuels have over the environment and the advantages of renewable energy sources; • compare different renewable energy technologies and choose the most appropriate based on local conditions; • perform simple energy, environmental and techno-economical assessments of renewable energy systems; • design, at least at a preliminary level, renewable/hybrid energy systems; • discuss how to utilize local energy sources to improve the sustainability of energy-related activities.
Other relevant keywords	Renewable energy sources, Biomass, Energy storage, Geothermal energy, Solar energy, Photovoltaic energy, Wind energy, Hydroelectric energy

Table 31: Learning Outcomes and Learning Materials: Renewable Energy Technologies

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
Describe fundamentals and main characteristics of renewable energy sources and technologies and their differences compared to fossil fuels.	Understand the working principle of renewable energy technologies.	Seminar slides
Evaluate the effects that current energy systems based on fossil fuels have over the environment and the advantages of	Evaluate the advantages of renewable energies with respect to fossil fuels.	Seminar slides

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
renewable energy sources.		
Compare different renewable energy technologies and choose the most appropriate based on local conditions.	Understand the main technical characteristics of renewable energy technologies and evaluate their suitability to a given application.	Seminar slides
Perform simple energy, environmental and techno-economical assessments of renewable energy systems.	Evaluate renewable energy systems from energy, economic and environmental viewpoints.	Seminar slides
Design, at least at a preliminary level, renewable/hybrid energy systems.	Understand and apply the basic design principles of renewable energy technologies.	Seminar slides
Discuss how to use local energy sources to improve the sustainability of energy-related activities.	Evaluate the impact related to the use of local, renewable energy sources.	Seminar slides

3.3.15 Energy and environment

Table 32: Program Overview: Energy and environment

Educational Programme Title	Energy and environment
SET Area	• integrating renewable technologies in the energy systems • energy efficiency for industry • renewable fuels and bioenergy • carbon capture and storage • new materials and technologies for buildings • energy efficiency
EQF level	6-7
Learning outcomes	• Relate the energy generation and consumption with the environment. • Recognize the impact to the local and global climate that the energy generation and consumption have. • Classify what is Renewable and non-renewable source of energy. • Describe the energy efficiency, ecolabel EU legislation

	• Select energy efficiency and energy savings actions in everyday life and especially in energy consumption, at appliance level, house level, enterprise level, country level. • Identify and select equipment and devices based on energy efficiency criterion. Ability to perform the studies and work and to assess their results considering this parameter. • Ability to use the principles of ecological design (Eco-Design) and environmental legislation regulations that define the design, operation and the end of life cycle of electrical equipment and installations, in his/her professional activity. • Describe the legislation on the end of life treatment and recycling potential of waste electrotechnical equipment, as a key activity related to energy consumption and environment • Recognize the relationship of the profession of Electrical Engineering and the environment and their interdependence. • Ability to apply that knowledge in his/her business life.
Other relevant keywords	Energy efficiency, energy transformation, energy market, energy efficiency, develop energy policy, identify energy needs, analyse energy consumption, develop energy saving concepts, renewable energy technologies, energy sector policies, fossil fuels, energy label, ecolabel, renewable energy sources, environmental impact, air pollution, GHG emissions, End-of-life equipment, Environmental impact, Climate change, Pollution, Climate crisis
Notes	Sources used to prepare the learning outcomes (e.g. other courses offered and organised around the same topic, etc.)

Table 33: Learning Outcomes and Learning Materials: Energy and environment

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
Relate the energy generation and consumption with the environment.	• Understand the emissions to the environment of different types of energy sources. The role of energy usage to cover human needs and the emissions associated. Types of fuels and their impact to the environment	• Seminar slides
Recognize the impact to the local and global climate that the energy generation and consumption have.	• Understand the impact of energy usage and generation in local scale: thermal island effect, locally increased humidity, change in the landscape from large infrastructures, deforestation, emission of different types of pollutants in air, water and soil, toxic emissions, etc. The global effects as	• Seminar slides, • Documentary from YouTube.

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
	ice banks melting, ozone depletion, global temperature increment	
Classify what is Renewable and non-renewable source of energy.	• Basic definitions and terminology on energy sources. Definition of the terms fossil and non-fossil, renewable and non-renewable in energy sources. Categorization on the types and kinds of energy sources, global reserves, the role of sun in renewables and non-renewables.	• Seminar slides
Describe the energy efficiency, ecolabel EU legislation	• The EU legislation on energy efficiency and eco label. Presentation, provisions, obligations and targets. Energy efficiency labelling and ecolabel. Global ecolabel initiatives. The role of the legislation on reducing the environmental impact of energy generation and consumption.	• Seminar slides, • EU Legislation documentation
Select energy efficiency and energy savings actions in everyday life and especially in energy consumption, at appliance level, house level, enterprise level, country level.	• Presentation of the energy efficiency in everyday life through specific actions. The role of human behaviour in energy saving. Energy efficient appliances and energy efficient actions at home. Energy efficiency decision making at domestic enterprise level. The role of state legislation on energy efficiency strategies. The energy savings concept and the relation to the economic factors.	• Seminar slides • Online tools for calculations • Case studies
Identify and select equipment and devices based on energy efficiency criterion. Ability to perform the studies and work and to assess their results considering this parameter.	• The concept of lifecycle costing on selecting equipment and appliances. The role of energy efficiency criterion and the selection based on total life cycle cost. • Lifecycle cost analysis and calculation for different types of appliances and equipment.	• Seminar slides • Online tools for calculations • Case studies
Ability to use the principles of ecological design (Eco-Design) and environmental	• Eco-design engineering approach: evaluation of the environmental impact of the total life of a product or service. The role of design on the	• Seminar slides

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
legislation regulations that define the design, operation and the end of life cycle of electrical equipment and installations, in his/her professional activity.	selection of raw materials, product production processes, logistics and transportation, packaging, use phase and end-of-life of a product. The role of recyclability and repairability of a product. The environmental impact of the end-of-life and the energy consumption associated. Alternatives with low energy actions. • The alternative but closely related activity and professional engagement fields of engineering profession, new environmental regulations that define the design and operation and the end of life cycle of electrical equipment and installations.	
Describe the legislation on the end of life treatment and recycling potential of waste electrotechnical equipment, as a key activity related to energy consumption and environment	• The criticalities of end-of-life equipment. The role of engineers on determine the end-of-life. The energy demand and consumption of the end-of-life processes. WEEE and waste management EU directives. Wastes as raw materials. Industry around the end-of-life equipment. Power consumption during end-of-life and energy reductions from using wastes as row materials. The role of purity of materials recovered through recycling in reducing the energy consumption of new products production.	• Seminar slides
Recognize the relationship of the profession of Electrical Engineering and the environment and their interdependence.	• Summarize of the relation paths between the profession of engineer in general and particularly of electrical engineer and the relation to the environment and energy consumption based on the presentation of the course	• Seminar slides
Ability to apply that knowledge in his/her business life.	• Problem solving for small case studies.	• Case studies

3.3.16 Electrical heat pumps in the energy transition framework

Table 34: Program Overview: Electrical heat pumps in the energy transition framework

Educational Programme Title	Electrical heat pumps in the energy transition framework
SET Area	Electrical heat pumps in the energy transition framework
EQF level	Level 3 /Level 4
Learning outcomes	At the end of the course, students will be able to: • Analyse the potential use of the electrical heat pump technology • Describe heating and cooling load profiles • Compute primary energy consumption and environmental impact • Describe the heat pump working principle • Illustrate different technologies • Compute the performance of a heat pump according to standards • Size a heat pump and run simulations • List technologies for heat storage with heat pumps • Describe best practices for application in complex systems
Other relevant keywords	Heat pumps, Energy savings in buildings

Table 35: Learning Outcomes and Learning Materials: Electrical heat pumps in the energy transition framework

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
Analyse the potential use of the electrical heat pump technology	Compare the heat pump technology to other options for heating and cooling of buildings in the energy transition framework / describe the rationale behind the use of heat pump coupled to renewable energy sources	Seminar slides
Describe heating and cooling load profiles	Analyse and compare typical load profiles for different types of buildings and climate both during summer and winter conditions.	Seminar slides
Compute primary energy consumption and environmental impact	Do calculations of energy consumption and environmental impact during simple situations where load is known of energy	Seminar slides

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
Describe the heat pump working principle	describe the heat pump working principle and the variation of the performance under variable boundary conditions	Seminar slides
Illustrate different technologies	Know the schematics and compare different technologies based on the final user needs (high performance chiller systems, multiple unit direct expansion systems, systems working with natural fluids)	Seminar slides
Compute the performance of a heat pump according to standards	Do simple calculations of seasonal performance indicators for a heat pump once known the map of performance under different conditions, following the standards	Seminar slides
Size a heat pump and run simulations	Size a heat pump and read critically the results of a dynamic simulation	Seminar slides
List technologies for heat storage with heat pumps	Describe the basics of thermal energy storage technologies for heat carriers at low and medium temperatures. Describe the options for heat storage application at a district scale	Seminar slides
Describe best practices for application in complex systems	Describe different options of heat pump integration in complex systems based on heating/cooling load peaks compared to total power needs	Seminar slides

3.3.17 Corporate and institutional communication and Social Responsibility

Table 36: Program Overview: Corporate and institutional communication and Social Responsibility

Educational Programme Title	Corporate and institutional communication and Social Responsibility
SET Area	New technologies and services for consumers
EQF level	6 and 7
Learning outcomes	• Compression of the basic knowledge on the relationship between corporate communication and organizational features in order to be able to design a communication plan (the case of energy corporate campaigns).

	• Evaluating the role and the importance of the ethical aspects and socio-environmental sustainability for energy companies.
Other relevant keywords	Communication strategies/needs, prosumerism & ethical critical consumption, ICT, energy companies.
Notes	No specific background required to attend the course. Participants will learn communication strategies and the role of social corporate responsibility tools. At the end of the course, attendants will be able to evaluate, investigate and design communication plan focusing on socio-environmental issues.

Table 37: Learning Outcomes and Learning Materials: Corporate and institutional communication and Social Responsibility

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
Compression of the basic knowledge on the relationship between corporate communication and organizational features in order to be able to design a communication plan (the case of energy corporate campaigns).	• Ability to recognize organizational models and communication needs. • Understanding the role of ICT and ethical issues in consumption and communication. • Acquiring basic element to describe and set a communication plan, focusing on new marketing strategies and public relations tools.	• Seminar slides and selected papers
Evaluating the role and the importance of the ethical aspects and socio-environmental sustainability for energy companies.	• Acquire the essential knowledge of the concept of social responsibility and the socio-environmental impacts. • Understand communication campaign strategies of energy companies for sustainability. • Ability to description of essential features to plan a communication campaign for energy companies.	• Seminar slides and selected papers

3.3.18 Innovation and Diversity in engineering

Table 38: Program Overview: Innovation and Diversity in engineering

Educational Programme Title	Innovation and Diversity in engineering
SET Area	Integrating renewable technologies in the energy systems (by sensitizing for users and developing user acceptance)
EQF level	EQF level 6-7
Learning outcomes	• Explain and compare different gender and diversity approaches • Discuss the context between diversity and innovation • Create transfer between stereotyping, labelling and social processes • Identify and discuss the cultural aspects of gender and diversity as well as its impact on the career choice, the task selection and the quality of developed solutions, design, technologies and products • Evaluate the complex impact of social aspects for learning and working in research, development and engineering • Demonstrate to work self-organized and improve their presentation competence, being able to work with the concepts of intersectionality (gender and diversity) as well as their ability to work in an interdisciplinary team
Other relevant keywords	• Engineering Education • Innovation • Engineering Culture
Notes	Other courses: Diversity and Innovation

Table 39: Learning Outcomes and Learning Materials: Innovation and Diversity in engineering

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
explain and compare different gender and diversity approaches	• Introduction of gender approaches • Introduction of diversity approaches	• Video lecture: Gender and diversity approaches • Exercise (group work): Comparing different approaches
discuss the context between diversity and innovation	• Understand how diversity affects innovations	• Video lecture: Innovation and diversity • Text work • Exercise: Discussion of the studies/Literature reflecting own experiences and assumptions

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
create transfer between stereotyping, labelling and social processes	• Concept of stereotyping and labelling • Stereotyping and labelling in engineering	• Video lecture: Innovation and ethics
identify and discuss the cultural aspects of gender and diversity as well as its impact on the career choice, the task selection and the quality of developed solutions, design, technologies and products	• Engineering Education • Understanding who becomes an engineer • Engineering Culture	• Video lecture: Culture and diversity • Video lecture: Engineering culture • Text work • Exercise: Role play
evaluate the complex impact of social aspects for learning and working in research, development and engineering	• Overview social aspects • Impact of social aspects in engineering	• Video lecture: The impact of social aspects
demonstrate to work self-organized and improve their presentation competence, being able to work with the concepts of intersectionality (gender and diversity) as well as their ability to work in an interdisciplinary team	• Presentation methods • Group work in interdisciplinary teams	• Text work • Role play

3.3.19 Understanding Responsibility in Research and Innovation

Table 40: Program Overview: Understanding Responsibility in Research and Innovation

Educational Programme Title	Understanding Responsibility in Research and Innovation
SET Area	Integrating renewable technologies in the energy systems
EQF level	7-8
Learning outcomes	• Examine the concept of responsibility in research and innovation • Asses how to involve stakeholders in an innovation process • Discuss social impact of research and innovation

	• Propose ways to improve the alignment of research with societal needs • Discuss "responsibility" in a case study
Other relevant keywords	• Responsible research and innovation (RRI) • university social responsibility (USR) • engineering ethics • public engagement

Table 41: Learning Outcomes and Learning Materials: Understanding Responsibility in Research and Innovation

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
Examine the concept of responsibility in research and innovation	This interactive workshop for junior and senior researchers, science and research managers, industry partners, etc. aims to raise awareness about the different aspects of social responsibility in innovation processes and research projects (ethics, public engagement, public outreach, etc.)	• lecture by instructor: slides • interactive discussions (partly based on video material) • card-based engagement exercise
Asses how to involve stakeholders in an innovation process	• Reflect on different ways of involving different stakeholders in the whole process of innovation (in ET context) • Learn about methods to facilitate dialogue and discussions on research and innovation with different societal actors	• lectures by instructor: slides • interactive discussions (partly based on video material) card-based engagement exercise
Discuss social impact of research and innovation	Discuss the relationship between science, research, innovation, and society and reflect on different aspects of social impact	• lectures by instructor: set of slides will be provided • interactive discussions (partly based on video material) • card-based engagement exercise • case study discussion or problem-based learning activity (in the specific context of energy transition)
Propose ways to improve the alignment of research with societal needs	Propose different adaptations to better align a research project with societal needs, values, and expectations	• lectures by instructor: set of slides will be provided • interactive discussions (partly based on video material) • case study discussion or problem-based learning activity

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
		(in the specific context of energy transition)
Discuss "responsibility" in a case study	Discuss the concept of "responsibility" in a case study on distribution grid operation, for instance	• interactive discussions • case study discussion or problem-based learning activity

3.3.20 Green professionalization and ethics

Table 42: Program Overview: Green professionalization and ethics

Educational Programme Title	Green professionalization and ethics
SET Area	New technologies and services for consumers
EQF level	6-7
Learning outcomes	• Recall the sociological terminology about the role of professionals and expert knowledge in society • Describe the professionalization process of the "green-collars" • Identify and recognize empirical experiences of green professionalization
Other relevant keywords	Professionalization, green jobs, ethics, sustainable development
Notes	Previous courses offered and organised around the same topic (i.e. Sociology of professions and energy transition.) Participants will be able to understand how the professional profiles of energy transition are intertwined with the overall process of social-technical change. Emerging compromises between technical and social skill will be detected and analysed. Furthermore, participants will be able to establish connection between the green professionalization process and the users' domain, in order to understand how to enhance new paths of sustainable energy consumption.

