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SMILE

Smart Island Energy Systems

Deliverable D7.5

Recommendations on standards and potential technical barriers

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Abstract

This report is a deliverable in the project SMILE funded by the European Horizon 2020 program.
The overall scope of SMILE project is to demonstrate, in real-life operational conditions, a set of both technological and non-technological solutions adapted to local circumstances targeting distribution grids to enable demand response schemes, smart grid functionalities, storage, and energy system integration with the final objective of paving the way for the introduction of the tested innovative solutions in the market in the near future. To this end, three large-scale demonstrators have been implemented in three island locations in different regions of Europe with similar topographic characteristics but different policies, regulations, and energy markets: Orkneys (UK), Samsø (DK) and Madeira (PT).
The report has investigated regulations and standards relevant for smart energy systems and in this context also recorded some of the technical barriers experienced during the installation and operation of the pilot sites.

The report contains mapping of relevant standards and assessment of their relevance and use. The standards are categorised in the following areas: Electricity storage, integration of heat and electricity, microgrids, balancing local grids, prosumers and aggregators, and interoperability. The report also addresses briefly relevant local regulations and European directives. In the Annex of the report a range of standards and regulations are listed.

An analysis of technical barriers met at the project pilots has been performed. The report assesses the connection between the technical barriers and the standards and regulations and discusses different possible solutions to mitigate the barriers in future projects about smart energy systems. Future European harmonisation activities are also discussed briefly. The report concludes that a few of the technical barriers can be mitigated by having relevant standards, but many of the barriers are more likely to be mitigated by implementing incentives and/or regulations on a common European level.

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Abbreviations

Table 0.1. Abbreviations

Abbreviation	Explanation
AC/ac/a.c.	Alternating Current
ANM	Active Network Management
API	Application program interface; a set of routines, protocols, and tools for building software applications. An API specifies how software components should interact and for programming graphical user interface (GUI) components.
BESS	Battery Energy Storage System
BMS	Battery Management System
CENELEC	Non-profit international association, forming the officially recognised European Standards Organisations (ESOS) together with CEN, the European Committee for Standardization and ETSI, the European Telecommunications Standards Institute
D#.#	Deliverable Within The SMILE Project
DC/dc/d.c.	Direct Current
DCC	Demand Connection Code
DSM	Demand Side Management.
DSO	Distribution System Operator
EMS	Energy Management System
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment, the EV charge point or charge station.
FCS	Frame Check Sequence
FTP	File Transfer Protocol
HTTP	Hypertext Transfer Protocol
HW	Hardware
IEC	International Electrotechnical Commission
IEC TC	International Electrotechnical Commission Technical Committee
IEC TR	International Electrotechnical Commission Technical Report
IEC TS	International Electrotechnical Commission Technical Specification
IEEE	The Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IP	Internet Protocol
ISO	International Organisation for Standardization
JPEG	Method of Compression for Digital Images
JSON	JavaScript Object Notation
MAC	Media Access Control
MS	Member State
OBD	On-Board-Diagnostics
OCPP	Open Charge Point Protocol
PNG	Portable Network Graphics
PV	Photovoltaic

RCD	Residual Current Device
RfG	Requirements for Generators
SCSM	Specific Communication Service Mapping
SES	Smart Energy System
SG	Smart Grid
SG Ready	Smart Grid Ready
SGAM	Smart Grid Architecture Model
SNMP	Simple Network Management Protocol
TCP	Transmission Control Protocol
TE	Transactive Energy
TR	Technical Regulation
TSO	Transmission System Operator
UDP	User Datagram Protocol
UPAC	Unit Of Production for Self-Consumption in Madeira, e.g., a house with a PV-system
USEF	Universal Smart Energy Framework
V2G	Vehicle to Grid
WMV	File format: Windows Media Video
WP	Work Package

1 Introduction

1.1 Scope and Objectives

The overall scope of SMILE project is to demonstrate, in real-life operational conditions, a set of both technological and non-technological solutions adapted to local circumstances targeting distribution grids to enable demand response schemes, smart grid functionalities, storage, and energy system integration with the final objective of paving the way for the introduction of the tested innovative solutions in the market in the near future. To this end, three large-scale demonstrators have been implemented in three island locations in different regions of Europe with similar topographic characteristics but different policies, regulations, and energy markets: Orkneys (UK), Samsø (DK) and Madeira (PT).

This document will address standardization requirements and recommendations relevant for the SMILE demonstrators and their goals set out to achieve utilizing the installed technological solutions and the demand side management (DSM) methods. This report, forming deliverable D7.5, analyses relevant standards and potential technical barriers to implementation, replicability and interoperability of solutions identified in the project. This information is relevant for future smart energy systems to exploit renewable energy resources better.

Within this framework, the document *map and analyse relevant technical regulations in force (i.e. locally enforced regulations, standard interfaces, grid codes and any recommended norms/standards and security measures for "smart" grids applicable to the three demonstrators in DK, PT, UK and to some extent in GR also)* by focusing on:

- Presentation of existing relevant standards and regulations on smart energy systems such as the systems demonstrated on the pilot sites in SMILE.
- List the experienced and potential technical barriers identified for smart energy systems.
- Some recommendations for further work in harmonisation activities through local regulations and standardisation regarding electric energy storage and DSM.

This work will focus on standards relevant on system integration level more than component design level. The selection of relevant standards will be based on relevance for pilot sites and similar systems. This work will thereby not cover all types and sizes of energy systems and the focus will be on European standards and norms primarily.

This report is based on the practical implementation of system solutions and analysis by the project's island-partners: Portugal, UK, Denmark and Greece. European and national legal provisions will be referenced in general terms and relevant standards will be mapped and discussed. The SMILE reports[1] D7.1, D7.2, D7.3 and D7.4 cover relevant regulations in detail.

This document focuses on a subset of the complete energy framework, where DSM is directly relevant. With reference to the Smart Grid Architecture Model (SGAM) this document will focus on the domain *customer premises*, herein consumers and prosumers, as the SMILE demonstration sites lies in this category. This covers electrical loads, local small-scale generation, and small to medium-sized storage. This framework covers distribution and transmission network on a very general level only and does not cover bulk power generation. The focus is on technical aspects for smart energy systems, but also (lack of) market mechanisms are touched briefly in relation to barriers for some areas.

[1] https://cordis.europa.eu/project/id/731249/results

1.1.1 Definition of terms

Extract from task description of SMILE Task 7.5:

> *Mapping at all three demonstrators will include locally enforced regulations, standard interface, grid codes and any recommended norms/standards and security measures for "smart" grids.*
> *Also, auxiliary and flexibility services requested and recognized locally including primary, secondary and tertiary control reserves and any operational framework for aggregators, storage, prosumers etc will be mapped.*
> *Recommendations based on the lessons learned and essential identified compliance gaps against e.g. the principles of the European Smart Grid Task Force work will be fed into the ongoing European harmonisation activities*

Ancillary and flexibility services:
Ancillary services are services that support the electric grid e.g., frequency reserves used to keep the grid frequency stable. A series of ancillary services already exist, especially on transmission level e.g., frequency stability and restoration services.
The terms ancillary services and auxiliary services are used interchangeable.
Flexibility services are services that enable e.g.

- increased use of variable production from renewable energy,
- increasing electricity demand by the consumers,
- more prosumers and distributed energy resources to be connected to the grid
- sector coupling e.g., integration of heat and electricity.

Buffering energy through storage can be a flexibility service, but also advancing or postponing consumption (DSM) can be a flexibility service.

Compliance gaps:
Compliance gaps are areas where a product does not fulfil the expected specific requirements or does not support a specific technology, software, communication protocol or similar.

Grid codes:
Local or National technical requirements that must be met when connecting to the public grid.

Locally enforced regulations:
Regulations that are implemented and active at a local level.

Operational framework:
Guideline to a company's procedures, standards, methodologies, and processes. It describes how a company works.

Recommended norms/standards
Norms and standards recommended by local, national, or European authorities or standards recommended by technical professionals.

Security measures:
Steps or actions taken to prevent criminal acts, terrorism, espionage, and sabotage. In this report especially for energy systems and especially cyber security for communication. Safety measures are

differentiated from security measures by being about the measures taken to minimize the risk of hazards and danger to equipment and personnel.

"Smart" grids:
Electricity grids with possibility of bidirectional energy flow and with a high level of sensors and management.

Standard interface:
Physical, electrical, mechanical, and digital interface between components/devices/actors/plants which is of common use or standardized through standards, technical recommendations and/or regulations.

1.2 Structure

The report contains firstly an introduction and understanding of the terms *replicability* and *interoperability*. Afterwards, mapping of technical barriers met during the SMILE project is presented as well as relevant standards, regulations, and directives. At the end, pilot particulars from the mapping are highlighted and the connection between the technical barriers are discussed and formed into recommendations for the European harmonisation activities.
Beside this report, deliverable D7.5 includes an Annex where the mapping of relevant standards, local regulations, European regulations/directives is reported.

Section 1 introduces the topic and describes the deliverable's structure and relationship with other deliverables in the SMILE project.

Section 2 clarifies the difference between regulations, directives, standards and similar terms used in this report and the legal status of the documents.

Section 3 provides understanding of the term interoperability and identifies and analyses technical barriers met during the SMILE project.

Section 4 maps the standards and regulations. This section covers the following six areas:
- Position of electricity storage in the energy chain
- Integration of heat and electricity
- The concept of microgrids
- Balancing local grids
- Prosumers and aggregators
- Interoperability

Section 5 describes how standards and regulation have been used or could potentially be used on the three demo sites and Greek Islands to help avoiding technical barriers for implementation and operation of smart energy systems.

Section 6 discusses barriers experienced during the SMILE project and possible solutions.

Recommendations for European harmonization activities are presented in section 7 and a conclusion is reached in section 8.

1.3 Relationship with other deliverables

Input from partners that have participated in the technical activities in the three demonstrators have been used in this deliverable when mapping standards and regulations and assessing the relevance and the use. Information about the legal regime for storage, integration of heat and electricity, microgrids and balancing local grids has been provided by deliverables D7.1, D7.2, D7.3 and D7.4.
Deliverable D8.5 has delivered information on barriers through a questionnaire answered by the partners.
This deliverable will provide knowledge about technical barriers to deliverable D9.5 about replication.

Table 1.1. Deliverables in SMILE with relation to this report, deliverable D7.5

Deliverable Number	Deliverable Title	Type	Dissemination level
D7.1	Regulating Electricity Storage	Report	Public
D7.2	Integrating electricity and heat supply systems	Report	Public
D7.3	Developing microgrids in the EU	Report	Public
D7.4	Balancing local grids	Report	Public
D8.5	Policy strategy recommendations	Report	Public
D9.5	Replication plans for all individual technologies	Report	Public

The above report can be found at the following link:
https://cordis.europa.eu/project/id/731249/results

2 Definition of standards, regulation etc.

It is important to clarify the level of bindingness of all the instruments to be mentioned in this deliverable, from directives to standards. Directives (such as the 2019 Electricity Market Directive [1]) are binding. Their provisions have to be transposed by Member States in their own national laws and regulations within a defined timeframe. Regulations (such as the 2019 Electricity Market Regulation [2]) are binding too. They directly apply in all Member States, without the need to be transposed in national law. Network codes or Grid codes (such as the Requirements for Generators (RfG) network code [3]) are also binding in EU law. Indeed, they are adopted via regulations, giving them direct legal bindingness. Some network codes are also adopted at a national level. Their level of bindingness depends on their adoption procedure. If adopted as a regulatory document or as mandated in a regulatory document, then they will inherit from its bindingness. For instance, Technical Regulation 3.3.1 on electricity storage in Denmark is adopted by the national TSO (Energinet) in application of an executive order, therefore getting the same bindingness level [4].
In Portugal, both decreto-lei (decree law) and decreto regulamentar regional (regional regulatory decree) are binding. The decree law is adopted at a national level by the government but most likely after an authorisation and/or with a validation from parliament (then it takes the level of a law, not only a decree). The regional one is adopted by the regional government and therefore will apply in the related region (in our case Madeira).

Standards differ from the above-mentioned instruments. They are “non-binding non-legal norms” [5], created by private actors, often by experts grouped in non-governmental organisations [6]. One such body is the International Organization for Standardization, developing the ISO norms, referred to later in this report. Another one, specialised in electricity and used extensively in this report is the International Electrotechnical Commission (IEC). Standards are not binding. Actors (especially producers of goods and providers of services) can decide to follow them or not. However, aside from the economic pressure to follow standards, there can be a legal incentive too. In technical fields, such as electricity, the legislation often integrates or directly refers to standards, providing them with the same bindingness level as law, and can task the public regulator to monitor and enforce the use of such standards [5] [6]. In EU law, the 2019 Electricity Market Directive and Electricity Market Regulation as well as various network codes explicitly request from Member States, national regulators and grid operators to take standards into consideration [7]. The European Commission can also request from a recognised European Standards Organisation (such as CENELEC) to create what is called a “harmonised standard”. These standards remain voluntary in their application, but they benefit from the fact that they aim to be the reference standard in the EU. As it is, there is one harmonised standard on energy efficiency and five such standards on Electric and electronic engineering [7]. Finally, other terms are sometimes used, such as (industrial) norms, but they essentially follow the same logic as standards.

3 Potential technical barriers for replicability and interoperability

This section describes some of the potential technical barriers for replicability and interoperability experienced in the SMILE project. The term *technical barriers* will cover [8]

- Challenges and barriers caused by technical aspects during the project
- Uncertainties in/missing technical definitions met during the project
- Unclear and/or missing standards about technical solutions

3.1 Understanding of interoperability

Interoperability is a broad concept that can be used in many contexts and with many interpretations. In the context of the SMILE project, *interoperability* is used to describe system components' ability to work together properly and coexist (stay connected to the same grid and the same communication networks) with other equipment without disturbing these. A definition for *interoperability* by the European Union is:

> ***'interoperability'** means, in the context of smart metering, the ability of two or more energy or communication networks, systems, devices, applications or components to interwork to exchange and use information in order to perform required functions;* [9]

Standards are normally the means to ensure interoperability. But the standards must cover all layers of communication and functions. Data transfer may take place via proven technology as e.g., RS232, RS485, CAN, TCP/IP or even application-level formats as Modbus. However, this does unfortunately not ensure interoperability or suitability for replication and scale-up. Proprietary communication and algorithms can exist even on open platforms like e.g., Raspberry Pi or even Microsoft Azure. In the SMILE pilots many different communication media and formats are used and DSM controls are implemented in several different ways, and some are not fully open domain.

3.1.1 Compatibility levels [8]

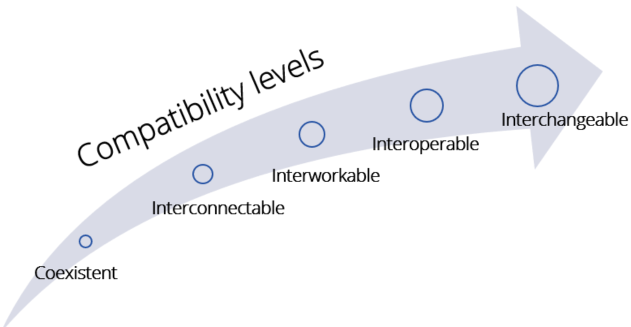
Interoperability can be seen as a level of compatibility, where incompatible is the lowest level and interchangeable is the highest level. Interoperability will lie somewhere in between, see Figure 3.1.

