PANTERA

Pan European Technology Energy Research Approach

Work Package 3

The state of R&I, standardisation and regulation

Deliverable D3.2

Report on Regulations, Codes and Standards in EU-28

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Abbreviations

AC	*Alternating Current*
AD	*Active Demand*
AI	*Artificial Intelligence*
AI2AI	*Artificial Intelligence to Artificial Intelligence*
AMM	*Advanced Meter Management*
AMI	*Advanced Meter Infrastructure*
BPIE	*Buildings Performance Institute Europe*
CAES	*Compressed-Air Energy Storage*
CAN	*Climate Action Network*
CAT	*Climate Action Tracker*
CEEP	*Central Europe Energy Partners*
CEER	*Council of European Energy Regulators*
CEN	*European Committee for Standardization*
CENELEC	*European Committee for Electrotechnical Standardization*
CG-SEG	*Coordination Groups on Smart Energy Grids*
CHP	*Combined Heat and Power*
CIM	*Common Information Model*
CoS	*Catalogue of Standards*
DA	*Distribution Automation*
DC	*Direct Current*
DCC	*Demand Connection Code*
DG ENER	*Directorate-General for Energy*
DER	*Distributed Energy Recourses*
DMS	*Distribution Management System*
DSO	*Distribution System Operator*
DSR	*Demand Side Response*
EC	*European Commission*
EDSO	*European Distribution System Operator*
EED	*Energy efficiency Directive*
EES	*Electrical Energy Storage*
EFTA	*European Free Trade Association*
EG	*Expert Group*
EIRIE	*European Interconnection for Research Innovation and Entrepreneurship*
EMC	*Electromagnetic Compatibility*
EMD	*Electricity Market Directive*
EMS	*Energy Management System*
ENTSO-E	*European Network of Transmission System Operators for Electricity*
EPBD	*Energy Performance of Buildings Directive*
ER	*Emergency and Restoration*
ETIP SNET	*Technology and Innovation Platform on Smart Networks for the Energy Transition*
ETS	*Emissions Trading Scheme*
ETSI	*European Telecommunications Standards Institute*
EU	*European Union*
EV	*Electric Vehicle*

FACDS	*Flexible Alternating Current Distribution System*
FACTS	*Flexible Alternating Current Transmission System*
GHG	*Greenhouse Gas*
GIS	*Geographic Information System*
GL	*Guidelines*
GNSS	*Global Navigation Satellite System*
GtV	*Grid to Vehicle*
HBES/BACS	*Home and Building Electronic Systems/ Building Automation and Control Systems*
HV	*High Voltage*
HVDC	*High Voltage Direct Current*
ICT	*Information and Communication Technology*
IEC	*International Electrotechnical Commission*
IEEE	*Institute of Electrical and Electronics Engineers*
IED	*Intelligent Electronic Device*
IEM	*Internal Energy Market*
IoT	*Internet of Things*
ISO	*International Organisation for Standardisation*
ITU	*International Telecommunication Union*
LAES	*Liquid Air Energy Storage*
LV	*Low Voltage*
M2M	*Machine to Machine*
MCC	*Modular Multilever Converter*
MV	*Medium Voltage*
NC	*Network Code*
NECP	*National Energy and Climate Plan*
NIST	*National Institute of Standards and Technology*
NRA	*National Regulatory Authority*
NZEB	*Nearly Zero Emissions Building*
OJEU	*The Official Journal of the European Union*
OpenADR	*Open Automated Demand Response*
OSGP	*Open Smart Grid Protocol*
P2G	*Power to Gas*
P2H	*Power to Heat*
PCI	*Project of Common Interest*
PLC	*Programmable Logic Controller*
PV	*Photovoltaics*
RCS	*Regulations, Codes and Standards*
RED	*Renewable Energy Directive*
RES	*Renewable Energy Sources*
RfG	*Requirements for Generators*
RICAP	*R&I status and Continuous gAP analysis*
SA	*Substation Automation*
SCADA	*Supervisory Control and Data Acquisition*
SEG	*Standardisation Evaluation Groups*
SEPA	*Smart Electric Power Alliance*
SGAM	*Smart Grid Architecture Model*
SGIP	*Smart Grid Interoperability Panel*

SGTF	*Smart Grid Task Force*
SM-CG	*Smart Meters Coordination Group*
SOGL	*System Operation Guidline*
SRG	*Systems Resource Groups*
SRI	*Smart Readiness Indicator*
STARGRID	*STandard Analysis supporting smart eneRgy GRID*
SyC	*System Committee*
TC	*Technical Committee*
T&C	*Testing and Certification*
TEN-E	*Trans-European Networks for Energy*
TRL	*Technology Readiness Level*
TR	*Technical Report*
TS	*Technical Specification*
TSO	*Transmission System Operator*
TYNDP	*Ten-Year Network Development Plan*
UK	*United Kingdom*
VtG	*Vehicle to Grid*
WAMS	*Wide Area Monitoring System*
WG 5	*Working Group 5*
WP	*Work Package*

1 Introduction

1.1 Purpose, Scope and Limitations of the Document

The work in this report is carried out under the Work Package three (WP3) 'The state of R&I (Research and Innovation), standardisation and regulation' of the Pan European Technology Energy Research Approach (PANTERA) project. This deliverable aims at reviewing Regulations, Codes and Standards (RCS) in the Smart Grid domain that will form valuable content to the EIRIE platform.

The report is committed to be a useful source of structured information on European RCS in the Smart Grid domain. It contains discussions on practical and legal aspects of RCS and their possibility to support R&I activities. Furthermore, the report provides the RCS analysis from the future energy system characteristics perspective, by utilising Functionalities concept developed by ETIP SNET platform (Technology and Innovation Platform on Smart Networks for the Energy Transition). The report it is intended to be a useful input to the EIRIE (European Interconnection for Research Innovation and Entrepreneurship) platform and be utilised by the PANTERA Working Teams it their endeavours to produce valuable contributions to the EIRIE platform in their targeted field of work.

It shall be noted, that analysing national level documents is out of the scope of this deliverable, although selected general information on relevant national organisations is provided. As for standards, the report includes a review of literature and a review work performed within Smart Grid standardisation domain and a high-level overview of standards developed by officially recognised European Standardisation Organisations (ESO). As for regulations and codes, the report incorporates the literature review and high-level review of the European Network Codes. All the referenced resources are to be linked to the EIRIE platform through dedicated subsections forming a valuable resource for the R&I community of Europe.

1.2 Structure of the Document

The D3.2 is structured to cover all aspects of the review. This document starts by introduction and general considerations on RCS review approach and expected outcomes. Then Section 2 describes the process of ETIP SNET Functionalities' review and its results which set the scene for RCS analysis. Section 3 focuses on standardisation review, whereas Section 4 covers the regulation review, including a review of the Network Codes. Finally, Section 5 concludes the document and summarises the results achieved.

1.3 RCS Review Methodology, Objectives and Expected Outcomes

Topics covered by regulations, codes and standards are rather broad and could be analysed from multiple perspectives and on different levels. In order to keep a unified review structure throughout the whole report, the review of RCS in the field of Smart Grid is performed under the prism of the Functionalities concept established by ETIP SNET. As defined by ETIP SNET, Functionalities represent the set of features enabling the functioning of an integrated energy system by the year 2030 and beyond. Hence, the review of RCS is built on the future energy system needs. At the same time, it is supported by extensive literature review aiming at unifying information on work performed and actual topics in the RCS field being discussed by the scientific community.

Furthermore, by adopting the functionalities-based approach, it is beneficial in the following way:

- PANTERA as a project under the Directorate-General for Energy (DG ENER) has also close working relations with ETIP SNET, therefore alignment is of fundamental importance in line with the ETIP SNET vision and its adapted Functionalities.
- Given that R&I roadmap for smart networks for energy transition as given by ETIP SNET has already engaged the different stakeholders, makes the review process under the functionalities to be familiar and easily acceptable by the whole R&I community.
- The EIRIE platform supported by the PANTERA project will serve both ETIP SNET and BRIDGE initiative. Having said that, a common architecture based on Functionalities is towards the correct direction leading to a universal approach for all interested stakeholders.
- The EIRIE platform builds processes to be sustainable including all the components that support it. This adaptability to any changes such as the evolution of the functionalities themselves - that can emerge in the future, is contributing to the sustainability of the process as well.

A significant part of the PANTERA project is a RICAP (R&I status and Continuous gAP analysis) process, described in D3.1 'Report on current status and progress in R&I activities: Technology' [1], bringing together the different dimensions, Regional Desks, Working Teams, and activities that will ultimately feed the EIRIE platform.

The results of this deliverable will be used to feed in and support the RICAP process and the EIRIE platform through the following ways:

- Offer an additional validation for the Technology Classification and their linking to the Functionalities through the extensive review of RCS;
- A developed process for linking the RCS and the Technologies/ Functionalities; Through the process, this deliverable will provide future users of the platform search capabilities linking technologies of projects to RCS and hence easily identify those RCS that are of interest to the project.
- Contribution to the R&I community of Europe covering the important RCS field that now is missing and thus offer a much-needed process for identifying the RCS needs of projects.
- Contributing to the maturity index of Functionalities under the RCS perspective that now is missing.
- Contributing to the replicability & scalability index of projects.

The results from RCS review would be included under the Data area of the EIRIE platform giving access to all users of the platform. In this way, this deliverable provides the initial input and methodology- where applicable- to the EIRIE platform for facilitating the "search and find" tool of the platform in finding specific standards, codes and regulations related to a technology/functionality. This process can thus be used for supporting projects in identifying their RCS needs. Similarly, the same process will facilitate the needs of tasks or sub-tasks of the ETIP-SNET road map. This process will be build on the already agreed mapping of functionalities vs technologies and reported in D3.1.

2 Review of ETIP-SNET Functionalities

2.1 Review Framework

Both standardisation and regulation in the energy field remain a hot discussion topic between all involved stakeholders in view of current challenges associated with energy system transformation and new technologies uptake. Therefore, a variety of reviews and analysis are publicly available. Literature reviews on standards and regulations (Section 3.3 and Section 4.2) include a summary of reports prepared by widely known international organisations, including Eurelectric, ETIP SNET, European Standardisation organisations, etc., as well as an overview of scientific papers on regulation issues. The objective of works performed within D3.2 is to review existing RCS from the perspective of identified Functionalities of the future grid and structure the existing information in the manner that might fit the EIRIE Platform. Unlike standards, which might have more or less evident connection to systems and technologies, regulations and codes linking to Functionalities might be more disputable. Therefore, it is necessary to deeper understand what requirements and features are hidden behind each Functionality.

The ETIP SNET R&I roadmap [2] identifies twelve Functionalities as a set of operational capabilities to archive energy system transition (see Table 1) in accordance with the Building Blocks defined in the ETIP SNET Vision 2050 [3]. The roadmap includes a considerable number of proposed dedicated research tasks involving technologies / systems / solutions, each contributing to a selection of Functionalities. This section, limits its analysis to the identified tasks contributing to the functionalities to be in line with the roadmap of ETIP SNET and not the technologies / systems / solutions that drive tasks to fruition.

Additionally, a maturity level for each task for different implementation periods, ending 2024, 2026, 2028 and 2030 and beyond 2030, is identified, thus giving the idea of tasks development in the course of time from research activities Technology Readiness Level (TRL 3-5) to demonstration (TRL 6-8) and deployment (TRL 9). Some tasks have only research-maturity as a goal and no follow-up demonstration maturity. Some tasks already begin with demonstration-maturity since research-maturity has already been reached before the implementation period 2021-2024. Some tasks do not show any research or demonstration maturity level, this means that according to ETIP SNET experts, all research and/or demonstration- goals have already been achieved before the first implementation period 2021-2024, and deployment-maturity is given from the beginning. In order to avoid unnecessary complication of the analysis described in the current subsection, it was decided to highlight the maturity level given for the first period only.

Table 1: ETIP-SNET Functionalities

Building Blocks	***Functionality full name***	***Short name***
The efficient organisation of energy systems	F1 Cooperation between system operators	F1 Cooperation
	F2 Cross-sector integration	F2 Cross-Sector
	F3 Integrating the subsidiarity principle - The customer at the centre, at the heart of the Integrated Energy System	F3 Subsidiarity
Markets as key enablers of the energy transition	F4 Pan-European wholesale markets	F4 Wholesale
	F5 Integrating local markets (enabling citizen involvement)	F5 Retail
Digitalisation enables new services for	F6 Integrating digitalisation services (including data privacy, cyber security)	F6 Digitalisation

Integrated Energy Systems		
Infrastructure for Integrated Energy Systems as key enablers of energy transition	F7 Upgraded electricity networks, integrated components and systems	F7 Electricity Systems and Networks
	F8 Energy System Business (incl. models, regulatory)	F8 Business
	F9 Simulation tools for electricity and energy systems (Software)	F9 Simulation
Efficient energy use	F10 Integrating flexibility in generation, demand, conversion and storage technologies	F10 Flexibility
	F11 Efficient heating and cooling for buildings and industries in view of system integration of flexibilities	F11 Heating & Cooling
	F12 Efficient carbon-neutral liquid fuels & electricity for transport in view of system integration of flexibilities	F12 Transport

The analysis incorporated the following steps performed for each of twelve Functionalities:

1. Creating a list of all the tasks linked to Functionality;
2. Selecting key words and phrases, which make the core of the task;
3. Mapping tasks by allocating key words to the most affected of identified domains and functional layers;
4. Cross-checking to avoid repeating key words.

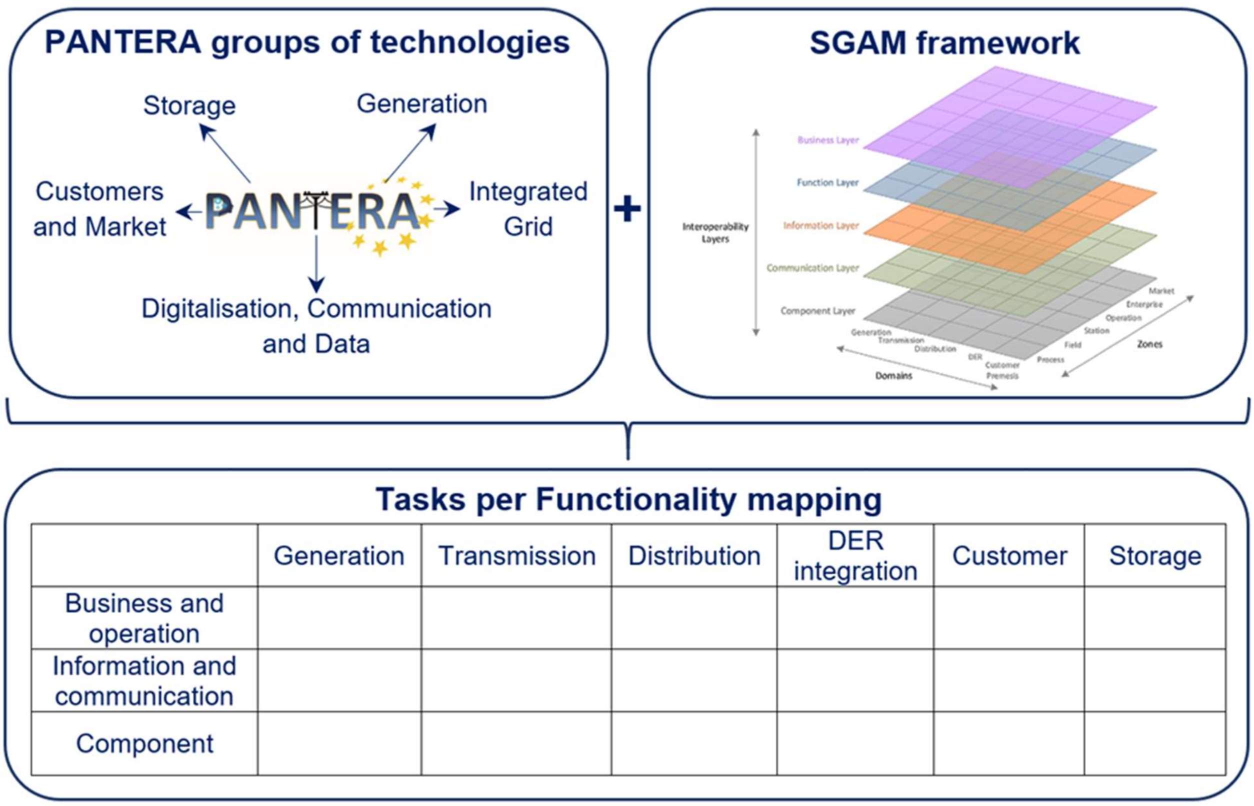

Figure 1: Functionality review framework

The proposed mapping is based on a synthesis approach combining categorization of groups of technologies provided in D3.1 [1], (the list of proposed technologies/systems / solutions included in

Annex 6.3) and “The Smart Grid Architecture Model (SGAM)”. SGAM is a very well-established and broadly acknowledged approach to Smart Grid, referred to in the many reviewed literature sources (see next subsections). Moreover, a functional layer approach is helpful in differentiating the role of standards, regulations and codes. Figure 1 briefly illustrates the combination logic and the resulted framework.

Cross-cutting tasks related to social acceptance, cyber security and data privacy were not separately highlighted as these to higher or lesser extent are connected to all domains and layers. Completed tasks mapping for each Functionality is presented in Annex 6.4.

It has to be mentioned that Annex 6.4 does not provide yet the exact matching of technologies / systems / solutions with the related RCS but highlight the relation and context.

The above referred methodology is critical for feeding the RICAP process and populate the Data area of the platform. To achieve this, the steps that will be included into the platform through the “Search and Find” tool are as follows:

- Each project classify itself under the technologies/systems/solutions that will advance within their time duration.
- So, these technologies / systems / solutions are going to be linked with the appropriate functionality. This mapping will be available through the EIRIE platform for the first time. In this way the R&I community can have a good overview of how different technologies / systems / solutions can contribute to the maturity of different functionalities.
- Through the different functionalities the projects are related to an exhaustive list of standard committees/standards, regulations and codes. Each project then can sort out the RCS of interest for the objectives that it serves and the technologies / systems / solutions that it advances.
- At the same time each project classifies itself against the SGAM model architecture and maps the selected RCS that serve the objectives of the project.
- In this way the technologies / systems / solutions are linked with the RCS throughout the smart grid plane.

The above duly presented in Figure 2, is of critical importance for feeding the RICAP process and asses the maturity of the technology/system/solution and at the same time it will feed the Replicability and Scalability process of BRIDGE through which the scalability and replicability indexes of the advancements of the technologies / systems / solutions are evaluated.

Moreover, it offers useful information for the data repository of the EIRIE platform. In this way, all technologies / systems / solutions and functionalities relate with the RCS and will be available for the R&I community in Europe.

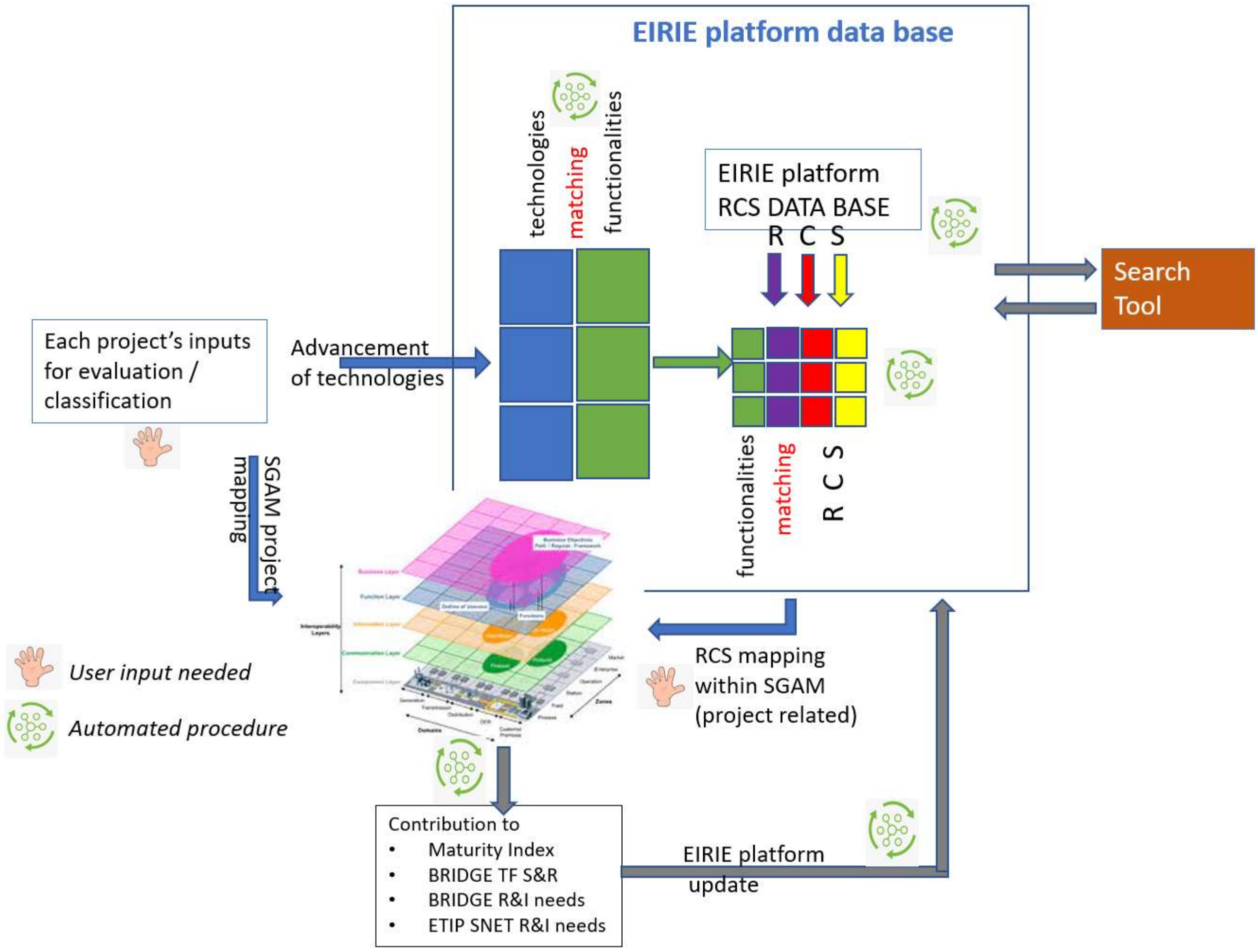

Figure 2 The main methodology for RCS mapping

2.2 RCS analysis related to Functionalities

The extensive mapping exercise described above forms a basis for the RCS analysis in relation to Functionalities and provides a broader picture of effort distribution between different Smart Grid stakeholders.

According to the analysis, most research and innovation efforts are concentrated in functionalities F10 Flexibility and F7 Electricity Systems and Networks covering all the domains with special attention to distribution. Meanwhile, F7 Electricity Systems and Networks related tasks (selected key words) are concentrated in component, information and communication layers, while most of F10 flexibility related tasks, refer to business and function layers. This illustrates the trend that a need might exist for more specific regulations and business cases covering flexibility issues.

It is worth mentioning that the distribution domain appears to be the most affected one. Therefore, more attention shall be paid to engaging distribution system operators (DSOs) in R&I strategies planning and implementation. For the work within the current task, DSO priorities in standardisation and regulation, reflected in literature shall be treated with special attention.

Consumer domain is the second most affected area. Consumer related R&I is crucial for F3

Subsidiarity and F12 Transport, as well as highly important for F5 Retail, F8 Business, Flexibility and F11 Heating & Cooling. In all of the above-mentioned functionalities, most of the tasks refer to the business and functional layer. Therefore, consumer participation related issues are also on the priority list in developments in the fields of regulation and creating a business case. It shall be noted once again that consumer awareness and data privacy were treated to be cross cutting issues and are excluded from the mapping.

Business and functional layer related research tasks contribute significantly to almost all functionalities and at the same time are likely to be most immature, meaning that research activities shall involve a broader range of stakeholders, including authorities and industry in order to be capable of creating use-cases and business models. Relevant topics include operation of coupled energy systems, market design for ancillary services, business models for promoting demand response and energy efficiency at end-user level, regulatory arrangements related to different aspects of storage operation and management, coordination between system operators, prosumer participation and other.

3 Review of European and International Standards on Smart Grids

3.1 Legal and Practical Aspects of Standardisation

Smart grids are expected to play a major role in achieving a decarbonised energy system. A smart grid can improve energy efficiency, increase the share of renewable connected to the grid, reduce peak loads and lead to a more secure and reliable energy system. A range of technologies must be developed and deployed to create these smart grids, including advanced metering infrastructure and information and communication technologies. Furthermore, continued innovation will be required in the areas of renewable energy generation, energy storage and energy efficiency. A vital component of a smart grid is the interoperability between the components of the network and the ability to not only communicate information, but to make sense of it and react accordingly. Given the range of technologies, producers and innovators involved, communication and cooperation to ensure efficient integration is vital.

Standardisation is being explored as a way of achieving this integration. Standardisation sets technical or quality specifications that are complied with by current or future technologies. In terms of the smart grid, standardisation would identify minimum performance standards for the digital equipment involved and provide rules for how these components interact and share information, thus eliminating differences that inhibit the flow of information and data. Currently, there is insufficient standardisation to achieve a decarbonised energy system, lacking in interoperability of technologies. With a range of technologies and systems being developed throughout Europe, the lack of standardisation means that there is an issue with compatibility.

Literature has emphasised the importance of stakeholder involvement and engagement in the development of standards. International and national bodies, developers, industry professionals, innovators and researchers should be consulted, thus ensuring that the standards are relevant and up to date, while also encouraging compliance.

3.1.1 Advantages of Standardisation

A common opposition to standardisation is the misconception that it hinders innovation. In fact, standards can be future focused and can foster research and innovation, improving competitiveness and promoting the development of new technologies. Furthermore, these standards can be adaptable, being updated to reflect the ever-changing markets and new developments. Standardisation can help to break down the technical barriers to a single energy market, reducing energy costs and improving competitiveness. [4]

There are many advantages associated with standardisation. Firstly, as mentioned previously, it allows for the integration of different technologies and the creation of synergies. Furthermore, standardisation improves the communication and sharing of information between innovators and developers, thus avoiding “reinventing the wheel”, which is wasteful in terms of time and resources. Instead, researchers can build on the knowledge of others and make improvements.

There is of course the issue of free-riding and the reluctance of researchers to share their findings, preferring to strive for intellectual property rights. However, this way of thinking is inefficient and does not align with the collaborative, interoperable concept of a smart grid and decarbonised energy system.

New markets can also benefit from the use of standards, as compliance can increase consumer confidence in quality, performance and safety, while critical mass can be achieved quicker than having a range of non-standardised technologies which are ultimately aiming to serve the same purpose [5]. Standardisation is therefore a method of transferring research into successful processes and products. Without this, existing systems will remain much longer, as it is more difficult to achieve significant market penetration and economies of scale.

At an international level, standards allow for the transfer of information, technologies and processes across borders and sectors to ensure the optimum use of resources and to achieve high quality new developments as quickly as possible. This is particularly relevant in achieving the goal of a single energy market.

As smart grids rely heavily on the use of smart metering on the demand-side, there are issues arising surrounding data protection and security. Standards will be vital in this area to ensure that consumers are protected and to increase acceptance of smart metering technologies [6]. Furthermore, while smart grids will require a range of new technologies, they must also be compatible with the existing components where possible, such as infrastructure, consumer devices and generators. Therefore, standardisation can ensure that these new technologies are compatible and can be used simultaneously.

Setting standards based on current technology ensures that innovation results in an actual improvement. It eliminates products that underperform and encourages consistency, ultimately leading to global markets and competitiveness. They are considered to be a repository of knowledge, making the information widely available for researchers and developers to use as a baseline for innovation.

Literature has highlighted that standardisation not only allows for the dissemination of knowledge within a particular domain but also between various domains, thus encouraging and catalysing innovation. The benefits of innovation are widely accepted and are evident throughout society. What is less known, is this synergistic relationship between innovation and standardisation, as standards allow research and new ideas to achieve their market potential. The goal with a smart grid is to integrate many different technologies into a single, over-arching system that is at once both complex and interoperable, which cannot be achieved without standardisation. Standards connect innovators, as they codify and diffuse knowledge, such as the current state of the art and best practice. This mediating function of standards is highlighted in literature as being one of the main advantages.[6] As the pace quickens to achieve a decarbonised society, standardisation will play a major role in ensuring that new technologies are developed in a timely manner, making the best use of available resources to create cohesive and secure systems.

3.1.2 Legal Definitions of Standards

Regulation 1025/2012 on European standardization [7] defines a 'standard' is 'a technical specification, adopted by a recognised standardisation body, for repeated or continuous application, with which compliance is not compulsory', and which is one of the following: international standard, European standard, harmonised standard or national standard.

'International standard' means a standard adopted by an international standardisation body, namely the International Organisation for Standardisation (ISO), the International Electrotechnical Commission (IEC) and the International Telecommunication Union (ITU).

'European standard' (EN) means a standard adopted by a European standardisation organisation (ESO), namely the European Committee for Standardization (CEN); the European Committee for Electrotechnical Standardization (CENELEC), the European Telecommunications Standards Institute (ETSI). In order to consider the inputs from different nations and to harmonise them in EU level standards ESOs bring together national standardization bodies.

'Harmonised standard' means a European standard adopted on the basis of a request made by the Commission for the application of Union harmonisation legislation. Manufacturers, other economic operators, or conformity assessment bodies can use harmonised standards to demonstrate that products, services, or processes comply with relevant EU legislation. The references of harmonised standards are published in the Official Journal of the European Union (OJEU). In the field of electric and electronic engineering harmonised standards are linked to Directives on electromagnetic compatibility, equipment for explosive atmospheres, low voltage, radio equipment and restriction of the use of certain hazardous substances.

