CONSOLIDATED VIEW OF THE ETP SG
(EUROPEAN TECHNOLOGY PLATFORM ON SMARTGRIDS)

ON RESEARCH, DEVELOPMENT & DEMONSTRATION NEEDS IN THE HORIZON 2020 WORK PROGRAMME 2016-2017

APRIL 2015

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Foreword

A lot of research effort and funds have been devoted in Europe and other parts of the world, in order to develop the secure, economic and sustainable energy system of the future. In particular in the last years, the developments in the Smartgrids area have revolutionized our conception of modern Energy Systems. Energy Systems are changing, but significant RD&D activities are still needed, in order to realize the necessary change. The European Technology Platform on Smartgrids (ETP SG), from its very beginning, has aimed to provide strategic advice to the European Commission on the medium- and long-term technological research and development needs in the area of Smartgrids. In the last years, this aim has been served by the publication of the ETP SG Strategic Research Agenda 2035 (SRA 2035) and its Priority on the SRA 2035 documents published in 2012. The current document is the next step in this direction. It provides the view of the ETP SG on the SmartGrids Research Development and Demonstration (RD&D) needs in the Work Programme (WP) 2016-2017. It is a document that is based on the expertise of over 100 members of the ETP SG Working Groups and provides the consolidated, unified and unbiased views of the wide variety of its stakeholders on the next RD&D priorities. On behalf of the immediate past chair and vice-chair Richard Charnah, the WG chairs, Venizelos Efthymiou, Jean-Baptiste Bart, Maher Chebbo and the Steering Committee members of the ETP SG, I would like to express our gratitude to all contributors to this document and especially the ETP SG Secretariat for the homogenization of all contributions and the final preparation of this report.

Nikos Hatziargyriou,

ETP SG Chair

April 2015

Introduction: ETP SG History and previous work

The ETP SG (European Technology Platform on SmartGrids) was established in 2006. Its current aims are to support the EU in ambitious Energy and Climate targets for 2020 and beyond to reduce greenhouse gas emissions, increase the share of renewable energies and improve energy efficiency. It supports the actions to achieve these objectives for advancing Europe along the path to an energy system that will deliver a competitive and secure energy supply which is sustainable.

The ETP SG is directed by its steering committee (SC) and supported by a Secretariat and currently three working groups (WG) formed by the SC:

- **Working Group 1: Network Operation and Asset Management**
- **Working Group 2: Integration of storage in the grid**
- **Working Group 3: Demand, Metering & Retail**

New working groups are currently being established.

The Steering committee, Secretariat and Working Group members of the ETP SG are listed in the contributor list at the end of this report. The term "ETP SG" refers to mainly these bodies. In addition, the ETP SG Secretariat has a list of more than 3800 persons and companies around Europe which are part of a regular correspondence by Newsletters, Emails, etc. Also, the ETP SG regularly organizes a General Assembly where the key stakeholders and the wider audience can share views on key topics in the area of Smart Grids.

In 2012 the ETP SG produced the Strategic Research Agenda 2035 (SRA 2035) which put forward the research and development needs towards 2035, many of which are now again seen in the Strategic Energy Technology Plan (SET Plan). With its Priority on the SRA 2035 document, the ETP SG has set out a long term priority plan for addressing the key research and developments questions.

The ETP SG strongly believes that RD&D in "Energy Efficiency", "Competitive Low-Carbon Energy" and "Smart Cities and Communities" and at all technology readiness levels must be continued to be pursued in these areas, i.e. from 'proof of concept' to applied research, pre-commercial demonstration and market uptake measures. From the point of view of SmartGrids, the areas have strong synergies with information and communication technologies. However, the ETP SG focuses on the research and development needs related to energy carrier based grid integration. Besides and along its core dedication to "Technology", the ETP SG also proposes complementary socio-economic research needs and priorities aiming at increasing the understanding of the complex energy system, improving the knowledge base for policy and regulatory development in the transition of the energy system.

Objective and scope of the report

With the current document, the ETP SG intends to identify to the European Commission and other stakeholders those areas and topics considered of utmost importance to be researched and demonstrated during the years to come. The scope of the document is innovation needs realized by research projects on grid based energy systems as a whole started during the 2016-2017 period. The ETP SG refers in particular to the needed research as will be requested by the European Commission in their up-coming work program 2016-2017 within H2020 (Horizon 2020). The view of the ETP SG also includes system aspects related to storage and generation. Consumer and citizen interaction, market integration and conversion between different energy forms must have highest relevance in the research work initiated during 2016-2017 as part of Horizon 2020.

This report is strongly based on the experience of the working group members that represent most of the interested Smart Grids stakeholders with varied background. In support for this work existing strategic documents were carefully analyzed by the members and used as an input for this work. The most important sources were:

- **Horizon 2020 - Work Programme 2014-2015: Secure, Clean and Efficient Energy**
  - http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/main/h2020-wp1415-energy_en.pdf
- **The SmartGrids Strategic Research Agenda (SRA) 2035**
  - http://www.smartgrids.eu/documents/sra2035.pdf
- **SmartGrids SRA 2035 - Summary of priorities of SmartGrids Research Topics**
  - http://www.smartgrids.eu/documents/sra/ETPSG%20-%2020130628%20-%20SRA_2035_Priorities_Short.pdf
- **EEGI (European Electricity Grid Initiative) Research and Innovation Roadmap 2013-2022**
  - http://www.edsoforsmartgrids.eu//wp-content/uploads/public/20130228_EEGI-Roadmap-2013-2022_to-print.pdf
- **EEGI Implementation Plan 2014 - 2016**
  - http://www.gridplus.eu/Documents/EEGI%20Implementation%20Plan%202014-2016_definitive.pdf
- **Mapping & Gap Analysis of current European Smart Grids Projects (from the Grid+ FP7-project)**
  - http://www.gridplus.eu/Documents/Deliverables/GRID+_D1.2%20FINAL.pdf
- **Strategic Energy Technology SET Plan: Towards an integrated roadmap: Research & Innovation Challenges and Needs of the EU Energy System**
  - https://setis.ec.europa.eu/system/files/Towards%20an%20Integrated%20Roadmap_0.pdf

- **SET PLAN - Energy Integrated Roadmap- Part II - Competitive, Efficient, Secure, Sustainable and Flexible Energy System:**
  - http://www.sintef.no/globalassets/project/eera-ccs/ir---annex-i-_-part-ii---detailed-contributions-from-the-stakeholders-v2014-10-20.pdf
- **European Energy 2020 strategy**
  - http://ec.europa.eu/energy/en/topics/energy-strategy/2020-energy-strategy
- **JRC (Joint Research Centre): Published map of smart grid projects in Europe**
  - http://ses.jrc.ec.europa.eu/ (see link for maps)

Naturally, the current Work Programme 2014-15 of the European Commission is a very important input and has been also taken into account. In particular, this report is compliant with the priorities set out in the SmartGrids SRA 2035 that was produced by ETP in 2012.

Structure of the report

The structure of this report is as follows: In chapter 1, the general challenges for the coming years are highlighted and the objectives are given. This chapter 1 is closely linked to the EEGI roadmap and the SRA2035, however the objectives are updated and the scope is extended.