Table 43: Learning Outcomes and Learning Materials: Green professionalization and ethics

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
Recall the sociological terminology about the role of professionals and expert knowledge in society	• Understand the social construction of competencies fields of jurisdiction in order to: 1 – question the social "power" of experts and professionals; 2 – investigate how professional ethics and social legitimation are interrelate in contexts of socio-technical transition.	• Seminar slides selected papers
Describe the professionalization process of the "green-collars"	• Understand the nexus between energy transition and emerging socio-technical skills. • Understand the role of the "green collars" in the environmental disputes related to the energy transition.	• Seminar slides and selected paper
Identify and recognize empirical experiences of green professionalization	• Acquire basic methodological notions of the sociological research in order to retrace empirical experiences of green professionalization	• Seminar slides and selected paper

3.3.21 Participatory planning tools and Social network analysis

Table 44: Program Overview: Participatory planning tools and Social network analysis

Educational Programme Title	Participatory planning tools and Social network analysis
SET Area	New technologies and services for consumers
EQF level	6-7
Learning outcomes	• Clarifying the meaning and implications of Energy Transition • Identifying the meaning and implication of Sustainable planning of Energy Transition • Recognising Social Network Analysis as a tool of Participatory Planning
Other relevant keywords	Sustainable development, territories, communities

Notes	No specific background required to attend the course. Participants will be able to understand the “social construction” of Energy Transition relating to: the territorial perspective, the social perspective and the environmental perspective. The concept of sustainability and of participatory planning will be analysed, specifically relating the implications in terms of cooperation/conflict. Furthermore, participants will be able to acquire basic notions of theoretical and methodological approach of the Social Network Analysis, specifically in order to identify: networks as tools of participatory planning; role, skills and weight of the brokers.

Table 45: Learning Outcomes and Learning Materials: Participatory planning tools and Social network analysis

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
Clarifying the meaning and implications of Energy Transition	Understand the social construction of Energy Transition from the: • territorial perspective; • social perspective; • environmental perspective.	Seminar slides and selected papers
Identifying the meaning and implication of Sustainable planning of Energy Transition	Understand the concept of sustainability and of participatory planning. Understand the implications in terms of cooperation/conflict using case studies.	Seminar slides and selected paper
Recognising Social Network Analysis as a tool of Participatory Planning	Acquire basic notions of theoretical and methodological approach of the Social Network Analysis, specifically in order to identify: • network as a tool of participatory planning; • role, skills and weight of the brokers.	Seminar slides and selected paper

3.3.22 Innovation processes in the energy sector

Table 46: Program Overview: Innovation processes in the energy sector

Educational Programme Title	Innovation processes in the energy sector
SET Area	New technologies and services for consumers
EQF level	4

Learning outcomes	• Understand Innovation Processes • To familiarise with Growth Mindset • To develop Design Thinking • To understand Lean Start-up Methods • To acquire basic knowledge about the Stage Gate Process in Corporations • To be able to design Innovation Structures in Corporations
Other relevant keywords	• Innovation Structure • Innovation Processes • Growth Mindset • Design Thinking • Lean Start-up Methods • Stage Gate Process in Corporations • Innovation Structures in Corporations • Education
	This course explains essential methods and tools of Innovation Management, targeted in the field of energy sector. Starting at fundamental definitions and the self-image of innovation managers, it covers Design Thinking, Lean Start-up methods, and innovation in corporations. To know these methods is essential for start-up founders, entrepreneurs, innovators, R&D experts and CEO's. It shows the basic framework in which complex innovation projects are successfully implemented.

Table 47: Learning Outcomes and Learning Materials: Innovation processes in the energy sector

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
Understand Innovation Processes	• Basic Terms of Innovation • Types of innovation • Innovation Management	• Presentation • Video
To familiarise with Growth Mindset	• Understand the Growth Mindset concept and the 4 principles of Growth Mindset • Experiment with the four principles	• Presentation • Video
To develop Design Thinking	• Understand the concept of design Thinking Process Model • Acquire knowledge about the basic principles of Design Thinking • Experiment with Design Thinking Toolbox • Develop Prototypes	• Presentation • Case Study

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
To understand Lean Start-up Methods	• To understand Lean Start-up Methods • To acquire basic knowledge of the Business Model Canvas and other Canvas Methods as tool for innovation process design	• Presentation • Case Study

To acquire basic knowledge about the Stage Gate Process in Corporations	• Understand the Stage Gate Process
	  ◦ The Strategy Process
	  ◦ The Ideation Process
	  ◦ The Evaluation Process
	  ◦ The Incubation Process
	  ◦ The Market Launch Process
	  ◦ Reasons for Failure
		• Presentation
		• Case Study

To be able to design Innovation Structures in Corporation	• Understand innovation structure • Experiment with the design of innovation structures using the relevant tools	• Presentation • Case Study

3.3.23 Energy Efficient and Ecological Design of Products and Equipment

Table 48: Program Overview: Energy Efficient and Ecological Design of Products and Equipment

Educational Programme Title	Energy Efficient and Ecological Design of Products and Equipment
SET Area	• Integrating renewable technologies in the energy systems • Energy efficiency for industry • Renewable fuels and bioenergy • Carbon capture and storage • New materials and technologies for buildings • Energy efficiency
EQF level	6-7
Learning outcomes	• Analyse the EU Energy Efficiency, EcoLabel, EcoDesign, RoHS and WEEE Directives. • Identify the connection of the energy and environmental aspects of the design process of a product and a system, during the total life cycle of a product. • Identify the Economics of Energy Efficient Design and EcoDesign of products and systems. • Identify the Consumer Orientation - Innovation through Eco-Design and Energy efficient Design, based on the total life cycle analysis approach. • Combine methods for developing and adopting strategies for Eco and Energy efficient design of products and systems through analysis of all phases in their life and reverse engineering approaches.

	• Analyse different components and methods for reducing the impact of a product or equipment in the environment during the different phases of its life cycle. • Combine the Concepts and Methodologies and Basic Tools for the Energy efficient and Eco Design of Products. • Ability to perform Life Cycle Analysis and Life Cycle Costing Analysis during the design of a product and the calculation of the Total Cost of Ownership • Intergrade RES during the energy efficient and ecological/sustainable design process or during improvement schemes for systems and products. • Ability to perform the studies and work and to assess their results considering this parameter. • 11. Ability to use the principles and methodologies of energy efficient and ecological / sustainable design (Eco-Design) in his professional activity.
Other relevant keywords	Sustainable design, ecological principles, Life Cycle Analysis, Life Cycle costing Analysis, analyse ecological data, environmental aspects of products, industrial design, analyse energy consumption, energy efficiency, develop energy policy, identify energy needs, analyse energy consumption, develop energy saving concepts, renewable energy technologies, product policies, energy label, ecolabel, end-of-life equipment, Environmental impact, energy sector policies, energy markets, renewable energy technologies, renewable energy sources, environmental impact, GHG emissions
Notes	Sources used to prepare the learning outcomes (e.g. other courses offered and organised around the same topic, etc.)

Table 49: Learning Outcomes and Learning Materials: Energy Efficient and Ecological Design of Products and Equipment

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
Analyse the EU Energy Efficiency, EcoLabel, EcoDesign, RoHS and WEEE Directives.	• Presentation and analysis of the EU legislation on Energy Efficiency, product policies, ecolabel, energy label, RoHS and WEEE directives. • Analysis of the concepts and implementation methods of the legislation.	• Seminar slides • Legislation Presentations
Identify the connection of the energy and environmental aspects of the design process of a product and a system, during the total life cycle of a product.	• Design process and what determines. Analysis of raw materials selection on environmental impact. • The role of packaging and logistics. Impact from the manufacturing or construction process.	• Seminar slides,

	• The role of design on end-of-life treatment alternatives. • The design for recyclability and repairability. • The design choices and their impact through specific cases studies.	
Identify the Economics of Energy Efficient Design and EcoDesign of products and systems.	• Understanding of the economics in design. The critical role of the energy efficient design or/and eco-design in cost. The requirements and provisions of eco-design legislation in the price and the economics related to the products or systems. Examples and case studies. The role of price for the consumer or customer.	• Seminar slides
Identify the Consumer Orientation - Innovation through Eco-Design and Energy efficient Design, based on the total life cycle analysis approach.	• Analysis of the consumer behaviour and needs and the connection to innovative approaches in design. The consumer need analysis and green products. The role of application and needs driven innovation. The role of life cycle approach in consumers and their perspective.	• Seminar slides,
Combine methods for developing and adopting strategies for Eco and Energy efficient design of products and systems through analysis of all phases in their life and reverse engineering approaches.	• Development of a methodological approach. System approach, process approach and component approach. • Estimation and analysis of energy consumption of products and equipment. • IEC, EU and other standards. • Setting priorities for determine the correct actions. • Evaluation of improvement potential via quantitative, semi quantitative and qualitative methods. • Strategies and methods. • Case studies.	• Seminar slides • Case studies
Analyse different components and methods for reducing the impact of a product or equipment in the	• Environmental impact assessment of products, equipment and systems.	• Seminar slides • Case studies

environment during the different phases of its life cycle.	• The role of reverse engineering and reverse analysis and product life cycle management methods. • Setting priorities for determine the most efficient actions. • Evaluation of improvement potential via quantitative, semi quantitative and qualitative methods. • The Environmental Performance Declaration. • Strategies and methods. The design for recyclability and repairability. • The criticalities of end-of-life equipment. The energy demand and consumption of the end-of-life processes. • Wastes as raw materials. Industry around the end-of-life equipment. • Case studies.	
Combine the Concepts and Methodologies and Basic Tools for the Energy efficient and Eco Design of Products.	• The MEErP method of EU. The role of boundaries. Focusing on specific life cycle part to maximize the benefits. • Evaluation of improvement potential via quantitative, semi quantitative and qualitative methods. • Strategies and methods. • Case studies.	• Seminar slides
Ability to perform Life Cycle Analysis and Life Cycle Costing Analysis during the design of a product and the calculation of the Total Cost of Ownership	• The Life-Cycle -Analysis and Life-Cycle -Cost Analysis methodologies implementation. • The role of boundaries and the impact of considerations and assumptions in the calculations. • The role of each life phase for potential improvement. • Total Cost of Ownership approach on design and analysis. • Case studies.	• Seminar slides • Case studies
Intergrade RES during the energy efficient and ecological/sustainable design process or	• Role of RES in Eco-Design.	• Seminar slides

during improvement schemes for systems and products.	• Small scale PVs and energy harvesting technologies integrated in products. • The role of RES in specific product life phases and their critical impact. • The RES in the energy mix used in calculations.	
Ability to perform the studies and work and to assess their results considering this parameter.	• Problem solving for small case studies.	• Case studies
Ability to use the principles and methodologies of energy efficient and ecological / sustainable design (Eco-Design) in his professional activity.	• Problem solving for small case studies.	• Case studies

3.3.24 Economics of energy sources and the optimal integration of renewable energies and energy conservation measures

Table 50: Program Overview: Economics of energy sources and the optimal integration of renewable energies and energy conservation measures

Educational Programme Title	The Economics of renewable energy sources including externalities
SET Area	Integrating renewable technologies in the energy systems
EQF level	6
Learning outcomes	• Apply the "fundamentals" of economics of energy to evaluate the evolution of the energy system • Identify and describe the most significant criticalities and the constraints affecting the organizational structures and the • Explain and apply concepts about successful integration of renewable sources in different sectors • Evaluate the impact of pricing scheme and of subsidies on management and new installations • Describe and discuss the dynamics affecting the speed of the transition
Relevant keywords	RES Integration, Levelized Cost of Energy, Net Energy, EROI, Economy, Efficiency, Marginal Cost of energy technologies, Externality Costs

Other relevant keywords	Dynamics of the energy transition, Sustainable energy, Components of the energy system, Economics of energy, Energy market, Pricing scheme, Energy Subsidies
Notes	Sources used to prepare the learning outcomes (e.g. other courses offered and organised around the same topic, etc.)

Table 51: Learning Outcomes and Learning Materials: Economics of energy sources and the optimal integration of renewable energies and energy conservation measures

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
Apply the "fundamentals" of economics of energy to evaluate the evolution of the energy system	• Analyse the dynamics of the low-carbon energy transition by applying the "fundamentals" of the energy economics • Determine optimum mixtures of renewable-energy sources and energy efficiency improvement measures to minimize costs of energy for end-user • Calculate economic indicators (i.e. NPV, IRR, PBT) to evaluate cost-effectiveness of new installations/ interventions (C)	• Seminar slides
Identify and describe the most significant criticalities and the constraints affecting the organizational structures and the functioning of the energy markets	• Identify and explain the components of the energy system (sources, vectors and end-uses) and the technical determinants of the production, transport, conversion and use of energy sources • Illustrate how EE improvements relate to improvements in quality of life (focus on the Rebound effect)	• Seminar slides
Explain and apply concepts for successful integration of renewable sources in different sectors	• Explain and apply methods to calculate the levelized cost of energy (LCOE) to make cost comparisons between various conventional and renewable energy generation technologies in order to understand which renewable energy generation technologies may be cost-competitive with conventional generation technologies, either now or in the future, and under various operating assumptions • Modelling and integration of RES system with the existing energy system	• Seminar slides
Evaluate the impact of pricing scheme (e.g. cost-reflective tariff vs progressive tariff of kWh) and subsidies on management and new installations	• Assess the potential for Energy Efficiency • Internalize the environmental Externalities • Describe the various forms of energy Subsidies	• Seminar slides

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
Describe and discuss the dynamics affecting the speed of the energy transition	• Identify and discuss the dynamics affecting the speed of the transition: rising fossil fuel costs, declining renewable energy costs, and implementing policies to speed up the transition (e.g. policies that internalize externalities to reflect the true costs of fossil fuels).	

