ETP Smartgrids Input paper consolidated response to

Issues Paper No.4 - DRAFT *(version 17/12/2015)*

Energy Systems (Increase the resilience, security, smartness of the energy system)

Introduction

The European Technology Platform on SmartGrids (ETP SG) welcomes and supports the ambitions of the Issues Paper n°4 on "Energy Systems" and agrees with the main elements of strategy targets and priorities.

Due to the very short time around Christmas / New Year 2015/2016, a fully consolidated view from all ETP SG stakeholders can not be available. As a consequence, this paper and the annexes provide strong opinions by key ETP SG stakeholders (Working group leaders in particular) and experts in the secretariat of the ETP SG. A fully consolidated document can be provided by the 20th of January.

Some of the ETP SG stakeholders organisations (EDSO, ENTSO-E, EERA) will provide their views in separate papers.

The following document is composed of 3 annexes:

- Annex I provides comments in track changes of the Issues paper itself (both the targets and the proposed actions)
- Annex II provides a preliminary ranking of the actions. Some of the comments include green-coloured actions which are considered to be of highest priority.
- Annex III includes a contribution from Working Group 1 of the ETP SmartGrids (Operations and Asset Management) with specific tasks related to Energy Grids actions and providing context to an already high quality starting document.

The ETP SG looks forward to working with the SET Plan Steering Group on translating these targets into concrete RD&I actions at European and Member States level.

[signed]

Nikos Hatziargyriou

Chair of the European Technology Platform on Smart Grids

08 January 2016

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Annex I: Comment to the Issues paper n°4 (17 December draft)

The following annex takes the content of the issue paper and its annex 1 as it was sent to the stakeholders consulted by the SET Plan secretariat on 17 December 2015 and includes comments in track changes. (both the targets and the proposed actions).

Purpose of this document

This document[1] is intended to progress the implementation of the actions contained in the SET-Plan Communication[2], and specifically the actions concerned with the priority related to "Energy systems". It is part of a series of Issues Papers jointly prepared by the European Commission and discussed with the representatives of the EU Member States and countries part of the SET-Plan, working together in the SET-Plan Steering Group.

The Issues Papers are sent to stakeholders for comments/feed-back. They are meant to propose to stakeholders strategic targets/priorities in different areas of the energy sector. They will frame the discussions of the SET Plan Steering Group with the stakeholders within the action area "Energy Systems" and will be used to come to an agreement on targets/priorities.

Stakeholders are invited to take position on the proposed targets in accordance with the guidelines set out in the paper The SET Plan actions: implementation process and expected outcomes and submit their positions to SET-PLAN-SECRETARIAT@ec.europa.eu by 08/01/2016 at the latest. All relevant documents and material are available on the SETIS website https://setis.ec.europa.eu/.

Introduction

In the 2020 and 2030 climate-energy packages, the EU committed itself to lower greenhouse gas emissions by 20% by 2020 and 40% by 2030, with respect to 1990, and to reach a share of renewables of 20% by 2020 and at least 27% by 2030. Renewable shares may further increase to 40-60% by 2050.

In this framework, the electricity network has a central role to play. In 2013, 22%[3] of our final energy consumption is satisfied using electricity as energy carrier, 26% of the EU's electricity was generated from re-

[1] This document is a working document of the European Commission services for consultation and does not prejudge the final form of any future decisions by the Commission.

[2] "Towards an Integrated Strategic Energy Technology (SET) Plan: Accelerating the European Energy System Transformation" (C(2015)6317)

[3] Mapping and analyses of the current and future (2020-2030), deliverable N°1, Nov 2015.

newables and 10% from variable sources such as wind and solar. The share of renewables in electricity would increase from 26% in 2013 to 34% in 2020[4] and could exceed 50% by 2030 with an increasing contribution coming from variable sources considering that the contribution of hydropower stays stable at around 11%. The energy system is characterized by assets with life times of 30-40 years and more. Therefore all developments should also be in line with a 2050 perspective.

Owing to the increasing number of electrical appliances and the expected uptake of low carbon technologies (e.g. heat pumps and electric vehicles), the share of electricity in the overall energy consumption is expected to rise.

In parallel, consumers – in particular residential energy users, user communities, and small and medium industrial and commercial actors - are expected to take an increasingly active role in the energy system.

Finally, digitalization of the energy system is also progressing: systems, processes and devices become more and more (inter)connected, opening the way towards new services, new market and business models with new players, more integration, increased energy efficiency, better forecast modelling, asset management and operations. This increased digitalization also introduces new risks regarding and requirements for (cyber) security.

Today, our EU energy system is still strongly determined by borders between Member States. Interconnections between the national electricity, networks are still limited; coordination among electricity, gas and heat networks is still in its infancy. Creating links between these networks would provide more flexibility, more resilience and allow a larger penetration of variable renewables by balancing over larger areas. This approach is underpinned by the recent 'Energy Union' Communication[5]. Collaboration between Member States and between regions has benefits by pooling of assets bringing security of supply and the resilience of the system in case of emergency conditions. This is also needed to achieve a fully integrated energy market and will allow us to make faster progress in the decarbonisation of our economy. Finally, the abovementioned Communication highlights the importance of a well-coordinated research and innovation as a key element for our competitiveness.

All this will require many changes not only in terms of new technologies (e.g. smart energy management systems, energy storage, conversion and delivery) but also in terms of planning, design and operation of infrastructures, interconnections inside and between Members States, regulatory environment, harmonization of standards, and new business models from end to end (energy production to final consumption).

To achieve this, a system approach is needed aiming at a greater flexibility and effective capacity of the electricity system to allow an ever-increasing share of variable renewables in an effective and efficient way and to cope with new variable consumption profiles owing to, for example, electric vehicles. To provide this flexibility to the system, a range of solutions must be developed not only across the entire chain (genera-

[4] Renewable energy progress report, COM(2015) 293 final

[5] A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy (Com(2015) 80 final
https://setis.ec.europa.eu/system/files/Communication_Energy_Union_en.pdf

tion, transmission, distribution and customers) but also to reinforce / create new links with other energy networks, namely power to heat, power to gas / fuel, connection with the electrical component of the transport network. Technologies, systems and services for more flexibility should therefore be developed in the following areas:

- Energy grids and systems efficiently linking all technologies,
- Storage, connection with other energy carriers,
- Demand response,
- Flexible backup and generation.,

Targets

As an overarching target, the SET-Plan R&I will aim at developing, maturing and demonstrating (up to TRL7 to 9) technologies, systems and services which have the potential of being cost effective so that the EU electricity system is capable of hosting 45% of variable renewables by 2030 and operate in a safe, stable and secure way.