In chapter 2, the challenges and objectives are translated into views of the ETP SG about what are considered as most urgent funding opportunities within the up-coming Work Programme 2016-2017. This should be interpreted as a list of priorities that are crucial to be researched in the coming years in order to integrate more renewable energy sources in the grid and to connect the complex energy system with consumer and market interaction. The recommendations put forward in this chapter might be of greater technical detail than the Work Programme 2016-2017 text itself. Rather than being exclusively a supportive document to draft the WP2016-2017, it highlights important challenges for the energy system that should be addressed by the specific projects.

In chapter 3, the ETP SG highlights regulatory challenges. These challenges should be interpreted as barriers for the implementation of the technology and market research questions raised in chapters 1 and 2. Although not being at the core of a technology related platform, ETP SG observes a strong relevance of these regulatory challenges with technological challenges and vice-versa.

1. Challenges and objectives identified by the ETP SG[1]

In the Strategic Research Agenda 2035 the long-term needs for RD&D in the area of SmartGrids have been defined in five main categories:

- **Area D: RD&D for Smart Distribution systems**
- **Area T: RD&D for Smart Transmission systems**
- **Area T&D: RD&D for the common T&D systems**
- **Area IS: RD&D for Integrated Systems including Storage**
- **Area RC: RD&D for Smart Retail and Consumers Systems, including Consumer Interaction and Market Integration**

This chapter follows this structure and indicates challenges and objectives in each of these research areas.

1.1 RD&D for Smart Distribution Systems (SRA 2035 Area D)

Active demand for increased network flexibility

Challenges:

Active Demand (AD) aims at providing domestic, commercial and industrial consumers with information on their consumption and the ability to modify their consumption in response to time-based prices and other types of incentives. Other incentives may include the possibility for reduction of CO2-footprint. In this case, information about the environmental effects of the energy consumed, next to price, should be provided.

Even though applications in the commercial and industrial sectors already exist today for AD, there is a major challenge in having millions of domestic consumers participating in AD. One of the major barriers to overcome is the high transaction and investment costs which are still generated when a large number of small customers are involved in AD. Additional barriers are, among others, favourable market and regulatory frameworks, appropriate communication infrastructures and sociological-acceptance by end-users..

Objectives:

Enable consumers' participation in the electricity market: Demand flexibility must be exploited to offer services to the different market participants enhancing consumer flexibility and adaptability, thus providing real-time optimisation of energy flows at local and global level. To this purpose, real-time metering data have the potential to facilitate active demand services.

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[1] For a list of members of the involved persons, including the three working groups, see the Annex of this document.

Integration of infrastructure to host Electrical Vehicles (EV)

Challenges:

The major car manufacturers have started the production and sales of EV with projections estimating one million electric vehicles circulating in Europe by 2020, which anticipates a significant expansion by 2030 and beyond. Therefore, there is a need to address the impact of different types of charging options on the LV (Low Voltage) and MV (Medium Voltage) distribution grids (and the electric system in general) and to enable the massive diffusion of electric vehicles. European Member States must guarantee that the most critical aspects relating to charging infrastructures have been tested and integrated into the electrical distribution grids, and consequently a number of proven technologies and solutions will be available in line with the arrival of electric cars.

Objectives:

Fully understand the threats and opportunities of massive electric vehicle charging on the distribution network and to propose solutions for the potential problems identified: Massive integration of EVs can have a number of negative consequences for the grid, like overloads and power quality (i.e. harmonics, voltage profiles) not conforming to international standards (e.g. EN 50160), but it also provides potential for load shaping and opportunities for ancillary services linked with the availability of distributed storage of EV batteries. In addition, interoperable EV charging solutions, including fast high power charging infrastructures, should be developed to offer innovative services to the customers and enable the massive diffusion of sustainable transportation.

Smart metering data utilisation

Challenges:

According to European Directive 2009/72/EC, by 2022, all EU member states must complete their smart metering roll out. Even though the first generation of smart meters in Europe is different from one member state to the other, a very large amount of data is being collected whose potential has been untapped.

Objectives:

Fully grasp the value of the two main metering data categories: grid external and grid internal data. Grid external data which deal with prosumers issues and grid internal data which deal with the capillary observability of the electricity network. **Determine the European added value in further processing of presently available data** to find new uses, prepare second generation of smart meters over Europe, explore new business models for network operators, and facilitating new services in the market relevant to energy efficiency, while preserving existing high quality standards and network security.

1.2 RD&D for Smart Transmission Systems (SRA 2035 Area T)

Planning methodology for future intra- and pan-European transmission systems

Challenges:

New network infrastructures are needed to connect energy generation sites involving variable RES (Renewable Energy Sources) and DER (Distributed energy Resources) with demand areas. Top-down planning approaches at intra- and pan-European level must be developed, involving a broad spectrum of novel technologies (generation, transmission, storage, demand management).

Objectives:

Develop simulation software to assess options of intra- and pan-European transmission system infrastructure; Facilitate system planning simulations at the intra- and pan-European level capable of comparing several design options based on various technical and economic criteria, taking into account emerging technologies: HVDC VSC (HighVoltage Direct Current transmission based on Voltage Sourced Converters), multi-terminal and HVDC network, PST (Phase Shifting Transformers), FACTS (Flexible AC Transmission Systems), fast storage technologies, high-capacity conductors, etc.

Demonstration of power technologies to increase network flexibility and operation means

Challenges:

The complexity of the pan-European network requires highly flexible development of transmission capacity and system operation to ensure security of supply. Furthermore, the advent of a single pan-European electricity market with increased flow of energy across multiple borders has led to increased cross-border power flows. Advanced transmission technologies must be tested and existing lines must be improved. The integration of new technologies into existing infrastructures presents interoperability issues that must be solved.

Objectives:

Demonstrate emerging transmission power technologies; Validate them to increase the flexibility and capacity of the existing power grid.

Advanced pan-European market tools for ancillary services and balancing, including active demand management

Challenges:

Current EU targets for integration of RES – in particular wind and solar energy – present significant challenges for balancing control and management of power and energy reserves within existing transmission grids. Balancing control can be seen as two fairly independent tasks: maintaining the grid frequency within definite limits and real-time management of network congestion arising from unplanned deviations. Novel market simulation tools are needed to properly design pan-European value streams.

Objectives:

Develop market tools that go beyond those currently used in member states. Stimulate RES involvement, active demand and storage systems, contribute to system balancing and provide ancillary services.

1.3 RD&D for Common Transmission and Distribution Systems (SRA 2035 Area TD)

Increased observability of the distribution system for transmission network management and control

Challenges:

A challenge for every network operator is to aggregate data that is coherent at all voltage levels and between operational areas. Moreover, especially in the presence of intermittent generation at all voltage levels, there is an increasing need to accurately monitor and model the load and DER. This data aggregation should cover different time horizons, ranging from short-term (real-time operational planning) up to long-term (network planning). Forecasting engines are needed to manage reserves in a timely and secure manner. Furthermore, the presence of PV (Photvoltaic), wind or CHP (Combined Heat and Power) units at the distribution level requires TSOs (Transmission System Operators) to foresee the real-time requirements of the distribution system to maintain operational security.