'National standard' means a standard adopted by a national standardisation body. National standardisation bodies are published in OJEU and are listed in Table 2 below.

This table below can be seen as informative content to the platform within the Info base related to RCS.

Table 2: National standardisation organisations [8]

Country	***National standardisation organisation***	***Acronym***
Austria	Austrian Standards International - Standardization and Innovation Website: https://www.austrian-standards.at/en	ASI
Belgium	Bureau de Normalisation/Bureau voor Normalisatie Website: https://www.nbn.be/en	NBN
Bulgaria	Bulgarian Institute for Standardization Website: https://www.bds-bg.org/en	BDS
Croatia	Croatian Standards Institute Website: https://www.hzn.hr/default.aspx?id=435	HZN
Cyprus	Cyprus Organization for Standardisation Website: https://www.cys.org.cy/index.php	CYS
Czech Republic	Czech Office for Standards, Metrology and Testing Website: https://www.unmz.cz/en/home/	UNMZ
Denmark	Dansk Standard Website: https://www.ds.dk/da	DS
Estonia	Estonian Centre for Standardisation Website: https://www.evs.ee/en	EVS
Finland	Suomen Standardisoimisliitto r.y. Website: https://www.sfs.fi/	SFS
France	Association Française de Normalisation Website: https://www.afnor.org/en/	AFNOR
Germany	Deutsches Institut für Normung Website: https://www.din.de/en	DIN
Greece	National Quality Infrastructure System Website: http://www.elot.gr/default_en.aspx	NQIS/ELOT
Hungary	Hungarian Standards Institution	MSZT

	Website: http://www.mszt.hu/homepage	
Ireland	National Standards Authority of Ireland Website: https://www.nsai.ie/	NSAI
Italy	Ente Nazionale Italiano di Unificazione Website: https://www.uni.com/	UNI
Latvia	Latvian Standard Ltd. Website: https://www.lvs.lv/en	LVS
Lithuania	Lithuanian Standards Board Website: https://www.lsd.lt/	LST
Luxembourg	Organisme Luxembourgeois de Normalisation Website: https://portail-qualite.public.lu/fr.html	ILNAS
Malta	The Malta Competition and Consumer Affairs Authority Website: https://mccaa.org.mt/	MCCAA
Netherlands	Nederlands Normalisatie-instituut Website: https://www.nen.nl/Home_EN.htm	NEN
Poland	Polish Committee for Standardization Website: https://www.pkn.pl/en	PKN
Portugal	Instituto Português da Qualidade Website: http://www1.ipq.pt/PT/Pages/Homepage.aspx	IPQ
Romania	Romanian Standards Association Website: https://www.asro.ro/en/	ASRO
Slovakia	Slovak Office of Standards Metrology and Testing Website: https://www.unms.sk/?home	UNMS SR
Slovenia	Slovenian Institute for Standardization Website: https://www.sist.si/en	SIST
Spain	Asociación Española de Normalización Website: https://www.en.une.org/	UNE
Sweden	Swedish Institute for Standards – SIS Website: https://www.sis.se/en/	SIS

Another form of standardisation related activity are specifications (often called as 'open specifications'), these should not be confused with standards.

A **'technical specification'** is a specification developed by a non-profit making organisation which is a professional society, industry or trade association in an open, consensus-based and transparent process. It is not controlled by a single company or individual or by a group with discriminatory membership criteria. Technical specifications are publicly available for implementation and use on reasonable terms (including for a reasonable fee or free of charge) and can be implemented under reasonable and non-discriminatory licensing terms.

3.1.3 Standardisation in Practice - Case Study

Activation Energy, now Enel X, has been a pioneer in demand response in Ireland, focusing on the industrial and commercial industries. Activation Energy was responsible for the first demand-side unit in the Republic of Ireland. Not only does this method of demand response improve system stability, it also provides a steam of income for the commercial and industrial energy users. Activation Energy proposed a solution to the challenge of monitoring the equipment available for demand response. Monitoring equipment was installed for a sample of equipment and the data shared with EirGrid, considered to be representative of all other equipment. As a result, large quantities of new capacity were identified that could be used for demand response.

3.2 Standardisation Bodies and Relevant Committees/Working Groups

At European level standards in the sector of smart grids, storage and local energy systems which is the area of interest to PANTERA, are developed and agreed by three officially recognized European Standardisation Organizations (ESOs):

- the European Committee for Standardisation (CEN - www.cen.eu),
- the European Committee for Electrotechnical Standardisation (CENELEC - www.cenelec.eu)
- the European Telecommunications Standards Institute (ETSI - www.etsi.org).

In order to consider the inputs from different nations and to harmonise them in EU level standards, ESOs bring together national standardisation bodies.

3.2.1 CEN-CENELEC-ETSI

CEN supports standardisation activities in relation to a wide range of sectors and, starting from 2010 it has started to closely collaborate with CENELEC (responsible for standardisation in the electrotechnical engineering field) on several aspects. This collaboration was consolidated by the creation of a common CEN-CENELEC Management Centre (www.cencenelec.eu).

ETSI is a standardisation organization for the Information and Communications Technologies (ICT) sector and in some cases, it collaborates with CEN-CENELEC on subjects of mutual interest. Smart Grid and in general the energy system is one of this cases.

In the following some of the initiatives of these three European Standardisation organization that are relevant for the smart grid development are reported.

CEN-CENELEC-ETSI Coordination Groups on Smart Energy Grids (CG-SEG)
https://www.cencenelec.eu/standards/Topics/Smartgrid/Pages/Default.aspx

According to the CEN-CENELEC-ETSI definition, a smart grid is an electricity network that can integrate in a cost-efficient manner the behaviour and actions of all users connected to it (generators and/or consumers) in order to ensure economically efficient, sustainable power system with high levels of quality and security of supply and safety. Smart grids allow companies and households to produce electricity (for example – using photovoltaic panels or wind turbines) and sell it on to other consumers through existing networks.

The work of this Coordination Group started in 2011 when the European Commission and the EFTA European Free Trade Association (that gathers Iceland, Liechtenstein, Norway and Switzerland) issued the Smart Grid Mandate M/490. The three European Standards Organizations (ESOs) CEN, CENELEC and ETSI accepted the mandate and started to develop a framework for smart grids standardisation. It was therefore established the CEN-CENELEC-ETSI Smart Grid Coordination Group (SG-CG).

Different reports were produced by the SG-CG and in particular the "Reference Architecture" report aimed at providing a technical reference architecture for smart grids able to represent the functional information data flows between the main domains considering several systems and subsystems architectures. The proposed Smart Grids Architecture Model (SGAM) framework introduces interoperability aspects and how they are considered via a domain, zone and layer-based approach.

The work done by the Coordination Group on Smart Energy Grids (CG-SEG) continued with the purpose to follow-up on the standardisation gaps and to provide best practice examples on smart energy grid specific use cases in order to show the applicability of existing and upcoming standards. Importance was given also to security standardisation targeting generic standards that are further monitored and analysed with the focus on two specific use cases: decentralized energy resource (DER) and substation automation, aiming to identify the standardisation gaps to be covered.

In the recent past, the CG-SEG established the 'Clean Energy Package' working group to ensure that the European Standards Organizations support the implementation of the outcome of the EC proposals for new rules for consumer-centred clean energy transition – the Clean Energy for All Europeans package. In this context, the key legal propositions of the Clean Energy Package which are considered as most relevant for standardisation as well as an initial assessment of priority topics with possible implications on CG-SEG deliverables and work programme has been assessed.

All the material produced by the Coordination Groups on Smart Energy Grids can be found at the above-mentioned link.

CEN-CENELEC eMobility Coordination Group
https://www.cencenelec.eu/standards/Topics/eMobility/Pages/Default.aspx

In the future Electric Vehicles (EVs) are foreseen to be an important resource for Smart Grids. The ability of EVs batteries to store electric energy and to participate to the grid control through demand side management strategies make in fact EVs not only a load but an active device supporting the management and operation of the electrical system. Therefore, the standardisation of EVs and of the recharging infrastructures is crucial. International work on the development of standards in this field is ongoing, CEN-CENELEC set up a coordination group on electro-mobility in 2011 in order to foster the standardisation work in this field.

CEN-CENELEC-ETSI Smart Meters Coordination Group (SM-CG)
https://www.cencenelec.eu/standards/Topics/SmartMetering/Pages/Default.aspx

The Smart Meters Coordination Group (SM-CG) was established in 2009 in reply to an EC and EFTA mandate to the development of an open architecture for utility meters involving communication protocols enabling interoperability.

In the first phase CEN-CENELEC and ETSI produced a European standard for smart metering communications identifying the functional entities and interfaces that the communication standards should address. Whereas in a second phase the standardisation bodies focused on the development of European Standards containing harmonized solutions for additional functionalities within interoperable frameworks.

In the following years the Smart Meters Coordination Group worked especially on the aspects related to the data privacy and security for smart meters delivering different reports analysing security threats, minimum security requirements and certification schemes.

Currently the Smart Meters Coordination Group still gives inputs to the development and maintenance of new and existing standards for advanced metering infrastructures in support of the

European roll-out of Smart Meters.

CEN-CENELEC Smart House Coordination Group
https://www.cencenelec.eu/standards/Topics/Smarthouse/Pages/Default.aspx

In Smart Houses different products and equipment are used together to build a smart system allowing an intelligent and automatic management of the different houses appliances. In order to foster their deployment is very important that products for commands and controls from multiple suppliers adopt suitable interoperability standards and appropriate coordination schemes.

The work related to smart houses started in 2010 when the European Commission funded the Smart House Roadmap project to develop a strategic roadmap about Smart Houses and of all the services, applications, systems and networks associated with it and to promote future market growth. After the completion of this project the coordination of the standardisation activities related to Smart House were taken over by CENELEC technical committees and CEN/TC 294 in coordination with CLC/TC 205.

CEN-CENELEC Energy Management & Energy Efficiency
https://www.cencenelec.eu/standards/Topics/EnergyEfficiency/Pages/default.aspx

The Energy Management & Energy Efficiency sector forum is aimed to enable the participation of CEN and CENELEC members in the identification of standardisation needs with respect to energy management and to facilitate the coordination of the different bodies active in this field. The Sector Forum normally meets three times per year and in 2019 has organized the event Blockchain in the energy sector: challenges and opportunities.

3.2.2 International standardisation organizations

The ESOs (CEN, CENELEC and ETSI) closely collaborate also with international standardisation organizations to harmonize standards at global level, to avoid duplication of effort and to reach agreements on common standards that can be applied throughout the world, thereby facilitating international trade. The main intonational standardisation organizations relevant for the electricity domain are:

- the International Electrotechnical Commission (IEC - www.iec.ch)
- the International Organization for Standardisation (ISO - www.iso.org)
- the International Telecommunication Union (ITU - www.itu.int)

IEC - International Electrotechnical Commission

The IEC brings together 165 countries and offers a global platform to experts dealing with electrical technologies. IEC develops International Standards that cover all aspects of safety, interoperability, efficiency, electromagnetic compatibility and environmental impact needed to make business in the global market.

IEC covers a vast variety of electrotechnical technologies (e.g. generation, transmission and distribution of electricity, products and systems that use electricity, as well as their interoperability, environmental impact, performance and safety) dealing with standardisation and conformity assessment activities. Several technological sectors (website: *www.iec.ch/technology*) are covered by IEC and Smart grids are clearly addressed (website: *www.iec.ch/smartgrid*). Moreover, many other technological sectors addressed by IEC are related to the smart grid deployment such as energy efficiency, renewable energies, EMC, and cyber security.

IEC System work

The large range of technologies and their convergence into large scale infrastructure are changing the needs in the standardisation approach demanding a more top-down view starting at the system architecture level rather than at the product level. Moreover, system standards are increasingly required in different sectors. This is raising also the need of an enhanced collaboration between different standardisation organizations. To deal with these new challenges IEC have set up the following types of collaborative environments:

- Standardisation Evaluation Groups (SEG)
- Systems Committees (SyC)
- Systems Resource Groups (SRG)

Two Systems Committees are in the scope of Smart Grids, in particular:

- **IEC - SyC Smart Cities (electrotechnical aspects of Smart Cities)** that aims to foster the development of standards in the field of electro-technologies to help with the integration, interoperability and effectiveness of city systems
- **IEC - SyC Smart Energy** that aims to provide systems level standardisation, coordination and guidance in the areas of Smart Grid and Smart Energy, including interaction in the areas of Heat and Gas.

ISO - International Organization for Standardisation

The International Organization for Standardisation (ISO) is an international standardisation body composed of representatives from various national standards organizations that develop standards for a vast range of sectors.

In particular the standard ISO 17800:2017 “Facility smart grid information model“ (website: *www.iso.org/standard/71547.html*) provides the basis for common information exchange between control systems and end-use devices found in buildings and industrial facilities independently on the communication protocol in use.

ITU - International Telecommunication Union

ITU is an agency of the United Nations responsible for the sector of information and communication technologies. ITU coordinates the shared global use of the radio spectrum and promotes international cooperation in assigning satellite orbits.

ITU cooperates with the IEC contributing the communications-related aspects of Smart Grid and has established some Study Groups (e.g. study group 15, website: *www.itu.int/en/ITU-T/about/groups/Pages/sg15.aspx*) to deal with coordination and standardisation activities considering also Smart Grid aspects.

IEEE - Institute of Electrical and Electronics Engineers

The IEEE, in addition to journals and conference proceedings, publishes also standards that are produced by its standardisation committees.

In particular the IEEE has several standards applicable in the Smart Grid field, the comprehensive list of which is available at: *https://smartgrid.ieee.org/resources/standards* .

3.2.3 Alliances Active in the Smart Grid Domain

Different alliances are active in the Smart Grid field collecting the interest on several companies that agree on specific ways to enable interoperability of their devices. We report here a brief description of some of them.

OpenADR alliance

The OpenADR Alliance (website: *www.openadr.org*) was created in 2010 and it is led by North American research labs and companies. It aims to standardise, automate, and simplify Demand Response (DR) and Distributed Energy Resources (DER) to enable utilities and aggregators to cost-effectively manage growing energy demand & decentralised energy production, and customers to control their energy future.

Zigbee Alliance

Zigbee Alliance (website: *https://zigbeealliance.org/*) proposes a *specification* for a suite of high-level communication protocols (based on an *IEEE 802.15.4*) to create *personal area networks* with home devices. In this way it is possible to build interoperable products that monitor, control, inform and automate the delivery and use of energy and water in buildings.

OSGP Alliance

The OSGP Alliance (website: *https://osgp.org/*) is an association dedicated to promoting the adoption of the Open Smart Grid Protocol (OSGP) and infrastructure for smart grid applications. It has members from industry, utilities, hardware manufacturers, service providers and system integrators. OSGP is based on ETSI work and comprises:

- ETSI TS 104 001 Open Smart Grid Protocol
- ETSI TS 103 908 Power Line Telecommunications (PLT) BPSK Narrow Band Power Line Channel for Smart Metering Applications.

3.3 Review of Literature and Work Performed

3.3.1 STARGRID Project

STARGRID project - STandard Analysis supporting smart eneRgy GRID development project - is a collaborative coordination and support action funded by the European Commission (EC) under the 7th Framework programme, aiming at the provision of a comprehensive analysis of the current standardisation efforts, considering also new industry developments and initiatives in the field. The project focuses on three Smart Grid Topics: distributed energy resources (DER) integration and grid control, Demand response and customer energy management, and smart metering. The project was carried out by a consortium of five partners from four European countries and ran for two years (October 2012 - September 2014).

The main objectives of the project were:

- To provide a publicly available overview on Smart Grid standardisation;
- To gather requirements and reactions on standardisation initiatives and disseminate information on standards to stakeholders;
- To provide recommendations to politics and stakeholders;
- To support the large-scale deployment of smart grid technologies.

The main outcome for the project is recommendations on integrating Smart Grids in distribution networks and Smart Grid Standardisation Information tool. This tool provides information to the stakeholders on Smart Grid Standards and related documents, as well as organisations and committees active in the field. This includes the classical standardisation organisations on International and European levels, and also open industrial initiatives. The database does not contain any standards themselves, but provides a classification and meta-information and links to a download page or online shop wherever possible.

The web interface allows searching for either documents (standards and related publications) or institutions (organisations and committees). Within these two search classes, a free text search is supported, as well as filtering by a given set of categories: Standards inventories (IEC Roadmap, CEN-CENELEC-ETSI Set of Standards, Smart Grid Interoperability Panel (SGIP) Catalogue of Standards) and SGAM Domain, Zone or Interoperability Layer). By combining different categories, it is possible to narrow down the selection to the desired level. The STARGRID Smart Grid Standardisation tool is available online under the following link: *https://der-lab.net/services/servicesdatabases/* . The last update of the database was done in 2016.

The STARGRID deliverable 'Smart Grid Standardisation Documentation Map' [9] includes an overview of relevant standardisation bodies and committees and a list of standardisation documents classified by standard reference, title, issuing committee, topic and relevance.

The STARGRID final report 'Recommendations on Integrating Smart Grids in Distribution Networks' [10] provides six sets of recommendations with respect to Smart Grid standardisation and regulation, addressed to standardisation bodies, policy makers, regulatory authorities and Smart Grid stakeholders:

- provision of harmonised core regulations at national / local level;
- preparation of new standards and regulations for system integration;
- prioritisation of interoperability tests specifications in Smart Grids standards;
- augmentation of information and communication security and privacy;
- augmentation of the stakeholders' participation in the standardisation processes;
- harmonisation of the regulation and standardisation framework for DER interconnection rules.

3.3.2 IEC Smart Grid Standardisation Roadmap

Meanwhile, the first version of IEC Smart Grid Standardisation Roadmap dated 2010 [11] is publicly available; the newest version of 2017 [12] is treated as IEC Technical Report and is available for purchase. Additionally, IEC has published a Systems reference Deliverable on top priority standards development status in the domain of smart energy [13]; it is available for purchase.

The aim of the IEC Smart Grid Standardisation Roadmap is to draft a technology-oriented strategy which represents the standardisation requirements for Smart Grid. According to [14] Smart Grid is a term which embraces an enhancement of the power grid to accommodate the immediate challenges of today (such as the integration of distributed energy resources) and provides a vision for the future power.

The roadmap [14] presents an inventory of existing and future standards and puts them into perspective regarding the different Smart Grid applications:

- standards in relation with electrotechnics (planning the grid, integrating DER, coping with power electronics, coping with DC grids, and impact on the low voltage installations).
- standards related to communicating systems, divided into 19 sections: generation management systems, FACTS, energy management systems (EMS), blackout prevention systems, advanced distribution management systems (DMS), distribution automation (DA) systems, smart substation automation (SA) systems, distributed energy resources operation systems, advanced meter infrastructure (AMI), meter-related back office systems, market place systems, demand response and load management systems, home and building electronic systems/ building automation and control systems (HBES/BACS), industrial automation systems, electrical storage management systems, electric vehicle (EV) systems, weather forecast systems, asset management and condition monitoring systems, and microgrid systems.
- standards which cover cross-cutting areas such as communication, data modelling, cyber security, authentication, authorization, accounting, clock management, EMC, power quality and functional safety.

At the current stage, the focus remains on the Smart Grids. This means that the full Smart Energy scope has not been addressed yet (i.e., the consideration necessary to include the interactions with other energies such as gas and heat).

The list of IEC identified Smart Grid Standards created in 2010 is available online for download under the following link: https://www.iec.ch/smartgrid/standards/. The standards are categorised by importance in their relation to Smart Energy applications and solutions (core, high, medium and low) and by applications (AMI, Communication, DA, DER, DMS, EMS, EV, FACTS, HVDC, SA, Storage, Smart Home).

The core standards could be grouped into seven family standards:

- IEC/TR 62357: Service Oriented Architecture
- IEC 61970: Common Information Model (CIM) / Energy Management
- IEC 61850: Power Utility Automation
- IEC 61968: Common Information Model (CIM) / Distribution Management
- IEC 62351: Security
- IEC 62056: Data exchange for meter reading, tariff and load control
- IEC 61508: Functional Safety of electrical/electronic/programmable electronic safety-related systems.

3.3.3 IEC Smart Grid Standards map

The Smart Grid Standards Map is an online tool that allows the smart grid stakeholders to easily and instantly identify the standards that are needed for any part of the Smart Grid. The tool defines the relationship between components and standards of the Smart Grid. Figure 3 shows a screenshot for the Smart Grid Standards Map. The x-axis presents the smart grid architecture model (SGAM) domains, while the y-axis presents the SGAM zones. By clicking on component inside the cluster, one will have access to a list of standards that apply to the component. There is a short description provided for each standard, and by clicking on the standard, one will have access to the table of contents of the standard.

The Smart Grid Standards Map is available online under the following link: http://smartgridstandardsmap.com/

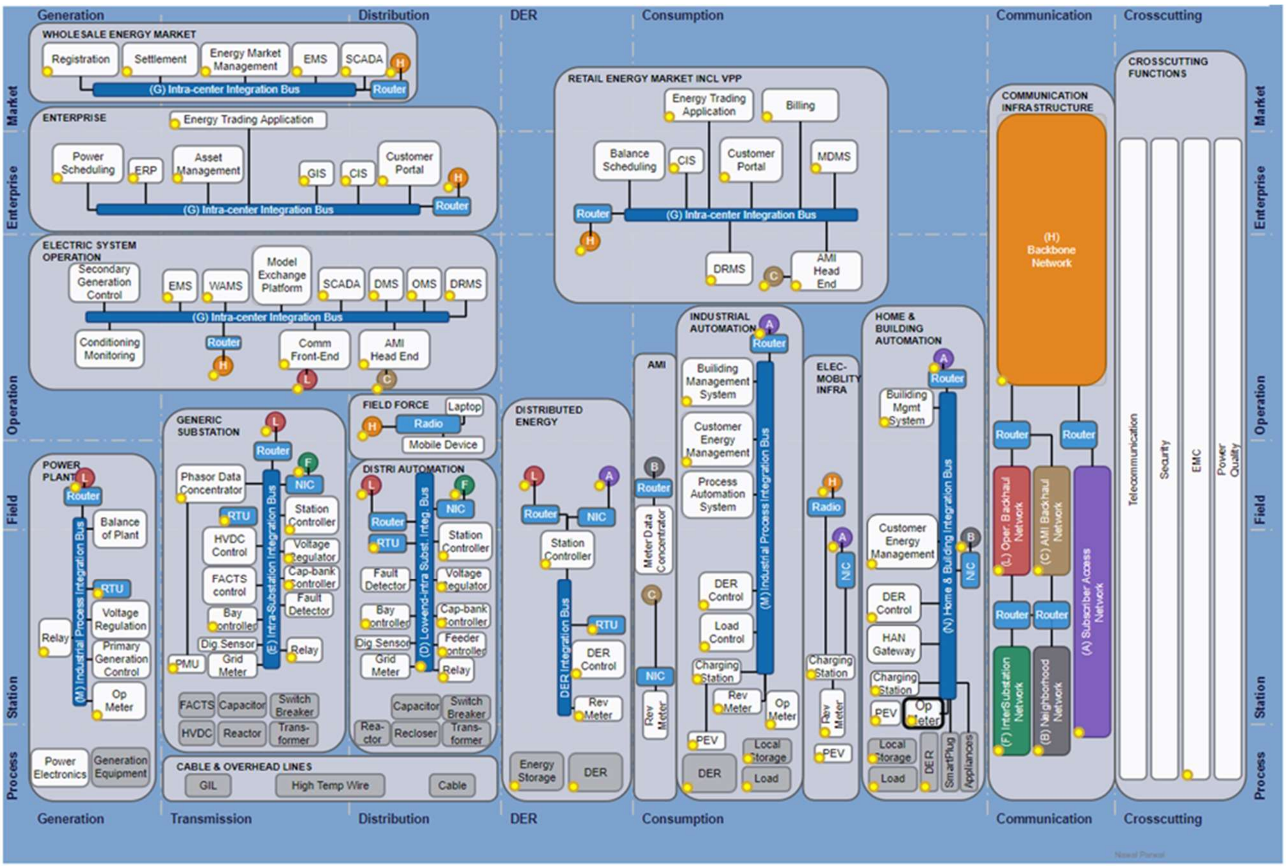

Figure 3: IEC Smart Grid standards map

3.3.4 CEN-CENELEC-ETSI Smart Grid Coordination Group Reports

Two main reports have been prepared by the CG-SEG:

Smart Grid Set of Standards report proposes a framework of standards which can support Smart Grids deployment in Europe based on CEN-CENELEC-ETSI experts' assessment. It provides a selection guide setting out, for the most common Smart Grid systems the relevant set of existing and upcoming standards to be considered, from CEN, CENELEC, ETSI and further from IEC, ISO, ITU or even coming from other bodies when needed. The latest publicly available version of the report was updated in early 2017.

Cyber Security & Privacy report includes monitoring of security standardisation specific to Smart Energy Grid and security standardisation targeting generic standards and analysis with the focus on two specific use cases: DER and substation automation. The report was produced in 2016.

Smart Grid Set of Standards report utilises standard classification approach based on standards mapping per systems which is somewhat similar to applications referred to in the IEC Standardisation roadmap.

The following systems are addressed in the report: generation management, transmission management (substation automation, blackout prevention – WAMPAC, EMS, FACTS), distribution management (substation automation, feeder automation, advanced DMS), DER operation including storage, smart metering (AMI and metering-related back office systems), demand and production flexibility (aggregated prosumers management), marketplace system (market places, trading systems), e-mobility, micro-grid, administration (asset and maintenance management, communication network management, clock reference, authentication, authorisation, accounting, device remote management and weather forecast and observation systems). Additionally, standards related to cross-cutting areas are presented: system approach, data modelling, communication, security, connection to the grid and installation of DER, EMC and power quality and functional safety.

One of the latest deliverables of CG-SEG is a Final Report of the Working Group Clean Energy Package, issued in 2019. The objective of this report is to assess and clarify relevant standardisation requirements resulting from the Clean Energy Package and provide recommendations for further work to CG-SEG and relevant standardisation committees, as well as provide input to the European Commission's Smart Grid Task Force (SGTF) and associated Expert Groups (EG): EG1 Interoperability requirements and procedures, EG2 Enhance capability and cooperation on cyber security and EG3 Deployment of demand response.

The main feedback on the Energy Efficiency Directive that CIM via IEC 61970 and IEC 61968 standards covers the possibility to evaluate the losses of the grid equipment by having a proper information model expressing the losses related to the grid. Nevertheless, further analysis on the methodology and standards methods to evaluate the losses are required. This has been put into action by asking CLC/TC 57 to check the information model expressing the losses related to the grid, aggregating information and reporting on grid performance indicators and asking CLC/TC 8 and TC 85 to evaluate the methodology used to evaluate the losses.

The main feedback on Energy Performance of buildings Directive that the Smart Readiness Indicators (SRI) should be checked whether they are well supported by standards or not. CLC/TC 205 (WG 18), CEN/TC 294 and TC13 will take an action to check it. As regards the Eco-design work plan, the EC and the Eco-Design Coordination Group of CEN/CENELEC need to clarify the requirements.

As a feedback on the renewable energy directive (RED), the standardisation should consider the different types of DER implemented in EU to address capacity market constraints and to provide adequate data models and services, e.g., to register a new DER including storage, grouping of DER. Furthermore, it was recommended to analyse the market information exchange for the complete chain from the market down to the device utilising the smart metering and CIM infrastructure.

The main feedback on the Electricity Market Directive (EMD) is that there is a need to develop new use cases, especially the use cases related to connecting smart building data to central platforms and switch aggregator. Furthermore, it was recommended to analyse the results of Horizon 2020 projects (EU SysFlex, Flexiciency) to identify missing standards based on identified system use cases. Regarding the dynamic electricity price contract for customers, it is recommended to analyse the complex model tariffs including all type of products available on energy market and the carbon dioxide emission monitoring.

3.3.5 DSO Priorities for Smart Grid Standardisation

The European standardisation organisations, the distribution companies represented by the EURELECTRIC and EDSO for Smart Grid have identified the major standardisation priorities for the distribution business and prepared a position paper on DSO priorities for Smart Grid Standardisation. This paper [15] summarised the DSO priorities for standards along the different smart grid functionalities and services. DSOs are already facing challenges related to an increasing share of intermittent and decentralised renewable generation. Given the impact this will have on the distribution network, technical standards related to connection and installations are of utmost importance for the distribution business.

In this position paper, EURELECTRIC and EDSO for Smart Grid focused on the following main application areas:

- Peak Demand Management
- DER integration and management
- EV integration and management
- Flexible load integration and management
- Power Quality management
- Grid Optimisation (Operation, maintenance and loss reduction)

The DSO priority clustering intends to cover, first, the improvement from ‘Business as usual’ to ‘Grid Optimisation’ including the right level of cyber security. In second step, a possibility is developed to use flexibilities connected to the distribution grid for further grid optimisation and for the market; in the second step, the DSO acts as a ‘market facilitator’.

3.3.6 Smart Electric Power Alliance

The Smart Electric Power Alliance (SEPA) is a non-profit organisation that envision a carbon-free energy system by 2050. SEPA produces the Catalogue of Standards (CoS) as a reference to the Electric Grid community with the intent of it serving as a useful resource for utilities, manufacturers, regulators, consumers and other Industry Grid Stakeholders. The Catalogue is a compendium of standards and practices considered to be relevant for the development and deployment of a robust, interoperable and secure Modern/Smart Grid.

Each standard listed in the Catalogue contains extensive information and has gone through a rigorous, multi-part review using objective criteria by industry experts. The Catalogue also provides a key, non-exclusive, source of input to the National Institute of Standards and Technology (NIST) process for coordinating the development of a framework of protocols and model standards for interoperable smart grid.