3.3.25 Behavioural change as a powerful drive to minimize the energy consumption while providing the same level of energy service

Table 52: Program Overview: Behavioural change as a powerful drive to minimize the energy consumption while providing the same level of energy service

Educational Programme Title	Behavioural change as a powerful drive to minimise the energy consumption while achieving the same level of energy service
SET Area	• New technologies and services for consumers • Smart resilience and Secure Energy System
EQF level	6
Learning outcomes	• Describe social barriers for EE improvement • Illustrate roles of actors in and impact on efficiency improvements • Discover human behaviour and the barriers to behavioural change • Describe behavioural change in the use of energy • Explain behavioural economics and cognitive bias • Develop behaviour change programs
Relevant keywords	Energy efficiency, behavioural change measures, energy saving, behavioural sciences
Other relevant keywords	boost responsible consumer behaviour; endorse responsible sustainable consumption; boost responsible sustainable consumption; encourage responsible sustainable consumption; endorse responsible consumer behaviour; encourage responsible consumer behaviour; advocate responsible consumer behaviour; advocate responsible sustainable consumption
Notes	Sources used to prepare the learning outcomes (e.g. other courses offered and organised around the same topic, etc.)

Table 53: Learning Outcomes and Learning Materials: Behavioural change as a powerful drive to minimize the energy consumption while providing the same level of energy service

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
Aware of Social barriers as part of a holistic analysis to improve EE	Understanding the deployment barriers for efficiency improvements	Seminar slides / MOOC

Learning Outcome	Definition/explanation of the Learning Outcome	Learning Materials
Understanding the roles of actors in and impact on efficiency improvements	Being aware of: ● the impact of (new) technical processes in their spatial and social context ● Social and behavioural impacts on EE	Seminar slides / MOOC
Getting an overview on human behaviour and behavioural change	Knowing: ● human behaviour and the barriers to behavioural change ● the potential for change in behaviour change programs	Seminar slides / MOOC
Aware of the behavioural change in the use of energy	Understanding: ● human behaviour and energy consumption ● behavioural economics and cognitive bias	Seminar slides / MOOC
Learning how to do from Practical guide to program development	Learning how to do: ● problem orientation and goal setting ● analysis of determinants and target groups ● design of behavioural change measures ● implementation of the measures ● measurement and evaluation of intermediate and final objectives ● monitoring: measurement and evaluation of message persistence	Seminar slides / MOOC
Learning from Case studies	Learning how to make quantitative analysis and evaluations	Seminar slides / MOOC
Learning by making exercises for drafting, presenting and managing behaviour change projects in the EE sector	Through a virtual practical laboratory to learn drafting, presenting and managing behavioural change projects in the energy efficiency sector	Seminar slides / MOOC

4. Learning Outcomes and KSC needs

In this section, the identified KSC needs from D2.2 are shown in the following table. In these tables, the needs that are highlighted, are the needs that the outcomes of the ASSET programmes will meet. This deliverable further elaborates on the mapping of the learning outcomes and the KSC needs by showing the KSC needs that each outcome of the ASSET programmes addresses. The formulation of the Learning Outcomes follows the guidelines laid out in [9].

Table 54: Addressed KSCs in the Energy Efficiency strand

Energy Efficiency				
Knowledge	**Competences**	**Skills**	**EQF**	**Type**
The factors that influence systemic energy efficiency, incl. integrating energy along life cycles and within the spatial/ geographic context (stakeholder group: 1,2,5,6) sector: all	The relationship between energy efficiency and life cycle (stakeholder group: 1-6) sector: all	Propose energy efficiency measures at process level, possibly underpinned by data gathering (stakeholder group: 1,2,6) sector: industry	Master	**Technical**
	EE technologies and planning methods in industry and buildings (stakeholder group: 1,2,6) sector: industry, building	Multi-physics modelling and simulation (stakeholder group: 1,2,6) sector: industry, building	PhD	**Technical**
	EE planning method (stakeholder group: 1,2,6) sector: industry	Energy efficiency assessment and evaluation Design and implementation of energy efficiency equipment and strategies	PhD	**Technical**
Instrumentation for energy measurement Measurement of energy consumption and losses Interpretation of energy data Design of new instruments and services for energy efficiency Non-intrusive load monitoring (stakeholder group: 1,2,6) sector: energy industry	Energy saving data Metering and Verification. Simulation results and data gathered from measured consumption to improve energy efficiency (stakeholder group: 1-6) sector: all	Propose energy efficiency measures and efficiency improvements in a life cycles perspective (stakeholder group: 1-6) sector: all	Master	**Technical**
Energy management (stakeholder group:	Technology use (stakeholder group: 1,2,6) sector: all	System Simulation/ Modelling (stakeholder group:	Master	**Technical**

Energy Efficiency				
Knowledge	**Competences**	**Skills**	**EQF**	**Type**
1,2,6) sector: all		1,2,6) sector: industry, building		
Thermodynamics Building Design (in terms of energy efficiency)	Building Design (in terms of energy efficiency) (stakeholder group: 1,2,6) sector: building	Energy System Control (stakeholder group: 1,2,6) sector: all	Master	**Technical**
Specific energy efficient technologies for residential, tertiary and industrial sectors Power plants O&M. Modules related to single efficient technology for the Tertiary, Residential and Industry sectors (e.g. CHP, LED, Building insulation, Heat Pumps, etc.) Integration of energy resources at building level Standards of the thermal and electrical energy system (stakeholder group: 1,2,6) sector: industry, building	Power plants O&M. Modules related to single efficient technology for the Tertiary, Residential and Industry sectors (e.g. CHP, LED, Building insulation, Heat Pumps, etc.) (stakeholder group: 1,2,6) sector: industry, building	Design of energy management systems for commercial buildings Efficient energy management systems for data centres (stakeholder group: 1,2,6) sector: building	Master	**Technical**
	Rebound effect. Understand through behaviour analysis: – how EE improvements relate to improvements in quality of life, and – how to incentivise a utility to foster the lowest possible level of end-user consumption (stakeholder group: 1-6) sector: all		PhD	**Technical**
Life cycle costs analysis of energy use with regards to generation efficiency (stakeholder group: 1,2,6) sector: all	Calculate economic indicators (i.e. NPV, IRR, PBT) to evaluate cost-effectiveness of new installations/ interventions (stakeholder group: 1,2,6) sector: all	Propose profitable and sustainable (costing) Energy Efficiency Improvement Measures (EEIMs) (stakeholder group: 1,2,6) sector: all	Master	**Economical**
The impact of pricing scheme (e.g. cost-reflective tariff vs. progressive tariff of kWh) on management and new installations	Evaluate the impact of the tariff structure on the exploitation of innovative efficient technologies (e.g. heat pumps, Evs, etc.) (stakeholder group: 1,2,3,6) sector: energy industry	Propose innovative business models for increased energy efficiency (uptake) (stakeholder group: 1,2,6) sector: all	Master	**Economical**

Energy Efficiency				
Knowledge	**Competences**	**Skills**	**EQF**	**Type**
(stakeholder group: 1,2,3,6) sector: energy industry				
The deployment barriers for efficiency improvements (stakeholder group: 1-6) sector: all	Social barriers as part of a holistic analysis to improve energy efficiency (stakeholder group: 1-6) sector: all	Propose and apply new models for fostering behavioural change by end-user (stakeholder group: 1,5,6) sector: all	Master	**Social**
	Social barriers as part of a holistic analysis to improve implementation/integration (stakeholder group: 1-6) sector: all	Consider social barriers (stakeholder group: 1-6) sector: all	Master	**Social**
The roles of actors in and impact on efficiency improvements (stakeholder group: 1-6) sector: all	The impact of (new) technical processes in their spatial and social context. Social and behavioural aspects of energy efficiency (stakeholder group: 1-6) sector: all	Interaction among different actors along the value chain/in the spatial context to improve systemic EE (stakeholder group: 1-6) sector: all	PhD	**Social**
Stakeholder interaction (consumers, prosumers, investors, etc.) for systemic energy efficiency (stakeholder group: 1,4,6) sector: all	Socio-technical issues: – how the various sectors use energy and interact within and with each other how RE technologies then penetrate the larger socio-technical status quo and transform the energy system (stakeholder group: 1-6) sector: all	Deep analysis on how innovation can create technological niches for energy efficiency (stakeholder group: 1,2,6) sector: industry, building	PhD	**Social**
Environmental regulations on efficiency and requirements (stakeholder group: 1-6) sector: all	Adequate incentives for citizens and companies to move towards better energy efficiency (stakeholder group: 1,3,4,6) sector: all	Foster the adoption of Minimum Environmental Criteria within Procurement processes in the Public sector. (stakeholder group: 1,4,6) sector: all	Master	**Legal, Regulatory**
Potential impact of economic incentives for energy (stakeholder group: 1-6) sector: all			Master	**Legal, Regulatory**

Table 55: Addressed KSCs in the Renewable Integration strand

Renewables Integration				
Knowledge	**Competencies**	**Employment Skills (Master level)**	**EQF level**	**Topics**
Basic knowledge of how energy systems influence energy flow (stakeholder group: 1,2,5,6) sector: all	Characteristics of energy vectors, including capacities, efficiencies, the importance of the rate of charge/ discharge and network location (stakeholder group: 1,2,6) sector: all	Approaches that maximise the contribution of renewable technologies including - Control and monitoring of systems with variable RES generation - Control and monitoring of DC systems - Control and monitoring of hybrid systems (stakeholder group: 1,2,5,6) sector: energy industry	6-8	**Technical**
Successful integration of renewable sources in different sectors (stakeholder group: 1-6) sector: all	The interconnection between established, mature technologies and new, renewable technologies Integration technologies based of HVDC Integration technologies based on AC-DC hybrid systems (stakeholder group: 1,2,6) sector: all	Modelling and integration of RES system with the existing energy system Integration technologies based of HVDC Integration technologies based on AC-DC hybrid systems (stakeholder group: 1,6) sector: energy industry	6-8	**Technical**
How to achieve an efficient overall energy system from production to end-user Optimization of renewable energy usage (stakeholder group: 1-6) sector: all	The comparison with non-RES energy sources and vectors. (stakeholder group: 1-6) sector: all	Different energy storage and buffering options for different energy vectors. Optimization of renewable energy usage (stakeholder group: 1,2,6) sector: energy industry	6-7	**Technical**
The current status and future potential of many RES and how each of them can be developed and brought together as a holistic system (stakeholder group: 1-6) sector: all	Overview of the technology (including working principles), markets, barriers and techno-economic performance (stakeholder group: 1-6) sector: all	Develop techno-economic data projections for the modelling community and policy makers (stakeholder group: 1,3,6) sector: all	6-8	**Technical**
The usability and management of different energy vectors, such as electricity, fuels, heat and hydrogen (stakeholder group: 1,2,5,6) sector: all	Energy system interaction to balance production with demand, across time and geography (stakeholder group: 1,2,5,6) sector: all	Approaches to controlling energy flows Control of power flow in local energy systems Integration of local energy systems and DSO (stakeholder group: 1,2,6) sector: energy industry	7-8	**Technical**

Renewables Integration				
Knowledge	**Competencies**	**Employment Skills (Master level)**	**EQF level**	**Topics**
The costs related to RES exploitation and operation (stakeholder group: 1,2,3,4,6) sector: energy industry	Determine: capital and operating costs; thermal efficiencies and technical lifetimes; GHG gas emissions, water consumptions (stakeholder group: 1,2,6) sector: all	Propose solutions consistent with the local energy market and required future shifts (stakeholder group: 1-6) sector: all	6-7	**Economical**
Energy market functioning (stakeholder group: 1-6) sector: energy industry	How energy market participation might affect control (stakeholder group: 1-6) sector: energy industry	Analyse energy markets, energy poverty, ownerships, system service and regulatory costs (stakeholder group: 1,2,3,4,6) sector: all	7-8	**Economical**
kW vs kWh tariffs, capacity/ consumption prices of smart meters (stakeholder group: 1,2,3,4,6) sector: energy industry	Business cases from a consumer, utility and/or aggregator point of view (stakeholder group: 1,2,5,6) sector: energy industry	Propose business models for complex energy systems (stakeholder group: 1,2,5,6) sector: all	7-8	**Economical**
The role of society and citizens in the take-up of renewable energy solutions, e.g. public perceptions of energy (stakeholder group: 1-6) sector: all	The value attributed from the society to energy-service (stakeholder group: 1,3,4,6) sector: energy industry	Create/propose new types of tariff which reflect the social value of RES (e.g. internalize the external costs associated to FF utilization) (stakeholder group: 1,3,4,6) sector: energy industry	6-7	**Social**
The social impact of using renewable energy to minimise environmental impact (stakeholder group: 1-6) sector: all	Shift approach from energy demand to energy services supply (stakeholder group: 1,2,5,6) sector: energy industry		6-7	**Social**
User engagement with their energy consumption (stakeholder group: 1-6) sector: all	Determine the limits and constraints of any technological solution and its integration (stakeholder group: 1,2,6) sector: energy industry	Analyse public perceptions of energy, energy practices, energy choices, prosumers, energy dialogues and the differing ways in which energy affects different clients (stakeholder group: 1,4,5,6) sector: energy industry	6-7	**Social**
How user involvement affects the energy system (stakeholder group: 1-6) sector: all	Country differences in regulatory environments - identify/propose future improvements (stakeholder group: 1,3,4,6) sector: all	Develop useful tool for policymakers for helping to identify future priorities for research, development and demonstration (RD&D) (stakeholder group: 1,3,4,6) sector: all	6-7	**Legal, Regulatory**

Renewables Integration				
Knowledge	**Competencies**	**Employment Skills (Master level)**	**EQF level**	**Topics**
Legal and Regulatory framework (stakeholder group: 1,3,4,6) sector: all	Potential legislation barriers for RES adoption and how to overcome them (stakeholder group: 1,3,4,6) sector: all	Act to ensure a level playing field for all competing energy sources (stakeholder group: 1,3,4,6) sector: all	6-7	**Legal, Regulatory**
		Develop effective economic and policy frameworks that engage and incentivise companies to adopt new renewable technologies. (stakeholder group: 1,3,4,6) sector: energy industry	6-7	**Legal, Regulatory**