New network codes integrate to some extent control over DER. This may ask for DER control centres to monitor, forecast and operate DER according to the needs of DSOs (Distribution System Operators) and TSOs. This provides more capabilities such as power flow control, load management, autonomous operation and control at the cell level, among others.

Objectives:

Develop and demonstrate approaches to increase monitoring and observability of the distribution system at all voltage levels, also for transmission network management and controllability owing to better forecasting and DER control capabilities.

Ancillary services provided through DSOs and other market stakeholders

Challenges:

Distribution companies formerly contributed to ancillary services in transmission systems through reactive compensation on the MV side of the HV/MV transformer. Load tripping schemes limit drops in frequency in the event of a loss of generation, etc. The underlying processes will be handled in different ways and by new types of interactions between traditional DSO/TSO and other stakeholders.

Objectives:

Develop approaches and demonstrate how new ancillary services can be provided by DSO in collaboration with new service providers, such as aggregators including those involved with electric vehicle charging; elaborate on the evolution of the electricity sector, accounting also for the need of integration of DERs to enable their participation to the management of the electricity system; Address the legal, contractual and market aspects affecting both TSOs and DSOs.

1.4 RD&D for Storage to contribute to a secure, fully integrated System (SRA 2035 Area IS)

Business Cases for Storage

Challenges:

Many storage technologies are not yet market-ready. The reason for this can be multifold: the cost of resources is too high, the integration into the grid is challenging or the energy loss is significant.

Objectives:

Develop business cases to enable the current storage technologies to enter the market. To demonstrate the integration of storage in the electricity system at several voltage levels, including low voltage, and develop solutions to provide various network/system services from storage.

Integration of Storage into Markets

Challenges:

In general, the market design has a crucial impact on the value of storage that may be beneficial for the society as a whole.

Objectives:

Develop market mechanisms and associated regulations; this is a top priority towards the achieving an efficient integration of the storage in the grid during the coming years.

Power electronics for the Control of Storage

Challenges:

On the technical side, much improvement is still necessary in the storage connected power electronic modules; in particular, reducing the cost of the power electronics management and conversion equipment, increasing its performance and efficiency, while adding new functions to the power electronic blocks that manage and control the storage devices. Also, due to the expected reduced rotating masses of generators, storage will need to be controlled by an integrated approach of the necessary inertia and smart power electronics to compensate for this effect.

Objectives:

Develop advanced power electronics signal processing that will allow the storage and DER together with the inertia of rotating masses to provide (ancillary) services to the power system and therefore to create efficient business models.

Use of storage across energy carriers

Challenges:

The power sector finds itself in a new situation: Increasing synergy between the different types of energy carriers (electric power, heat, gas, …) is observed. Hybrid Energy Storage together with Hybrid Energy Management is capable to play the main role in the cooperative action of those different energy carriers.

Electric power to heat/cold, electric power to gas, electric power to hydrogen are some of the examples of opportunity for energy storage to find new business models.

“Electric power to heat” will be especially promising, as almost 50% of the European final energy demand is in the form of heat.

Objectives:

Develop approaches to integrate the increased efficiency of the thermal storage into the power system as a whole.

1.5 RD&D for Consumer Interaction and Market Integration (SRA 2035 Area RC)

The integration of demand side management at DSO level into TSO operations

Challenges:

The potential benefits of load control, such as peak shaving and energy savings, must involve large-scale participation of end consumers in order to assess their impact on TSO planning and operations.

New technologies such as smart meters and intelligent home controllers add value to traditional demand response and raise awareness about consumption patterns and foster active customer participation in the energy market.

Objectives:

Develop processes for commercial actors (e.g., VPP, aggregators, retail companies) to operate in localized markets with DSO, TSO, or market stakeholders.

Demand segmentation models

Challenges:

Flexibility of end consumers can be defined as the amount of consumption/production that can be shifted in time. This flexibility could be used to reduce and alleviate grid congestions (both distribution and transmission level), reduce the electricity bill for end consumers by providing demand side flexibility during different periods through dynamic pricing and energy efficiency services, or provide balancing services to the Balancing Responsible Parties (for balancing power/energy) or directly to the TSO (for regulating power).

Objectives:

Develop approaches to determine, monitor and control the extent of demand response to effectively use the available flexibility and enhance energy efficiency, while assuring proper integration into the network; Develop the most appropriate business case (or combinations)

Sociological aspects of the end consumer

Challenges:

Still many open questions exist regarding the sociological aspects and the knowledge of the end consumer behaviour.

Objectives:

Determine approaches to address the acceptance of the end consumer towards innovative demand response technologies and the commitment of the end consumer to adapt to DR technology in the longer term.

Market integration

Challenges:

One of the challenges is the integration of the end consumer in a harmonized European electricity market consisting of Pan-European and retail market elements.

Objectives:

Determine new market approaches (including for retail) and harmonization at European level. Determine new market approaches that allow RES with high capital investment and zero operational costs to maximize their penetration, while ensuring the economic viability of the necessary thermal generation, in order to maintain the system security and reliability.

2. SmartGrids RD&D Funding Opportunities for the Work Programme 2016-2017 in H2020

It is expected that the work Work Programme 2016-2017 of H2020 will include a list of research areas and topics which cover more than the following priorities. ETP SG however, wants to highlight those R&D areas which are seen as most urgent from the “system integration point of view”. These are seen as most essential and critical for a fast implementation of renewables, assuming a continued secure and economic energy/electricity system service to grid users / customers, as the necessary pre-requisite.

The following priorities have been determined also using the gap analysis done within the GRID+ project which did, however, not include an analysis of those projects funded from the first call in the year 2014 of the WP 2014-2015. Also, the following does not take into account those RD&D projects, which are not yet finished and have not yet produced conclusive results. The works and conclusions from the recently started project following GRID+STORAGE will be considered in future updates of this document.

In this chapter, challenges and objectives highlighted in the previous chapter are translated into the practical funding needs of the Horizon2020 call in 2016-2017.

The following funding topics should be addressed in the frame of the upcoming Work Programmes in H2020, where relevant areas[2] in the current WP2014-2015 are given in the footnote.

