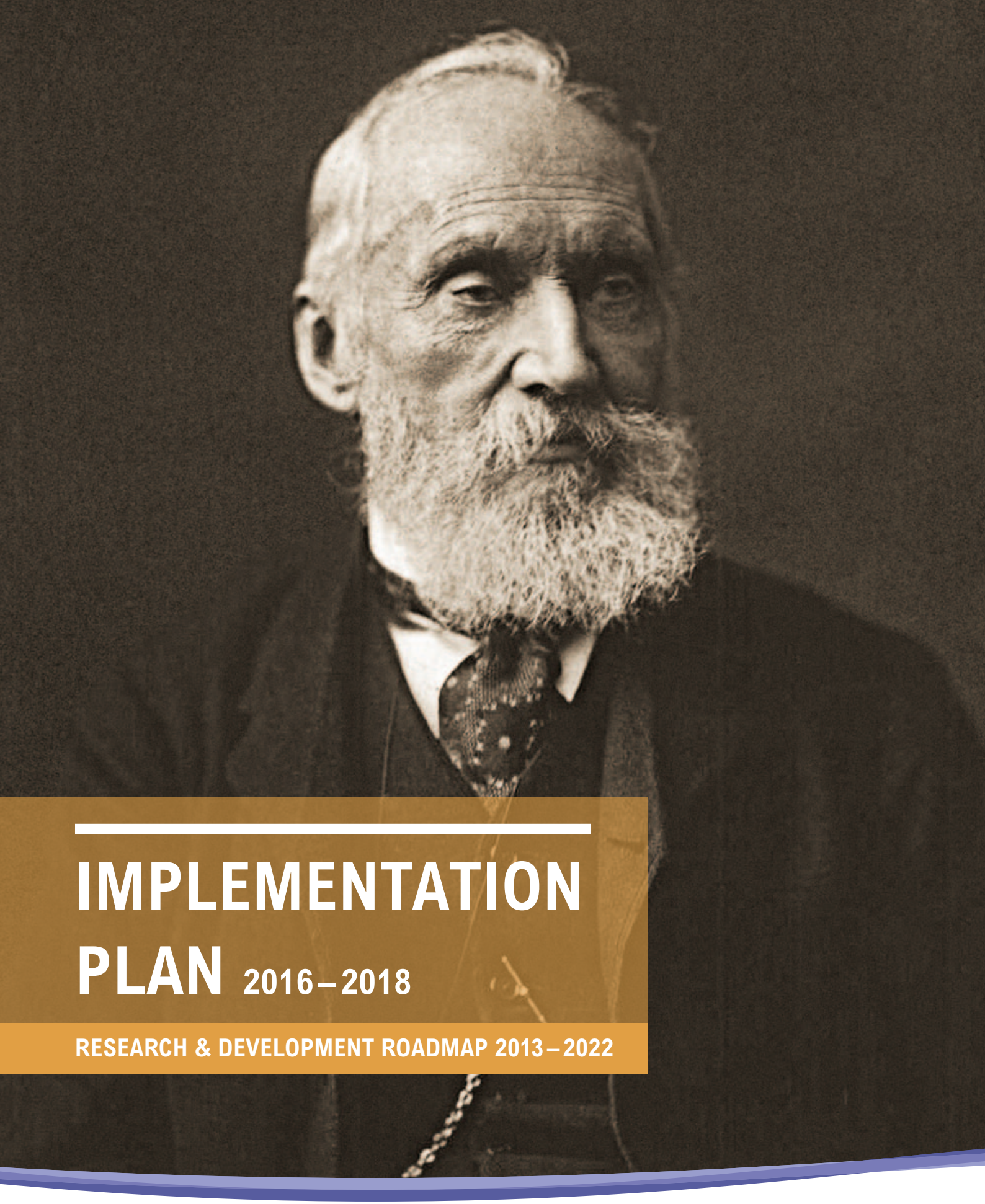


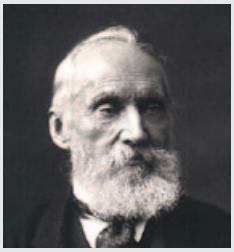
IMPLEMENTATION PLAN 2016–2018

RESEARCH & DEVELOPMENT ROADMAP 2013–2022

European Network of
Transmission System Operators
for Electricity

entsoe

“When you are face to face with a difficulty, you are up against a discovery.“



WILLIAM THOMSON, 1ST BARON KELVIN
(26 June 1824 – 17 December 1907) was an Irish-born British mathematical physicist and engineer. At the University of Glasgow he did important work in the mathematical analysis of electricity and formulation of the first and second laws of thermodynamics, and did much to unify the emerging discipline of physics in its modern form.

CONTENTS

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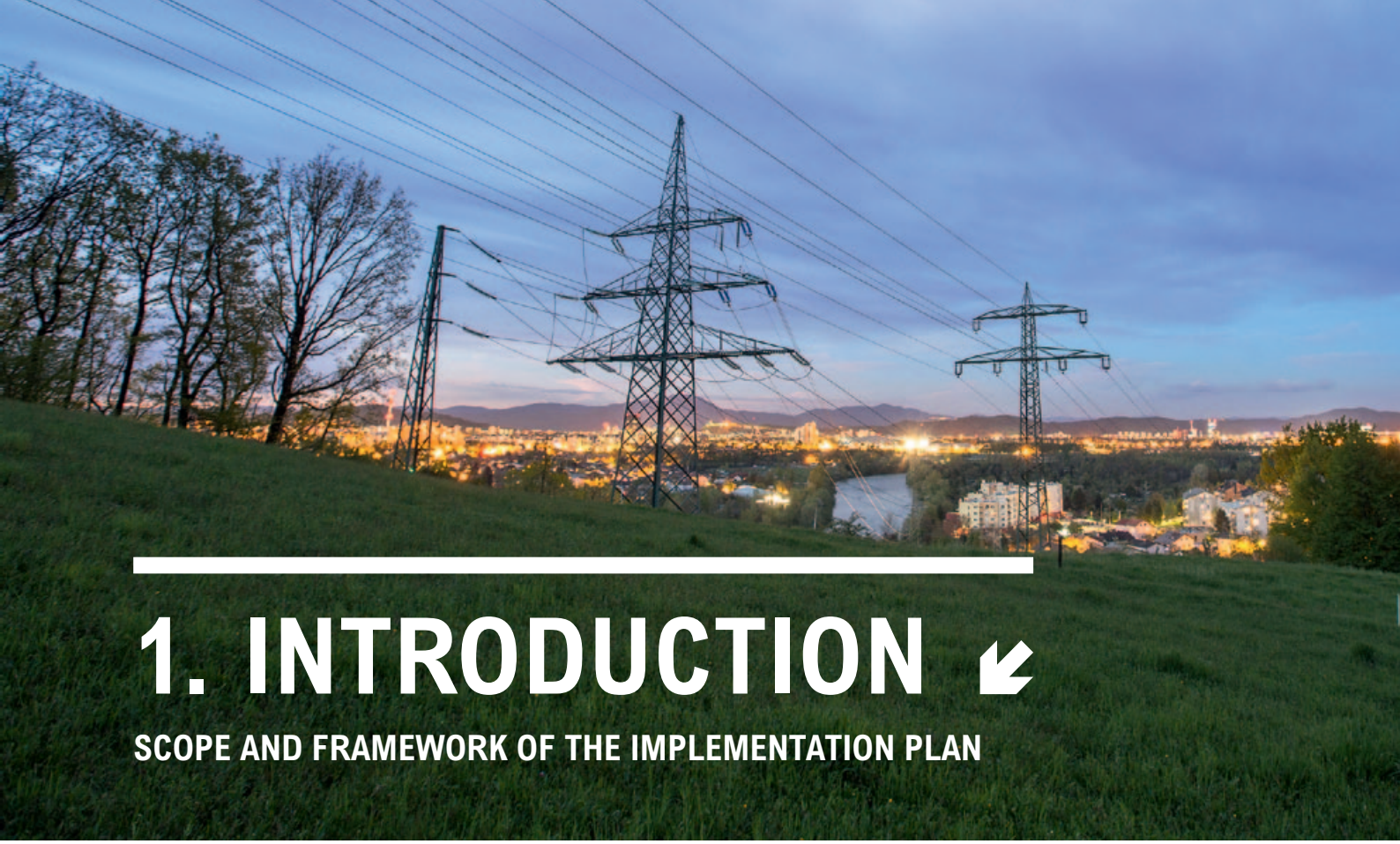


1. INTRODUCTION

SCOPE AND FRAMEWORK OF THE IMPLEMENTATION PLAN

WHAT IS ENTSO-E IMPLEMENTATION PLAN?