Table 56: Addressed KSCs in the Smart Grids and Energy Systems strand

Smart Grids and Energy Systems				
Knowledge	**Competencies**	**Skills**	**EQF level**	**Type**
The functionality of grid components and distribution of grid dynamics such as grid dynamic behaviour in power electronics power systems (stakeholder group: 1,2,6) sector: energy industry	The interplay of distributed generation/local use/network operation constraints to ensure grid stability and energy efficiency dynamic of systems of systems (stakeholder group: 1,2,6) sector: energy industry	Propose solutions to update network operation to emerging constraints, with the ability to work across borders between different systems (stakeholder group: 1,2,6) sector: energy industry	6-8	**Technical**
Individual/multi energy grid components and (multi-energy) system theories/interactions (stakeholder group: 1,2,6) sector: energy industry	Holistic system analysis and modelling of electrical grids, thermal and gas distribution systems as multi source/carrier systems (stakeholder group: 1,2,6) sector: energy industry	Overall energy system analyses and implementations to improve energy flexibility by playing on the different energy vectors Design of control and monitoring for multi-energy systems (stakeholder group: 1,2,6) sector: all	6-8	**Technical**
Energy Infrastructure-Smart Grids-Distribution Networks (stakeholder group: 1,2,6) sector: energy industry	Control and communication structures for smart grid systems, including big data elements Digital automation of distribution systems Big data	Integrate correlated information and synchronized measurements Digitalization of automation in distribution Integration of energy and smart city services	6-7	**Technical**

Smart Grids and Energy Systems				
Knowledge	**Competencies**	**Skills**	**EQF level**	**Type**
	Artificial Intelligence techniques for energy Cloud services for energy New communication technologies (e.g. LTE) for automation and energy management Platforms for energy and the smart city Micrograds (stakeholder group: 1,2) sector: all	Programming and data management (for start-ups in energy services) (stakeholder group: 1,2) sector: all		
The costs related to grid operation (stakeholder group: 1,6) sector: energy industry	Design and propose innovative tariff schemes to positively influence the energy market in certain directions (stakeholder group: 1,6) sector: energy industry	Propose solutions compatible with the local energy market and required future shifts (stakeholder group: 1,3,6) sector: energy industry	6-8	**Economical**
Energy markets (stakeholder group: 1,3,5,6) sector: energy industry	How energy market participation might affect control (stakeholder group: 1,3,5,6) sector: energy industry	Optimise market participation for different actors (stakeholder group: 1,2,3,6) sector: energy industry	7-8	**Economical**
kW vs kWh tariffs, capacity/ consumption prices of smart meters (stakeholder group: 1,3,6) sector: energy industry	Business models for technologies serving different grids (stakeholder group: 1,3,6) sector: energy industry		6-7	**Economical**
The role of society and citizens in the take-up of renewable energy solutions, e.g. public perceptions of energy (stakeholder group: 1,5,6) sector: energy industry	The value of critical energy infrastructure for different consumer types (stakeholder group: 1,5,6) sector: all	Create/propose new types of utility/ prosumer contracts and interaction with existing regulatory environments (stakeholder group: 1,3,5,6) sector: all	6-7	**Social**
The social impact of the various energy markets (stakeholder group: 1,2,5,6) sector: all	Solutions for overcoming potential barriers (stakeholder group: 1,2,5,6) sector: all	Problem-solving from the start to the end of a project (stakeholder group: 1,2,5,6) sector: all	6-8	**Social**
User engagement with their energy consumption (stakeholder group: 1,5,6) sector: all	How user involvement affects the energy system (stakeholder group:1,5,6) sector: all	Professional, social/environmental contextual awareness (stakeholder group: 1-6) sector: all	6-8	**Social**
The role of regulators and grid codes (stakeholder group: 1,2,3,6) sector: energy industry	Country differences in regulatory environments - identify/propose future improvements	Apply grid codes Design to meet regulatory mandates	7-8	**Legal, Regulatory**

Smart Grids and Energy Systems				
Knowledge	**Competencies**	**Skills**	**EQF level**	**Type**
	Influence factors in policy making Pre-standardization activities: testing, use case definition, technical argumentation (stakeholder group: 1,2,3,6) sector: energy industry	Design for flexibility for expected regulatory changes Ability to propose and support changes to standards and regulation (stakeholder group: 1,2,3,6) sector: energy industry		
Legislation issues and potential multi-scale governance of energy systems (stakeholder group: 1-6) sector: all	Potential legislation barriers for multi-energy systems and how to overcome them (stakeholder group: 1-6) sector: all	Appreciate the importance of legislation and standardization (stakeholder group: 1,3,6) sector: all	7	**Legal, Regulatory**
The political agendas of actors along the energy value chain (stakeholder group: 1-6) sector: all		Interact with different actors along the energy value chains (stakeholder group: 1-6) sector: all	6-8	**Legal, Regulatory**

Table 57: Addressed cross sectoral KSCs

Cross Sectoral KSC				
Knowledge	**Competencies**	**Skills**	**Level**	**Type**
Digital innovation and transformation (stakeholder group: 1-6) sector: all	Implications for practitioner and e-leadership skills in SMEs and start-ups (stakeholder group: 1,6) sector: all		Master	**Technical**
DIGITAL MEDIA SPECIALIST ROLE (stakeholder group: 1-6) sector: all	Designs and maintains the holistic architecture of business processes and information systems (stakeholder group: 1,2,6) sector: all	Lead inter-disciplinary staff, and influence stakeholders across boundaries (functional, geographic) (stakeholder group: 1,6) sector: all	Master	
INFORMATION SECURITY MANAGER ROLE (stakeholder group: 1,6) sector: all	Business Savvy skill: Innovate business and operating models, delivering value to organisations (stakeholder group: 1,6) sector: all	- Forecasting needs for information - Understanding customer needs - Solution orientation - Communication (stakeholder group: 1,6) sector: all	Master	
DIGITAL EDUCATOR ROLE (education in the context of business incubator and accelerator schemes) (stakeholder group: 1,6) sector: all	Digital Savvy skill: Envision and drive change for business performance, exploiting digital technology trends as innovation opportunities	• Big data analytics & tools • Cloud computing & virtualization (stakeholder group: 1,6) sector: all	Master	

Cross Sectoral KSC				
Knowledge	**Competencies**	**Skills**	**Level**	**Type**
	(stakeholder group: 1,6) sector: all			
Basic Knowledge on digital Entrepreneurship (stakeholder group: 1,2,4,5,6) sector: all	A partnership approach (stakeholder group: 1,6) sector: all		MOOC	

In order to connect the ASSET environment with the broader world of international knowledge creation and dissemination, the following table provides a summary of the relation between - ASSET topics, now clearly connected to KSC in the previous tables of this section, - SET plan areas, related to the European strategy for competitiveness, and the fields of science and technology of the Frascati manual (ed. 2015). This last dimension is broadly accepted worldwide as basis for quantifying assessing and analysing in an internationally comparable way, the knowledge creation and dissemination. This table indicates how ASSET contributes to such knowledge creation and dissemination and provides a first classification for national or international statistical data collection, comparison and benchmarking.

Because of the clear connection between ASSET topics and KSC, then this table also implicitly relates the Frascati fields with the KSC of the energy transition, thus closing the circle linking international "standards", EU strategy and energy transition needs.

Table 58: Relation between ASSET topics, SET Plan Areas and the fields of science and technology

Field of Science and Technology[6]	SET Plan Area[7]	ASSET topic (ASSET Educational programme title)
Electrical engineering, electronic engineering, information engineering	Integrating renewable technologies in the energy systems	Multi-terminal DC grids
Engineering and technology/ electrical engineering, electronic engineering	• Integrating renewable technologies in the energy system • New technologies and services for consumers • Resilience and security of energy systems	AC Microgrids

[6] https://read.oecd-ilibrary.org/science-and-technology/frascati-manual-2015_9789264239012-en#page61

[7] https://ec.europa.eu/energy/en/topics/technology-and-innovation/strategic-energy-technology-plan#content-heading-0

Engineering and technology/ electrical engineering, electronic engineering	• Integrating renewable technologies in the energy system • Resilience and security of energy systems • Energy efficiency for industry	Power Quality in Microgrids
Engineering and technology/ electrical engineering, electronic engineering	• Integrating renewable technologies in the energy system • New technologies and services for consumers • Resilience and security of energy systems • New materials and technologies for buildings	DC Microgrids
Electrical engineering, electronic engineering, information engineering	Integrating renewable technologies in the energy systems	Challenges and solutions in Future Power Networks
Electrical engineering, electronic engineering, information engineering	Integrating renewable technologies in the energy systems	Monitoring and distributed control for power systems
Electrical engineering, electronic engineering, information engineering	Integrating renewable technologies in the energy systems	Implementation of automation functions for monitoring and control
Engineering and technology/ electrical engineering, electronic engineering	• Integrating renewable technologies in the energy system • Renewable Fuels and Bioenergy • Reducing the cost of technologies	Maritime Microgrids
Electrical engineering, electronic engineering, information engineering	Integrating renewable technologies in the energy systems	Power Systems Dynamics
Electrical engineering, electronic engineering, information engineering	Integrating renewable technologies in the energy systems	Case study on distribution grid operation
Electrical engineering, electronic engineering, information engineering	• Integrating renewable technologies in the energy system • Energy efficiency for industries • Reducing the cost of technologies	Optimization Strategies and Energy Management Systems

Engineering and technology/ Electrical engineering, Electronic engineering, Other technologies (electrolysis, fuel cell)	Integrating renewable technologies in the energy systems, Renewable fuels.	Hydrogen as energy vector
Materials Engineering	Integrating renewable technologies in the energy systems	New Materials for solar cells applications
Engineering and technology/ electrical engineering Engineering and technology/ environmental engineering, Engineering and technology/ mechanical engineering	• Integrating renewable technologies in the energy systems • Energy efficiency for industry • Renewable fuels and bioenergy	Energy and environment
Engineering and technology / Mechanical engineering	• New technologies and services for consumers • New materials and technologies for buildings	Electrical heat pumps in the energy transition framework
Social Sciences (Sociology)	New technologies and services for consumers	Corporate and institutional communication and Social Responsibility
Social Sciences: Education, Sociology Humanities and arts: Philosophy, ethics and religion	Integrating renewable technologies in the energy systems (by sensitizing for users and developing user acceptance)	Innovation and Diversity in engineering/Scientific Integrity
Other social sciences, education, other humanities	Integrating renewable technologies in the energy systems	Understanding Responsibility in research and Innovation
Social Sciences (Sociology)	New technologies and services for consumers	Green professionalization and ethics
Social Sciences (Sociology)	New technologies and services for consumers	Participatory planning tools and Social network analysis
Education	New technologies and services	Innovation processes in the energy sector
Engineering and technology/ electrical engineering, Engineering and technology/ environmental engineering, Engineering and technology/ mechanical engineering, Engineering and technology/ industrial engineering	• Integrating renewable technologies in the energy systems • Energy efficiency for industry • Renewable fuels and bioenergy • Reducing costs of technologies	Energy Efficient and Ecological Design of Products and Equipment

	• New technologies and services for consumers	
Other engineering and technologies	• Integrating renewable technologies in the energy systems - Action 1: "to sustain technological leadership by developing highly performant renewable technologies and their integration in the EU's energy system"	Economics of energy sources and the optimal integration of renewable energies and energy conservation measures
Other engineering and technologies	• New technologies and services for consumers - Action 3: "Create technologies and services for smart homes that provide smart solutions to energy consumers • Smart resilience and Secure Energy System - Action 4: "Increase the resilience, security and smartness of the energy system"	Behavioural change as a powerful drive to minimize the energy consumption while providing the same level of energy service

5. Replicability and expansion potential

5.1 Introduction

To identify the sectors and disciplines in which ASSET approach can be replicated, the identification of the key principles and the benefits they bring is a prerequisite. Once these are defined, we seek for other sectors/themes that exhibit the same characteristics with energy transition and then we need to discuss how ASSET approach could be adopted in these. Thus, the structure of this chapter follows this methodological approach:

- **Step 1:** Identification of the characteristics of energy transition, definition of the ASSET principles and specifications of the anticipated benefits.
- **Step 2:** Search for sectors that exhibit similar intricacies
- **Step 3:** Exploration of the adoption of ASSET approach in the sectors defined in step 2.

It is worth noticing that the findings of this first study will be disseminated in order to gather feedback from representative of these sectors. Based on the outcomes of this process, the current guidelines will be refined close to the project end.

5.2 The intricacies of Energy Transition theme and ASSET principles

The main intricacies of energy transition as outlined in many publications and report include:

- ASSET Intricacy 1: For energy transition to become a reality, awareness in society needs to be raised. People need to understand the severity of the physical resource sustainability problem and how their actions can affect the situation. The understanding of shared responsibility is at the moment quite low.
- ASSET Intricacy 2: Energy transition relies on the evolution of multiple and very diverse scientific disciplines ranging from mechanical engineers and nano-technology to flexibility service design which is pretty much a business development topic. These mandates intensifying the scientific research in multiple domains at a really high pace.
- ASSET Intricacy 3: Energy transition employees need (in their majority) interdisciplinary understanding, while most of them graduated years or even decades ago when interdisciplinarity was not at the forefront of education systems. Educating such large numbers of individuals in few years is almost impossible and brings training efficiency into the scene.
- ASSET Intricacy 4: Problem-based solving and case-based solving is a very important issue as the problems in each new energy facility is quite unique in the sense that there are few replicas similar enough that the same methodologies can be blindly applied. This also points at the need for highly educated/trained people in this sector.
- ASSET Intricacy 5: Life-long learning is (and should be) the new learning pattern of workers and more in general individuals, with obvious consequences on the need for own-pace learning material, remote and on-demand learning offer. At the moment such material and offers are not structured and in particular traditional learning institutions are slow to transition and support this new learning schema.

To address these intricacies, ASSET has defined and is implementing the following key principles:

1. Perform research on societal aspects to understand the interplay in the developments of the energy sector.
2. Bring all actors together in an ecosystem so that they interact smoothly and understand others' needs: society with policy makers, companies with educational/training actors, citizens with companies and so on.
3. Establish a framework that will significantly boost educational/training efficiency so that larger numbers of people are educated/trained at lower cost/effort.

4. Establish communication between companies and educational actors, so that the latter emphasize interdisciplinarity, problem-based solving and match their offerings to real market and society needs. Energy transition is primarily a societal need and secondly a market need.

The anticipated benefits are:

- Better understanding of people's attitudes, so that energy campaigns take into account the society's feelings.
- Society understands energy transition as a sustainability problem for which the responsibility is shared.
- Policy makers and companies have a direct link with the rest of the actors.
- Educational/training actors have direct links with companies, so that they offer them the required up-skilling/retraining.
- Educational/training actors have stable links with the companies, so that they sense the needs of the industry and that they easily apply problem-based solving approaches.

5.3 Sectors/themes with intricacies similar to energy transition

In our search for sectors and themes with intricacies similar to energy transition, we first realised that more than ever before, specific skills that are needed and are in shortage across multiple sectors are: problem solving, willingness to learn/be continuously trained, soft skills and interdisciplinarity. This comes as no surprise, as our societies are moving towards a knowledge-based economy, which means that the times when a worker learned and executed one specific process or use specific machinery throughout her/his work-life have passed.