The list of standards in CoS and Navigation tool are available online under the following link:

https://sepapower.org/knowledge/catalog-of-standards/

Figure 4 illustrates how standards are classified in the CoS Navigation Tool.

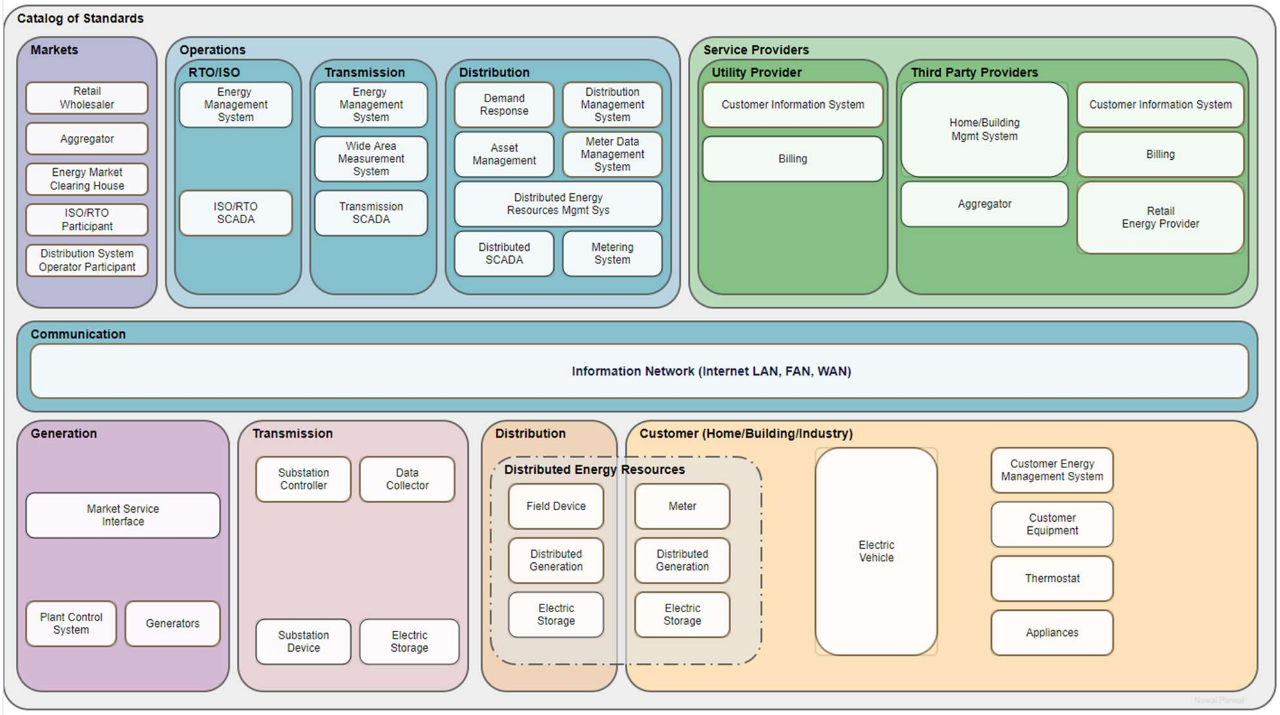

Figure 4: SEPA Catalogue of Standards

3.3.7 NIST Technical Note 2042

The National Institute of Standards and Technology (NIST) Smart Grid Program seeks to accelerate the development of conformity assessment or testing and certification (T&C) programs for smart grid interoperability standards to ensure that the implementations conform to the standards' requirements and therefore enhance interoperability of smart grid devices and systems. In 2018, the NIST prepared a document presenting a review of the current state of T&C for smart grid standards using a set of metrics developed from functional aspects of the standards – Technical Note 2042 'Review of Smart Grid Standards for Testing and Certification Landscape Analysis [16]. These functional metrics include information model mapping, communication protocol and protocol mapping, device physical performance, test methodologies, guidelines and best practices and cyber security. The NIST reviewed 240 individual standards from twenty-two standards development organisations covering more than thirty-four families of standards. The 240 smart grid standards analysed, were drawn primarily from three resources: The Smart Electric Power Alliance (SEPA) Catalogue of Standards (CoS), the 2014 release of NIST's Framework and Roadmap for Smart Grid Interoperability Standards Release 3.0, and the Union of the Electricity Industry (Eurelecric) and European Distribution System Operator (EDSO) priorities for Smart Grid Standardisation position paper.

The results showed that out of the 240 standards reviewed, 169 standards were found to be functionally related to interoperability and of those only a small percentage were found to have T&C programs of any form - either existing or planned. The review results showed important trends about the standards evaluated:

- Only 21% of 169 interoperability standards have independent T&C programs.
- There is no existing or planned path to device certification for the substantial majority of interoperability relevant smart grid standards.
- Physical performance standards are most likely to have T&C programs, but the substantial majority of those are not independent.

In appendix B of the NIST technical note 2042 document, there is a complete list of smart grid standards reviewed for T&C availability and functional categorisation. Standards are classified according to mentioned before functional metrics and linked to domains proposed by SEPA and illustrated in Figure 4 above.

3.4 Standards Search Methodology and Examples

Having reviewed ETIP-SNET functionalities as described in previous section and based on the obtained results accumulated in the Annex 6.4, it becomes possible to link standardisation committees of CEN, CENELEC, ETSI, IEC and ISO with ETIP-SNET functionalities. This exercise was performed for the most relevant committees where Smart Grid standardisation efforts are concentrated. The committees were mostly selected based on a STARGRID Smart Grid Standardisation Document Map [17], a EURELECTRIC/EDSO position paper on DSO priorities for Smart Grid standardisation [15] and CEN-CENELEC-ETSI Report of the Working Group Clean Energy Package [18]. The results are summarised in Table 3 and is a significant intermediate outcome as it links the functionalities and thus technologies with the relevant committees of the main standardisation bodies.

Table 3: Most important CEN, CENELEC, ETSI, IEC and ISO committees related to ETIP-SNET functionalities

IEC abbreviation	***CENELEC abbreviation***	***Title***	***Relevant Functionality***
IEC SyC Smart Energy		Smart Energy	F1, F2, F3, F4, F5, F6, F7, F8, F9, F10, F11, F12
IEC TC 8	CLC TC 8X	System aspects of electrical energy supply	F1, F2, F3, F4, F5, F6, F7, F8, F9, F10, F11, F12
IEC TC 8/SC 8A		Grid Integration of Renewable Energy Generation	F1, F2, F4 F5, F6, F7, F8, F9, F10, F11, F12,
IEC TC 8/SC 8B		Decentralized Electrical Energy Systems	F2, F3, F5, F6, F7, F8, F9, F10, F11
IEC TC 13	CLC TC 13	Electrical energy measurement and control	F1, F5, F6, F7, F8, F9, F10
IEC TC 22	CLC TC 22X	Power electronic systems and equipment	F1, F7, F9, F10
IEC SC 22F		Power electronics for electrical transmission and distribution systems	F1, F7, F9
IEC TC 23/SC 23H	CLC TC 23H	Plugs, Socket-outlets and Couplers for industrial and similar applications, and for Electric Vehicles	F2, F5, F8

IEC TC 23/SC 23K	CLC TC 23K	Electrical Energy Efficiency products	F5, F8, F10, F11
IEC TC 38	CLC TC 38	Instrument transformers	F1, F6, F7, F9, F10
IEC TC 57	CLC TC 57	Power systems management and associated information exchange	F1, F4, F6, F7, F8, F9, F10
IEC TC 65	CLC TC 65X	Industrial-process measurement, control and automation	F3, F6, F7, F10, F11
IEC TC 69	CLC TC 69X	Electrical power/energy transfer systems for electrically propelled road vehicles and industrial trucks	F2, F7, F10, F12
IEC TC 88	CLC TC 88	Wind energy generation systems	F4, F8,
IEC TC 95	CLC TC 95X	Measuring relays and protection equipment	F1, , F7,
IEC TC 115	CLC SR 115	High Voltage Direct Current (HVDC) transmission for DC voltages above 100 kV	, F7,
IEC PC 118		Smart grid user interface	F1, F2, F3, F4, F5, F6, F7, F8, F9, F10, F11, F12
IEC TC 120	CLC SR 120	Electrical Energy Storage (EES) Systems	F4, F5, F8F10, , F12,
IEC TC 122	CLC SR 122	UHV AC transmission systems	F1, F7
ISO abbreviation			
ISO TC 22/SC31		Road vehicles/Data communication	F2, F5, F6, F8, F9
ISO TC 265		Carbon dioxide capture, transportation, and geological storage	F2, F5, F6, F8, F10,
ISO TC 268		Sustainable cities and communities	F3, F11
ISO TC 301		Energy management and energy savings	F3, F11, F12
CEN/CENELEC abbreviation			
CEN/CENELEC JTC 14		Energy management and energy efficiency in the framework of energy transition	F3, F11, F12
CEN/CENELEC JTC 15		Energy management plan for organisations	F3, F11, F12
CEN abbreviation			
CEN TC 247		Building Automation, Controls and Building Management	F3, F6, F8, F10, F11
CEN TC 294		Communication systems for meters	F3, F6, F11
CEN TC 371		Energy Performance of Buildings project group	F3, F6, F8, F10 F11
Joint working group			
CEN/CENELEC/ ETSI SMCG		Coordination Group on Smart Meters	F1, F6, F7, F8

In the above table there is some information missing that is related to standards of very specific themes that can be characterised of cross curring nature. These, once R&I projects come across they should take specific care to identify explicitly prior to taking any appropriate decisions. For this reason, in the frame of the current report, these other somewhat related committees are summarised separately in Table 4.

For completeness, Table 4 can be used within the planned search tool of EIRIE as well. The only difference is that in this case there is not linkage with functionalities.

Table 4 Other relevant CEN, CENELEC, ETSI, IEC and ISO committees

IEC abbreviation	***CENELEC abbreviation***	***Title***
IEC SyC Smart Cities		Electrotechnical aspects of Smart Cities
IEC CISPR/I		Electromagnetic compatibility of information technology equipment, multimedia equipment and receivers
IEC TC 17		High-voltage switchgear and control gear
IEC TC 17/SC 17A	CLC TC 17AC	Switching devices
IEC TC 21	CLC TC 21X	Secondary cells and batteries
IEC TC 22/SC 22F		Stabilized power supplies
IEC TC 22/SC 22G		Adjustable speed electric drive systems incorporating semiconductor power converters
IEC TC 35	CLC SR 35	Primary cells and batteries
IEC TC 64	CLC TC 64	Electrical installations and protection against electric shock
IEC TC 65/SC 65B		Measurement and control devices
IEC TC 65/SC 65C		Industrial networks
IEC TC 65/SC 65E		Devices and integration in enterprise systems
IEC TC77		Electromagnetic compatibility
IEC TC 77/SC 77A		MC - Low frequency phenomena
IEC TC 77/SC 77B		High frequency phenomena
IEC TC 77/SC 77C		High power transient phenomena
IEC TC 82	CLC TC 82	Solar photovoltaic energy systems
IEC TC 105	CLC TC 105	Fuel cell technologies
IEC TC 114		Marine energy - Wave, tidal and other water current converters
IEC TC 117	CLC SR 117	Solar thermal electric plants
	CLC TC 205	Home and Building Electronic Systems (HBES)
	CLC TC 205A	Mains communicating systems
	CLC TC 210	Electromagnetic Compatibility (EMC)
	CLC WS 04	Interoperability framework requirements specification for services to the home (IFRS)
	CLC WS 05	Flow batteries - Requirements and test methods
ISO/IEC abbreviation		
ISO/IEC JTC 1		Information technology
ISO/IEC JTC 1/SC 6		Telecommunications and information exchange between systems
ISO/IEC JTC 1/SC 25		Interconnection of information technology equipment
ISO/IEC JTC 1/SC 27		Information security, cybersecurity and privacy protection

ISO/IEC JTC 1/SC 32	Data management and interchange
ISO/IEC JTC 1/SC 35	User interfaces
ISO/IEC JTC 1/SC 38	Cloud Computing and Distributed Platforms
ISO/IEC JTC 1/SC 41	Internet of things and related technologies
ISO/IEC JTC 1/SC 42	Artificial Intelligence
ISO abbreviation	
ISO TC 59/SC 17	Sustainability in buildings and civil engineering works
ISO TC 163	Thermal performance and energy use in the built environment
ISO TC 180	Solar energy
ISO TC 204	Intelligent transport systems
ISO TC 211	Geographic information/Geomatics
ISO TC 238	Solid biofuels
ISO TC 241	Road traffic safety management systems
ISO TC 241	Asset management
ISO TC 255	Biogas
ISO TC 300	Solid Recovered Fuels
ISO TC 307	Blockchain and distributed ledger technologies
CEN/CENELEC abbreviation	
CEN/CENELEC JTC 13	Cybersecurity and Data Protection
CEN/CENELEC JTC 17	Fuel Cell Gas Appliances with Combined Heat and Power
CEN/CENELEC JTC 19	Blockchain and Distributed Ledger Technologies
CEN TC 278	Intelligent transport systems
CEN abbreviation	
CEN TC 383	Sustainably produced biomass for energy applications
CEN TC 408	Natural gas and biomethane for use in transport and biomethane for injection in the natural gas grid
ETSI abbreviation	
ETSI ATTM	Access, Terminals, Transmission and Multiplexing
ETSI EE	Environmental Engineering
ETSI OEU	Industry Specification Group (ISG) on Operational energy Efficiency for Users
ETSI smartM2M	Smart Machine-to-Machine Communications
ETSI oneM2M	One Machine-to-Machine Partnership Project
ETSI cyber	Cyber Cybersecurity

Thereafter a standard search for F10 Flexibility was performed with the objective to validate proposed search methodology and have a possibility of evaluating a progress made over the past years in Smart Grid standards development. This methodology will be critical when identifying the R&I needs through the RICAP process and of course for the Replicability and Scalability indexes of each project.

F10 Flexibility was selected as it is the most demanding functionality covering all layers and being at the heart of Smart Grid. A search for standardisation documents (that included standards, technical reports (TR) and technical specifications (TS)) was performed within the CENELEC, IEC, ISO databases available on relevant bodies' web pages using the identified committees. As a result, a list including more than five hundred publications was generated, that includes publications currently in force and publications which are currently being developed and already have the identification number (standard reference).

The number of publications linked to F10 Flexibility and the fact that the resulting list includes all core Smart Grid standards as identified by IEC [19], prove that linking committees instead of standards itself is the right and efficient direction.

In order to validate the approach, a search using a carefully selected list of keywords was performed within CENELEC and IEC database. Keywords used for additional search were: smart grid, storage, distributed generation, interface, SCADA, platform, market, smart meter, microgrid, demand-response, aggregation, ancillary services, prosumer and forecasting. Only few publications that were not included at first were identified during the additional search by keywords, which proves that the proposed search methodology is effective and exhaustive.

One additional important finding that is supportive to the adapted methodology, is the fact that continuously ongoing work within the standardisation domain, shows that the family of standards tend to continuously grow or modified and utilizing the proposed methodology will always lead to the most update list of related standards.

The above procedure is an important step for providing the following outcome: the linking of the standards with the technologies through the functionalities and the committees. This is an outcome of substance for the EIRIE platform as each project by choosing the family of technologies that will serve can relate to the relevant family of standards. The responsibility of every project is to select from the family of standards generated through the surge the ones that are directly related to the development work targeted through the project. Following a similar procedure, the relevant family of regulations and codes can be identified.

3.5 Results

The review proved that all core standards have been modified and/or enhanced during the past three years (2018-2020). Additionally, completely new standards or standards parts have been developed or are being developed at the moment. In order to understand the scale of activities currently being carried out in the Smart Grid standardisation area, newly developed standards and parts of standards were extracted from the obtained database of F10 Flexibility related standards. The resulting list is presented in Table 5 (it does not include amendments of existing standards). While not pretending to be completely exhaustive, it includes all major developments in the field of Smart Grid standardisation and demonstrates that activities are taking place across multiple technical committees and thematic directions, including DER connection and management, electric vehicles, storage, microgrids, virtual power plants, prosumers' equipment, market communications and energy efficiency.

While storage, prosumer and demand response related issues are partially addressed within existing and planned standards, it appears that issues related to sector coupling are not covered at all at the moment and certainly could require more investigation and standardisation efforts.

Table 5 Newly developed standards and work in progress

Technical Committees	***EN reference***	***IEC reference***	***Title***
CLC/TC 8X	EN 50549-1:2019		Requirements for generating plants to be connected in parallel with distribution networks - Part 1: Connection to a LV distribution network - Generating plants up to and including Type B
CLC/TC 8X	EN 50549-2:2019		Requirements for generating plants to be connected in parallel with distribution networks - Part 2: Connection to a MV distribution network - Generating plants up to and including Type B
CLC/TC 8X	CLC/TS 50654-1:2020		HVDC Grid Systems and connected Converter Stations - Guideline and Parameter Lists for Functional Specifications - Part 1: Guidelines
CLC/TC 8X	CLC/TS 50654-2:2020		HVDC Grid Systems and connected Converter Stations - Guideline and Parameter Lists for Functional Specifications - Part 2: Parameter Lists
CLC/TC 8X / IEC TC 8/ SC 8B	prEN IEC 63189-1	prIEC 63189-1	Virtual Power Plants - Part 1: Architecture and Functional Requirements
IEC/TC 8/SC 8B		prIEC TS 63189-2	Virtual Power Plants- Part 2: Use Cases
IEC/TC 8		prIEC TS 62786-1	Distributed energy resources connection with the grid - Part 1: General requirements
IEC/TC 8		prIEC TS 62786-2	Distributed energy resources connection with the grid – Part 2 Additional requirements for PV generation
IEC/TC 8		prIEC TS 62786-3	Distributed energy resources connection with the grid – Part 3 Additional requirements for Stationary Battery Energy Storage System
IEC/TC 8		prIEC TS 62786-41	Distributed energy resources connection with the grid – Part 41 Requirements for frequency measurement used to control DER and loads
IEC/TC 8		prIEC TR 63282	Assessment of standard voltages and power quality requirements for LVDC distribution
IEC/TC 8/SC 8A		prIEC TR 63043	Renewable Energy Power Forecasting Technology
IEC/TC 8/SC 8A		prIEC TS 63102	Grid code compliance assessment methods for grid connection of wind and PV power plants
IEC/TC 8/SC 8B		IEC TS 62898-1:2017	Microgrids - Part 1: Guidelines for microgrid projects planning and specification
IEC/TC 8/SC 8B		IEC TS 62898-2:2018	Microgrids - Part 2: Guidelines for operation
IEC/TC 8/SC 8B		prIEC TS 62898-3-1	Microgrids - Part 3-1: Technical requirements - Protection and dynamic control
IEC/TC 8/SC 8B		prIEC TS 62898-3-2	Microgrids – Part 3-2: Technical requirements - Energy management systems
IEC/TC 8/SC 8B		prIEC TS 62898-3-3	Microgrids - Part 3-3: Technical requirements – Self-regulation of dispatchable loads
IEC/TC 8/SC 8B		prIEC TS 63276	Guideline for the hosting capacity evaluation of distribution networks for distributed generations
CLC/TC 13	CLC/TS 50586:2019		Open Smart Grid Protocol (OSGP)
CLC/TC 22X, IEC TC 22E	EN IEC 62909-1:2018	IEC 62909-1:2017	Bi-directional grid-connected power converters - Part 1: General requirements
CLC/TC 22X, IEC TC 22E	EN IEC 62909-2:2019	IEC 62909-2:2019	Bi-directional grid-connected power converters - Part 2: Interface of GCPC and distributed energy resources
IEC SC 22F		IEC TR 63262:2019	Performance of unified power flow controller (UPFC) in electric power systems

CLC/SR 23K, IEC/TC23 SC 23K	EN IEC 62962:2019	IEC 62962:2019	Particular requirements for load-shedding equipment (LSE)
CLC/SR 23K, IEC/TC23 SC 23K	prEN IEC 62991	prIEC 62991	Particular requirements for Source-Switching Equipment (SSE)
CLC/TC 57, IEC TC 57	EN IEC 62325-451-6:2018	IEC 62325-451-6:2018	Framework for energy market communications - Part 451-6: Publication of information on market, contextual and assembly models for European-style markets
CLC/TC 57, IEC TC 57	prEN IEC 62325-451-7:2020	prIEC 62325-451-7	Framework for energy market communications - Part 451-7: Balancing processes, contextual and assembly models for European style market
CLC/TC 57, IEC TC 57	prEN IEC 62325-451-8	prIEC 62325-451-8	Framework for energy market communications - Part 451-8: HVDC processes, contextual and assembly models for European style market
CLC/TC 57, IEC TC 57	prEN IEC 62325-451-10:2020	prIEC 62325-451-10	Framework for energy market communications - Part 451-10: Profiles for energy consumption data ("My Energy Data")
CLC/TC 64, IEC TC 64	HD 60364-8-2:2018	IEC 60364-8-2:2018	Low-voltage electrical installations - Part 8-2: Prosumer's low-voltage electrical installations
IEC TC 64		IEC 60364-8-1:2019	Low-voltage electrical installations - Part 8-1: Functional aspects - Energy efficiency
IEC TC 64		IEC 60364-8-1:2019/COR1:2019	Low-voltage electrical installations - Part 8-1: Functional aspects - Energy efficiency
IEC TC 64		IEC TS 60364-8-3:2020	Low-voltage electrical installations - Part 8-3 : Functional aspects - Operation of prosumer's electrical installations
CLC/TC 69X, IEC TC69	prEN IEC 63110-1:2020	prIEC 63110-1	Protocol for Management of Electric Vehicles charging and discharging infrastructures - Part 1: Basic Definitions, Use Cases and architecture
IEC TC 69		prIEC 63110-2	Protocol for Management of Electric Vehicles charging and discharging infrastructures - Part 2: Technical protocol specifications and requirements
IEC TC 69		prIEC 63110-3	Protocol for Management of Electric Vehicles charging and discharging infrastructures - Part 3: Requirements for conformance tests
CLC/TC 69X, IEC TC69	prEN IEC 63119-2	prIEC 63119-2	Information exchange for Electric Vehicle charging roaming service Part 2: Use cases
IEC TC 69		prIEC 63119-3	Information exchange for Electric Vehicle charging roaming service - Part 3: Message structure
IEC TC 69		prIEC 63119-4	Information exchange for Electric Vehicle charging roaming service - Part 4: Cybersecurity and information privacy
IEC TC 69		prIEC 63243	Interoperability and safety of dynamic wireless power transfer (WPT) for electric vehicles
IEC PC 118		IEC 62746-10-1:2018	Systems interface between customer energy management system and the power management system - Part 10-1: Open automated demand response
CLC/SR 118, IEC PC 118	EN IEC 62746-10-3:2018	IEC 62746-10-3:2018	Systems interface between customer energy management system and the power management system - Part 10-3: Open automated demand response - Adapting smart grid user interfaces to the IEC common information model
IEC PC 118		prIEC PAS	Systems interface between customer energy

		62746-10-1/FRAGF	management system and the power management system - Part 10-1: Open Automated Demand Response (OpenADR 2.0b Profile Specification)
IEC PC 118		IEC TS 62939-2:2018	Smart grid user interface - Part 2: Architecture and requirements
CLC/SR 120, IEC TC120	prEN IEC 62933-1	prIEC 62933-1	Electrical energy storage (EES) systems - Part 1: Vocabulary
CLC/SR 120, IEC TC120	EN IEC 62933-2-1:2018	IEC 62933-2-1:2017	Electrical energy storage (EES) systems - Part 2-1: Unit parameters and testing methods - General specification
IEC TC120		prIEC TS 62933-2-2	Unit parameters and testing methods – Applications and Performance testing
IEC TC120		prIEC TR 62933-2-200	Case study of EES Systems located in EV charging station with PV
IEC TC120		IEC TS 62933-3-1:2018	Electrical energy storage (EES) systems - Part 3-1: Planning and performance assessment of electrical energy storage systems - General specification
IEC TC120		prIEC TS 62933-3-2	Electric Energy Storage Systems: Part 3-2: Planning and performance assessment of electrical energy storage systems - Additional requirements for power intensive and for renewable energy sources integration related applications
IEC TC120		prIEC TS 62933-3-3	Electrical Energy Storage (EES) systems - Part 3-3: Planning and performance assessment of electrical energy storage systems - Additional requirements for energy intensive and backup power applications
IEC TC120		prIEC TR 62933-4-200	Electrical Energy Storage (EES) systems Part 4-200: Guidance on environmental issues - Greenhouse gas (GHG) emission reduction by electrical energy storage (EES) systems
IEC TC120		prIEC 62933-4-2	Electric Energy Storage System part4-2- environment impact assessment requirement for electrochemical based systems failure
IEC TC120		prIEC 62933-4-3	Electrical energy storage (EES) systems; part4-3: – The protection requirements of BESS according to the environmental conditions and location types
IEC TC120		prIEC 62933-4-4	Electrical energy storage (EES) systems- Part 4-4: Environmental requirements for BESS using reused batteries in various installations and aspects of life cycles
CLC/SR 120, IEC TC120	EN IEC 62933-5-2:2020	IEC 62933-5-2:2020	Electrical energy storage (EES) systems - Part 5-2: Safety requirements for grid-integrated EES systems - Electrochemical-based systems
IEC TC120		prIEC 62933-5-3	Electrical energy storage (EES) systems Part 5-3: Safety requirements for electrochemical based EES systems considering initially non-anticipated modifications - partial replacement, changing application, relocation and loading reused battery

To support the work performed within different TC and ensure systems level coordination, the Systems Committee Smart Energy (SyC Smart Energy) recently published multiple reports which might be of various Smart Grid stakeholder interest, including scientific community. Hence, it might be useful to include references/links to these documents in the EIRIE platform. These reports are available for purchase only; the titles and references are summarised in Table 6.

Table 6 Reports developed by SyC Smart Energy

Reference	***Title***
IEC TR 63097:2017	Smart grid standardization roadmap
IEC SRD 62913-1:2019	Generic smart grid requirements - Part 1: Specific application of the Use Case methodology for defining generic smart grid requirements according to the IEC systems approach
IEC SRD 62913-2-1:2019	Generic smart grid requirements - Part 2-1: Grid related domains
IEC SRD 62913-2-2:2019	Generic smart grid requirements - Part 2-2: Market related domain
IEC SRD 62913-2-3:2019	Generic smart grid requirements - Part 2-3: Resources connected to the grid domains
IEC SRD 62913-2-4:2019	Generic smart grid requirements - Part 2-4: Electric transportation related domain
IEC SRD 63199:2020	Top priority standards development status in the domain of smart energy
IEC Technology Report Cyber security:2019	Cyber security and resilience guidelines for the smart energy operational environment
prIEC TS 63200 ED1	System Reference Deliverable SRD: Definition of Extended SGAM Smart Energy Grid Reference Architecture
prIEC TS 63268 ED1	SRD: Energy and data interfaces of users connected to the smart grid with other smart grid stakeholders - Standardisation landscape

A complementary outcome of the standardisation review is related to the introduced in D3.2 PANTERA System/Technology classification (see Annex 6.3). A general recommendation is to extent the description of the of technology ‘Digitalisation, Communication and Data’ to include wider issues identified by the CEN-CENELEC-ETSI in Smart Grid Set of Standards report [20] as well: in addition to Digitalisation, Communication and Data to include issues related to cyber security, data privacy, social acceptance, and data modelling.

4 Review of European Regulations on Smart Grids

4.1 Legal Aspects and Definitions of Regulations

The European Union is based on the rule of law. Every action taken by the EU is based on treaties that have been approved democratically by its members. The objectives of the EU treaties are achieved through EU laws. These laws put EU policies into practice. There are two types of EU laws – primary and secondary.

Treaties are the starting point for EU law and are known as primary law. Treaties are the binding agreements between EU member countries and set EU objectives and rules. The body of law that comes from the principles and objectives of the treaties is known as secondary law. It includes regulations, directives, decisions, recommendations and opinions. Regulations, directives and decisions are binding legal instruments, whereas recommendations and opinions are non-binding instruments.

The European Commission defines regulations as 'the legal acts that apply automatically and uniformly to all EU countries as soon as they enter into force, without needing to be transposed into national law'. Regulations are binding in their entirety on all EU countries.

Directives are also legal acts that apply to all EU countries. The difference between regulations and directives is that directives require EU countries to achieve a certain result, but leave them free to choose how to do so. EU countries must adopt measures to transpose directives into national law in order to achieve the set objectives. National authorities must communicate these measures to the European Commission. There is a deadline to be respected for the transposition into national law (generally within 2 years from when the directive was adopted). If a country does not transpose a directive, the Commission may initiate infringement proceedings.

Decisions are EU laws relating to specific cases and concern individual or several Member States. They are binding upon those to whom they are addressed. Recommendations and opinions have no binding force and do not impose any legal obligation. Recommendations allow the EU institutions to make their views known and to suggest a line of action. Opinions allow the EU institutions to make a statement.

As for national level legislation, each Member State of the European Union has its own legal system. Member state law can consist of both law at the national level and law applicable only to a certain area, region or city in the Member State. EU countries publish their law in their official language(s) and it is legally binding only in this/these language(s). Certain acts of Member State law may be available in languages other than its official language(s) for information purposes. Many laws of the Member States implement EU law. This is the case for national law implementing EU directives.

The sources of Member States' law are various: the constitution, the statutes or legislation, the regulations by government agencies, etc. Member States' law is divided into private and public law. Private law (or civil law) governs the relationships between individuals or groups, whereas public law affects the relationship between individuals and the state, its entities and authorities.

National regulations consist of legal acts that are enforceable as law in an EU Member State. Due to differing legal systems and languages in Europe, these legal acts can have different forms and names (law, decree, order, binding precedent) and include jurisprudence. Dispositions that are not directed to all, not sanctioned or of a contractual nature are not considered as regulations. National regulations can be withdrawn or modified.

