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# GRID+

## SUPPORTING THE DEVELOPMENT OF THE EUROPEAN ELECTRICITY GRIDS INITIATIVE (EEGI)

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## D 2.4

## INTERACTION BETWEEN SMART GRIDS INITIATIVES – COMPARISON OF ROADMAPS AND IMPLEMENTATION PLANS

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| Abstract |
|---|
| Fostering a networking process and exchange of information between grid stakeholders and initiatives is a key overall objective in GRID+ project and in particular WP2 (Interaction). The purpose of this document is to propose a coherent picture of the R&I roadmaps on electricity networks in EU28, focusing on the interactions between EEGI Roadmap and/or other roadmaps developed by other relevant European Smart Grids Initiatives. |


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# Acronyms and definitions

| | |
|---|---|
| **DER** | Distributed Energy Resources |
| **DSM** | Demand side management |
| **DSO** | Distribution System Operator |
| **EASE** | European Association for Storage of Energy |
| **EEGI** | European Electricity Grid Initiative |
| **EERA** | European Research Area Network |
| **ETP-SG** | European Technology Platform Smart Grids |
| **EU** | European Union |
| **ICT** | Information and Communication Technologies |
| **IEA** | International Energy Agency |
| **MRL** | Manufacturing Readiness Level |
| **PV** | Photovoltaic |
| **r** | Review |
| **R&D** | Research and Development |
| **R&I** | Research and Innovation |
| **RES** | Renewable Energy Sources |
| **SET-Plan** | Strategic Energy Technology Plan |
| **TRL** | Technological Readiness Level |
| **TSO** | Transmission System Operator |
| **v** | Version |
| **WP** | Work Package |

# EXECUTIVE SUMMARY

The present report aims at comparing and linking several R&I roadmaps which have been published in EU28 to address smart grid innovation issues in recent years. This comparison follows a top-down approach. Whereas, all roadmaps have the same overarching goal (improve the electricity system flexibility with a network approach), it is shown that amongst the several dimensions which could be used to compare them, the most relevant one is the Technology leadenness level (TRL) of the expected outputs. Based on this proposal, six roadmaps have been positioned along this dimension. It shows that a distinction must be made between the TRL scale of the manufacturers (who innovate at world level) and the TRL of European network operators (who innovate to address EU28 challenges for transmission and distribution networks). Thus, technology pushes roadmaps (ETP Smart Grids, EERA, EASE/EERA, REALISEGRID and IRENE40) feed to technology-based innovations into the EEGI roadmap which addresses essentially system integration and market design issues (while covering planning, operations and asset management activities of network operators). This report delivers also comparison inputs at functional level which will help completing the on-going Integrated Roadmap development of the SET-Plan.

# 1 BACKGROUND AND STUDIED ROADMAPS

Since 2010, there are several R&I roadmaps at European level which claim addressing the R&I activities required to help network operators anticipating the low carbon economy transition by 2050.

- The latest version of the EEGI roadmap, published in December 2013
- The latest version of the ETP Smart Grids Strategic Research Agenda published in March 2012, which covers research and development topics from 2020 to 2035.
- The EERA R&D programme (EERA JP Smart Grids): the EERA28 (European Energy Research Alliance) Joint Program on Smart Grids initiated an extended cross-disciplinary cooperation involving several Research and Development (R&D) participants with different and complementary expertise and facilities. This cooperation aims at addressing, within a medium to long-term research perspective, the effective acceleration of smart grid development and deployment.

These Roadmaps addressing non-specifically the transmission network and storage technologies are also considered which embrace issues at European level.

- The first version of the EASE/EERA storage roadmap [1]
- The REALISEGRID transmission network roadmap
- The IRENE40 transmission network roadmap

A high level description of the main objectives of each Roadmap is given below.

## 1.1 EEGI R&I roadmap

The single overarching goal of the EEGI Research and Innovation (R&I) Roadmap is: “to allow European electricity networks continuously deliver an effective flexible capacity to integrate actions of grid users at affordable costs”.

The roadmap aims at delivering a portfolio of innovative pathways for preparing European electricity networks to enable the ambitious 2050 agenda adopted by European Member States: a low carbon economy leaning on the three pillars of European energy policy, i.e. sustainability, energy market competitiveness, and security of supply.

The enabling capability of electrical networks means their effective flexible capacity to connect renewable electricity generation (sustainability), serving customers according to affordable electricity pricing (market competitiveness), while keeping the system reliability at levels compatible with societal needs (security of supply). The electrical networks must be ready to provide connection solutions for all grid users going from existing and new generation (e.g. RES) to existing and new demands (e.g. electric vehicles), while combining with the other industrial initiatives to be in line with the SET Plan orientations.

Overall, the EEGI R&I roadmap focuses on the enabling factors that network operators must put in place to face whatever energy scenarios occur between 2015 and 2050.

## 1.2 ETP Smart Grids strategic research agenda

The goal of the SmartGrids Strategic Research Agenda 2035 is the exploration of the longer-term (Years 2020+) Smart Grids research, innovation, development and deployment needs.

These research activities aim at creating the basis for a high quality, economically affordable and sustainable electricity supply transition from today via progress achieved through the EEGI (European Electricity Grid Initiative) by 2020 towards the energy and electricity system for the year 2035, leading to a CO2 free electricity system by 2050.

The technological priorities of this Research Agenda are:

- Small- to medium-scale distributed storage systems for distributions systems exposed to a massive penetration of renewable electricity generation
- Real-time metering of energy end uses and state monitoring systems which increase the real-time knowledge about network behaviour
- Grid modelling technologies
- Communication technologies
- Protection systems for distributions systems exposed to a massive penetration of renewable based electricity generation
- Non-technological network issues which have a direct impact on technologies.

## 1.3 EERA Smart Grids roadmap

Ten leading European Research Institutes have taken up the challenge to found a European Energy Research Alliance (EERA). The key objective of the EERA is to accelerate the development of new energy technologies by conceiving and implementing Joint Research Programmes in support of the Strategic Energy Technology (SET) plan, by pooling and integrating activities and resources, combining national and Community sources of funding and maximising complementariness and synergies. The Joint Programme on SmartGrids was officially launched at the SET Plan Conference in Madrid (June 2010). The present Joint Programme aims at addressing, in a medium to long term research perspective, the most critical areas directly impacting the acceleration of smart grid deployment.

Three Steering Committee meetings have been held, and the following Sub-Programmes (SP) make part of the Smart Grids Joint Programme:

- Network Operation: to contribute to the development of new control methods and technical solutions in electrical grid operation in order to improve the grid stability in presence of high penetration of Distributed Energy Resources (DER) and controllable loads. This should lead to a generic "Primary" Smart Grid Control structure.

- Energy Management: to optimise the management of distribution networks in presence of DER and load control in an energy and market perspective. Technical and economic scenarios are considered for the active distribution network development.

- Control System Interoperability: to contribute to the development and evaluation of interoperable control systems enabling large scale DER integration. Interoperability is

considered at different levels: from grid and device level interactions up to business and e-Market level interactions.

- Gateway architectures to address security aspects to develop architecture-driven security management approaches requiring architecture modelling risk, identification risk, integration and compliance checking.