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[2] The content of this section are mainly related to the following parts of the Horizon 2020 Work Programme 2014-2015:
EE 6: Demand response in blocks of buildings
EE 10: Consumer engagement for sustainable energy
EE 11: New ICT based solutions for energy efficiency
LCE 6: Transmission grid and wholesale market
LCE 7: Distribution grid and retail market
LCE 8: Local / small-scale storage
LCE 9: Large scale energy storage
LCE 10: Next generation technologies for energy storage
LCE 18: Supporting Joint Actions on demonstration and validation of innovative energy solutions
LCE 19: Supporting coordination of national R&D activities
LCE 20: The human factor in the energy system
LCE 21: Modelling and analysing the energy system, its transformation and impact

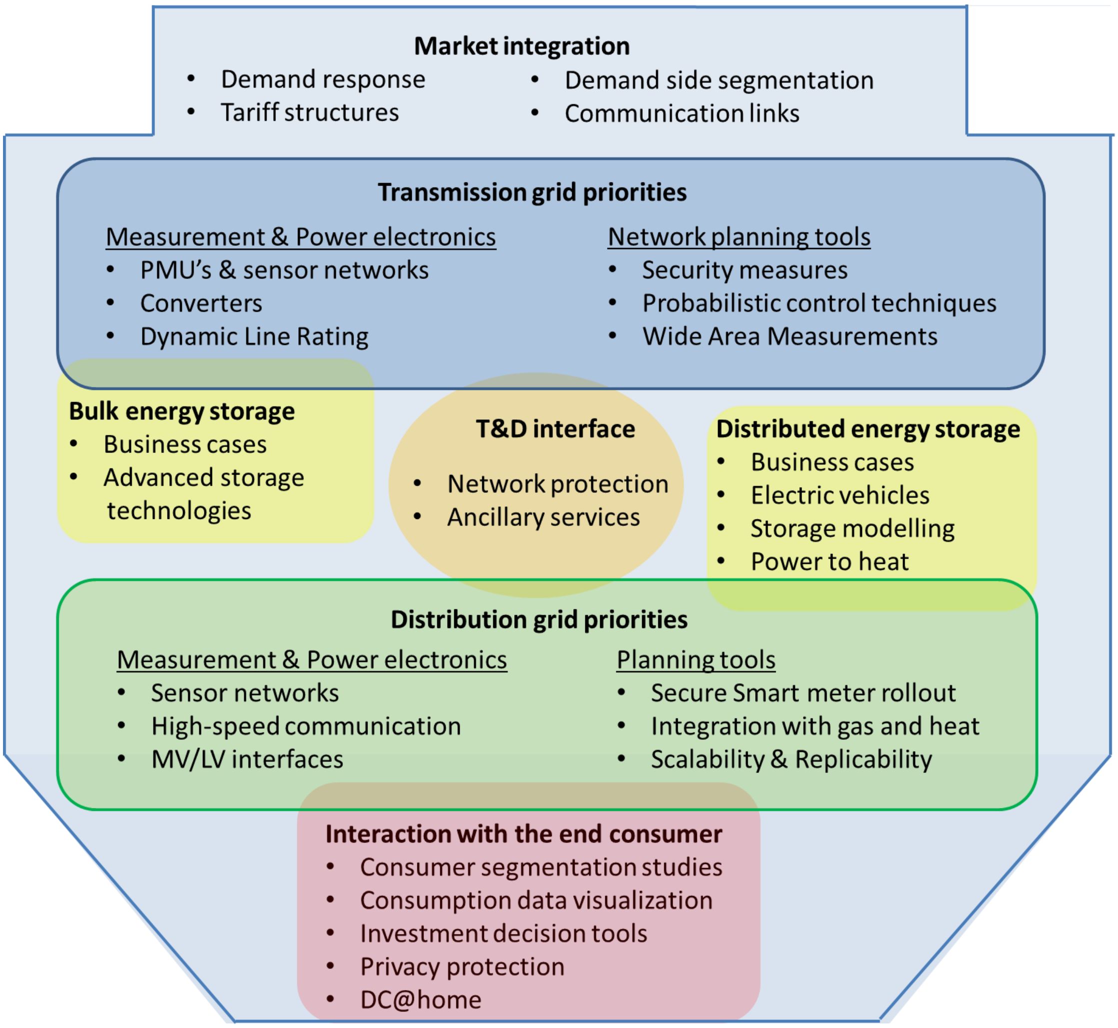

Figure 1: Priority areas for research in WP 2016-2017 of H2020 in order to achieve a higher penetration of renewables in the grid.

Figure 1 gives an overview of the priorities which are the most relevant for WP 2016-2017 within H2020 according to the ETP SG. The aim is to achieve the 2020 goals and beyond, towards 2030 and 2035, as pointed out in the Strategic Research Agenda 2035. From the grid perspective, increased monitoring and control capabilities will be crucial, as renewable energies might cause local congestions in the grid. This will require a fast communication link to timely transmit a large amount of data, both for transmission and distribution grids. One of the key issues here is an integrated approach for security measures. With millions of smart meters installed already, it is essential that customer's metering data are protected at all times.

Storage is another very important asset to successfully integrate renewables in the grid. Not only can it provide shifting of the time when renewable energy is fed into the grid when needed by end consumers, but equipped with fast control schemes, it can be used to support the frequency and voltage in the grid, at transmission and/or distribution level. The most challenging and important issue with these technologies is currently the establishment of business cases, so techno-economic models should be prioritized in the coming years. Finally, in the future energy landscape the ETP SG envisions a central role for the end consumer, who can improve the system by reacting to dynamic pricing or providing demand response.

In the next section, the elements of figure 1 are described in more detail.

2.1 Transmission grid priorities

To achieve a higher amount of renewable energy in the grid without experiencing local congestions, serious frequency problems or voltage unbalances, the two main priorities are hardware and power electronics that enable to measure the parameters needed to monitor the grid, and data handling procedures including control that allow congestion and outage management by the TSOs (Transmission System Operators).

Measurement infrastructure & Power electronics

PMU's and sensor networks

Develop monitoring devices, such as PMUs (Phasor Measurement Units) with potential for synchronized measurements in combination with sensors that improve load and renewable generation forecasting. These sensors can measure electrical grid parameters (Voltage, Current, Power Quality…) with various level of accuracy. Sensor technologies will enable TSOs and DSOs to obtain more accurate online monitoring of grid use. By that, more efficient use of available grid capacities can be realized by the right control mechanisms, i.e. PMU and sensor information can be used to develop new operational policies on real-time measurement and control needs.

Dynamic line rating

Develop tools which allow dynamic and real time use of transmission lines and cables depending on their thermal conditions by using cost-efficient sensors and high-speed communication. This technology can significantly reduce the amount of new power line constructions and also reduce the height and size of new conductor infrastructures.

Converters

Develop large-scale back to back converters which can be used to provide controllable interconnections between countries and different areas of network. This allows the decoupling and control of power exchange between areas of network in terms of power flow, frequency and voltage level. In general, attention should be given to solving problems of interconnecting networks, where there is a big angular voltage difference between two areas of network and also where greater interconnection may cause fault level problems.

Network planning tools

Security measures

Develop new, standardized, plug-and-play-approaches to improve cyber security within the network and at end points, such as Smart Meters: Energy networks are critical types of infrastructures and potential targets for attacks, both physical and cyber. Hence measures are required for physical monitoring and protection of power lines and distribution points, as well as protection of data networks transmitting information regarding operation of the infrastructures. Increased focus on Smart Grid technologies also increases risks of cyber threats either with a purpose of affecting the performance of energy distribution as a whole or distorting consumption data at local scales for fraud.

Monitoring and control techniques

Develop planning tools that benefit more than the relative merits of centralized and decentralized/distributed control approaches.

More specifically, develop hybrid architectures which include both decentralized and centralized techniques, such that the data efficiency and robustness benefits of decentralized techniques are realized, but also the global knowledge can be used and global optima possible from centralized techniques can be reached.