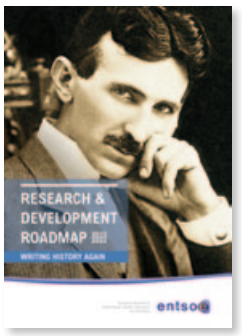
ENTSO-E Implementation Plan details the current implementation of research and development (R&D) activities in the European electricity system. As with each edition, Implementation Plan 2016–2018 identifies and describes all of the R&D concepts, topics and projects (Figure 1) addressed by ENTSO-E over a three-year period. All R&D work is performed with the goal of achieving the targets stipulated by ENTSO-E R&D Roadmap 2013–2022. Using a clear and systematic approach, Implementation Plan provides general discussion and clarification of R&D priorities as they pertain to TSOs, decision-makers, regulators, funding institutions, manufacturers, research institutes and other stakeholders. For a comprehensive discussion of each R&D concept and topic, readers are directed to the Appendix. Wherever appropriate, Implementation Plan makes use of data, tables and figures to accompany the text.

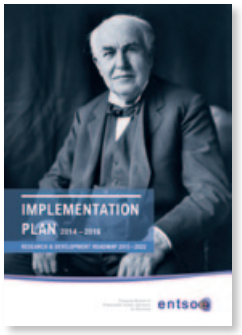
BACKGROUND

In December 2012, ENTSO-E published the first edition of Implementation Plan 2014–2016 along with R&D Roadmap 2013–2022. Since then, Implementation Plan has been published annually and summarises R&D activities over a three-year period as stipulated in ENTSO-E R&D Roadmap 2013–2022 (Figure 2).

Main Levels	Priorities	Time Horizon
PROJECTS	▮▮▮▮	next year
TOPICS	▮▮▮▮▮▮	+ 2 years
CONCEPTS	▮▮▮▮▮▮▮▮▮	+ 4/5 years

Figure 1: Time frame of the R&D Implementation Plan





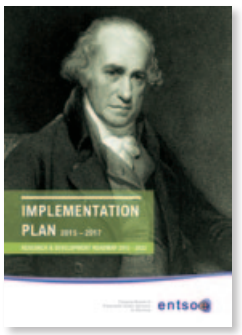


Figure 2: Previous ENTSO-E R&D publications

The Implementation Plan 2016–2018 describes in great detail the R&D projects planned for 2016 whilst outlining suggested R&D topics and concepts for 2017 and 2018. Ever since the first Implementation Plan 2014–2016, priorities for the projects, topics and concepts are continuously and carefully subjected to objective consideration by member TSOs and other stakeholders. This includes public consultation and dissemination of results.

OBJECTIVES & VISION

Each Implementation Plan reviews R&D projects on an annual basis by looking at what has been achieved, how technology and business are evolving and suggesting how priorities should be set going forward. By constantly reassessing R&D priorities and setting clear review points on the ENTSO-E Roadmap, Implementation Plan is an instrument for focussing research, development and demonstration (RD&D) efforts with the overarching goal of establishing and maintaining an interconnected European transmission system that is efficient and reliable.

Implementation Plan 2016–2018 is framed within the challenging environment of:

- Emerging integrated European energy market with rapid paradigm shift towards distributed power generation from renewable energy sources (RES) that are mostly non-dispatchable at the moment
- Increasing role of Demand-Side Response (DSR)

Thus, the Implementation Plan must be accommodated within a broader framework wherein new climate goals and energy policies are being pursued by the EU. As such, R&D efforts must be aligned to strategic EC documents such as SET Plan, Horizon 2020 funding programme, European Electricity Grid Initiative (EEGI), Integrated Roadmap and others, thus mobilizing leading European R&D institutes, universities, manufacturers, DSOs and others. The synergies ensuing from Implementation Plan have led to several successful large-scale European projects such as GRID+, GARPUR and BEST PATHS financed by the European Commission 7th Framework Programme for Research and Development (FP7).

ENTSO-E IMPLEMENTATION PLAN AND THE INTEGRATED IMPLEMENTATION PLAN 2016–2018 OF GRID+STORAGE PROJECT UNDER SERVICE CONTRACT WITH EUROPEAN COMMISSION

ENTSO-E together with Technofi (consulting company) as project coordinator, EDSO-SG, EASE, RSE and Vito is part of the consortium which won the competition for the Horizon 2020 call for tender B2.16 on "Support to R&D strategy in the area of SET plan activities in smart grids and energy storage".

The "Grid+Storage" project started on 19 December 2014 and will last 2 years. The main deliverables of this project are two R&D Implementation Plans and one R&D Roadmap which will identify actions focused on the integration of transmission, distribution and storage capabilities in order to deliver cost effective solutions for a flexible power system. They will also support the implementation of the SET Plan Integrated Roadmap and the development of Horizon 2020 Work Programmes.

The first deliverable is an Implementation Plan 2016–2018 due as draft in March 2015, consulted publically for 3 weeks during April and delivered as final document to EC in May 2015. ENTSO-E Implementation Plan 2016–2018 serves as an input for the development of the "Grid +Storage" project Integrated Implementation Plan 2016–2018.

GRID+ was a Coordination and Support Action for providing operational support for the development of the European Electricity Grids Initiative (EEGI) – see also the footnote on page 9. GARPUR project looks at new reliability criteria to better balance the reliability and costs. BEST PATHS project looks at developing high capacity transmission networks through the repowering of AC corridors and multi terminal HVDC systems.

2. EVOLVING IN A CHANGING CONTEXT

DISCONTINUITIES & EU POLICY

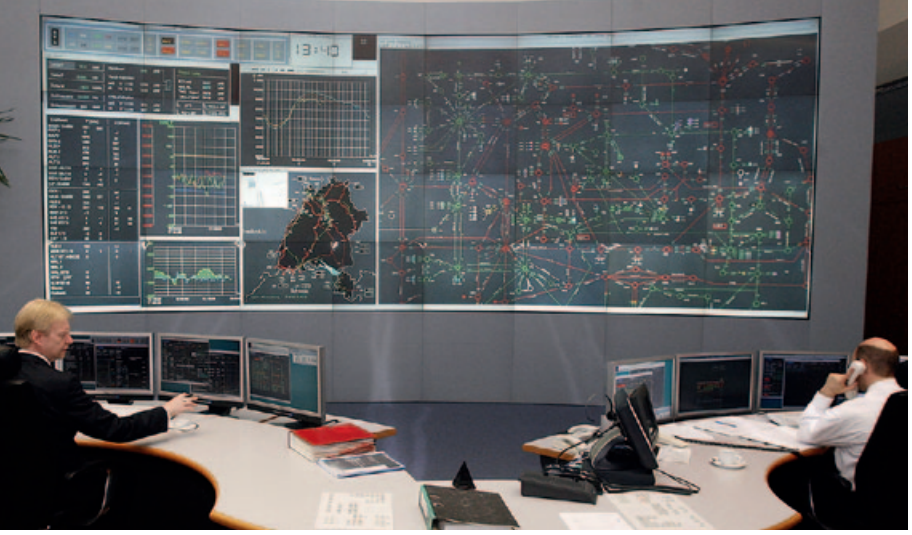
The framework and context of Implementation Plan is constantly evolving. The political environment has changed significantly since the previous Implementation Plan 2015–2017 was launched. At the EU level, new targets were agreed on 14 October 2014 pertaining to renewables, emissions reductions and energy efficiency for 2030. EU Council has stipulated a 40 % domestic reduction of greenhouse gas emissions, a minimum 27 % consumption share of renewable energy and an indicative target of 27 % for improving energy efficiency. Furthermore, the EU Council has agreed that Member States must take urgent measures to achieve a minimum 10 % electricity interconnection target by no later than 2020 with the objective of arriving at a 15 % interconnection target by 2030. Both targets regarding interconnections will be attained by implementing Projects of Common Interest (PCIs) as addressed in the Ten Year Network Development Plan (TYNDP). Implementation Plan also supports this by prioritizing work on HVDC technology, interconnectors and by promoting joint operational activities through increased cross border flows and exchange of grid services.

This year saw a fundamental change in how TSOs R&D is financed in Europe. The previous European Commission (EC) Financing Programme for R&D (FP7) has expired and been replaced by Horizon 2020. With exceptionally fast turnover, the first work program for Horizon 2020 was published and calls have already been issued for the first biennium (2014–2015). Horizon 2020 calls for 2014–2015 are broader in scope and more closely aligned to Integrated Roadmap – a new initiative from the EC. Secondly, EC commenced the development of Integrated Roadmap during the second half of 2013 with stakeholders input. The Integrated Roadmap is intended to be a cross-technological strategy for reaching the SET Plan goals. ENTSO-E welcomes this cross-sectoral approach and sees it as a very important and necessary step to achieve full integration of energy markets and to enable efficient and smooth integration of non-dispatchable generation. To cope with the new European framework, ENTSO-E has put much work during 2014 into the development of the Integrated Roadmap.

These many challenges require ENTSO-E to respond with a vast set of workstreams and to encourage the participation of diverse stakeholders. These workstreams are based on a number of assumptions regarding the power system users with respect to their likely needs, expected changes and potential effects on the development and operation of the power system over a variety of time horizons: short (1–5 years), medium (5–15 years) and long-term (15 years and more).

Since these changes in the political and technical framework have led to significant re-assessments of the overall priorities for R&D Roadmap, it was necessary to make major adjustments to Implementation Plan 2016–2018.