- Electrical Storage Integration: to enhance the integration and control of storage solutions in smart grid applications, involving the techno-economic evaluation of storages and the integration of electric vehicles into the grid. The research addresses the role of storage systems to create flexible control functions for vertical and horizontal integrated controls of the network under normal and disturbed conditions. Moreover, the potential impact on networks as well as opportunities coming from current and future energy markets (e.g. offering ancillary services, reserves, peak shaving or balancing services) will be analysed.

- Transmission Networks: to contribute to the development of tools and methods for planning and operation of transmission networks which are needed to achieve a high share of renewable energy sources in the supply mix while maintaining an acceptable level of security of supply in the system. Smart transmission technologies and new components to be operated to ensure stability and security in future power systems are also covered.

Transmission network system evolution has been proposed by SINTEF and RSE. Storage is now merged with the EASE approach.

## 1.4 EASE/EERA roadmap on energy storage

The R&I roadmap aims at *"Setting up recommendations for R&D actions in the timeframe of Horizon2020, in line with the wider EU 2030 Energy & Climate Framework, which can assist in integration of renewable energy in Europe and at the same time lead to commercial European manufacturing and international marketing of energy storage devices/facilities*".

It is rather a technology-push roadmap to shape an energy storage value chain which can address the European Energy needs by 2020, where large scale demonstrations would be ready to validate the system integration on innovative solutions.

Clearly storage technologies complement a panel of other solutions to increase system flexibility which are addressed up front in the EEGI roadmap. Indeed, several solutions come into competition to provide such flexibility improvements, with staged costs and benefits, viz.:

- Increased Pan European interconnections, since increased grids decrease the need for flexibility (fluctuations in generation (wind and PV) and demand are equilibrated across larger and larger distances )
- Improved transmission/distribution grids
- Operation of combined heat-and-power and biomass plants according to electricity demand
- Improved flexibility of fossil-fueled power plants (minimum output, lower start-up times
- Avoiding generation peaks from wind and PV or use them for heating

- Electricity storage

Integrated R&I about grid connected storage solutions at European level ought therefore to be prioritized according to the direct and indirect competition coming from other potential solutions.

## 1.5 REALISEGRID roadmap

The research project REALISEGRID (http://realisegrid.rse-web.it/) aimed at developing a set of criteria, metrics, methods and tools to assess how the transmission infrastructure should be optimally developed to support the achievement of a reliable, competitive and sustainable electricity supply in the EU. **A TSO-targeted Technology Roadmap [2] was proposed for the integration of promising innovative power transmission technologies into the pan-European power system from 2020 to 2040,** a time frame which will be critical for the evolution of the European power system towards a low carbon economy by 2050.

## 1.6 IRENE40 roadmap

The IRENE-40 roadmap [3] has been devised to reach the objectives below:

- Develop a credible vision for technology, infrastructure and policy development to inform stakeholders and investors.
- Tackle the challenge of utilising latent capacity in infrastructure across national networks without compromising system security and operation while maximising power trading opportunities.
- Propose interconnection strategies between member states to create a single pan-European grid, including harmonisation of technical standards and development of new markets for cross-border trade.
- Define general deployment strategies as well as methods to assess energy technology from a system perspective.
- Alleviate risks and increase the sustainability, security and competitiveness of electrical energy systems.

# 2 SCANNING THE VARIABLES AGAINST WHICH R&I ROADMAPS CAN BE COMPARED

It is quite rare to compare R&I roadmaps, since, at least at private level, they are confidential documents owned by companies and directly related to their growth strategy. For instance, Booz, Allen and Hamilton [4] publishes **yearly** analysis of the 1.000 biggest private R&D budget spenders which have shown the loose **links between R&D spending and company growth though innovation,** or the **role of digital tools to improve on the innovation effectiveness.**

But these studies are based on ex-post analyses of yearly company performances without addressing the details of each of their confidential project portfolios: they only measure the short term impacts of innovation investments.

In the present section, the comparison involves an ex-ante analysis of the programme portfolios based on a mix of roadmap design parameters including:

- The overarching goal(s) of the R&I investments,
- The time perspective to deliver outputs out of the R&I roadmap,
- The maturity of the developed solutions to allow proper grid integration and validation at a scale, large enough to perform dedicated cost and benefit analysis,
- The detailed RTD&D project portfolio contents.

## 2.1 Overarching goals of the studied roadmaps

Decarbonizing the European electricity generation chain by 2050 requires that significant amounts of low carbon and renewable energy sources (RES) capacity be installed, which, in turn, increases the balancing needs of the electric system. Indeed, variable RES generation has intrinsic variability which adds to the typical variations in electricity demand. Since in the current market designs, RES production has generally feed-in priority, the remaining capacity has to adjust its outputs to balance total electricity production and demand, in the absence of massive electricity storage facilities. Yet, electricity demand as well as electricity outputs from RES may change rapidly, very often in opposite directions. Since the demand side is currently not very flexible, system operators require therefore that generation capacity be able to respond quickly to such changes.

The impact of RES deployment on electricity markets has thus become increasingly important over the recent years: variable RES generates electricity at very low marginal costs which pushes thermal capacity higher up in, or completely out of, the merit order, thus leading to reduced operating hours and less revenue for thermal capacity. In addition, subsidized RES output depresses further electricity prices, which make the feasibility of thermal plants even more challenging. But as seen above, thermal capacity is still needed in a high RES electric system in order to balance the system, but with a lower profitability of the corresponding assets.

Several EU Member states have pinpointed that the market may bring forward insufficient capacity under current market arrangements, this resulting from plant closures and lack of investments in new capacities. Without appropriate price signals, there is a “missing flexibility” issue which constitute a market failure: the value of flexibility is neither recognized, nor valued in present market arrangements, as shown by a recent Wartsila study. Moreover, “appropriate types” of capacities are requested, since it is a sufficiently flexible mix which must be made available to network operators.

Today, network operators are calling for flexibility [5] coming from:

- Endogenous electric network solutions from the network operators themselves, by addressing planning and network architecture, network operations and market designs with innovative solutions.
- Exogenous solutions from the generation side to balance the fluctuations of variable renewable generation. This is where the core value of system flexibility comes from. In the foreseen future EU power system, flexibility should become a visible and high value product of power generation.
- Development of demand response to make the load more flexible than it is today, possibly through aggregation of small loads.
- Development of storage solutions, possibly at generation, consumption and grid levels.
- A combination of the above solutions: the mix of flexibility will indeed become a key parameter in the power system design and optimization. For instance, demand response and distributed generation MAY reduce system costs, including at the distribution level, where they can also address, as a secondary outcome, congestion, losses, and inadequate network infrastructure, provided that non-discriminatory access in the wholesale market is possible.

The challenges to be addressed encompass, amongst others:

- Valuing storage: electricity storage—mechanical, thermal, or chemical—does face technology, economic, policy and regulatory barriers which prevent storage from participating in centralized markets. Emerging solutions could induce more optimal use of the storage option.
- Increasing demand response participation: significant barriers remain before these resources contribute in a significant way to system operation because traditional markets follow 20th century demarcations between wholesale and retail sides. Moreover, demand response will require much higher electricity prices to become attractive.
- Integrating distributed generation: local factors must be considered in future market designs leading to coordinated deployment of centralized and distributed energy resources, including the use of microgrids.
- Valuing system reliability since the comparison between centralized and decentralized (DSM, storage, PV…) involves network infrastructures for both options with specific impacts on the resulting system reliability.
- Making the best of existing network infrastructures (more software-based improvements which make grids smarter), since the evolution of electricity consumption and decentralized generation remain uncertain for the near future.