The definition of terms is important to have a common understanding of what we are dealing with. We use the basic terms Interoperability and Conformance as two different, but also linked definitions. **Conformance** determine whether a component or system meets the required specification or standard. Compatibility requires conformance to the same standard or set of requirements.

There are several levels of **Compatibility** based on the ability for a given component or system to be compatible with another component or system of a different type (vendor).
The matrix in Figure 3.1 illustrates the definition of compatibility levels versus the technical interface for a given component or system. Two components can be defined as 'Interconnectable' if the physical interfaces match (connectors) and the protocol interfaces match (Ethernet and TCP/IP) – but they do not use the same service interface (REST vs. OPC UA). So basically, they can 'see' each other on a network and coexist, but they are not able to work together or be 'Interworkable'.
Interoperability is defined as the ability for components and systems to co-exist and operate together from a physical, logical, and operational point of view.

The six different compatibility levels (more details follow after the figure):

1. Incompatible
2. Coexistent
3. Interconnectable
4. Interworkable
5. Interoperable – requires the same physical interface, protocol interface, service interface and information interface (communication protocol and interface, data access, data types, parameter semantics and application functionalities (not same dynamic behaviour)).
6. Interchangeable – requires the same physical interface, protocol interface, service interface, information interface and application interface.



Device feature	Incompatible					
Dynamic behaviour						X
Apllication functionality					X	X
Parameter semantics					X	X
Data types				X	X	X
Data access			X	X	X	X
Communication interface			X	X	X	X
Communication protocol		X	X	X	X	X

Figure 3.1. IEC TC65: INDUSTRIAL PROCESS MEASUREMENT AND CONTROL. TC65 has made a 'Device Profile Guideline' where they define five compatibility levels based on conformance to the different levels of device features.

Incompatibility

Incompatibility is the inability of two or more devices to work together in the same distributed application. Incompatibility can result from differences in application functionality, data semantic, data types, and communications interface, or even communications protocols used by the affected devices. Incompatible devices may even interfere with or prevent each other's proper communication or functioning (possibly even destructively), if placed in the same distributed application network.

Coexistence

Coexistence is the ability of two or more devices, regardless of manufacturer, to operate independently of one another at the same communications network, or to operate together using some or all of the same communications protocols, without interfering with the functioning of other devices on the network.

NOTE: no agreement needs to exist regarding the communication services.

Interconnectability
Interconnectability is the ability of two or more devices, regardless of manufacturer, to operate with one another using the same communication protocols, communication interface.
NOTE: the devices allow data exchange without agreements about the data types. A data type conversion may be necessary.

Interworkability
Interworkability is the ability of two or more devices, regardless of manufacturer, to support transfer of device parameters between devices having the same communication interface and data types of the application data.
NOTE: if a device is replaced with a similar one of a different manufacture, it can be necessary to reprogram the application.

Interoperability
Interoperability is the ability of two or more devices, regardless of manufacturer, to work together in one or more distributed applications. In case of replacement with a similar device of any manufacture, all distributed applications involving the replaced device will continue to operate as before the replacement, but with possible different dynamic responses. Interoperability is achieved when both a field device and a system support the same combination of mandatory and optional parts of the same standard.
NOTE: Manufacturer-specific extensions in field devices or systems from different manufacturers may prevent interoperability.

Interchangeability
Interchangeability is the ability of two or more devices regardless of manufacturer to work together in one or more distributed applications. The devices will be using the same communication protocol and interface. The data and functionality of each device is defined so that any distributed applications involving a replaced device will continue to operate as before the replacement, including identical dynamic responses of the distributed applications.

OSI model - Open Systems Interconnection Model
The function on each layer is depending on the services of the below layers. Replicability through open domain application require all the supporting services to be open domain also or at least globally available for open domain applications.

Table 3.1 Description of layers in OSI model

Layer No.	Layer	Data unit	Protocol (examples)	Function (examples)
7	Application	Data	HTTP, SNMP, FTP	High level APIs, Remote file access
6	Presentation	Data	WMV, JPEG, PNG	Translation, incl. encoding, compression and encryption of data between a networking service and an application
5	Session	Data	Connection Management	Managing Communication sessions, e.g. information exchange between nodes
4	Transport	Segment, Datagram	TCP, UDP	Transmission of data segments between network points (including segmentation, acknowledgement, multiplexing)

3	Network	Packet	IP	Addressing, routing and traffic control on a multi-node network
2	Data link	Frame	MAC, FCS	Physical layer transmission of data frames between two nodes
1	Physical	Bit or symbol	Data encoding, coax, wires	Raw bit streams transmission and reception over a physical medium

Figure 3.2 illustrates that communication between higher levels can only happen through the lower layers with an example of application data (YouTube). To replicate the application elsewhere the main application must be suited for replication and scalability and moreover, access is needed to all the sub-functions and services.

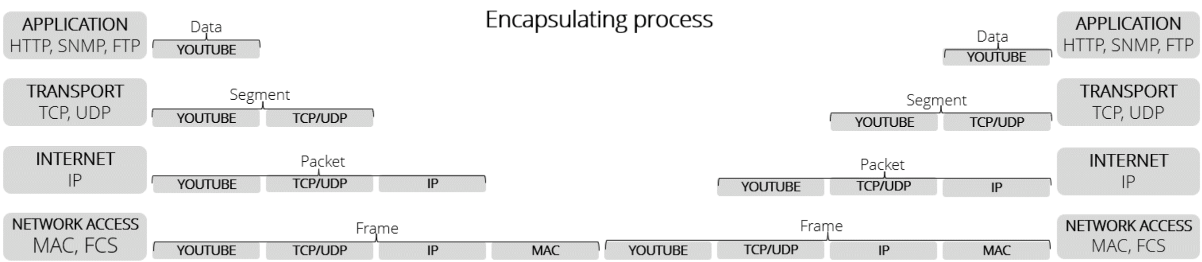


Figure 3.2 Encapsulation example of application data (YouTube), illustrating that communication between higher levels can only happen through the lower layers. [10]

3.1.2 Smart Grid Architecture Model (SGAM)

To give a better understanding of how interoperability is used in this framework, the Smart Grid Architecture Model (SGAM) is used. SGAM is a three-dimensional model with the following dimensions:

- **Domains**: Identify a set of roles associated with 5 different areas of the energy grid
- **Zones**: Represent the six hierarchical levels of power system management
- **Layers**: Represent the five aspects of information exchanges.

The model is shown in Figure 3.3, where red areas illustrate which domains, zones and interoperability layers this framework covers. The focus of interoperability in this report lies in the customer premises domain. This domain covers all kind of consumers – industries, households, harbours, communities etc. – and prosumers with local small-scale electricity production for self-consumption.
This framework will look at all interoperability levels, but only the lowest zones are covered (process, field, station, and operation).
Figure 3.3 details how the model is applied to SMILE and which areas of SMILE that is contained in each field of the model.

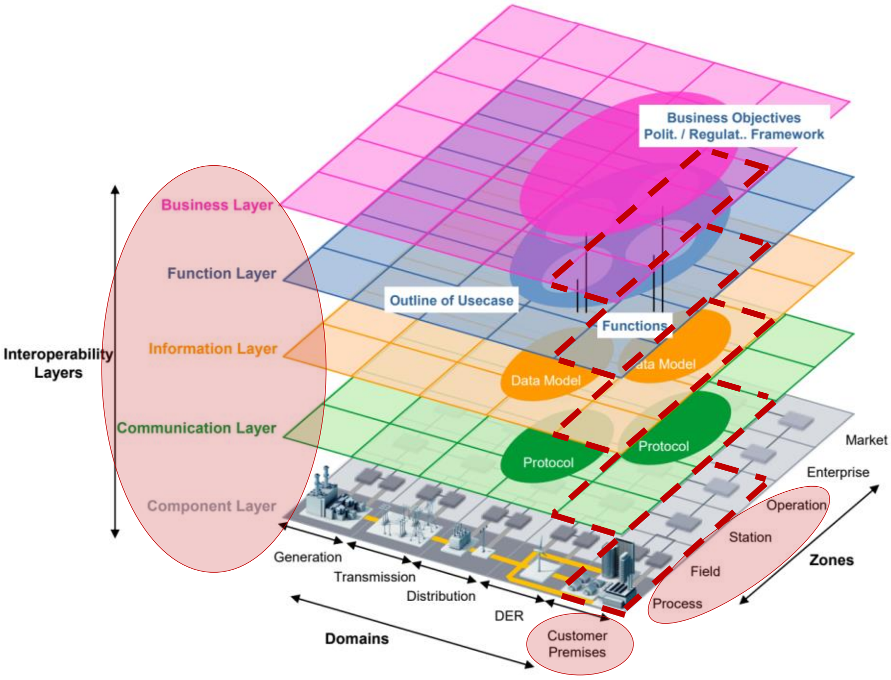


Figure 3.3: Smart Grid Architecture Model (SGAM). Red areas are those covered in this framework. The figure originates from the European Mandate M/490 Smart Grid Mandate Standardization Mandate to European Standardisation Organisations (ESOs) to support European Smart Grid deployment: CEN-CENELEC-ETSI Smart Grid Coordination Group Smart Grid Reference Architecture [11].

Table 3.2. Short generic descriptions of the SGAM supplemented with some examples from the SMILE project for the domain "Customer premises".

Zones / Layers	Process	Field	Station	Operation
Component layer	Physical network infrastructure between loads, storages (BESS and heat storage), EV chargers and generators. Example: OVO platform use a VCharge Dynamo-unit as hardware interface to local heater equipment.	Physical network infrastructure for control and monitoring equipment. Example: VCharge Dynamo-unit use Wi-Fi for connection to communication infrastructure.	Equipment and infrastructure for local SCADA and supervision. Example: Router with Wi-Fi	Physical network infrastructure: Example: broadband interface to internet-router

Communication layer	Protocol for loads, PV, EV chargers, thermal storages and BESS	Protocol for BMS, meters and control units	Protocol e.g., for LiBal data cloud	Communication protocol for energy management system e.g., for the OVO load controller/ aggregator platform
Information layer	Naming of collected data	Naming of collected data	Structure and naming of data in cloud	Naming of collected data
Function layer	Interpretation and dissemination of data	Interpretation and dissemination of data	Interpretation and dissemination of data	Interpretation and dissemination of data. E.g., Route Monkey forecasts and OVO load controller/ aggregator platform
Business layer	Map standards and regulations. Example: OVO platform can quantify flexible energy potential for trading	Map standards and regulations	Map standards and regulations	Map standards and regulations. Example: OVO energy company can trade flexibility in form of energy

One step against interoperability is to ensure that interfaces between zones are standardised. This includes the physical dimension illustrated in the component layer of SGAM and the communication protocol in the communication layer. Interoperability cannot be achieved if e.g., the communication protocol is unique for each zone or each domain. To achieve a fully functional smart energy system all these interfaces need to be aligned in each interoperability layer.

3.2 Replicability

To have replicability of a system it is important to have proper documentation of the used solutions. Moreover, replicability requires uses of common available technologies and interoperability of solutions. Interoperability of solutions is necessary if a solution shall be able to implement in a new location with different infrastructures, networks, and physical boundaries than originally. Interoperability can be obtained by using standardised solutions and technologies especially for interfaces between components.

This deliverable does not focus on whether the implemented systems are replicable or not, but rather on potential barriers for replicability. SMILE Deliverable D9.5 assesses the replicability of the system solutions developed in SMILE.

3.3 Technical barriers met during the SMILE project

This section presents technical barriers met during the project. The technical barriers are collected from the partners of SMILE and their experiences are described. Technical barriers, in this context, are factors that complicates or hinders the proliferation of smart energy systems.

3.3.1 Mapping of technical barriers

A mapping of technical barriers met during the project has been made and the results are presented in this section. The barriers have been collected at workshops with the partners contributing to Task 7.5 and with input from a questionnaire made in Task 8.5. The barriers are summarised in Table 3.3.

The technical barriers are categorised in three groups consistent to the use in D8.5[2]:

- Infrastructure, grid and HW (hardware)
- Citizen's engagement
- Ownership of SES (Smart Energy System)

Moreover, it is assessed whether the barrier is a barrier for implementation of smart energy systems (SES), for replicability or for interoperability. Technical barriers for interoperability will also be barriers for replicability.

Table 3.3. Mapping of technical barriers met during the project period

Technical barriers	Applies to	Barrier for:	Possible solution
Remote access / unstable Internet connection limits or inhibits both cloud-based SES and local smart control using external status information like e.g., weather-forecast or price-forecast.	All	Implementation of SES	Regulation to improve the available internet e.g., by increased density of connection points. Or incentives to private customers to invest in better internet to improve internet at domestic level
Many charging points are incompatible with OCPP 1.6 (does not conform to the full standard). Causes issues with implementation and cyber security	Orkney	Interoperability	Standard/norm for conformance test
Shortcomings in EVs communication with smart chargers - Mode 3 AC. E.g., lack of charge status from the vehicle inhibits optimisation of charging.	Madeira	Interoperability	EU regulation to require that needed information is available
Difficulties in finding the applicable standards to energy systems and its components complicates the design phase and implementation	All	Interoperability	Information

[2] https://cordis.europa.eu/project/id/731249/results

Different data format e.g., time format, makes analysis and data handling difficult	Samsø	Interoperability	Too many standards – need harmonisation
Lack of communication between technology providers and between their technologies	All	Interoperability	Incentives for cooperation and too many standards
Lack of literacy in terms of distributed energy generation and energy efficacy limits the citizens engagement and support	Madeira	Replicability	Information
Little incentives for anyone to tie domestic energy systems into a smart grid means that technologies installed must just meet the home's requirements without consideration of the rest of the grid/system.	Orkney	Interoperability	Incentives
Electrical grid constraints make it hard to foster optimal operation of energy systems from prosumers perspective as coordination with the grid operator is needed and they might have conflicting goals	Madeira	Implementation of SES	Incentives
Limited options for hot water storage in households as only few mature technologies exist	Orkney	Implementation of SES	Incentives for development of new technologies
Rigid DSO-limit on export power to ensure an acceptable voltage quality at low substation load.	Samsø	Implementation of SES	Incentives for e.g., flexibility market/services
Cables to mainland are operating close to maximum capacity.	Samsø & Orkney	Implementation of SES	Incentives for e.g., flexibility market/services
Grid reinforcements are needed somewhere to support the grid if the control mechanism of the smart grid fails.	Orkney	Implementation of SES	Incentives for e.g., flexibility market/services or expansion to promote RE, regulations about back-up systems or about actions when e.g., internet fails in a larger area
Many houses are not suited for domestic-scale heating and hot water smart energy systems due to age of building and lack of sufficient insulation.	Orkney	Implementation of SES	Incentives
Integration of energy surplus in the public grid will lead to high costs of re-sizing of components (lines/cables, transformers, etc.)	Madeira	Implementation of SES	Incentives for e.g., smart grids, flexibility market/services or expansion to promote RE
Some cars are incompatible with OBD which means that there will be a lack of access to car data	All	Interoperability	Regulation

Support from technology providers can be difficult in some geographical areas (rural areas)	All	Implementation of SES	Incentives
Technical grid compliance differs from region to region which makes it difficult to design systems that fit all electrical regions in Europe	All	Replicability	Incentives to standardise the format of requirements
A payment system that is so complex and technical, that some people refuse to use it cannot be used for DSM-incentives.	Samsø	Implementation of SES	Incentive
BESS at Samsø initially tripped the residual current device (RCD) in the distribution board and installation of an expensive and inefficient isolation transformer was necessary	Samsø	Interoperability	Standard
Lacking acquisition of consumption/production data from UPACs (quality of the installation) has complicated the preliminary analysis and design	Madeira	Implementation of SES	Incentives, standards, and regulations
Grid codes are based on centralised generation and not suited for distributed generation, bidirectional power flow and prosumers	All	Implementation of SES	Regulations

3.3.2 Analysis of technical barriers met in the SMILE project

Grid constraints

On Samsø Ballen Marina there is a limit on the export of electricity to the grid set by the local DSO to avoid potential overvoltage of other installations on the same substation. This limit does not prohibit increasing the PV-production capacity or sizing up the BESS but excess PV-power that cannot be utilised in the Marina or stored in the BESS is wasted since it cannot be sold to the grid.