Workstreams: As illustrated by the ENTSO-E Power System Vision and Action Paper which aims firstly to provide stakeholders with a clear vision of the immediate challenges facing the European power system and secondly to demonstrate how ENTSO-E has responded these challenges with various actions and deliverables.



ENTSO-E R&D ROADMAP VERSUS EC INTEGRATED ROADMAP

ENTSO-E R&D Roadmap 2013–2022 is structured around the achievement of the following eleven milestones:

1. **Integration of advanced power technologies**
2. **Optimal asset management**
3. **New market incentives and mechanisms**
4. **Active distribution grid**
5. **New system services and market designs**
6. **New operating practices**
7. **New grid architecture**
8. **New network operation and planning**
9. **Integrated grid expansion and maintenance**
10. **Integrated electricity market**
11. **Coordinated network operation and planning**

Since the above-mentioned milestones are interrelated and mutually coordinated, ENTSO-E R&D Roadmap represents a holistic approach towards achieving progress for Europe's electricity system. Only once sustainable advances and innovations have been made in all of these areas will it be possible to assess their overall efficiency and impact. Thus, even though achieving a single milestone represents an improvement in that particular area, the synergistic benefits of achieving several milestones will have a much larger impact on the system as a whole.

On the other hand, the approach of EC Integrated Roadmap is to place consumers at the centre of energy system. It considers all R&D efforts relevant to the energy system – from clean generation technologies to methods of reducing energy consumption at the consumer level. To differentiate, Europe's TSOs are mainly concerned with providing sufficient network capacity that can reliably host new technologies while continuously serving existing grid users.

As electricity enablers, TSOs are responsible for:

- **Sustainability** through adequate integration of renewable energy sources
- **Flexibility** with respect to system operation and serving customers
- **Market competitiveness** through affordable electricity pricing
- **Security of supply** in compliance with societal needs

Even though both the EC Integrated Roadmap and ENTSO-E R&D Roadmap have practically the same objectives regarding transmission systems, there are still technical differences between the two:

- ENTSO-E considers storage to be the key enabler for achieving a green energy economy in Europe. It has therefore been identified as an essential component of the planning, grid integration and market design stages. For this reason, ENTSO-E has put more stress on the need of having storage for system planning and operation than for developing technology when, in fact, the latter is the first barrier to be solved. Integrated Roadmap addresses this gap and ensures that R&D reflects this.
- Demand-Side Response (DSR) issue is similar to storage, ENTSO-E R&D Roadmap highlights the need of activating demand as a new tool for system operation and integrating it into planning and operating stages as well as market design. However it does not emphasise characterisation and activation of resources, instead leaving this task to DSOs, aggregators or other system players. In any case, DSR has been identified as one of the outstanding issues to be addressed jointly with DSOs.
- Offshore wind generation and marine generation have been identified in Integrated Roadmap as technologies with a key contribution to the general electricity outlook. ENTSO-E R&D Roadmap tackles this issue mainly in terms of technology adequacy in order to enable the integration of these technologies into the transmission grid.

	Integrated Roadmap > Goals for Energy Grids	ENTSO-E Implementation Plan Coverage	Notes
1	Extended asset life time	Topic 2 - 2015, Topic 1 - 2018	
2	Increased RES and DER hosting capacity	Topic 1 - 2015, Topic 2 - 2018	
3	Reduced energy curtailment of RES and DER	Topic 1 - 2016	
4	Increased flexibility from energy players	Topic 3 - 2015, Topic 4 - 2016	
5	Increased quality of service and supply	Topic 1 - 2014, Topic 2 & 3 - 2016, Topic 2 & 3 - 2017	
6	Improved competitiveness of the electricity market	Topic 1 - 2017	Depends more on regulation and market operators than TSOs
7	Decreased network congestions		Rather a Planning and Operational issue: new lines vs load control actions
8	Increased hosting capacity for Electric Vehicles and other new loads		Impacts directly the DSOs

Table 1: Correspondences between Integrated Roadmap and ENTSO-E Implementation Plan

Should EC policy demand that TSOs pave the technology path for off-shore grid development, ENTSO-E must account for this development in its R&D clusters.

- Integrated Roadmap underlines the added value of developing new materials, since they are the key factor in improving efficiency, environmental impact and more. This fact is not adequately covered in ENTSO-E R&D Roadmap.

- In contrast to Integrated Roadmap, cybersecurity and detailed implementation of recent IT trends such as big data or clouds have not been specifically addressed in ENTSO-E R&D Roadmap. This is due to the fact that TSOs are users and not developers of IT technology.

Both ENTSO-E R&D Roadmap and Integrated Roadmap consider the entire innovation chain from research to development and from proof of concept to final demonstration in the grid. Integrated Roadmap adds a section devoted to market uptake. In this regard, ENTSO-E's view is that the best market uptake mechanism is to demonstrate and integrate novel technologies and solutions under real operating conditions. ENTSO-E also suggests pilot runs or tests using representative prototypes that are fully developed.

Table 1 is the synthesis of gap analysis that compares the declared goals of the Energy Grids section in Integrated Roadmap with the topics of this Implementation Plan 2016–2018 (see section 5). Clearly, this Implementation Plan covers many of the goals set forward in the Integrated Roadmap.

ADDED VALUE THROUGH EUROPEAN COOPERATION

One of the main benefits of addressing R&D centrally at the European level is the added value stemming from cooperation between European TSOs. By sharing targets and resources, synergies develop that are beneficial to TSOs and the power system alike, as well as for other stakeholders. By pooling skills, knowledge, experience and R&D personnel, duplication of work is avoided and financial resources can be optimised. Moreover, all cooperating parties operate at the same level and benefit from being aligned with state-of-the-art solutions and technologies. The focus of new projects is on achieving targets beyond the state-of-the-art.

This cooperation is extended to other stakeholders such as universities, research centres and national programmes. Thus collaborations between various countries allow each member to contribute their specific strengths – some countries are strong in knowledge, some offer industrial infrastructure, while other countries may be able to dedicate specific resources.

3. RATIONALE AND PROCESS IN DEFINING PRIORITIES

PROCESS OVERVIEW

The Implementation Plan uses a three-level process starting with concepts that progress to topics and ultimately become projects.

Figure 3 displays the various process levels of Implementation Plan and this is the key link between ENTSO-E R&D Roadmap and specific R&D projects. Thus, theoretical concepts can smoothly evolve into practical applications.

Particular attention has been placed on maintaining consistency with ENTSO-E's general priorities and coordinating efforts with the GRID+ project. External stakeholders have also collaborated and given their feedback to this present edition of Implementation Plan. In particular, these stakeholders include distribution system operators (DSOs), manufacturers (through the Technology Platform Smart Grids, T&D Europe, Europa cable), research community (European Energy Research Alliance), generators (EWEA, Eurelectric) and Agency for the Cooperation of Energy Regulators (ACER) etc.