Bringing satisfactory answers to such challenges will require coordinated European answers, much beyond the national ambitions as seen to-day within the 2020 perspectives. This include the R&I early steps needed to deliver the large scale demonstrations which appear compulsory to perform reliable cost/benefit analysis prior to large scale deployment.

The studied roadmaps are all addressing grid flexibility issues by combining technology development and grid integration, as summarized in the table below.

| R&I roadmaps | Main focus |
|---|---|
| EEGI | Grid integration of methodologies and technologies |
| SmartGrids Strategic Research Agenda 2035 | Critical technologies for grids |
| EASE/EERA roadmap on energy storage | Energy storage technologies |
| REALISEGRID roadmap | Power transmission technologies |
| IRENE40 roadmap | Power transmission technologies |
| EERA | Network operation, energy management and control system interoperability |

**Table 1: Main focus of the analysed Roadmaps**

All roadmaps are focused on increasing the flexibility of pan-European grids at transmission and distribution levels, with different solution maturities studied going from basic research down to system integration at a scale that allows preparing scaling up and replication in various parts of the grids in EU28.

All roadmaps are focused on increasing the flexibility of pan-European grids at transmission and distribution levels, with different solution maturities studied going from basic research down to system integration at a scale that allows preparing scaling up and replication in various parts of the grids in EU28.

## 2.2 Time perspective to deliver outputs

The table below summarizes the timeline of the covered R&I roadmaps.

| R&I roadmaps | Timeline |
|---|---|
| EEGI | 2014-2023 |
| SmartGrids Strategic Research Agenda 2035 | 2021-2035 |
| EASE/EERA roadmap on energy storage | 2015-2030 |
| REALISEGRID roadmap | 2015-2040 |
| IRENE40 roadmap | 2015-2040 |
| EERA Smart grids | 2015-2030 |

**Table 2: Timeline of the analysed Roadmaps**

This timeline comparison summarizes the complementariness and overlaps of the studied roadmaps: however it is not distinctive enough to show the intricacies between the various roadmaps.

## 2.3 Maturity of the developed solutions

There are clearly dissents between grid operators and power manufacturers on several aspects of the gap analysis performed by the GRID + project, in support of the R&I roadmap topics of the EEGI: they do not share indeed the same point of view about the technology maturity scale when defining

the capability of a given technology to integrate European grids. A simple explanation to understand this dissent can be offered:

- Power manufacturers address a world market with network configurations, regulations and standards deployment which may differ significantly from what Europe is experiencing.
- There are therefore examples of innovative technology or market-based solutions which meet the functional specifications of the R&I EEGI roadmap, and which are already operational in other parts of the world: they have been tested, validated and deployed according to other local network conditions.
- Provided that, within clear disclosure conditions, the details of these technology deployments can be made available to European network operators, this interaction between power manufacturers and network operators will accelerate of the market take up of state-of-the-art innovations by network operators in Europe, and also reinforce the competitiveness of power manufacturers worldwide.

Overall, European network operators should then be keener to prepare technology integration experiments typical of the approach recommended in the EEGI roadmap, and using novelties that have been tested somewhere else in the world. Accordingly, large scale demonstrations of such existing innovative technologies implemented in one or several areas of European networks can be designed and launched, which would allow:

- Innovation tests in other regulatory environments and end-use demands (local profiles, climates…),
- Innovation adaptation of interfaces or integration standards in order to comply with real life constraints brought by European networks,
- Innovation cost/benefit analysis, moreover leaning on the real life figures already gained in other parts of the world by poser manufacturers

Overall, such integration demonstrations which are already part of the EEGI R&I roadmap, are needed to negotiate with the regulators the deployment scenarios, which may include regulatory evolutions or standard adaptation in order to maximize the benefits brought by network operators to some or all of the network users.

It is therefore proposed to develop a comparison of the roadmaps using two Readiness Level scales, based on the following definitions for the power technologies as viewed by manufacturers and network operators:

**TECHNOLOGICAL READINESS LEVEL (TRL) SCALE**

| LEVEL | DESCRIPTION |
|---|---|
| 1 | TRL 1 – basic principles observed |
| 2 | TRL 2 – technology concept formulated |
| 3 | TRL 3 – experimental proof of concept |
| 4 | TRL 4 – technology validated in lab |
| 5 | TRL 5 – technology validated in the relevant environment |
| 6 | TRL 6 – technology demonstrated in the relevant environment |
| 7 | TRL 7 – system prototype demonstration in operational environment |
| 8 | TRL 8 – system complete and qualified |
| 9 | TRL 9 – actual system proven in operational environment |

This means that manufacturers must have reached an early level of technology maturity which makes product deployment possible for network operators, together with the parent technology manufacturing level for manufacturers ready enough to make large scale demonstrations possible:. As a matter of fact, two intertwined TRL scales co-exist:

- The TRL scale of the world based manufacturers may exhibit earlier maturity levels than observed in EU28, thanks to prior deployment in other parts of the world (this also implies that the manufacturing readiness level (MRL) has reached a stage where demonstrations are possible)

**MANUFACTURING READINESS LEVEL (MRL) SCALE**

| LEVEL | DESCRIPTION |
|---|---|
| 1 | Basic manufacturing implications identified |
| 2 | Manufacturing concepts identified |
| 3 | Manufacturing proof of concept developed |
| 4 | Capability to produce the technology in a laboratory environment |
| 5 | Capability to produce prototype components in a production relevant environment. |
| 6 | Capability to produce a prototype system or subsystem in a production relevant environment. |
| 7 | Capability to produce systems, subsystems or components in a production representative environment. |
| 8 | Pilot line capability demonstrated. Ready to begin low rate production. |
| 9 | Low rate production demonstrated. Capability in place to begin full rate production. |
| 10 | Full rate production demonstrated and lean production practices in place. |

- The TRL scale of the European Grid operators indicates where integration innovation is still required to prepare the cost benefit analysis which regulators will request before authorizing large scale infrastructure investments. This integration innovation process is addressed in the EEGI roadmap.

The diagram below proposes a TRL-based positioning of the covered roadmaps. The EEGI roadmap is fed mainly with power technologies coming from thither roadmap at various integration steps into the grids.