Probabilistic techniques

Develop control tools for handling probabilistic information next to deterministic information. The use of dynamic ratings, stochastic generation, storage and demand side response mean that probabilistic techniques are essential to plan future networks that can exploit these technologies.

Data handling for Wide Area Measurements

Develop methodologies for Wide Area Measurements, such as data management systems, to develop planning methodologies for TSOs at European level. For these mechanisms, cloud computing techniques to enable the efficient and standardized sharing of data across the European grid should be developed.

2.2 Distribution grid priorities

The role of the DSO and interaction possibilities is increasingly important. DSOs are usually the physical connection with the end consumer side, having to cope with large amounts of renewable generation injected in the MV (medium voltage) and LV (low voltage) grids. This leads to the need of increased observability, which requires monitoring and control tools and network data handling, in analogy to the TSO. By 2020 more than 200 million smart meters will be rolled out in Europe, while already millions of smart meters are installed today. However, this is not happening in a standardized way, with a lot of different technology choices made by the different DSOs in Europe. Also, DSOs are the physical connection to the end consumers and are a key player to integrate them in a market mechanism. These points are further discussed in chapter 3. Below we outline the current research priorities for a secure and economic grid.

Measurement infrastructure & Power electronics

Sensor networks

Roll out low cost sensor networks to detect anomalies and the degradation of assets over time, in order to make investment decisions. In this way, the lifetime of assets can be optimized. This technology can also be used for predictive maintenance, the right timing for upgrades and replacement of technology, but also to predict residual capacity in real time.

High-speed communication

Implement high-speed broad band communication, in order to enable the development of grid-scale real-time, measurement infrastructure for a stable and secure use of MV networks considering strongly volatile grid flows (including generation). This communication could be realized either by public or private networks. Together with the hardware of the sensor networks, the increased observability in MV and LV grids enables supporting services, such as protection, power quality, risk and fault management, preventive measures, capacity management and system services. These services, e.g. new voltage monitoring and management techniques, can be less costly than the traditional alternative of grid upgrades. Examples are the developments of on-load tap changers (OLTC), in-line voltage regulators, capacitor banks/shunt reactors etc.

MV/LV interfaces

Develop tools for handling the right interactions between MV and LV networks: Not only should the interaction be improved between distribution and transmission operators related to the detection and correction of critical grid states (voltage, line current, fault currents, etc.), but also tools should be developed for handling more interactions between MV and LV networks. This includes considering the impact of LV on MV networks, and control philosophies behind the network monitoring schemes of MV grids that can influence LV and vice-versa.

Planning tools

Secure smart meter rollout

Implementation of smart metering is already ongoing in many Member States. From a technological point, there are many different solutions and possibilities to implement smart meters. The functionalities can greatly vary from simple electronic metering to those with integrated functions to follow dynamic prices.

Several technologies are used to communicate smart meter data to various server architectures (central, hierarchical, distributed, etc.). Guidelines for a swift, secure and reliable implementation of smart meters are extremely useful for future roll-outs, as they are unlocking and supporting various applications, like in–home management technologies and demand response.

Integration with gas and heat networks

Develop planning tools that can handle heat and power and cooling requirements in an integrated manner, where for instance CHPs and power-to-heat technologies are the bridges between gas, electricity and heat networks.

Scalability & replicability

Develop tools together with the relevant stakeholders to reduce the uncertainties when going from research and demonstration towards business: One of the key points for business case in distribution grids is the ability to scale up the developed solution and replicate it in many demonstration sites. The scalability and replicability of novel technologies used in smart grid solutions is dependent on the costs of the new technologies at a market uptake phase, standardization and regulatory conditions. Uncertainty within these areas presents a risk to investment and this is another barrier to the large scale deployment of these solutions.

2.3 Transmission & Distribution interface

European TSO interfaces

Develop tools for automated and reliable interfaces between the transmission systems of different European countries and/or bidding zones in order to provide economic and stability benefits. In these developments, protection coordination, adaptive protection and inter-tripping schemes between countries across Europe also require attention.

Ancillary services

Investigate the contribution of an ancillary services market - traditionally provided only at the transmission level - also at the distribution level. Such a combined TSO/DSO service can substitute grid investments leading to the equivalent technical and operational performance.

2.4 Energy storage

Storage is one of the main promising technologies to increase the amount of renewable energy in the grid, either centrally controlled or distributed. Technologically, large-scale, long term storage is perfectly possible. However, work has still to be done to commercialize the available technologies and bring them to the market in a competitive way.

Bulk energy storage

Business cases

Develop approaches for an economic assessment of which storage technologies will be the most interesting in the coming years. A very important aspect of bulk energy storage is the business case associated with implementation of the technologies. Large-scale demonstration project implementing storage technologies should be accompanied by an associated cost-benefit analysis.

Advanced Storage Technologies

Develop storage based approaches contributing to the overall requirements of a secure power system supply. These include:

Storage based methods for the long term, large-scale conversion of electrical energy and its integration into the electricity/energy system. One way to do this includes approaches to convert Electric Power to hydrogen by low temperature electrolysis, with the goal of low cost and effective technologies (materials and design).

Storage based methods for the more flexible use of pumping and generation in Pumped Hydro Storage (PHS): This is especially useful to cope with ageing equipment to cope with new PHS underground.

Long-duration heat storage technologies.

Integration approaches for innovative compressed air storage solutions.

Distributed energy storage

Business cases

Research the economic and technical efficiency of storage with the goal to compensate the intermittency of RES. Develop business cases e.g. for the synergy between battery storage and wind farms.

Battery technologies

Develop batteries for households and similar, where new materials and cell/battery designs are implemented to aim for lower cost per energy/power level. New chemistry technologies can also be used to reduce the degradation of the batteries. Research their contribution to a secure power system supply

Power to heat

Develop small “power to heat” storage facilities including their monitoring and control where the development of thermal energy storage technologies supports the power to heat facilities. Research approaches which can significantly improve performance, availability, durability, safety and lower the costs and contribute to the overall requirements of a secure power system supply.

Electric Vehicles

Exploit the use of Electric Vehicle batteries in their first life (in the car) and their second life (reused and connected to the grid). Also exploit the V2G (Vehicle to Grid) functionalities that batteries in cars could have. Exploit the synergies of power electronics that is present in PV converters, Electric Vehicles and Charging Poles. Research and demonstrate the implementation of LV DC (Direct current) grids.

Storage models

Develop integration concepts of the energy storage services into energy and power market models where all services are covered: long-term, day-ahead, intra-day, balancing, ancillary services, etc. Develop models to optimize the combined services that storage can deliver e.g. ancillary services and grid support. The near-future energy management systems and strategies will make use of advanced procedures with generation and demand forecast and related ICT infrastructure for the integration of storage into the grid.

AC/DC interaction

Develop efficient and flexible storage monitoring and control systems with the goal of a flexible synergy between the existing AC (Alternative Current) system and the DC + HVDC grids considering the integration with (mostly) DC (Direct Current) storage technologies.

2.5 Market Integration

Business cases

Assess the market readiness of the developed solutions and products: Economic models and financial analyses (cost efficiency improvement, economic viability …) must be integrated in technology projects.