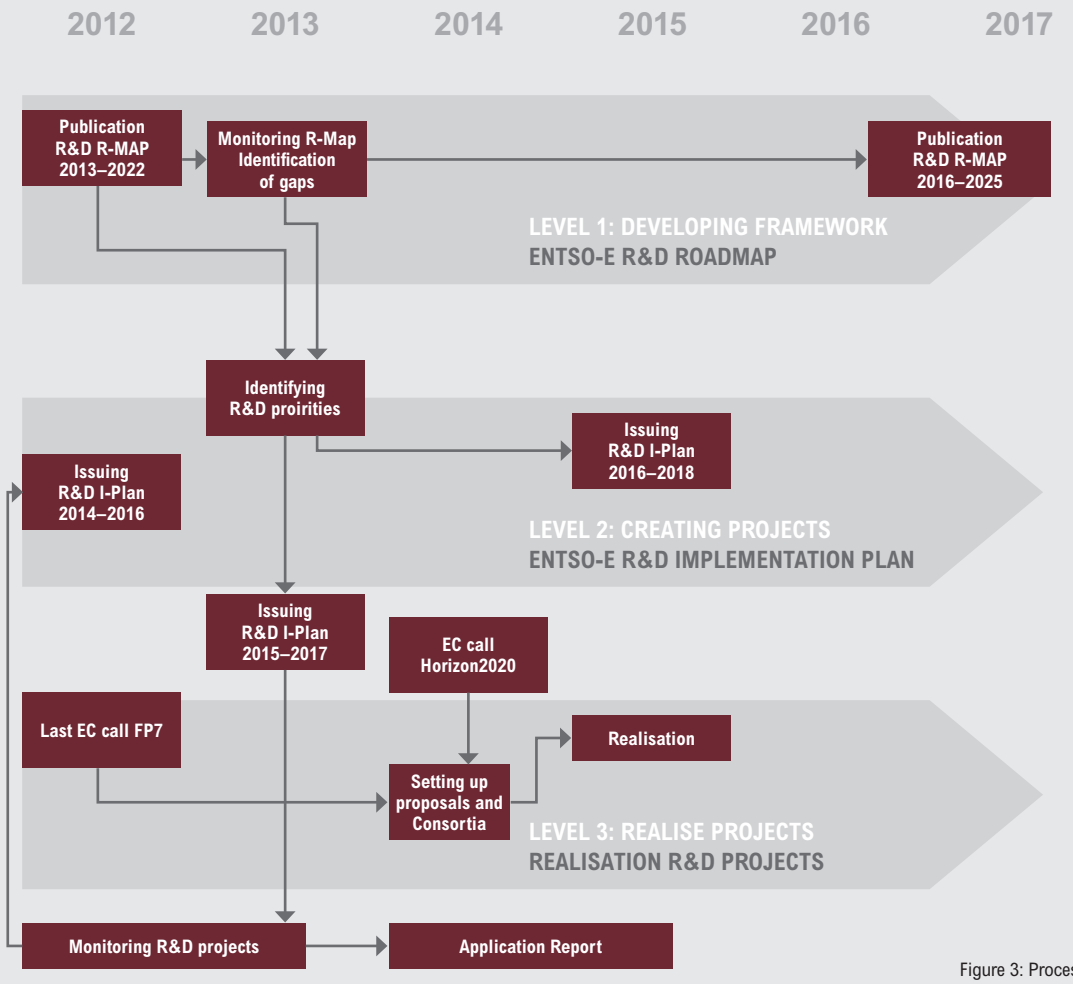


Figure 3: Process of R&D Roadmap and Implementation Plans

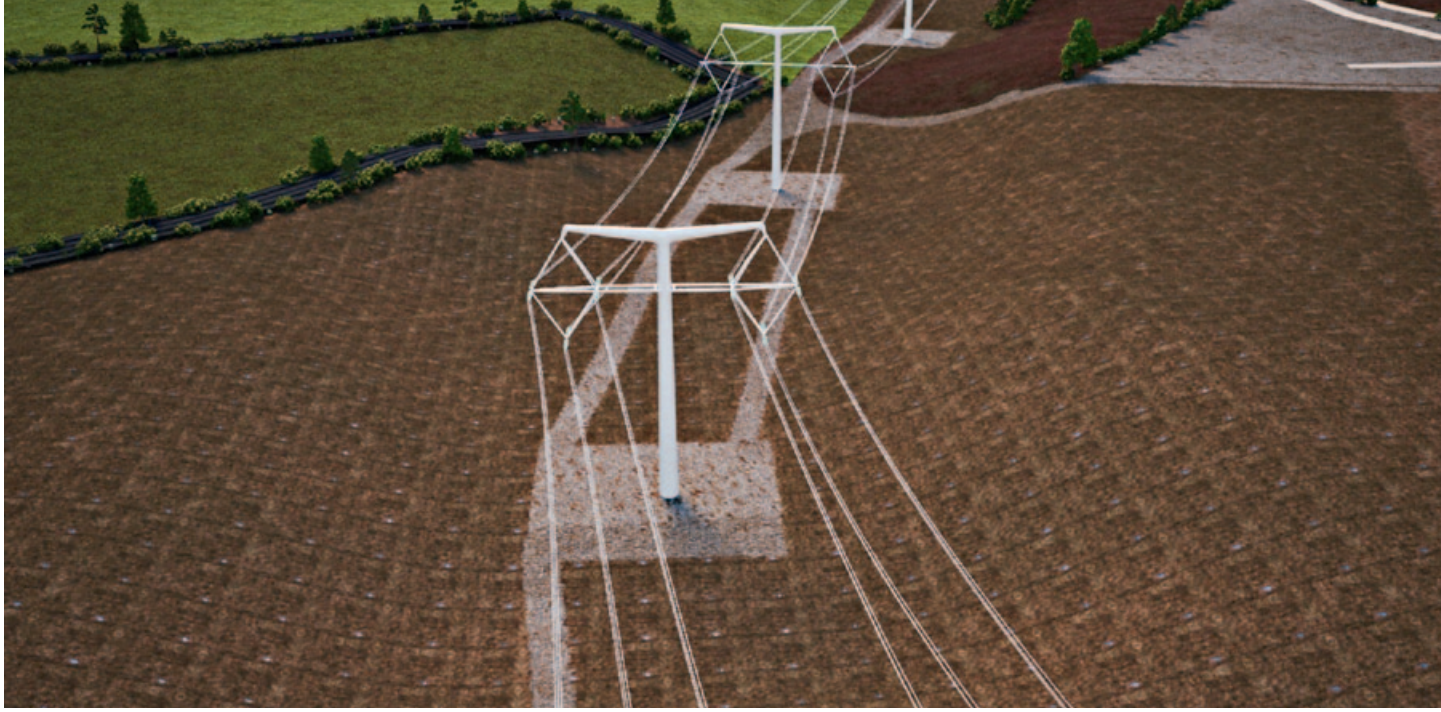


Figure 3 illustrates the iterative R&D process within the ENTSO-E framework. ENTSO-E R&D Roadmap, planned to be released every five years*, defines the overarching research fields for the coming decade. It strives to list all technical, economical and socially acceptable solutions needed to cope with the challenges facing pan-European transmission. Since its long-term focus is on framework development, this high-level Roadmap does not offer a practical implementation strategy for R&D. This is instead covered by ENTSO-E R&D Implementation Plan. Based on the structure of ENTSO-E R&D Roadmap, the Implementation Plan describes concepts and specific R&D topics to be tackled over the short and medium terms. With a clear focus on just a few prioritised topics per year, Implementation Plan represents a crucial step in making innovation happen.

One central feature of the overall process is reviewing, which is handled by dedicated monitoring at all three research levels. Feedback from the review makes it possible to continuously update priorities and improve work. In 2014 ENTSO-E took the initiative to develop an "R&D Application Report" which assess the R&D results of EU funded projects carried out by TSOs in terms of potential applications and their relevance for TSOs daily operation.

The two-level approach of ENTSO-E R&D Roadmap and Implementation Plan ensures that:

- A stable and reliable framework will be established for the next five years
- All R&D needs of the transmission system will be covered
- Implementation options remain flexible through yearly updated realisation plans
- Priorities are correctly identified so that R&D activities are launched at the right time
- Real needs remain the focus and no "nice to have research on" is performed
- R&D solutions will continue to progress through monitoring and knowledge-sharing

GRID+ project which was finalised in October 2014 was an FP7 EU co-funded project created to provide operational assistance for the European Electricity Grid Initiative (EEGI). EEGI is one of the European Industrial Initiatives (EII) in the Strategic Energy Technology Plan (SET Plan). This EII proposes a 9-year European research, development and demonstration (RD&D) programme to accelerate innovation and development in European electricity networks. This project served to coordinate and provide support in resolving the five critical issues facing electricity systems: costs, benefits, KPIs, knowledge sharing and financing involving all stakeholders. The GRID+ project was finalised in October 2014. A follow-up service contract with European Commission under the frame of Grid+Storage project is looking to an integrated approach to the development of R&D activities for the European power system. ENTSO-E together with the Distribution System Operators and storage community are developing two Integrated R&D Implementation Plans for the period 2016–2018 and 2017–2019 and a Roadmap looking to longer term perspective to 2025.

* Taking into account development within the policy framework the 5 years period can be shortened

RATIONALE FOR DEFINING PRIORITIES

The Implementation Plan also builds on input received from TSOs through surveys carried out during 2014, from the R&D Committee, from dedicated workshops and also direct requests submitted to TSOs.

With 41 TSOs within ENTSO-E, it can be a challenge to find consensus on priorities for R&D projects and activities. To ensure an open and fair process, the final priorities must be defined using a balanced combination of top-down and bottom-up approaches that conforms to the Roadmap and reflects TSO interests and urgencies.

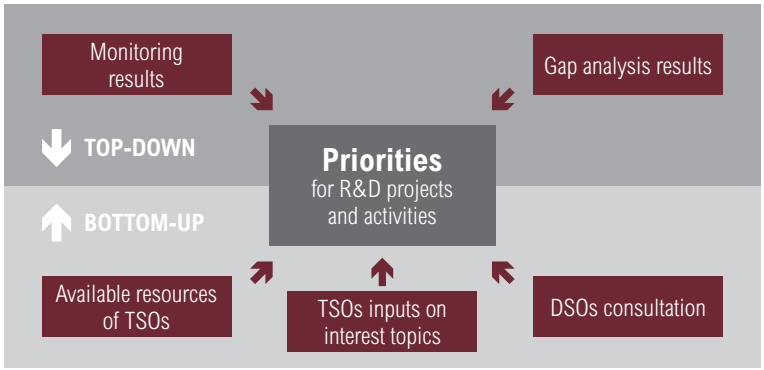


Figure 4: Combining different approaches when defining the Implementation Plan

The top-down approach is a product of the monitoring and gap analysis in R&D Roadmap 2013–2022 carried out by WG Monitoring and Knowledge Sharing. Since the functional objectives are defined to support the European energy and climate goals, the top-down approach is closely linked with EU policy goals of security of supply, 80–95% utilisation of fossil-free energy by 2050, and establishment of an Internal Electricity Market.