National regulations have to comply with EU harmonization legislation. If this is not the case, the European Commission has to solve the problem. It is the responsibility of EU institutions to monitor the implementation of EU harmonization legislation.

Each Member State is required to designate a single National Regulatory Authority (NRA) in order to ensure the independence of national energy regulators. NRAs are responsible for: fixing or approving the transmission and distribution tariffs or their methodology, enforcing the consumer protection provisions, issuing binding decisions on electricity undertakings and imposing effective, proportionate and dissuasive penalties.

The Council of European Energy Regulators (CEER) is a platform for cooperation, information exchange and assistance between Europe's national energy regulators and is their interface at EU and international level. The CEER works very closely with, and supports, the ACER. The main objective of CEER is to facilitate the creation of a single, competitive, efficient and sustainable internal market for gas and electricity in Europe.

Table 7 presents the National Regulatory Authority (NRA) of each EU Member State, as well as the corresponding national legal acts in the energy sector [21].

Again, this table can be included within the Info data base of the EIRIE platform along with the national standards committees table.

Table 7: National Regulatory Authorities

EU Member State	***National Regulatory Authority (NRA)***	***National legal acts in energy sector***
Austria	E-control https://www.e-control.at/en/	Regulations of the European Parliament and of the Council, Directives, Law (national), Decisions
Belgium	Commission for Electricity and Gas Regulation https://www.creg.be/en	Regulations of the European Parliament and of the Council, Directives, Recommendations, Decisions, Opinions
Bulgaria	Energy and Water Regulatory Commission https://www.dker.bg/en/home.html	Regulations of the European Parliament and of the Council, Directives, Laws (national), Resolutions
Croatia	Croatian Energy Regulatory Agency https://www.hera.hr/en/html/index.html	Regulations of the European Parliament and of the Council, Directives, Laws (national), Decisions
Cyprus	Cyprus Energy Regulatory Authority https://www.cera.org.cy/en-gb/home	Regulations of the European Parliament and of the Council, Directives, Law (national), Regulations (national), Orders, Rules of Electricity Supply, Transmission and Distribution Rules, Electricity Market Rules
Czech Republic	Energy Regulatory Office https://www.eru.cz/en/o-uradu	Regulations of the European Parliament and of the Council, Directives, Law (national)
Denmark	Energy Regulatory Authority https://ens.dk/en	Regulations of the European Parliament and of the Council, Directives, Law (national)
Estonia	Estonian Competition Authority https://erranet.org/member/eca-estonia/	Regulations of the European Parliament and of the Council, Directives, Law (national), Electricity Market Act
Finland	Energy Authority	Regulations of the European Parliament and

	https://energiavirasto.fi/en/frontpage	of the Council, Directives, Law (national)
France	Regulatory Commission of Energy https://www.ferc.gov/	Regulations of the European Parliament and of the Council, Directives, Laws (national), Orders, Decrees, Deliberations
Germany	Federal Network Agency https://www.bundesnetzagentur.de	Regulations of the European Parliament and of the Council, Directives, Energy Industry Act, Incentive regulation of gas and electricity network operators
Greece	Regulatory Authority for Energy http://www.rae.gr/old/en/	Regulations of the European Parliament and of the Council, Directives, Law (national), Regulations (national)
Hungary	Hungarian Energy Office https://www.gvh.hu	Regulations of the European Parliament and of the Council, Directives, Law (national)
Ireland	Commission for Regulation of Utilities https://www.cru.ie/	Regulations of the European Parliament and of the Council, Directives, Law (national)
Italy	Regulatory Authority for Electricity, Gas and Water https://arera.it/it/inglese/index.htm	Regulations of the European Parliament and of the Council, Directives, Laws (national), Regulations (national)
Latvia	Public Utilities Commission https://www.sprk.gov.lv/en	Regulations of the European Parliament and of the Council, Directives, Law (national), Regulations of the Minister Cabinet (national), Legal acts of regulator (national), ACER documents
Lithuania	National Control Commission for Prices and Energy https://www.regula.lt/en/Pages/default.aspx	Regulations of the European Parliament and of the Council, Directives, Laws (national), Regulations (national), Resolutions, Operating rules
Luxembourg	Luxembourger Regulatory Institute https://guichet.public.lu/fr.html	Regulations of the European Parliament and of the Council, Directives, Laws (national), Regulations (national)
Malta	Regulator for Energy and Water Services https://www.rews.org.mt/#/en/home	Regulations of the European Parliament and of the Council, Directives, Regulator For Energy and Water Services Act and Subsidiary Legislation, Regulations (national), Orders
The Netherlands	Authority for Consumers and Markets https://www.acm.nl/en	Regulations of the European Parliament and of the Council, Directives, Regulations (national), Decisions
Poland	Energy Regulatory Office https://www.ure.gov.pl/en	Regulations of the European Parliament and of the Council, Directives, Law (national)
Portugal	Regulatory Entity for Energy Services https://cms.law/en/int/	Regulations of the European Parliament and of the Council, Directives, Law (national)
Romania	Energy Regulatory Authority https://www.anre.ro/en/	Regulations of the European Parliament and of the Council, Directives, Law (national), Decisions, Orders
Slovakia	Regulatory Office for Network Industries http://www.urso.gov.sk/	Regulations of the European Parliament and of the Council, Directives, Laws (national), Acts, Ordinances of the Government
Slovenia	Energy Agency https://www.agen-rs.si/web/en	Regulations of the European Parliament and of the Council, Directives, Energy Act
Spain	National Commission for Markets and Competition https://www.cnmc.es/en	Regulations of the European Parliament and of the Council, Directives, Regulations (national), Decisions
Sweden	Energy Markets Inspectorate https://ei.se/en/	Regulations of the European Parliament and of the Council, Directives, Law (national)

Considering the above, it can be concluded that term ‘regulation’ might be interpreted in different ways: in a broader perspective it is treated as a law, in a narrower perspective as a type of EU legal act or on National level as a legal document issued by the NRA. In the frame of the current report regulation is treated from broader perspective and therefore a literature review is provided aiming at creating a common picture of European legislation in energy field. More detailed analysis is performed for European network codes and guidelines which all at the same time are the EU regulations.

4.2 Literature Review

4.2.1 Assessments of The Clean Energy for All Europeans Package

The Climate Action Tracker's (CAT) report on the key opportunities for transitioning to a zero emissions society for the EU [22] examines the potential to scale up climate action in different focus areas. The study identifies options for increased sectoral action that would move the EU towards a pathway compatible with the Paris Agreement's long-term temperature limit. More precisely, the report analyses areas where the EU could accelerate its climate action and illustrates the induced GHG emissions reductions. The study first makes a review of the European current policy framework and sectoral developments, and then focuses on three areas that have promising potential to increase mitigation efforts: electricity supply, residential buildings and passenger road and rail transport. Increasing climate action would initiate the transition towards a zero-emissions society, reduce reliance on energy imports, decrease air pollution and create additional employment.

As regards of electricity supply, the transition from fossil fuels towards renewables is crucial for the EU climate policy. Accelerated action on the electricity sector, as an enabler of decarbonisation in other sectors, would lead to a full decarbonisation of this sector by 2050. Strengthening the EU Emissions Trading Scheme (EU ETS), the adoption of the Renewable Energy Directive II (RED II) and the development of national policy in many EU Member States to phase out coal electricity generation, are steps leading to the achievement of this target.

As for the residential buildings, the EU needs to scale up action in this sector. Renovation rate is currently at around 1% and there are different Nearly Zero Emissions Buildings (NZEBs) standards for new buildings in different EU countries, as well as different depths of renovation. However, in order to be compatible with the Paris Agreement, the study estimates that renovation rates have to be increased to 5% annually, all new and renovated buildings have to be carbon neutral and water and space heating have to be fully electrified. The EU's Energy Performance of Buildings Directive from 2018 requires that all new and existing buildings are NZEBs. Nevertheless, the renovation rate of 3% suggested in the Directive is not sufficient to reach this target and the CAT's report considers it not to be compatible with the Paris Agreement.

The Eco-design Directive and the Energy Labelling Regulation could accelerate improvements in the energy efficiency of domestic appliances.

Regarding the passenger rail and road transport, the CAT's report estimates that in order to align with the Paris Agreement, the sector has to be almost fully electrified using low carbon electricity by 2040, with the last new internal combustion car sold before 2035. Decreasing costs of electric vehicles and Member States banning the sale of combustion cars will lead to reaching this target. However, the electrification of the transport sector has to be accompanied by full decarbonisation of the electricity sector. The adoption of the proposed Clean Vehicles Directive, which includes minimum targets for clean vehicle procurement in 2025 and 2030, will accelerate electrification of public transport. The EU should consider increasing the respective goals similarly to the upward revision clause in RED II. Increasing the share of public transport by implementing additional policies in Member States will also contribute to be in line with the Paris Agreement.

The CAT's scaling up climate action report confirms that the policies negotiated and adopted in the EU in 2018 are steps in the right direction. However, the EU has to make an upward revision of the renewable energy and energy efficient targets in 2023 in order to align with the Paris Agreement's 1.5°C limit. In addition, Member States have to transpose and implement the respective EU directives to reach and exceed those targets as the basis for the upward revision.

The article in [23] published by the Buildings Performance Institute Europe (BPIE) and the Regulatory Assistance Project (RAP) assesses the European Union's Energy Efficiency Policy and examines whether the Winter Package will deliver on the 'Efficiency First' principle. The Winter Package (or Clean Energy for All Europeans Package) is an energy legislation package that contains proposals for energy-related issues, such as: energy markets, energy infrastructure, renewable energy, climate policy and energy demand. The aim of the paper is to make a review of the proposals and explore how they are connected to energy efficiency. The EU adopted the 'Efficiency First' principle through the Energy Union Communication in 2015. The study assesses the extent to which the Winter Package puts energy efficiency first and analyses the following legislative acts: the revised Energy Efficiency Directive (EED), the Energy Performance of Buildings Directive (EPBD), the Directive on common rules for the Internal Energy Market for electricity (IEM), the Regulation on the electricity market, and the Regulation on Governance of the Energy Union. The paper shows that while there are many improvements across the different EU legislative acts, the Winter Package fails to comprehensively reflect the 'Efficiency First' principle. The study provides policy recommendations in order to better incorporate this principle into the proposed set of EU legislation. Two improvements proposed for the EED are to rectify the lack of clarity regarding additionality of building codes applying to new buildings and to link the current period with the new period. As for the EPBD, the study explains that the obligation to renovate public buildings is not directly aligned with the building renovation strategy. In order to make the Directive more effective, fundamental revisions are required for harmonizing the targets for buildings set out in the EPBD with the new 2030 framework. Regarding the Electricity Directive and Regulation, regulators must provide incentive frameworks and cost recovery for innovative measures to raise the energy efficiency of their networks. This could be a strong stimulus for investment in energy efficiency. DSOs are enabled to invest in energy efficiency but are not required to do so. Simply creating an enabling framework is unlikely to stimulate investment in energy efficiency. The Governance Regulation outlines the crucial role that energy efficiency must play in meeting the EU 2030 and 2050 targets. However, the Regulation reveals a striking gap between assessment and enforcement. It does not establish rules that would cause Member States, utilities and system operators to invest in efficiency where it is less expensive or more valuable than supply-side options.

Eurelectric's feedback on the RED II is established in [24]. Eurelectric outlines the necessity to adopt a coherent policy approach between the EU ETS and 2030 targets to ensure consistency between different policies and measures. The priority should be to leverage the revision of the RED II to support direct electrification in end-use sectors where fossil fuels remain the main fuel: transport, buildings and industry. Eurelectric draws attention to clean hydrogen, produced through decarbonised electricity. Along with other renewable gases, it will have a key role in decarbonising sectors where direct electrification is not possible. Thus, it will help bring the gap towards EU climate neutrality and zero pollution target. Eurelectric's feedback on transport and buildings indicates a further stimulation of the use of renewable electricity in these two sectors. Moreover, the review of RED II and the Energy Efficiency Directive should be consistent and conflicts between RES measures and energy efficiency measures should be avoided. Eurelectric's feedback suggests as well a market-based and competitive development of sustainable gases. Power-to-gas has not reached maturity yet. Therefore, Eurelectric does not support the introduction of sub-targets for renewable gas penetration. However, specific incentives should lift the penetration of renewable sources across all sectors. Decarbonised and renewable gases (electrolytic hydrogen, synthetic methane, biogas biomethane) should have a clear classification with relevant and simple definitions established by the EC in a consistent manner. The main criteria of this classification should be the emissions of the gaseous products over its whole lifecycle.

The briefing paper on the EU Winter Package presented in [25] explores the challenges and issues induced by the ambitious plan for EU's electricity market. The rapidly increasing share of RES in electricity generation, the more decentralised production and self-consumption call into question traditional electricity market models. A decentralised market creates new roles such as aggregators and prosumers, but at the same time EU's electricity market is better interlinked through interconnecting networks. The aim of the briefing paper is to outline some of the main challenges for specific actors in the energy value chain: generation, wholesale market, distribution, retail markets. Regarding generation, the paper identifies the following issues: ensuring long-term stability and predictability for investors in RES, defining the consequences of an eventual missing of the EU targets, opening up national support schemes, defining the legitimate role of capacity market mechanisms. As for wholesale markets, the paper lists the following challenges: identifying the role of Regional Operational Centres (ROCs) and the costs of regionalization, making regulatory decisions about the ROCs, integrating prosumers and demand response into the wholesale market. Concerning distribution, the examined issues are: incentives to innovate, DSO-TSO cooperation, a new DSO entity for electricity, DSO unbundling, storage and EV-charging networks, community networks. As for retail markets, the identified challenges are: achieving market-based retail prices, billing, data management, prosumers and aggregators.

4.2.2 Coal Regions in Transition

The report 'Just Transition or Just Talk' [26] published in May 2019 by Climate Action Network (CAN) Europe and Sandbag examines draft National Energy and Climate Plans (NECPs) and reveals that some EU countries are planning to stick with coal power beyond 2030. There are 21 Member States that are still using coal for electricity generation: 8 Member States have a clear commitment to phase out coal over the NECP period (2021-2030); 2 Member States will phase out coal, but not as an explicitly stated objective in their draft NECPs; 11 Member States do not plan to phase out coal by 2030, instead most of them show very little or no coal capacity decrease vs. 2019. By 2030, the vast majority of the EU's remaining coal power capacity will be located in just 6 Member States: Poland, Germany, Czech Republic, Bulgaria, Romania and Greece. Many of the Member States with no plans to move away from coal are already benefiting from various EU energy transition support schemes. The support and funding are reaching these countries, including through the EU Commission's Coal Regions in Transition Platform initiative. However, the draft NECPs show that in most of the benefitting countries the move away from coal has not yet been planned. EU countries need to stop burning coal for electricity by 2030 in order to fulfil the Paris Agreement and limit the global temperature rise to 1.5°C. Nevertheless, the report makes clear that the EU is currently set to miss this target by a wide margin.

The analysis suggests policy recommendations for the achievement of a coal-free EU electricity system by 2030. The EC must ensure that EU governments consider the quality of their draft NECPs, and make recommendations for the inevitable phase out of coal in an orderly manner. Climate laggards should not be tolerated. In addition, the EC must make sure that the provided EU support for the just transition in the coal regions is conditional. Member States receiving such a support must have credible energy transition commitments that are explicitly present in their NECPs. Another policy recommendation suggests that EU Member States should accelerate their coal phase out plans and move towards renewables-based energy systems. This will induce GHG emissions reductions and help meet the Paris Agreement targets. Furthermore, EU Member States should outline in their NECPs when and how they will develop and implement concrete just transition plans for their coal regions, as well as the corresponding funding needs. A timely and ambitious coal phase out is a crucial element of the path toward a net-zero carbon economy by 2050.

4.2.3 Discussion on The Trans-European Networks for Energy Regulation

The Trans-European Networks for Energy [27] (TEN-E) is a policy focused on connecting the energy infrastructure of EU Member States. The policy identifies nine priority corridors and three priority thematic areas. The EU supports countries in priority corridors and priority thematic areas and helps them to work together to develop better connected energy networks, while providing funding for new energy infrastructure. The nine priority corridors cover electricity, gas and oil infrastructure in different geographic regions. The support provided by the EU will connect regions currently isolated from European energy markets, strengthen existing cross-border interconnections and help integrate renewable energy. The three priority thematic areas include smart grids deployment, electricity highways and a cross-border carbon dioxide network.

The European Green Deal calls for a review of the TEN-E Regulation to ensure consistency with the climate neutrality objective. The infrastructure framework needs to be revised to reflect new policy developments such as the accelerated take-up of renewable energy sources and the smart sector integration, which links energy sectors to help them decrease carbon emissions.

The revision of the TEN-E guidelines has received numerous feedbacks from various European energy institutions. Central Europe Energy Partners [28] (CEEP) welcomes the initiative to review the TEN-E. According to CEEP, it is crucial to enable financing also for network development needed for RES integration, even if such network has limited cross-border relevance. As it may raise concerns due to the very large number of RES projects, the relevant threshold may be introduced. The current threshold for assessing cross-border relevance (500 MW) seems unjustifiably high and it may limit the possibility for DSOs' projects to obtain financing, as their levels of cross-border relevance are significantly lower than the TSOs' ones. Therefore, CEEP believes this threshold should be lowered. The feedback also suggests that gas projects remain within the scope of TEN-E, as gas is a stable and low emission source that can back up intermittent RES generation. Furthermore, the new TEN-E regulation should promote projects ensuring security of supply and market integration. The revision should also consider the need for greater flexibility of energy systems and digital services. CEEP proposes that the scope of TEN-E should be expanded to include: renewable gases, biogas, hydrogen and other low carbon gaseous fuels; undergrounding of electricity transmission lines; cybersecurity with cross-border projects; energy storage systems, particularly pumped storage plants; smart grids at all voltage levels; transborder RES projects, particularly offshore wind hubs; e-mobility and electrification of heating and cooling.

The ENSTO-E feedback [29] on the TEN-E revision suggests that there should be consistency between the TEN-E regulation and the design of new financial instruments under the EU taxonomy regulation to support financing of future projects in line with EU climate objectives. Furthermore, procurement rules and standards should be upgraded to increase EU attractiveness for technology providers and extend EU standards, solutions and know-how to other parts of the world. The new TEN-E regulation should bridge better R&I and Projects of Common Interest (PCIs), facilitate and leverage flexibilities through enabling new services at the TSO/DSO interface and the digitalization of networks. The revision should also provide a framework for the development and use of critical technological solutions (offshore hybrid connections, HVDC connections, digitalization, etc.), as well as innovation support for technologies for the grids of the future.

The Eurelectric feedback [30] on the TEN-E revision proposes to significantly increase the deployment of smart grids at all voltage levels in order to enable the integration of renewables and support the development of e-mobility and electrification of heating and cooling. The new regulation should ensure that only projects contributing to a carbon-neutral economy will be eligible as projects of common interest. Moreover, the reviewed TEN-E should be aligned with the European Green Deal, the revised Ten-Year Network Development Plan (TYNDP) and the EU financing instruments. The increased need for flexibility in the energy system provided by multiple sources should be considered in the new regulation. Synergies with other sectors, such as transport, digital, heating, cooling and industry, should be identified and developed. The level of ambition for the deployment of electric transmission and interconnectors projects, also including those in non-EU countries, should be maintained.

4.2.4 Review of Scientific Papers

Scientific articles related to European regulation on smart grids, electricity flexibility, energy storage and local energy systems have been reviewed. The articles selected as most relevant will be presented briefly in the following paragraphs.

European smart grid prospects, policies and challenges have been studied in [31]. The article focuses on the development of smart grids, the relevant European legislation and the difficulties faced by EU Member States, electricity networks and their stakeholders. The development of policies and technologies run in parallel. This is why smart grids are supported by the Union and the joint EU Energy and Climate Package. The EU, along with its agencies and commissions, has established directives and policies to promote smart grids among Member States. Smart grid innovation and implementation are stimulated by the need to generate electricity with low greenhouse gas emissions and from renewable and sustainable sources, as well as to ensure security, reliability and quality of electricity supply.

The document studies the EU policy drivers for smart grids. The smart grid electricity network is more flexible, reliable and assessable than the existing grid that has served well for years but is facing more and more challenges with the increased demand from consumers. The factors that determine the restructuring of existing grids into smart grids include climate change, depletion of fossil fuel, aging infrastructure of electricity network, and internal European energy market. The study suggests that the drivers for smart grid transactions are inspired by the EU Climate and Energy Package, energy policy goals and the Third Energy Package. The EU Climate and Energy Package is targeting increase in the use of renewable energy sources, decrease in the greenhouse gas emissions, and increase in the energy efficiency. The energy policy's main goals are to: develop a sustainable energy system, secure supply and competitiveness in the electricity market; integrate renewable energy sources at the generation and distribution sides; reduce CO_2 pollution. The EU Third Energy Package was adopted in 2009 and aims to cover security issues and actualize a single market for gas and electricity among members.

The assessment of the energy security, regulatory, and social and ethical aspects of smart grids in the EU has been presented in [32]. The article provides an analysis of smart grids in the EU as a solution to reach sustainable energy. The study represents a significant milestone in the upscaling of the various aspects of smart grid technology across the EU. Smart grid deployment and its impact on energy with a view to a more significant role of active consumers in the energy market are analysed in the document. Smart grid regulation is as well studied. The existing legal frameworks that impact smart grids in the EU are examined. Existing EU Directives are outlined and the level of implementation of these Directives in various EU Member States is assessed. The article also evaluates the extent to which the existing policies facilitate the development of smart grids and proposes areas of further regulatory consideration. The social and ethical dimension of smart grids in the context of collaborative economy, circular economy and digital technology is as well explored.

A study on market integration of local energy systems is proposed in [33]. Achieving the ambitious 2030 European climate targets depends on the market penetration of large- and small-scale renewable energy systems and on the deployment of energy efficiency measures and policies. The aim of the article is to examine the compatibility of local energy management with European regulation for retail competition. Many opportunities for local energy management are being created as a result of the growing penetration of distributed energy sources. The article defines local energy management as the coordination of decentralized energy supply, storage, transport, conversion and consumption within a given geographical area. Competition is concentrated at the wholesale level due to European electricity market liberalization. This is why local energy management at the distribution side is likely to create new roles and responsibilities for existing and new actors. The article studies the appropriateness of organizational models for flexibility management to guarantee retail competition and feasibility for upscaling. By using an analytical approach, three projects in the Netherlands and one in Germany have been examined. These four cases are real-life local energy management systems and their compatibility for flexibility management with the European electricity retail competition context has been analysed.

A study on aggregation of demand side flexibility in a smart grid is proposed in [34]. The increase in the share of electricity generation from renewable sources and the integration of distributed generation result in an increase in the need of flexibility of the electricity system. The article focuses on the potential of demand response which is one of the tools to increase this flexibility. In order to activate the full range of customers in the demand response, aggregators are needed. These aggregators are the new market intermediary actors whose role is to aggregate the resources in an adequate technical and economical format. Aggregators are flexibility providers supporting security of supply by taking into consideration network, generation and consumers constraints. However, aggregators are not self-emerging in many European Member States. This article’s main goal is to identify the barriers responsible for this lack of aggregators in Europe and to provide a policy review for European market designs that support aggregation. The document also presents case studies of existing aggregators in France and the United Kingdom in order to outline working solutions and projects.

Market and regulatory factors influencing smart grid investment in Europe are explored in [35]. In order to achieve energy policy goals, distribution system operators have to invest in system innovation and integration of smart grids. Consequently, regulatory reforms encouraging DSOs investments are a policy priority. The study is based on a review of the European regulatory status and uses a dataset of 459 innovative smart grid projects. The analysis focuses on market and regulatory factors and performs a series of statistical tests. The aim is to investigate how the different factor levels affect smart grid investments in Europe. The results show that there are three key enablers of smart grid investment. First, less concentrated distribution markets are expected to effectively induce investment-incentives for the implementation of smart grid pilot projects. Second, the analysis shows that regulatory schemes could sustain more incentive-based outputs and encourage smart grid investment and innovation. Third, the study provides evidence that the adoption of innovation-stimulus mechanisms by regulation is rather successful in promoting smart grid investments.

Policy recommendations for smart grid and energy storage are presented in [36]. Truly dynamic power grids require energy storage. This article defines energy storage as a distinct asset class within the electric grid system supported with effective regulatory and financial policies for development and deployment. Energy storage technologies create significant opportunities to further increase the efficiency and develop the operation of the grid. Energy storage has the ability to provide application-specific energy services across different components of the grid, which makes it the perfect solution for quick and effective respond to signals throughout the smart grid. The article provides a smart grid policy overview and explains the benefits of integrating renewables into the grid. The key role of energy storage within a smart grid is explored and its advantages are outlined. Storage requires investments and policy support. The article gives the following policy recommendations: research, development and demonstration policies will improve operational experience and reduce costs; investment tax credits will accelerate investment in storage projects; and continued market deregulation will increase revenue streams, enhance competition, and provide more accurate prices for storage services.

A study on flexible electricity generation, grid exchange and storage for the transition to a 100% renewable energy system in Europe is proposed in [37]. The article examines two scenarios towards 100% renewable energy power sector by 2050 in Europe. The simulations are done using the Lappeenranta University of Technology Energy System Transition model. The first scenario is a Regions scenario, where regions are modelled independently. The second one is an Area scenario, which has transmission interconnections between regions. The model uses hourly resolution for 5-year time intervals, from 2015 to 2050. Current capacities and ages of power plants are considered, as well as projected increases in future electricity demands. Results of the simulations show that the levelized cost of electricity could fall from 69 €/MWh to 56 €/MWh in the Regions scenario and 51 €/MWh in the Area scenario by adopting low cost, flexible renewable energy generation and energy storage. Increasing transmission interconnections can result in further savings by a factor of approximately four. Consequently, a further development of a European Energy Union can be achieved, one that provides clear governance at a European level, but proposes solutions for development that is appropriate for regional contexts. Given the assumptions used in this study, a 100% renewable energy system appears achievable for Europe by 2050. Such a system is economically competitive, technologically feasible and consistent with targets of the Paris Agreement. However, supportive policies at EU and local level must be further enhanced to reach this goal. The article suggests that cooperation between Member States of geographical closeness can result in benefits for all.

An overview of smart grid technologies can be found in [38]. The article describes smart grids as reliable and flexible intelligent systems, providing security of electricity supply. The study analyses the state-of-the-art of smart grids. Their technical aspect is examined, as well as management, security and optimization of smart grids. The article provides a brief overview of the EU regulatory framework involved in the development of a smart grid.

Particular studies of smart grids in Italy, Portugal and the United Kingdom are presented in [39]. The article describes the integration between the grid and both upstream and downstream elements. The improvement of communications among the elements has led to a more flexible and reliable structure: the smart grid. The study examines the evolution of EU policy related to the development of smart grids and the solutions to exploit their potential. The article describes and analyses what has been achieved by the regulators of Italy, Portugal and the United Kingdom. These three countries share the same goal but seek to reach it by distinct paths. It is showed how, in each case, policy is influenced by the characteristics of competition dynamics of their respective national electricity markets.

The article starts with a justification of the need for alternative solution and a definition of smart grids. The next part presents the main challenges and difficulties of implementation within an established network, introducing the role of the regulator. Data protection and cyber security are outlined as areas of concerns as the amount of sensitive customer information transmitted by the grid is important. The study lists smart grid initiatives at EU level (EU 7th Framework Programme, Horizon 2020, the European Electricity Grid Initiative, the Smart Grid Task Force, the EU energy infrastructure legislative package). The article finishes by presenting and analysing the three countries' experiences (Italy, Portugal and the United Kingdom). The three countries have different energy markets in terms of historical evolution, market size and competition characteristics, but have in common the fact that national energy policy and regulatory practice have explicitly promoted innovation in the 'smartening' of electricity grids. Italy's energy regulator's task is to protect the interests of consumers and to promote competition, efficiency and deployment of services with adequate levels of quality through regulation and control. Regulatory measures also address congestion management and losses, to which the regulator has granted additional remuneration for the cost of capital for a pre-specified time period. As for Portugal, the regulator has the task to protect consumers through appropriate pricing and quality of service, while assuring an adequate economic return to the regulated companies and promoting the internal energy market. The Portuguese approach to smart grid innovation is based exclusively on the potential benefits of the solution. The lack of competition in distribution (a single DSO covers all of continental Portugal) has required a more intrusive role for the regulator in terms of defining criteria, allocating incentives and measuring compliance. Concerning the United Kingdom, the entity responsible for the regulation of the sector is the Office of Gas and Electricity Markets. As an independent regulator, its attributions include the issuing, modification and enforcement of existing licenses as well as the setting of price controls for the TSOs and DSOs. The UK has a competitive market that has a large number of operators. Thus, the UK is making use of its flexible regulation mechanisms to create the necessary incentives for smart grid solutions.

The institutional challenges caused by the integration of renewable energy sources in the European electricity sector are outlined in [40]. Fundamental challenges to the operation and governance of the energy system appear when a large amount of variable renewable energy is integrated. The article first explains how the variable and unpredictable nature of wind and solar energy increases the demand for flexible resources. Potential sources of flexibility are as well discussed. Next, the paper examines the need for more flexibility which influences the market design of todays liberalized energy systems. The key areas where there is a need for a more integrated approach to research and policy making are explored. The need for such an approach is motivated by exposing a number of critical interdependencies between technical and institutional sub-systems.

The article identifies a number of key challenges, such as: the necessary reforms of short-term electricity markets, the coordination of energy trade and network management, the coordination of CO_2 policies with renewable energy policy and the international harmonization of energy policies. As for the integrated approach to research and policy making, it is not only a necessary condition for shaping the energy system of the future, but is a challenge in itself to develop such an approach. Consequently, in order to effectively guide the transition process, new modelling and decision-making tools need to be developed that can capture the complex interdependencies of a renewable sources based energy system.