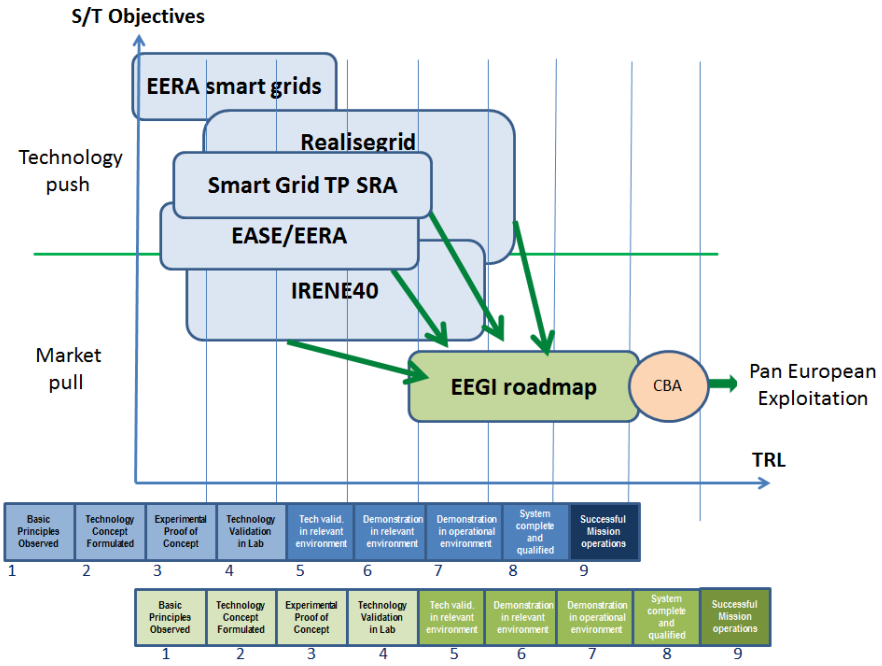


**Figure 2: Positioning of the covered roadmaps**

The main issue is then to find the right time where the flexibility system needs of at least one transmission or one distribution operator will require to integrate such technologies into the system and to find the adequate market rules to optimize the integration.

This is illustrated below using the system flexibility needs as a key driver for the development and deployment of such innovative solutions.

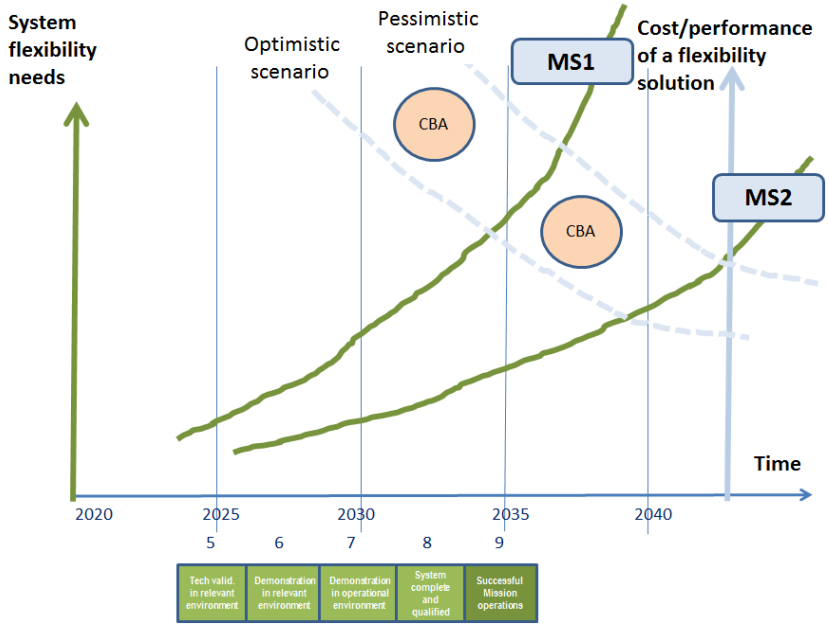


**Figure 2: System flexibility needs**

Optimistic and pessimistic technology development scenarios for Member State 1 aim at meeting the most urgent needs as the renewable generation penetration grows at a given time frame (here before or after 2035). The objective of R&I activities is to reach the right cost to performance ratio, i.e. when system needs can absorb the related innovation investment.

This is a complex and dynamic issue for EU 28 Member States, since two electric systems in Europe, while interconnected, may not have the same needs at the same time. In the diagram above, Member State 2 has integration needs of the same solution later on, say beyond year 2040.

## 2.4 Detailed RTD&D project portfolio content

The three roadmaps (EEGI, ITO Smart Grids and EERA) have also been compared at functional level, crossing functional objectives (EEGI roadmap) and technology topics (ETP Smart Grids and EERA). The results of this extensive analysis can be found in the annex.

## 2.5 Detailed portfolio matching between the Draft SET Plan roadmap and the EEGI roadmap

Many of the GRID+ Consortium members have contributed directly or indirectly to the construction of the draft Integrated Roadmap of the SET PLAN from September 2013 to June 2014.

A similar analysis can thus be performed by matching the EEGI roadmap contents with the draft SET Plan roadmap. The results are shown below, assuming that the SET Plan integrated roadmap is the one available in June 2014.With reference to the format of this Integrated Roadmap as of June 2014, the following table illustrates how the EEGI team RTD&D clusters match with the activities of the SET plan integrated roadmap.

For the advanced research programme, the listed actions are:

- **Action 1:** New methodologies to design grid architectures and plan transmission and distribution networks
- **Action 2:** Research for energy system compatible renewables and new user integration
- **Action 3:** Research and tools development for grid asset management to increase network flexibility and continuity of supply
- **Action 4:** Development of innovative tools for grid operation
- **Action 5:** R&D of tools to support new market designs at Pan-European and regional levels
- **Action 6:** tools for scaling up innovative demonstrations

These actions match the functional projects (see description in the next report section) of the existing EEGI roadmap ($D_i$, $T_j$, $TD_k$) as follows:

| | Actions | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Advanced Research Programme | | | | D7 | | |
| | | D1 | | D8 | | |
| | D11 | D2 | D12 | D9 | | |
| | T1 | D3 | T15 | D10 | T10 | |
| | T2 | D4 | T16 | T6 | T11 | TD5 |
| | T14 | D5 | T17 | T7 | T12 | |
| | | D6 | | T8 | TD3 | |
| | | T3 | | T9 | | |
| | | T4 | | TD1 | | |
| | | T5 | | TD3 | | |
| | | TD2 | | TD4 | | |

For the Industrial research and demonstration programme, the listed actions are:

- **Action 1:** Demonstration of novel interoperable technologies integrated into energy Grids
- **Action 2:** Demonstration of grid integration of RES, storage and new users
- **Action 3:** Demonstration of novel grid assets management techniques
- **Action 4:** Demonstration of tools for improved grid operation
- **Action 5:** Demonstration of tools validation to prepare recommendations for novel market design

These actions match the functional projects of the existing EEGI roadmap ($D_i$, $T_j$, $TD_k$) as follows:

| | Actions | | | | |
|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** |
| **Industrial research and demonstration program** | **T3** | **D1** | **D12** | **D7** | **D13** |
| | **T4** | **D2** | **T15** | **D8** | **T10** |
| | **T5** | **D3** | **T16** | **D9** | **T11** |
| | | **D4** | **T17** | **D10** | **T12** |
| | | **D5** | | **T6** | |
| | | | | **T7** | |
| | | | | **T8** | |
| | | | | **T9** | |
| | | | | **TD1** | |
| | | | | **TD3** | |
| | | | | **TD4** | |

For the Market take-up programme, the listed actions are:

- **Action 1:** Modular development plans of the pan European transmission system based on new planning and grid architectures
- **Action 2:** Scaling up and replication
- **Action 3:** Interoperability of standards for data and knowledge exchange
- **Action 4:** Improved awareness and acceptance by the pubic of new grid infrastructures and energy metering and use
- **Action 5:** Increasing stakeholders acceptance of novel energy market design and products
- **Action 6:** Training tools and EU level

These actions match the functional projects of the existing EEGI roadmap ($D_i$, $T_j$, $TD_k$) as follows:

| | Actions | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Market take-up | T2 | | | | D1 | |
| | T14 | TD5 | TD5 | T14 | D2 | T8 |
| | | | | | T14 | |

# 3 COHERENCE OF THE ROADMAP CONTENTS

Based upon the above TRL positioning, the comparison of the roadmaps can then be made on a project content basis.