On the island of Samsø there are two transmission lines to Jutland, but they are operating close to maximum most of the time due to wind generation at Samsø. This can in the future become a barrier on increasing renewable production on the island unless at least smart controls of flexibility are implemented.

On Orkney and Madeira too, there are some grid constraints which inhibit the implementation of e.g., distributed energy resources. The grid on Orkney is connected to mainland Scotland and these power lines are already congested so that wind generation on Orkney must often be curtailed.

On Madeira there is no transmission line to mainland to help the local grid on the island. For grid-quality and stability reasons prosumers could not sell excess PV production to the grid before a new decree law came into force in 2021 (DLR 1/2021). With the implementation of the network grid code and regional legislation (DLR 1/2021) this limitation/constraint has been overpassed. Now prosumers can sell the excess to the low voltage grid, they just need to establish a bilateral contract with the local DSO EEM, and the installation must fulfil all the grid-code requirements. The hope is that SES for homes and electric vehicles can postpone investments in grid reinforcements on Madeira.

According to the SMILE partners, constraints on the electrical grid has been a barrier on Madeira. Grid constraints limit the opportunities for optimization of operation of the energy systems as it creates a need for coordination between the grid operator and the energy management system. If grid injection is limited or non-existing the optimization comes down to increasing self-consumption. To mitigate this issue, digital twins have been used to evaluate strategies that consider more advanced aspects for energy management such as energy arbitrage.

It will be necessary to reinforce the public grid at some points to support the grid if the smart management system fails. As reinforcements can be rather expensive this is not necessarily prioritised by the operator. These challenges incentivise smart energy systems but can at the same time constitute barriers for implementation of the most effective solution. A barrier for implementation of smart energy systems is that integration of surplus energy in the grid requires resizing of components such as transformers, cables etc., which can have high costs. This barrier is particularly relevant for Madeira since, given its isolated nature, an increase in RES penetration requires the upgrade of the grid infrastructure to ensure the power system's stable operation. Since grid injection was not possible, many of the installations have been curtailing the excess production. Therefore, it was not possible to measure the full production. In order to mitigate this barrier, especially permissions for grid injection had to be issued by the DSO (after testing the micro-production installations).
These barriers are not barriers for interoperability but can be barriers for replicability in other locations with similar constraints.

Another important barrier is the general view of the grid and the grid topology, as the grid is primarily seen as a "supply grid" rather than an infrastructure for bidirectional power flow, prosumers, and distributed generation. The existing directives and grid codes are only starting to integrate prosumers, energy communities and other new actors and mixed roles and moving from an approach divided between producers and consumers as separate groups.

Fall back system
When there is a communication failure to one or more controllable assets, there is a need to have a coherent approach on fall-back control mechanisms. The communication failure can be due to unstable internet, which all SMILE pilots have experienced, but it can also be due to hardware failure on components, firmware updates or loss of power. On Madeira and Samsø the BESS systems default to optimised self-consumption if communication with the installation is lost. On Orkney the heat-storage can discharge as needed but recharging will require remote control via internet.
It is a technical and economical barrier for implementation of smart energy systems if there is need for redundant systems.

EVs and charging
To optimise EV charging from the grid it is essential to know the charge-status of the vehicles. There is no standard for getting access to this information but in most cases the information can be accessed via the On-Board-Diagnostics (OBD) connecter that all internal combustion engine (ICE) vehicles must have. Many electric vehicles are compatible with OBD, but not all. This makes it more complicated to communicate with the cars and it is a barrier for implementation of smart charging systems. Route Monkey uses OBD to get information about e.g., the battery SOC. Smart charging is part of the smart energy management system and therefore data exchange between charging station and car is required to implement a smart energy system. As car manufacturers use proprietary diagnostic methods, it creates a barrier for interoperability between the charging stations and the smart energy system management.

Another barrier has been the communication between the EVs and the chargers (Mode 3 AC). There is currently no requirement for an EV to communicate charge-status to the charger for Mode-3 AC charge but for Mode-4 DC the data is exchanged. In Madeira it was necessary to develop an EV charging infrastructure from scratch to mitigate this issue.

Internet

All three SMILE demonstrator islands Madeira, Orkney and Samsø has experienced unstable internet, which is a barrier for implementation of a smart energy system. Reliable communication coverage is needed for smart energy systems. Internet is a severe issue at Orkney.

In order to allow communication between the different components of the system (EMS, monitoring equipment installed on-site and XOLTA BESS Cloud), a stable internet connection is a requirement. Optimising EV-charging and self-consumption with or without energy storage requires access to real-time data, lack of stable internet connection is a practical barrier for optimal function. For this reason, in some cases, the local partners had to improve the existing communication infrastructure by installing dedicated networks (through 4G routers or 3G sim card), hence adding to the costs of the solution. Yet, with the advent of 5G and Wi-Fi 6 it is expected that these issues become less frequent, but probably not eliminated.

For the residential cases especially houses with thick walls are challenging to work inside. Orkney has tried to overcome the bad internet connection by using sim cards with 4G, but they could neither ensure a reliable mobile signal.

The amount of data to be transferred is not often an issue in densely populated areas but exchange of redundant data can be both a practical issue when the bandwidth is limited and an economical issue when there is a payment per amount of data. Requiring large amounts of data frequently to improve a control algorithm may directly cause bottlenecks in database servers – Xolta/Lithium Balance has experienced this issue with their database in the SMILE project.

Support by technology providers

Support from technology providers is dependent on geographical location and remote areas are not prioritized by them. This makes implementation of smart energy systems rather difficult in remote areas, as many different providers are involved in such systems. This issue has been a real barrier at Orkney, where some of the pilot installations are located on islands with less frequent transport options – ferry connection once per day or every second day. When there is an issue with the internet or an equipment, it is very difficult to persuade a technician to visit the site, since it may take three days to fix an issue that would take ½ an hour elsewhere. This geographic barrier can make any small issue a major challenge.

Grid code compliance

Grid compliance differs from country to country, which is a challenge when designing systems e.g., power converters, that shall be able to comply with many locations. The different requirements can be about harmonics, power quality and reactive power compensation.

Heat and electricity integration

The integration of heat pumps has been challenging and the solution has ended up being proprietary and thus less suited for replication. Sunamp has developed control algorithms focusing on a high degree of independency from the systems they are used in together with a simple interface to be compatible and interoperable with many kind of systems.

Moreover, many houses are not suited for domestic-scale heating and hot water smart energy systems due to age of buildings and their (lack of) insulation level. This is a technical barrier for implementation of smart energy systems rather than a barrier for interoperability.

Communication and data

On Samsø the format of the collected data differs with the different technology providers which makes data analysis more complex. This can be a technical barrier for successful replicability as data availability is a good basis for replicability.
Closed loop operation via cloud is cumbersome with different data formats, as it requires ability of the next link in the communication chain to read the data format.
On Madeira the developed Energy Management System (EMS) supports multiple data formats, which helps to mitigate this issue. Still, it is a very relevant aspect particularly when interfacing with smart meters from different brands.
Operation with different data formats is a barrier for interoperability.

Communication between different technologies can be a challenge.
In order to mitigate the latter barrier, the PRSMA EMS (the backbone of the Madeira demonstrator) was designed to be input-agnostic, thus highly compatible with different third-party systems. However, to ensure interoperability, third-party systems should comply with minimum requirements (e.g., support communication through the MODBUS protocol in the case of smart-meter providers).

Due to grid constraints on Madeira, it is complicated to foster optimal operation of energy systems from the prosumer's perspective, as the management should be coordinated with the grid operator. Conflicting goals between different actors can be a barrier for implementation of smart energy systems.

In the early stages of the project, 2017, only a few Madeira UPACs had access to historical data. As such, data analysis at scale (i.e., with all the participants) has not been possible before all the installations were concluded. This barrier is primarily a barrier for implementation and replication of smart energy systems, as access to historical data will help when planning and designing the system. It will also allow investors to assess benefits of the initiatives.

Some of the UPACs recruited on Madeira have been dropped because of the poor installation of the photovoltaic systems or because it has not been possible to install the SMILE metering system (needed in those units that did not have one). The latter issue was mainly due to the installation of the so-called plug-and-play solar systems, which are not connected to the main electricity board but instead to a socket. This have limited the acquisition of consumption and production data from the UPACs. The experience of poor installations is a barrier for replicability, as it will not make sense to install similar systems elsewhere.
Data collected from UPACS are noisy due to the battery inverters and therefore not suited for data analysis, e.g., used for remote capacity tests of the battery systems. This is a barrier for proper operation and analysis of the system rather than for implementation, interoperability nor replicability.

Citizen engagement

The payment procedure at Ballen Marina, Samsø is rather complex and technical. However, only a small fraction of the tourists may choose not to return to the marina in the future for this reason. Some boat owners refuse to use the payment system as not everyone uses a credit card. Yet, all boat owners can pay manually in the harbour master's office during opening hours if they prefer. This is a barrier for citizen engagement in DSM but not a barrier for interoperability nor replicability.

At Madeira there is a general lack of literacy on existing technologies and energy efficiency practices. This could reduce adoption and effectiveness of the solutions being tested and could potentially be a barrier for replication in other locations with similar lack of literacy. This lack of literacy was particularly challenging when explaining the rationale behind the selection of the UPACs that would receive batteries.

The optimal use of distributed generation and smart grid technologies also depends on consumer knowledge and behaviour.

4 European and national standards, norms and regulations

The section gives an overview of European and national regulations and standards relevant for the following subjects in the context of SMILE:

1. Electricity storage
2. Integrating electricity and heat supply systems
3. Microgrids
4. Balancing local grids
5. Prosumers and aggregators
6. Interoperability

The national and regional regulations for bullets 1-4 are covered in detail in SMILE deliverable D7.1-D7.4[3].

4.1 Mapping of relevant standards and norms

This section describes how the relevant standards are organised in the context of this report and how standards are selected and prioritized. Moreover, it gives a qualitative analysis of some of the relevant standards seen in SMILE-context.
Standards covering general practice when working with electrical installations e.g., about safety and EMC, are not mentioned here but are obviously relevant and is considered general knowledge for qualified installers of such equipment. Instead, this report focuses on standards specifically relevant for the pilots and similar systems in the SMILE project.
Standards found and presented in this task focus on system level installation methods and precautions e.g., grid connection and interfaces, physical as well as digital. The standards are covering technical aspects of the following subjects:

1. Electricity storage
   - Battery energy storage system (BESS)
2. Integrating electricity and heat supply systems
   - Heat storage systems
   - Heat pumps
3. Microgrids
4. Balancing local grids
   - Flexibility services
5. Aggregators and prosumers
6. Interoperability
   - Communication
   - Security measures for smart grids
   - EV charging

The mapping does not only cover standards by standardization organizations but also industrial norms, labelling scheme, and market frameworks e.g., Universal Smart Energy Framework (USEF).

[3] https://cordis.europa.eu/project/id/731249/results/

4.1.1 Standards and norms concerning electricity storage

In this section standards regarding electricity storage are covered. This includes standards covering electricity storage design, safety of personnel, fire hazards, chemical hazards, grid connection etc. in relation to electrical storage. Standards about electrical installations, EMC, short circuit calculations and similar are not included, but are applicable in the EU including all pilot sites. Instead, the focus is on standards especially relevant for application with electrical storages.

The IEC 62485-5 series is covering safety requirements for stationary lithium-ion batteries, which is relevant in SMILE as all the developed and installed BESS's consist of lithium-ion batteries and are used in a stationary application.
A new standard-family, including IEC 62933-5-1 and -2, has been issued after the project started, and it describes safety considerations for grid integrated electrical energy storage systems. This includes among others electrical, mechanical, explosion, fire, and temperature hazards.
IEC 62619 is also about safety requirements for secondary cells (rechargeable battery cells) but for industrial applications. This standard is relevant when choosing battery modules for a BESS as the batteries should comply to this to be safe to operate.
Partners of SMILE have mentioned BS 7671 as relevant for the project. That is why it is included even though general requirements for electrical installations are out of scope of this report. This standard is a British standard and therefore only relevant for the UK. There are similar standards on European level and on national level for the other pilots e.g., the IEC 60364 series.
Some of the relevant standards for SMILE under this subject are presented in Table 4.1.

Table 4.1. Some of the relevant standards concerning the position of electricity storage in the energy chain

Standard nr.	Name
IEC 62485-5	Safety requirements for secondary batteries and battery installations - Part 5: Safe operation of stationary lithium-ion batteries
IEC 62933-5-1	Electrical energy storage (EES) systems - Part 5-1: Safety considerations for grid-integrated EES systems - General specification
IEC 62933-5-2	Electrical energy storage (EES) systems - Part 5-2: Safety requirements for grid integrated EES systems - electrochemical based systems
IEC 62619	Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications
BS 7671 - 18th Ed.	Requirements for electrical installations (for UK installations only)

4.1.2 Standards and norms concerning integration of electricity and heat supply systems

Standards concerning integration of electricity and heat supply systems are covered in this section. The list includes standards about heat pumps and thermal storage for households.

In Germany it is common practice that heat pumps are certified as Smart Grid Ready (SG Ready) [12]. This label certifies that the heat pump has a specified control technology consisting of a two-bit signal, which allows four different operation modes. This creates a standard for implementation of loads, that are ready for Smart Grid control and improves the flexibility of the grid and in this case integration of heat and electricity.
Some of the relevant standards for SMILE under this subject are presented in Table 4.2 below.

Table 4.2. Some of the relevant standards concerning integration of electricity and heat supply systems

Standard nr.	Name
IEC 60335-2-51	Household and similar electrical appliances – Safety – Part 2-51: Particular requirements for stationary circulation pumps for heating and service water installations
IEC 60335-2-61	Household and similar electrical appliances - Safety - Part 2-61: Particular requirements for thermal-storage room heaters
SG READY-LABEL	Bundesverband Wärmepumpe e.V, “SG READY-LABEL”

4.1.3 Standards and norms concerning the concept of microgrids

This section covers standards describing the concept of microgrids and technical specifications to promote the implementation of microgrids. One series have been found, IEC 62898, which introduces microgrids. Part 1 is giving general guidelines for microgrid projects and defines the term *microgrid.* IEC 62898 only covers AC-microgrids and defines them as: *“Electrical systems with loads and distributed energy resources (DER) at low or medium voltage level*” [13]. Moreover, two classes of microgrids are defined: *Isolated microgrids* and *Non-isolated microgrids.*
Isolated microgrids do not have an electrical connection to the main grid. Non-isolated microgrids have an electrical connection to the main grid and can operate either grid-connected or islanded. A more in-depth definition of microgrids and framework for regulations concerning microgrids can be found in deliverable 7.3 [14].