To achieve this target, all flexibility options should be combined in an optimum way:

- Energy grids and systems efficiently linking all technologies together including other energy sectors: smart technologies, systems and services are developed allowing real-time monitoring and control as well as advanced asset management across the entire energy grid in such a way that the power network operates in a safe, stable and secure way, better or at least with the same level of performance as today in terms of interruptions, speed of restoration of services, etc.. This would also entail a reduced curtailment of RES and DER. These technologies, services and systems shall target minimization of losses in the system and enable increasing levels of transfer capacity and facilitate more cooperation, at regional and European wide level. They will also increase the efficiency of planning the transmission and distribution grids. Systems of systems should be developed which are capable of integrating all actors (demand-response, storage, flexible backup and power generation); they will increasingly rely on ICT technologies for technical responsive systems and consumer interaction. These raise new challenges of data handling, privacy and security i.e. resistance to threats and resilience.

- Storage: an ensemble of cost-competitive storage solutions must be developed in Europe to service the electricity system at different levels (generation, transmission, distribution, consumers) and different timescales (Of particular importance is handling in an effective and efficient way, imbalances between the current, daily or even seasonal portions of the electricity generation and consumption at local (consumer level) or more global basis). 'Storage' encompasses re-electrification (including the potential offered by electric vehicles) and production of storage and non-storable energy particularly for power to heat which is already cost competitive in several situations[6], and other applications (for instance power to gas/fuel).

- Demand-response: an ensemble of services and associated technological solutions (hardware, software, data exchange and market mechanisms) and societal solutions must be developed in order to increase efficiency and safety of the Power Systems. It will enable customers and prosumers to play a role in the energy system by providing energy and services to the energy system (distribution grid, transmission grid, retailers, generators, …) ; this will require the emergence of new actors such as energy service providers, cooperatives, aggregators etc. for residential, commercial and industrial consumers. These solutions should allow customer to activate their 'assets' via automated home energy consumption, variable energy production, electric cars, , building energy management systems, industrial systems, etc. This will strongly rely on automation and secured data handling with non-discriminatory access to data.

- Flexible backup and generation: in the context of the SET-plan, integration of flexible backup and generation solutions will be privileged that can at the same time provide short and long term services and significantly decrease of GHG emissions. Solutions should aim to economically provide the services required for balance, stability and adequacy of the power system and exploit the potential capabilities of both thermal and renewable generation.

Monitoring of the target:

The EU electricity system is capable of hosting 45% of variable renewables by 2030 and with a perspective of up to xx% by 2050.
While it is difficult to fix shares and targets for each of the flexibility and delivery capacity options, the contribution of the different options and the progress can be assessed based on EU energy system modelling and to a range of realistic scenarios which can verify that the system can handle daily and seasonal variations and will ultimately deliver the share of variable renewables enabled by these solutions. These 45% at EU28 level will of course represent an average across both regions and sources which means that locally systems with very high shares of renewables will be operating while in other regions, this share will be more modest. Modelling should provide a panorama of the expected requirements in terms of local hosting capacities, transfer capacities, storage and conversion capacities, demand-response and flexible backup and generation.

The EU electricity system is capable of operating in a safe, stable and secure way.
To measure the progress in this domain, it is proposed to define indicators for stability, safety and security with grid operators who bear the responsibility for these matters. Reference values should then be established based on historical data and the evolution of the situation predicted. These are clearly non-trivial

[6] Baumgartner (2015)

issues, requiring work and most likely the use of extended robust electricity system models. A framework shall be defined and deployed in the energy system for the accurate, reliable collection of these indicators.

Technologies, systems and services have the potential of being cost competitive

Cost competitiveness can be assessed following two different approaches:

- regarding the cost of energy (production, distribution, transmission), the 'usual' indicators can be employed (CAPEX, OPEX, price per kWh) and the comparison made with technologies, systems and services in place; Particular approaches should be used to assess deferral of traditional grid reinforcements (copper and iron) against increased intelligence (sensors & ICT).
- regarding services to the grid, the assessment is less straight forward but one can assess the extra cost and spread it over the volume of energy serviced as an indicator.

In any case, the actual cost will depend on the way the market will adopt these technologies (speed, scale, consumer acceptance, etc.) and in the R&I phase, these costs can only be extrapolated. It will also depend on the eventual system usage and asset loading profiles resulting from the collective behavior of market actors.

Monitoring R&I progress in technologies, services, systems

In addition, it is proposed to monitor the progress in the development of technologies, services and systems in terms of TRL over the year. This 'board' should asses at what pace R&I progress is achieved (the pace can vary depending on the technologies) and when these elements will be available / ready for deployment, and should determine the condition under which a technology, service, system is introduced in the energy system modelling.

Other important elements:

Continuity should be ensured in the maturation of solutions ranging from advanced research programmes, industrial research and demonstration programmes, innovation and market uptake programmes as well as the socio-economic sciences relevant in this context. Also, in particular for the higher TRLs and the most integrated projects, these developments should be accompanied by analysis of the regulatory environment and the business models.

Also, sharing experiences in the scaling-up and system integration of new technologies across actors in Europe is crucial to ensure a swift and efficient deployment of technologies, especially among non-competing regulated actors.

Proposed actions

While Horizon 2020 will continue to support this action via Calls for Proposals, the goal of this round of consultation is to consult stakeholders and Member States to identify a limited number of priority actions which:

- have a strong added value to be carried out at EU level and or through collaboration between Member States,

- have a strong leverage i.e. will need a limited or no support from Horizon 2020 but will pool together a number of resources,

- for which the progress and achievements can be monitored with indicators.