Demand side segmentation

Assess how much flexibility is readily available at the end consumer side: The current European electricity demand can be characterized in three different segments: Industrial, Commercial and Residential consumers. The exact potential of each of these sectors for shifting consumption in time is not yet clear. For residential consumers, projects are currently ongoing to assess the economic potential; a complete overview in Europe is, however, not yet available. For industrial consumers, flexibility will depend strongly on the sector which is considered and the type of activity of the respective company. A worked out segmentation of industrial consumers and analysis of available flexibility in each segment could provide valuable insight in the strategic and commercial decisions which should be taken towards demand response in general.

Communication links

Research the merging of the “Internet of Things” and consumer energy devices: This requires to approach this topic from both the ICT side and the energy side. In order to enable the integration of the flexibility of end consumers, also for market integration, ICT is required to communicate the information from and to the consumer.

Investigate how the latest ICT technologies can be used for unlocking demand flexibility. Low-cost communication is often available due to already installed internet, wireless and mobile connections.

Tariff structures

Research the adaption of the (regulated) grid and renewable subsidy tariff structures to the massive introduction of renewables. In many member states a simple day-night grid tariff still prevails, while dynamic tariffs could take into account the strong variability of grid use. To this end, support of the legislator/regulator is a key issue that must be taken up in the coming years.

Develop tools to support the regulator in making decisions on the shape, concept and amount of the electricity grid tariffs in accordance with market designs and concepts for the energy prices.

Research how in a Time-of-Use pricing scheme, not only energy prices but also distribution grid tariffs can be useful when being dependent on the grid/system state.

Demand response

Explore the combined input of renewables installations and demand response programmes at the residential level for households and community-owned installations (prosumers): Aggregators can provide the link with the market and participate in e.g. balancing services. However, reliable and auditable measurement and verification are needed to both assess the response of the consumers and to check the effective delivery of the products/services provided by aggregators and/or flexibility operators. Such mechanisms must be legally robust and be accepted by all involved stakeholders.

Define appropriate reference or baselines to assess the modification of consumers demand: Measurement & Verification is essential for the assessment of the unbalances and the resulting settlement. In this respect the role that smart meters can play must be further investigated.

2.6 Interaction with end consumer

Several projects are already investigating these topics, however, a conclusive answer that can be scaled to Europe remains unknown. A very important aspect is that social studies should be conducted in close interaction with technology projects.

Consumer segmentation studies

Explore the ‘technically available’ flexibility and the actual potential to exploit the flexibility for e.g. balancing purposes: An important factor here is that studies of the end consumer behaviour are closely linked to demand response. Projects dealing with end consumers via e.g. demand response should involve a statistical representative set of the population. Consumers should receive a questionnaire before and after each project to assess the evolution in the perception towards the innovative technologies. In addition, modelling the behaviour of the different end-consumers can provide valuable insights. For instance, self-learning and prediction algorithms of electricity consumption can improve reliability of flexibility services provided.

Consumption data visualization

Research the types of data and information that are sent from the smart meters to regulated and deregulated players in the electricity market: In order to exploit the smart meter data for potential energy savings and added value through demand response programs, visualization of smart meter data is sensitive aspect. Already several visualization interfaces to interact with the consumption data have been developed; new studies must consider the fact that not all interactions have proven to be useful and accepted by the consumer. In addition to this, new research should be done on gamification of the use of smart meters and its effect on consumer behaviour and consumer acceptance.

Investment decision tools

Explore informative tools to provide the EU citizens with advice on personal investment decisions on SmartGrids technologies. This would mean an extension to ongoing activities by organizations like Eurelectric or ESMIG.

Privacy protection

Explore the protection of the privacy of end consumers when their consumption is shifted in time: Data of end consumers are highly sensitive. Unfortunately, there is no room for a learning process like in the past for security in the banking sector, given the fact that the rollout in many countries is already ongoing and the installed meters should be in place for many years.

Research the optimum life time and costs of installed Smart Meters knowing that computing power and intelligence to prevent cyber attacks will improve quickly within Smart Meter Technology in the years to come.

Interaction with in-home management systems

Develop innovative customer services: Use close to real time data to develop innovative customer services. In-home energy management systems - if properly integrated with the distribution electricity system - have the potential to allow an active customer involvement. Close to real time data will be used to develop innovative customer services and to enable active demand while fostering interoperable and innovative solutions for home energy systems and automation integrated into the electricity network to increase energy efficiency while assuring system security and enable the full exploitation of flexibility potential.

DC @ home

Develop fundamentally new approaches including sensors, controls, for the integration of DC into existing AC home networks. Consider even their replacement to understand the implications. The option of using DC (Direct Current) in the home network has several advantages, for example in the more efficient integration of solar panels and batteries.

3. Regulatory challenges identified by the ETP SG

Although not at the core of the research needs and priorities investigated by the ETP SG, it has become clear that regulatory challenges affect the evolution of technology, technical solutions and the way these business that these solutions are implemented. In the following ETP SG highlights priorities where non-technological research needs to be pursued as soon as possible. Missing insights into these areas could lead to costly old or redundant new technology implementation (e.g. double metering and monitoring of the same quantity; costly interfaces; etc.)

3.1 European R&D incentives and funding

National TSO schemes for recovering of R&D costs

Research the distortion of competition by differences in the tariff structures for the attribution of the costs of transport in the Member States: This distorts competition and hinders innovation in the energy sector. Member States are to a large extent free to establish transport tariffs for the transport systems of electricity. The transport costs are attributed to the different groups of consumers and producers. There are capacity tariffs, tariffs per kWh or a mixture of both. Large consumers complain about the differences in the Member States and the distortion of competition.

SMEs participation in innovation for electricity systems

Research the necessary incentives for SMES to participate in innovation for electricity systems: Regarding Horizon 2020 European Research Framework, although the Commission promotes an increased participation of SMEs in European research, it has removed all financial incentives for SMEs to participate in such projects. SMEs have been offered in H2020 the same conditions as large enterprises, actually making it less attractive for them to participate due to larger indirect costs than for larger companies.

Financial instruments to promote smart grids

Research proper financial instruments to promote smart grids: Apart from Horizon 2020 calls for proposals, which focus on much needed research, development and demonstrations (RD&D), there is currently no financial mechanism promoting implementation of smart grids. The PCIs (Project of Common Interest) claim to provide some additional support, however the criteria in the TEN-E (TransEuropean Energy Networks – Electricity) regulations make it very difficult for smart grids at distribution to apply.

At national level, the situation varies from one country to another. Among others, the United Kingdom and Italy have set up various schemes to support network operators' innovation efforts, but this is still not common practice across Europe.

Ideally, DSOs should have the possibility to recover RD&D expenses through network tariffs, according to the framework defined by the regulator. In any case, the additional technical and regulatory risk incurred by RD&D in Smart Grids must be taken into account by the regulatory authorities.

Whilst it can be argued that, if Smart Grids contribute to increased efficiency for grid operators, they should not need particular support, it must also be recognized that the implementation of Smart Grid technologies has an influence on the Operator's CAPEX/OPEX balance, and regulation should play a role in promotion of their implementation.