Another important finding is that the needs of each sector change nowadays very rapidly as things are moving faster, fuelled by the rapid evolution of technology. For the society and economy to reap the benefits of new technologies, continuous re-training of employees and strong links between companies and educational/training actors should be in place for the benefits of both groups and of the society.

5.3.1 Artificial Intelligence

A theme (rather than sector) that exhibits quite similar characteristics with the energy transition is the adoption of Artificial Intelligence (AI) (and Machine Learning) in diverse sectors of our lives and economy. Like almost all digital technologies, AI adoption is argued to benefit many sectors including manufacturing, health, transportation, education, public services among others. The difference with the rest of digital technologies is that AI application in various domains requires a quite thorough understanding of the processes in each of these sectors. While basic understanding and rigorous user specifications suffices for other digital solutions in most sectors, this is not the case for AI. In parallel, many sectors urge the adoption of such solutions but AI expertise is in shortage. As such, we consider that Artificial Intelligence adoption in many sectors has the following intricacies in common with energy transition:

- AI Intricacy 1: For artificial intelligence to penetrate to diverse sectors, user acceptance is currently a barrier as people are rather sceptical about it, fearing that decisions are left to not-humans and job positions will be lost. *Similar to ASSET Intricacy 1*.
- AI Intricacy 2: To apply AI in different domains, thorough understanding of the specific processes in place is needed by the AI experts to design and appropriate solution. This is usually not the case as AI experts know very little about manufacturing, transportation, agriculture and public services. *Similar to ASSET Intricacy 2.*
- AI Intricacy 3: For AI to penetrate different sectors, the current workforce has to be able to understand the basic principles of AI so that they are a) positive in its adoption and b) capable of identifying the processes where applying AI will be of higher benefit for them. To educate large numbers of people in few years is almost impossible and brings training efficiency into the scene. *Similar to ASSET Intricacy 3.*

- AI Intricacy 4: Problem-based solving and case-based solving is a very important issue as the problems faced in each sector is quite unique in the sense that the datasets required for the training of the AI algorithms are different and not necessarily available. This requires from the AI solution designers and adopters' additional skills to define a data gathering process. *Similar to ASSET Intricacy 4.*
- AI Intricacy 5: AI technology is constantly being advanced and developed and workers and learners are expected to advance their knowledge and look for acquiring it from scratch in different stages of their learner life. *Similar to ASSET Intricacy 5.*

The review of the ASSET principles for energy transition and the determination of their validity for the AI theme yields the following:

1. Perform research on societal aspects to understand the concerns raised by citizens. (instead of understanding of interplay with the developments in the energy sector). *Principle valid upon re-orientation.*
2. Bring all actors together in an ecosystem so that they interact smoothly and understand each other's needs: society with policy makers, companies with educational/training actors, citizens with companies and so on. *Remains valid.*
3. Establish a framework that will significantly boost educational/training efficiency so that larger numbers of people are educated/trained at lower cost/effort. *Remains valid.*
4. Establish communication between companies and educational actors so that the latter emphasis on interdisciplinarity, problem-based solving and match their offerings to real market and society needs. *Remains valid.*

With the intricacies and principles remaining valid for AI-enabled solutions, we consider that expanding ASSET ecosystem or replicating it to AI technologies would be an excellent affair/attempt.

5.3.2 Big Data / Data-Driven Economy

Another field that shares many intricacies with energy transition is the field of Big Data (BD) and specifically Data-Driven Economy. In the book "New horizons for a data-driven economy: a roadmap for usage and exploitation of big data in Europe" [9], the authors report that multiple dimensions or intricacies have to be addressed for a successful big data ecosystem:

- BD Intricacy 1: There is a need to increase social awareness on the benefits that big data can deliver to society, namely, in the fields of healthcare efficiency, liveability in cities, government transparency and improved sustainability. This social awareness will lead more citizens to support the development of big data technologies and will allow institutions to take advantage of big-data opportunities. Similar to energy transition, literacy also plays a big role in social awareness for big-data in Europe. *Similar to ASSET Intricacy 1.*
- BD Intricacy 2: The big data ecosystem also needs multiple disciplines to develop together. This multidisciplinary growth will involve technical disciplines for large-scale data acquisition, data storage, and massive real-time data processing. It will also involve the discipline of business management to transform existing businesses and create new start-ups that can take advantage of the benefits of big-data. The discipline involving legal matters also need to evolve to tackle legal issues on data ownership, usage, protection, and privacy. *Similar to ASSET Intricacy 2.*
- BD Intricacy 3: People from different disciplines also need to work together to create value through big data. For example, experts in the field of big-data need to work with people in the energy industry to understand the potential and requirements for smart metering systems. They can also work with government institutions for establishing Open Government data portals. *Similar to ASSET Intricacy 3.*
- BD Intricacy 4: Problem-based solving and case-based solving: Similar to energy transition, big-data also needs to have innovative problem-based and case-based solutions that are validated and delivered in a working ecosystem. Case-studies will allow learners to benefit from actual experiences in the field and help in understanding the concepts through more concrete use

cases. Examples of these case studies are data acquisition and analysis in the health and manufacturing sectors. *Similar to ASSET Intricacy 4.*

The review of the ASSET principles for energy transition and the determination of their validity for the BD theme yields the following:

1. Perform research on societal aspects to understand the concerns of the citizens and the possible large scale political and societal effects (instead of understanding of interplay with the developments in the energy sector). *Principle valid upon re-orientation*.
2. Bring all actors together in an ecosystem so that they interact smoothly and understand one another's needs: society with policy makers, companies with educational/training actors, citizens with companies and so on. *Remains valid.*
3. Establish a framework that will significantly boost educational/training efficiency so that larger numbers of people are educated/trained at lower cost/effort. *Remains valid.*

Establish communication between companies and educational actors so that the latter emphasise interdisciplinarity, problem-based solving and match their offerings to real market and society needs. (Energy transition is primarily a societal need and secondly a market need.) *Remains valid.*

5.3.3 Industry 4.0

Industry 4.0 is another theme with similar intricacies. These intricacies are briefly summarized below:

- Industry 4.0 Intricacy 1: Citizen Awareness, particularly employers, employees and trade unions, is critical for success [10]. S*imilar to ASSET Intricacy 1.*
- Industry 4.0 Intricacy 2: Evolution of Multiple Disciplines - In addition to the technical field of cyber-physical systems (in itself multi-disciplinary), Industry 4.0 needs the disciplines of organisational and management science [10] to develop, especially in cases where the move e.g. from centralized to decentralized decision making, may lead to restructuring. Other fields involved are cybersecurity, business theories that help companies stay competitive, economics, finances, and logistics. S*imilar to ASSET Intricacy 2.*
- Industry 4.0 Intricacy 3: Interdisciplinary understanding is also important in Industry 4.0 to achieve a successful organisational readiness assessment and a good business-employee-customer relation. For example, the understanding of the interactions of business and technology plays a key role towards the acceptance of Industry 4.0 solutions in the SME industry [11]. S*imilar to ASSET Intricacy 3.*
- Industry 4.0 Intricacy 4: the re-training of worker, new workers at all levels represents a massive effort which requires training material and facilities for hands on activities. Similar to ASSET Intricacy 5.

The review of the ASSET principles for energy transition and the determination of their validity for the Industry 4.0 theme yields the following:

1. Perform research on societal aspects to understand the concerns of the citizens and the possible large scale political and societal effects (instead of understanding of interplay with the developments in the energy sector). *Principle valid upon re-orientation.*
2. Bring all actors together in an ecosystem so that they interact smoothly and understand one another's needs: society with policy makers, companies with educational/training actors, citizens with companies and so on. *Remains valid.*
3. Establish a framework that will significantly boost educational/training efficiency so that larger numbers of people are educated/trained at lower cost/effort. *Remains valid.*

Establish communication between companies and educational actors so that the latter emphasize interdisciplinarity, benefits of new technologies, problem-based solving and match their offerings to real job market and society needs. Energy transition is primarily a societal need and secondly a market need. *Remains valid.*

5.4 Replication guidelines

To replicate ASSET approach in Artificial Intelligence theme, we need to:

1. Perform research of societal aspects
2. Create an ecosystem and relevant digital platform. Here, we have to name which actors should play the role of EASE, ENOSTRA, LS.
3. The framework of learning graph for sharing resources remains valid so we have to bring in the ecosystem excellent universities across EU. The universities involved in ASSET could bring the departments relevant to AI which for example for UNIWA it will be the department of informatics, for RWTH would be the Institute for Theory of Science and Technology.
4. The marketplace can be extended to cover AI. Organisations of interest would be public sector organization as well as IT companies which could enter the marketplace to find trainings.

Beside these actions, two more activities would be needed: a) marketplace for AI experts who will declare the sector in which they are working so that multiplicative effects can occur and b) deliver a comprehensive catalogue of dataset marketplaces (https://datafloq.com/public-data/).

5.5 Conclusions

ASSET consortium considers that there are other sectors/themes where ASSET principles can be applied. Close to the project end, we will review a) the sectors that are most in need and b) the feedback that will be collected through ASSET activities by the diverse stakeholders in order to define whether ASSET ecosystem should/would be extended to cover additional themes or should/would be replicated driven by other actors, more active in the relevant sectors.

6. Conclusion

The material provided in this deliverable establishes the ASSET Vocabulary of the energy transition learning in form of learning outcomes and the resources to define the relevant keywords. These learning outcomes correspond to specific innovation areas of the SET Plan and to specific areas of the Frascati manual, and directly address the knowledge, skills and competences in need for the Energy Transition. This classification provides the impact on competitiveness, science, and research that each learning outcome produces. This vocabulary can be used in different ways by the stakeholders of the Energy Transition. For example, a tutor may create a new academic programme choosing and combining the learning outcomes of the ASSET Vocabulary thus clearly indicating to the learners/students how they benefit and how the acquired competences push a successful Energy Transition.

7. References

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8. Annex I: Learning Outcomes and KSCs

8.1 Multi-terminal DC grids

Table 59: Mapping of outcomes and KSC: Multi-terminal DC grids

Learning Outcome	Addressed KSC Needs
Explain the application areas of multi-terminal DC (MTDC) grids	Competencies • The interconnection between established, mature technologies and new, renewable technologies • Integration technologies based of HVDC • Integration technologies based on AC-DC hybrid systems • Determine the limits and constraints of any technological solution and its integration
Identify and describe the differences in operation and control between AC and DC systems	Skills • Modelling and integration of RES system with the existing energy system • Integration technologies based of HVDC • Integration technologies based on AC-DC hybrid systems Competencies • The interconnection between established, mature technologies and new, renewable technologies • Integration technologies based of HVDC • Integration technologies based on AC-DC hybrid systems • Determine the limits and constraints of any technological solution and its integration
Recognise and discuss the main challenges for control of MTDC grids	Skills • Modelling and integration of RES system with the existing energy system • Integration technologies based of HVDC • Integration technologies based on AC-DC hybrid systems Competencies • The interconnection between established, mature technologies and new, renewable technologies • Integration technologies based of HVDC • Integration technologies based on AC-DC hybrid systems • Determine the limits and constraints of any technological solution and its integration

Learning Outcome	Addressed KSC Needs
Determine and establish the control objectives of converter-level control	Skills • Modelling and integration of RES system with the existing energy system • Integration technologies based of HVDC • Integration technologies based on AC-DC hybrid systems Competencies • The interconnection between established, mature technologies and new, renewable technologies • Integration technologies based of HVDC • Integration technologies based on AC-DC hybrid systems • Determine the limits and constraints of any technological solution and its integration
Clarify the main features of advanced control methods applied to converter-level control	Skills • Modelling and integration of RES system with the existing energy system • Integration technologies based of HVDC • Integration technologies based on AC-DC hybrid systems Competencies • The interconnection between established, mature technologies and new, renewable technologies • Integration technologies based of HVDC • Integration technologies based on AC-DC hybrid systems • Determine the limits and constraints of any technological solution and its integration
Determine and establish the control and energy management objectives of system-level control for MTDC grids	Skills • Modelling and integration of RES system with the existing energy system • Integration technologies based of HVDC • Integration technologies based on AC-DC hybrid systems Competencies • The interconnection between established, mature technologies and new, renewable technologies • Integration technologies based of HVDC • Integration technologies based on AC-DC hybrid systems

<table>
<tr><th>Learning Outcome</th><th>Addressed KSC Needs</th></tr>
<tr><td></td><td>Determine the limits and constraints of any technological solution and its integration</td></tr>
<tr><td>List and describe different control strategies for system-level control of MTDC grids</td><td>Skills
Modelling and integration of RES system with the existing energy system
Integration technologies based of HVDC
Integration technologies based on AC-DC hybrid systems
Competencies
The interconnection between established, mature technologies and new, renewable technologies
Integration technologies based of HVDC
Integration technologies based on AC-DC hybrid systems
Determine the limits and constraints of any technological solution and its integration</td></tr>
<tr><td>Explain and analyse the main challenges for monitoring and measurements in MTDC grids</td><td>Skills
Modelling and integration of RES system with the existing energy system
Integration technologies based of HVDC
Integration technologies based on AC-DC hybrid systems
Competencies
The interconnection between established, mature technologies and new, renewable technologies
Integration technologies based of HVDC
Integration technologies based on AC-DC hybrid systems
Determine the limits and constraints of any technological solution and its integration</td></tr>
<tr><td>Explain and formulate state estimation methods for MTDC grids</td><td>Skills
Modelling and integration of RES system with the existing energy system
Integration technologies based of HVDC
Integration technologies based on AC-DC hybrid systems
Competencies
The interconnection between established, mature technologies and new, renewable technologies
Integration technologies based of HVDC</td></tr>
</table>

Learning Outcome	Addressed KSC Needs
	• Integration technologies based on AC-DC hybrid systems • Determine the limits and constraints of any technological solution and its integration
Describe the challenges for fault detection in MTDC grids	Skills • Modelling and integration of RES system with the existing energy system • Integration technologies based of HVDC • Integration technologies based on AC-DC hybrid systems Competencies • The interconnection between established, mature technologies and new, renewable technologies • Integration technologies based of HVDC • Integration technologies based on AC-DC hybrid systems • Determine the limits and constraints of any technological solution and its integration
Clarify the main features of methods for fault detection in MTDC grids	Skills • Modelling and integration of RES system with the existing energy system • Integration technologies based of HVDC • Integration technologies based on AC-DC hybrid systems Competencies • The interconnection between established, mature technologies and new, renewable technologies • Integration technologies based of HVDC • Integration technologies based on AC-DC hybrid systems • Determine the limits and constraints of any technological solution and its integration

8.2 AC Microgrids

Table 60: Mapping of outcomes and KSC: AC Microgrids

Learning Outcome	Addressed KSC Needs
Illustrate the concepts and Modelling of distributed AC power systems and AC microgrids.	Knowledge • The functionality of grid components and distribution of grid dynamics such as grid dynamic behaviour in power electronics power systems