We are therefore looking for your views / proposals. The annex below reproduces the titles of actions which were identified in the annex of the document 'Towards an Integrated Roadmap: Research & Innovation Challenges and Needs of the EU Energy System' and can be used as a basis but proposals for priority actions do not necessarily need to be based on this list. With more than 70 actions listed, it is clear that a more integrated and prioritized perspective needs to be adopted.

Annex:1 Relevant actions of the 'Towards and Integrated Roadmap document' needed to achieve the targets

HEADING 2: Ensuring Energy System Integration

Challenge 1: Energy Grids

ADVANCED RESEARCH PROGRAMME

Action 1: New methodologies to design grid architectures and plan transmission and distribution networks

Action 2: Development of electric grid infrastructure and systems for merging seamlessly with renewables and enabling / facilitating active participation of end users individually or in aggregate form

Action 3: Development of novel tools for grid asset management in order to increase network flexibility and continuity of power supply

Action 4: Development of innovative tools for grid operations

Action 5: Develompent of tools to support responsive market designs capable of effectively handling the emerging technologies and systems. Research and development of tools to support new market designs at Pan-European and regional levels.

Action 6: Research for methodologies and development of tools which enable scaling up and replicating the results of innovative demonstrations

Action 7: Research and development of new materials for grid applications

Action 8: Data handling to achieve protection, cyber security and efficient utilization of the generated data by all affected stakeholders and users

INDUSTRIAL RESEARCH AND DEMONSTRATION PROGRAMME

Action 1: Demonstration of novel interoperable power technologies integrated into Electricity Grids

Action 2: Demonstration of electric grid infrastructure and systems for integrating seamlessly renewables, storage and enabling / facilitating active participation of end users in isolation or aggregated form the grid integration of renewable generation, electricity storage and new users

Action 3: Demonstration of novel grid asset management techniques

Action 4: Demonstration of tools for improved Grid operations

Action 5: Demonstration of novel tools to support responsive market designs capable of effectively handling the emerging technologies and systems at Pan-European and regional levels and prepare recommendations for novel market designs

Action 6: Demonstration of small generators upgraded for Network Code compliance

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INNOVATION AND MARKET-UPTAKE PROGRAMME

Action 1: Modular development plans of the pan European transmission system based on new planning and grid architectures

Action 2: Scaling up and replication platform to support the market uptake on innovative grid operation and electricity market solutions

Action 3 Interoperabilityof standards for data and knowledge exchange

Action 4: Improved awareness and acceptance by the public of new grid infrastructures and electricity metering use

Action 5: Increasing stakeholder acceptance of novel energy market designs and products.

Action 6: Training tools and workforce certification at EU level

Challenge 2: Storage (Heat and Cold, Electricity, Power to Gas or other energy Vectors)

ADVANCED RESEARCH PROGRAMME

Action 1: Enhanced Storage materials

Action 2: New Technologies for Next Generation Central and De-central Storage Technologies of any scale

Action 3: Improved second generation technologies for Next Generation Central and De-central Storage Technologies of any scale

Action 4: Storage System interfaces

INDUSTRIAL RESEARCH AND DEMONSTRATION PROGRAMME

Action 1: Storage System Integration and Benefit Assessment via Simulation of System Embedding

Action 2: Central and De-central Storage Technology Demonstration of any scale

Action 3: Storage System integration Demonstration

Action 4: Storage Manufacturing Processes

Action 5: Storage Recycling

INNOVATION AND MARKET-UPTAKE PROGRAMME

Action 1: Storage Standardisation

Action 2: Storage Business Case Evaluation in global market environment/systems

Action 3: Storage Business Cases in local market environment/systems

Action 4: Soft Aspects and Society Acceptance

Action 5: Closed storage material loop

Challenge 3: Demand Response

ADVANCED RESEARCH PROGRAMME

Action 1: Tool development to support new electricity energy market designs that support Demand Response

Action 2: Develop mechanisms to enable the participation to the electricity market of all relevant actors and to ensure the full exploitation of Demand Response

Action 3: Develop integrated solutions to maximise value chain performance and cost competitiveness of Demand Response

Action 4: Develop holistic communication systems to provide security, oversight and participation opportunities between DSO, TSO, Aggregators

Action 5: Develop load forecast tool with full integration of Demand Response

Action 6: Functional and Virtual Power Storage

INDUSTRIAL RESEARCH AND DEMONSTRATION PROGRAMME

Action 1: Demonstration of the integration of Demand Response in electricity energy grids

Action 2: Demonstrate the full value chain performance, the cost competitiveness and the system integration capability of Demand Response

Action 3: Demonstrate system services from Demand Response

Action 4: Demonstrate the capability of smart interfaces, management modes and new services to increase the integration of Demand Response in the energy system

Action 5: Control of distributed energy resources for demand response

INNOVATION AND MARKET-UPTAKE PROGRAMME

Action 1: Demand Response and new users integration: scaling up and replication

Action 2: Standardisation needs.

Action 3: Market framework and business models for demand response

Action 4: Regulatory aspects to enable Demand Response

Action 5: Demonstration of and regulatory development support for demand response aggregation

Action 6: Demonstration of and regulatory development support for further visibility and manageability of demand

Challenge 4: Flexible /Back-up Energy Generation

ADVANCED RESEARCH PROGRAMME

Action 1: Innovative Tools to support new market designs and mechanisms at EU level

INDUSTRIAL RESEARCH AND DEMONSTRATION PROGRAMME

Action 1: Improve accuracy for production forecast and flexibility of the production from all RES technologies

Action 2: Programme in design and demonstration of new generation of turbine and generator: Hydro plant upgraded for better grid-balancing

Action 3: Efficient and Responsive Thermal Power Plants

Action 4: Flexible and Efficient Gas and Steam Turbines

Action 5: Programme in design and demonstration of new generation of turbine and generator: New generation of hydropower turbine and generator design

Action 6: Programme in improving power converters to permit variable-speed operation: Power electronics and converter technology for hydro projects