On the other hand, the bottom-up approach better reflects the present needs of individual TSOs since R&D priorities differ across Europe. The various member states operate at different technological levels and the topographies of transmission grids and types of electricity production vary substantially from country to country.

If a stringent top-down approach was used, the functional objectives with the largest proportion of 'not started' activities would be prioritised. Monitoring of Roadmap 2013–2022 (see section 4) has indicated that strong efforts are still required to establish projects within clusters 4 and 5.

Individual TSOs or groups thereof, however, may have other more urgent requirements that are not reflected in the monitoring process. Therefore, priorities from the top-down process must be balanced with actual TSO requirements. Moreover, TSO involvement in implementing the ENTSO-E R&D Roadmap is limited by a lack of available resources (financial and manpower). R&D activities are often overwhelmed by operation and planning activities due to their more urgent nature. In order to define the priorities and to find a balance between top-down and bottom-up approaches, monitoring and gap analyses are now expanded with the input and interests of the TSOs (see Figure 4). Within the Research and Development Committee (RDC) of ENTSO-E, there has been a process wherein TSOs suggest project topics of interest and estimate what resources are available.

DSO priorities have also been taken into account and cluster 6 is especially dedicated to this purpose.

The resulting list of prioritised topics given in section 5 is therefore a result of a complex and comprehensive process. Groups of TSOs have committed themselves to working on these topics in collaboration with qualified partners such as universities, manufacturers and DSOs.

4. WHERE WE ARE TODAY

ACHIEVEMENTS AND MONITORING OF THE R&D ROADMAP

The clusters and functional objectives from R&D Roadmap 2013–2022 are presented in Table 2 for reference.

The fulfilment of the R&D achievements as at 2013 is represented in Figure 5. The figure shows the overall fulfilment of each cluster and of R&D Roadmap as a whole. The fulfilment levels are grouped into four categories: 'Completed', 'Ongoing', 'Proposed', and 'Not started'. The results are taken from Monitoring Report 2013, which is assessed from responses from the coordinators of projects related to the R&D Roadmap. There were 38 projects shortlisted for monitoring. The selected projects were EU or nationally funded, relevant to TSOs and focused on ongoing, proposed or recently finished projects (2010 onward)[1].

The degree of completion for each cluster is calculated from how much of the allocated budget has been spent, how many tasks have been performed, what results have been achieved and a comprehensive estimate from the project coordinator. Projects flagged as 'Completed' serve as a good proxy to know which activities have been well covered. The 'Not started' flag suggests potential gaps in upcoming R&D actions.

1) ENTSO-E Monitoring Report (edition 2013)

Cluster		Functional Objectives
C1 Grid Architecture	T1	Definition of scenarios for pan-European network expansion
	T2	Planning methodology for future pan-European system
	T14	Towards increasing public acceptance of transmission infrastructure
C2 Power Technologies	T3	Demonstration of power technology to increase network flexibility and operation means
	T4	Demonstration of novel network architectures
	T5	Interfaces for large-scale demonstration of renewable integration
C3 Network Operation	T6	Innovative tools and methods to observe and control the pan-European network
	T7	Innovative tools and methods for coordinated operation 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
C4 Market Designs	T10	Advanced pan-European market tools for ancillary services and balancing, including active demand management
	T11	Advanced tools for capacity allocation and congestion management
	T12	Tools and market mechanisms for ensuring system adequacy and efficiency in electric systems integrating very large amounts of RES generation
C5 Asset Management	T15	Developing approaches to determine and to maximise the lifetime of critical power components for existing and future networks
	T16	Development and validation of tools which optimise asset maintenance at the system level, based on quantitative cost/benefit analysis
	T17	Demonstrations of new asset management approaches at EU level
C6 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 at DSO level into TSO operations
	TD3	Ancillary services provided through DSOs
	TD4	Improved defence and restoration plan
	TD5	Methodologies for scaling-up and replicating

Table 2: R&D Roadmap 2013–2022

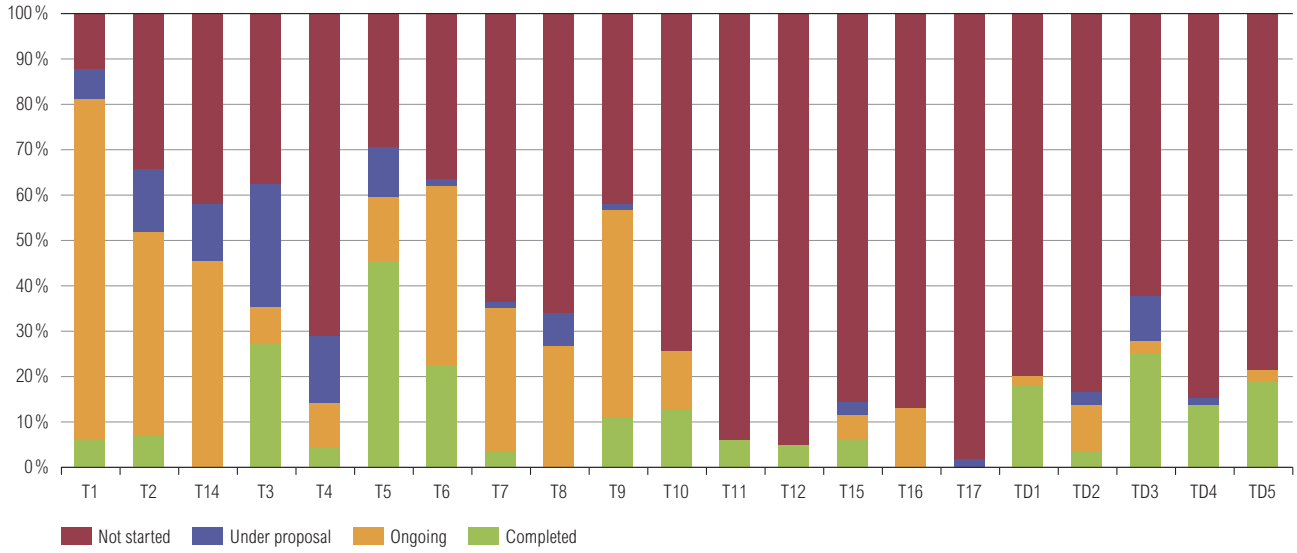


Figure 5: Roadmap progress by cluster

Monitoring Report 2013 shows that a significant share of the R&D Roadmap has been addressed. Approximately, 11 % of R&D Roadmap is completed, 19 % is ongoing and 6 % is under proposal. However, a huge effort is still needed to cover the 64 % which has not yet been started.

The breakdown of results into functional objectives in Figure 4 shows that the majority of work has been allocated to clusters 1 to 3 and the least to cluster 5. The low amount of R&D dedicated to cluster 4 is attributable to the fact that TSOs resources have already been dedicated to short-term development of European target models for electricity to complete the Internal Energy Market (Day Ahead and Balancing markets). Cluster 5 has only been introduced very recently (in terms of R&D).

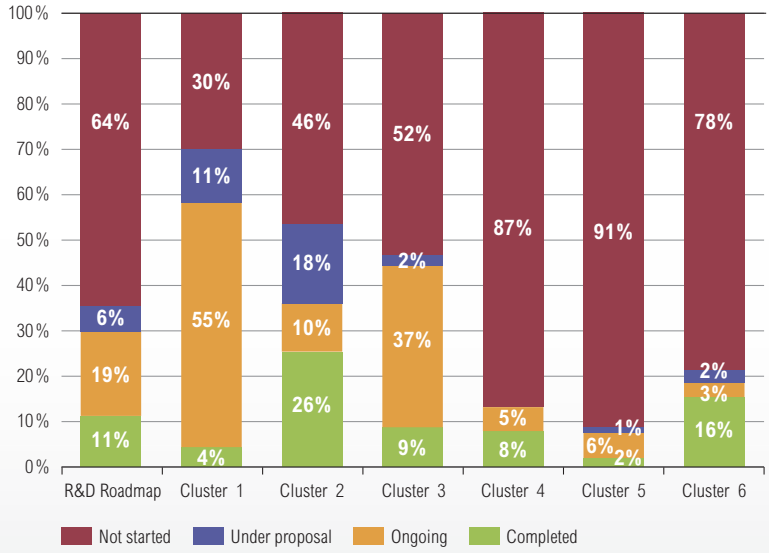


Figure 6: Roadmap progress by functional objective

Cluster 6 is being covered more than clusters 4 and 5 but it requires much more close coordination between TSOs and DSOs. Moreover, since every DSO in Europe is active nationally or in much smaller regions, this often makes the establishment of pan-European projects including DSOs more challenging.

The proportion of the tasks 'Completed', 'Ongoing', 'Proposed' and 'Not started' are shown in Figure 6 for each functional objective.

The progress analysis shows that many tasks in clusters 4 and 5 have yet to be started. This might be attributable to the fact that these clusters are more recent in origin. Also the overall progress in cluster 6 appears to be lower than the average, although the proportion of tasks already completed is considerable.