Learning Outcome	Addressed KSC Needs
	• Individual/multi energy grid components and (multi-energy) system theories/interactions Skills • System modelling/simulation Competencies • Holistic system analysis and modelling of electrical grids, thermal and gas distribution systems as multi source/carrier systems
Design various control schemes for power electronic converters including voltage source inverter (VSC)	Knowledge • The functionality of grid components and distribution of grid dynamics such as grid dynamic behaviour in power electronics power system
Design the control schemes for the parallel operation of power converters including master slave and droop control.	Skills • Energy System Control • Approaches that maximise the contribution of renewable technologies including - Control and monitoring of systems with variable RES generation - Control and monitoring of DC systems - Control and monitoring of hybrid systems Competencies • Control and communication structures for smart grid systems
Design the control schemes for the parallel operation of power converters including master slave and droop control.	Skills • Energy System Control • Approaches that maximise the contribution of renewable technologies including - Control and monitoring of systems with variable RES generation - Control and monitoring of DC systems - Control and monitoring of hybrid systems Competencies • Control and communication structures for smart grid systems
Design the converter control for soft starting, harmonic current sharing and low voltage ride through capability.	Skills • Approaches that maximise the contribution of renewable technologies including - Control and monitoring of systems with variable RES generation - Control and monitoring of DC systems - Control and monitoring of hybrid systems (Skill)
Illustrate the operation of an AC microgrids cluster and interconnections of multiple AC microgrids clusters	Knowledge • Individual/multi energy grid components and (multi-energy) system theories/interactions

Learning Outcome	Addressed KSC Needs
	Skills • Propose solutions to update network operation to emerging constraints, with the ability to work across borders between different systems Competencies • The interplay of distributed generation/local use/network operation constraints to ensure grid stability and energy efficiency dynamic of systems of systems
Apply consensus and cooperation strategies for microgrids using networked multi-agent systems.	Knowledge • Propose solutions to update network operation to emerging constraints, with the ability to work across borders between different systems • Energy markets

8.3 Power Quality in Microgrids

Table 61: Mapping of outcomes and KSC: Power Quality in Microgrids

Learning Outcome	Addressed KSC Needs
Illustrate the power quality problems including harmonics, power-frequency deviations, voltage fluctuations, voltage dips, swells, interruptions and voltage unbalance	Knowledge • The factors that influence systemic energy efficiency, incl. integrating energy along life cycles Competencies • Overview of the technology (including working principles), markets, barriers and techno-economic performance
Apply various techniques for power quality improvement in microgrids including active power Injection, reactive power sharing, harmonic current sharing and voltage regulation via smart loads	Skills • Propose solutions to update network operation to emerging constraints, with the ability to work across borders between different systems
Design microgrid hierarchical architecture for voltage regulation and reactive power sharing	Competencies • Overview of the technology (including working principles), markets, barriers and techno-economic performance
Design virtual impedance loops for load sharing and power quality Improvement	Skills • Approaches that maximise the contribution of renewable technologies including - Control and monitoring of systems with variable RES generation - Control and monitoring of DC systems - Control and monitoring of hybrid systems
Apply Primary and Secondary Control for Compensation of Voltage Unbalance and Harmonics in Microgrids	Skills • Energy System Control

Learning Outcome	Addressed KSC Needs
	● Approaches that maximise the contribution of renewable technologies including - Control and monitoring of systems with variable RES generation - Control and monitoring of DC systems - Control and monitoring of hybrid systems
Employ Current-/Voltage-Controlled Inverters for Power Quality Improvement in Microgrids	Skills ● Energy System Control ● Approaches that maximise the contribution of renewable technologies including - Control and monitoring of systems with variable RES generation - Control and monitoring of DC systems - Control and monitoring of hybrid systems
Design synchronization techniques for power converters including open loop, Phase-locked loops (PLLs) and Frequency-locked loops (FLLs) based synchronization techniques	● System modelling/simulation ● Energy System Control

8.4 DC Microgrids

Table 62: Mapping of outcomes and KSC: DC Microgrids

Learning Outcome	Addressed KSC Needs
Recognize the importance of DC Microgrids as a reliable, resilient and efficient technology for the integration, distribution, and utilization of renewable / non-renewable based generation and storage resources	Skills ● Overall energy system analyses and implementations to improve energy flexibility by playing on the different energy vectors ● Design of control and monitoring for multi-energy systems Competencies ● Overview of the technology (including working principles), markets, barriers and techno-economic performance
Illustrate various architectures, configurations and applications of DC Microgrids at the residential, commercial and industrial level	Skills ● Overall energy system analyses and implementations to improve energy flexibility by playing on the different energy vectors Design of control and monitoring for multi-energy systems (Skill) Competencies ● Overview of the technology (including working principles), markets, barriers and techno-economic performance
Design various control schemes on the individual power electronic converters for DC microgrids	Skills ● Energy System Control

Learning Outcome	Addressed KSC Needs
	• Control and monitoring of systems with variable RES generation - Control and monitoring of DC systems - Control and monitoring of hybrid systems
Design various control schemes on the parallel converters for DC microgrids	Skills • Energy System Control • Control and monitoring of systems with variable RES generation - Control and monitoring of DC systems - Control and monitoring of hybrid systems
Design and Implementation of various layers of hierarchical control including primary, secondary and tertiary control for DC microgrids	Knowledge • Energy Management Skills • Energy System Control • Control and monitoring of systems with variable RES generation - Control and monitoring of DC systems - Control and monitoring of hybrid systems

8.5 Challenges and solutions in Future Power Networks

Table 63: Mapping of outcomes and KSC: Challenges and solutions in Future Power Networks

Learning Outcome	Addressed KSC Needs
List and explain the challenges in future power systems	Knowledge • Successful integration of renewable sources in different sectors • The functionality of grid components and distribution of grid dynamics such as grid dynamic behaviour in power electronics power systems Skills • Propose solutions to update network operation to emerging constraints, with the ability to work across borders between different systems Competencies • The interplay of distributed generation/local use/network operation constraints to ensure grid stability and energy efficiency dynamic of systems of systems
Explain and analyse how new control techniques can be used for addressing the challenges	Knowledge • The functionality of grid components and distribution of grid dynamics such as grid dynamic behaviour in power electronics power systems Skills

<table>
<tr><th>Learning Outcome</th><th>Addressed KSC Needs</th></tr>
<tr><td></td><td>Propose solutions to update network operation to emerging constraints, with the ability to work across borders between different systems
Competencies
The interplay of distributed generation/local use/network operation constraints to ensure grid stability and energy efficiency dynamic of systems of systems</td></tr>
<tr><td>Explain how real time simulations help in testing new solutions for future power systems</td><td>Knowledge
The functionality of grid components and distribution of grid dynamics such as grid dynamic behaviour in power electronics power systems
Skills
Propose solutions to update network operation to emerging constraints, with the ability to work across borders between different systems</td></tr>
<tr><td>Explain how monitoring systems enable key functions in future power systems</td><td>Knowledge
Energy Infrastructure-Smart Grids-Distribution Networks
Skills
Approaches that maximise the contribution of renewable technologies including
Control and monitoring of systems with variable RES generation
Control and monitoring of DC systems
Control and monitoring of hybrid systems
Integrate correlated information and synchronized measurements</td></tr>
</table>

8.6 Monitoring and distributed control for power systems

Table 64: Mapping of outcomes and KSC: Monitoring and distributed control for power systems

<table>
<tr><th>Learning Outcome</th><th>Addressed KSC Needs</th></tr>
<tr><td>To investigate and apply the basics of uncertainty propagation in measurements</td><td>Knowledge
Energy Infrastructure-Smart Grids-Distribution Networks
Skills
Integrate correlated information and synchronized measurements</td></tr>
</table>

Learning Outcome	Addressed KSC Needs
	Competencies ● Control and communication structures for smart grid systems, including big data elements
To assess the applications of measurements in power systems	Knowledge ● Energy Infrastructure-Smart Grids-Distribution Networks Skills ● Integrate correlated information and synchronized measurements Competencies ● Control and communication structures for smart grid systems, including big data elements
To examine and appraise the application of distributed measurements in power systems	Knowledge ● Energy Infrastructure-Smart Grids-Distribution Networks Skills ● Integrate correlated information and synchronized measurements Competencies ● Control and communication structures for smart grid systems, including big data elements
To investigate and apply the fundamentals of distributed intelligence in power system	Knowledge ● Energy Infrastructure-Smart Grids-Distribution Networks Skills ● Integrate correlated information and synchronized measurements Competencies ● Digital automation of distribution systems ● Big data ● Artificial Intelligence techniques for energy ● Cloud services for energy ● New communication technologies (e.g. LTE) for automation and energy management

8.7 Implementation of automation functions for monitoring and control

Table 65: Mapping of outcomes and KSC: Implementation of automation functions for monitoring and control

Learning Outcome	Addressed KSC Needs
to explain and apply the basics of IEC61850	Knowledge • Energy Infrastructure-Smart Grids-Distribution Networks Skills • Digitalization of automation in distribution • Integration of energy and smart city services • Programming and data management (for start-ups in energy services) Competencies • Control and communication structures for smart grid systems, including big data elements • Digital automation of distribution systems
to employ Intelligent Electronic Devices for monitoring, distribution and protection functions	Knowledge • Energy Infrastructure-Smart Grids-Distribution Networks Skills • Digitalization of automation in distribution • Integration of energy and smart city services • Programming and data management (for start-ups in energy services) Competencies • Control and communication structures for smart grid systems, including big data elements • Digital automation of distribution systems
to examine and criticise the IED and substation configuration recognize and define the main features of advanced control methods applied in converter-level control	Knowledge • Energy Infrastructure-Smart Grids-Distribution Networks Skills • Digitalization of automation in distribution • Integration of energy and smart city services • Programming and data management (for start-ups in energy services) Competencies • Control and communication structures for smart grid systems, including big data elements

Learning Outcome	Addressed KSC Needs
	• Digital automation of distribution systems

8.8 Maritime Microgrids

Table 66: Mapping of outcomes and KSC: Maritime Microgrids

Learning Outcome	Addressed KSC Needs
Illustrate the shipboard power system and integrated electric applications in ships.	Knowledge • Successful integration of renewable resources in different sectors Competencies • Technology use
Analyse maritime microgrid characteristics and power quality challenges in shipboard microgrid power systems	Skills • Overall energy system analyses and implementations to improve energy flexibility by playing on the different energy vectors Competencies • Overview of the technology (including working principles), markets, barriers and techno-economic performance
Apply signal processing techniques to analyse power quality disturbances in maritime microgrids	Knowledge • Instrumentation for energy measurement • Measurement of energy consumption and losses Interpretation of energy data • Design of new instruments and services for energy efficiency • Non-intrusive load monitoring Competencies • Solutions for overcoming potential barriers
categorise the ship power systems evolution and identify the directions for future research challenges	Competencies • Overview of the technology (including working principles), markets, barriers and techno-economic performance
Analyse the stability of Multi-converter shipboard MVDC power system.	Skills • Design of control and monitoring for multi-energy systems Competencies • The interplay of distributed generation/local use/network operation constraints to ensure grid stability and energy efficiency dynamic of systems of systems

8.9 Power Systems Dynamics

Table 67: Mapping of outcomes and KSC: Power Systems Dynamics

Learning Outcome	Addressed KSC Needs
to explain and apply the principles of power system dynamics	Knowledge • The functionality of grid components and distribution of grid dynamics such as grid dynamic behaviour in power electronics power systems Competencies • The interplay of distributed generation/local use/network operation constraints to ensure grid stability and energy efficiency dynamic of systems of systems Skills
to describe and show the fundamentals of the associated network components	Knowledge • The functionality of grid components and distribution of grid dynamics such as grid dynamic behaviour in power electronics power systems Competencies • The interplay of distributed generation/local use/network operation constraints to ensure grid stability and energy efficiency dynamic of systems of systems Skills
to classify the division of power system dynamics	Knowledge • The functionality of grid components and distribution of grid dynamics such as grid dynamic behaviour in power electronics power systems Competencies • The interplay of distributed generation/local use/network operation constraints to ensure grid stability and energy efficiency dynamic of systems of systems Skills
to explain and apply stability control	Knowledge • The functionality of grid components and distribution of grid dynamics such as grid dynamic behaviour in power electronics power systems Skills • Propose solutions to update network operation to emerging constraints, with the ability to work across borders between different systems Competencies • The interplay of distributed generation/local use/network operation constraints to ensure grid

Learning Outcome	Addressed KSC Needs
	stability and energy efficiency dynamic of systems of systems Skills

8.10 Case study on distribution grid operation

Table 68: Mapping of outcomes and KSC: Case study on distribution grid operation

Learning Outcome	Addressed KSC Needs
Explain the new measurement and monitoring needs in distribution systems	Knowledge ● Energy Infrastructure-Smart Grids-Distribution Networks Skills ● Digitalization of automation in distribution ● Integration of energy and smart city services ● Programming and data management (for start-ups in energy services) Competencies ● Control and communication structures for smart grid systems, including big data elements ● Digital automation of distribution systems
Explain the automation requirements in distribution systems for measurement and monitoring	Knowledge ● Energy Infrastructure-Smart Grids-Distribution Networks Skills ● Digitalization of automation in distribution ● Integration of energy and smart city services ● Programming and data management (for start-ups in energy services) Competencies ● Control and communication structures for smart grid systems, including big data elements ● Digital automation of distribution systems
Explain the problems and automation solutions for monitoring based on an actual implementation on a distribution grid	Knowledge ● Energy Infrastructure-Smart Grids-Distribution Networks Skills ● Digitalization of automation in distribution ● Integration of energy and smart city services ● Programming and data management (for start-ups in energy services)

Learning Outcome	Addressed KSC Needs
	Competencies • Control and communication structures for smart grid systems, including big data elements • Digital automation of distribution systems

8.11 Optimization Strategies and Energy Management Systems

Table 69: Mapping of outcomes and KSC: Optimization Strategies and Energy Management Systems

Learning Outcome	Addressed KSC Needs
Relate process system engineering with modelling and optimization techniques used in power systems	Knowledge • Optimization of renewable energy usage Skills • System Simulation/ Modelling • Optimization of renewable energy usage
Apply different optimization tools for solving continuous, semi continuous and discrete optimization problems in energy systems.	Skills • System Simulation/ Modelling Competencies • EE planning method
Employ EXCEL, MATLAB, and GAMS for solving continuous, semi continuous and discrete optimization problems	Competencies • EE planning method
Employ various optimization and planning tools including heuristic optimization, and population-based optimization.	Knowledge • Energy Infrastructure-Smart Grids-Distribution Networks • The costs related to grid operation • Stakeholder interaction (consumers, prosumers, investors, etc.) for systemic energy efficiency Skills • Forecasting needs for information
Design the schemes for supply and demand side management including unit commitment, economic power dispatch, peak shaving, and load shifting.	Knowledge • Energy markets • Stakeholder interaction (consumers, prosumers, investors, etc.) for systemic energy efficiency Skills • Forecasting needs for information • Optimise market participation for different actors