Technology innovation system analysis of electricity smart metering in the EU is proposed in [41]. The penetration rate of electricity smart meters in the EU is currently growing and is expected to continue to increase. The rapid development of smart metering is progressing in a complex multi-actor innovation system which is strongly dependent on EU institutions and policies. The article lays down the comprehensive technology innovation system analysis of electricity smart metering development in the EU with a focus placed on regulatory aspects. The key elements of the smart metering innovation system, such as technologies and infrastructure, actors and networks, institutions and policies, are identified in this study. The paper characterizes the interaction of these elements based on a desk research and a critical assessment of regulations, statistics and market reports. The main enablers and barriers for smart metering development at EU level are examined. The major driving force for EU level smart metering technology innovation system is the clear and evolving vision of EU actors for the smart metering deployment founded on the grounds of energy conservation and empowerment of customers. On the other hand, the major barrier is an inadequate and insufficient regulatory framework for smart metering roll-outs, which does not fully ensure interoperability, data protection and security standards, a competition for the best solutions or organizational effectiveness of smart metering roll-outs at the national level. Several regulations (e.g., on auditing), financial instruments (e.g., tax reliefs or exemptions, GHG emission allowances trading scheme) and soft instruments are not effectively used, creating other important barriers for the smart metering technology innovation system development.

4.2.5 Summary

Considering all of the reviewed documents, reports and articles, it can be concluded that, while the establishment of many of the legal acts currently in force is a step in the right direction, there is still space for improvement and strengthening of EU policies. On the one hand, there are legislative packages, such as the Third Energy Package and the Clean Energy for All Europeans Package, which lay down EU's regulatory framework for the energy field. These packages consist of regulations and directives which impose the rules EU Member States have to follow in order to facilitate the transition towards cleaner energy and meet EU's Paris Agreement targets for decreasing greenhouse gas emissions. Moreover, the connection of the energy infrastructure of EU Member States laid down by the TEN-E policy contributes to achieving those goals. On the other hand, many policy recommendations for the improvement of EU's regulatory framework have been reviewed. Residential buildings, electricity supply and passenger road and rail transport are three areas that have promising potential to increase mitigation efforts.

Regarding residential buildings, the Energy Performance of Buildings Directive sets an insufficient renovation rate and it has to be increased in order to be compatible with the Paris Agreement. As for electricity supply, many EU countries are planning to stick with coal electricity generation beyond 2030. The European Commission must ensure that EU governments consider the quality of their NECPs and that the provided EU support for the just transition in the coal regions is conditional. Member States receiving such a support must have credible energy transition commitments that are explicitly present in their NECPs. As regards passenger road and rail transport, the electrification of the transport sector has to be accompanied by full decarbonisation of the electricity sector. Another gap in the current EU regulatory framework is that the revised Energy Efficiency Directive, the Energy Performance of Buildings Directive, the Directive on common rules for the Internal Energy Market for electricity, the Regulation on the electricity market, and the Regulation on Governance of the Energy Union fail to comprehensively reflect the ‘Efficiency First’ principle.

An important policy recommendation suggests that decarbonised and renewable gases should have a clear classification with relevant and simple definitions established by the EC in a consistent manner. The main criteria of this classification should be the emissions of the gaseous products over its whole lifecycle. Another valuable recommendation proposes that EU policies have to impose market designs that support aggregation. In addition, distribution system operators have to invest in system innovation and integration of smart grids. Consequently, regulatory reforms encouraging DSOs investments should be a policy priority. The EU should as well support energy storage development. Storage requires investments and the establishment of efficient legal acts. Research, development and demonstration policies will improve operational experience and reduce costs.

It is important to note that the European Green Deal calls for a review of the TEN-E Regulation to ensure consistency with the climate neutrality objective. In this context, many well-known organizations have given their position on the TEN-E revision. Some experts suggest that the threshold for assessing cross-border relevance for RES projects should be lowered. Moreover, the new TEN-E regulation should promote projects ensuring security of supply and market integration and consider the need for greater flexibility of energy systems and digital services. Other well-known organizations suggest that there should be consistency between the TEN-E regulation and the design of new financial instruments under the EU taxonomy regulation to support financing of future projects in line with EU climate objectives. In addition, the new regulation should ensure that only projects contributing to a carbon-neutral economy will be eligible as PCIs.

4.3 Legal and Practical Aspects of Network Codes and Guidelines

4.3.1 Definitions on Network Codes and Guidelines

In general, Network/Grid codes (NCs) are defined as the rules for the power system and energy market operation, to ensure the operational stability, security of supply and well-functioning of wholesale markets. These rules are usually drawn up nationally. Each country has its own transmission system operator (TSO), such as EirGrid in Ireland, who is responsible for the development and maintenance of the Grid Codes.

As electricity is increasingly interconnected between countries, such as in EU, who aims to establish European smart grid network and thus developing the EU-wide network rules to effectively manage these electricity flows for the EU’s internal energy market. The cross-border electricity networks are operated according to these EU-wide rules that help govern the work of network operators and determine how access to electricity is given to users across the EU countries. These rules are known as network codes (NCs) or guidelines (GLs) and are legally binding as ‘Regulations’ within the European Commission. NCs are not only useful in fully unbundled the power and energy markets. As technical rules, they regulate grid access and network user operation regardless of whether the power system is operated and supervised by a specific operator or by a vertically integrated utility.

Sometimes the new rules are adopted as GLs rather than NCs but they have the same status – they are both legally binding regulations. In general, NCs and GLs are rules to harmonise technical, operational and market rules governing the EU's electricity grids and gas networks, making an integrated EU internal energy market possible. The main practical difference is the work to be done during the implementation phase. In general, NCs are more detailed than GLs. The reason is that the GLs shift a larger share of the further development to the implementation phase, which can allow for more flexibility but can also slow down or complicate the overall process.

Though the EU’s internal energy market concept was adopted first under the ‘First Energy Package’ in 1996, the improved functional structure of the market with legal regulations was introduced in 2009 by the ‘Third Energy Package [42]. This Package consists of two Directives and three Regulations. Directive 2009/72/EC deals with the common rules for the internal market in electricity and Directive 2003/54/EC is for natural gas. Regulation (2009/714/EC [43]) defines the conditions for network access for cross-border electricity exchanges, whereas (2009/715) is for access to gas transmission networks. Regulation (2009/713) is for establishing an ACER. This legislation package also clearly defines the duties of national regulatory authorities (NRA), including cooperation with the ACER. It improves consumers' rights and provided a number of measures for the fully functioning and interconnected internal energy market. This internal energy market is also crucial for maintaining security of energy supply, increasing competitiveness and ensuring that all consumers can buy energy at affordable prices. It is to be noted that the Electricity Directive (2009/72/EC) will remain in force until the end of 2020. The simple EU regulatory framework (formation of regulation for NCs/GLs) is shown in Figure 5.

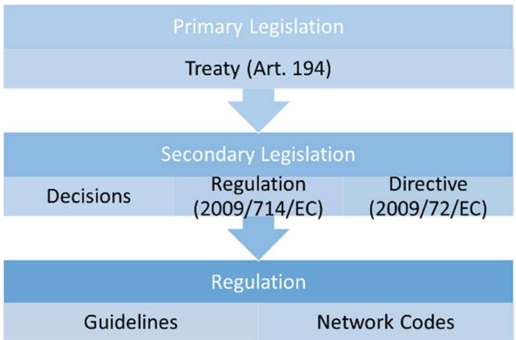

Figure 5 EU regulatory framework

Consumer is in the heart of energy transition and thus they should be able to participate in the energy market from any part of the network. Hence, in 2019, Fourth Energy Package (Clean Energy for All Europeans Package - CEP) is implemented where the new Electricity Directive 2019/944/EU (common rules for the internal market for electricity) and Regulation 2019/943/EU replace the old one Directive (2009/72/EC) and Regulation (2009/714/EC) respectively. This package also introduces new electricity market rules to meet the needs of clean energy from renewable energy sources (RES) and to attract investments. Besides updating the ACER roles, this package also forms the European entity for distribution system operators ('EU DSO Entity / EDSOs') and sets out the key roles for ENTSOs and for the EC to work in close cooperation with all relevant stakeholders on the development of network codes.

4.3.2 A Brief Description of the Legal Entities

ACER: The **European Union Agency for the Cooperation of Energy Regulators** (ACER) [44] was established in March 2011 by the Third Energy Package legislation as an independent body to foster the integration and completion of the European Internal Energy Market (IEM) both for electricity and natural gas. ACER is continuously working towards a single energy market to the benefit of all EU consumers. It ensures:

- a more competitive, integrated market, offering consumers more choice,
- an efficient energy infrastructure and networks, enabling energy to move freely across borders, the integration of renewable sources, and therefore ensuring a higher degree of security of supply,
- a monitored and transparent energy market guaranteeing consumers fair, cost-reflective prices and a limitation of market abusive behaviours.

ENTSO-E [45]: The **European Network of Transmission System Operators for Electricity**, represents 42 electricity transmission system operators (TSOs) from 35 countries across Europe. ENTSO-E was established and given legal mandates by the EU's Third Legislative Package for the Internal Energy Market in 2009, which aims at further liberalising the gas and electricity markets in the EU. In general, ENTSOs develop Ten Years Network Development Plan, Generation Adequacy, Network Codes and Methodologies. The Regulation 2009/714/EC[5] primarily defines the task of ENTSO-E in developing network codes in 12 areas. These are as follows;

i. network security and reliability rules including rules for technical transmission reserve capacity for operational network security;
ii. network connection rules;
iii. third-party access rules;
iv. data exchange and settlement rules;
v. interoperability rules;
vi. operational procedures in an emergency;
vii. capacity-allocation and congestion-management rules;
viii. rules for trading related to technical and operational provision of network access services and system balancing;
ix. transparency rules;
x. balancing rules including network-related reserve power rules;
xi. rules regarding harmonised transmission tariff structures including locational signals and inter-transmission system operator compensation rules; and
xii. energy efficiency regarding electricity networks.

ENTSO-E finally defines the overall network codes in three different categories, as shown in Figure 6. Some of the details are discussed in the following sub-sections.

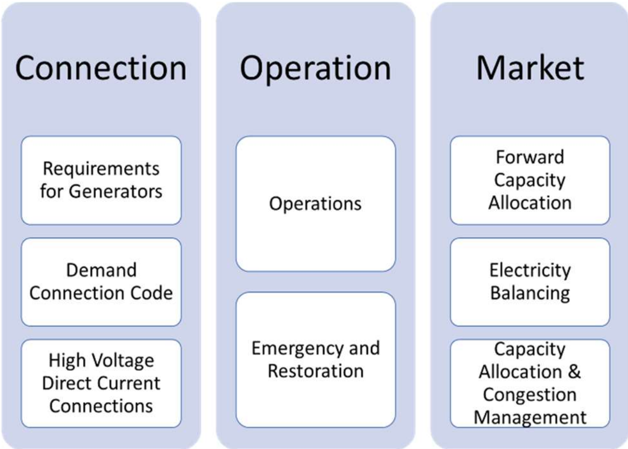

Figure 6 The Network Code Families (ENTSO-E)

ACER and ENTSO-E co-organise three European Stakeholder Committees (ESCs), one for each family of electricity codes (market codes, operational codes, and connection codes). They complement rather than replace legal obligations to consult and inform stakeholders during the implementation of electricity network codes.

EU DSO Entity [46]: A new association for the **European Distribution System Operators (EDSOs)**, has been formally established by the Electricity Regulation (2019/943/EU) under the CEP in order to increase efficiencies in the electricity distribution networks in the Union and to ensure close cooperation with TSOs and ENTSO-E. The EU DSO Entity will be fully set up by 1st quarter of 2021. The EU DSO entity will focus on technical issues and is assigned with tasks such as the development of Network Codes. Thus, it will be the only means of representation of the DSOs regarding the development of network codes and guidelines. The Entity aims at:

i. Reflecting the new central role of DSOs in the energy transition
ii. Strengthening the cooperation between DSOs
iii. Creating a forum of expertise and exchange of views between DSOs on a range of topics that relate to their business and the development of network codes
iv. Facilitating the DSO/TSO cooperation as well as the technical expertise dialogue with other stakeholders

ERF: **The Electricity Regulatory Forum (Florence Forum)** [47] was set up to discuss the creation of the internal electricity market. It is currently addressing cross-border trade of electricity, in particular the tarification of cross-border electricity exchanges and the management of scarce interconnection capacity. Participants include national regulatory authorities, EU countries' governments, the European Commission, transmission system operators, electricity traders, consumers, network users, and power exchanges. Since 1998 the forum has met once per year in Florence, Italy where they discuss the general update on network codes, development of new network codes and guidelines.

SGTF [48]: The **Smart grids task force** was set up in 2009 to advise on issues related to smart grid deployment and development. It is made up of stakeholder representatives from industry, regulators, consumer groups and the European Commission (EC). The task force is composed of five expert groups (EG) focusing on: (i) Standards for smart grids (EG1); (ii) Regulatory recommendations for privacy, data protection and cyber-security (EG2); (iii) Regulatory recommendations for smart grids deployment (EG3); (iv) Smart grid infrastructure deployment (EG4) and (v) Implementation of Smart Grid Industrial Policy (EG5). Their work shape EU smart grid policies and the policy framework. To boost the clean energy transition, in 2017, the EC also establishes stakeholder working group (Deployment of demand side flexibility) under the Smart Grids Task Force to prepare the ground for future EU action, for example through network codes, on:

- demand response, including aggregation;
- energy-specific cybersecurity rules; and
- data exchange and settlement rules.

NC IMG [49]: There is another forum, called "**Network Code Implementation and Monitoring Group** (NC IMG)" has also been created to maintain the high-level strategic coordination among the EC, the ACER, the ENTSO-E and ENTSO-G. The NC IMG oversees the implementation and monitoring of electricity network codes and gas network codes in the EU

4.3.3 Development of Network Codes and Guidelines

The process of developing network codes and the areas in which network codes can be developed are defined in Articles 58 and 59(1,2) of the Electricity Regulation (2009/714/EC). Besides the possibility to develop NCs, the EC can develop guidelines on its own initiative. To achieve the network decarbonisation and common energy market target by 2050, the EC can also establish an 'annual priority list' of areas to be included in the development of new NCs for electricity, with input from a public consultation [50]. The Commission then asks for input from the ACER and the ENTSO-E to adopt proposals for network codes. The proposals for network codes are then checked by an Electricity cross-border committee of specialists from national energy ministries and follow the procedure as mentioned in Figure 7 to adopt these as "Commission Regulation".

Figure 7 Formation of EC Regulation

In EU level, ENTSO-E plays a key role in drafting the electricity NCs/GLs. ENTSO-E also monitors the implementation of the NCs/GLs governing the electricity system, and to register and discuss suggestions to improve them, where necessary. The meaning of the established NCs/GLs and their regulatory information are given in Table 8.

Table 8: Established NCs/GLs and their regulatory information

NCs/GLs	***Meaning of Codes***	***Regulation***
Requirements for Generators	These are the codes for Generators in harmonising standards that generators must respect to connect to the grid. These harmonised standards across Europe will	REGULATION (EU) 2016/631

(RfG)	boost the market of generation technology and increase competitiveness.	
Demand Connection Code (DCC)	These codes set harmonised requirements for connecting large renewable energy production plants as well as demand response facilities. These will ease the integration of 260 gigawatts of photovoltaic & wind (almost tripling the current installed capacity in Europe) as well as 11 gigawatts of demand response in Europe (which could mean the sparing of 11 coal generation plants).	REGULATION (EU) 2016/1388
High Voltage Direct Current Connections (HVDC)	These codes specify the requirements for long distance direct current (DC) connections. These are used to link offshore wind parks to mainland or to connect countries over long distances (for example the longest existing interconnector in Europe, NorNed, links Norway and The Netherlands with an HVDC submarine cable of 580 km long).	REGULATION (EU) 2016/1447
Operations (SOGL)	The System Operation specifies what TSOs should do in managing their grid. The fact that the generation mix in Europe is integrating more and more renewables, that there is more and more interconnections and cross-border competition has been considered in the System Operation Guideline. It lays the ground for the next power system and for example makes regional coordination a legal obligation for grid operators.	REGULATION (EU) 2017/1485
Emergency and Restoration (ER)	These codes set-up the processes that the TSOs must follow when they face an incident on their grid. The highest standards and practice in dealing with emergency situations will thus apply in all Europe.	REGULATION (EU) 2017/2196
Forward Capacity Allocation (FCA)	These codes deal with rules for long term markets, the forward markets. These have an important role in allowing market participants to secure capacity on cross border lines a long time in advance and therefore have a sort of trade insurance.	REGULATION (EU) 2016/1719
Electricity Balancing (EB)	These codes are about creating a market where countries can share the resources used by their TSOs to make generation equal demand always. It is also about allowing new players such as demand response and renewables to take part in this market. All in all, the Balancing Guideline should help increase security of supply, limit emissions and diminish costs to customers.	REGULATION (EU) 2017/2195
Capacity Allocation &	These guidelines set out the methods for calculating how much space can market participants use on cross border	REGULATION (EU)

Congestion Management (CACM)	lines without endangering system security. It also harmonises how cross border markets operate in Europe to increase competitiveness but renewables' integration. CACM is the cornerstone of a European single market for electricity.	1222/2015

From the technical point of view, NCs define the technical requirements in the area of connection, operation and market of the power and energy network. For example, when it comes to the connection NCs, the requirements for generators NCs define the (i) voltage and frequency operation ranges, (ii) power quality, (iii) reactive power capability for voltage control, (iv) frequency support, (v) fault behaviour, (vi) active power management, (vii) protection etc. Details can be obtained from each regulatory document as mentioned in the table 6.1.

When it comes to the regional level, the Pan-European boundary/network is divided into five regional Groups [51] and these are (i) Continental Europe, (ii) Nordic, (iii) Baltic, (iv) Great Britain, and (v) Ireland-Northern Ireland. Each region may consider some additional aspects depending on the regional requirements. Regional NCs are also importance for some specific reasons. For example, NCs for renewable energy generators (under the requirement for generators NCs) depend on the overall renewable energy share of the interconnected system across several countries and cross-border electricity trading mechanism. Thus, the involvement of regional stakeholders is very important in the development process of regional NCs.

Similarly, at national level, NCs for generator connection requirement could vary from country to country and it may depend on the network condition, voltage level, generator capacity etc along with the national energy policy. Some common aspects of NCs in relation to RE connection at national level are outlined by IRENA [52]. The role of relevant stakeholders in developing national grid code are also given in Table 9.

Table 9: Roles of stakeholders in developing a grid code

Stakeholders	***Role in developing grid code***
Policy maker	Take decision to require grid code on the basis of country's energy policy and consultation with other stakeholders. The grid code is typically mandated by law.
Regulator	Responsible for ensuring a grid code is written. Approves the finalised grid code.
Network operator	Responsible for preliminary studies, grid code draft, consulting other stakeholders, finalising grid code and then implementing, enforcing and revising grid code.
Manufacturers Generator owners, installers, manufacturers, consumers	Consulted during development of grid code.

In general, all European NCs (adopted by ENTSO-E) do not replace regional or national NCs, instead they provide a common framework for NCs requirements and set minimal standards that all regional/national (within EU) NCs must meet. This allows the flexibility for regional/national NCs to set country-specific requirements. Responsible entities are also heavily involved in drafting and revising their NCs to avoid conflict.

4.3.4 Stakeholders Consultation Process

It is mentioned that the EC can take initiative to stablish new network codes based on annual priority list and ask for consultation from the relevant stakeholders. The very recent consultation was on the 'Priority list for the development of network codes and guidelines on electricity for the period 2020-2023 and on gas for 2020 (and beyond)' [53]. Commission has identified the two key areas where new proposals for developing harmonised rules/codes could be required: (i) Cybersecurity and (ii) Demand Side Flexibility. Smart Grids Task Force plays an important role here to identify these new areas.

ENTSO-E is mainly responsible to provide a response based on the stakeholders' input in the consultation document. Thus, in response to the stakeholders' input, ENTSO-E believes that the priority list for NCs for the next three years should focus on a new NC on Cybersecurity. [54] ENTSO-E recommends to first clarify the framework for drafting and submitting new NCs in cooperation between ENTSO-E and the EDSO Entity introduced by the CEP before moving forward with new regulation.

In terms of NCs for Demand side flexibility, even though ENTSO-E agrees that the current legal framework should be expanded to include topics such as demand side flexibility, it does not recommend the drafting of new Network Codes in this field, at least not until the existing NCs/GLs are completely implemented and a need for additional regulation has been identified and assessed in a transparent manner. In case a new Network Code on Demand Side Flexibility would be required, ENTSO-E deems it essential that the EDSO Entity is in place as well as the co-development process for Network Codes by ENTSO-E and EDSO Entity.

4.3.5 Network Codes in Practise – Case Study

As the new energy sources are increasingly integrated into power systems, the utilities should guarantee the stability of supply and a high level of power quality by maintaining a high level of standard through implementing the state-of-the-art and updated network codes. RESERVE project was a Pan-European project, which explored the solutions to pave the way towards the fully renewable-based electricity systems by researching new energy system concepts as new system support services. Such services enable distributed and multi-level control of the energy system. To implement the futuristic control schemes, the pan-European unified network connection codes needed to be revisited.

The results of RESERVE project include published models and mechanisms for implementing system support services and performance tests using pan-European real-time simulations. The feasibility of proposed solutions was also tested on a number of real-life distribution feeders in Ireland.

As a significant achievement, a series of pan-European unified network connection codes and actions were proposed to promote results to the related standardization organizations. Deliverables 3.8 [55] and 3.9 [56] of RESERVE project presented the updated Ancillary Services and Network codes definitions developed in WP3 of RESERVE project. These network codes and validations are related to the dynamic and static active voltage management of distributed energy resources, as the key enablers of European energy transition, in Medium Voltage and especially Low Voltage distribution networks. The trial network codes related to the technical aspects and ancillary services, ICT testing as well as the related simulation activities were reported in these deliverables of RESERVE project.

The power factor requirements and controllable operating range of different DER technologies were discussed and mathematically formulated. Additionally, the standard operating voltage conditions in different network codes were investigated. The concept of decentralized voltage control strategy using Volt-var curves was explained and discussed and a novel active voltage management using Volt-var optimization was presented, tested and standardized as a powerful tool in futuristic distribution networks. The description of how the ICT architectures proposed in RESERVE project were used to implement this active voltage management technique in the field and also the role of 5G in fulfilling the key requirements were also reported in [55] and [56]. The network codes and ancillary services definition arising from the Dynamic Voltage Stability Monitoring technique were defined and elaborated. A programmable impedance measurement device was proposed and developed in RESERVE. It was proposed that every grid connected household PV inverter should act as an impedance sensor allowing the grid operator to monitor and counteract instability.

The proposed models and network codes were tested on a relatively large number of LV distribution feeders in Ireland [57] through a collaboration between ESB Networks, which is the distribution system network operator of Ireland, University College Dublin (UCD), Telecommunications Software and Systems Group (TSSG) in Waterford and RWTH Aachen University. The aforementioned updated pan-European unified network connection codes were shared with the relevant organizations.

4.4 Network Codes and Guidelines supporting ETIP-SNET Functionalities

The ETIP SNET R&I roadmap [2] identifies R&I tasks towards energy transition, each task supports achievement of some Functionalities. Each task is to implement / develop technologies / systems to meet its targeted objectives and thus relate functionalities with technologies / systems advancements. Hence, the maturity of Functionalities builds through the implementation of the identified tasks that achieve targeted developments of technologies / systems' hence extend their maturity that eventually contribute to the maturity of system functionalities. The evolution of functionalities call for new or revised EU and national NCs/GLs.

In general, regulations are technologies/systems neutral. However, depending on the placement of technologies/systems in the network and for its specific ability to contribute to the maturity of Functionalities, EU/national regulations may need to be adjusted or enriched. Other way, it can be expressed as that in some cases present regulation or absence of regulation hinders the technology to demonstrate/deliver the specific Functionality. For example, regulation for energy storage connection behind the meter in LV network is not present for many countries and energy storage behind the meter also can't participate in retail market. In this case, certain storage technologies are matured to participate in different markets such as wholesale and ancillary services, but the ETIP SNET functionalities F5 Retail, F10 Flexibility will not reach its maximum level of maturity. Another example, recent stakeholder consultation process has identified that new EU NCs are required for cybersecurity and demand side flexibility. In that case as well, relevant technologies/systems may not be matured yet and ENTSO-E needs support from EDSO authority to develop the NC for demand side flexibility. This will certainly impact achieving the maturity of F1 Cooperation, F8 Business and

F10 Flexibility. These examples reflect how the regulations (NCs/GLs) are also supporting advancing of technologies and hence achieving matured Functionalities.

ENTSO-E has developed own R&I roadmap. In the previous roadmap [58] (2017-2026), ENTSO-E have clearly outlined how R&I activities complements the set of other mandated deliverables of ENTSO-E, such as, updating/developing new EU regulations (NCs/GLs) and the Ten-Year Network Development Plan (TYNDP). While TYNDP concentrates on ‘hardware’ issues (technologies/systems), regulation deals with ‘software’ (rule adaptations) issues. The R&I roadmap includes both the ‘hardware’ and the ‘software’ issues over a 10-year window. TYNDP discusses the technology that is mature and currently available. The regulations nurture harmonisation and adoption of best practices in a pan-European perspective. Each of these mandates makes an important contribution on the way to achieving Europe’s energy policy goals. Hence, it is very important for ETIP SNET as well, to adopt the maturity level of technologies/systems and Functionalities in the R&I roadmap and the implementation plan. As it is already discussed, achieving the maturity of technologies/systems and Functionalities is directed by the regulations, hence this roadmap should also consider the impact of regulations to the technologies/systems and Functionalities in future. Therefore, the full maturity can’t be achieved without linking the technologies/systems and Functionalities to regulations.

As a part of the project evaluation process to identify the maturity of Functionalities by 2030, ETIP SNET has already adopted the PANTERA proposed technologies/systems classification in ETIP SNET knowledge sharing platform. PANTERA team is also jointly working with ETIP SNET WG5 to develop the maturity index for technologies/systems and Functionalities. One of the purposes of this review is to identify the links of RCS to the ETIP SNET roadmap and be included within the EIRIE platform for wider use and benefit. The effort is also to align with the RICAP approach and to get a tangible outcome on R&I status (technology, regulations and policy) and gaps at EU level.

To identify the impact of regulations (NCs/GLs) on achieving the maturity of technologies/systems, this review points out that some NCs/GLs are directly linked to achieving the maturity of some of the technologies/systems (marked as **green** in Table 10), e.g., some NCs are directly linked to generators, HVDC, controlled loads, energy storage, etc. in supporting certain Functionalities. Therefore, such NCs are considered as fully relevant to these Functionalities (➡). Similarly, NCs/GLs are indirectly linked to some technologies/systems such as outage management, fault finding and associated equipment (including protection), equipment for sensing, monitoring, measuring for analysis, solutions and control, etc. to provide other Functionalities. Thus, these have been considered here as partly relevant (↱). Where NCs/GLs does not have any link to Functionalities and corresponding systems/technologies, these have been considered as not relevant (✖). Table 10 illustrates the details of this study and links.

Under the Grid Connection family there are three NCs/GLs (RfG, HVDC and DCC). One of the key features of this family is to minimize the cross-border impact by maintaining the same frequency-related requirements at all voltage levels and coordination of voltage ranges between interconnected systems, so that the stable operation of the grid can be achieved. The technical requirements (capacity, connection and operational boundaries) for the specific power generation technologies/systems under these regulations are clearly defined. The key points for each of these NCs/GLs are outlined in Table 10. Key technologies from every group related to each of the NCs/GLs are also identified which is followed by the identifying the relevance of NCs/GLs to the

Functionalities.