Some of the relevant standards for this subject are presented in table 6 below. As the pilots in SMILE are not operated as microgrids, these standards have not been used during the project. They are though relevant for future smart energy systems that might be operated as microgrids.

Table 4.3. Some of the relevant standards concerning microgrids

Standard nr.	Name
IEC TS 62898-1:2017	Microgrids - Part 1: Guidelines for microgrid projects planning and specification
IEC TS 62898-2:2018	Microgrids - Part 2: Guidelines for operation
IEC TS 62898-3-1: 4	Microgrids - Part 3-1: Technical requirements – Protection and dynamic control

4.1.4 Standards and norms concerning local grid balancing

This section covers flexibility services such as technical requirements for frequency control reserves used for primary, secondary, and tertiary control.
Moreover, it presents technical barriers and safety measures that needs to be handled when working with “smart” grids.

No standards specifically covering balancing of local grids have been found. Standards for operation and control of microgrids has been included as many of the same parameters has to be controlled to balance local grids.
The IEC 62264 series describes control methods for enterprise-control systems in general semantic way and can thereby be applied to local grids and microgrids as done in the report "Microgrids in Active Network Management – Part I Hierarchical Control, Energy Storage, Virtual Power Plants, and Market Participation" by Aalborg University, 2014 [15].
In Denmark there are some guidelines for grid connection of power-generating plants that has its origin in the RfG (Requirements for Generators). [16] These guidelines set limits for e.g., power quality emissions, immunity of the plant and requirements to power control which is an important aspect of balancing local grids. [17] The *Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation* [18] specifies minimum requirements for primary control reserves (Frequency Containment Reserve (FCR)) and states that the TSOs are responsible for defining technical requirements for secondary reserves (Frequency restoration reserve (FRR)) and prequalification of the reserves. As an example of a technical specification for implementation of primary, secondary and tertiary control, the document “Prequalification of plants and aggregated port folios intended for system services in Denmark” is included. The transmission system operator in Denmark, Energinet, has a procedure for prequalification of plants intended for frequency reserves in Denmark, which is described in this document. [19] [20]
The mentioned standards and guidelines are presented in the table below.

Table 4.4. Some of the relevant standards concerning local grid balancing

Standard nr.	Name
IEC 62264-1:2013	Enterprise-control system integration — Part 1: Models and terminology
-	Guide for connection of power-generating plants to the medium and high-voltage grid (>1 kV)
-	Guide for connection of power-generating plants to the low-voltage grid (<1 kV)
-	Prækvalifikation af anlæg og aggregerede porteføljer (Prequalification of plants and aggregated port folios intended for system services in Denmark)
USEF	Universal Smart Energy Framework

USEF
The organisation Universal Smart Energy Framework (USEF) describes a market for smart energy systems – how to trade electricity and how communication between aggregators (AGR) and distribution operators (DSO) is executed. USEF is part of the European Smart Grid Task Force Expert Group 3. [21]
The latest publication is a white paper about flexibility deployment in Europe. The flexibility services described are: [22]

- Wholesale services: Help balance responsible party (BRP)
- Constraint management services: Help TSO or DSO
- Balancing services: Help TSO
- Adequacy services: To TSO or BRP

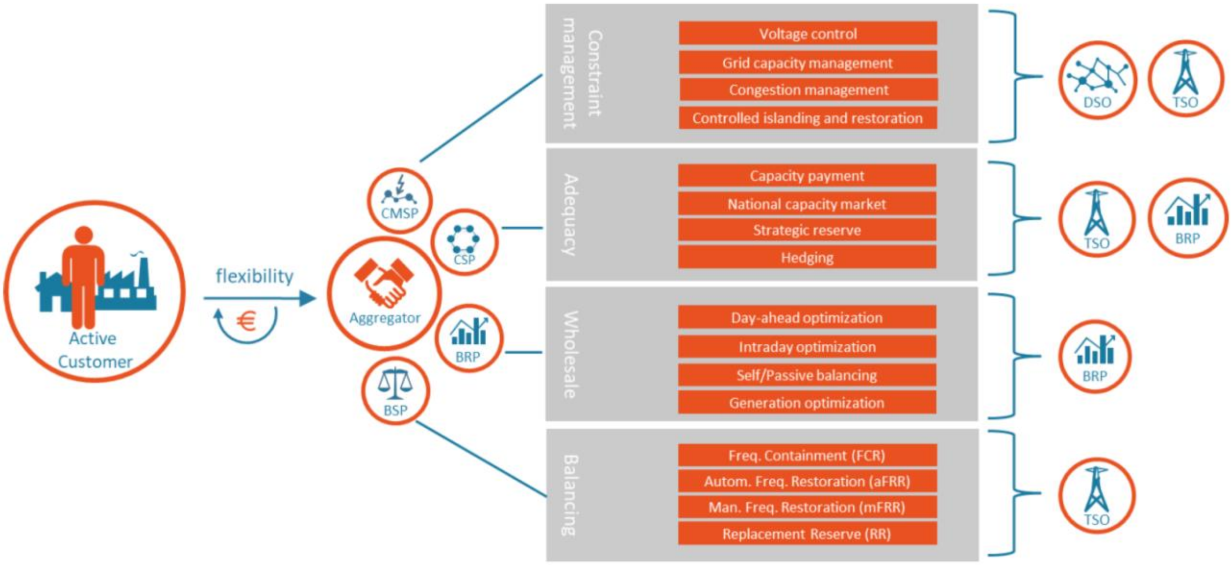


Figure 4.1: USEF market model [22]

4.1.5 Standards and norms concerning prosumers and aggregators

Prosumers are only found in one standard, which is in the series for low-voltage electrical installations. In Denmark, the current recommendations and guidelines focus on either producers or consumers. This is both when looking at plants connected to low voltage, medium voltage, and high voltage.
The role of prosumers and aggregators as actors in the energy market are covered in section 4.2 about regulations.
Some of the relevant standards for SMILE under this subject are listed in Table 4.5.

Table 4.5. Some of the relevant standards concerning prosumers and aggregators

Standard nr.	Name
IEC 60364-8-2	Low-voltage electrical installations - Part 8-2: Prosumer's low-voltage electrical installations
IEC 61850-7-420	Communication networks and systems for power utility automation - Part 7-420: Basic communication structure - Distributed energy resources logical nodes

4.1.6 Standards and norms concerning interoperability

As the interoperability is mainly about communication between components, different aspects of communication are covered in this mapping. Standards and norms concerning interoperability covers communication between energy components on different level are covered in IEEE 1547 and the technical report ISO/IEC TR 15067-3-8. Moreover, communication networks for power utility are covered by selected parts of the IEC 61850 series. Norms and standards for security measures are mapped as well.

There are a few standards and open standards dedicated to interoperability in electric power systems. The IEEE 1547 standard are addressing interoperability in electric energy systems focussing on the connection between the utility grid and distributed energy resource.
The technical report 15067-3-8 from ISO/IEC is about transactive energy (TE). Transactive energy allows electricity generated locally by consumers using wind, solar, storage, etc., at homes or buildings, to be sold into a competitive market. The report provides guidance for enhancing interoperability among distributed energy resources involved in energy management systems at homes and buildings. This technical report has not been used in the SMILE project but might be relevant for similar projects about smart energy systems.
The IEC 61850 series covers communication for power utility automation. Some parts of this series are relevant for energy systems like in SMILE. The relevant parts are listed in the Table 4.6. These parts concerns distributed energy resources and e-mobility. These standards have not been used actively in the SMILE project.
Moreover, the standards IEC 61970-301 and 61334-4-32 are relevant concerning communication. These standards have been used in the SMILE context by relevant partners.
The IEC 61851 series concerning electric vehicle conductive charging system is relevant for smart energy systems with electric vehicles included as in SMILE. These standards have been used by SMILE partners in the project.
ISO 15118 is also relevant, as it describes communication for vehicle to grid (V2G) applications which may be a part of many future smart energy systems. A standard for communication between EVs and the charger is also relevant as it enables the possibility for interoperable e-mobility and flexible energy storage.
Some standards concerning cyber security have been used in the SMILE projects. This includes IEC 62351-3 and 27001 and some proposed standards published by the Internet Engineering Task Force (IETF) about HTTP authentication and JSON Web Token.
To have an interoperable energy system it is also necessary to have a standardised physical interface. For the industrial power plugs there are standards, but for usual plugs the form and functionality differ from country to country. The standardised plugs are covered by EN 60309-2 and -3 and EN 62196-2.
There is a series of open standards or industrial norms concerning interoperability herein SunSpec Alliance, SG Ready and OCPP.
Sunspec Alliance is an example of well-defined industry de facto specifications for interoperability of PV-components.
SG Ready (Smart Grid Ready) is a German norm for heat pumps, that specifies a simple communication format to make heat pumps smart grid ready. More than 1700 heat pumps are registered with this label in Germany. [12]
The industrial norm OCPP covers charging of electric vehicles and is widely used by electric vehicle charging station manufactures. It is ensuring interoperability and setting frames for cyber security.

Table 4.6. Some of the relevant standards concerning interoperability

Standard nr.	Name
	Interoperability in electric power systems
IEEE 1547	IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces
ISO/IEC TR 15067-3-8:2020	Information technology — Home Electronic System (HES) application model — Part 3-8: GridWise transactive energy framework
	SunSpec Alliance
SG READY-LABEL	Bundesverband Wärmepumpe e.V, “SG READY-LABEL” [12]
	Communication
IEC 61850-7-420	Communication networks and systems for power utility automation - Part 7-420: Basic communication structure - Distributed energy resources logical nodes
IEC 61850-8-1	Communication networks and systems for power utility automation - Part 8-1: Specific communication service mapping (SCSM) - Mappings to MMS (ISO 9506-1 and ISO 9506-2) and ISO/IEC 8802-3
IEC 61850-90-7	Communication networks and systems for power utility automation - Part 90-7: Object models for power converters in distributed energy resources (DER) systems
IEC 61850-90-8	Communication networks and systems for power utility automation - Part 90-8: Object model for E-mobility
IEC 61970-301: 2020	Energy management system application program interface (EMS-API) - Part 301: Common information model (CIM) base
IEC 61334-4-32	Data communication protocols – Section 32: Data link layer – Logical link control (LLC)
	Electric vehicles and V2G
IEC 61851-1	Electric vehicle conductive charging system - Part 1: General requirements
IEC 61851-21-1: 2017	Electric vehicle conductive charging system - Part 21-1 Electric vehicle on-board charger EMC requirements for conductive connection to AC/DC supply
IEC 61851-21-2: 2018	Electric vehicle conductive charging system - Part 21-2: Electric vehicle requirements for conductive connection to an AC/DC supply - EMC requirements for off board electric vehicle charging systems
IEC 61851-23: 2014	Electric vehicle conductive charging system - Part 23: DC electric vehicle charging station
IEC 61851-24	Electric vehicle conductive charging system - Part 24: Digital communication between a d.c. EV charging station and an electric vehicle for control of d.c. charging
ISO 15118-1: 2019	Road vehicles — Vehicle to grid communication interface — Part 1: General information and use-case definition

ISO 15118-2: 2014	Road vehicles — Vehicle-to-Grid Communication Interface — Part 2: Network and application protocol requirements
ISO 15118-3: 2015	Road vehicles — Vehicle to grid communication interface — Part 3: Physical and data link layer requirements
ISO 15118-8: 2018	Road vehicles — Vehicle to grid communication interface — Part 8: Physical layer and data link layer requirements for wireless communication
OCPP 1.6	Open charge Point Protocol 1.6
OCPP 2.0	Open charge Point Protocol 2.0
Guideline for EVs UK	Making the right connections - General procurement guidance for electric vehicle charge points
Cyber security	
IEC 62351-3	Encrypted communications over TLS
IETF RFC 7617	Basic-Authentication
IETF RFC 7519	JSON Web Token (JWT)
ISO/IEC 27001	Information technology — Security techniques — Information security management systems — Requirements
Plugs	
EN 60309-2	Plugs, fixed or portable socket-outlets and appliance inlets for industrial purposes - Part 2: Dimensional compatibility requirements for pin and contact-tube accessories
EN 60309-4	Plugs, fixed or portable socket-outlets and appliance inlets for industrial purposes - Part 4: Switched socket-outlets with or without interlock
EN 62196-2	Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 2: Dimensional compatibility and interchangeability requirements for a.c. pin and contact-tube accessories

4.2 Mapping of European and national regulations

European and national regulations are gathered in this section. Deliverables D7.1, D7.2, D7.3 and D7.4 have discovered regulations and made qualitative analysis of these in the following four areas:

1. Positioning electricity storage in the energy chain (Deliverable D7.1) [23]
2. Integrating electricity and heat supply systems (Deliverable D7.2) [24]
3. Microgrids (Deliverable D7.3) [25]
4. Balancing local grids (Deliverable D7.4) [26]

The two first deliverables listed above were written in 2019 and the two last ones in 2021. Most of the regulations that are mentioned in these deliverables are still in force and relevant. Some national regulations in the first two deliverables may have been amended to an extent.
New or additional regulations have been added to fulfil the mapping of relevant regulations.
The EU directives cover many topics of relevance for the SMILE project, including the electricity market, low voltage installations, batteries, reduction of hazardous substances (RoHS) and promotion of

energy from renewable energy sources. The national regulations are mainly implementations of these directives which have to be transposed in national law.

4.2.1 European directives and requirements

Several European directives are relevant for smart energy systems. The directives are listed in the Annex.

Two specifically relevant directives regarding smart energy systems are the 2018 Directive on promotion of the use of energy from renewable sources, and the 2019 Directive on common rules for the internal market for electricity. Among other elements, both directives allow for the creation of energy communities. As a result, Citizen energy communities have been transposed to Danish law in 2020. This was too late to develop such initiative under the SMILE project though. It might be relevant for Ballen Marina, Samsø, to investigate and clarify if there are new opportunities regarding the generation, storage, consumption or even grid ownership, payments of tariffs etc.

The Commission Regulation (EU) 2016/631 for generators (or Network Code on Requirements for Generators (RfG)) addresses all electric production including renewables and how island operation shall be performed by generators. This is a very interesting topic, as the ability of islanded operation is the main characteristic of a microgrid, and therefore an important topic to define and cover in regulations. The possibility to perform islanded operation, both from a technical perspective and a regulatory perspective, may increase the flexibility of the main electricity grid.

According to the RfG it is the system operator and relevant TSO who defines whether power generating modules shall be able to perform island operation. In Denmark it is only required that type D plants (>25 MW) can perform island operation. The RfG does not yet cover battery electric storage systems.

There is a similar commission regulation for demand, COMMISSION REGULATION (EU) 2016/1388 (or Network Code on Demand Connection Code (DCC)). This is primarily about requirements for distribution systems connected to the transmission network or to demand directly connected to the transmission network. Also, Commission Regulation (EU) 2017/2196 of 24 November 2017 establishing a network code on electricity emergency and restoration is relevant especially regarding island operation of energy systems.