8.12 Hydrogen as energy vector

Table 70: Mapping of outcomes and KSC: Hydrogen as energy vector

<table>
<tr><th>Learning Outcome</th><th>Addressed KSC Needs</th></tr>
<tr><td>Identify hydrogen properties and applications.</td><td>Knowledge
The usability and management of different energy vectors, such as electricity, fuels, heat and hydrogen
Competences
Characteristics of energy vectors, including capacities, efficiencies, the importance of the rate of charge/ discharge and network location
The value attributed from the society to energy-service
Potential legislation barriers for RES adoption and how to overcome them
Skills
Different energy storage and buffering options for different energy vectors.</td></tr>
<tr><td>Recognise industrial hydrogen production processes.</td><td>Knowledge
The current status and future potential of many RES and how each of them can be developed and brought together as a holistic system
Competences
The interconnection between established, mature technologies and new, renewable technologies.
Determine capital and operating costs
Skills
Approaches that maximise the contribution of renewable technologies</td></tr>
<tr><td>Explain electrolysis technology working.</td><td>Knowledge
How to achieve an efficient overall energy system from production to end-user
Competences
The interconnection between established, mature technologies and new, renewable technologies.
Overview of the technology (including working principles), markets, barriers and techno-economic performance.
Determine capital and operating costs.
Determine the limits and constraints of any technological solution and its integration.
Skills
Approaches to controlling energy flows</td></tr>
<tr><td>Describe hydrogen storage technology.</td><td>Knowledge</td></tr>
</table>

Learning Outcome	Addressed KSC Needs
	• The usability and management of different energy vectors, such as electricity, fuels, heat and hydrogen Competences • Determine capital and operating costs Skills • Different energy storage and buffering options for different energy vectors
Explain electricity generation through the use of fuel cells.	Knowledge • The usability and management of different energy vectors, such as hydrogen Competences • Overview of the technology (including working principles), markets, barriers and techno-economic performance. • The interconnection between established, mature technologies and new, renewable technologies. • Determine capital and operating costs. • Determine the limits and constraints of any technological solution and its integration Skills • Propose solutions consistent with the local energy market and required future shifts
Calculate a hydrogen energy storage system.	Knowledge • How to achieve an efficient overall energy system from production to end-user. • The social impact of using renewable energy to minimise environmental impact Competences • Energy system interaction to balance production with demand, across time and geography. • Business cases from a consumer, utility and/or aggregator point of view. • Determine: capital and operating costs; thermal efficiencies and technical lifetimes; GHG gas emissions, water consumptions. • Potential legislation barriers for RES adoption and how to overcome them Skills • Propose business models for complex energy systems

8.13 New Materials for solar cells applications

Table 71: Mapping of outcomes and KSC: New Materials for solar cells applications

Learning Outcome	Addressed KSC Needs
Recall the history of Solar Cells	• Back to the history of Solar cells
Identify the importance of Solar Energy	• Solar Energy materials
Define the Power generation from solar cells	• Power generation
Recall the operation of solar cells	• Knowledge and operation of solar cells
Describe the Production of solar cells	• Production Steps
List thin films solar cells	• Description of thin films solar cells
Describe the polymer solar cells	• Description of polymer solar cells
Define Methodology and Importance of materials characterization	• Methodology – steps and instrumentation
Describe Solar cells technology	• New solar cells technology
List the Characterization techniques	• New techniques for characterisation
Describe the optical measurements	• Instrumentation for energy measurement
Identify materials properties and characterization	• New materials and characterization
Define implement Solar Energy Spectrum and the Necessity of Band Gap Tuning	• BGT and solar energy spectrum

8.14 Renewable Energy Technologies

Table 72: Mapping of outcomes and KSC: Renewable Energy Technologies

Learning Outcome	Addressed KSC Needs
Describe fundamentals and main characteristics of renewable energy sources and technologies and their differences compared to fossil fuels.	Knowledge • Successful integration of renewable sources in different sectors. Skills • Modelling and integration of RES system with the existing energy system. Competencies • The interconnection between established, mature technologies and new, renewable technologies.
Evaluate the effects that current energy systems based on fossil fuels have over the environment and the advantages of renewable energy sources.	Knowledge • How to achieve an efficient overall energy system from production to end-user. • Optimization of renewable energy usage. Skills

Learning Outcome	Addressed KSC Needs
	• Optimization of renewable energy usage. Competencies • The comparison with non-RES energy sources and vectors.
Compare different renewable energy technologies and choose the most appropriate based on local conditions.	Knowledge • Successful integration of renewable sources in different sectors. • The current status and future potential of many RES and how each of them can be developed and brought together as a holistic system. Skills • Modelling and integration of RES system with the existing energy system. • Develop techno-economic data projections for the modelling community and policy makers. Competencies • The interconnection between established, mature technologies and new, renewable technologies. • Overview of the technology (including working principles), markets, barriers and techno-economic performance.
Perform simple energy, environmental and techno-economical assessments of renewable energy systems.	Knowledge • The current status and future potential of many RES and how each of them can be developed and brought together as a holistic system. Skills • Develop techno-economic data projections for the modelling community and policy makers. Competencies • Overview of the technology (including working principles), markets, barriers and techno-economic performance.

Learning Outcome	Addressed KSC Needs
Design, at least at a preliminary level, renewable/hybrid energy systems.	Knowledge • The current status and future potential of many RES and how each of them can be developed and brought together as a holistic system. • The costs related to RES exploitation and operation. Skills • Develop techno-economic data projections for the modelling community and policy makers. • Propose solutions consistent with the local energy market and required future shifts. Competencies • Overview of the technology (including working principles), markets, barriers and techno-economic performance. • Determine: capital and operating costs; thermal efficiencies and technical lifetimes; GHG gas emissions, water consumptions.
Discuss how to use local energy sources to improve the sustainability of energy-related activities.	Knowledge • The current status and future potential of many RES and how each of them can be developed and brought together as a holistic system. • The costs related to RES exploitation and operation. Skills • Develop techno-economic data projections for the modelling community and policy makers. • Propose solutions consistent with the local energy market and required future shifts. Competencies • Overview of the technology (including working principles), markets, barriers and techno-economic performance. • Determine: capital and operating costs; thermal efficiencies and technical lifetimes; GHG gas emissions, water consumptions.

8.15 Energy and Environment

Table 73: Mapping of outcomes and KSC: Energy and Environment

Learning Outcome	Addressed KSC Needs
Relate the energy generation and consumption with the environment.	Knowledge • Basic knowledge of how energy systems influence energy flow • The factors that influence systemic energy efficiency, incl. integrating energy along life cycles and within the spatial/ geographic context

Recognize the impact to the local and global climate that the energy generation and consumption have.	Competencies • Technology use • Climate Crisis evaluation Skills • Evaluation of environmental impact of energy generation and consumption.
Classify what is Renewable and non-renewable source of energy.	Competencies • The interconnection between established, mature technologies and new, renewable technologies • The comparison with non-RES energy sources and vectors. Skills • Develop effective economic and policy frameworks that engage and incentivize companies to adopt new renewable technologies • Optimization of renewable energy usage
Describe the energy efficiency, ecolabel EU legislation	Knowledge • Environmental regulations on efficiency and requirements Skills • Appreciate the importance of legislation and standardization • Interaction among different actors along the value chain/in the spatial context to improve systemic EE
Select energy efficiency and energy savings actions in everyday life and especially in energy consumption, at appliance level, house level, enterprise level, country level.	Knowledge • Specific energy efficient technologies for residential, tertiary and industrial sectors • The role of society and citizens in the take-up of renewable energy solutions, e.g. public perceptions of energy • User engagement with their energy consumption Competencies • EE technologies and planning methods in industry and buildings • Power plants O&M. Modules related to single efficient technology for the Tertiary, Residential and Industry sectors (e.g. CHP, LED, Building insulation, Heat Pumps, etc.) Skills • Propose energy efficiency measures at process level, possibly underpinned by data gathering
Identify and select equipment and devices based on energy efficiency criterion. Ability to perform the studies and work and to assess their results considering this parameter.	Knowledge • User engagement with their energy consumption Competencies • The relationship between energy efficiency and life cycle Energy saving data Metering and Verification. • Simulation results and data gathered from measured consumption to improve energy efficiency

	Skills • Energy efficiency assessment and evaluation • Design and implementation of energy efficiency equipment and strategies • Problem-solving from the start to the end of a project
Ability to use the principles of ecological design (Eco-Design) and environmental legislation regulations that define the design, operation and the end of life cycle of electrical equipment and installations, in his professional activity.	Knowledge • Life cycle costs analysis of energy use with regards to generation efficiency Competencies • The relationship between energy efficiency and life cycle • Technology use Skills: • Propose energy efficiency measures and efficiency improvements in a life cycles perspective • Propose profitable and sustainable (costing) Energy Efficiency Improvement Measures (EEIMs)
Describe the legislation on the end of life treatment and recycling potential of waste electrotechnical equipment, as a key activity related to energy consumption and environment	Skills: • Professional, social/ environmental contextual awareness • Interact with different actors along the energy value chains • Appreciate the importance of legislation and standardization
Recognize the relationship of the profession of Electrical Engineering and the environment and their interdependence.	Skills: • Professional, social/environmental contextual awareness • Interact with different actors along the energy value chains • Propose solutions consistent with the local energy market and required future shifts
Ability to apply that knowledge in his/her business life.	Skills: • Professional, social/ environmental contextual awareness • Problem-solving from the start to the end of a project • Propose solutions consistent with the local energy market and required future shifts

8.16 Electrical heat pumps in the energy transition framework

Table 74: Mapping of outcomes and KSC: Electrical heat pumps in the energy transition framework

Learning Outcome	Addressed KSC Needs
Analyse the potential use of the electrical heat pump technology	Knowledge: • Integration of energy resources at building level
Describe heating and cooling load profiles	Knowledge: • Interpretation of energy data

Learning Outcome	Addressed KSC Needs
Compute primary energy consumption and environmental impact	Knowledge: • Environmental regulations on efficiency and requirements Skills • Energy efficiency assessment and evaluation
Describe the heat pump working principle	Knowledge: • Specific energy efficient technologies for residential sector; Skills: • Heat Pumps
Illustrate different technologies	Knowledge: • Specific energy efficient technologies for residential sector; Skills: • Heat Pumps
Compute the performance of a heat pump according to standards	Skills: • Energy efficiency assessment and evaluation
Size a heat pump and run simulations	Skills: • Multi-physics modelling and simulation
List technologies for heat storage with heat pumps	Competencies: • Different energy storage and buffering options for different energy vectors
Describe best practices for application in complex systems	Knowledge: • The usability and management of different energy vectors, such as electricity, fuels, heat and hydrogen Skills: • Multi-physics modelling and simulation

8.17 Corporate and institutional communication and Social Responsibility

Table 75: Mapping of outcomes and KSC: Corporate and institutional communication and Social Responsibility

Learning Outcome	Addressed KSC Needs
Compression of the basic knowledge on the relationship between corporate communication and organizational features in order to be able to design a communication plan (the case of energy corporate campaigns.	Knowledge • the social impact of the various energy markets Competencies • solutions for overcoming potential barriers • problem-solving from the start to the end of a project
Evaluating the role and the importance of the ethical aspects and socio-environmental sustainability for business activities for energy companies.	Knowledge • the role of society and citizens in the take-up of renewable energy solutions Skills • the value of critical energy infrastructure for different consumer types Competencies • create/propose new types of utility/prosumer contracts and interaction with existing regulatory environments

8.18 Innovation and Diversity in engineering

Table 76: Mapping of outcomes and KSC: Innovation and Diversity in engineering

Learning Outcome	Addressed KSC Needs
explain and compare different gender and diversity approaches	Skills • Consider social barriers • Professional, social/environmental contextual awareness
discuss the context between diversity and innovation	Skills • Consider social barriers • Professional, social/environmental contextual awareness Competencies • Social barriers as part of a holistic analysis to improve implementation/integration
create transfer between stereotyping, labelling and social processes	Skills • Consider social barriers • Professional, social/environmental contextual awareness Competencies • Social barriers as part of a holistic analysis to improve implementation/integration
identify and discuss the cultural aspects of gender and diversity as well as its impact on the career choice, the task selection and the quality of	Skills • Consider social barriers • Professional, social/environmental contextual awareness

Learning Outcome	Addressed KSC Needs
developed solutions, design, technologies and products	Competencies • Social barriers as part of a holistic analysis to improve implementation/integration • Social and behavioural aspects of energy efficiency
evaluate the complex impact of social aspects for learning and working in research, development and engineering	Skills • Professional, social/environmental contextual awareness • Consider social barriers Competencies • Social and behavioural aspects of energy efficiency
demonstrate to work self-organized and improve their presentation competence, being able to work with the concepts of intersectionality (gender and diversity) as well as their ability to work in an interdisciplinary team	Skill • Professional, social/environmental contextual awareness

8.19 Understanding Responsibility in Research and Innovation

Table 77: Mapping of outcomes and KSC: Understanding Responsibility in Research and Innovation

Learning Outcome	Addressed KSC Needs
Examine the concept of responsibility in research and innovation	Knowledge • The role of society and citizens in the take-up of renewable energy solutions, e.g. public perceptions of energy • The social impact of using renewable energy to minimise environmental impact • How user involvement affects the energy system Skills • Analyse public perceptions of energy, energy practices, energy choices, prosumers, energy dialogues and the differing ways in which energy affects different clients Competencies • Social barriers as part of a holistic analysis to improve energy efficiency • The relationship between energy efficiency and life cycle • The impact of (new) technical processes in their spatial and social context. • The value attributed from the society to energy-service

Learning Outcome	Addressed KSC Needs
Asses how to involve stakeholders in an innovation process	Knowledge • The role of society and citizens in the take-up of renewable energy solutions, e.g. public perceptions of energy • User engagement with their energy consumption • How user involvement affects the energy system • The roles of actors in and impact on efficiency improvements • Stakeholder interaction (consumers, prosumers, investors, etc.) for systemic energy efficiency Skills • Propose and apply new models for fostering behavioural change by end-user • Interaction among different actors along the value chain/in the spatial context to improve systemic EE • Interact with different actors along the energy value chains Competencies • The relationship between energy efficiency and life cycle • The impact of (new) technical processes in their spatial and social context. Social and behavioural aspects of energy efficiency • The value attributed from the society to energy-service
Discuss social impact of research and innovation	Knowledge • The role of society and citizens in the take-up of renewable energy solutions, e.g. public perceptions of energy • The social impact of using renewable energy to minimise environmental impact • The deployment barriers for efficiency improvements • The roles of actors in and impact on efficiency improvements Skills • Propose and apply new models for fostering behavioural change by end-user • Develop effective economic and policy frameworks that engage and incentivise companies to adopt new renewable technologies.