Challenge 5: Cross-technology Options

ADVANCED RESEARCH PROGRAMME

Action 1: Cross Sector Chemical Storage Technologies

Action 2: Small hydro power plant as active component in a VPP

Action 3: Research for high cyber security

Action 4: Research for "big data" in the cloud, in real-time

Action 5: Enhancing Network Interaction and synergies – Gas and Electric networks

Action 6: Energy Systems Integration – Testing and Evaluation of Integrated Energy Systems

INDUSTRIAL RESEARCH AND DEMONSTRATION PROGRAMME

Action 1: Demonstration of high cyber security

Action 2: Demonstration of "big data" in the cloud, in real-time

Action 3: Demonstrate the flexibility of PEM electrolysers at large scale

Action 4: Optimised integration of renewable energy sources and surplus heat in DHC and enhancement of thermal energy storage at system level

Action 5: Demonstration of large Smart Thermal Grids

Action 6: Take into account the electrical network needs to Optimize centralized Hydrogen production (spot price, load curtailments (on peak), over consumption (off peak))

INNOVATION AND MARKET-UPTAKE PROGRAMME

Action 1: Improved, highly efficient substations for both present and future lower temperature networks

Annex II: Ranking of actions

Annex II provides a preliminary ranking of the actions. Some of the comments include green-colored actions which are considered to be of highest priority.

Challenge 1: Energy Grids

ADVANCED RESEARCH PROGRAMME

Action 1: New methodologies to design grid architectures and plan transmission and distribution networks

Action 2: Develop electric grid infrastructure and systems for merging seamlessly with renewables and enabling / facilitating active participation of end users in isolation or aggregate form

Action 3: Develop Research and development of novel tools for grid asset management in order to increase network flexibility and continuity of power supply

Action 4: Develop innovative tools for grid operations

Action 5: Develop tools to support responsive market designs capable of effectively handling the emerging technologies and systems

Action 6: Research for methodologies and development of tools which enable scaling up and replicating the results of innovative demonstrations

Action 7: Research and development of new materials for grid applications

(NEW) Action 8: Data handling to achieve protection, cyber security and efficient utilization of the generated data by all affected stakeholders and users

The ETP SG considers that the largest missing factors in the action list are data handling and cyber security measures. Electricity grids are critical infrastructures and increased connectivity inherently leads to an increased security risk. This technological challenge is severe, as the installed technologies have to be robust and secure for many years while potential threats evolve as well. Therefore, the ETP added Action 8 related to these issues which are considered very important.
Actions 1, 2, 3, and 4 of the energy grid challenge are indeed a high priority. Appropriate tools need to be developed to adequately perform asset management, which was already pointed out

in the gap analysis of the Grid+ project and which is a topic on which the WG1 of the ETP SG is preparing a draft position paper. Action 7 of the list is considered to be less critical, as scaling up, knowledge sharing and replication tools have been studied in several other projects like Grid+, Grid+Storage and Grid4EU. Often, existing grid architectures and/or regulations require a similar, but distinctly different approaches in the member states. In addition, the research of new materials for grid operation looks very promising in the long-term, but the ETP SG currently considers this to be a less critical focus point for European research.

INDUSTRIAL RESEARCH AND DEMONSTRATION PROGRAMME

Action 1: Demonstration of novel interoperable power technologies integrated into Electricity Grids

Action 2: Demonstration of electric grid infrastructure and systems for merging seamlessly with renewables, storage and enabling / facilitating active participation of end users in isolation or aggregated form the grid integration of renewable generation, electricity storage and new users

Action 3: Demonstration of novel grid asset management techniques

Action 4: Demonstration of tools for improved Grid operations

Action 5: Demonstration of novel tools to support responsive market designs capable of effectively handling the emerging technologies and systems at Pan-European and regional levels prepare recommendations for novel market designs

Action 6: Demonstration of small generators upgraded for Network Code compliance

For the industrial R&D programme, the actions 1, 2, 4 and 5 are highly relevant, in line with the priority actions from the advanced research programme above. Action 3 is very important as well. However, as the currently used core assets of the electricity grids will continue to be functional for the coming years, the demonstration of assets management techniques itself is less pressing and the focus can be on the development of the tools and methodologies. The demonstration of small generators upgraded for network code compliance is important, however the ETP SG leaves the option open whether to pursue this issue at European or local level.

INNOVATION AND MARKET-UPTAKE PROGRAMME

Action 1: Modular development plans of the pan-European transmission system based on new planning and grid architectures

Action 2: Scaling up and replication platform to support the market uptake on innovative grid operation and electricity market solutions

Action 3: Implementing Interoperability standards supporting interoperability in of standards for data and knowledge exchange

Action 4: Improved awareness and acceptance by the public of new grid infrastructures and electricity metering use

Action 5: Increasing stakeholder acceptance of novel energy market designs and products.

Action 6: Training tools and workforce certification at EU level

Action 1 is indeed a very important topic, but to a certain extent this is already available through already ongoing projects such as Best Paths. Also action 2 is important, however a certain amount of projects and/or initiatives are already ongoing on pan-European market design and market platforms, like e.g. USEF and eBadge. The ETP SG considers action 3 to be the most pressing one in this list. As well as grid operation and new business opportunities for consumers and aggregators, the ongoing digitalisation enables new market models and hence requires interoperability and standardized solutions. Action 4 is somewhat less essential, in our opinion the consumer does not need to be aware of new grid infrastructures. Instead, the awareness and stakeholder acceptance of novel market designs and products (action 5) is key, along with emerging business cases for the consumer. Once the consumer is confronted with new business cases like smart appliances and dynamic pricing, he will automatically understand that smart metering is an enabler for these opportunities, which is more effective than raising awareness on metering itself. Training tools for workforce certification will mainly be important in the area of data handling and security, as this requires a combination of competences.

Challenge 2: Storage (Heat and Cold, Electricity, Power to Gas or other energy Vectors)

ADVANCED RESEARCH PROGRAMME

Action 1: Enhanced Storage materials

Action 2: New Technologies for Next Generation Central and De-central Storage Technologies of any scale

Action 3: Improved second generation technologies for Next Generation Central and De-central Storage Technologies of any scale

Action 4: Storage System interfaces

Action 1 is an important issue, mainly in the long term, however this action can well be addressed at the level of the individual research labs. Action 2 is considered to be the most essential of this list, however with the remark that the title of this action covers a very broad range of possible research. Action 3 logically follows action 1 in time, and with a lot of storage demonstrations ongoing it depends on the exact technology that is considered. System interfaces are developed on local level, and there could be added value to address this at European level. However, the ETP SG considers this action somewhat less critical.