## 3.1 EEGI roadmap

Transmission and Distribution operators are regulated companies for which the value chain of services involves similar skills used in similar activities, even though their detailed legal obligations may differ from Member State to Member State.

The innovation activities proposed at European level in the EEGI roadmap cover the full value chain of activities performed by Network Operators grouped into eleven clusters as shown on the Figure below.

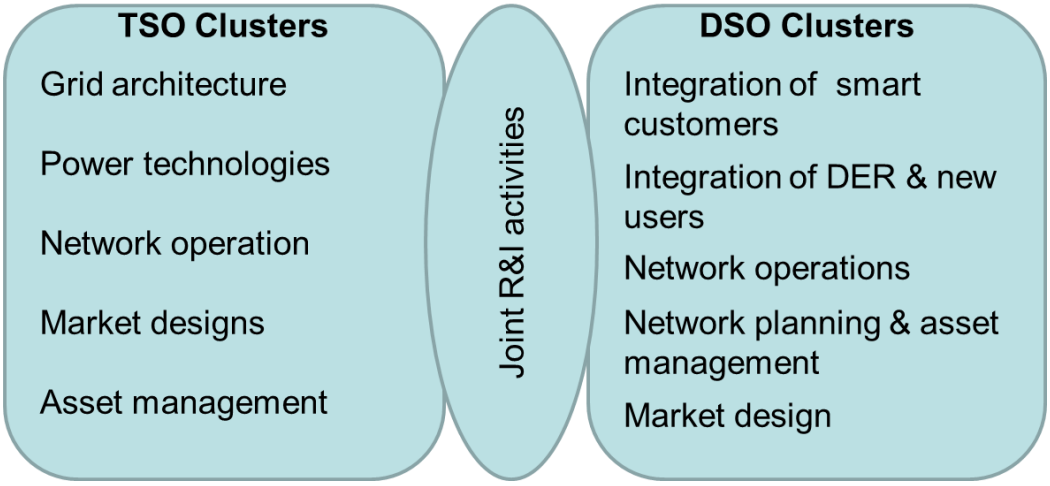


**Figure 3: EEGI Roadmap Clusters**

## 3.2 Contribution of the other R&I roadmaps to the EEGI roadmap

The whole R&I roadmaps are contributing to feed mainly the following clusters:

- TSO: power technologies, network operations and asset management,
- DSO: integration of DER and new uses, network operations and asset management,

The three tables below recall the functional projects retained by the TSOs and DSOs were power technologies developed in the other roadmaps have a direct impact.

| TSOs clusters | | Corresponding functional objectives | |
|---|---|---|---|
| **C2** | Power Technologies For the Future Pan-European Transmission Grid | T3 | Demonstration of power technology for increased network flexibility |
| | | T4 | Demonstration of power technology for novel network architecture |
| | | T5 | Demonstration of renewable integration with ICT |
| **C3** | Network Operation | T6 | Innovative tools and methods for pan-European network observability and controlability |
| | | T7 | Innovative tools and methods for coordinated operations with stability margin evaluation |
| | | T8 | Improved training tools and methods to ensure better coordination at the regional and pan-European levels |
| | | T9 | Innovative tools and approaches for pan-European network reliability assessment |
| **C5** | Asset Management | T15 | Methodologies to determine and expand the life span of power equipment |
| | | T16 | Methods and tools to optimize asset management |
| | | T17 | Implementation of Advanced Asset Management (AAM) |

**Table 3: TSO Functional Objectives with potential impacts from other roadmaps**

| DSOs clusters | | Corresponding functional objectives | |
|---|---|---|---|
| **C2** | Integration of DER and new uses | D3 | DSO integration of small DER |
| | | D4 | System integration of medium DER |
| | | D5 | Integration of storage in network management |
| | | D6 | Infrastructure to host EV/PHEV |
| **C3** | Network Operation | D7 | Monitoring and control of LV network |
| | | D8 | Automation and control of MV network |
| | | D9 | Network management tools |
| | | D10 | Smart metering data processing |
| **C5** | Network Asset Management | D12 | Asset management |

**Table 4: DSO Functional Objectives with potential impacts from other roadmaps**

| | | |
|---|---|---|
| **Joint TSO/DSO R&D activities** | TD1 | Increased observability of the distribution system for transmission network management and control |
| | TD2 | The integration of demand side management into TSO operations |
| | TD3 | Ancillary services provided by DSOs |
| | TD4 | Improved defense and restoration plans |
| | TD5 | Joint task force on IT system protocols and standards |

**Table 5: Joint TSO/DSO Functional Objectives with potential impacts from other roadmaps**

The innovation cycle of power technologies is indeed in the hands of power technology providers and manufacturers. Europe has a world leadership: such players make strategic innovation choices based on a world market appraisal, the needs of which very often do not match very well European expectations. European network players are therefore compelled to design system development and integration projects at reduced or full scale (where they share development and early industrialization costs with their industry counterpart), before they propose to regulatory authorities deployment plans economically secured by such integration projects.

## 3.3 Potential gaps between the EEGI roadmap on the other technology roadmaps

Three roadmaps - EERA/EASE, EERA smart grids and SmartGrids Research agenda are lacking contributions to the EEGI roadmap in the following clusters:

- Network architecture and planning
- Market design
- Integration of smart customers

# 4 CONCLUSIONS

The present report proposes to link the six RTD&D roadmaps existing so far at European level to address electricity network innovation. The herein developed top down approach uses two TRL scales: the one of the power manufacturers and the one of European network operators to show how the mostly technologies-push roadmaps (ETP Smartgrids, EERA, EASE/EERA, REALISEGRID and IRENE40) are feeding into the rather market-pull EEGI roadmap (since addressing the needs of electricity network operators as electric system and market enablers).

A detailed analysis of the functional and technology topics built into the EEGI, ETP Smartgrids and EERA roadmaps shows how these roadmaps do complement each other.

Last, a link between the EEGI roadmap and the draft Integrated Roadmap of the SET Plan (version June 2014) is proposed: it shows how to connect the functional objectives of the EEGI roadmap with the activity approach of the draft SET Plan integrated roadmap, as of June 2014.

# 5 REFERENCES

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**[2]** "A mid-term roadmap for advanced technologies integration in transmission networks" S. Galant, A. Vaféas, T. Pagano, E. Peirano, (Technofi, France), G. Migliavacca, A. Angelo L'Abbate, (RSE S.p.A., Italy), Springer Verlag

**[3]** DELIVERABLE 4.0: Roadmap towards a future electricity network

**[4]** B. Jaruzelski, K. Dehoff, R. Bordia « The Booz Allen Hamilton Global Innovation 1000 : Money Isn't Everything », Winter 2005 "Booz & Company's annual study of R&D spending reveals the tools that are transforming innovation-from customer insight to product launch". by Barry Jaruzelski, John Loehr, and Richard Holman (2013)

**[5]** A flexible power system can both rapidly supplement periods of low variable generation to meet demand as required, and manage large surpluses when demand is low. A flexible system is able to transport, store, trade and consume electricity to maintain reliable supply in the face of rapid changes and potentially large disturbances in supply and demand. IEA Energy Technology Perspectives 2010, p. 149.