Table 10 Linking NCs/GLs with Technologies and Functionalities

	Grid Connection (NCs/GLs)			
		RfG	***HVDC***	***DCC***
Key Points		* generators operating synchronously and have permanent connection * requirements for different types of generators (A to D) and power park modules are defined. * connection point below 110kV * to ensure system security, generators remain connected to the network for specified frequency and voltage ranges. * impacts on TSO, DSO network and coordination are considered. * in general, combined CHP modules are not considered as generator. * there could have separate code for distribution network at national level, but coordination with national TSO is well-maintained.	* regulations for HVDC systems connecting synchronous areas or control areas, DC connected PPM, embedded HVDC systems within one control area * in general, connection point is above 110kV * consider TSO DSO robust coordination and regional specificities when establishing network connection. * technical requirements for stable connection, restoration and control capabilities are defined.	* requirements for connecting large renewable energy production plants as well as demand response facilities unless they provide demand response services to relevant system operators and relevant TSOs. * pump-storage station that only provides pumping mode shall also be treated as a demand facility. * technical capability to remain connected to the network and operating at the frequency ranges and time periods are defined.
	Relevant Key Technologies/Systems (PANTERA Technology Classification)			
Digitalization, Communication and Data	**Integrated Grid**	Flexible ac transmission systems (FACTS), Forecasting (RES), Asset	**HVDC,** Asset management, Models, Tools, Systems for the operation	Asset management, Outage management, fault finding and

		management, Outage management, fault finding and associated equipment (including protection), Equipment and apparatus of the integrated grid, Equipment, sensing, monitoring, measuring for analysis, solutions and control.	analysis, control and the development of the integrated grid including cost elements, Outage management, fault finding and associated equipment (including protection), Equipment, sensing, monitoring, measuring for analysis, solutions and control	associated equipment (including protection), Advance distributed load control, Smart metering infrastructure,
	Generation	**Solar including PV, Wind, Hydropower, Other Generation.**		
	Storage	**Storage Electric, Pumped Storage.**	Storage Electric [59]	**Storage Electric, Pumped storage**
	Customer & Market	Energy Communities, Electricity market.	Electricity market	Distributed flexibility, load management & control and demand response including end devices, communication infrastructure and systems, Smart appliances, Building control, automation and energy management systems, Electricity market
	Linking to Functionalities			
F1 Cooperation		➡	➡	➡
F2 Cross-Sector		✖	✖	✖
F3 Subsidiarity		✖	✖	↱

F4 Wholesale	↱	↱	↱
F5 Retail	↱	↱	↱
F6 Digitalisation	↱	↱	↱
F7 Electricity Systems and Networks	➡	➡	➡
F8 Business	↱	↱	↱
F9 Simulation	➡	➡	➡
F10 Flexibility	↱	↱	↱
F11 Heat & Cool	✖	✖	✖
F12 Transport	✖	✖	✖

	Operation (NCs/GLs)		
		SOGL	***ER***
Key Features		* rules on system operation for TSOs, DSOs and significant grid users (SGUs) * applies to all systems as defined under the RfG, HVDC and DCC. * defines the rules and responsibilities for the cooperation, coordination and data exchange among the TSOs, DSOs, and SGUs, in operational planning and in close to real-time operation, outage coordination, frequency curtailment and restoration reserve, adequacy control, ancillary services, scheduling between TSOs control areas.	* rules for the management and coordination of system operation across the Union in case of emergency, blackout and restoration states. * applies to all systems as defined under the RfG, HVCD and DCC * defines the demand disconnection criteria, system defence, restoration plan, information exchange and communication, tools and facilities
	Relevant Key Technologies (PANTERA Technology Classification)		
Digitalization, Communication and Data	**Integrated Grid**	FACTS, Models, Tools, Systems for the operation analysis, control and the development of the integrated grid including cost elements, Forecasting (RES), Asset management, Outage management, fault finding and	Same as SOGL

		associated equipment (including protection), Equipment, sensing, monitoring, measuring for analysis, solutions and control, Equipment and apparatus of the integrated grid, Feeder auto-restoration / self-healing	
	Generation	Systems under RfG, HVDC, DCC	Same as SOGL
	Storage	Systems under RfG, HVDC, DCC	Same as SOGL
	Customer & Market	Distributed flexibility, load management & control and demand response including end devices, communication infrastructure and systems,	Same as SOGL
	Linking to Functionalities		
F1 Cooperation		→	→
F2 Cross-Sector		✗	✗
F3 Subsidiarity		✗	✗
F4 Wholesale		↱	↱
F5 Retail		↱	↱
F6 Digitalisation		↱	↱
F7 Electricity Systems and Networks		→	→
F8 Business		↱	↱
F9 Simulation		→	→
F10 Flexibility		↱	↱
F11 Heat & Cool		✗	✗
F12 Transport		✗	✗

Market (NCs/GLs)			
	FCA	***EB***	***CACM***
Key	* rules on optimising the	* establishes technical,	* guidelines on

Features	calculation and allocation of long-term cross-zonal capacity in the forward markets, * towards the establishing a common methodology to determine long-term cross-zonal capacity, a single allocation platform at EU level offering long-term transmission rights for subsequent forward capacity allocation or transfer long-term transmission rights between market participants.	operational and market rules to govern the functioning of electricity balancing markets. * specifically, for the procurement and settlement of frequency containment reserves, restoration reserves and replacement reserves and a common methodology for the activation of frequency restoration reserves and replacement reserves. * ensures the optimal management and coordinated operation of the EU electricity transmission system, while supporting the achievement of the Union's RE penetration targets, as well as providing benefits for customers.	cross-zonal capacity allocation, congestion management and electricity trading in the day-ahead and intraday markets. * ensures optimal use of the transmission infrastructure; operational security; optimise the calculation and allocation of cross-zonal capacity.
Relevant Key Technologies (PANTERA Technology Classification)			
Integrated Grid	Models, Tools, Systems for the operation analysis, control and the development of the integrated grid including cost elements, Advance distributed load control, Smart metering infrastructure, Forecasting (RES), Equipment, sensing, monitoring, measuring for analysis, solutions and control	Same as SOGL	Models, Tools, Systems for the operation analysis, control and the development of the integrated grid including cost elements, Advance distributed load control, Smart metering infrastructure, Forecasting (RES), Equipment, sensing, monitoring, measuring for analysis, solutions and control
Generation	Same as SOGL	Same as SOGL	Same as SOGL

Storage	Same as SOGL	Same as SOGL	Same as SOGL
Customer & Market	**Distributed flexibility, load management & control and demand response including end devices, communication infrastructure and systems, Electricity market**	**Distributed flexibility, load management & control and demand response including end devices, communication infrastructure and systems, Building control, automation and energy management systems, Electricity market**	**Distributed flexibility, load management & control and demand response including end devices, communication infrastructure and systems, Electricity market**
ICT & Digitalisation	Same as SOGL	Same as SOGL	Same as SOGL
Linking to Functionalities			
F1 Cooperation	➡	➡	➡
F2 Cross-Sector	✖	✖	✖
F3 Subsidiarity	✖	✖	✖
F4 Wholesale	➡	➡	➡
F5 Retail	➡	➡	➡
F6 Digitalisation	↱	↱	↱
F7 Electricity Systems and Networks	➡	➡	➡
F8 Business	↱	↱	↱
F9 Simulation	➡	➡	➡
F10 Flexibility	↱	↱	↱
F11 Heat & Cool	✖	✖	✖
F12 Transport	✖	✖	✖

Main findings of the review are as follow:

- NCs/GLs under the grid connection and operation families are very much relevant to F1 Cooperation, F7 Electricity Systems and networks, F9 Simulation, partly relevant to F3

Subsidiarity (DCC), F4 Wholesale, F5 Retail, F6 Digitalisation, F8 Business, F10 Flexibility, and not relevant to F2 Cross-Sector, F11 Heating & Cooling and F12 Transport.

- NC/GLs under the market family are very much relevant to F1 Cooperation, F4 Wholesale, F5 Retail, F7 Electricity Systems and networks, F9 Simulation, partly relevant to F6 Digitalisation, F8 Business, F10 Flexibility and not relevant to F2 Cross-Sector, F3 Subsidiarity, F11 Heating & Cooling, F12 Transport.
- Existing NCs/GLs have clear gaps in accommodating the technologies and functionalities related to F2 Cross-Sector, F3 Subsidiarity, F11 Heating and Cooling and F12 Transport.
- As there is no contribution found yet from the EDSO entity on demand side flexibility, thus no new codes are available yet, hence the coordination between transmission and distribution network operators may need some more attention in the coming years.
- Cross sector/sector-coupling areas are less focused. None of the NCs/GLs have link with F2 Cross-Sector.

The very recently published ENTSO-E Research, Development & Innovation Roadmap 2020 – 2030 [60] has identified three major research, development and investment Areas/Clusters addressed by six Flagship projects, as shown in Figure 8 below.

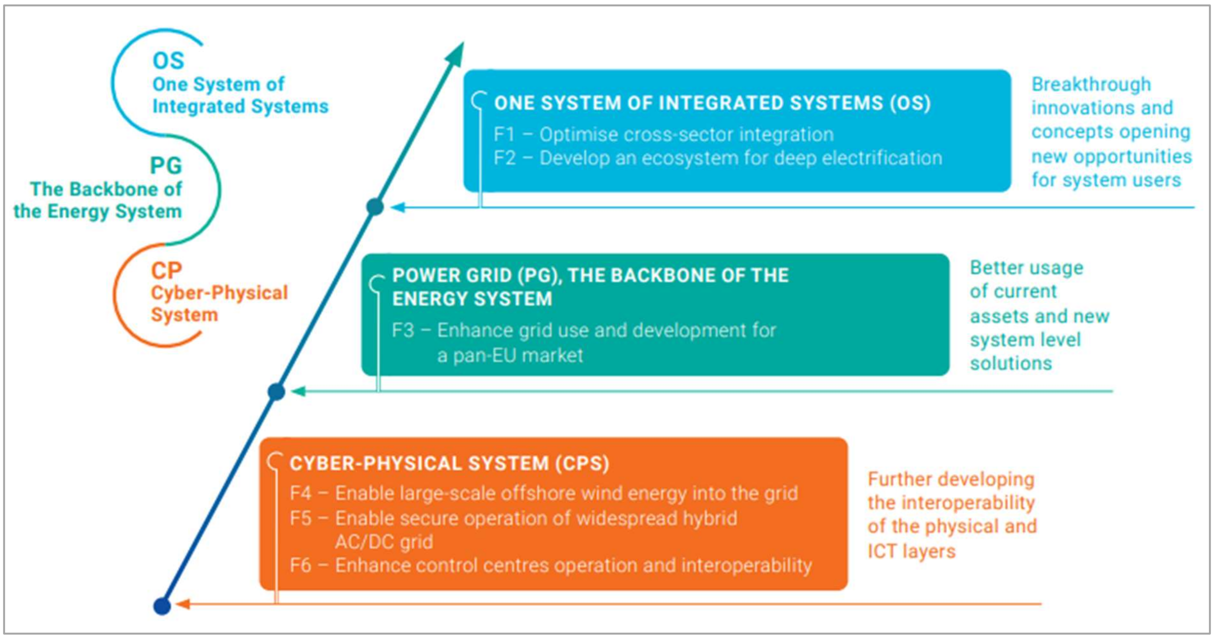

Figure 8 ENTSO-E R&I priority area and flagship projects *[60]*

This roadmap shows that the ENTSO-E R&I priorities (2020-2030) cover most of the missing links with the Functionalities of ETIP SNET. Such as activities related to Cluster 1 (One System of Integrated Systems) and Cluster 2 (Power Grid) will support to achieve the F1 Cooperation, F2 Cross-Sector, 11 Heating & Cooling and F12 Transport. Activities related to Cluster 3 (Cyber-Physical System) will assist to mature the F2 Cross-Sector, F3 Subsidiarity, F6 Business, F7 Electricity Systems and Networks and F10 Flexibility).

The advancement towards the integrated grid requires an update of the tools (hardware and software) that are required for power system and market operation and control. This includes development and validation of new technologies, protection schemes and the upgrade of power flow control tools. In this context controllability, stability, and reliability assessments of the integrated energy system including upgrade in regulations and NCs/GLs are of utmost importance. For example, as outlined in ENTSO-E new roadmap, TSOs will require new optimisation techniques to exploit the best new functionalities of hybrid systems (under Cluster Cyber-Physical System Flagship 5 Enable secure operation of widespread hybrid AC/DC grid). Hence, before 2025, consolidated and validated NCs/GLs updated with requirements for the DC side of grid forming converters are needed. The R&I activity within this cluster will define a new regulatory framework supporting to fully exploit the new ancillary services of grid forming converters, such as synthetic inertia response and fast frequency primary reserves. Thus, the new regulation will help to achieve the maturity of the technology and this finally help to achieve the maturity of F7 Electricity Systems and networks and F10 Flexibility.

5 Conclusions

RCS review is an inherent part of the PANTERA process contributing to the development of the EIRIE platform and supporting collaborative work with ETIP SNET and the steps of how related content will be populated is established through this report. The steps of how each technology / system / solution can be related with RCS is of critical importance for the R&I community and hence the EIRIE platform. This report covers this work and it is an important contribution to the RICAP process.

The report highlights the impact of standardisation on the acceleration of innovation and the importance of regulations in incentivising development and utilisation of technologies / systems / solutions enabling energy system transformation. Managing the resource giving the valued-on information on RCS is structured from the prism of ETIP SNET Functionalities to serve the needs of the EIRIE platform and provide substantial support to the R&I community through the search data tool of the EIRIE platform. Thus, a valuable contribution of the work reported through this deliverable is a developed methodology for identifying standards, regulations and codes related to selected Functionalities with the main steps identified as follows:

- Each project classifies itself under the technologies/systems/solutions that will advance within their time duration.
- Technologies /systems / solutions are linked with the functionalities through the EIRIE platform in an automated way.
- The projects are related to an exhaustive list of standard committees/standards, regulations and codes.
- Each project then can sort out the RCS of interest for the objectives that it serves and the technologies / systems / solutions that it advances.
- At the same time each project classifies itself against the SGAM model architecture and map the selected RCS.

The above is of critical importance as it offers substantial impact for:

- The data repository of the EIRIE platform. In this way, all technologies / systems / solutions and functionalities relate with the RCS and will be stored to be available for the R&I community.
- The RICAP process for assessing the maturity of the technology/system/solution and
- The BRIDGE process of Replicability and Scalability TF that defines scalability and

replicability indexes for each project for the advancements of the technologies /systems / solutions.

These outcomes are then fed to the data base of the EIRIE platform so that every member of the R&I community can have access.

A variety of topics considered relevant to Smart Grid by international standardisation organisations and areas covered by ETIP SNET 12 Functionalities along with the results of literature review emphasises a move from traditional definition of Smart Grids, as an electricity network that can cost efficiently integrate the behaviour and actions of all users connected to it [61], to provide a broader understanding of this term covering different aspects of the integrated energy system.

The overview of ETIP SNET Functionalities related to the business and functioning of an integrated energy system, and thus relevant to development of regulations, contribute significantly to all Functionalities. Relevant topics include technologies / systems / solutions linked to operation of coupled energy systems, market design for ancillary services, business models for promoting demand response and energy efficiency at end-user level, regulatory arrangements related to different aspects of storage operation and management, coordination between system operators and prosumer participation. The literature review illustrates that significant efforts have been made in regulation domain at European level. However, more changes are still needed in order to enable the true flexibility and sustainability of energy system. Hence, providing analysis of different incentives and best practise examples in regulation through the EIRIE platform and/or supportive PANTERA webinars could be useful for stakeholders, especially those from less active countries.

A lot of work is carried out also in the standardisation domain, focusing on interoperability issues. Developments in the field of Smart Grid standardisation are taking place across multiple technical committees and thematic directions, including DER connection and management, electric vehicles, storage, microgrids, prosumers' equipment, market communications and energy efficiency. Meanwhile, issues related to sector coupling are not covered in standardisation at the moment and are subject for coordinated work in the coming years. Similarly, this area is less addressed by regulation.

However, this report lays the foundations of a sound methodology / process of linking RCS to the functionalities of the 10-year plan of ETIP SNET and this will serve the R&I community in Europe for effective management of their projects in the direction of:

- Easily linking RCS to the research objectives of the project that are related to specific developments of technologies / systems.
- Enrich the methodology for evaluating the maturity index of functionalities through the effective link with technologies / systems
- Enrich the methodology for evaluating the scalability and replicability indices of projects through effective linking of RCS with the planned developments of technologies / systems.

References

[1] S. Khadem, L. Sanchez, C. Papadimitriou, V. Efthymiou, R. Stanev, A. Tsitsanis, P. Carroll, „Deliverable D3.1, Report on current status and progress in R&I activities: Technology”, [Online]. Available: https://pantera-platform.eu/wp-content/uploads/2020/07/D3.1-Report-on-current-status-and-progress-in-RI-activities-Technology.pdf [Accessed: 2020.08.03]

[2] ETIP-SNET, „ETIP SNET R&I Roadmap 2020-2030, June 2020”, [Online]. Available: https://www.etip-snet.eu/wp-content/uploads/2020/02/Roadmap-2020-2030_June-UPDT.pdf [Accessed: 2020.08.03]

[3] ETIP-SNET, “Vision 2050”, [Online]. Available: https://www.etip-snet.eu/wp-content/uploads/2018/06/VISION2050-DIGITALupdated.pdf [Accessed: 2020.08.03]

[4] CEN, CENELEC, „Work Programme 2020”, [Online]. Available: https://www.cencenelec.eu/News/Publications/Publications/CEN-CENELEC_WP_2020_EN.pdf [Accessed: 2020.08.03]

[5] K. Blind, „The Impact of Standardization and Standards on Innovation”, [Online]. Available: https://media.nesta.org.uk/documents/the_impact_of_standardization_and_standards_on_innovation.pdf [Accessed: 2020.08.03]

[6] ISO-CERN, „Standardization and innovation”, [Online]. Available: https://www.iso.org/files/live/sites/isoorg/files/store/en/PUB100404.pdf [Accessed: 2020.08.03]

[7] Official Journal of the European Union, „REGULATION (EU) No 1025/2012 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL”, [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012R1025&from=EN [Accessed: 2020.08.07]

[8] Official Journal of the European Union, „Publication of the list of national standardisation bodies pursuant to Article 27 of Regulation (EU) No 1025/2012 of the European Parliament and of the Council on European standardisation”, [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013XC0927(02)&from=EN [Accessed: 2020.08.07]

[9] I. Gómez, J.E. Rodríguez, E. Aghinii, S. Stomff, J. Jimeno, C. Nölle, „D2.1–SMART GRID STANDARDIZATION DOCUMENTATION MAP”, [Online]. Available: http://stargrid.eu/downloads/2013/11/STARGRID_WP2_D2.1_v1.3_20131108.pdf [Accessed: 2020.08.07]

[10] C. Nölle, D. Nestle, G. Franchioni, M. Calin, D. Dragomir, J.E. Rodríguez, „RECOMMENDATIONS FOR SMARTER DISTRIBUTION NETWORKS”, [Online]. Available: http://stargrid.eu/downloads/2016/11/STARGRID_REPORT_for-web.pdf [Accessed: 2020.08.07]

[11] SMB Smart Grid Strategic Group (SG3), „IEC Smart Grid Standardization Roadmap”, [Online]. Available: https://www.iec.ch/smartgrid/downloads/sg3_roadmap.pdf [Accessed: 2020.08.07]

[12] SyC Smart Energy, „IEC TR 63097:2017 Smart grid standardization roadmap”, [Online]. Available: https://webstore.iec.ch/publication/27785 [Accessed: 2020.08.07]

[13] SyC Smart Energy, „IEC SRD 63199:2020 Top priority standards development status in the domain of smart energy”, [Online]. Available: https://webstore.iec.ch/publication/62688 [Accessed: 2020.08.07]

[14] IEC, „IEC TR 63097 TECHNICAL REPORT", [Online]. Available: https://webstore.iec.ch/preview/info_iectr63097%7Bed1.0%7Den.pdf [Accessed: 2020.08.17]

[15] EURELECTRIC, EDSO for Smart Grid, „DSO PRIORITIES FOR SMART GRID STANDARDISATION", [Online]. Available: https://www.edsoforsmartgrids.eu/wp-content/uploads/public/DSO-Priorities-Smart-Gird-Standardisation.pdf [Accessed: 2020.08.17]

[16] E. Y. Song, C. Nguyen, A.Gopstein, „Review of Smart Grid Standards for Testing and Certification Landscape Analysis", [Online]. Available: https://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.2042.pdf [Accessed: 2020.08.17]

[17] I. Gómez, J.E. Rodríguez, S. Stomff, J. Jimeno, C. Nölle, „D2.1 –SMART GRID STANDARDIZATION DOCUMENTATION MAP", [Online]. Available: http://stargrid.eu/downloads/2013/07/STARGRID_Standardization_Documentation_Map_v1.0.pdf [Accessed: 2020.08.17]

[18] CEN, CENELEC, „Smart Grid", [Online]. Available: https://www.cencenelec.eu/standards/Topics/Smartgrid/Pages/Default.aspx [Accessed: 2020.08.17]

[19] IEC, „Core IEC Standards, Smart Grid", [Online]. Available: https://www.iec.ch/smartgrid/standards/ [Accessed: 2020.09.01]

[20] CEN, CENELEC, „Smart grids", [Online]. Available: https://www.cencenelec.eu/standards/Sectorsold/SustainableEnergy/SmartGrids/Pages/default.aspx [Accessed: 2020.09.01]

[21] European Commission, „National regulatory authorities", [Online]. Available: https://ec.europa.eu/energy/topics/markets-and-consumers/energy-consumer-rights/protecting-energy-consumers/national-regulatory-authorities_en [Accessed: 2020.09.01]

[22] Climate Action Tracker, „Scaling up climate action. Key opportunities for transitioning to a zero emissions society. FULL REPORT. EUROPEAN UNION", [Online]. Available: https://climateactiontracker.org/documents/505/CAT_2018-12-06_ScalingUp_EU_FullReport.pdf [Accessed: 2020.09.01]

[23] J. Rosenow, R. Cowart, E. Bayer, M. Fabbri, „Assessing the European Union's Energy Efficiency Policy: Will the Winter Package deliver on 'Efficiency First'?", [Online]. Available: http://bpie.eu/wp-content/uploads/2017/04/Assessing-the-EUs-EE-policy_BPIE_RAP.pdf [Accessed: 2020.09.01]

[24] Eurelectric, „Commission's call for feedback on the Renewable Energy Directive -RED", [Online]. Available: https://www.eurelectric.org/media/4697/eurelectric_feedback_to_red_ii_ia-2020-030-0563-01-e-h-8ECF23EE.pdf [Accessed: 2020.09.01]

[25] L. Hancher, B.M. Winters, „The EU Winter Package. Briefing Paper", [Online]. Available: https://fsr.eui.eu/wp-content/uploads/The-EU-Winter-Package.pdf [Accessed: 2020.09.01]

[26] J. Flisowska, C. Moore, „Just transition or just talk? Draft National Energy and Climate Plans reveal some EU countries are planning to stick with coal power beyond 2030", [Online]. Available: http://www.caneurope.org/docman/coal-phase-out/3545-just-transition-or-just-talk/file [Accessed: 2020.09.01]

[27] European Commission, „Trans-European Networks for Energy", [Online]. Available:

https://ec.europa.eu/energy/topics/infrastructure/trans-european-networks-energy_en [Accessed: 2020.09.01]

[28] CEEP, „CEEP feedback on the roadmap of the revision of Regulation on guidelines for trans-European energy infrastructure(TEN-E Regulation)", [Online]. Available: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12382-Revision-of-the-guidelines-for-trans-European-Energy-infrastructure/F524396 [Accessed: 2020.09.08]

[29] ENTSO-E, „ENTSO-E Response to the EC consultation on TEN-E Regulation review", [Online]. Available: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12382-Revision-of-the-guidelines-for-trans-European-Energy-infrastructure/F524377 [Accessed: 2020.09.08]

[30] Eurelectric, „10 Key Points for a Revised Trans-European Energy (TEN-E) Regulation", [Online]. Available: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12382-Revision-of-the-guidelines-for-trans-European-Energy-infrastructure/F523801 [Accessed: 2020.09.08]

[31] N. IqtiyaniIlham, M. Hasanuzzaman, M. Hosenuzzaman, „European smart grid prospects, policies, and challenges", [Online]. Available: https://fardapaper.ir/mohavaha/uploads/2017/10/32231-1.pdf [Accessed: 2020.09.08]

[32] R. Leal-Arcas, F. Lasniewska, F. Proedrou, „Smart grids in the European Union: Assessing energy security, regulation & social and ethical considerations", [Online]. Available: https://eprints.soas.ac.uk/25074/1/lesniewska-SSRN-id3062957.pdf [Accessed: 2020.09.08]

[33] C. Eid, L.A. Bollinger, B. Koirala, D. Scholten, E. Facchinetti, J. Lilliestam, R. Hakvoort, „Market integration of local energy systems: Is local energy management compatible with European regulation for retail competition?", [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0360544216311859 [Accessed: 2020.09.08]

[34] C. Eid, P. Codani, Y. Chen, Y. Perez, R. Hakvoort, „Aggregation of demand side flexibility in a smart grid: A review for European market design", [Online]. Available: https://hal-centralesupelec.archives-ouvertes.fr/hal-01266912/document [Accessed: 2020.09.08]

[35] C. Cambini, A. Meletiou, E. Bompard, M. Masera, „Market and regulatory factors influencing smart-grid investment in Europe: Evidence from pilot projects and implications for reform", [Online]. Available: https://www.sciencedirect.com/science/article/pii/S095717871630073X [Accessed: 2020.09.08]

[36] K.K. Zame, C.A. Brehm, A.T. Nitica, C.L. Richard, G.D. Schweitzer III, „Smart grid and energy storage: Policy recommendations", [Online]. Available: https://fardapaper.ir/mohavaha/uploads/2017/09/32322615645945615 2459.pdf [Accessed: 2020.09.08]

[37] M. Child, C. Kemfert, D. Bogdanov, C. Breyer, „Flexible electricity generation, grid exchange and storage for the transition to a 100% renewable energy system in Europe", [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0960148119302319 [Accessed: 2020.10.12]

[38] L. Ardito, G. Procaccianti, G. Menga, M. Morisio, „Smart Grid Technologies in Europe: An Overview", [Online]. Available: https://www.mdpi.com/1996-1073/6/1/251 [Accessed: 2020.10.12]

[39] J.Crispim, J. Braz, R. Castro, J. Esteves, "Smart Grids in the EU with smart regulation: Experiences from the UK, Italy and Portugal", [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0957178714000678 [Accessed: 2020.10.12]

[40] R.A. Verzijlbergh, L.J. De Vries, G.P.J. Dijkema, P.M.Herder, “Institutional challenges caused by the integration of renewable energy sources in the European electricity sector”, [Online]. Available: https://www.sciencedirect.com/science/article/pii/S1364032116307651 [Accessed: 2020.10.12]

[41] M. Kochański, K. Korczak, T. Skoczkowski, “Technology Innovation System Analysis of Electricity Smart Metering in the European Union”, [Online]. Available: https://www.mdpi.com/1996-1073/13/4/916 [Accessed: 2020.10.12]

[42] European Commission, “Third energy package”, [Online]. Available: https://ec.europa.eu/energy/topics/markets-and-consumers/market-legislation/third-energy-package_en [Accessed: 2020.10.12]

[43] Official Journal of the European Union, “REGULATION (EC) No 714/2009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL”, [Online]. Available: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:211:0015:0035:EN:PDF [Accessed: 2020.10.12]

[44] ACER, “About ACER”, [Online]. Available: http://www.acer.europa.eu/en/The_agency/Pages/default.aspx [Accessed: 2020.10.12]

[45] ENTSO-E, “Who is ENTSO-E? ENTSO-E objectives”, [Online]. Available: https://www.entsoe.eu/about/inside-entsoe/objectives/ [Accessed: 2020.10.12]

[46] EU DSO Entity, “EU DSO Entity”, [Online]. Available: https://www.eudsoentity.eu/ [Accessed: 2020.10.12]

[47] European Union Newsroom, “Meeting of the European electricity regulatory forum (Florence Forum)”, [Online]. Available: https://europa.eu/newsroom/events/meeting-european-electricity-regulatory-forum-florence-forum_en [Accessed: 2020.10.12]

[48] European Union, “Smart grids task force”, [Online]. Available: https://ec.europa.eu/energy/topics/markets-and-consumers/smart-grids-and-meters/smart-grids-task-force_en [Accessed: 2020.10.12]

[49] ACER, “Network Code Implementation and Monitoring Group”, [Online]. Available: https://www.acer.europa.eu/en/the_eu_energy_market/Pages/Network-Code-Implementation-and-Monitoring-Group.aspx [Accessed: 2020.10.12]

[50] European Commission, “Electricity network codes and guidelines”, [Online]. Available: https://ec.europa.eu/energy/topics/markets-and-consumers/wholesale-energy-market/electricity-network-codes_en?redir=1 [Accessed: 2020.10.12]

[51] ENTOS-E, “Regional Groups”, [online]. Available: https://www.entsoe.eu/about/system-operations/#regional-groups [Accessed: 2020.10.12]

[52] IRENA, “Scaling up Variable Renewable Power: The Role of Grid Codes”, [Online]. Available: https://www.irena.org/publications/2016/May/Scaling-up-Variable-Renewable-Power-The-Role-of-Grid-Codes [Accessed: 2020.10.12]

[53] European Commission Directorate – General for Energy, “Targeted Stakeholder Consultation Paper. Priority list for the development of network codes and guidelines on electricity for the period 2020-2023 and on gas for 2020 (and beyond)”, [Online]. Available: https://ec.europa.eu/energy/sites/ener/files/07-02-2020-targeted_stakeholder_consultation-2020-

2023-for_europa.pdf [Accessed: 2020.10.12]

[54] ENTSO-E, “RESPONSE TO THE EUROPEAN COMMISSION’S PUBLIC CONSULTATION TO ESTABLISH THE PRIORITY LIST OF NETWORK CODES”, [Online]. Available: https://eepublicdownloads.azureedge.net/clean-documents/news/200512_ENTSO-E_s_reponse_to_the_EC_consultation_on_priority_list_for_network_codes.pdf [Accessed: 2020.10.12]

[55] Á. Soroudi, A. Nouri, A. Keane, S.K. Gurumurthy, A. Monti, D. Ryan, M. Ponce De Leon, N. Grant, “D3.8 v1.0”, [Online]. Available: http://www.re-serve.eu/files/reserve/Content/Deliverables/727481_deliverable_D3.8.pdf [Accessed: 2020.10.12]

[56] Á. Soroudi, A. Nouri, A. Keane, S.K. Gurumurthy, A. Monti, D. Ryan, M. Ponce De Leon, N. Grant, D. Leniston, Z. Mehdi, R. Farac, R. Murphy,T. Clancy, A. Löwen, “D3.9”, [Online]. Available: http://www.re-serve.eu/files/reserve/Content/Deliverables/727481_RESERVE_D3.9.pdf [Accessed: 2020.10.12]

[57] S. Gurumurthy, M. Mirz, D. Ryan, M. Ponce de Leon, N. Grant, R. Lawton, J. Sandham, R. Murphy, D. Fogarty, A. Nouri, A. Soroudi, A. Keane, “D5.2 v1.0 Report on field trial of voltage control concepts in Ireland and validation of initial network codes and ancillary service definitions”, [Online]. Available: http://www.re-serve.eu/files/reserve/Content/Deliverables/727481_deliverable_D5.2.pdf [Accessed: 2020.10.12]