Moreover, Directive (EU) 2018/1972 establishing the European Electronic Communications Code is relevant regarding SMILE. As an example, the directive addresses areas as availability of broadband internet to customers.

As battery energy storage systems have been a significant part of the SMILE project and might be a significant part of similar smart energy systems it is also relevant to mention a new proposed European regulation concerning batteries and waste batteries[4].

The list of directives also includes the low voltage directive, EMC directive, RoHS directive and WEEE directive, among others.

4.2.2 Samsø, Denmark

The national regulations for Denmark cover grid connected battery plants, electrical installations, electricity supply and heat supply. The technical regulations TR 3.3.1 for grid connected of battery plants is of high relevance for the pilot site at Samsø. Compliance test according to TR 3.3.1 has been

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[4] https://ec.europa.eu/environment/topics/waste-and-recycling/batteries-and-accumulators_en

made for the BESS at Samsø. The technical regulations for PV power plants and for thermal power plants are not valid anymore, as they are replaced by the European RfG. The regulations are valid for all of Denmark, only the regulations on fire hazards are manage by Østjyllands Brandvæsen (Eastern Jutland fire department) and valid for a regional area of Denmark, herein Samsø.
A list of laws and regulations for Denmark can be found in the Annex.

4.2.3 Madeira, Portugal

The national regulations for Portugal cover renewable energy generation and electric mobility.
DL 162/2019 defines the legal regime for UPACs and Renewable Energy Communities and is locally adapted as the Regional Decree Law (RDL) 1/2021/M [27]. It defines the legal regime for self-consumption from RES that applies in Madeira.
Moreover, Decree Law 153/2014 is valid for renewable energy production destined to self-consumption and for sale.
On electric mobility Decree Law DL 39/2010 and Decree Law 90/2014 are valid together with a regulation on electric mobility “2020 Regulamento da Mobilidade Elétrica”.
A list of laws and regulations for Portugal can be found in the Annex.

4.2.4 Orkney, Scotland and UK

The national regulations for United Kingdom cover electricity distribution and generation, heat network, heat decarbonisation and electric vehicles. The *Heat Policy Statement* is valid only for Scotland, the other regulations are valid for United Kingdom.
The act “Automated and Electric Vehicles Act” applies to Orkney and is relevant when working with electric vehicles. It might though be relevant for similar smart energy systems where electric vehicles and/or charging stations are involved.
In UK Engineering Recommendations G98, G99 and G100 are covering technical requirements for generation equipment and customer export.
Also, Water Regulations Advisory Scheme (WRAS) are relevant for the Orkney pilot as heat storage systems interacts with the hot water systems.
A list of laws and regulations for United Kingdom and Scotland can be found in the Annex.

4.2.5 Greece

The national regulations for Greece cover renewable energy sources, energy communities, electric mobility, and electrical system operation code for non-interconnected islands.
Law 47110/2020 on promotion of electric mobility gives motivations for the development of electromobility e.g., by tax incentives.
A list of laws and regulations for Greece can be found in the Annex.

5 Pilot particulars

In the previous section pilots have been mentioned in connection with different standards and regulations. This section summarises only briefly some of the pilot areas involving standards used at the demonstration sites.

5.1 The Orkneys – United Kingdom

All pilot installations have been installed by local qualified subcontractors with knowledge on the regulations and requirements. Regarding installation and safety of electricity storages, guidance to the subcontractor has been provided by Lithium Balance as technology provider.
Similar for the heat installations where Sunamp have given technology guidance. The responsible installation subcontractors have handled the certification requirements.

Route monkey worked to ensure interoperability and cyber security through abiding to OCPP 1.6 protocol for smart chargers as many producers of OCPP 1.6 compatible charge point do not comply with the full protocol including cyber security.

Internet stability has been a real issue throughout the demonstration. At some of the remote sites it could seem like the options for broadband communication are fewer if the transport access is more complicated. In urban areas it is often possible to have several alternative providers of broadband service but at remote sites on islands users can just to count on what is possible via a telephone line (unless willing to pay for e.g. satellite-based internet) because installation cost for higher quality service is very high if available at all. Moreover, when there are technical issues with internet equipment at remote sites, users may have to wait long for a repair service visit due to expensive and time-consuming travelling for service engineers. At lightly populated islands with ferry connection only every second or third day, technical service visits will be postponed indefinitely unless service is regulated through contract or legislation.

5.2 Samsø – Denmark

The BESS installation at Samsø Ballen Marina was the first grid-connected BESS-system the local DSO had to approve according to Danish TR 3.3.1. It required several interactions to reach a documentation level, that was considered sufficient by the DSO. A DSO grid-analysis identified a potential low load voltage problem at the substation connecting to the BESS, which resulted in a permanent maximum limit on the output power from the BESS to the grid.

Analysing the potential for DSM requires acquiring data from BESS, PV-systems and load-measurements on the Samsø Ballen Marina. The data has been provided by both technology providers in the project and external technology providers, which means that not all data formats and structures have followed the architecture agreed upon inside the SMILE project. This is a practical real-world example of interoperability challenges, as different data formats require more handling afterwards. Moreover, there has been a need for cleaning the data from errors before analysis could be made.
Data has been collected for the following four assets:

- The PV production at Ballen Marina is distributed over more buildings and different inverters. Information from the inverters production is sent to a Fronius site, but DTI did not get access to the Fronius site and the data frequency was too low for any smart operation of the BESS. To get real time data Lithium Balance installed a dedicated meter with MODBUS interface on the common connection of the three larger PV-inverters. The summarized PV data excluding a small few m^2 flat roof PV-system with inline converters was made available via the Lithium Balance data cloud for the BESS systems.

- The Lithium Balance cloud has come to work fairly well after migrating the system to a larger server system with more bandwidth for requests. Frequent requests can still congest the system, so it is important to limit data-requests to only the necessary to allow for possible real-time control.
- Forecast of weather data, forecast of electricity prices and the Marina booking calendar needs to be accessed at different sites in different ways.
- The aggregated data related to the overall marina consumption received by DTI from external third party seemed sometimes not fully consistent in format or range checked, which require a lot of data-washing and consistency checks.

Even though plenty of data has been collected it has been challenging to combine the data in the management systems, in analysis, and in modelling and simulations.
An example of limited interoperability is PV-inverters, that needs to be setup to match the local set of grid codes. Even though Denmark is a small area at least two different grid codes must be "preset" or available from the manufacturer to sell inverters into the Danish market.

5.3 Madeira – Portugal

All the electrical energy storage systems implemented on the island, are recent and the norms are followed by the entities who installed these systems, which are responsible for the minimum period of the warranty.

Cyber security has been addressed and worked with on the Madeira pilot:
1. All the communications within the scope of the SMILE Madeira pilots are performed using the HTTPS protocol.
2. Authentication is performed before establishing any communication
    1. From client to server (data upload): Basic-Authentication over HTTPS using authentication tokens (e.g., by using the standard IEC 62351 and IETF for authentication)
    2. API Calls: JSON Web Token (JWT) according to IETF RFC 7519.

Moreover, the standard IEC 61334-4-32 for data communication protocols has been used and ISO 15118 has been recognised as relevant for future project that includes vehicle to grid communication. At Madeira the island's electricity company operates powerplants including the water powerplants. These are used for ancillary services, so Madeira has no prequalification procedure for frequency reserve services. EEM has internal guidelines in the production that are overseen and managed by the Dispatch Center. The primary major powerplant that drives the frequency in the island is the thermal powerplant of 'Vitoria'. Other powerplants help guarantee services to the grid. The designed criticality level is N-1 (~15 MW). Some hydro powerplants contribute through synchronous compensation and frequency contention reserve.

5.4 Greek Islands – Greece

As there is no pilot site at the Greek Islands there are not yet specific experience to highlight. Depending on what kind of energy system that will be planned, some of the mentioned standards might be relevant to consider. E.g., the relevance of the standards concerning microgrids are confirmed and SMILE-partner Dafni are already looking into these standards in other projects they are involved in.

6 Discussion on barriers and potential solutions

Ideally grid constraints could be a driver for development and implementation of smart energy systems due to the high costs of reinforcement and resizing. Smart energy systems should be able to provide flexibility services and help supporting the grid. Smart energy systems will though have a minimum requirement for infrastructure of the grid and the fact that the smart energy management system can fail leads to concerns if the grid is too weak.
Several SMILE partners have experienced grid constraints at Samsø and Madeira as a barrier rather than a driver. This could be due to missing guidelines, procedures, or experiences to have more active and flexible interaction between the prosumers and the grid. During the project a new Regional Decree Law at Madeira has come into force (DLR 1/2021) and together with the network grid code at Madeira it allows prosumers to sell to the grid, which has not been an opportunity earlier.

Transmission lines to mainland are operating close to their maximum capacity which is a barrier to implementation of renewable generation on islands. This is the core problem investigated at the SMILE WP2 demonstrator, where energy available during curtailment is utilized instead of lost as usual. The energy can e.g., be used to alleviate high costs of heating homes on Orkney. By storing the otherwise curtailed energy for heating purpose in either heat storages or electrical batteries, congested transmission lines can be helped simultaneously with the supply of cheaper available energy by SES – but only if stable internet is available to optimise the use of the storage devices vs. diverse forecasts.

On Samsø the DSO has defined an export power limit for the marina which is a barrier for optimal and intelligent usage of renewable energy. Since the cause of concern for the DSO is overvoltage in case of low load on the substation, the limit criteria could instead of a fixed power limit have been a flexible current limit dependent on the actual voltage at the point of connection. As both PV-systems and the BESS can react to a voltage setpoint, any limits could potentially be based on the actual voltage – or even a combined maximum voltage limit vs. current. An agreement could also be made between the DSO and Ballen Marina that the marine should react on voltage set points to compensate voltage swells and drops by providing active and reactive power to the grid.
Future cooperation with the local DSO about flexibility services is a potential area of investigations.
If taking it a step further than individual agreements about flexibility services, it would be relevant in many locations to a have a market for such voltage supporting services that flexible consumers, producers, and prosumers can provide. Such a market might be able to meet conflicting goals from DSOs and connected customers and could be considered to accommodate both DSO's needs and customer's rights. The USEF (Universal Smart Energy Framework) organisation has suggested the USEF-model as a model for a flexibility market defining actors, roles, and practices. The Horizon 2020 project X-Flex has analysed different flexibility models including the principles from USEF [28].
USEF are collecting news about flexibility markets, but there is not yet documentation from any use of their market models anywhere. In Danish context, research projects have looked into aspects of flexibility market, with focus on using existing meters, communication, and market platforms rather than implementing new ones. [29] The first Danish pilot study focuses on constraints in a local meshed transmission grid and the TSO requires bids for at least 1 MW in a flexibility market. DSOs are looking into expanding the flexibility market for distribution grids also but there seems to be many barriers to handle before a flexibility market for DSM is available at 400 volts level.
Most likely standards could not have helped on the grid constraints barrier. Instead, incentives for flexibility services or regulation on available capacity for renewable energy production might be possible solutions.
The principles described in USEF could maybe serve as a basis for an agreement between e.g., the DSO and Ballen Marina on Samsø, if the DSO could be regulatorily allowed to make such agreements. In similar future projects it will be advantageous to look into cooperation or services before the energy

system is implemented and in operation as it might affect the design. If the DSO have defined methods and principles of agreements for flexibility services, e.g., based on USEF it will be easier for customers to plan and design energy systems that work with the interests of the local grid.
It will be even more advantageous if the European Commission sets some guidelines as it will lead to higher interoperability of systems developed in different regions.

The different grid connection requirements have been a barrier for interoperability as systems designed for one location will not necessarily comply to the grid code in another area.
The focus in grid codes on Madeira seems to be on voltage stability and quality due to voltage swells and sags, frequency variations and rate of change of frequency rather than on harmonics and other aspects of power quality. Managing an isolated electrical grid has this kind of priorities in order to prevent load shed or even blackouts in a worst-case scenario. The standard IEC 50160 has been mentioned by SMILE partners as a reference for power quality. This standard though, only covers voltage quality and defines characteristics for the voltage supplied by the public electricity network and not the power quality that each connected customer must comply to. In Denmark, the distribution operators have design limits for emissions in the grid stricter than those in IEC 50160 which all production plants must follow. These are described in "Guide for connection of power-generating plants to the low-voltage grid (≤1 kV)" and a similar one for medium and high voltage connected plants [17]. It is the local network companies' responsibility to define emission limits for their customers which lead to high variety of requirements across regions. As some countries or regions have a weaker grid it will be more difficult to keep a good power quality and from that perspective it makes sense that the requirements differ from region to region.
Instead of trying to force all regions to have the same requirements, it could be helpful if the format of the requirements were harmonised across Europe to make it easier to adjust products and make them compliant to new regions.

Another important barrier addressed is the difficulties in communication between technologies from different providers. On the technical levels of communication and domestic smart grid management there is real and practical challenges in finding the right norms or standards to use. There seems to be too many standards and too many possible and accepted solutions for communication protocols, data format and data interpretation that can be combined in countless combinations to form full communication through all the OSI layers as discussed in section 3. SMILE partners have referred to many communication elements like RS232, MODBUS, internet, JSON, IEC 61334-4-32, IEC 61850. As an example, the PRSMA EMS has been designed to be input-agnostic, thus highly compatible with different third-party systems. However, to ensure interoperability, third-party systems should comply with a minimum of requirements (e.g., support communication through the MODBUS protocol in the case of smart-meter providers).
The multitude of possible communication protocols may seem complex but there is less standardisation when it comes to smart grid systems. It is hard to find any obvious focus or trending solution gaining support from a major group of users. Fortunately, there are large communities that maintain repositories with publicly accessible open software tools and routines. The SMILE smart grid solutions have mostly been built from open software and proven subfunctions and solutions to minimize the risk of ending up with a niche-solution without long time support and to ensure a system which is supported by a large network of users.

Access to historic empirical data is often needed to model optimised smart functions. In many cases it is necessary to establish a data logging setup and a logging period to establish baseline data before smart functions can be modelled and designed. For instance, the ability to have access to historical data would have enabled an analysis of the Madeira UPACs earlier in the project. This could be mitigated if technology and energy providers were required to provide historical data to their customers. With access to more data about the energy system and its operation it will be easier to invest in smart energy systems and give better transparency and insight in optimisation possibilities. To accommodate this, it will be necessary first of all to ensure privacy and data security to protect customers as it is sensitive data. It will also be necessary to have more smart meters installed that collect frequent data and to have a common energy database e.g., in Europe, where data can be stored and accessed. To make such data useful for as many as possible it is important to define a robust and secure structure and format for the data. Inside SMILE there has been made architecture of the data formats and communication structures to ensure interoperability. There have though also been external providers involved without a standardised data format and communication structure why it has been rather time consuming to use these data in analysis and modelling. Having more standardised data formats and interpretation would improve interoperability of the management systems.

Most of the smart control systems rely on stable communication channels. Access to stable internet connection is a critical issue for many practical demonstrations and has been a barrier for all pilots in SMILE for implementation and proper operation of the smart energy systems. Increased energy flexibility will depend on stable means of communication. Regulations are needed to improve the access to internet and the internet stability to mitigate this barrier. In this regard, it is important to be aware of cyber security of the system as it is seen in the SMILE project that the smart energy systems implemented are very dependent on stable and reliable internet connection and they could therefore also be vulnerable to potential hacker attacks. However, in the framework of the project, starting from an analysis of existing assets and potential threats, a risk assessment with respect to cyber security has been carried out and predictive and mitigations measures were defined by using also devoted developed tools. Regarding loss of communication, it must always be expected as a likely event and all systems must have a safe and grid-friendly fall-back operational mode in case of communication interruption.