In addition to Monitoring Report 2013, the Knowledge Sharing Platform (www.gridinnovation-on-line.eu) created as support for the SET Plan European Electricity Grid Industrial under the Grid+ project provides a good database and information for grid (TSOs, DSOs) projects.

KEY PERFORMANCE INDICATORS AND USE OF EC FUNDS BY TSOS

The Key Performance Indicators (KPIs) for electricity networks (including transmission networks) were created within the framework of the European Electricity Grid Initiative (EEGI). They were developed together with the GRID+ project and in collaboration with WG Monitoring and Knowledge Sharing at ENTSO-E.

EEGI R&I Roadmap covers transmission and distribution networks as well as the intersection between the two. It was written with the goal of allowing European electricity networks to affordably and flexibly integrate the actions of grid users. The set of KPIs developed here look at two aspects:

- Implementation Effectiveness KPI
- Expected Impact KPIs

The Implementation Effectiveness KPI measures the completion percentage of Research and Innovation (R&I) objectives as defined in EEGI R&I Roadmap. The methodology behind this KPI involves evaluating activities that are 'Completed', 'Ongoing', 'Proposed' or 'Not started'.

The Expected Impact KPIs consist of:

- **Overarching KPIs:** limited set of network and system performance indicators
- **Specific KPIs:** providing an overview of other specific technical parameters relevant for network operators and related to the different innovation Clusters and Functional Objectives of the EEGI Roadmap
- **Project KPIs:** proposed by each R&I project of the EEGI Roadmap

The Expected Impact KPIs have not yet been reported by the projects and activities carried out under the Implementation Plan 2015–2017. However, they are expected to be available starting from the year 2015.

ENTSO-E investigated the already completed R&D projects and looked on how the applications which have been demonstrated were deployed by TSOs involved in the projects during the last few years[1]. To keep the accuracy of the assessment, only nine relevant EU-funded[2] projects that were finalised between 2009 and 2013 and involved one or more TSO members of ENTSO-E were investigated.

A certain time lag is needed to allow TSOs to demonstrate and deploy the results in daily operations. The elements considered in the assessment regarding the applications of R&D projects were: improvements in technical, operational, regulatory, social, environmental and economic framework, demonstration and/or deployment of the results of the project, wide-scale results towards the outside community and lessons learnt. The monetisation regarding the return on the R&D spending was not in the scope of this assessment.

PROJECTS UNDER DEVELOPMENT IN HORIZON 2020

The projects under development in the framework of the first call of Horizon 2020, issued at the end of year 2013, are listed in Table 3. This table also displays how the calls correspond to the previous Implementation Plan 2015–2017. In fact, some work was required to adapt the traditional alignment between the priorities expressed by TSO and the targets from EC funding policies.

As it can be seen, several previous topics have been combined and presented under the new Horizon 2020 perspective such as with call LCE6. Some other calls have been postponed due to emergence of new topics stemming from the rapidly changing business environment. However, no previous topics were cancelled nor were any pushed out of EC funding schemes, which would have led to major financing problems.

As Horizon 2020 opened a new approach regarding the development of the calls, by trying to provide solutions to challenges in the energy systems, new topics, other than in the Implementation Plan of ENTSO-E appeared. Nonetheless, in some of them the participation of ENTSO-E/TSOs is a must.

Table 4 (next page) depicts the requirements which were not foreseen by ENTSO-E/TSOs in the previous Implementation Plan.

1) ENTSO-E R&D Application Report 2014

2) The EU funded projects investigated: ANEMOS Plus, EWIS, ICOEUR, MERGE, OPTIMATE, PEGASE, REALISEGRID, TWENTIES and WINDGRID

List of topics and concepts from previous Implementation Plan 2015–2017	Status under Horizon 2020 or Implementation Plan 2016–2018
Smart stations	Under development for Horizon 2020 LCE6-2015
Cross border balancing	Under development for Horizon 2015 LCE6-2015
Inertia in large inverter-based systems	Under development for Horizon 2015 LCE6-2015
Methods & tools for asset management	Under development for Horizon 2015 LCE6-2015
Power load control at TSO and DSO level	Postponed to 2016 (from 2015)
UHV lines	Postponed to 2018 (from 2016)
Ancillary services through DSOs and agrgregators	Maintained for 2016
Data &Information for system operation and asset management	Postponed to 2018 (from 2017)
Advanced tools for new market models	Maintained for 2017
Improved defence and restoration plan	Maintained for 2017
Market modelling and system adequacy	Maintained for 2017

Table 3: Transition from Implementation Plan 2015–2017 to Horizon 2020 calls (2014–2015)

Adjusted match under EC funding, proposal under development
Maintaining the actions as planned and no EC funding yet
Postponements due to lack of EC funding or reprioritisation by TSOs

List of new topics by Horizon 2020 (2014–2015) different from ENTSO-E Implementation Plan	ENTSO-E/TSOs involvement and relevance
LCE5 – HVDC meshed offshore grid	ENTSO-E/TSOs involvement required by the call Individual TSO could participate. At the moment of publication, ongoing discussion within ENTSO-E.
Call for tenders to support the development Road-maps, models, etc.	
B.2.16 Support R&D in smart grids and energy storage	ENTSO-E involvement and relevance for R&D activities, contract awarded
B.2.6 Reliable and stable energy supply sys-tems: Energy and market modelling for climate and energy policy	Appropriate for modelling/scenario analysis ENTSO-E requested to contribute to the project of the winning consortium
B.2.7 Energy storage Mapping and Planning	ENTSO-E involvement limited

Table 4: Horizon 2020 additional topics (2014–2015) and requirements for ENTSO-E/TSOs

High match Horizon 2020 and ENTSO-E
New topics Horizon 2020 different from ENTSO-E Implementation Plan – involvement required
New topics Horizon 2020 different from ENTSO-E Implementation Plan – involvement limited

5. R&D PRIORITIES AND TOPICS FOR 2016–2018

The suggested topics are shown in Table 5 and have been determined using a mixture of top-down and bottom-up approaches as described previously. The R&D priorities and topics for 2016–2018 are based on the following:

- Roadmap framework, which serves as a reference
- Monitoring past and ongoing projects, consequent gap analysis vs. roadmap targets
- EU Integrated Roadmap and SET Plan as an overarching framework
- TSO expectations, individual and national R&D programs and limitations to resources

Table 5 displays the proposed topics, their timing and relevant functional objectives as defined in ENTSO-E R&D Roadmap 2013–2022. For the sake of continuity and comprehensiveness, topics from 2014 and 2015 are also taken from the previous Implementation Plan.

The following focuses on year 2016 where the proposals are most concrete. The R&D topics for 2016 concentrate on increased integration of energy storage, demand-side management and on balancing and ancillary services. Here is a review of the four R&D topics for 2016:

- **Topic 1 – 2016:** Fast storage technologies are to be developed from rapid technological advancements being made in the power sector. It is crucial that TSOs strictly follow upcoming technology upgrades and remain in close contact with relevant manufacturers so that the impact of this technology is maximised in terms of time-to-market development and ultimately, performance in real applications.

- **Topic 2 – 2016:** Real-time tools are to be developed that provide European control centres with advanced methods of improving power system security so that systems to be operated closer to their limits without increasing risk levels.

- **Topic 3 – 2016:** Monitoring tools are to be developed that provide better information on the life status of individual components. This will lead to significant improvements in network performance in terms of power quality and security of supply, consequently benefiting the electricity market.

Topic	Titles	Functional Objectives
	TOPICS 2014	
Topic 1 – 2014	Demonstration of future smart HV substations	**T17,** T4
	TOPICS 2015	
Topic 1 – 2015	Inertia, control and protection of large power systems with a large amount of inverter-based components	**T6,** T9, T4, T5
Topic 2 – 2015	Methods and tools to optimise asset management	**T16,** T15, T17
Topic 3 – 2015	Novel cross border balancing market mechanisms and tools for ensuring system reliability	**T10,** T11, T9
	TOPICS 2016 & 2017	
Topic 1 – 2016	Fast storage technologies needed by TSOs	**T3,** T7
Topic 2 – 2016	Control System of the future: real time tools for control centres	**T6,** T8
Topic 3 – 2016	Monitoring & observation tools for power network infrastructures	**T6,** T16
Topic 4 – 2016	Demand Side Response: load control mechanisms and ancillary services at TSO and DSO levels	**TD2,** TD3, T10
Topic 1 – 2017	Advanced tools for new market models	**T12**
Topic 2 – 2017	Improved defence and restoration plan	**TD4,** TD5, T9, T7, T6
Topic 3 – 2017	Market modelling and system adequacy assessment for long-term planning	**T2,** T1, T12
	CONCEPTS 2018	
Concept 1 – 2018	Data & information management for system operation and asset management	**T15,** T6, T16, T7, T9
Concept 2 – 2018	Realisation of ultra-high-voltage lines with partial underground cabling	**T14,** T2, T3

Table 5: List of topics and concepts

- **Topic 4 – 2016:** Load control mechanisms and ancillary services are to be developed at TSO and DSO levels to allow Demand-Side Response (DSR). This topic continues work begun in Topic 3 – 2015 and Concept 2 – 2016 of the previous edition of Implementation Plan and takes advantage of market inputs and increased collaboration between TSOs and DSOs.

