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Energy Systems

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

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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.

[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)

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 renewables 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 appliances and to the expected penetration of heat pumps and electric vehicles, the share of electricity in the overall energy consumption is expected to rise.

In parallel, consumers - including individual energy users, user groups, and small and medium industrial and commercial actors - will further increase their expectations and will take an increasingly active role in the energy system.

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

The present energy systems in Europe are to a large part progressively approaching their design end of life, and hence massive investments are expected in the decades to come. The Smart Grids paradigm represents the cost-effective solution to the new and increasing energy system challenges, but calls for technological innovations in the electrical power sector, the ICT domain and in the merged "Smart Grids domain". This calls for a stepwise development towards an observable, flexible, controllable and sustainable electricity/energy system at a minimal/affordable cost.

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

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

Today, the European 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 obvious benefits for the mutualisation of resources increasing the security of supply and the resilience of the system in case of crisis. This is also needed to achieve a fully integrated energy market and will allow to make faster progress in the decarbonisation of the European economy. Finally, the above-mentioned Communication highlights the importance of a well-coordinated research and innovation as a key element for 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 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 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 (generation, transmission, distribution and customers) but also to reinforce / create new links with other 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 integration,
- Storage, connection with other energy networks/carriers
- Demand response,
- Flexible backup and generation,
- Accelerated electricity grid modernization.

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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:

[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

- **Energy grids, systems and integration:** smart technologies, systems and services are developed allowing real time monitoring and fast reaction asset management in such a way that the power network operates in a safe, stable and secure way, at least with the same level of performance as today in terms of availability and quality of supply, speed of restoration of services, etc. This would also entail a reduced curtailment of Renewable Energy Sources (RES) and Distributed Energy Resources (DER). These technologies, services and systems may contribute to some extent to minimize losses in the system, enable increasing levels of transfer capacity and enhancing cooperation from regional to European level. Pan-European grid architectures must fulfil the low-carbon requirements of Energy Roadmap 2050 and enable effective power delivery throughout Europe, on- as well as offshore. 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 systems and for 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 to serve the grid at different levels (generation, transmission, distribution, consumers) and different timescales (from real-time balancing to variations on daily and longer time frames). '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 that enable customers and prosumers to play a role in the energy system by trading energy and services to the energy system; 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 nondiscriminatory 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 create services and significantly decrease GHG emissions. Solutions should aim to economically provide the services required for balance and stability of the power system and exploit the potential capabilities of both thermal and renewable generation.

- **Accelerated electricity grid modernization:** transmission and distribution technologies must increase the abilities of new components to be operated to ensure stability and security in future power systems and strengthen collaborations between TSOs and DSOs in their efforts to integrate distributed energy resources. The future electricity systems with mixed HVAC- and HVDC-grids are highly dependent on well-functioning and efficient converter technologies. Furthermore, the electricity grid will undergo an evolution with massive reinvestments taking place in the coming decades and we expect new electricity network architectures to arise. These investments must be "future proof" with regard to utilizing maximal component life of existing and future components, as well as constituting a plan for a stepwise electricity system modernization taking benefit of increased electricity grid observability, flexibility and hence inherent controllability. For acceleration of innovation to take full effect, it is believed that stable and clear innovation policies are needed, and that there exists synergies between member state innovation activities that must be exploited.

[6] Baumgartner (2015)

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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 60% 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 issues, requiring work and most likely the use of advanced robust electricity system models. Stable and secure system operation will rely on much higher level as compared to today of system observability, flexibility and hence controllability.

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&smart systems).
- the massive investments taking place in the coming decades must take advantage of new knowledge and technologies to exploit power components in a cost optimal way. This implies a trade-off between grid assets versus sensors & ICT, in addition to exploiting true component life by extended use of dynamic rating concepts. There lie huge potentials for life extension and exploitation – and with important economic benefits in terms of reduced and postponed investment and reinvestment costs.
- regarding services to the grid, the assessment is less straightforward 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 behaviour 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 years. This assessment should indicate 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, or system is introduced

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in the energy system modelling. The monitoring, together with eventual stimuli to innovation, should cover the whole innovation chain that is from available knowledge and experiences at R&D organizations, manufacturers, and utilities.

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 an accurate identification of the regulatory requirements and of the most appropriate market design and 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 jnvolve 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.

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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: Research for electric grid compatible renewable and new user integration

Action 3: Research and 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: Research and development of tools development 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

INDUSTRIAL RESEARCH AND DEMONSTRATION PROGRAMME

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

Action 2: Demonstration of 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 prepare recommendations for novel market designs

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

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: Interoperability 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

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 grid market designs and mechanisms at EU level

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

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