[58] ENTSO-E, “RESEARCH, DEVELOPMENT & INNOVATION ROADMAP 2017–2026”, [online]. Available: http://riroadmap.entsoe.eu/wp-content/uploads/2016/06/entsoe_ri_roadmap_2017-2026.pdf [Accessed: 2020.10.12]

[59] Cigre, “PROPOSAL FOR THE CREATION OF A NEW WORKING GROUP”, [Online]. Available: https://www.cigre.org/userfiles/files/News/2019/TOR-WG%20B4_84_Feasibility%20study%20and%20application%20of%20electric%20energy%20storage%20systems%20embedded%20in%20HVDC%20systems.pdf [Accessed: 2020.10.12]

[60] ENTSO-E, “Research, Development&Innovation Roadmap 2020 – 2030”, [online]. Available: https://eepublicdownloads.azureedge.net/clean-documents/Publications/RDC%20publications/entso-e-rdi_roadmap-2020-2030.pdf [Accessed: 2020.10.12]

[61] European Commission, “Smart Grids”, [Online]. Available: https://s3platform.jrc.ec.europa.eu/smart-grids [Accessed: 2020.09.01]

[62] ETIP-SNET, “ETIP SNET R&I Roadmap 2020-2030. January 2020”, [Online]. Available: https://docplayer.net/184626257-Etip-snet-r-i-roadmap.html [Accessed: 2020.08.07]

6 Annex

6.1 List of Figures

6.2 List of Tables

6.3 PANTERA proposed Technologies and Systems for Integrated Energy System

	Technologies and Systems in support of the Functionalities		
No.	Group of technologies	Technologies	Description
1	Integrated Grid	Flexible ac transmission systems (FACTS)	Controllable power electronic equipment that will support the Transmission smart grid operations
2		Models, Tools, Systems for the operation analysis, control and the development of the integrated grid including cost elements	Advanced models, tools, systems for the operation analysis, control, state estimation and the development of the integrated grid (TYNDP etc) including cost elements
3		HVDC	High Voltage Direct Current overhead and underground grid.
4		Forecasting (RES)	Advanced forecasting tools (RES) that will allow a low estimation error and provide an accurate feedback for the actors that need these types of services. E.g. aggregators, operators, RES owners, ESP, the market operator etc.
5		Asset management	The methodology, procedures, the devices and software that allow the efficient management of assets of the integrated grid.
6		Outage management, fault finding and associated equipment (including protection)	The methodology, procedures, the devices and software that allow the efficient management of outages including fault finding of the integrated grid.
7		Equipment and apparatus of the integrated grid	All the primary equipment (rated at the rated voltage of the system) and apparatus constituting the integrated grid including Power guards and limiters.
8		Equipment, sensing, monitoring, measuring for analysis, solutions and control	Equipment, sensing, monitoring, measuring for analysis, solutions and control including procedures and software that make observable the integrated grid. These include the devices and the procedures that allow PMUs, PDCs and GPS to be efficient tools of the smart grid paradigm
9		Advance distributed load control	Software or hardware devices or procedures that allow advanced distributed control of distributed assets of the grids including different type of DERs and load
10		Feeder auto-restoration / self-healing	Advanced procedures and systems that facilitate the feeder auto-restoration thus implementing the self- healing of the interconnected system
11		Smart metering infrastructure	All the procedures and systems that are related to smart meters as devices and complete bi-directional communication link between metering data management systems and end users.
12	Customers and market	Distributed flexibility, load management & control and demand response including end devices, communication infrastructure and systems	All procedures, controls and devices that facilitate distributed flexibility, load management including explicit demand response and system

13		Smart appliances	Smart appliances that allow customer market participation and smart load control.
14		Building control, automation and energy management systems	All procedures, controls and devices that secure smart building automation including home energy management, active control, monitoring and market participation
15		Electric vehicles	Electric vehicles are vehicles based on battery or fuel cell resource for transport needs.
16		Energy communities	Its primary purpose is to provide environmental, economic or social community benefits to its members or shareholders or to the local areas where it operates. May engage in generation, including from renewable sources, distribution, supply, consumption, aggregation, energy storage, energy efficiency services or charging services for electric vehicles or provide other energy services to its members or shareholders;
17		Lighting	Any apparatus emitting light and related systems.
18		Electricity market	All elements of the electricity market including platforms that enable wholesale, retail, real time pricing / spot, flexibility, aggregated and peer to peer trading including ancillary services, etc.
19	**Storage**	Storage Electric	In the electricity system, apparatus capable of deferring the final use of electricity to a moment later than when it was generated, or the conversion of electrical energy into a form of energy which can be stored, the storing of such energy, and the subsequent reconversion of such energy into electrical energy.;
20		Thermal Storage	The main parts and all auxiliary components that form a ready to integrate device capable of storing thermal energy for use at a later stage.
21		Power to gas	The main parts and all auxiliary components that form a ready to integrate device from technologies that uses electrical power to produce a gaseous fuel for storing or use otherwise.
22		Pumped storage	The main parts and all auxiliary components that form a ready to integrate system to operate as a Pumped storage system which is the process of storing energy by using two vertically separated water reservoirs. Water is pumped from the lower reservoir up into a holding reservoir. Pumped storage facilities store excess energy as gravitational potential energy of water.
23		Other Storage	The main parts and all auxiliary components that form a ready to integrate device capable of storing energy other than the above systems.
24	**Generation**	Flexible generation	The main parts and all auxiliary components that form a ready to integrate device
25		Solar including PV & CSP	The main parts and all auxiliary components that form a ready to integrate systems capable of generating electricity from PV or CSP

			technologies.
26		Wind	The main parts and all auxiliary components that form a ready to integrate systems capable of generating electricity from wind technologies.
27		Hydropower	The main parts and all auxiliary components that form a ready to integrate system capable of generating electricity from flowing hydro.
28		Hydrogen & sustainable gases	The main parts and all auxiliary components that form a ready to integrate systems capable of generating electricity from hydrogen and other sustainable gases.
29		Other generation	The main parts and all auxiliary components that form a ready to integrate systems capable of generating electrical energy other than the above.
30	**Digitalization, Communication and Data**	Communication networks including devices and systems for signals and data connectivity and solutions	Any combination of equipment and systems forming a communications network as a group of nodes interconnected by links that are used to exchange messages between the nodes. The links may use a variety of technologies based on the methodologies of circuit switching, message switching, or packet switching, to pass messages and signals including Local Area Networks, Home Area Networks and web-based solutions and cloud services for smart gird operations
31		Digital Twins	Any combination of equipment and systems forming Digital twins that are virtual replicas of physical devices that can used to run simulations before actual devices are built and deployed.
32		Artificial intelligence	Any combination of equipment and systems forming Artificial intelligence that simulates human intelligence in machines that are programmed to think like humans and mimic their actions.
33		Data and cyber security including repositories	Any combination of equipment and systems offering Cyber security for defending computers, servers, mobile devices, electronic systems, networks, and data from malicious attacks, including generated data from the interconnected system with related repositories other than that related to the MDMS (Meter and Data Management System).

6.4 Mapping of Research Tasks per Functionality

Mapping of research tasks performed based on the first version of ETIP SNET roadmap [62].
As already explained Research tasks linked to the Business and Operation layer reflect requirements to regulations and codes. Similarly, tasks linked to the Information and Communication and Component layer mostly reflect expectations from standards.

The colouring in the mapping below is representing:

- Regulations requirements related
- Codes requirements related
- Standards requirements related

<table>
<tr><th colspan="6">F1 Cooperation Between System Operators</th><th>Related Technologies/Systems/Solutions</th></tr>
<tr><td colspan="6">Related Research Tasks: 1.1.3, 1.2.1, 2.2.1, 2.2.2, 2.2.3, 2.2.4, 2.2.5, 2.2.6, 2.2.8, 2.2.9, 2.2.10, 2.2.11, 2.2.12, 2.2.16, 2.3.2, 2.3.3, 2.3.4, 2.3.6, 3.1.1, 3.1.2, 3.1.3, 3.1.5, 3.1.7, 3.1.9, 3.1.11, 3.1.12, 3.1.14, 3.1.16, 3.1.18, 3.2.3, 3.3.3, 3.4.1, 3.4.4, 3.4.8, 3.4.9, 3.5.1, 3.5.2, 3.5.4, 3.5.5, 3.5.6, 4.1.8, 4.1.9, 4.1.17, 4.1.19, 4.1.23, 4.2.1, 4.2.2, 4.2.3, 4.2.7, 4.4.4, 4.4.5, 5.1.2, 5.1.3, 5.1.5, 5.2.8 I, 5.4.3, 5.5.1, 6.1.1, 6.1.4, 6.1.8, 6.3.7, 6.3.9, 6.4.1, 6.4.7, 6.4.8, 6.4.9, 6.4.11, 6.5.2, 6.5.11, 6.5.13, 6.5.14, 6.5.15, 6.5.17, 6.1.7, 6.3.2</td><td>• Asset management
• Outage management, fault finding and associated equipment (including protection)
• Equipment and apparatus of the integrated grid
• Equipment, sensing, monitoring, measuring for analysis, solutions and control
• Advance distributed load control
• Feeder auto-restoration / self-healing
• Smart metering infrastructure</td></tr>
<tr><td></td><td colspan="3">Integrated Grid</td><td colspan="2"></td><td></td></tr>
<tr><td>Generation</td><td>Transmission</td><td>Distribution</td><td>DER integration</td><td>Customers</td><td>Storage</td><td></td></tr>
<tr><td colspan="6">Business and operation</td><td></td></tr>
<tr><td colspan="6">Pan-European market design</td><td></td></tr>
<tr><td colspan="6">Cross-border market design for ancillary services</td><td></td></tr>
<tr><td colspan="6">Operation of coupled energy systems</td><td></td></tr>
<tr><td></td><td></td><td colspan="3">Aggregation, market rules and mechanisms for provision of ancillary services</td><td></td><td></td></tr>
<tr><td></td><td colspan="2">National regulatory schemes to foster cross-border coordination</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="2">Grid restoration plans at the pan-European level</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td>Thermal storage for participation in electricity and heating markets</td><td></td></tr>
</table>

Prosumers, local and virtual energy markets

Coordinated HV and MV electricity transmission with storage infrastructure and gas and heat infrastructures

Bulk storage (P2G, CAES, LAES)

Optimal TSO-related DSR utilization

DER and storage contribution to pan-European system black start restoration

Micro and nano grid power system stability support

Information and communication

M2M or AI2AI telecommunications solutions

Open protocols (expert systems) handling of market operations

Redundant backup systems for ICT and software

Universal virtual and open device interface and protocols to enable DSO and TSO information exchanges with DER

Interfaces between Big Data management

Energy Management Platforms

Digitalisation of TSO/DSO, digital twin

Information exchange for coordinated reactive power and load management (load control, load shedding)

Coordination between LV and MV grids, including protocols for 5G or broadband PLC, BigData applications

AI based decisionmaking

Advanced ICT-based approaches (IoT, edge computing, cloud computing), distributed online analytical data streaming and processing

Innovative control architecture

	and solutions for real-time voltage and balancing (frequency) control			
	Expert systems for load and generation forecast, optimal power flow			
		LV and MV telecommunication and control architectures including information models		
	Coordinated use of WAMS			
Component				
	Standardised strategic HV and Ultra-HV components			
Wind based power generation solutions for vendor-independent, HVDC multiterminal networks				
	Coordinated use of FACTS, HVDC links, superconductivity, energy storage, fault current limiters and other technologies			
New actuators and new sensors (fault detectors, voltage and current sensors) allowing flexibility				
	Power flow control devices			

F2 Cross-sector integration						**Related Technologies/Systems/Solutions**
Related Research Tasks: 1.1.1, 1.1.3, 1.1.4, 1.2.1, 1.3.3, 2.1.6, 2.2.4, 2.2.5, 2.2.6, 2.2.7, 2.2.8, 2.2.10, 2.2.1.2, 2.2.13, 2.2.14, 2.2.15, 3.1.6, 3.1.7, 3.1.12, 3.1.16, 3.1.17, 3.2.1, 3.2.2, 3.2.3, 3.5.1, 3.5.2, 4.1.8, 4.1.9, 4.1.15, 4.1.16, 4.1.18, 4.1.19, 4.1.23, 4.1.24, 4.1.25, 4.2.3, 4.2.4, 4.2.5, 4.2.8, 4.3.12, 4.4.2, 5.1.1, 5.1.3, 5.1.4, 5.1.5, 5.2.1, 5.2.2, 5.2.3, 5.2.4, 5.2.7, 5.2.8, 5.2.9, 5.2.10, 5.3.1, 5.3.3, 5.3.4, 5.3.5, 5.3.6, 5.3.7, 5.5.1, 5.5.2, 5.5.3, 6.1.4, 6.4.1, 6.4.14, 6.4.16, 6.5.1, 6.5.7, 6.5.12, 6.5.15, 6.5.16, 6.5.17						• Electric vehicles • Electricity market • Thermal Storage • Power to gas • Pumped storage • Other Storage • Flexible generation • Solar including PV & CSP • Hydrogen & sustainable gases
	Integrated Grid					
Generation	**Transmission**	**Distribution**	**DER integration**	**Customers**	**Storage**	
Business and operation						
Cross-border market design for ancillary services (procurement of reserves, sharing of reserves, fast ramping services, frequency response, inertia response, reactive power, and voltage control)						
		Aggregation, market rules and mechanisms for provision of ancillary services				
Operation of coupled energy systems						
Geospatial and grid-expedient sizing of assets						

				System services (balancing) brought from aggregated heating and cooling devices		
					Thermal storage for participation in electricity and heating markets	
				Prosumers, local- and virtual energy markets		
					Bulk storage (P2G, CAES, LAES)	
		CHPs connected to district heating networks, operation through virtual power plants				
	Coordinated HV and MV electricity transmission with storage infrastructure and gas and heat infrastructures					
		Balancing services brought by gas network operators				
		VtG, GtV				
	Optimal TSO-related DSR utilization					
		Balancing services brought by drinking water and network operators				
Information and communication						
M2M or AI2AI telecommunications solutions adapted for the future energy grid						
	Universal virtual and open device interface and protocols to enable DSO and TSO information exchanges with DER					
	digitalisation of TSO/DSO, digital twin					
	Energy Management Platforms					
		Management systems integration of EV charging infrastructures				

Communication interfaces on LV secondary substation level (EMS, SCADA, IED)	
Advanced ICT-based approaches (IoT, edge computing, cloud computing), distributed online analytical data streaming and processing	
Innovative control architecture and solutions for real-time voltage and balancing (frequency) control	
LV and MV telecommunication and control architectures including information models	
Solutions for forecasting of aggregated load	
Blockchain technology for peer to peer user communication	
Component	
Smart meters to contribute to monitoring in critical zones (non-GNSS systems for time synchronisation and timestamping, latency, loss of packets, jitter in end-to-end communications)	
Standardised strategic HV and Ultra HV components	
Storage systems integrated with conventional power generators	
Integrated PV+Storage systems, 2nd life batteries	
Multicarrier hybrid storage system, Power2Heat for balancing and storage, inertia of	

<table>
<tr><td></td><td></td><td></td><td></td><td></td><td>thermal loads</td><td></td></tr>
<tr><td colspan="6">New actuators and new sensors (fault detectors, voltage and current sensors) allowing flexibility</td><td></td></tr>
<tr><td></td><td></td><td colspan="3">ICT infrastructure supporting PV integration</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Direct load control via the smart meters and/or the energy boxes</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="2">Stand-alone systems for living quarters and small/medium sized industries (P2G, P2H, P2fuels, P2chemicals)</td><td></td></tr>
<tr><td></td><td></td><td>Testing smart meters with capabilities to contribute to almost real-time monitoring in critical zones</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Improved lifetime, fast cycling ability, fuel flexibility of thermal generation</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

<table>
<tr><th colspan="6">F3 Integrating the subsidiarity principle – The customer at the center, at the heart of the Integrated Energy System</th><th>Related Technologies/Systems/Solutions</th></tr>
<tr><td colspan="6">Related Research Tasks: 1.1.1, 1.1.2, 1.1.3, 1.1.5, 1.1.6, 1.1.7, 1.1.8, 1.1.9, 1.1.10, 1.2.1, 1.2.2, 1.2.3, 1.2.4, 1.2.5, 1.2.6, 1.2.7, 1.2.8, 1.2.9, 1.3.1, 1.3.2, 1.3.3, 2.1.1, 2.2.1, 2.2.2, 2.2.3, 2.2.6, 2.2.9, 2.3.1, 2.3.6, 2.3.7, 3.3.1, 3.1.15, 3.1.17, 3.2.3, 3.4.2, 3.4.3, 3.4.5, 4.1.13, 4.1.23, 4.2.3, 4.4.4, 5.1.1, 5.3.1, 6.3.4, 6.4.6, 6.4.14, 6.5.1, 6.5.14</td><td>Load management & control and demand response including end devices, communication infrastructure and systems
Building control, automation and energy management systems
Electricity market</td></tr>
<tr><td></td><td colspan="3">Integrated Grid</td><td colspan="2"></td><td></td></tr>
<tr><td>Generation</td><td>Transmission</td><td>Distribution</td><td>DER integration</td><td>Customers</td><td>Storage</td><td></td></tr>
<tr><td colspan="6">Business and operation</td><td></td></tr>
<tr><td colspan="6">Operation of coupled energy systems</td><td></td></tr>
<tr><td colspan="5">Business models for all actors promoting energy efficiency at the end-user level</td><td></td><td></td></tr>
<tr><td></td><td></td><td colspan="3">Aggregation, market rules and mechanisms for provision of ancillary services</td><td></td><td></td></tr>
<tr><td></td><td colspan="3">Regulatory arrangements to allow temporary use of distributed DER for-</td><td></td><td></td><td></td></tr>
</table>

	grid management purposes by DSO and TSO				
			Consumer awareness, large-scale participation on AD schemes		
			Prosumers, local and virtual energy markets		
				Thermal storage for participation in electricity and heating markets	
			Tariff schemes, incentives and network regulation for EV integration		
			Flexibilization of industry (as prosumer)		
			Micro and nano grid power system stability support		
Information and communication					
M2M or AI2AI telecommunications solutions					
Open protocols (expert systems) handling of market operations					
	Energy Management Platforms				
	Solutions for forecasting of EV charging loads				
	Innovative control architecture and solutions for real-time voltage and balancing (frequency) control				
			Visualization and control (via protocols and standardization) of prosumers', wireless technologies, PLC, smart phones		
			Direct Messaging Channels		
			Energy management systems of		

	microgrids, local multi-energy streams operation		
	Blockchain technology for peer to peer user communication		
Component			
AMI to measure electricity consumption, generation and send time-of use			
	Direct load control via the smart meters and/or the energy boxes		
	In-home ICT technologies, connections with smart appliances, smart plugs, voltage clamps, in-home displays, web portals, smartphone apps		
	Stand-alone systems for living quarters and small/medium sized industries (P2G, P2H, P2fuels, P2chemicals)		

F4 Pan-European wholesale markets						**Related Technologies/Systems/Solutions**
Related Research Tasks: 1.2.1. 1.2.2, 1.2.3, 1.2.4, 1.2.7, 1.2.9, 1.3.3, 2.1.1, 2.1.2, 2.1.3, 2.1.5, 2.1.6, 2.1.7, 2.2.3, 2.2.4, 2.2.5, 2.2.6, 2.2.7, 2.2.8, 2.2.10, 2.2.11, 2.2.13, 2.3.2, 2.3.3, 2.3.4, 2.3.8, 3.1.1, 4.2.4, 4.2.10, 4.4.1, 5.1.1, 5.4.3, 6.1.2, 6.3.8, 6.4.7, 6.4.9						• Forecasting (RES) • Electricity market • Storage Electric • Flexible generation • Solar including PV & CSP • Wind
	Integrated Grid					
Generation	**Transmission**	**Distribution**	**DER integration**	**Customers**	**Storage**	
Business and operation						
Pan-European market design						
Cross-boarder market design for ancillary services (procurement of reserves, sharing of reserves, fast ramping services, frequency response, inertia response, reactive power, and voltage control)						
Business models for all actors promoting energy efficiency at the end-user level						
		Aggregation, market rules and mechanisms for provision of ancillary services				
	Regulatory framework to promote the use of Demand Response					

National regulatory schemes to foster cross-border coordination	
Flexible coordination between TSO and DSO	
Grid restoration plans at the pan-European level	
Thermal storage for participation in electricity and heating markets	
Storage in dedicated electricity networks for transportation, ancillary services provided by this	
Prosumers, local- and virtual energy markets	
Ancillary services provided by prosumers	
DER and storage contribution to pan-European system black start restoration	
Flexibilization of industry (as prosumer)	
Information and communication	
Open protocols (expert systems) handling of market operations	
Component	
AMI to measure electricity consumption, generation and send time of use	
Coordinated use of FACTS, HVDC links, superconductivity, energy storage, fault current limiters and other technologies	
Power flow control devices	

F5 Integrating local markets (enabling citizen involvement)	Related Technologies/Systems/Solutions
Related Research Tasks: 1.1.1, 1.1.3, 1.1.10, 1.2.1, 1.2.2, 1.2.3, 1.2.4, 1.2.7, 1.2.8, 1.3.1, 1.3.2, 1.3.3, 2.1.1, 2.1.2, 2.1.6, 2.1.7, 2.2.1, 2.2.2, 2.2.3, 2.2.4, 2.2.6, 2.2.7, 2.2.9, 2.2.10, 2.2.11, 2.2.12, 2.2.13, 2.2.16, 2.2.18, 2.2.19. 2.2.20, 2.3.1, 2.3.2, 2.3.3, 2.3.4, 2.3.5, 2.3.6, 2.3.7, 2.3.8, 3.1.1, 3.1.7, 3.1.10, 3.1.15, 3.1.16, 3.1.9, 3.2.3, 3.3.3, 3.4.3, 3.4.5, 3.4.10, 3.5.2, 3.5.5, 4.1.12, 4.1.13, 4.1.16, 4.1.25, 4.2.4, 4.2.10, 4.4.3, 4.4.5, 5.1.1, 5.1.3, 5.1.4, 5.3.1, 5.3.4, 5.3.8, 5.4.2, 5.5.1, 5.5.2, 5.5.3, 6.1.2, 6.1.8, 6.2.1, 6.3.2, 6.3.6, 6.3.9, 6.4.17, 6.5.1, 6.5.3, 6.5.4, 6.5.5, 6.5.11, 6.5.15, 6.5.16, 6.5.17, 6.5.2	• Forecasting (RES) • Load management & control and demand response including end devices, communication infrastructure and systems • Smart appliances • Electric vehicles • Energy communities

<table>
<tr><td colspan="6"></td><td>

- Electricity market
- Storage Electric
- Flexible generation
-

</td></tr>
<tr><td></td><td colspan="3">Integrated Grid</td><td colspan="2"></td><td></td></tr>
<tr><td>Generation</td><td>Transmission</td><td>Distribution</td><td>DER integration</td><td>Customers</td><td>Storage</td><td></td></tr>
<tr><td colspan="6">Business and operation</td><td></td></tr>
<tr><td colspan="6">Pan-European market design</td><td></td></tr>
<tr><td colspan="6">Cross-border market design for ancillary services (procurement of reserves, sharing of reserves, fast ramping services, frequency response, inertia response, reactive power, and voltage control)</td><td></td></tr>
<tr><td colspan="6">Business models for all actors promoting energy efficiency at the end-user level</td><td></td></tr>
<tr><td></td><td></td><td colspan="3">Aggregation, market rules and mechanisms for provision of ancillary services</td><td></td><td></td></tr>
<tr><td></td><td colspan="4">Regulatory framework to promote the use of Demand Response</td><td></td><td></td></tr>
<tr><td></td><td colspan="2">Grid restoration plans at the pan-European level</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="2">National regulatory schemes to foster cross-border coordination</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="3">Regulatory arrangements to allow temporary use of distributed DER for-grid management purposes by DSO and TSO</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Prosumers, local and virtual energy markets</td><td></td><td></td></tr>
<tr><td></td><td colspan="2">Flexible coordination between TSO and DSO</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td>Thermal storage for participation in electricity and heating markets</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>System services (balancing) brought from aggregated heating and cooling devices</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td>Islanding with DER</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>VtG, GtV</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Tariff schemes, incentives and network regulation for EV integration</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>New regulatory options for local energy communities</td><td></td><td></td></tr>
</table>

Information and communication

M2M or AI2AI telecommunications solutions

Open protocols (expert systems) handling of market operations

Universal virtual and open device interface and protocols to enable DSO and TSO information exchanges with DER

Energy Management Platforms

Digitalisation of TSO/DSO, digital twin

AMM

Management systems integration of EV charging infrastructures

Solutions for micro grids with islanding capabilities

Improved RES forecasting

Storage duty cycle standards

Advanced ICT-based approaches (IoT, edge computing, cloud computing), distributed online analytical data streaming and processing

Innovative control architecture and solutions for real-time voltage and balancing (frequency) control

Standardised models for encrypted and authenticated market orders common for all stakeholders

Solutions for forecasting of aggregated load

Visualization and control (via protocols and standardization) of prosumers', wireless technologies, PLC, smart phones

Energy management systems of microgrids, local multi-energy streams operation

Blockchain technology for peer to peer user

		communication		
Component				
AMI to measure electricity consumption, generation and send time-of use				
	LV DC grids			
			Mobile storage provided by DSOs	
			Integrated PV+Storage systems, 2nd life batteries	
			Multicarrier hybrid storage system, Power2Heat for balancing and storage, inertia of thermal loads	
New actuators and new sensors (fault detectors, voltage and current sensors) allowing flexibility				
Synthetic inertia from power electronic converters and additional damping of oscillations, Variable Frequency Transformer				
	Smart inverters providing grid support functions			
		In-home ICT technologies, connections with smart appliances, smart plugs, voltage clamps, in-home displays, web portals, smartphone apps		
		Direct load control via the smart meters and/or the energy boxes		
		Stand-alone systems for living quarters and small/medium sized industries (P2G, P2H, P2fuels, P2chemicals)		

	Urban e-mobility, including e-charging stations		

F6 Integrating digitalisation services (including data privacy, cybersecurity)						Related Technologies/Systems/Solutions
Related Research Tasks: 1.2.2, 1.2.3, 1.2.4, 1.2.5, 1.2.7, 1.2.8, 1.3.1, 1.3.2, 1.3.3, 2.1.1, 2.1.2, 2.1.3, 2.1.5, 2.2.9, 2.2.10, 2.2.11, 2.2.16, 2.3.2, 3.1.2, 3.1.3, 3.1.4, 3.1.5, 3.1.6, 3.1.7, 3.1.8, 3.1.9, 3.1.10, 3.1.11, 3.1.12, 3.1.13, 3.1.14, 3.1.15, 3.1.16, 3.1.17, 3.1.18, 3.2.1, 3.2.2, 3.2.3, 3.2.4, 3.3.1, 3.3.2, 3.3.3, 3.4.1, 3.4.2, 3.4.3, 3.4.4, 3.4.5, 3.4.6, 3.4.7, 3.4.8, 3.4.9, 3.4.10, 3.5.1, 3.5.2, 3.5.3, 3.5.4, 3.5.5, 3.5.6, 4.1.1, 4.1.4, 4.1.22, 4.1.23, 4.1.26, 4.3.2, 4.3.4, 4.3.5, 4.3.6, 4.3.7, 4.3.8, 4.3.9, 4.3.10, 4.3.11, 4.3.14, 4.4.9, 5.1.1, 5.1.3, 5.1.5, 5.2.5, 5.2.6, 5.3.1, 5.3.2, 6.1.1, 6.1.3, 6.1.4,6.1.7, 6.3.2, 6.3.4, 6.3.6, 6.3.11, 6.3.12, 6.4.1, 6.4.6, 6.4.10, 6.4.17, 6.5.1, 6.5.6, 6.5.10, 6.5.11, 6.5.12, 6.5.13, 6.5.14, 6.5.15, 6.5.16, 6.5.17, 6.5.19						• Equipment, sensing, monitoring, measuring for analysis, solutions and control • Smart metering infrastructure • Smart appliances • Communication networks including devices and systems for signals and data connectivity and solutions • Digital Twins • Artificial intelligence • Data and cyber security including repositories
	Integrated Grid					
Generation	**Transmission**	**Distribution**	**DER integration**	**Customers**	**Storage**	
Business and operation						
Business models for all actors promoting energy efficiency at the end-user level						
	Grid restoration plans at the pan-European level					
	New methodologies for capacity calculations of transmission and distribution grids					
				Ancillary services provided by prosumers		
	Optimal TSO related DSR utilization					
					Energy storage services associated to thermal power plants	
Information and communication						
M2M or AI2AI telecommunications solutions						
	Interfaces between Big Data management					
	Universal virtual and open device interface and protocols to enable DSO and TSO information exchanges with DER					
	Information exchange for coordinated reactive power and load management (load control,					

load shedding)

Digitalisation of TSO/DSO, digital twin

Energy Management Platforms

Coordination between LV and MV grids, including protocols for 5G or broadband PLC, BigData applications

Communication interfaces on LV secondary substation level (EMS, SCADA, IED)

HV-system using AI methods for modelbased detection of component failures

IoT in TSO activities

AMM

Improved RES forecasting

Solutions for forecasting of EV charging loads

Storage duty cycle standards

Advanced ICT-based approaches (IoT, edge computing, cloud computing), distributed online analytical data streaming and processing

Innovative control architecture and solutions for real-time voltage and balancing (frequency) control

Solutions for forecasting of aggregated load

LV and MV telecommunication and control architectures including information models