Since each Implementation Plan deals with a rolling 3-year period, the topics and concepts of years 2017 and 2018 serve here as preliminary indicators and are to be confirmed and/or updated in upcoming versions of Implementation Plan. Recent changes – some of which are still underway – to the framework and mechanisms of EU financing schemes (FP7 replaced by Horizon 2020) and guidelines (introduction of Integrated Roadmap) require a re-alignment with respect to timing and process. Therefore, the content and sequence of topics for 2017 and 2018 in this edition of Implementation Plan are similar to the previous ones but have been modified to reflect the current priorities of the participating TSOs.

This is also consistent with the next edition of ENTSO-E Roadmap to be issued in 2016.

6. FROM PLANNING TO IMPLEMENTATION

RESOURCES AND FINANCING SCHEMES

ENTSO-E R&D Roadmap 2013–2022 estimates the costs of implementation to be approximately € 1 billion including the joint activities performed by TSOs and DSOs. This budget has been estimated by assigning an average volume of resources to each project based on R&D that has already been performed on EC-funded projects. Furthermore, the type of project also plays a role in determining the required finances and resources, that is, whether the project involves research, innovation and/or demonstration under real operating conditions.

Integrated Roadmap contains no direct specifications pertaining to finances and resources. For instance, heading 2 /challenge 1 – dedicated to energy grids – does not disclose any budgeting details. However, there are some challenges contained in Integrated Roadmap from which information can be gleaned that at least allows the orders of magnitude of financial and resource requirements to be estimated. With the first calls and tenders of Horizon 2020 work program, the EU has already established a reference for the funding and development of certain areas. Based on the first calls EC contributions through Horizon 2020 to R&D on electricity networks and storage could be estimated reaching approximately € 100 million/year.

However, contrary to previous research framework programmes, Horizon 2020 uses a challenge-response methodology. This allows topics to be defined more openly and to establish a competitive culture with respect to financial resources.

Taking all this into consideration, it is now clear that it will be challenging to achieve all of the ENTSO-E Roadmap objectives solely through EC-funded projects. In any case, since EC-funding only covers a portion of the costs – typically up to 70 % – strong support will be required from self-financing instruments in order to achieve the targets.

Another source of financing could be found through the Connecting Europe Facility (CEF Energy), a European Programme with a budget of € 5.85 billion dedicated to improving the trans-European energy infrastructure from 2014–2020. ENTSO-E's Ten Year Network Development Plan (TYNDP) is mandated as the sole instrument for the Projects of Common Interest (PCIs). Based on previous criteria assessments, some of these projects could become candidates for CEF Energy. Some of the PCIs financed through CEF Energy are in an early stage of development. For demonstration and close-to-market projects, CEF Energy could be an option, such as the call for proposal made by Horizon 2020 Work Programme 2015.

REGULATORY APPROACH TOWARDS R&D

Any gap between the ultimate cost of a project and its European funding must be covered by TSOs and other stakeholders participating in the project. At the same time, directive 2009/72/EC, art 37.8 stipulates that National Regulatory Authorities (NRAs) are responsible for ensuring that TSOs and DSOs are incentivised to support R&D expenditures.

In spite of this provision – and five years after adopting Third Internal Energy Market Package – only a few EU countries[1)] currently account for R&D expenses explicitly through tariff structures. When there is no explicit national regulation for R&D expenses, these financial efforts are mostly considered as operational expenses. These costs are, therefore, recovered through normal tariff mechanisms updated accordingly and in many cases subject to efficiency mechanisms, hence with the incentive to reduce them.

This is the main reason why the Transmission System Operators have no means to getting new R&D expenses included in their allowed costs -thus making it extremely difficult to step-up to the R&D challenges as laid out in the R&D roadmap and resulting implementation plans.

Some countries are of the opinion that research institutes and universities are better equipped to perform R&D in all fields including power systems, while also claiming that TSOs should instead develop expertise in integrating third-party solutions into the grid. Other countries have opted to finance energy-related R&D through national research programmes and to delegate the responsibility of implementing solutions to national energy agencies or similar organisations. In contrast, some other countries wish to retain accountability through a regulatory framework and are pushing towards utilising European funds, which they perceive as a transparent financing mechanism.

1) Denmark, Belgium, Germany, UK and France

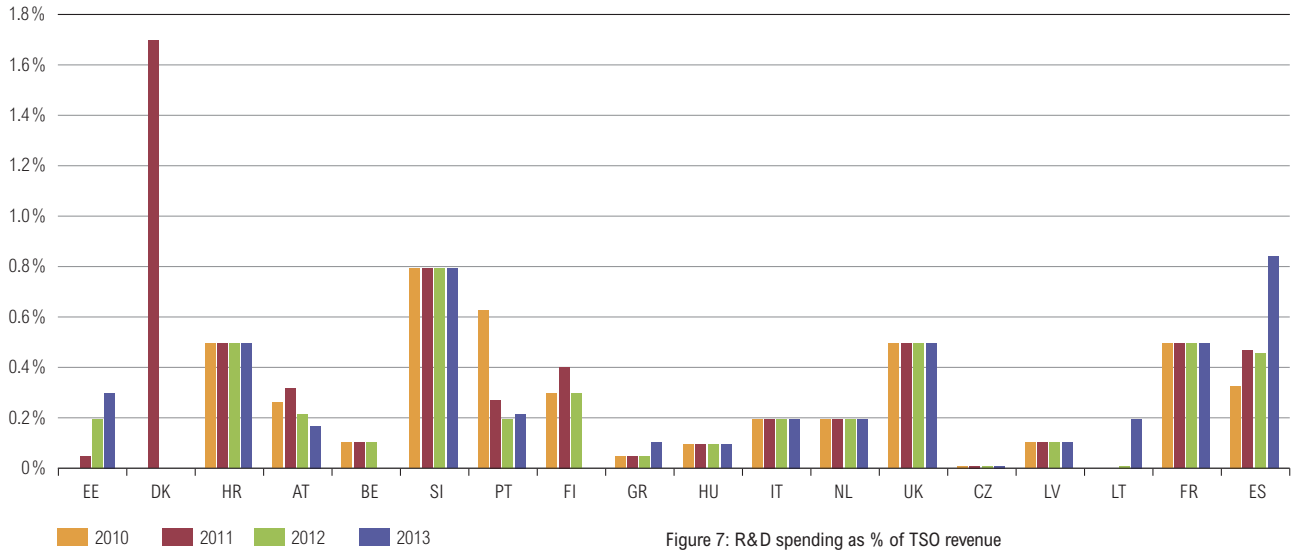


Figure 7: R&D spending as % of TSO revenue

In the future, official recognition from NRAs and ACER/CEER of the need for covering R&D expenses would bring benefits. It would encourage TSOs to make long-term investments such as hiring and developing qualified R&D personnel responsible for identifying promising topics, developing strong relationships with other stakeholders, operating and managing research programmes, and disseminating results.

An expanded R&D budget would allow TSOs to launch more projects to fill knowledge and research gaps identified in ENTSO-E R&D Roadmap or to match the EC Horizon 2020" innovation actions" type of calls requiring TSOs involvement.

There are also other potential benefits such as:

- Establishing long-term strategy for TSO R&D activities at both national and European levels
- Ensuring consistent collaboration between TSOs and other stakeholders in pursuit of a fully integrated energy system
- Better uptake of projects into the market applications

The following aspects should be addressed:

- Cost-effective use and access to various financial instruments at national and European levels for R&D activities on transmission systems
- Recognition of leading role TSOs and ENTSO-E have in determining the actions required to integrate various energy/ICT technologies into European energy system
- Market uptake of grid technologies must be fostered by supporting the development of a regulatory framework in line with European/regional developments of the power system

Horizon 2020 Innovation Actions (up to 70% of the eligible costs of the projects are covered by EC funding, the rest of the costs should be covered by the consortium partners)

For Denmark, Energinet.dk is responsible for managing a yearly budget of € 17.5 million for RD&D activities in the area of environmentally friendly electricity production. The estimations for investments related only to transmission networks were done for the year 2011 (representing € 10.5 million). It can be assumed that in the other years the R&D investments in transmission networks are in the same range.

NATIONAL/TSOs PROGRAMMES

National R&D and innovation programmes and other financing schemes are in place to augment EC-funding. To maximise synergies and avoid redundancies, national and international programmes must be coordinated though for instance avoiding the duplication of projects funding.

The present Implementation Plan 2016–2018 identifies a need for approximately €100 million for the year 2016 mainly in demonstration projects for the TSO R&D activities. The EC Horizon 2020 has made available funds in 2014 and 2015 for R&D projects requiring the involvement of TSOs. Most of this projects are labelled as innovation actions as noted previously and therefore need to be match by TSOs own funding. The EC funding for R&D transmission related projects raised in the period 2014 – 2015 to € 80 million.