Without a robust and safe fall-back control mechanism there can be adverse effects on the grid as well as the local system. Moreover, the fall-back control mechanism should be easily repeatable and sophisticated enough to cater for different systems.

Some regulation and incentive may be needed to ensure predictable and robust fall-back solutions, that will not be an extra risk for the grid stability. Too much regulation on individual asset under such circumstances may discourage private investment but there is a scope to have a balanced approach to safeguard the grid performance.

It has been a barrier for the development of e.g., smart energy control of EV chargers that the applicable standards have been difficult to interpret. When developing the EV charger management although plenty of information has been available online, it has not been easy to understand the impacts of the different standards. This has required considerable amounts of experimentation to fully understand the practical implementations of such protocols. This is not a technical barrier in itself, but it can lead to many technical issues, that could potentially have been avoided if proper standards had been used.

Access to the actual charge status of an EV is essential to optimise when to charge and plan the needed energy. There are no requirements for EVs to communicate their charge status when using Mode 3 AC, which has been a barrier for integration of EVs in the smart energy management. The only formal access to this information is via DC-charge connection. For AC charging there are no status communication available via the charge plug. For smart charge control battery status information is sometimes acquired via the OBD connector in the car. There are no standards for the accessible status data but in most cases reverse engineering has found ways to the required data. There are currently no regulation ensuring availability of battery status information and some car manufacturers want to remove the OBD connector since it has no legal function when there is no combustion engine in the car. Route Monkey has until now found the needed data via the OBD but the barrier for accessible data exchange still exists. There is currently a legal discussion going on between stakeholders, car manufactures and the EU regarding future requirements for access to vehicle and battery data for electric vehicle owners and third parties like Route Monkey. A regulation setting requirements for having proper and widely accepted data communication standards to EV-battery status could make EV-charging a more active flexibility asset for the grid.

One of the main but not clearly visible barriers slowing down the implementation of Demand Side Management and flexibility services is the supply-focused topology of the electricity grid – both at the physical level but maybe even more in the thinking. The physical grid only requires minor adaptions to support distribution of power in both directions, but the grid management regime must be changed from "supplying central generated energy to electric consumption" to "distributing energy services between all grid-connected installations". Many grid codes are still modelled over the classic concept where the centralised generation is responsible for providing stability and voltage quality. The classic thinking attempts to shift the responsibility for stability to the new distributed renewable generation as centralised generation is phased out. Consumers and prosumers are mostly seen as a challenge rather than an asset that can contribute to stability via e.g., DSM and flexibility measures such as storage. Progress in this area is expected with the national transpositions of the directives in the Clean Energy for all Europeans Package. A part of the package is concerning the electricity market, where the purpose is to establish a more flexible and more market-based electricity market and a market that supports integration of a higher share of renewable energy. [30] A major change to the management barriers will require political incentives and leadership at a European level.

7 Recommendations for European harmonisation activities

The experiences from the SMILE project and demonstration of smart energy systems at islands have helped identifying subjects that European harmonization activities could contribute to.
The mapping of technical barriers met in the project has shown that there are several areas where political initiatives to support the integration of smart energy systems are needed more than standards. Incentives to make prosumers an active part of the grid could encourage these actors to work together with the grid operator rather than just being a load. Progress in this area is expected with the national transposition of the directives in the Clean Energy for all Europeans Package. Actually, most of the barriers addressed by the SMILE partners are best mitigated by political engagement, incentives, and regulations.

There seems to be a harmonized overall regulation of the European TSOs for ensuring grid quality and stability. The focus is on transmission networks and frequency stability and markets have successfully been established to support trading of energy and frequency services but not yet flexibility services. Most of the energy consumption and most of the flexibility potential from Demand Side Management is found in the distribution grids under DSO responsibility. The extent to which DSOs can "work with" consumers and prosumers depend on various factors, such as their revenue model (does it incentivise such cooperation). One of the main instruments to incentivise DSOs to actually buy flexibility services to consumers/prosumers are local flexibility markets (LFMs), as developed in SMILE Deliverable D7.4. The problem is that in many EU countries, such markets have not been implemented. UK have one of the more developed flexibility markets. In Denmark the DSO currently have limited freedom to encourage consumers and prosumers to work with the local grid. In Denmark only some specific flexibility cases have been investigated in a project. There seems to be a need for a dedicated flexibility market covering down to the local distribution radials and incentives for DSOs to make agreements with customers, including prosumers and energy communities. Increased flexible operation can support the grid and give the customer more freedom. Harmonized standards and guidelines to make such a setup cost effective should be selected – there are maybe too many overlapping norms and standards available on the market today. The 2019 Electricity market Directive requires member states to incentivise and allow DSOs to set up flexibility markets so there is an opportunity. A central focus from national or EU-level authorities might need to make the total setup more effective and predictable but with focus on robustness and security. It may be difficult for TSOs and local DSOs to find solutions without central help since some conflicting interests have been identified e.g., in the project between the Nordic TSOs about local flexibility [29].

A related overall theme issue has been identified that may delay or even impede a full transition towards a fully flexible electric grid in Europe. The current supply-focused topology of the electric grid – both at the physical level but maybe even more in the thinking is slowing down the implementation of Demand Side Management and flexibility services. The thinking of the electricity grid as a supply grid should change to a bidirectional distribution grid for exchange of electric energy, rather than defined for delivering energy from central generators to consumers. It is therefore recommended that grid codes are reworked to include prosumers, aggregators, storage systems and energy communities and meet the special needs of these actors.

In SMILE a need for standardization of smart grid control and demand side management communication has been seen. This could be that energy assets must use the same communication protocol or at least the same family of protocols.

Moreover, partners of SMILE have identified a need for a common energy data space to create better conditions for smart energy systems and improve the interoperability of smart grid components. The data space should also provide value to DSOs and for their operations.

Access to robust and cybersecure internet is essential for smart systems to work effectively. So, a European requirement for stable and robust means of communication to be available to all grid-connected installations even the remote ones would be very relevant.

TSO, DSO and other stakeholders are unlikely to find common ground on the above issues due to some conflicting interests. Where the relevant actors cannot propose a solution that is acceptable to all of them and fulfills the required objectives (environmental, economic, etc.), it is recommended that the European Commission is leading such activities.

8 Conclusions

This document has investigated regulations and standards relevant for smart energy systems and in this context highlighted some of the technical barriers experienced during the installation and operation of the pilot sites.
After assessment of the barriers and the connection to the mapped standards, it is concluded that a few of the technical barriers may be mitigated by having relevant standards, but many of the barriers are more likely to be mitigated by implementing incentives and/or regulations on a common European level.

Grid constraints have also been perceived as a barrier for implementation and operation of the smart energy systems in SMILE even though it was the initial driver for developing and demonstrating smart energy systems. Grid reinforcements are seen as necessary in some areas both to improve stability in case of failing smart grid control systems and with increased electrification. As this involves high costs it is seen as a barrier for promotion of renewable energy unless any incentives for expansion or for flexibility services are developed.
Another challenge addressed is the general perception of the grid and its role as a supply-grid rather than an infrastructure for energy exchange. The existing grid codes European and national level are rooted in a system setup where central generation is the main responsible for grid quality and stability – a thinking which is challenged by bidirectional power flow, distributed fluctuating generation and prosumers.

Access to stable internet connection is a dominating issue for many practical demonstrations and has been a barrier for all pilots in SMILE for implementation and proper operation of the smart energy systems. Regulations may be needed to improve secure access to internet and internet stability to mitigate this barrier. Overall, cyber security aspects of the smart energy systems have been analysed and handled in the SMILE project.
Another dominant barrier in the project has been communication between different technology providers. Data may often be available but different data formats often restricts communication between technology providers. This challenge is presumably due to availability of too many standards and norms for communication and information exchange and might be solved by having incentives for technology providers to cooperate and harmonise their solutions. The partners in SMILE have worked with standardised protocols, but the interaction between many different technologies has still been a challenge. The architecture of the communication and data flow made at the beginning of SMILE has defined the frame for the internal partners. Protocols for communication and data exchange with external third parties have required more work and customization.
EV-charging is a good example of an area with few uniformed norms/standards. Still, it was found that several suppliers of OCPP 1.6 compatible EV-charge points did not conform to the full OCPP norm giving challenges with implementation of replicable cyber secure charging solutions. Access to EV battery status information via OBD-test connector for advanced fleet charge planning are getting more restricted by EV-producers and central regulation are likely needed to ensure future opportunities for battery status based smart charging.
Some of the houses wanting to exploit smart grid solutions and storage are not suited for domestic-scale smart solutions due to the age of the building, the insulation level or the space available. Incentives for development of new technologies that fits these houses, combined with regulations for new buildings that require a minimum level of preparedness for smart and flexible energy solutions could help. With little or no incentives for smart grid, the installed technologies will just meet the home’s requirements without consideration of the rest of the grid/system and long-term efficiency. Moreover, lack of literacy in terms of distributed energy generation, energy efficiency and smart energy systems makes it hard to engage citizens.

The SMILE project's location of pilot demonstration on islands has illustrated that it is unrealistic for technology providers to offer the same high service at remote areas due to time consuming travel challenges for physical visits. This can be a barrier for implementation of smart energy systems in these areas, where the need for smart energy systems may often be higher due to a weaker grid. Incentives for technology providers and improved internet at remote locations may be needed to mitigate this. Remote assistance could also be a solution in many cases instead of a physical visit where possible e.g., remote testing or maintenance guiding – but it will require stable and sufficient internet bandwidth.

Finding the applicable standards is a practical challenge that has been faced during the project. The availability of different suggested norms and standards for information exchange and smart grid solutions can be overwhelming when they appear equally good. This can result in lacking interoperability and difficulties in replicating the system if proprietary solutions are used. Many of the technology providers are though aware of this and are working on solutions that can fit as many systems as possible by using standards were possible but by having fewer centrally recommended norms and standard to focus on, the implementation of smart energy solution would likely accelerate.

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D7.5 Annex

1 Annex - EU Directives and Regulations

ID	Regulation/law	Title	Comments
1	Directive 2014/94/ EU	DIRECTIVE 2014/94/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 22 October 2014 on the deployment of alternative fuels infrastructure	
2	Directive (EU) 2019/944	DIRECTIVE (EU) 2019/944 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU	Especially relevant regarding energy communities.
3	Directive (EU) 2018/2001	DIRECTIVE (EU) 2018/2001 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018 on the promotion of the use of energy from renewable sources	To be recast under fit for 55 package
4	Regulation (EU) 2019/943	REGULATION (EU) 2019/943 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 5 June 2019 on the internal market for electricity	
5	Directive 2006/66/EC	DIRECTIVE 2006/66/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 6 September 2006 on batteries and accumulators and waste batteries and accumulators and repealing Directive 91/157/EEC	
6	Directive 2014/35/EU	Low voltage directive (LVD)	LVD
7	Directive 2014/30/EU	DIRECTIVE 2014/30/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 26 February 2014 on the harmonisation of the laws of the Member States relating to electromagnetic compatibility (recast)	EMC directive
8	Directive 2006/66/EC	Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment	RoHS
9	Directive 2012/19/EU	Directive 2012/19/EU waste electrical and electronic equipment (WEEE)	WEEE
10	Commission regulation (EU) 2016/631	Commission Regulation (EU) 2016/631 of 14 April 2016 establishing a network code on requirements for grid connection of generators	Especially relevant regarding island operation

11	Commission Regulation (EU) 2016/1388	Commission Regulation (EU) 2016/1388 of 17 August 2016 establishing a Network Code on Demand Connection	
12	Commission Regulation (EU) 2017/1485	Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation	Especially relevant regarding frequency control reserves
13	Commission Regulation (EU) 2017/2196	Commission Regulation (EU) 2017/2196 of 24 November 2017 establishing a network code on electricity emergency and restoration	Especially relevant regarding island operation
14	New REGULATION proposal concerning batteries and waste batteries	Regulation of the European Parliament and of the Council concerning batteries and waste batteries, repealing Directive 2006/66/EC and amending Regulation (EU) No 2019/1020	Not in force yet. https://ec.europa.eu/environment/topics/waste-and-recycling/batteries-and-accumulators_en
15	Directive 2012/27/EU	Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency	To be recast under fit for 55 package
16	Directive (EU) 2018/1972	Directive (EU) 2018/1972 establishing the European Electronic Communications Code	

2 Annex - National Laws and regulations

ID	Regulation/law	Title	Applies to	Category	Comments
1	TR 3.3.1	Technical regulation 3.3.1 for battery plants	Denmark	Storage	Grid code. It defines technical minimum tolerances and limits for grid connected battery storages. Hereunder Tolerances for frequency and voltage deviations, power quality, control, protection, data communication, verification, documentation and simulation.
2	LBK nr 26 af 10/01/2019	The Electrical Safety Act	Denmark	Electrical safety	Danish short title: Elsikkerhedsloven
3	LBK nr 119 af 06/02/2020	The Electricity Supply Act	Denmark	Generation	Danish short title: Elforsyningsloven
4	BEK nr 2252 af 29/12/2020	Executive Order on Citizens 'Energy Communities and the Relationship between Citizens' Energy Communities and Electricity Trading Companies and Collective Electricity Supply Companies	Denmark	Energy community	Danish title: Bekendtgørelse om borgerenergifællesskaber og forholdet mellem borgerenergifællesskaber og elhandelsvirksomheder og kollektive elforsyningsvirksomheder
5	Heat Supply Act of 1979	Heat Supply Act of 1979	Denmark	Heat	Danish short title: Varmeforsyningsloven
8		Kommunalfuldmagten (Municipal power of attorney)	Denmark	Municipality	The municipality can neither install nor operate public charging stations for electric vehicles. The municipality must not compete with private enterprises.
9	LBK nr 310 af 01/04/2011	Bekendtgørelse af lov om afgift af elektricitet (promulgation of law on taxation of electricity	Denmark	Taxes	Danish short title: Elafgiftsloven

10		Regulations on fire hazards	Denmark, Samsø	Fire safety	The housing for the BESS and the installation of the BESS on Ballen Marina complies with the local fire regulations.
11	Law 3851/2010	Accelerating the development of Renewable Energy Sources to deal with climate change and other regulations addressing issues under the authority of the Ministry of Environment, Energy and Climate Change	Greece	Generation	
12	Law 4513/2018	Law 4513/2018, ‘Energy Communities and other provisions’	Greece	Energy community	
13	Law 3468/2006	Generation of Electricity using Renewable Energy Sources and High-Efficiency Cogeneration of Electricity and Heat and Miscellaneous Provisions	Greece	Generation	Especially relevant for integration of heat and electricity
14	Law 4414/2016	New Support Scheme of Renewable Energy and CHP Plants- Provisions concerning the Legal and Administrative Unbundling of Natural Gas Supply and Distribution and Miscellaneous Provisions	Greece	Renewable energy resources	
15		Electrical System Operation Code for Non-Interconnected Islands (NII)	Greece		