INDUSTRIAL RESEARCH AND DEMONSTRATION PROGRAMME

Action 1: Storage System Integration and Benefit Assessment via Simulation of System Embedding

Action 2: Central and De-central Storage Technology Demonstration of any scale

Action 3: Storage System integration Demonstration

Action 4: Storage Manufacturing Processes

Action 5: Storage Recycling

One of the major barriers that currently exists for implementing storage is the cost of the system integration. Therefore, Action 1 is crucial for the road to market of all storage technologies in the coming years. An optimal system integration, where several services are provided with storage assets are key. The ETP SG would focus on the system integration (Action 3) rather than on the demonstration of the technology itself (Action 2), evidently both actions can be combined in a single project. Investigations towards storage manufacturing processes can most efficiently be addressed at local level. Storage recycling (Action 5) will become a topic of high focus in the coming years, so timewise this would be a strong focus point in a second round of upcoming R&D projects.

INNOVATION AND MARKET-UPTAKE PROGRAMME

Action 1: Storage Standardisation

Action 2: Storage Business Case Evaluation in global market environment/systems

Action 3: Storage Business Cases in local market environment/systems

Action 4: Soft Aspects and Society Acceptance

Action 5: Closed storage material loop

Storage standardization is a very important topic, the ETP SG did however, not achieve consensus on the pressing nature of the Action 1. As already mentioned in the previous paragraph, research to several business cases, and integrating the storage assets in the market with the appropriate roles for the market actors is one of the biggest challenges of storage today. Local business cases are a bit more straightforward, and the ETP SG notes that a combination of local and market business cases could be pursued for a single storage asset as well, so Actions 2 and 3 are not mutually exclusive and of high importance. Society acceptance of storage is inherently high, most of the population will understand the benefit of storage of renewable energy production, which is less straightforward for e.g. metering. Different business cases, like neighbourhood investments in storage assets can be pursued, however this evolutions will become important mainly after the cost effectiveness of the current technologies has improved. Action 5 can be addressed at local level.

Challenge 3: Demand Response

ADVANCED RESEARCH PROGRAMME

Action 1: Tool development to support new electricity energy market designs that support Demand Response

Action 2: Develop mechanisms to enable the participation to the electricity market of all relevant actors and to ensure the full exploitation of Demand Response

Action 3: Develop integrated solutions to maximise value chain performance and cost competitiveness of Demand Response

Action 4: Develop holistic communication systems to provide security, oversight and participation opportunities between DSO, TSO, Aggregators

Action 5: Develop load forecast tool with full integration of Demand Response

Action 6: Functional and Virtual Power Storage

Actions 1, 2 and 3 (although action 2 is somewhat vague) summarize major challenges that demand response is facing, including an appropriate market design and cost effectiveness across the entire value chain. Regulation is a main barrier for demand response, in addition to further development of relevant market products. Secure and reliable communication systems are naturally key for full exploitation of consumption flexibility. The development of standardized platforms that provide efficient information exchange between DSO, TSO and Aggregators are essential in the future energy system. However in many member states initiatives in this direction are already ongoing. Load forecast tools can improve the energy system in general and reduce the need for storage or demand flexibility. Action 6 could be interpreted in several ways, one could have a semantic discussion on the definition of virtual power storage.

INDUSTRIAL RESEARCH AND DEMONSTRATION PROGRAMME

Action 1: Demonstration of the integration of Demand Response in electricity energy grids

Action 2: Demonstrate the full value chain performance, the cost competitiveness and the system integration capability of Demand Response

Action 3: Demonstrate system services from Demand Response

Action 4: Demonstrate the capability of smart interfaces, management modes and new services to increase the integration of Demand Response in the energy system

Action 5: Control of distributed energy resources for demand response

Demand response is already commercially active in certain member states on the industrial level, and the concept has been proven to be cost competitive to alternative sources of flexibility. Several business cases for demand flexibility are already pursued, like balancing, arbitrage or ancillary services. Therefore, additional research or demonstration should be focused beyond the commercially existing, either to small consumers, either with different business cases like e.g. the DSO balancing the local grid, Smart interfaces (action 4) can be addressed in a second round of projects.

INNOVATION AND MARKET-UPTAKE PROGRAMME

Action 1: Demand Response and new users integration: scaling up and replication

Action 2: Standardisation needs.

Action 3: Market framework and business models for demand response

Action 4: Regulatory aspects to enable Demand Response

Action 5: Demonstration of and regulatory development support for demand response aggregation

Action 6: Demonstration of and regulatory development support for further visibility and manageability of demand

Action 1 is very important, however the concept of demand response itself has already proven to be quite scalable and replicable. New control software has already been developed by companies to efficiently manage a large number of customers and optimize the portfolio in view of the different valorisation possibilities. Actions 2, 3 and 4 are highly important. Many regulatory barriers exist (The ETP SG does not discuss the actual barriers at this point; for this the ETP SG refers to the ETP SG report of 2015, 'ETP view on WP 2016-2017'). Appropriate market products are highly essential, for which already some projects examples exist like the R3-DP in the Belgian market. It is not entirely clear to the ETP SG where Action 5 differs from action 4.

Challenge 4: Flexible /Back-up Energy Generation

ADVANCED RESEARCH PROGRAMME

Action 1: Innovative Tools to support new grid market designs and mechanisms at EU level

Flexibility at the generation side is already well integrated into the market, however improvements can still be made, for instance a pay-for-performance system when providing ancillary services.