# 6 ANNEXES

## 6.1 Matching of functional objectives and R&I innovation topics between EERA/EEGI Roadmaps

| | | Grid Architecture | | | Power Technologies | | | Network Operation | | | | Market Designs | | | Asset Management | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | TSO 1 | TSO 2 | TSO 14 | TSO 3 | TSO 4 | TSO 5 | TSO 6 | TSO 7 | TSO 8 | TSO 9 | TSO 10 | TSO 11 | TSO 12 | TSO 15 | TSO 16 | TSO 17 |
| | | Scenarios for pan-European network expansion | Planning methodology for future pan-European transmission system | Public acceptance of transmission infrastructure | Demonstration of power technology to increase network flexibility and operation means | Demonstration of novel network architectures | Interfaces for large-scale demonstration of renewable integration | Innovative tools and methods to observe and control the pan-European network | Innovative tools and methods for coordinated operation with stability margin evaluation | Training tools to ensure better coordination at the regional and pan-European levels | Innovative tools and approaches for pan-European network reliability assessment | Market tools for ancillary services and balancing, including active demand management | Advanced tools for capacity allocation and congestion management | Tools and market mechanisms for ensuring system adequacy and efficiency in electric systems integrating very large amounts of RES generation | Maximization the lifetime of critical power components for existing and future networks | Development and validation of tools which optimize asset maintenance at the system level, based on quantitative cost/benefit analysis | Demonstrations of new asset management approaches at EU level |
| Network Operation | Primary control cycle and automation | | | | ■ | | | ■ | | | ■ | ■ | ■ | | | | |
| | Network monitoring system and ICT | | | | | | | ■ | ■ | ■ | ■ | | | | | | |
| | Ancillary services | ■ | ■ | ■ | | | | | ■ | ■ | ■ | | | | | | |
| | Fault and outage management | | | | | | | | | | ■ | | | | | | |
| | Distributed Generation (DG) management | | | | | | | | ■ | | | | | | | | |
| | Load (ED) management | | | | ■ | | | | ■ | | | | | | | | |

| | | Grid Architecture | | | Power Technologies | | | Network Operation | | | | Market Designs | | | Asset Management | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | TSO 1 | TSO 2 | TSO 14 | TSO 3 | TSO 4 | TSO 5 | TSO 6 | TSO 7 | TSO 8 | TSO 9 | TSO 10 | TSO 11 | TSO 12 | TSO 15 | TSO 16 | TSO 17 |
| Energy Management | System simulation and analysis frameworks and data sets | | | | | | | ■ | | | | | | | | ■ | |
| | System operation | | | | | | | | | | | | | | | | |
| | Market design and analysis | | | | | | | | | | | ■ | ■ | ■ | | | |
| | Distribution network planning procedures | | | | | | | | | | | | | | ■ | ■ | ■ |
| | DER technologies | | | | | | ■ | | | | | | | | | | |
| ICT for Smart Grid control systems and Interoperability | Communication technologies for smart grids | | | | | | | | ■ | | | | | | | | |
| | Operation of E-markets | | | | | | | | | | | | | | ■ | ■ | ■ |
| | DSO/TSO congestion management systems | ■ | ■ | | | | | | | | | | | | | | |
| | Energy Management systems | | | | | ■ | ■ | | | | | | | | | | |
| | Home/Industrial integration systems | | | | | | | | | | | | | | | | |
| | Novel control concepts for smart grids | | | | | | | | | | | | | | | | |
| | Standardization | | | | | | | | | | | | | | | | |
| | Security | | | | | | | | | | | | | | | | |

| | | Grid Architecture | | | Power Technologies | | | Network Operation | | | | Market Designs | | | Asset Management | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | TSO 1 | TSO 2 | TSO 14 | TSO 3 | TSO 4 | TSO 5 | TSO 6 | TSO 7 | TSO 8 | TSO 9 | TSO 10 | TSO 11 | TSO 12 | TSO 15 | TSO 16 | TSO 17 |
| Electrical Storage integration | Integration of storage resources to smart grids and ancillary services | | | | | | | | | | | | | | | | |
| | Controllable flexibility achieved by storages in the smart grid applications | | | | | | | | | | | | | | | | |
| | Economic and technical benefits of incorporating an ESS onto network | | | | | | | | | | | | | | | | ■ |
| | Integration of EV into grid | | | | | | | | | | | | | | | | ■ |
| Transmission Networks | Transmission planning model and methods | | ■ | | | | | | | | | | | | | | |
| | Development of pan-European electricity markets | | | | | | | | | | | ■ | ■ | ■ | | | |
| | Advanced transmission system control and protection | | | | | | | | | | ■ | | | | | | |
| | Co-planning and interfaces for full integration of pan-European operation of the power system | ■ | ■ | ■ | | | | | | | | | | | | | ■ |
| | HVDC systems and components | | | | | ■ | | | | | | | | | | | |
| | Structures and enabling technologies for a pan-European super-grid | ■ | ■ | ■ | | | | | | | | | | | | | |

| | | Integration of smart customers | | Integration of DER and new uses | | | | Network operations | | | | Network Planning and asset management | | Market Design |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | DSO 1 | DSO 2 | DSO 3 | DSO 4 | DSO 5 | DSO 6 | DSO 7 | DSO 8 | DSO 9 | DSO 10 | DSO 11 | DSO 12 | DSO 13 |
| | | Active demand for increased flexibility | Energy Efficiency from integration with Smart Homes | DSO integration of small DER | System integration of medium DER | Integration of storage in network management | Infrastructure to host EV/PHEV | Monitoring and control of LV network | Automation and control of MV network | Network management tools | Smart metering data processing | New planning approaches for distribution networks | Asset management | Market Designs |
| Network Operation | Adaptation of primary control cycle and automation | | | | | | | ■ | ■ | ■ | | | | |
| | Network monitoring system and ICT | | | | | | | | | ■ | | | | |
| | Ancillary services | | | | | | | ■ | ■ | ■ | | ■ | | |
| | Fault and outage management | | | | | | | ■ | ■ | | | | | |
| | Distributed Generation (DG) management | | | ■ | ■ | | | | | | | | | |
| | Load (ED) management | ■ | | | | | | | | | | | | |
| Energy Management | System simulation and analysis frameworks and data sets | | | | | | | | | | ■ | ■ | ■ | |
| | System operation | | | | | | | | | ■ | | | | |
| | Market design and analysis | | | | | | | | | | | | | ■ |
| | Distribution network planning procedures | | | | | | | | | | | ■ | ■ | |
| | DER technologies | | | ■ | ■ | | | | | | | | | |