16	Law 47110/2020	Promotion of electric propulsion.	Greece	Mobility	Relevant for EVs. Motivations for the development of electromobility. Tax incentives for the development of electromobility
17	Decree-Law 39/2010/Decree-Law 90/2014	Decree-Law 39/2010 on electric mobility, last amended by Decree-Law 90/2014	Portugal	Mobility	Relevant for EVs
18	Decree-Law 189/88	The Independent Power Production (IPP) Law	Portugal	Generation	Regulates renewable electricity generation. Allows for public or private entities or private individuals to generate electricity from renewable energy sources (including small hydro) and sell it to the grid, provided certain technical conditions for interconnection are guaranteed.
21	Decree-Law 312/2001		Portugal	Generation	This decree-law regulates the uptake and intake capacities of the public electricity grid, access to the grid and plant operators' entitlement to electricity purchase agreements.
22	Decree-Law 153/2014	Law on Self-consumption	Portugal	Generation	Legal regimes for the production of electricity destined to self-consumption and to the sale to electric public network originating from renewable resources, through Small Production Units
23	DL 162/2019		Portugal	Generation	DL 162/2019 (and it's 'local' adaptation - i.e., RDL 1/2021/M) define the legal regime for UPACs and Renewable Energy Communities.
24	Decreto Regulamentar Regional n.º 8/2019/M		Portugal	Generation	Approves the Regulation of the Electric Energy Transmission and Distribution Network of the Autonomous Region of Madeira. It establishes the technical conditions for connecting new electricity production facilities to the grid.
25	Decreto Legislativo		Portugal	Generation	

	Regional n.º 1/2021/M				
26		2020 Regulamento da Mobilidade Elétrica (Regulation on Electric Mobility management)	Portugal	Mobility	
27	Heat Policy Statement	Towards Decarbonising Heat: Maximizing the Opportunities for Scotland	Scotland	Heat	
28	Electricity act of 1989	Electricity distribution licence conditions 31D.1(a) and 43B.1(a).	UK	Storage	Storage itself is not covered, but is seen as generation (which is covered).
29	Engineering recommendation G99	Requirements for the connection of generation equipment in parallel with public distribution networks on or after 27 April 2019	UK	Generation/ Storage	Storage itself is not covered, but is seen as generation (which is covered).
30	Engineering Recommendation G100	Technical Requirements for Customer Export Limiting Schemes	UK	Generation/ Storage	Storage itself is not covered, but is seen as generation (which is covered).
33	Heat Network (Metering and Billing) Regulations 2014, no 3120		UK	Heat	These Regulations implement Articles 9(1) and (3), 10 and 11 of Directive 2012/27/EU of the European Parliament and of the Council on energy efficiency (OJ No. L315, 14.11.2012, p.1), amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC.
34	Automated and Electric Vehicles Act, adopted in 2018		UK	Mobility	

35	Engineering Recommendations G98	Requirements for the connection of Fully Type Tested Micro-generators (up to and including 16 A per phase) in parallel with public Low Voltage Distribution Networks on or after 27 April 2019	UK	Generation	
36	2002 No. 2665	The Electricity Safety, Quality and Continuity Regulations 2002	UK	Electrical safety	
37		Water Regulations Advisory Scheme	UK	Heat	UK short title: WRAS. Relevant for heat storages combined with hot water installations

3 Annex - Standards

Legend	
Category 1	Electrical storage
Category 2	Integration of electricity and heat (including heat storage)
Category 3	Microgrids
Category 4	Balancing local grids
Category 5	Prosumers and aggregators
Category 6	Interoperability (including communication, EV charging, cyber security)
Not included in report	Not included in report, but could potentially be relevant for some applications/systems

ID	Standard/ Norm	Title	Area	D7.5 category number	Directive/ regulation/ law	Summary/Comments
1	IEC 62485-5	Safety requirements for secondary batteries and battery installations - Part 5: Safe operation of stationary lithium ion batteries	Storage	Category 1		Describes protection during normal operation and under fault conditions
2	IEC 62933-5-1	Electrical energy storage (EES) systems - Part 5-1: Safety considerations for grid-integrated EES systems - General specification	Storage	Category 1		Safety consideration for safe application and safe use of grid connected EES. E.g. hazards identification, risk assessment, risk mitigation etc. Covers e.g. mechanical, fire, explosion and EMC validation and test and electrical design requirements.
3	IEC 62933-5-2	Electrical energy storage (EES) systems - Part 5-2: Safety requirements for grid integrated EES systems - electrochemical based systems	Storage	Category 1		For electrochemical-based systems. Safety aspects for people, safety matters related to the surroundings and living beings for grid-connected EES (electrochemical-based).

4	IEC 62619	Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications	Battery safety	Category 1		Fire hazards (propagations)
5	BS 7671 - 18th Edition	Requirements for electrical installations	Electrical installation/equipment	Category 1		
6	IEC 60335-2-51	Household and similar electrical appliances – Safety – Part 2-51: Particular requirements for stationary circulation pumps for heating and service water installations	Integration of heat and electricty	Category 2		
7	IEC 60335-2-61	Household and similar electrical appliances - Safety - Part 2-61: Particular requirements for thermal-storage room heaters	Integration of heat and electricity	Category 2	Low-voltage directive	
8	IEC TS 62898-1:2017	Microgrids - Part 1: Guidelines for microgrid projects planning and specification	Microgrid	Category 3		Covers the following areas: - microgrid application, resource analysis, generation forecast, and load forecast; - DER planning and microgrid power system planning; - high level technical requirements for DER in microgrids, for microgrid connection to the distribution system, and for control, protection and communication systems; - evaluation of microgrid projects.

9	IEC TS 62898-2:2018	Microgrids - Part 2: Guidelines for operation	Microgrid	Category 3, Category 4		Applies to operation and control of microgrids, including: - operation modes and mode transfer; - energy management system (EMS) and control of microgrids; - communication and monitoring procedures; - electrical energy storage; - protection principle covering: principle for non-isolated microgrid, isolated microgrid, anti-islanding, synchronization and reclosing, power quality; - commissioning, maintenance and test
10	IEC TS 62898-3-1: 4	Microgrids - Part 3-1: Technical requirements – Protection and dynamic control	Microgrid	Category 3, Category 4		Guidelines for protection and control of isolated or non-isolated AC microgrids (single or three phase).
11	-	Guide for connection of powergenerating plants to the medium and high-voltage grid (>1 kV)	Production	Category 4	RfG	Requirements for immunity for frequency and voltage variations, power regulation, protection and power quality. Comments: Guideline by Danish Energy. Danish title: "Vejledning for nettilslutning af produktionsanlæg til mellem- og højspændingsnettet (> 1 kV)". Gives overview of nescessary documenation needed before grid connection of production plant
12	-	Guide for connection of power-generating plants to the low-voltage grid (≤1 kV)	Production	Category 4	RfG	Requirements for immunity for frequency and voltage variations, power regulation, protection and power quality. Comments: Guideline by Danish Energy. Danish title: "Vejledning for nettilslutning af produktionsanlæg til lavspændingsnet (< 1 kV)". Gives overview of nescessary documenation needed before grid connection of production plant

13		Prækvalifikation af anlæg og aggregerede porteføljer	Frequency control reserves	Category 4		Technical prequalification of plants (production or consumption) with intended use for system services (frequency reserves) in Denmark. (A non-numbered note from the Danish TSO). Comments: Not a standard/norm, but the requirements by the TSO Energinet for plants with intended use for system services in Denmark
14	IEC 62264-1:2013	Enterprise-control system integration — Part 1: Models and terminology	Control	Category 4		Main focus of the standard seems to be integration of enter-prise-control systems in manufacturing companies. The standard defines five levels of control: 0) Production process, 1) Sensing and actuation, 2) Monitoring, supervision and control, 3) Manufacturing operations and control, 4) Business planning and logistics.
15	IEC 60364-8-2	Low-voltage electrical installations - Part 8-2: Prosumer's low-voltage electrical installations	Prosumer	Category 5		Requirements, proper behaviour and actions for low voltage electrical installlations including local production and/or energy storage (PEI: Prosumer's Electrical Installations). Should ensure compability with existing and future electricity delivering by means of local sources and s.
16	IEC 61850-7-420	Communication networks and systems for power utility automation - Part 7-420: Basic communication structure - Distributed energy resources logical nodes	Communication	Category 5, Category 6		IEC 61850-7-420:2009 defines IEC 61850 information models to be used in the exchange of information with distributed energy resources (DER), which comprise dispersed generation devices and dispersed storage devices, including reciprocating engines, fuel cells, microturbines, photovoltaics, combined heat and power, and energy storage. Utilizes existing IEC 61850-7-4 logical nodes where possible, but also defines DER-specific logical nodes where needed. Generic resource class and composition models of single or combinations of DER producer, consumer or storage equipment including mixed aggregations

17	IEEE 1547	IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces	Distrubuted energy resources	Category 6		Focus is the connection between utility grid (EPS) and distributed energy resources (DERs). It provides requirements relevant to the performance, operation, testing, safety considerations, and maintenance of the interconnection. Comments: Considers DER's as 60 Hz
18	ISO/IEC TR 15067-3-8:2020	Information technology — Home Electronic System (HES) application model — Part 3-8: GridWise transactive energy framework	Energy community	Category 6		Technical Report, related to transactive energy (TE). Transactive energy allows electricity generated locally by consumers using wind, solar, storage, etc., at homes or buildings to be sold into a competitive market. Guidance for enhancing interoperability among distributed energy resources involved in energy management systems at homes and buildings.
19	IEC 61850-8-1	Communication networks and systems for power utility automation - Part 8-1: Specific communication service mapping (SCSM) - Mappings to MMS (ISO 9506-1 and ISO 9506-2) and ISO/IEC 8802-3	Communication	Category 6		IEC 61850-8-1:2011+A1:2020 specifies a method of exchanging time-critical and non-time-critical data through local-area networks by mapping ACSI to MMS and ISO/IEC 8802-3 frames. Defines a standardized method of using the ISO 9506 services to implement the exchange of data. For those ACSI services defined in IEC 61850-7-2 that are not mapped to MMS, this part defines additional protocols. It describes real utility devices with respect to their external visible data and behaviour using an object oriented approach. The objects are abstract in nature and may be used to a wide variety of applications.

20	IEC 61850-90-7	Communication networks and systems for power utility automation - Part 90-7: Object models for power converters in distributed energy resources (DER) systems	Communication	Category 6		IEC/TR 61850-90-7:2013(E) describes the functions for power converter-based distributed energy resources (DER) systems, focused on DC-to-AC and AC-to-AC conversions and including photovoltaic systems (PV), battery storage systems, electric vehicle (EV) charging systems, and any other DER systems with a controllable power converter. It defines the IEC 61850 information models to be used in the exchange of information between these power converter-based DER systems and the utilities, energy service providers (ESPs), or other entities which are tasked with managing the volt, var, and watt capabilities of these power converter-based systems. These power converter-based DER systems can range from very small grid-connected systems at residential customer sites, to medium-sized systems configured as microgrids on campuses or communities, to very large systems in utility-operated power plants, and to many other configurations and ownership models.
21	IEC 61850-90-8	Communication networks and systems for power utility automation - Part 90-8: Object model for E-mobility	Communication	Category 6		IEC TR 61850-90-8:2016(E) shows how IEC 61850-7-420 can be used to model the essential parts of the E-Mobility standards related to Electric Vehicles and Electric Vehicle Supply Equipments (IEC 62196, IEC 61851, IEC 15118) and the Power system (IEC 61850-7-420), in order to secure a high level of safety and interoperability.
22	IEC 61851-1	Electric vehicle conductive charging system - Part 1: General requirements	EV	Category 6		Electric road vehicles (EV) cover all road vehicles, including plug-in hybrid road vehicles (PHEV), that derive all or part of their energy from on-board rechargeable energy storage systems (RESS). The aspects covered in this standard include: - the characteristics and operating conditions of the EV supply equipment;

						- the specification of the connection between the EV supply equipment and the EV; - the requirements for electrical safety for the EV supply equipment.
23	IEC 61851-21-1:2017	Electric vehicle conductive charging system - Part 21-1 Electric vehicle on-board charger EMC requirements for conductive connection to AC/DC supply	EV	Category 6		Requirements for conductive connection of an electric vehicle (EV) to an AC or DC supply. It applies only to on-board charging units either tested on the complete vehicle or tested on the charging system component level (ESA - electronic sub assembly). This document covers the electromagnetic compatibility (EMC) requirements for electrically propelled vehicles in any charging mode while connected to the mains supply.
24	IEC 61851-21-2:2018	Electric vehicle conductive charging system - Part 21-2: Electric vehicle requirements for conductive connection to an AC/DC supply - EMC requirements for off board electric vehicle charging systems	EV	Category 6		EMC requirements for any off-board components or equipment of such systems used to supply or charge electric vehicles with electric power by conductive power transfer (CPT), with a rated input voltage, according to IEC 60038:2009, up to 1 000 V AC or 1 500 V DC and an output voltage up to 1 000 V AC or 1 500 V DC.
25	IEC 61851-23	Electric vehicle conductive charging system - Part 23: DC electric vehicle charging station	EV	Category 6		Requirements for d.c. electric vehicle (EV) charging stations, herein also referred to as "DC charger", for conductive connection to the vehicle, with an a.c. or d.c. input voltage up to 1 000 V a.c. and up to 1 500 V d.c. according to IEC 60038. It provides the general requirements for the control communication between a d.c. EV charging station and an EV.