INDUSTRIAL RESEARCH AND DEMONSTRATION PROGRAMME

Action 1: Improve flexibility of the production from RES flexible technologies

Action 2: Programme in design and demonstration of new generation of turbine and generator: Hydro plant upgraded for better grid-balancing

Action 3: Efficient and Responsive Thermal Power Plants

Action 4: Flexible and Efficient Gas and Steam Turbines

Action 5: Programme in design and demonstration of new generation of turbine and generator: New generation of hydropower turbine and generator design

Action 6: Programme in improving power converters to permit variable-speed operation: Power electronics and converter technology for hydro projects

In this list only Action 1 is considered to be a pressing issue in the current energy system. Improvements in flexibility of wind, solar or other renewable technologies will lead to a higher hosting capacity, which is necessary to lower greenhouse gas emissions. The other actions can be researched in individual laboratories or local demonstration cases.

Challenge 5: Cross-technology Options

ADVANCED RESEARCH PROGRAMME

Action 1: Cross Sector Chemical Storage Technologies

Action 2: Small hydro power plant as active component in a VPP

Action 3: Research for high cyber security

Action 4: Research for "big data" in the cloud, in real-time

Action 5: Enhancing Network Interaction and synergies - Gas and Electric networks

Action 6: Energy Systems Integration - Testing and Evaluation of Integrated Energy Systems

The ETP SG ranks Action 3 and Action 4 as absolutely essential and this should be a strong point of focus in Europe. Certain lessons on data security can be learnt from other sectors like banking and telecom. However the energy system faces an exponential increase in connectivity in very few years, and in view of the critical nature of grid data there is no time for a learning curve as far as cyber security is concerned. Actions 5 and 6 are somewhat less pressing, but nonetheless a very promising way to expand the flexibility of the energy system. In Action 5, interaction with heat networks should be included as well. Action 1 could be pursued in a second round of projects, while Action 2 is more suitable for a local demonstration.

INDUSTRIAL RESEARCH AND DEMONSTRATION PROGRAMME

Action 1: Demonstration of high cyber security

Action 2: Demonstration of "big data" in the cloud, in real-time

Action 3: Demonstrate the flexibility of PEM electrolysers at large scale

Action 4: Optimised integration of renewable energy sources and surplus heat in DHC and enhancement of thermal energy storage at system level

Action 5: Demonstration of large Smart Thermal Grids

Action 6: Take into account the electrical network needs to Optimize centralized Hydrogen production (spot price, load curtailments (on peak), over consumption (off peak))

For the same reasons we stated above, Action 1 and Action 2 are the most essential in this list. The second action should be more specified, using big data is not an objective in itself rather than an enabler for e.g. more efficient grid management. The other actions are considered to be very interesting but not extremely urgent. When considering heat networks, for instance in Action 5, the interplay between gas, heat and electricity is a very interesting topic, for instance ancillary services on the electricity market using the energy storage capacity of a heat network.

Annex III Energy Grids: contribution to proposed actions

Annex III includes a contribution from Working Group 1 of the ETP SmartGrids (Operations and Asset Management) with specific tasks related to Energy Grids actions and providing context to an already high quality starting document.

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Advanced Research Programme: **Action 1:** New methodologies to design grid architectures and plan transmission and distribution networks	**Specific tasks:** 1. To investigate state-of-the-art planning software, technology portfolios and different regulatory frameworks, such that emerging technologies and systems can timely be integrated into existing planning tools for evaluation and replication. 2. To develop new algorithms and database functions for network simulation enabling the integration of new emerging technologies such as HVDC, FACTS, GIL and different types of storage. 3. To model embedded HVDC/HVAC grids for planning simulation. 4. To develop software tools for cost-benefit assessments of expansion options and validating impact on grid planning for coordinated design of architecture, power flow control devices, and other technologies. 5. To develop planning software to optimize location, coordination, control and integration of new technologies within existing and future system architecture and operation. 6. To develop long-term planning methods to combine electricity market analyses, production capacities (all types including RES), storage facilities and infrastructure for system adequacy assessment in view of strengthening expected weak points on the grid.

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	7. To develop planning tools to improve the protection, coordination and control of power flows at transmission interfaces between TSOs and DSOs. 8. To develop planning tools of the electrical transmission and distribution infrastructure taking into account the interactions and interdependence with other energy infrastructures such as gas and thermal energy. New approaches to size and operate distribution networks in districts, with new architectures, considering "city master planning", limiting the sizing of physical infrastructure and taking into account boundary conditions such as available space. 9. Development of tools to design and sizing this kind of integrated energy networks. New network modelling and stochastic optimisation tools. Transform planning tools from being deterministic to being able to use probabilistic techniques. 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 new technologies. Develop planning tools that can look at heat and power and cooling requirement in an integrated manner. 10. Simulation tools giving indication of DSOs of where to connect new generators and storage on the basis of different criteria. 11. System integration of new power technologies and impact on network planning by utilizing active distribution network, dynamic rating and microgrid principles. 12. Tools that take into account standardisation of technologies and infrastructures. 13. New models that describe products and services to be tested on selected segments of customers and their impact on future ancillary services in the presence of large-

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	scale DER integration. 14. To develop simulation tools and methods that detect weaknesses in the system with respect to reconnecting DER and storage systems. 15. To develop simulation tools and methods of assessing the risk of breakdowns during reconnection.
Action 2: Develop electric grid infrastructure and systems for merging seamlessly with renewables and enabling / facilitating active participation of end users in isolation or aggregate form	**Specific Tasks:** 1. To develop local state models with a sufficient level of intelligence at the substation level and to use this valuable information with state estimators and dynamic simulation tools. These models will be aggregated for assessing the observability and controllability at the pan-European level. 2. To increase observability and improve state estimation accuracy (both steady state and dynamic) through adequate modelling (including not only modelling protection and system automatic schemes to some extent, but also by merging transmission and distribution models). 3. To exploit the information provided by forecasts of variable generation and flexible demand for observability and controllability purposes. To assess the effectiveness of control actions that deliver the right level of reliability while facing uncertainties from the large-scale deployment of RES and market integration, 4. To develop approaches for optimal provisioning, dimensioning and sourcing of reserves together with local and/or regional distribution to maintain security of supply; to deliver dynamic management of system