| | | Integration of smart customers | | Integration of DER and new uses | | | | Network operations | | | | Network Planning and asset management | | Market Design |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | DSO 1 | DSO 2 | DSO 3 | DSO 4 | DSO 5 | DSO 6 | DSO 7 | DSO 8 | DSO 9 | DSO 10 | DSO 11 | DSO 12 | DSO 13 |
| ICT for Smart Grid control systems and Interoperability | Communication technologies for smart grids | | | | | | | | | | | | | |
| | Operation of E-markets | | | | | | | | | | | | | ■ |
| | DSO/TSO congestion management systems | | | | | | | | | ■ | | | | |
| | Energy Management systems | | | | | | | | | ■ | | | | |
| | Home/Industrial integration systems | ■ | ■ | | | | | | | | | | | |
| | Novel control concepts for smart grids | | | | | | | ■ | ■ | | | | | |
| | Standardization | | | | | | | | | | | | | |
| | Security | | | | | | | | | | | | | |
| Electrical Storage integration | Integration of storage resources to smart grids and ancillary services | | | | | ■ | | | | | | | | |
| | Controllable flexibility achieved by storages in the smart grid applications | | | | | ■ | | | | | | | | |
| | Economic and technical benefits of incorporating an ESS onto network | | | | | ■ | | | | | | | ■ | ■ |
| | Integration of EV into grid | | | | | | | | | | | | ■ | |
| Transmission Networks | Transmission planning model and methods | | | | | | | | | | | ■ | | |
| | Development of pan-European electricity markets | | | | | | | | | | | | | |
| | Advanced transmission system control and protection | | | | | | | | | | | | | |
| | Co-planning and interfaces for full integration of pan-European operation of the power system | | | | | | | | | | | ■ | | |
| | HVDC systems and components | | | | | | | | | | | | | |
| | Structures and enabling technologies for a pan-European super-grid | | | | | | | | | | | | | |

| | | Joint TSO/DSO R&D Activities | | | | |
|---|---|---|---|---|---|---|
| | | TDO 1 | TDO 2 | TDO 3 | TDO 4 | TDO 5 |
| | | Increased observability of the distribution system for transmission network management and control | The integration of demand side management into TSO operations | Ancillary services provided through DSOs | Improved defence and restoration plans | Methodologies for scaling-up and replicating |
| Network Operation | Adaptation of primary control cycle and automation | | | ■ | | ■ |
| | Network monitoring system and ICT | ■ | | | | |
| | Ancillary services | | | ■ | | ■ |
| | Fault and outage management | | | | ■ | ■ |
| | Distributed Generation (DG) management | | ■ | | | |
| | Load (ED) management | | ■ | | | |
| Energy Management | System simulation and analysis frameworks and data sets | | ■ | | | |
| | System operation | | | ■ | | |
| | Market design and analysis | | ■ | | | |
| | Distribution network planning procedures | | | ■ | | |
| | DER technologies | | | | | |
| ICT for Smart Grid control systems and Interoperability | Communication technologies for smart grids | ■ | ■ | | | |
| | Operation of E-markets | | ■ | | | |
| | DSO/TSO congestion management systems | ■ | | | | |
| | Energy Management systems | ■ | | | | |
| | Home/Industrial integration systems | | ■ | | | |
| | Novel control concepts for smart grids | | ■ | ■ | | |
| | Standardization | | | | | |
| | Security | | | | ■ | |

| | | Joint TSO/DSO R&D Activities | | | | |
|---|---|---|---|---|---|---|
| | | TDO 1 | TDO 2 | TDO 3 | TDO 4 | TDO 5 |
| Electrical Storage integration | Integration of storage resources to smart grids and ancillary services | | | | | |
| | Controllable flexibility achieved by storages in the smart grid applications | | | | | |
| | Economic and technical benefits of incorporating an ESS onto network | | | | | |
| | Integration of EV into grid | | | | | |
| Transmission Networks | Transmission planning model and methods | | | | | |
| | Development of pan-European electricity markets | | | | | |
| | Advanced transmission system control and protection | | | | | |
| | Co-planning and interfaces for full integration of pan-European operation of the power system | | | | | |
| | HVDC systems and components | | | | | |
| | Structures and enabling technologies for a pan-European super-grid | | | | | |

## 6.2 Matching of functional objectives and R&I innovation topics between EERA/ETP Roadmaps

### 6.2.1 TSO

| | | Power technology to increase network flexibility | Monitoring and control technologies to observe and control the 2035 pan-European network | Pan-European market tools for 2035 ancillary services and balancing needs | Market mechanisms for ensuring system adequacy and efficiency in electric systems by 2035 | Long-term assets management |
|---|---|---|---|---|---|---|
| Network Operation | Adaptation of primary control cycle and automation | | ■ | | | |
| | Network monitoring system and ICT | ■ | ■ | | | |
| | Ancillary services | | | ■ | | |
| | Fault and outage management | | | | | |
| | Distributed Generation (DG) management | | | | | |
| | Load (ED) management | | | | | |
| Energy Management | System simulation and analysis frameworks and data sets | | ■ | ■ | | |
| | System operation | ■ | | ■ | | |
| | Market design and analysis | ■ | | ■ | ■ | |
| | Distribution network planning procedures | | | ■ | | |
| | DER technologies | ■ | | | | |
| ICT for Smart Grid control systems and Interoperability | Communication technologies for smart grids | | | | | |
| | Operation of E-markets | ■ | | | ■ | |
| | DSO/TSO congestion management systems | ■ | | | | |
| | Energy Management systems | ■ | | | | |
| | Home/Industrial integration systems | | | | | |
| | Novel control concepts for smart grids | ■ | | | | |
| | Standardization | | | | | |
| | Security | | | | | |

| | | Power technology to increase network flexibility | Monitoring and control technologies to observe and control the 2035 pan-European network | Pan-European market tools for 2035 ancillary services and balancing needs | Market mechanisms for ensuring system adequacy and efficiency in electric systems by 2035 | Long-term assets management |
|---|---|---|---|---|---|---|
| Electrical Storage integration | Integration of storage resources to smart grids and ancillary services | | | | | |
| | Controllable flexibility achieved by storages in the smart grid applications | | | | | |
| | Economic and technical benefits of incorporating an ESS onto network | | | | | |
| | Integration of EV into grid | | | | | |
| Transmission Networks | Transmission planning model and methods | | | | | |
| | Development of pan-European electricity markets | | | | | |
| | Advanced transmission system control and protection | | | | | |
| | Co-planning and interfaces for full integration of pan-European operation of the power system | | | | | |
| | HVDC systems and components | | | | | |
| | Structures and enabling technologies for a pan-European super-grid | | | | | |

### 6.2.2 DSO

| | | Modelling Power Systems and ICT together | Observability at Distribution Level | Power Electronics Technologies | EVI (Electric Vehicle Integration) | Risk based operation | Cyber Security | Microgrids | DC distribution grids & DC distribution integrated into to AC grids |
|---|---|---|---|---|---|---|---|---|---|
| Network Operation | Adaptation of primary control cycle and automation | | ■ | | | | | | |
| | Network monitoring system and ICT | ■ | ■ | | | | | | |
| | Ancillary services | | | | | | | | |
| | Fault and outage management | | | | | | | | |
| | Distributed Generation (DG) management | | | | | | | ■ | |
| | Load (ED) management | | | | | | | ■ | |
| Energy Management | System simulation and analysis frameworks and data sets | ■ | | | | | | | |
| | System operation | ■ | | ■ | | | | | |
| | Market design and analysis | | ■ | | ■ | | | | |
| | Distribution network planning procedures | | ■ | | | | | | |
| | DER technologies | | | ■ | | | | ■ | |
| ICT for Smart Grid control systems and Interoperability | Communication technologies for smart grids | | | | | | | | |
| | Operation of E-markets | | | | | | | | |
| | DSO/TSO congestion management systems | | ■ | ■ | | | | | |
| | Energy Management systems | | ■ | | | | | ■ | |
| | Home/Industrial integration systems | | | | | | | ■ | |
| | Novel control concepts for smart grids | ■ | ■ | | | | | ■ | |
| | Standardization | | | | | ■ | | | |
| | Security | | | | | ■ | ■ | | |