26	IEC 61851-24	Electric vehicle conductive charging system - Part 24: Digital communication between a d.c. EV charging station and an electric vehicle for control of d.c. charging	EV	Category 6		Digital communication between a d.c. EV charging station and an electric road vehicle (EV) for control of d.c. charging, with an a.c. or d.c. input voltage up to 1 000 V a.c. and up to 1 500 V d.c. for the conductive charging procedure.
27	ISO 15118-1:2019	Road vehicles — Vehicle to grid communication interface — Part 1: General information and use-case definition	EV	Category 6		Communication (High level communication (HLC)) between EV communication controller (EVCC) and EV supply equipment (EVSE). Applies to manual or automatic connection devices. This document is also applicable to energy transfer either from EV supply equipment to charge the EV battery or from EV battery to EV supply equipment in order to supply energy to home, to loads or to the grid. This document provides a general overview and a common understanding of aspects influencing identification, association, charge or discharge control and optimisation, payment, load levelling, cybersecurity and privacy. It offers an interoperable EV-EV supply equipment interface to all e-mobility actors beyond SECC
28	ISO 15118-2:2014	Road vehicles — Vehicle-to-Grid Communication Interface — Part 2: Network and application protocol requirements	EV	Category 6		Specifies the communication between battery electric vehicles (BEV) or plug-in hybrid electric vehicles (PHEV) and the Electric Vehicle Supply Equipment. Aspects are specified to detect a vehicle in a communication network and enable an Internet Protocol (IP) based communication between EVCC and SECC
29	ISO 15118-3:2015	Road vehicles — Vehicle to grid communication interface — Part 3: Physical and data link layer requirements	EV	Category 6		Requirements of the physical and data link layer for a high-level communication, directly between battery electric vehicles (BEV) or plug-in hybrid electric vehicles (PHEV), based on a wired communication technology and the fixed electrical charging installation (EVSE)

30	ISO 15118-8:2018	Road vehicles — Vehicle to grid communication interface — Part 8: Physical layer and data link layer requirements for wireless communication	EV	Category 6		Requirements of the physical and data link layer of a wireless High Level Communication (HLC) between Electric Vehicles (EV) and the Electric Vehicle Supply Equipment (EVSE).
31	IEC 61970-301:2020	Energy management system application program interface (EMS-API) - Part 301: Common information model (CIM) base	Communication	Category 6		Lays down the common information model (CIM), which is an abstract model that represents all the major objects in an electric utility enterprise typically involved in utility operations. Comments: Relevant for future development of energy management systems. Relevant for CIM
32	OCPP 1.6	Open charge Point Protocol 1.6	EV	Category 6		
33	OCPP 2.0	Open charge Point Protocol 2.0	EV	Category 6		
34	IEC 61334-4-32	Data communication protocols – Section 32: Data link layer – Logical link control (LLC)	Communication	Category 6		
35	IEC 62351-3	Encrypted communications over TLS	Cyber security	Category 6		
36	IETF RFC 7617	The 'Basic' HTTP Authentication Scheme	Cyber security	Category 6		Defines the "Basic" Hypertext Transfer Protocol (HTTP) authentication scheme, which transmits credentials as user-id/password pairs, encoded using Base64. Published by Internet Engineering Task Force (IETF).
37	IETF RFC 7519	JSON Web Token (JWT)	Cyber security	Category 6		JSON Web Token (JWT) is a compact, URL-safe means of representing claims to be transferred between two parties. The claims in a JWT are encoded as a JSON object that is used as the payload of a JSON Web Signature (JWS) structure or as the plaintext of a JSON Web Encryption (JWE) structure, enabling the claims to

						be digitally signed or integrity protected with a Message Authentication Code (MAC) and/or encrypted. Published by Internet Engineering Task Force (IETF).
38	EN 60309-2	Plugs, fixed or portable socket-outlets and appliance inlets for industrial purposes - Part 2: Dimensional compatibility requirements for pin and contact-tube accessories	Plugs	Category 6		Applies to plugs, fixed or portable socket-outlets, and appliance inlets, hereinafter referred to as accessories, with a rated operating voltage not exceeding 1 000 V DC or 1 000 V AC with a frequency not exceeding 500 Hz and a rated current not exceeding 125 A, primarily intended for industrial use, either indoors or outdoors.
39	EN 60309-4	Plugs, fixed or portable socket-outlets and appliance inlets for industrial purposes - Part 4: Switched socket-outlets with or without interlock	Plugs	Category 6		Applies to self-contained products primarily intended for industrial use, either indoors or outdoors that combine the following items within a single enclosure: – a fixed or portable socket-outlet according to IEC 60309-1 or IEC 60309-2 with a rated operating voltage not exceeding 1 000 V DC or 1 000 V AC with a frequency not exceeding 500 Hz and a rated current not exceeding 800 A; – a switching device.
40	EN 62196-2	Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 2: Dimensional compatibility and interchangeability requirements for a.c. pin and contact-tube accessories	Plugs	Category 6		Applies to plugs, socket-outlets, vehicle connectors and vehicle inlets with pins and contact-tubes of standardized configurations, herein referred to as accessories. They have a nominal rated operating voltage not exceeding 480 V a.c., 50 Hz to 60 Hz, and a rated current not exceeding 63 A three-phase or 70 A single phase, for use in conductive charging of electric vehicles

41	ISO/IEC 27001	Information technology — Security techniques — Information security management systems — Requirements	Cyber security	Category 6		Specifies the requirements for establishing, implementing, maintaining and continually improving an information security management system within the context of the organization. It also includes requirements for the assessment and treatment of information security risks tailored to the needs of the organization.
42		Making the right connections - General procurement guidance for electric vehicle charge points	EV	Category 6		Guidelines made by UK Electric Vehicle Supply Equipment Association on procurement, project management, marketing etc.
43	IEC 62932	Flow battery energy systems for stationary applications	Storage	Not included in report		Specifies methods of test and requirements for the flow battery system (FBS) and the flow battery energy system (FBES) for the verification of their performances.
44	IEC 61000-6-1	Electromagnetic compatibility (EMC) - Part 6-1: Generic standards - Immunity standard for residential, commercial and light-industrial environments	EMC	Not included in report	EMC directive	EMC immunity requirements to electrical and electronic equipment intended for use in residential, commercial, public and light-industrial locations
45	IEC 61000-6-4	Electromagnetic compatibility (EMC) - Part 6-1: Generic standards - Emission standard for industrial environments	EMC	Not included in report	EMC directive	Emission requirements applies to electrical and electronic equipment intended for use within the environment existing at industrial (see 3.1.12) locations
46	IEC 61000-6-3	Electromagnetic compatibility (EMC) - Part 6-3: Generic standards - Emission standard for equipment in residential environments	EMC	Not included in report	EMC directive	Emission requirements applies to electrical and electronic equipment intended for use within the environment existing at residential environments (see 3.1.12) locations

47	EN 55011	Industrial, scientific and medical (ISM) radio-frequency equipment – Electromagnetic disturbance characteristics – Limits and methods of measurement.	EMC	Not included in report	EMC directive	Emission requirements related to radio-frequency (RF) disturbances in the frequency range of 9 kHz to 400 GHz.
48	EN 55016-2-1	Specification for radio disturbance and immunity measuring apparatus and methods - Part 2-1: Methods of measurement of disturbances and immunity - Conducted disturbance measurements	EMC	Not included in report	EMC directive	Specifies the methods of measurement of disturbance phenomena in general in the frequency range 9 kHz to 18 GH
49	EN 62321	Determination of certain substances in electrotechnical products	RoHS	Not included in report	ROHS directive	Determination of levels of lead (Pb), mercury (Hg), cadmium (Cd), hexavalent chromium (Cr(VI)), polybrominated biphenyls (PBB) and polybrominated diphenyl ethers (PBDE)
50	HD 60364-4-41	Low-voltage electrical installations -- Part 4-41: Protection for safety – Protection against electric shock	Electrical installation/equipment	Not included in report	The Electrical Safety Act (Danish)	Protection of personnel
51	HD 60364-4-42	Low-voltage electrical installations – Part 4-42: Protection for safety – Protection against thermal effects	Electrical installation/equipment	Not included in report	The Electrical Safety Act (Danish)	Measures for the protection of persons, livestock and property
52	HD 60364-4-43	Low-voltage electrical installations - Part 4-43: Protection for safety -	Electrical installation/equipment	Not included in report	The Electrical Safety Act (Danish)	Protection of live conductors

		Protection against overcurrent				
53	HD 60364-5-54	Low-voltage electrical installations - Part 5-54: Selection and erection of electrical equipment - Earthing arrangements and protective conductors	Electrical installation/equipment	Not included in report		Earthing arrangement to secure safety of the electrical installation
54	UN38.3	UN Manual of Tests and Criteria, 4th Revised Edition, Lithium Battery Testing Requirements	Storage	Not included in report		Test requirements for transportation of Li-ion battery cells and packs, e.g altitude test, vibration test, shock test, temperature test, short circuit test etc.
55	EN 61660-1	Short-circuit currents in d.c. auxiliary installations in power plants and substations - Part 1: Calculation of short-circuit currents	Electrical installation/equipment	Not included in report		Safety of DC subsystem
56	EN 61660-2	Short-circuit currents in d.c. auxiliary installations in power plants and substations - Part 2: Calculation of effects	Electrical installation/equipment	Not included in report		Safety of DC subsystem
57	IEC 60664-1	Insulation coordination for equipment within low-voltage supply systems - Part 1: Principles, requirements and tests	Electrical installation/equipment	Not included in report		Impulse withstand voltage protection. Impulse voltage is tested at BESS level
58	HD 60364-6	Low voltage electrical installations - Part 6: Verification	Electrical installatio	Not included in report		Insulation resistance. Insulation resistance test is carried out

			n/equipment			
59	IEC 62477-1	Safety requirements for power electronic converter systems and equipment - Part 1: General	Electrical installation/equipment	Not included in report		Enclosure strength against impact
60	IEC 60079-7	Explosive atmospheres - Part 1: Equipment protection by flameproof enclosures "d"	Explosive atmosphere	Not included in report		Ventilation. Internal and external provided ventilation systems are tested
61	EN 61000-6-7	Electromagnetic compatibility (EMC) - Part 6-7: Generic standards - Immunity requirements for equipment intended to perform functions in a safety-related system (functional safety) in industrial locations	EMC	Not included in report		Hazards arising from electric, magnetic, and electromagnetic fields. Safety functions of BESS complys with IEC 61000-6-7
62	IEC 62368-1	Audio/video, information and communication technology equipment - Part 1: Safety requirements	Auxilliary	Not included in report		Protection from hazards arising from auxiliary, control and communication system malfunctions. Guidance on conducting single fault conditions on control and other circuits can be found in IEC 62368-1
63	IEC 61850-3	Communication networks and systems for power utility automation - Part 3: General requirement	Communication	Not included in report		Utility communication and automation IEDs (intelligent electronic devices) and systems in power plant and substation environments.
64	IEC 61850-4	Communication networks and systems for power utility automation - Part 4: System and project management	Communication	Not included in report		Automation systems of power utilities (UAS, utility automation system), like e.g. substation automation systems (SAS).

65	IEC 61850-5	Communication networks and systems for power utility automation - Part 5: Communication requirements for functions and device models	Communication	Not included in report		Power utility automation systems with the core part of substation automation systems (SAS); it standardizes the communication between intelligent electronic devices (IEDs) and defines the related system requirements to be supported.
66	IEC 61850-7-1	Communication networks and systems for power utility automation - Part 7-1: Basic communication structure - Principles and models	Communication	Not included in report		Introduces the modelling methods, communication principles, and information models that are used in the various parts of the IEC 61850-7 series. The purpose is to provide - from a conceptual point of view - assistance to understand the basic modelling concepts and description methods for: - substation-specific information models for power utility automation systems, - device functions used for power utility automation purposes, and - communication systems to provide interoperability within power utility facilities.
67	IEC 61850-7-2	Communication networks and systems for power utility automation - Part 7-2: Basic communication structure - Abstract communication service interface (ACSI)	Communication	Not included in report		IEC 61850-7-2:2010+A1:2020 applies to the ACSI communication for utility automation.
68	IEC 61850-7-3	Communication networks and systems for power utility automation - Part 7-3: Basic communication structure - Common data classes	Communication	Not included in report		Device models and functions of substations and feeder equipment. Attribute classes and common data classes related to substation applications.

69	IEC 61850-7-4	Communication networks and systems for power utility automation - Part 7-4: Basic communication structure - Compatibale logical node classes and data object classes	Communication	Not included in report		Information model of devices and functions generally related to common use regarding applications in systems for power utility automation and sub stations. Communication between intelligent electronic devices (IED).
70	IEC 61850-7-410	Communication networks and systems for power utility automation - Part 7-410: Basic communication structure - Hydroelectric powerplants - Communication for monitoring and control	Communication	Not included in report		IEC 61850-7-410:2012+A1:2015 specifies the additional common data classes, logical nodes and data objects required for the use of IEC 61850 in a hydropower plant.
71	IEC 61850-9-2	Communication networks and systems for power utility automation - Part 9-2: Specific communication service mapping (SCSM) - Sampled values over ISO/IEC 8802-3	Communication	Not included in report		IEC 61850-9-2:2011 defines the specific communication service mapping for the transmission of sampled values according to the abstract specification in IEC 61850-7-2. The mapping is that of the abstract model on a mixed stack using direct access to an ISO/IEC 8802-3 link for the transmission of the samples in combination with IEC 61850-8-1.
72	IEC 62325-301:2018	Framework for energy market communications - Part 301: Common information model (CIM) extensions for markets	Communication	Not included in report		IEC 62325-301:2018 specifies the common information model (CIM) for energy market communications. The CIM facilitates integration by defining a common language (i.e. semantics) based on the CIM to enable these applications or systems to access public data and exchange information independent of how such information is represented internally. The object classes represented in the CIM are abstract in nature and may be used in a wide variety of applications. The use of the CIM goes far beyond its application in a market management system.

73	IEC 62325-450:2013	Framework for energy market communications - Part 450: Profile and context modelling rules		Not included in report		
74	ISO 15118-4:2018	Road vehicles — Vehicle to grid communication interface — Part 4: Network and application protocol conformance test	EV	Not included in report		Specifies conformance tests in the form of an Abstract Test Suite (ATS) for a System Under Test (SUT) implementing an EVCC or SECC according to ISO 15118-2
75	ISO 15118-5:2018	Road vehicles — Vehicle to grid communication interface — Part 5: Physical and data link layer conformance test	EV	Not included in report		Specifies conformance tests in the form of an Abstract Test Suite (ATS) for a System Under Test (SUT) implementing an Electric Vehicle or Supply Equipment Communication Controller (EVCC or SECC) with support for PLC-based High Level Communication (HLC) and Basic Signaling according to ISO 15118-3
76	IEC 62325-301:2018	Framework for energy market communications - Part 301: Common information model (CIM) extensions for markets	Communication	Not included in report		Specifies the common information model (CIM) for energy market communications. The CIM facilitates integration by defining a common language (i.e. semantics) based on the CIM to enable these applications or systems to access public data and exchange information independent of how such information is represented internally. The object classes represented in the CIM are abstract in nature and may be used in a wide variety of applications. The use of the CIM goes far beyond its application in a market management system.
77	61968-11:2013	Application integration at electric utilities - System interfaces for distribution management - Part 11: Common information model (CIM) extensions for distribution	Communication	Not included in report		The scope of this standard is the information model that extends the base CIM for the needs of distribution networks, as well as for integration with enterprise-wide information systems typically used within electrical utilities

78	ISO 14000	Environmental management	Manage ment	Not included in report		
79	ISO 9001	Quality Management	Manage ment	Not included in report		
80	IEC SRD 63199:202 0	Top priority standards development status in the domain of smart energy	Standard develop ment	Not included in report		IEC SRD 63199:2020 presents the current status of the IEC systems committee Smart Energy (SyC SE) development plan for readers (not limited to IEC smart energy related members). The document identifies items that require standardization, their current status and work required, possibly by multiple technical committees or working groups, to address any issues. Since the content of this document represents a snapshot of the dynamic/living standardization processes to be updated, it is subject to future changes. Users' perspectives are considered. For example, the analysis of influences of each item (development impact and chance to fill gaps) are stated.

81	IEC TR 63097:2017	Smart grid standardization roadmap	Standard development	Not included in report		It provides standards users with guidelines to select a most appropriate set of standards and specifications. These standards and specifications are either existing or planned, and are provided by IEC or other bodies also fulfilling use cases. It also aims at creating a common set of guiding principles that can be referenced by end-users and integrators who are responsible for the specification, design, and implementation of Smart Energy Systems. As a living document, this roadmap will be subject to future changes, modifications and additions, and will be incorporated into future editions. At the current stage, the focus remains 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) and will be considered in a future edition of this document
82	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	Smart grid	Not included in report		It describes a common approach for IEC technical committees to define generic smart grid requirements for further standardization work. It uses as input the Use Case methodology defined as part of the IEC 62559 series, and provides a more detailed methodology for describing Use Cases and extracting requirements from these Use Cases. This is necessary to achieve a consistent and homogeneous description of generic requirements for the different areas which make up the smart grid environment
83	IEC TS 63200 ED1	System Reference Deliverable SRD: Definition of Extended SGAM Reference Architecture	Smart grid	Not included in report		