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	reserves at regional and pan-European levels. 5. Utilize monitoring devices such as PMUs, accurate forecasting tools to provide TSOs and DSOs with new information for accurate online monitoring. Based on this develop new operational policies on real time measurements that enhance historical data. 6. To validate mechanisms for control, protection and inertia provision of large amount of inverter based RES generation with particular consideration of the absence/limited inertia of power electronic interfaced generation and the harmonics produced by it. 7. To monitor and control the network using advanced ICT technologies to integrate multiple control systems and control devices to avoid large-scale intra-zone oscillations. 8. To validate integration scenarios where the network becomes more resilient and copes with variable generation from RES. 9. To demonstrate linking technologies for effective energy mix of conventional and RES resources. Models for simulating and studying the impacts of DER on MV / LV network based on local climate and resources in order to quantify their hosting capabilities and the value of DER control including reactive power provision and power curtailment 10. Models and methods for evaluation of power quality focused on harmonic distortion and power oscillations in MV / LV network 11. Models and methods to understand the observability requirements (i.e., monitoring infrastructure and sampling intervals) for different active control solutions as well as the corresponding cost and/or complexity

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	12. Inverters with grid support capabilities, adapted to LV distribution network requirements and needs 13. Network monitoring systems and related communication infrastructure suitable for monitoring small scale DER integration in medium / low voltage networks 14. Bi-directional communication systems possibly integrated with AMM Network management/control systems with, inter alia, self-healing capabilities for fault management in MV / LV network 15. Development of control options of DER (responsive loads, storage, electric vehicles in V2G and V2H modes, electric heat pumps) as well as the use of distribution network management technologies(OLTC, in-line voltage regulators, capacitor banks/shunt reactors, etc.) or the active configuration of LV circuits considering the potential interactions with MV networks. Models to compare the cost effectiveness of the various methods are also needed. 16. New actuators (e.g. switches) and new sensors (e.g. fault detectors, voltage and current sensors) for MV / LV network, leading to new protection and control strategies 17. Technologies and tools for active and reactive power control of DER, with TSO/DSO coordination to provide extra power flow control, load management and islanding.
Action 3: Develop novel tools for grid asset management in order to increase network flexibility and continuity of power supply	**Specific tasks:** 1. To identify the parameters (climate conditions, operating conditions, among others) that impact the lifespan of components. 2. To establish evaluation/estimation protocols for component statuses that are com-

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	parable across TSOs / DSOs, with in-depth analysis and shared experiences. 3. To develop a methodology to determine and expand the lifespan of components including conventional components (conductor, insulator, tower, breaker, etc.) and new components such as power electronic and digital devices. 4. To propose dedicated, intelligent monitoring and analysis of results from equipment operation. If necessary, specify new measurement devices and associated ICT system. 5. To validate the added value of individual lifetime assessment compared to an average assessment of several similar components based on generic parameters (age of equipment, switching steps, etc.). 6. To assess the benefits of partially renewing small components (joints, etc.) or adding new protective layers (paint coating) to extend life span. A methodology is to be developed that assesses the capability of each component to be partially repaired or where the coating is to be replaced. 7. To develop new ways of detecting component failure based on failure models. 8. To define methods and tools to optimize asset management at the system level. The methodology should provide an assessment of risks of different asset management strategy, including interactions between equipment, impacts on security and quality of supply and also environmental and safety constraints. The organization of maintenance work, availability of spare parts (supply chain, quantity of spare parts and location) are part of the global optimization challenge 9. Provide tools for dynamic management of

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	outage planning & maintenance schedules. To identify the parameters (climate conditions, operating conditions, potential for hardware and software, among others) that impact the lifespan of components. 10. Ageing modelling under real network conditions, as affected by the introduction of DER, EV, and storage. 11. Conditional and risk-based maintenance models incorporating new IT solutions. 12. New IT systems and solutions that make use of large new quantities of data and are used for conditional and risk-based maintenance purposes. 13. New systems for field components wear and tear monitoring in order to" predict" failures. 14. Investigate "new" stresses (electrical, mechanical, thermal, etc.) that could be introduced or existing stresses of distribution component, such as transformers, cables, switchgear, etc. which are not considered important today. . It would be relevant to identify such stresses and assess how they affect the components. Review component standards to assess if they take such stresses into account.
Action 4: Develop innovative tools for grid operations	**Specific tasks:** 1. To implement solutions for wide-area monitoring systems and demonstrate how to utilize such information in a coordinated manner during operations. 2. To increase network controllability by proposing methods and tools for optimal and coordinated use of flexible equipment such as FACTS, PSTs and HVDC links, resulting in safe and cost-effective system operations

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	(e.g., maximizing the global social welfare). Advanced energy management systems to enable load/production forecasting (localised and short term) and active customer participation taking advantage of an automated metering infrastructure. 3. Multilevel system operation of a distribution network. 4. Secondary substation with an islanding capability of parts of a district to be activated in emergency situations in the form of Microgrids. The district covering several neighbouring secondary substations on the same feeder (active approach taking into account demand side management and local storage, use of power electronics to facilitate grid integration (voltage management, fault current management)) ; The feeder connected to the district and other loads of a city where the energy management system simultaneously responds to the needs coming from the network and ensures local operation of the feeder (optimal split of total load between primary substations). 5. Interfaces to enable two way communication between DSO's/TSO's central systems, home automation and energy management systems, web portals, in-home displays and smartphone apps, smart plugs and voltage clamps, smart appliances, solutions for direct load control and smart energy boxes. 6. New algorithms to optimize system topology. New operational scheduling tools that provide an indication of optimal grid configuration based on day-ahead forecasting and real network data to optimize objective functions (i.e. avoid network congestions, minimize network losses, reduce reverse