Standardization of certain functionalities of the Geographic Information System (GIS)

Tools for condition-based maintenance

Coordinated use of WAMS

Visualization and control (via protocols and standardization) of prosumers', wireless technologies, PLC, smart phones

Direct Messaging Channels

Blockchain technology for peer to peer user communication

Component	
Smart meters to contribute to monitoring in critical zones (non-GNSS systems for time synchronisation and timestamping, latency, loss of packets, jitter in end-to-end communications)	
AMI to measure electricity consumption, generation and send time-of use	

LV DC grids

Standardised strategic HV and Ultra-HV components

High-performance and high-speed communication infrastructure for TSO

AI based decisionmaking

Smart substations

ICT infrastructure supporting PV integration

Testing smart meters with capabilities to contribute to almost real-time monitoring in critical zones

In-home ICT technologies, connections with smart appliances, smart plugs, voltage clamps, in-home displays, web portals, smartphone apps

				Direct load control via the smart meters and/or the energy boxes		
				Modular electricity system infrastructures, AC, AC/DC hybrid and DC microgrids and local storage		
				Stand-alone systems for living quarters and small/medium sized industries (P2G, P2H, P2fuels, P2chemicals)		
Sensors and systems which predict the optimal maintenance interval for hydropower and pumpedstorage units						

F7 Upgraded electricity networks, integrated components and systems						**Related Technologies/Systems/Solutions**
Related Research Tasks: 1.2.4, 1.3.3, 2.1.2, 2.2.5, 2.2.8, 2.2.13, 3.1.2, 3.1.3, 3.1.4, 3.1.5, 3.1.6, 3.1.7, 3.1.8, 3.1.9, 3.1.10, 3.1.12, 3.1.13, 3.1.16, 3.1.18, 3.2.1, 3.2.2, 3.2.3, 3.2.5, 3.3.1, 3.3.2, 3.4.1, 3.4.4, 3.4.6, 3.4.7, 3.4.8, 3.4.9, 3.5.3, 3.5.4, 3.5.5, 4.1.1, 4.1.2, 4.1.3, 4.1.4, 4.1.5, 4.1.6, 4.1.7, 4.1.8, 4.1.9, 4.1.10, 4.1.11, 4.1.12, 4.1.13, 4.1.15, 4.1.16, 4.1.17, 4.1.18, 4.1.20, 4.1.21, 4.1.22, 4.1.24, 4.2.1, 4.2.2, 4.2.4, 4.2.5, 4.2.6, 4.2.7, 4.2.8, 4.2.11, 4.2.12, 4.3.1, 4.3.2, 4.3.3, 4.3.4, 4.3.5, 4.3.6, 4.3.7, 4.3.8, 4.3.12, 4.3.15, 4.3.15,4.3.16, 4.3.17, 4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.6, 4.4.7, 4.4.8, 4.4.9, 5.2.1, 5.2.2, 5.2.3, 5.2.4, 5.2.6, 5.2.8, 5.2.10, 5.2.11, 5.2.12, 5.3.2, 5.3.7, 5.4.1, 5.4.2, 5.4.3, 5.5.1, 5.5.2, 5.5.3, 6.1.1, 6.1.3, 6.1.4, 6.1.5, 6.1.7, 6.1.8, 6.2.1, 6.3.2, 6.3.5, 6.3.8, 6.3.9, 6.3.10, 6.3.11, 6.3.12, 6.4.2, 6.4.5, 6.4.6, 6.4.8, 6.4.9, 6.4.10, 6.4.11, 6.4.12, 6.4.13, 6.4.14, 6.4.15, 6.4.16, 6.5.1, 6.5.2, 6.5.4, 6.5.5, 6.5.6, 6.5.7, 6.5.8, 6.5.9, 6.5.10, 6.5.11, 6.5.12, 6.5.13, 6.5.14, 6.5.16, 6.5.19						• Flexible ac transmission systems (FACTS) • HVDC • Asset management • Outage management, fault finding and associated equipment (including protection) • Equipment and apparatus of the integrated grid • Equipment, sensing, monitoring, measuring for analysis, solutions and control • Advance distributed load control • Feeder auto-restoration / self-healing • Smart metering infrastructure • Load management & control and demand response including end devices, communication infrastructure and systems
	Integrated Grid					
Generation	**Transmission**	**Distribution**	**DER integration**	**Customers**	**Storage**	
Business and operation						
Pan-European market design						
		Aggregation, market rules and mechanisms for provision of ancillary services				
	New methodologies for capacity calculations of transmission and					

distribution grids	
Coordinated HV and MV electricity transmission with storage infrastructure and gas and heat infrastructures	
Islanding with DER	
Geospatial and grid-expedient sizing of assets	
VtG, GtV	
Information and communication	
M2M or AI2AI telecommunications solutions	
Interfaces between Big Data management	
Universal virtual and open device interface and protocols to enable DSO and TSO information exchanges with DER	
Dynamic capacity management and reserve allocation	
Storage duty cycle standards	
Digitalisation of TSO/DSO, digital twin	
IoT in TSO activities	
HV-system using AI methods for modelbased detection of component failures	
Coordination between LV and MV grids, including protocols for 5G or broadband PLC, BigData applications	
On-line monitoring and algorithms for conditional maintenance	
Software for removing large-scale intra-zone oscillations	
Management systems integration of EV charging infrastructures	
Automatic LV and MV System Topology identification	
Energy Management Platforms	
LV and MV telecommunication and control architectures including information models	
Standardization of certain	

functionalities of the Geographic Information System (GIS)	
Coordinated use of WAMS	
Solutions for forecasting of aggregated load	
Energy management systems of microgrids, local multi-energy streams operation	
Blockchain technology for peer to peer user communication	
Component	
Smart meters to contribute to monitoring in critical zones (non-GNSS systems for time synchronisation and timestamping, latency, loss of packets, jitter in end-to-end communications)	
LV DC grids	
DC grid protection, protection relays and breakers,multi-vendor solutions	
Lower and higher frequency AC networks as an alternative to DC	
Standardised strategic HV and Ultra-HV components	
HVDC meshed grids	
Parallel routing of DC and AC lines in the same tower	
Coordinated use of FACTS, HVDC links, superconductivity, energy storage, fault current limiters and other technologies	
High-performance and high-speed communication infrastructure for TSO	
Multicarrier hybrid storage system, Power2Heat for balancing and storage, inertia of thermal loads	

Integrated PV+Storage systems, 2nd life batteries

Storage systems integrated with conventional power generators

DC/DC converters, alternative topologies to the extended modular multilevel converter (MCC)

Wind based power generation solutions for vendor-independent, HVDC multiterminal networks

New actuators and new sensors (fault detectors, voltage and current sensors) allowing flexibility

ICT infrastructure supporting PV integration

Power flow control devices

Smart substations

Self-healing network solutions using smart controllers in smart secondary substations.

Testing smart meters with capabilities to contribute to almost real-time monitoring in critical zones

Modular electricity system infrastructures, AC, AC/DC hybrid and DC microgrids and local storage

Synthetic inertia from power electronic converters and additional damping of oscillations, Variable Frequency Transformer

Improved lifetime, fast cycling ability, fuel flexibility of thermal generation

Increased operational flexibility to hydropower and pumped storage plants	
Smart inverters providing grid support functions	
DC and hybrid AC/DC networks, connected to AC through FACDS or MV/ LV DC	
New actuators, new sensors fault detectors, voltage and current sensors) for MV network	
Urban e-mobility, including e-charging stations	

F8 Energy System Business (incl. models, regulatory)	Related Technologies/Systems/Solutions
Related Research Tasks: 1.1.3, 1.1.10, 1.2.1, 1.2.2, 1.2.3, 1.2.4, 1.2.5, 1.2.6, 1.2.7, 1.3.3, 2.1.1, 2.1.2, 2.1.3, 2.1.4, 2.1.5, 2.1.6, 2.1.7, 2.2.1, 2.2.2, 2.2.3, 2.2.4, 2.2.5, 2.2.6, 2.2.9, 2.2.12, 2.2.13, 2.2.14, 2.2.15, 2.2.16, 2.3.2, 2.3.3, 2.3.4, 2.3.5, 2.3.6, 2.3.7, 2.3.8, 3.1.1, 3.1.2, 3.1.3, 3.1.4, 3.1.9, 3.1.13, 3.1.14, 3.1.15, 3.1.19, 3.2.4, 3.3.1, 3.3.2, 3.3.3, 3.4.1, 3.4.10, 3.5.3, 3.5.4, 3.5.5, 4.1.9, 4.1.16, 4.1.17, 4.1.23, 4.1.25, 4.2.1, 4.2.3, 4.2.4, 4.2.8, 4.2.10, 4.2.12, 4.3.3, 4.4.2, 5.1.4, 5.1.5, 5.2.5, 5.2.6, 5.2.11, 5.3.1, 5.3.2, 5.3.4, 5.3.5, 5.3.8, 5.4.2, 5.5.3, 6.4.17, 6.5.1, 6.5.2, 6.5.3, 6.5.4, 6.5.11, 6.5.16, 6.5.17	• Smart metering infrastructure • Load management & control and demand response including end devices, communication infrastructure and systems • Smart appliances • Building control, automation and energy management systems • Electric vehicles • Energy communities • Electricity market • Storage Electric • Thermal Storage • Power to gas • Pumped storage • Other Storage • Flexible generation • Solar including PV & CSP • Wind • Hydropower • Hydrogen & sustainable gases • Other generation
Integrated Grid	

Generation	Transmission	Distribution	DER integration	Customers	Storage	
Business and operation						
Pan-European market design						
Cross border market design for ancillary services (procurement of reserves, sharing of reserves, fast ramping services, frequency response, inertia response, reactive power, and voltage control)						
Business models for all actors promoting energy efficiency at the end-user level						
Operation of coupled energy systems						
		Aggregation, market rules and mechanisms for provision of ancillary services				
	Regulatory framework to promote the use of Demand Response					
	Regulatory arrangements to allow temporary use of distributed DER for grid management purposes by DSO and TSO					
	National regulatory schemes to foster cross-border coordination					
	Flexible coordination between TSO and DSO					
	Grid restoration plans at the pan-European level					
				Prosumers, local and virtual energy markets		
					Storage in dedicated electricity networks for transportation, ancillary servises provided by this	
					Thermal storage for participation in electricity and heating markets	
				System services (balancing) brought from aggregated heating and cooling devices		
		Balancing services brought by gas network operators				
	New methodologies for capacity calculations of transmission and					

distribution grids	
Islanding with DER	
Tariff schemes, Incentives and network regulation for EV integration	
Ancillary services provided by prosumers	
Ancillary services provided by EVs	
Balancing services brought by drinking water and network operators	
Optimal TSO-related DSR utilization	
New regulatory options for local energy communities	
Information and communication	
Open protocols (expert systems) handling of market operations	
AMM	
Digitalisation of TSO/DSO, digital twin	
Coordination between LV and MV grids, including protocols for 5G or broadband PLC, BigData applications	
Energy Management Platforms	
IoT in TSO activities	
Management systems integration of EV charging infrastructures	
Solutions for micro grids with islanding capabilities	
Standardised models for encrypted and authenticated market orders common for all stakeholders	
Innovative control architecture and	

	solutions for real-time voltage and balancing (frequency) control					
	Planning methods that respect the variability of RES, demand response, storage, self-consumption					
		Solutions for forecasting of aggregated load				
				Direct Messaging Channels		
				Blockchain technology for peer to peer user communication		
Component						
AMI to measure electricity consumption, generation and send time-of use						
					Multicarrier hybrid storage system, Power2Heat for balancing and storage, inertia of thermal loads	
	Smart substations					
		Smart inverters providing grid support functions				
				Stand-alone systems for living quarters and small/medium sized industries (P2G, P2H, P2fuels, P2chemicals)		

F9 Simulation tools for electricity and energy systems (software)						**Related Technologies/Systems/Solutions**
Related Research Tasks: 1.2.3, 2.1.3, 2.1.5, 2.2.5, 2.2.13, 2.3.2, 2.3.7, 3.1.1, 3.1.7, 3.2.5, 3.4.1, 3.4.4, 3.4.8, 3.4.9, 3.5.1, 3.5.3, 3.5.5, 4.1.1, 4.1.5, 4.1.6, 4.1.7, 4.1.8, 4.1.9, 4.1.14, 4.1.17, 4.1.18, 4.1.19, 4.1.20, 4.1.21, 4.1.23, 4.1.25, 4.1.26, 4.1.27, 4.2.1, 4.2.3, 4.2.4, 4.2.5, 4.2.6, 4.2.7, 4.2.8, 4.2.10, 4.2.11, 4.2.12, 4.3.2, 4.3.3, 4.3.15, 4.3.16, 4.3.17, 4.4.1, 4.4.2, 4.4.7, 4.4.8, 4.4.9, 5.1.2, 5.2.1, 5.2.2, 5.2.11, 5.2.13, 5.2.14, 5.3.1, 5.3.2, 5.3.6, 5.3.8, 5.4.1, 6.1.1, 6.1.2, 6.1.4, 6.1.5, 6.6.1, 6.1.8, 6.3.1, 6.3.2, 6.3.3, 6.3.4, 6.3.5, 6.3.6, 6.3.7, 6.3.8, 6.3.12, 6.4.1, 6.4.2, 6.4.3, 6.4.4, 6.4.5, 6.4.6, 6.4.7, 6.4.8, 6.4.9, 6.4.14, 6.4.16, 6.5.1, 6.5.3, 6.5.4, 6.5.5, 6.5.6, 6.5.7, 6.5.16, 6.5.18						• Models, Tools, Systems for the operation analysis, control and the development of the integrated grid including cost elements • Forecasting (RES) • Asset management • Digital Twins • Artificial intelligence
	Integrated Grid					
Generation	**Transmission**	**Distribution**	**DER integration**	**Customers**	**Storage**	
Business and operation						
Pan-European market design						
Operation of coupled energy systems						
		Aggregation, market rules and mechanisms for provision of ancillary				

services

Grid restoration plans at the pan-European level

Regulatory arrangements to allow temporary use of distributed DER for grid management purposes by DSO and TSO

Geospatial and grid-expedient sizing of assets

Storage in dedicated electricity networks for transportation, ancillary services provided by this

Ancillary services provided by prosumers

Coordinated HV and MV electricity transmission with storage infrastructure and gas and heat infrastructures

Bulk storage (P2G, CAES, LAES)

Islanding with DER

DER and storage contribution to pan-European system black start restoration

Information and communication

Open protocols (expert systems) handling of market operations

Universal virtual and open device interface and protocols to enable DSO and TSO information exchanges with DER

Dynamic capacity management and reserve allocation

On-line monitoring and algorithms for conditional maintenance

Digitalisation of TSO/DSO, digital twin

Software for removing large-scale intra zone oscillations

Solutions for micro-grids with islanding capabilities

Improved RES forecasting

Solutions for forecasting of EV charging loads

Innovative control architecture and solutions for real-time voltage and balancing (frequency) control	
Expert systems for load and generation forecast, optimal power flow	
Solutions for forecasting of aggregated load	
LV and MV telecommunication and control architectures including information models	
Component	
HVDC meshed grids	
Parallel routing of DC and AC lines in the same tower	
LV DC grids	
DC grid protection, protection relays and breakers,multi-vendor solutions	
Wind based power generation solutions for vendor-independent, HVDC multiterminal networks	
DC/DC converters, alternative topologies to the extended modular multilevel converter (MCC)	
Modular electricity system infrastructures, AC, AC/DC hybrid and DC microgrids and local storage	
Stand-alone systems for living quarters and small/medium sized industries (P2G, P2H, P2fuels, P2chemicals)	

F10 Integrating flexibility in generation, demand, conversion and storage technologies	**Related Technologies/Systems/Solutions**

<table>
<tr><td colspan="6">Related Research Tasks: 1.1.3, 1.1.8, 1.1.9, 1.1.10, 1.2.1, 1.2.2, 1.2.3, 1.2.7, 1.2.8, 1.2.9, 1.3.1, 1.3.2, 1.3.3, 2.1.1, 2.1.13, 2.1.5, 2.1.6, 2.1.7, 2.2.1, 2.2.2, 2.2.3, 2.2.4, 2.2.5, 2.2.6, 2.2.7, 2.2.8, 2.2.9, 2.2.10, 2.2.11, 2.2.12, 2.2.13, 2.2.14, 2.2.15, 2.2.16, 2.2.18, 2.2.19, 2.2.20, 2.3.1, 2.3.2, 2.3.3, 2.3.6, 2.3.7, 2.3.8, 3.1.1, 3.1.5, 3.1.6, 3.1.7, 3.1.9, 3.1.10, 3.1.5, 3.1.16, 3.1.17, 3.1.19, 3.2.2, 3.2.3, 3.3.3, 3.4.3, 3.4.10, 4.1.1, 4.1.6, 4.1.7, 4.1.7, 4.1.8, 4.1.9, 4.1.15, 4.1.16, 4.1.17,4.1.18, 4.1.19, 4.1.23, 4.1.24, 4.1.25, 4.2.2, 4.2.3, 4.2.4, 4.2.5, 4.2.6, 4.2.7, 4.2.8, 4.2.9, 4.2.11, 4.2.12, 4.3.2, 4.3.3, 4.3.12, 4.3.13, 4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.8, 4.4.9, 5.1.1, 5.1.2, 5.1.3, 5.1.4, 5.1.5, 5.2.1, 5.2.2, 5.2.3, 5.2.4, 5.2.5, 5.2.6, 5.2.7, 5.2.8, 5.2.9, 5.2.10, 5.2.11, 5.2.12, 5.2.13, 5.2.14, 5.3.1, 5.3.2, 5.3.3, 5.3.4, 5.3.5, 5.3.6, 5.3.7, 5.3.8, 5.4.2, 5.5.2, 5.5.3, 6.1.1, 6.1.2, 6.1.3, 6.1.4, 6.1.6, 6.2.1, 6.3.1, 6.3.2, 6.3.3, 6.3.4, 6.3.6, 6.3.7, 6.4.1, 6.4.2, 6.4.4, 6.4.7, 6.4.10, 6.4.12, 6.4.14, 6.4.17, 6.5.1, 6.5.2, 6.5.3, 6.5.4, 6.5.7, 6.5.8, 6.5.11, 6.5.12, 6.5.13, 6.5.15. 6.5.16, 6.5.17, 6.5.19</td><td>Load management & control and demand response including end devices, communication infrastructure and systems
• Building control, automation and energy management systems
• Energy communities
• Lighting
• Electricity market
• Storage Electric
• Thermal Storage
• Power to gas
• Pumped storage
• Other Storage
• Flexible generation
• Hydropower
• Hydrogen & sustainable gases
• Other generation</td></tr>
<tr><td></td><td colspan="3">Integrated Grid</td><td colspan="2"></td><td></td></tr>
<tr><td>Generation</td><td>Transmission</td><td>Distribution</td><td>DER integration</td><td>Customers</td><td>Storage</td><td></td></tr>
<tr><td colspan="6">Business and operation</td><td></td></tr>
<tr><td colspan="6">pan-European market design</td><td></td></tr>
<tr><td colspan="6">cross-boarder market design for ancillary services (procurement of reserves, sharing of reserves, fast ramping services, frequency response, inertia response, reactive power, and voltage control)</td><td></td></tr>
<tr><td colspan="6">business models for all actors promoting energy efficiency at the end-user level</td><td></td></tr>
<tr><td colspan="6">operation of coupled energy systems</td><td></td></tr>
<tr><td colspan="4">geospatial and grid-expedient sizing of assets</td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="3">regulatory arrangements to allow temporary use of distributed DER for grid management purposes by DSO and TSO</td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="2">grid restoration plans at the pan-European level</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="2">coordinated HV and MV electricity transmission with storage infrastructure and gas and heat infrastructures</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="4">regulatory framework to promote the use of Demand Response</td><td></td><td></td></tr>
<tr><td></td><td></td><td colspan="3">aggregation, market rules and mechanisms for provision of ancillary services</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>prosumers, local- and virtual</td><td></td><td></td></tr>
</table>

				energy markets		
					storage in dedicated electricity networks for transportation, ancillary services provided by this	
					thermal storage for participation in electricity and heating markets	
				system services (balancing) brought from aggregated heating and cooling devices		
		CHPs connected to district heating networks, operation through virtual power plants				
		VtG, GtV				
			islanding with DER			
				ancillary services provided by prosumers		
				tariff schemes, incentives and network regulation for EV integration		
					bulk storage (P2G, CAES, LAES)	
		balancing services brought by gas network operators				
	DER and storage contribution to pan-European system black start restoration					
		balancing services brought by drinking water and network operators				

	optimal TSO-related DSR utilization					
				flexibilization of industry (as prosumer)		
				micro- and nanogrid power system stability support		
Information and communication						
Open Protocols (expert systems) handling of market operations						
M2M or AI2AI telecommunications solutions						
	universal virtual and open device interface and protocols to enable DSO and TSO information exchanges with DER					
	interfaces between Big Data management					
	Energy Management Platforms					
	on-line monitoring and algorithms for conditional maintenance					
		coordination between LV and MV grids, including protocols for 5G or broadband PLC, BigData applications				
		communication interfaces on LV secondary substation level (EMS, SCADA, IED)				
		improved RES forecasting				
					storage duty cycle standards	
				solutions for micro-grids with islanding capabilities		
		management systems integration of EV charging infrastructures				
		solutions for forecasting of EV charging loads				
standardised models for encrypted and authenticated market orders common for all stakeholders						
	innovative control architecture and solutions for real-time voltage and balancing (frequency) control					

expert systems for load and generation forecast, optimal power flow	
visualization and control (via protocols and standardization) of prosumers', wireless technologies, PLC, smart phones	
solutions for forecasting of aggregated load	
blockchain technology for peer to peer user communication	
Component	
AMI to measure electricity consumption, generation and send time-of use	
LV DC grids	
multicarrier hybrid storage system, Power2Heat for balancing and storage, inertia of thermal loads	
integrated PV+Storage systems, 2nd life batteries	
storage systems integrated with conventional power generators	
wind based power generation solutions for vendor-independent, HVDC multiterminal networks	
improved lifetime, fast cycling ability, fuel flexibility of	

thermal generation						
new actuators and new sensors (fault detectors, voltage and current sensors) allowing flexibility						
	power flow control devices					
	synthetic inertia from power electronic converters and additional damping of oscillations, Variable Frequency Transformer					
		ICT infrastructure supporting PV integration				
				modular electricity system infrastructures, AC, AC/DC hybrid and DC microgrids and local storage		
				stand-alone systems for living quarters and small/medium sized industries (P2G, P2H, P2fuels, P2chemicals)		
		smart inverters providing grid support functions				
				in-home ICT technologies , connections with smart appliances, smart plugs, voltage clamps, in-home displays, web portals, smartphone apps		
				direct load control via the smart meters and/or the energy boxes		

F11 Efficient heating and cooling for buildings and industries in view of system integration of flexibilities	**Related Technologies/Systems/Solutions**
Related Research Tasks: 1.1.10, 1.2.8, 1.3.1, 1.3.2, 2.1.1, 2.1.3, 2.1.5, 2.1.6, 2.1.7, 2.2.1, 2.2.6, 2.2.9, 2.2.10, 2.2.12, 2.2.13, 2.2.14, 2.2.15, 2.3.1, 2.3.8, 3.1.9, 3.1.17, 4.1.1, 4.1.6.4.1.7, 4.1.8, 4.1.9, 4.1.15, 4.1.16, 4.1.19, 4.1.23, 4.1.23, 4.1.25, 4.1.27, 4.2.2, 4.2.3, 4.2.4, 4.2.8, 4.2.11, 4.2.12, 4.3.12, 4.4.1, 4.4.2, 4.4.5, 5.1.1, 5.1.2, 5.1.3, 5.1.4, 5.1.5, 5.2.1. 5.2.2, 5.2.3, 5.2.4, 5.2.5, 5.2.6, 5.2.7, 5.2.8, 5.2.9, 5.2.10, 5.3.1, 5.3.2, 5.3.3, 5.3.4, 5.3.5, 5.3.6, 5.3.7, 5.3.8, 5.5.2, 5.5.3, 6.1.1, 6.1.4, 6.1.6, 6.3.1, 6.3.2, 6.3.4, 6.3.6, 6.3.9, 6.4.1, 6.4.2, 6.4.4, 6.4.8, 6.4.17, 6.5.1, 6.5.2, 6.5.3, 6.5.12, 6.5.13, 6.5.15, 6.5.17	• Load management & control and demand response including end devices, communication infrastructure and systems • Building control, automation and energy management systems • Energy communities • Electricity market • Thermal Storage • Pumped storage

	Integrated Grid					
Generation	**Transmission**	**Distribution**	**DER integration**	**Customers**	**Storage**	
Business and operation						
Cross-border market design for ancillary services (procurement of reserves, sharing of reserves, fast ramping services, frequency response, inertia response, reactive power, and voltage control)						
Business models for all actors promoting energy efficiency at the end-user level						
Operation of coupled energy systems						
	Regulatory framework to promote the use of Demand Response					
		Aggregation, market rules and mechanisms for provision of ancillary services				
					Storage in dedicated electricity networks for transportation, ancillary services provided by this	
					Thermal storage for participation in electricity and heating markets	
				Ancillary services provided by prosumers		
				System services (balancing) brought from aggregated heating and cooling devices		
		CHPs connected to district heating networks, operation through virtual power plants				
		VtG, GtV				
					Bulk storage (P2G, CAES, LAES)	
		Balancing services brought by gas network operators				
		Balancing services brought by drinking water and network operators				
	Optimal TSO-related DSR utilization					
				Flexibilization of industry (as prosumer)		

Information and communication						
		Coordination between LV and MV grids, including protocols for 5G or broadband PLC, BigData applications				
		Improved RES forecasting				
	Energy Management Platforms					
				Solutions for micro grids with islanding capabilities		
		Solutions for forecasting of aggregated load				
	Innovative control architecture and solutions for real-time voltage and balancing (frequency) control					
				Visualization and control (via protocols and standardization) of prosumers', wireless technologies, PLC, smart phones		
Component						
		LV DC grids				
					Multicarrier hybrid storage system, Power2Heat for balancing and storage, inertia of thermal loads	
					Integrated PV+Storage systems, 2nd life batteries	
					Storage systems integrated with conventional power generators	
Improved lifetime, fast cycling ability, fuel flexibility of thermal generation						
New actuators and new sensors (fault detectors, voltage and current sensors) allowing						

flexibility						
				Modular electricity system infrastructures, AC, AC/DC hybrid and DC microgrids and local storage		
				Stand-alone systems for living quarters and small/medium sized industries (P2G, P2H, P2fuels, P2chemicals)		
				Direct load control via the smart meters and/or the energy boxes		
				In-home ICT technologies, connections with smart appliances, smart plugs, voltage clamps, in-home displays, web portals, smartphone apps		

F12 Efficient carbon-neutral liquid fuels & electricity for transport in view of system integration of flexibilities						Related Technologies/Systems/Solutions
Related Research Tasks: 1.1.10, 1.2.8, 1.3.2, 2.1.1, 2.1.3, 2.1.5, 2.2.9, 2.2.10, 2.2.12, 2.2.13, 2.2.14, 2.3.1, 2.3.8, 3.1.17, 4.1.1, 4.1.6, 4.1.7, 4.1.8, 4.1.9, 4.1.12, 4.1.15, 4.1.16, 4.1.19, 4.1.24, 4.1.27, 4.2.1, 4.2.3, 4.2.4, 4.2.8, 4.2.11, 4.2.12, 4.4.5, 5.1.1, 5.1.3, 5.1.4, 5.1.5, 5.2.4, 5.2.5, 5.2.10, 5.3.1, 5.3.2, 5.3.5, 5.3.6, 5.5.1, 5.5.2, 5.5.3, 6.1.1, 6.1.4, 6.1.6, 6.3.1, 6.3.2, 6.3.4, 6.4.1, 6.4.2, 6.4.4, 6.4.17, 6.5.1, 6.5.2, 6.5.12, 6.5.13, 6.5.15, 6.5.16, 6.5.17						1. Energy communities 2. Electricity market 3. Storage Electric 4. Hydrogen & sustainable gases **5.** Other generation
	Integrated Grid					
Generation	**Transmission**	**Distribution**	**DER integration**	**Customers**	**Storage**	
Business and operation						
Business models for all actors promoting energy efficiency at the end-user level						
Operation of coupled energy systems						
	Regulatory framework to promote the use of Demand Response					
		Aggregation, market rules and mechanisms for provision of ancillary services				
		Balancing services brought by gas network operators				
					Storage in dedicated electricity networks for transportation, ancillary services provided by this	

				Tariff schemes, incentives and network regulation for EV integration		
				Ancillary services provided by prosumers		
		VtG, GtV				
	Optimal TSO-related DSR utilization					
Information and communication						
		Coordination between LV and MV grids, including protocols for 5G or broadband PLC, BigData applications				
		Management systems integration of EV charging infrastructures				
		Solutions for forecasting of EV charging loads				
		Solutions for forecasting of aggregated load				
Component						
		LV DC grids				
					Multicarrier hybrid storage system, Power2Heat for balancing and storage, inertia of thermal loads	
					Integrated PV+Storage systems, 2nd life batteries	
Increased thermal power plants flexibility for using CO2-						

neutral fuels				
New actuators and new sensors (fault detectors, voltage and current sensors) allowing flexibility				
		Modular electricity system infrastructures, AC, AC/DC hybrid and DC microgrids and local storage		
		Stand-alone systems for living quarters and small/medium sized industries (P2G, P2H, P2fuels, P2chemicals)		
		Direct load control via the smart meters and/or the energy boxes		
		In-home ICT technologies, connections with smart appliances, smart plugs, voltage clamps, in-home displays, web portals, smartphone apps		
		urban e-mobility, including e-charging stations		