<table>
<tr><th>Learning Outcome</th><th>Addressed KSC Needs</th></tr>
<tr><td></td><td>Interact with different actors along the energy value chains
Competencies
Social barriers as part of a holistic analysis to improve energy efficiency
The relationship between energy efficiency and life cycle
The impact of (new) technical processes in their spatial and social context. Social and behavioural aspects of energy efficiency
The value attributed from the society to energy-service</td></tr>
<tr><td>Propose ways to improve the alignment of research with societal needs</td><td>Knowledge
The role of society and citizens in the take-up of renewable energy solutions, e.g. public perceptions of energy
The social impact of using renewable energy to minimise environmental impact
How user involvement affects the energy system
The deployment barriers for efficiency improvements
The roles of actors in and impact on efficiency improvements
Skills
Propose and apply new models for fostering behavioural change by end-user
Interaction among different actors along the value chain/in the spatial context to improve systemic EE
Analyse public perceptions of energy, energy practices, energy choices, prosumers, energy dialogues and the differing ways in which energy affects different clients
Develop effective economic and policy frameworks that engage and incentivise companies to adopt new renewable technologies.
Interact with different actors along the energy value chains
Forecasting needs for information
- Understanding customer needs
- Solution orientation
- Communication
Competencies</td></tr>
</table>

Learning Outcome	Addressed KSC Needs
	- Social barriers as part of a holistic analysis to improve energy efficiency - The relationship between energy efficiency and life cycle - The impact of (new) technical processes in their spatial and social context. Social and behavioural aspects of energy efficiency - The value attributed from the society to energy-service
Discuss "responsibility" in a case study	Knowledge - The social impact of using renewable energy to minimise environmental impact - User engagement with their energy consumption - How user involvement affects the energy system - The deployment barriers for efficiency improvements - The roles of actors in and impact on efficiency improvements - Stakeholder interaction (consumers, prosumers, investors, etc.) for systemic energy efficiency Skills - Propose and apply new models for fostering behavioural change by end-user - Interaction among different actors along the value chain/in the spatial context to improve systemic EE - Analyse public perceptions of energy, energy practices, energy choices, prosumers, energy dialogues and the differing ways in which energy affects different clients - Interact with different actors along the energy value chains - Forecasting needs for information - Understanding customer needs - Solution orientation - Communication Competencies - Social barriers as part of a holistic analysis to improve energy efficiency - The relationship between energy efficiency and life cycle

Learning Outcome	Addressed KSC Needs
	• The impact of (new) technical processes in their spatial and social context. Social and behavioural aspects of energy efficiency • The value attributed from the society to energy-service

8.20 Green professionalization and ethics

Table 78: Mapping of outcomes and KSC: Green professionalization and ethics

Learning Outcome	Addressed KSC Needs
Recall the sociological terminology about the role of professionals and expert knowledge in society	Knowledge • User engagement with their energy consumption; Skills • How user involvement affects the energy system; Competencies • Professional, social/environmental contextual awareness
Describe the professionalization process of the "green-collars"	Knowledge • User engagement with their energy consumption; Skills • How user involvement affects the energy system; Competencies • Professional, social/environmental contextual awareness
Identify and recognize empirical experiences of green professionalization	Knowledge • User engagement with their energy consumption; Skills • How user involvement affects the energy system; Competencies • Professional, social/environmental contextual awareness

8.21 Participatory planning tools and Social network analysis

Table 79: Mapping of outcomes and KSC: Participatory planning tools and Social network analysis

Learning Outcome	Addressed KSC Needs
Clarifying the meaning and implications of Energy Transition	Knowledge • The deployment barriers for efficiency improvements Skills • Propose and apply new models for fostering behavioural change by end-user Competencies • Social barriers as part of a holistic analysis to improve energy efficiency
Identifying the meaning and implication of Sustainable planning of Energy Transition	Knowledge • The roles of actors and impact on efficiency improvements Skills • Interaction among different actors along the value chain/in the spatial context to improve systemic EE Competencies • The impact of (new) technical processes in their spatial and social context. • Social and behavioural aspects of energy efficiency
Recognising the Social Network Analysis as a tool of Participatory Planning	Knowledge • Stakeholder interaction (consumers, prosumers, investors, etc.) for systemic energy efficiency Skills • Interaction among different actors along the value chain/in the spatial context to improve systemic EE Competencies • Social barriers as part of a holistic analysis to improve implementation/integration.

8.22 Innovation processes in the energy sector

Table 80: Mapping of outcomes and KSC: Innovation processes in the energy sector

Learning Outcome	Addressed KSC Needs
Understand Innovation Processes	Knowledge • Basic Knowledge on digital Entrepreneurship Skills • Digital innovation and transformation
Familiarise with Growth Mindset	Skills

Learning Outcome	Addressed KSC Needs
	● Business Savvy skill: Innovate business and operating models, delivering value to organisations
Develop Design Thinking	Skills ● Business Savvy skill: Innovate business and operating models, delivering value to organisations ● Solution orientation
Understand Lean Start-up Methods	Skills ● Business Savvy skill: Innovate business and operating models, delivering value to organisations
To acquire basic knowledge about the Stage Gate Process in Corporations	Competence ● Designs and maintains the holistic architecture of business processes and information systems
To be able to design Innovation Structures in Corporations	Competence ● Digital Savvy skill: Envision and drive change for business performance, exploiting digital technology trends as innovation opportunities

8.23 Energy Efficient and Ecological Design of Products and Equipment

Table 81: Mapping of outcomes and KSC: Energy Efficient and Ecological Design of Products and Equipment

Learning Outcome	Addressed KSC Needs
Analyse the EU Energy Efficiency, EcoLabel, EcoDesign, RoHS and WEEE Directives.	Knowledge ● Legal and Regulatory framework ● Environmental regulations on efficiency and requirements Skills ● Appreciate the importance of legislation and standardization
Identify the connection of the energy and environmental aspects of the design process of a product and a system, during the total life cycle of a product.	Knowledge ● Environmental regulations on efficiency and requirements ● Skills ● Interaction among different actors along the value chain/in the spatial context to improve systemic EE ● Evaluation of environmental impact of energy generation and consumption. ● Environmental Impact Assessment Study

Learning Outcome	Addressed KSC Needs
Identify the Economics of Energy Efficient Design and EcoDesign of products and systems.	• Knowledge • Environmental regulations on efficiency and requirements • The role of society and citizens in the take-up of renewable energy solutions, e.g. public perceptions of energy • Skills • Develop effective economic and policy frameworks that engage and incentivize companies to adopt new renewable technologies
Identify the Consumer Orientation - Innovation through Eco-Design and Energy efficient Design, based on the total life cycle analysis approach.	• Knowledge • The role of society and citizens in the take-up of renewable energy solutions, e.g. public perceptions of energy • Skills • Deep analysis on how innovation can create technological niches for energy efficiency • Interaction among different actors along the value chain/in the spatial context to improve systemic EE
Combine methods for developing and adopting strategies for Eco and Energy efficient design of products and systems through analysis of all phases in their life and reverse engineering approaches.	Knowledge • Determine: capital and operating costs; thermal efficiencies and technical lifetimes; GHG gas emissions, water consumptions Competence • Power plants O&M. Modules related to single efficient technology for the Tertiary, Residential and Industry sectors (e.g. CHP, LED, Building insulation, Heat Pumps, etc.) • EE technologies and planning methods in industry and buildings Skills • Propose profitable and sustainable (costing) Energy Efficiency Improvement Measures (EEIMs) • Design and implementation of energy efficiency equipment and strategies • Propose energy efficiency measures at process level, possibly underpinned by data gathering • Propose energy efficiency measures and efficiency improvements in a life cycles perspective

Learning Outcome	Addressed KSC Needs
	• Propose solutions consistent with the local energy market and required future shifts
Analyse different components and methods for reducing the impact of a product or equipment in the environment during the different phases of its life cycle.	Knowledge • The roles of actors in and impact on efficiency improvements Competence • Solutions for overcoming potential barriers • The relationship between energy efficiency and life cycle Skills • Propose energy efficiency measures and efficiency improvements in a life cycles perspective • Design and implementation of energy efficiency equipment and strategies • Foster the adoption of Minimum Environmental Criteria within Procurement processes in the Public sector.
Combine the Concepts and Methodologies and Basic Tools for the Energy efficient and Eco Design of Products.	Competence • Determine the limits and constraints of any technological solution and its integration Skills • Propose profitable and sustainable (costing) Energy Efficiency Improvement Measures (EEIMs) • Problem-solving from the start to the end of a project • Foster the adoption of Minimum Environmental Criteria within Procurement processes in the Public sector • Propose energy efficiency measures and efficiency improvements in a life cycles perspective
Ability to perform Life Cycle Analysis and Life Cycle Costing Analysis during the design of a product and the calculation of the Total Cost of Ownership	Knowledge • How to achieve an efficient overall energy system from production to end-user Competence • The relationship between energy efficiency and life cycle • Determine the limits and constraints of any technological solution and its integration Skills

Learning Outcome	Addressed KSC Needs
	• Develop techno-economic data projections for the modelling community and policy makers • Develop useful tool for policymakers for helping to identify future priorities for research, development and demonstration (RD&D) • Propose and apply new models for fostering behavioural change by end-user • Propose energy efficiency measures and efficiency improvements in a life cycles perspective
Intergrade RES during the energy efficient and ecological/sustainable design process or during improvement schemes for systems and products.	Knowledge • Life cycle costs analysis of energy use with regards to generation efficiency Competence • Determine the limits and constraints of any technological solution and its integration Skills • Optimization of renewable energy usage • Professional, social/ environmental contextual awareness • Interact with different actors along the energy value chains
Ability to perform the studies and work and to assess their results considering this parameter.	Skills • Professional, social/environmental contextual awareness • Interact with different actors along the energy value chains • Propose solutions consistent with the local energy market and required future shifts • Foster the adoption of Minimum Environmental Criteria within Procurement processes in the Public sector.
Ability to use the principles and methodologies of energy efficient and ecological / sustainable design (Eco-Design) in his professional activity.	Skills • Professional, social/ environmental contextual awareness • Problem-solving from the start to the end of a project • Propose solutions consistent with the local energy market and required future shifts

Learning Outcome	Addressed KSC Needs
	• Foster the adoption of Minimum Environmental Criteria within Procurement processes in the Public sector

8.24 Economics of energy sources and the optimal integration of renewable energies and energy conservation measures

Table 82: Mapping of outcomes and KSC: Understanding Responsibility in Research and Innovation

Learning Outcome	Addressed KSC Needs
Apply the "fundamentals" of economics of energy to evaluate the evolution of the energy system	Knowledge • Identify basic concept and main characteristics of various RES and specific energy efficient technologies for residential, tertiary and industrial sectors Skills • Identify and show examples of profitable and sustainable (costing) EE Improvement Measures Competencies • Clarify and present the characteristics of energy vectors, including capacities, efficiencies, the importance of the rate of charge/ discharge and network location • How to determine optimum mixtures of renewable-energy sources and energy efficiency improvement measures (equality of marginal costs to achieve economic efficiency) • How to calculate economic indicators (i.e. NPV, IRR, PBT) to evaluate cost-effectiveness of new installations/ interventions
Identify and describe the most significant criticalities and the constraints affecting the organizational structures and the functioning of the energy markets	Knowledge • Identify the components of the energy system (sources, vectors and end-uses) and the technical determinants of the production, transport, conversion and use of energy sources. • How EE improvements relate to improvements in quality of life (focus on the Rebound effect) • How to incentivise a utility to foster the lowest possible level of end-user consumption
Explain and apply concepts about successful integration of renewable sources in different sectors	Skills • How to calculate the levelized cost of energy (LCOE) to make cost comparisons between different energy sources • Modelling and integration of RES system with the existing energy system
Understand Evaluate the impact of pricing scheme (e.g. cost-reflective tariff vs progressive tariff of kWh) and	Knowledge

subsidies on management and new installations	• Assess the impact of pricing scheme (e.g. cost-reflective tariff vs progressive tariff of kWh) on management and new installations • Describe the main forms of energy Subsidies Skills • Propose innovative business models for increased energy efficiency uptake (S) Competencies • Clarify the relationship between energy efficiency and life cycle (C) • Evaluate the impact of the tariff structure on the exploitation of innovative efficient technologies (e.g. heat pumps, Evs, etc.) (C)
Describe and discuss the dynamics affecting the speed of the energy transition	Knowledge • Identify the main barriers to RES exploitation and energy efficiency improvement measures implementation • Discuss what kind of engineering, economic, and policy adjustments will be needed to accommodate renewable energy sources

8.25 Behavioural change as a powerful drive to minimize the energy consumption while providing the same level of energy service

Table 83: Mapping of outcomes and KSC: Behavioural change as a powerful drive to minimize the energy consumption while providing the same level of energy service

Learning Outcome	Addressed KSC Needs
Describe social barriers as part of a holistic analysis to improve EE	Knowledge • The deployment barriers for efficiency improvements Skills • Consider social barriers Competencies • Social barriers as part of a holistic analysis to improve energy efficiency
Illustrate the roles of actors in and impact on efficiency improvements	Knowledge • The roles of actors in and impact on efficiency improvements • Stakeholder interaction (consumers, prosumers, investors, etc.) for systemic energy efficiency • The deployment barriers for efficiency improvements Skills • Interaction among different actors along the value chain/in the spatial context to improve systemic EE

Get an overview on human behaviour and behavioural change	Knowledge ● User engagement with their energy consumption Competencies ● Social and behavioural aspects of energy efficiency ● How the various sectors use energy and interact within and with each other
Describe the behavioural change in the use of energy	Knowledge ● Stakeholder interaction (consumers, prosumers, investors, etc.) for systemic energy efficiency Skills ● Interaction among different actors along the value chain/in the spatial context to improve systemic EE Competencies ● Social and behavioural aspects of energy efficiency
Explain how to do from Practical guide to program development	Skills ● Consider social barriers ● Analyse public perceptions of energy, energy practices, energy choices, prosumers, energy dialogues and the differing ways in which energy affects different clients Competencies ● How the various sectors use energy and interact within and with each other
Illustrate case studies	Knowledge ● Stakeholder interaction (consumers, prosumers, investors, etc.) for systemic energy efficiency Competencies ● How the various sectors use energy and interact within and with each other
Practice drafting, presenting and managing behavioural change projects in the EE sector	Knowledge ● The social impact of using renewable energy to minimise environmental impact Skills ● Analyse public perceptions of energy, energy practices, energy choices, prosumers, energy dialogues and the differing ways in which energy affects different clients ● Analyse energy markets, energy poverty, ownerships, system service and regulatory costs