Legal rules/ regulatory instruments for smart energy systems in European members states

Research and compare legal rules/ regulatory instruments in smart energy systems in European members states: Study the legal rules/ regulatory instruments in smart energy systems in the different Member States, describe the (potential) barriers to smart grid systems, compare the barriers in the different Member States, find best practices and recommendations for effective instruments.

Research community funded by a mix of energy agencies, regulators, national governments

Research and explore the effectiveness of the research communities funded and driven by energy agencies, regulators, national governments: Some countries consider that research institutes and universities are better equipped to carry out RD&D activities in all fields of power systems, while operators should refrain from this activity. Some other countries opt for financing of RD&D activities for all energy related sectors through national research programmes with the responsibility for implementation being delegated to national energy agencies or similar type of organisations. Finally, in other countries, the accountability is important for regulators and therefore there is push towards the use of EC funds which are perceived as transparent mechanisms for financing.

Furthermore not all NRAs (National Research Agencies) are monitoring the relevant research and demonstration activities and consequently there is not enough knowledge at the regulatory level to pursue on this type of regulation.

Relying on fragmented and incompatible projects to answer the urgency needs of the European power system by 2020 and beyond could lead to higher investments and delays in the delivery of acceptable system wide results

Companies (and SMEs) participating from different countries in joint transnational RD&D funding projects

Research the consequence of mismatches between companies (and SMEs) participating from different countries in joint transnational RD&D funding projects: Joint EU-National funding programs, where each country participates with a different budget and sets different conditions for companies, including SMEs, to participate. This causes mismatches between companies participating from different countries, leading to large discrepancies in funding and, as such, in the capability to contribute to project work.

For example in one project under Greece-Israel program, three Greek partners receive one third (hard limit by Greek national funding body!) of the money that the Israeli side receives, causing a large discrepancy in their research capabilities in the project and consequently lower percentage of revenue (program funds development of pre-products) from the sale of the product resulting from the project.

Strict financial management of R&D funding in all member states

Research the effects of strongly differing financial management of RD&D funding in the European member states: In frameworks like Artemis and Ambient Assisted Living Joint Programme (AAL), different management of funds by national bodies leads to extreme cases where projects have been funded, executed and completed more than two years ago, but the funding still has not been paid to partners from several countries. This calls for better and more strict financial management of research funding by European Commission and related organisations how the funds are distributed locally by National bodies.

3.2 System operator roles and their regulation

Increase recoverable expenditures in R&D by TSOs and DSOs in proportion to annual turnover

Research the need, costs and effectiveness to foster innovation funding and cost recovery in the field of electricity networks, given that their level of investments in RD&D activities is lower than in other energy technologies. For example, expenditures in research and development by TSOs represent less than 1% of their annual turnover, which is considerably lower than what Europe's 2020 (Lisbon) strategy set as objective: 3% for RD&D intensity (R&D expenditure as a percentage of the GDP).

In a longer term, the recognition of the need of RD&D expenses in the power system by the NRAs (National Research Agencies) and ACER/CEER would bring benefits. It would enable TSOs and DSOs to invest in the long term in order to hire staff having the skills and the experience to manage RD&D activities: identify promising topics, develop strong relationships with partners, manage research programs and disseminate the results.

Actions related to threatened safety and security of supply

Research the necessary legislation/rules and regulation for System operators, to determine when to intervene, if safety or the security of supply is threatened: DSO do not have clear rules about the right balance between preventive efforts and associated investment and operation costs versus short-term corrective actions, in case of emergencies, which might lead to very costly blackouts.

Role of Distribution System Operators (DSOs) and Transmission System Operators (TSOs) in providing ancillary services.

Research the legislation needs about separation of DSO and TSO goals, responsibilities and duties in a changing world: DSOs are not given full jurisdiction over the Distribution network, for which they are responsible and asked to deliver. Transmission system operators tend to consider, DG, ancillary services, frequency and voltage control (e.g.) as issues that are related to their area of responsibility. DSOs should be responsible for taking care in their areas in full cooperation with the Transmission System Operators (TSOs) and in full compliance to system needs.

Responsibilities for Grid and Retail data

Research the unclear division of responsibilities between Grid Data and Retail data by the DSO and new retail market entities: Data on the grid is inherently linked with the Operators' functions. However, whatever is related to retail should be given to the appropriate participant for market functions. Many DSOs today believe that in their role as market facilitators, they can efficiently respond to system needs and aggregate useful data of other market participants and deliver it, meeting all requested attributes: quantity, latency, frequency etc.

3.3 Storage

Managing storage of energy for the control of the electricity system

Research the responsibilities, tasks and rights about “Storage of energy” between the many involved entities, both for the secure control of the electricity system, but also for minimizing investments into consumer flexibility, volatile renewable generation and grid capacity. The handling of storage systems should be judged on the role it plays on the network and/or in the market. Ancillary services are currently the Operator's responsibility, while energy is a tradable commodity, hence it should follow market rules.

European regulation on energy storage

Research the need of a common European legislation framework for storage: In the absence of one European specific regulation on energy storage, each Member State has a tendency to define its national, that only addresses part of the whole topic and is different for each country: for example, the participation conditions of energy storage to ancillary services is different in each Member

State. Furthermore, currently, the grid fees for handling energy storage based ancillary services are different for each Member State.

3.4 Markets and actors

Demand-side services

Research the roles and responsibilities of electricity markets actors regarding demand-side services: In the current network codes, too much room is left for interpretation leading to many unsolved situations and distorts the market. Bi-lateral agreements between unequal actors, claims regarding unfair balance settlement and European market fragmentation should be prevented by proposing a set of rules framing each actor's role along the different steps of a demand-side event (load curtailment/load increase).

It is widely considered that Demand Side Management (DSM) is a retail matter that the market will sort out. However, DSM affects investments in infrastructure and hence the operators need to know where their responsibilities are. Operators have the legal obligation to offer access to the network to new applicants against specific financial and technical terms. As loads are modified (use of electrical cars for e-mobility, use of heat pumps for heating and cooling etc.) the available grid infrastructure needs to be studied for possible reinforcement to meet the new loads that are connected. DSM can help to avoid infrastructure investments and hence reduces cost to all interconnected users. In this respect it is vitally important to include the Operators in the DSM process, in order to achieve optimal investments and hence lower use of system charges for all users. There is no clarity in this and there is no consistency in regulation in Member States.

Microgrids

Research the roles and responsibilities of microgrid architectures: There is no clarity as to who owns and operates microgrids and clarity on the issue of islanding mode. There is a need to clarify through regulation that microgrid system operators fully comply to the system operation to which they are connected.

Non-uniform implementation of EU regulation

Non-uniform implementation of EU-regulation may hinder innovation in the single market. In some Member States it is rather easy to experiment with local energy systems, in others not. Moreover, Member States may have specific rules that impede smart grids and local initiatives, for example by requiring specific permits to deliver energy or because of the tariff schemes for transport. In the Netherlands, for example, experiments with local systems are hindered by the limited possibilities to introduce local network management. Due to differences in legal rules/regulatory instruments in the Member States, it may be difficult to scale up successful solutions from one Member State to another. Underpinning evidence stems among others from studies in The Netherlands with respect to IPIN-experiments and the EU-project E-hub.