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Action 5: Develop tools to support responsive market designs capable of effectively handling the emerging technologies and systems at Pan-European and regional levels	power flows to TSO, etc.). 7. Investigate options for self-healing grids i.e. the ability of a power system to automatically prevent, detect, counteract and repair itself. 8. Investigate the autonomous self-controlling and healing grids (dynamic topology, power re-routing) that can respond to calculable conditions in a dynamic way using distributed logic and suitable sensors. **Specific tasks:** 1. To model aggregated RES/DER, flexible conventional generation, demand and storage systems to be used for market design, market mechanisms and simulation tools for planning and operation purposes. 2. To design market mechanisms for incentivizing both maximization of the provision of ancillary services (including aggregated RES, cogeneration and high-efficiency production, demand, storage etc.) and minimize the use of ancillary services; the aim is to harmonize the requirements of provider licenses with supervision, control and recording of services provided. 3. To develop a new tool for detailed analyses of various balancing market designs to identify best practices and to perform large-scale experiments with metered customers that demonstrate the costs and benefits of demand-side management required at the pan-European level. 4. To design and develop mechanisms and platforms for cross-border balancing and power reserve services, moving towards possible future development of regional/pan-regional platforms and even markets

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	based on economic and technical analyses, while operating within the required security margins. 5. To develop a set of data exchange templates and ICT infrastructures to enable ancillary and balancing services at the EU level. 6. New business models for providing new energy services and recommendation of new tariff systems. Application of time-of use/dynamic tariffs and real time prices. 7. New market rules to continue promoting the deployment of distributed generation based on renewables (replacing feed-in tariffs). 8. Assessment of possible impacts and benefits of new market models according to different locations or time frame. 9. Recommendations for valuation of ancillary services brought by DER. Recommendations on market rules and mechanisms for provision of ancillary services (e.g. reactive power provision) provided by MV network. 10. Recommendations for new regulations to provide personalized services and tariffs to individual customers. 11. Coordination between technical grid control and market based power balancing (e.g. technical virtual power plants vs. market based virtual power plant). 12. Recommendations on new market rules for islanding modes of operation (Microgrids). 13. Design and operation of ancillary service market at distribution level. 14. Identify key changes in Regulation to address the new role of DSO as provider of ancillary services and responsible of distribution network reliability being a regulated entity.

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	15. Analysis of legal, contractual and regulatory aspects of ancillary services provided by distributed generation and/or loads, allowing for more aggregated business models. 16. Develop methods of compensating the lack of inertia in future grids where distributed energy resources in general do not possess rotating inertial mass. A future grid where a large part of central generation is being replaced by distributed generation has much less synchronous rotating mass compared to the grid as it is now resulting in low electro-mechanical time constant of the power system creating stability issues to the operation of the system. Other means for providing the required synchronised inertial response should be investigated for stabilizing future grids in an optimal and effective way. 17. Novel ways of providing ancillary services through loads and their impact on transmission networks; the highly variable and unpredictable nature of DER and RES places new constraints on these ancillary services. 18. Simulation environments to demonstrate the viability and options of ancillary services provision by aggregated loads at DSO level.
Action 6: Research for methodologies and development of tools which enable scaling up and replicating the results of innovative demonstrations	**Specific Tasks:** 1. To investigate the acceptable levels of risk and uncertainty in studies in order to adequately assess the scaling-up and replication potentials of solutions and their requirements. 2. To document the methodology for future project participants so that they can assess the experimental data requirements necessary to design a smart grid demonstration.

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Action 7: Research and development of new materials for grid applications	3. To develop information models for the smart grid security, taking into account business interactions and the physical processes of delivering electricity, and also the disruption of business communications, or of the delivery of electricity. 4. To analyse data exchange protocols that reinforce interoperability constraints at the pan-European level with an adequate level of security. 5. To study appropriate confidentiality constraints in the developed toolbox to ensure appropriate sharing of results while at the same time preserving stakeholder interests. 6. To define open standard data models that ensure interoperability between different data exchange protocols for smart grid applications and to increase competitiveness. 7. Develop methodologies and tools which enable scaling up and replicating the results of innovative demonstrations. Develop tools able to mimic the network behaviour using the demonstrated innovative solution. Investigate the acceptable levels of risk and uncertainty of demonstration studies in order to adequately assess the scaling up and replication potentials of solutions and their requirements. 8. Develop demonstration platform for customers to significantly engage in the planning and deployment of smart grids at demonstration stage and full scale rollout. **Specific tasks:** 1. To perform research on the devices and concepts required to materialize multi-terminal DC grids able to cope with current system needs and sources, such as offshore

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Action 8: Data handling to achieve protection, cyber security and efficient utilization of the generated data by all affected stakeholders and users	generation. 2. To investigate the influence of parallel routing of DC and AC lines on the same tower or parallel paths to facilitate existing infrastructure paths in an optimal manner. 3. To investigate emerging technologies: HVDC VSC, multi-terminal and HVDC net-work, PST, FACTS, high-capacity conductors, etc. **Specific Tasks:** 1. To propose data exchange procedures for adequate system simulation, exploiting in-novative ways to collect huge amounts of data (e.g. crowd sensing for weather fore-casts). 2. Investigate the use of intensive data man-agement techniques such as cloud compu-ting techniques to enable the fast sharing and processing of data across the TSOs and DSOs in the European grid, considering benefits and data security. 3. Mapping of privacy and data protection issues and strategies/solutions to mitigate risks. 4. Data protection and cyber security meth-odologies. Large data mining processes considering operational and planning appli-cations. 5. Data protection tools (access, authentica-tion, encryption). 6. Distributed online analytical stream pro-cessing system with spatial and temporal dimensions. 7. Development of mathematical approaches to describe consumption behaviour. 8. Mathematical models of the network using data from smart meters.

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	9. Models and methods to understand the cost-effectiveness of data and granularity needs for operational and/or planning purposes. 10. Standardisation of data models. 11. New IT solutions to process large data streams (cooperation with the bank industry). 12. Data publishing systems. 13. Data storing systems (E.g. web dashboards for managing data, etc.). 14. Ageing and life spans of respective components (smart meters, communication infrastructures, grid) models for providing new energy services. 15. Best practices and recommendations for data privacy and data use by the different stakeholders of the electric system. Practices for ensuring customer acceptance. 16. Identify data concentration characteristics (type of information, volume of data, time resolutions, data sampling step) at the interface between TSO and DSO, so that the TSO can continue to securely operate the system while handling the minimum required amount of information from the distribution level. 17. Identify suitable modalities for data aggregation and synthesis of information at the TSO-DSO interface taking into account the interactions with multiple aggregators of both the TSO and the DSO.