| | | Modelling Power Systems and ICT together | Observability at Distribution Level | Power Electronics Technologies | EVI (Electric Vehicle Integration) | Risk based operation | Cyber Security | Microgrids | DC distribution grids & DC distribution integrated into to AC grids |
|---|---|---|---|---|---|---|---|---|---|
| Electrical Storage integration | Integration of storage resources to smart grids and ancillary services | | | | | | | | |
| | Controllable flexibility achieved by storages in the smart grid applications | | | | | | | | |
| | Economic and technical benefits of incorporating an ESS onto network | | | | | | | | |
| | Integration of EV into grid | | | | | | | | |
| Transmission Networks | Transmission planning model and methods | | | | | | | | |
| | Development of pan-European electricity markets | | | | | | | | |
| | Advanced transmission system control and protection | | | | | | | | |
| | Co-planning and interfaces for full integration of pan-European operation of the power system | | | | | | | | |
| | HVDC systems and components | | | | | | | | |
| | Structures and enabling technologies for a pan-European super-grid | | | | | | | | |

### 6.2.3 JOINT DSO/TSO

| | Network Operation | | | | | | Energy Management | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Adaptation of primary control cycle and automation | Network monitoring system and ICT | Ancillary services | Fault and outage management | Distributed Generation (DG) management | Load (ED) management | System simulation and analysis frameworks and data sets | System operation | Market design and analysis | Distribution network planning procedures | DER technologies |
| The integration of demand side management 2035 at DSO level into TSO operations | | | | | | | | | | | |
| Ancillary services provided through DSOs | | | | | | | | | | | |

| | ICT for Smart Grid control systems and Interoperability | | | | | | | | Electrical Storage integration | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Communication technologies for smart grids | Operation of E-markets | DSO/TSO congestion management systems | Energy Management systems | Home/Industrial integration systems | Novel control concepts for smart grids | Standardization | Security | Integration of storage resources to smart grids and ancillary services | Controllable flexibility achieved by storages in the smart grid applications | Economic and technical benefits of incorporating an ESS onto network | Integration of EV into grid |
| The integration of demand side management 2035 at DSO level into TSO operations | | | | | | | | | | | | |
| Ancillary services provided through DSOs | | | | | | | | | | | | |

| | Transmission Networks | | | | | |
|---|---|---|---|---|---|---|
| | Transmission planning model and methods | Development of pan-European electricity markets | Advanced transmission system control and protection | Co-planning and interfaces for full integration of pan-European operation of the power system | HVDC systems and components | Structures and enabling technologies for a pan-European super-grid |
| The integration of demand side management 2035 at DSO level into TSO operations | | | | | | |
| Ancillary services provided through DSOs | | | | | | |

## 6.3 Matching of functional objectives and R&I innovation topics between EEGI/ETP Roadmaps

| | Grid Architecture | | | Power Technologies | | | Network Operation | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | TSO 1 | TSO 2 | TSO 14 | TSO 3 | TSO 4 | TSO 5 | TSO 6 | TSO 7 | TSO 8 | TSO 9 |
| | Definition of scenarios for pan-European network expansion | Planning methodology for future pan-European transmission system | Towards increasing public acceptance of transmission infrastructure | Demonstration of power technology to increase network flexibility and operation means | Demonstration of novel network architectures | Interfaces for large-scale demonstration of renewable integration | Innovative tools and methods to observe and control the pan-European network | Innovative tools and methods for coordinated operation with stability margin evaluation | Improved training tools and methods to ensure better coordination at the regional and pan-European levels | Innovative tools and approaches for pan-European network reliability assessment |
| Power technology to increase network flexibility | | | | | | | | | | |
| Monitoring and control technologies to observe and control the 2035 pan-European network | | | | | | | | | | |
| Pan-European market tools for 2035 ancillary services and balancing needs | | | | | | | | | | |
| Market mechanisms for ensuring system adequacy and efficiency in electric systems by 2035 | | | | | | | | | | |
| Long-term assets management | | | | | | | | | | |

| | Market Designs | | | Asset Management | | |
|---|---|---|---|---|---|---|
| | TSO 10 | TSO 11 | TSO 12 | TSO 15 | TSO 16 | TSO 17 |
| | Advanced pan-European market tools for ancillary services and balancing, including active demand management | Advanced tools for capacity allocation and congestion management | Tools and market mechanisms for ensuring system adequacy and efficiency in electric systems integrating very large amounts of RES generation | Developing approaches to determine and to maximize the lifetime of critical power components for existing and future networks | Development and validation of tools which optimize asset maintenance at the system level, based on quantitative cost/benefit analysis | Demonstrations of new asset management approaches at EU level |
| Power technology to increase network flexibility | | | | | | |
| Monitoring and control technologies to observe and control the 2035 pan-European network | | | | | | |
| Pan-European market tools for 2035 ancillary services and balancing needs | | | | | | |
| Market mechanisms for ensuring system adequacy and efficiency in electric systems by 2035 | | | | | | |
| Long-term assets management | | | | | | |

| | Integration of smart customers | | Integration of DER and new uses | | | | Network operations | | | | Network Planning and asset management | | Market Design |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | DSO 1 | DSO 2 | DSO 3 | DSO 4 | DSO 5 | DSO 6 | DSO 7 | DSO 8 | DSO 9 | DSO 10 | DSO 11 | DSO 12 | DSO 13 |
| | Active demand for increased flexibility | Energy Efficiency from integration with Smart Homes | integration of small DER | System integration of medium DER | Integration of storage in network management | Infrastructure to host EV/PHEV | Monitoring and control of LV network | Automation and control of MV network | Network management tools | Smart metering data processing | New planning approaches for distribution networks | Asset management | Market Designs |
| Modelling Power Systems and ICT together | ■ | | | | | | | | ■ | ■ | | | ■ |
| Observability at Distribution Level | | | | | | | ■ | | | | | | |
| Power Electronics Technologies | | | | | | | | | ■ | | | ■ | |
| EVI (Electric Vehicle Integration) | ■ | | | | | | | | | | | ■ | ■ |
| Risk based operation | | | | | | | ■ | ■ | | | | | |
| Cyber Security | | | | | | | ■ | | | | | | |
| Microgrids | | | ■ | ■ | | | | | | | | | |
| DC distribution grids & DC distribution integrated into to AC grids | | | | | | | | | | | ■ | | |

| | Joint TSO/DSO R&D Activities | | | | |
|---|---|---|---|---|---|
| | TDO 1 | TDO 2 | TDO 3 | TDO 4 | TDO 5 |
| | Increased observability of the distribution system for transmission network management and control | The integration of demand side management into TSO operations | Ancillary services provided through DSOs | Improved defence and restoration plans | Methodologies for scaling-up and replicating |
| The integration of demand side management 2035 at DSO level into TSO operations | | | | | |
| Ancillary services provided through DSOs | | | | | |