Aggregators

Research the roles and responsibilities of aggregators: Aggregators are not operators. Today, there is confusion in the applied regulation concerning the role of aggregators. Aggregators are market participants. System operational needs should refer to the system operator and its connected resources; Trading issues (by aggregators) should refer to market operators.

Real-time metering data

Research the effects of making metering data available in real time to interested stakeholders: Metering data used with consumers consent would be a significant contribution to the creation of innovative services including flexibility of the electric system.

Access to smart meters implies that their data is made available close to real time and in a not discriminatory way to interested stakeholders (i.e. retailers, but also new or existing service providers). Currently, metering data are primarily made available for settlement by the DSO and the retailer connected to the customer and there is no or limited transfer of data and information to other third parties. DSOs believe that this has the potential to foster innovation and that, as a neutral market facilitator, they can play a key role.

Retailers could offer new services by announcing the wholesale prices to the consumer who could avoid peak prices (scarcity of energy) and take advantage of low prices (abundance of energy). This could improve the business case of renewables and help to limit current renewable support schemes. However, needs for investments should be appropriately considered, taking into account country specific features and infrastructures.

Real-life experiments with new regulations and/or energy tariff systems.

Explore more real-life experiments with new regulations and/or energy tariff systems: Perform real-life experiments with new regulations and/or energy tariff systems. Besides Time-of-Use (ToU) fees for energy, other capacity fees could be used, such as TOU schemes or nodal pricing.

Annex - Contributor list: Persons participating in the drafting and review of this report

Members of the Secretariat ETP SG

- Marie Latour, Zabala Innovation Consulting
- Rainer Bacher, BACHER ENERGIE AG
- Pieter Vingerhoets, K.U. Leuven
- Manuela Wunderlich, DER lab

Members of the Steering Committee ETP SG

- Chairman/Vice-Chairman: Nikos Hatziargyriou, National Technical University of Athens
- Vice-Chairman/Chairman: Richard Charnah, Alstom
- WG1 Chair: Venizelos Efthymiou, University of Cyprus
- WG2 Chair: Jean-Baptiste Bart, EDF R&D
- WG3 Chair: Maher Chebbo, SAP
- Chavdar Ivanov, ENTSO-E
- Christian Wurhofer, SIEMENS
- Dumitru Federenciuc, Electrica
- Goran Strbac, Imperial College London
- Greg Arrowsmith, EUREC Agency
- Jean-François Faugeras, EDF R&D
- Jerry O'Sullivan, ESB Networks
- Jochen Kreusel, ABB
- Jon Stromsather, ENEL
- Luciano Martini, EERA & RSE
- Marko Delimar, University of Zagreb
- Miguel Sánchez-Fornié, Iberdrola
- Norberto Santiago, CG-ZIV
- Per Lund, Energinet dk
- Ana Aguado, EDSO4SG
- Thierry Pollet, Landis+Gyr
- Werner Friedl, CEER
- Ana Aguado Cornago, EDSO

Members of the WG 1 of the ETP SG

- Chair: Venizelos Efthymiou, University of Cyprus
- Andrea Paolo Bondi, Trentorise
- Dag Eirik Nordgård2, Sintef
- Eduardo Garcia, REE
- Goran Strbac, Imperial college
- Irene Bonvissuto, European Commission
- Jane Duffill-Grant, Newcastle university
- Javier Gonzalez, Zabala
- John De Roche, Actaron/AVQ
- Jovan Todorovic, Elektroprenos BIH

- Joao Pecas Lopes, University of Porto
- Jens Zoëga Hansen, Dansk Energi
- Klaas Visscher, TNO
- Luciano Martini, RSE
- Luis Ochoa, University of Manchester
- Nikos Hatziargyriou, National Technical University of Athens
- Pierluigi Mancarella, University of Manchester
- Patrick Van Hove, European Commission
- Peter Verboven, Energyville
- Phil Taylor, Newcastle University
- Pieter Vingerhoets, Energyville
- Rainer Bacher, Bacher Energie
- Susanna Mocci, University of Cagliari
- Thierry Pollet, Landys&Gyr
- Vesselin Chobanov, University of Sofia

Members of the WG 2 of the ETP SG

- Chair: Jean-Baptiste Bart, EDF R&D
- Allan Schrøder Pedersen, Denmark Technical University
- André Botelho, EDP
- Andreas Zucker, European Commission
- Andrei Nekrassov, EDF
- Angel Diaz, Tecnalia
- Clarie Couet, Eurelectric
- Frederic Barth, h2nova
- Frederik Geth, Energyville
- Goran Strbac, Imperial college
- Hauptmeier, Erik, RWE
- Irene Bonvissuto, European Commission
- Jean-Michel Durand - EASE, EASE
- Jose Angel Alzola, Tecnalia
- Luciano Martini, RSE
- Luis Manuel Santos Moro, EDP
- Patrick Van Hove, European Commission
- Peter Verboven, Energyville
- Pieter Vingerhoets, Energyville
- Seppo Hanninen, VTT technical research centre
- Stanimir Valtchev, University of Lisbon
- Suzanne Nies, Eurelectric
- Vincent Rious, Microeconomix
- Yannick Perez, Supelec

Members of the WG 3 of the ETP SG

- Chair: Maher Chebbo, SAP
- Alexander Lurf, cyber grid
- Andreas Hoehnen, Landis & Gyr
- Antonio Gabaldon, Technical University of Cartagena

- Arantza Martin, Cluster Energia
- Artur Krukowski, RFSAT
- Benedict O'Donnell, Heocs
- Carlos Alvarez, University of Valencia
- Carton Tamayo, Gonzalo, Iberdrola
- Elisa Penalvo, UPV net
- Emile Elewaut, TNO
- Eric Duys, Electrabel
- Fernando Garcia, gasNatural
- Friedrich Georg Schwarzlaender, SAP
- Gaspar, Miguel, SAP
- George Huitema, TNO
- Goran Strbac, Imperal colege
- Ignacio Delgado, ITE
- Irene Bonvissuto, European Commission
- Jiri Borkovec, Czech smart grid technology platform
- Javier Gonzalez, Zabala
- Jean-Noel Patillon, CEA
- Jessica Stromback, Smart Energy Demand Coalition (SEDC)
- Jonathan Leucci, Scottish Enterprise
- Karnouskos Stamatis, SAP
- Mamula Ondrej, CEZ
- Marko Svetina, Cyber Grid
- Mihai Sanduleac, ECRO
- Norberto Santiago, ZIV
- Patrick Van Hove, European Commission
- Peter Claes, Febeliec
- Peter Nemcek, Cyber Grid
- Peter Verboven, Energyville
- Pieter Vingerhoets, Energyville
- Regine Belhomme, EDF
- Robert Denda, Endesa
- Roland Tual, SEDC
- Rolf Adam, Cisco
- Seppo Kärkkäinen, Electraflex
- Simone Pin, Yellostrom
- Thierry Pollet, Landis&Gyr
- Viola Rocher, EnBW

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