TSOs are currently spending less than 0.5% of their annual turnover on R&D, which is far below Europe's 2020 objective of 3% (R&D expenditure as a percentage of the GDP).

European TSOs have invested an estimated € 60 million/year (reference year 2010) on R&D. These investments (see Figure 7) are restricted to just a few countries:

- RTE (France): approx. € 20 million/year
- Energienet (Denmark): € 10.5 million in 2011
- National Grid (UK): approx. € 7 million/year
- REE (Spain): approx. € 5 million/year
- Terna (Italy): approx. € 4 million/year

7. SUMMARY

This is the third edition of the ENTSO-E R&D Implementation Plan within the framework of ENTSO-E R&D Roadmap 2013–2022. As with each edition, Implementation Plan 2016–2018 reflects on what progress has been achieved, discusses how the European power system is currently evolving, and considers the challenges facing TSOs and stakeholders with respect to R&D in the energy sector.

It also describes the appropriate research and development topics and actions needed to be carried out in the period 2016–2018. The list of topic and chronologic priorities is given in section 5, while their detailed description is given in Appendix.

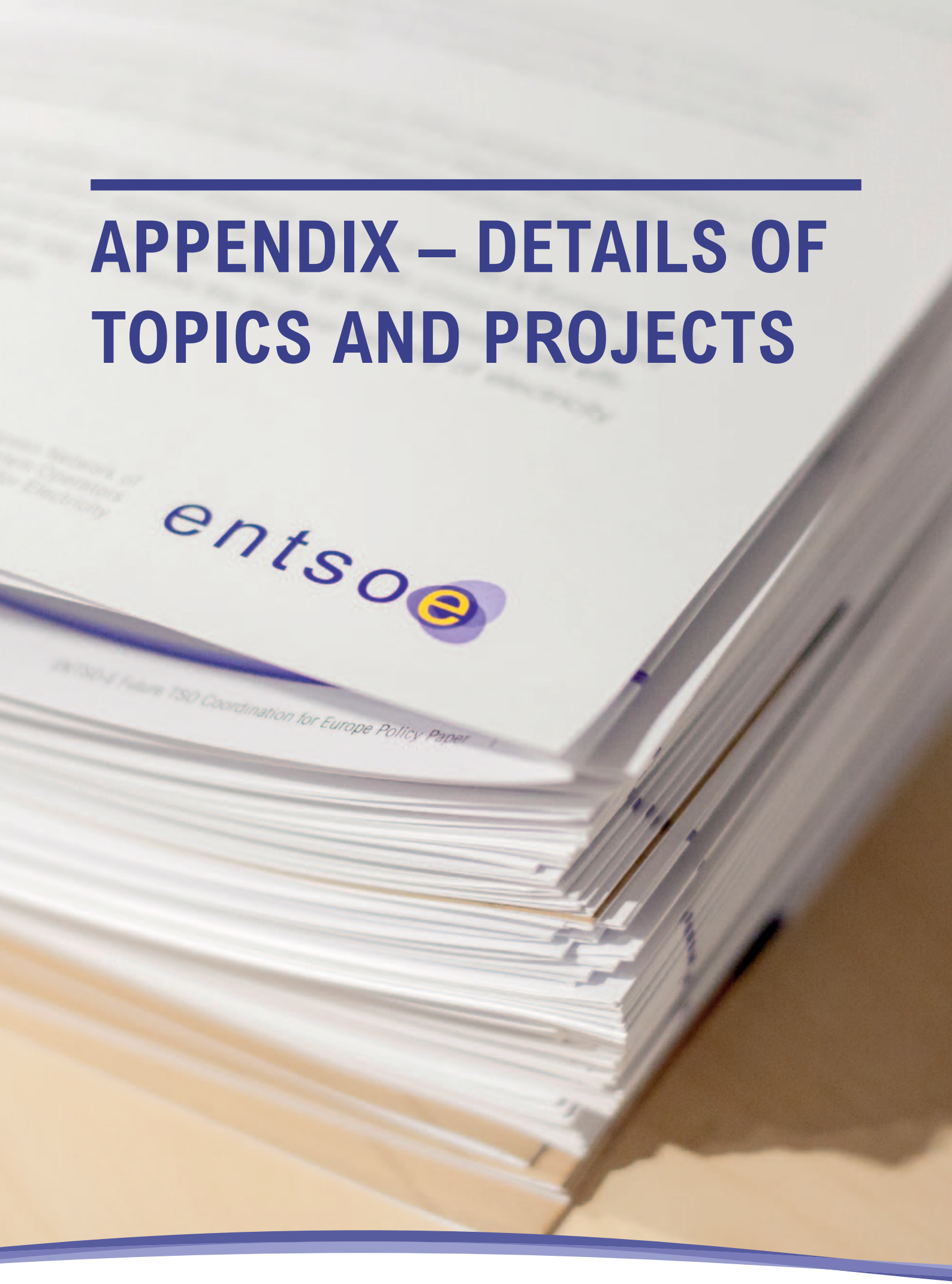
To ensure an open and fair process, Implementation Plan attempts to establish final R&D priorities through a balanced combination of top-down and bottom-up approaches. In the top-down approach, R&D is prescribed by Integrated Roadmap of SET Plan and Horizon 2020. The bottom-up methodology allows TSOs to present their needs through ENTSO-E. With these two approaches, ENTSO-E strives to set priorities and define actions for achieving European energy targets to the benefit of TSOs and consumers alike.

Through a monitoring and knowledge-sharing process making use of dedicated KPIs, ENTSO-E is able to ensure that R&D progresses steadily and to disseminate findings amongst European stakeholders for their mutual benefit. Now that many projects have been completed and/or are ongoing, a stable base has been established for upcoming concepts, topics and projects.

Much R&D is still required in Europe to integrate growing shares of RES, to increase efficiency while generating less CO_2, improve flexibility and security of supply, and to fully integrate the entire energy market. All of Europe stands to benefit from a flexible, competitive, effective, carbon-free and reliable pan-European electricity grid.

The lack of harmonised regulatory frameworks in Europe remains a significant obstacle to allocating financial aid and other resources to the research, development, demonstration and implementation of innovative concepts for the European transmission grid. Since TSOs are not currently able to self-finance R&D in a reasonable amount of time, external financing is necessary if Europe is to achieve the targets set out in ENTSO-E R&D Roadmap 2013–2022. By promoting and supporting suitable energy policies, European Member States and institutions can accelerate the search for solutions to the current challenges. Although some projects are currently receiving financial support from Europe, there is still a need for more resources for continuing R&D efforts.

APPENDIX – DETAILS OF TOPICS AND PROJECTS



Topic 1 – 2015	Inertia, control and protection and inertia of large power systems with large share of inverter-based components
Main Functional Objective	**T6**
Supported Functional Objectives	T9, T4, T5
Motivation	The integration of large amounts of renewable generation with power electronic interfaces and introduction of HVDC links into the power system will necessitate a review of how to operate and control transmission networks.
Specific challenge	The goal of this topic is to investigate how power systems will behave when the transmission network is fed by large amounts of inverter-based generation, and identify what must be done to allow this equipment to be integrated into the system safely. More and more components in the European power system are based on power electronics. This equipment feeds harmonic current into the system that, in some cases, can lead to unstable behaviour and impair the reliability of the power system. Entire areas might potentially be fed only by inverter-based generation, such as from HVDC offshore energy. Therefore, fault detection, power system stability and control, de-rating of transformers due to higher harmonics and harmonic distortion must all be studied. Appropriate tools and methods for building models must be identified for this purpose. Current control and protection schemes must be reviewed and may need to be redefined to allow stable, reliable and economic operation of the network.
Funding Scheme	Collaborative project, research and technological development
Expected Impact	• Maximising the volume of renewable generation input while keeping the system stable. • Anticipation of future potential problems. • Clarification of how this may lead to new control/projection schemes and definition of grid connection rules.
Additional Information	The consortium should be led by European TSOs with strong involvement of university and research centres
Proposal Duration	3 years
Total Budget	€ 9 million

Topic 2 – 2015	Methods and tools for optimizing asset management
Main Functional Objective	**T6**
Supported Functional Objectives	T9, T4, T5
Motivation	The integration of large amounts of renewable generation with power electronic interfaces and introduction of HVDC links into the power system will necessitate a review of how to operate and control transmission networks.
Specific challenge	Asset management has a decisive impact on network performance in terms of quality and security of supply and consequently on the electricity market. Innovative methodologies developed in this project will allow costs and benefits to be assessed accordingly to different management strategies and propose a risk-based approach for estimations at the system level. By implementing smart maintenance, higher levels of flexibility will be possible. One challenge is to develop a standardised approach for life duration modelling so that the behavioural database can be expanded. One of the main goals will be to discover the most beneficial asset management strategy per euro paid out.
Funding Scheme	Collaborative project, research and technological development
Expected Impact	• Efficient solution for optimising asset maintenance costs during operation, while increasing the performance of existing assets • Easier integration of renewable generation due to the greater flexibility of grid provided by the optimal asset management • Greater grid capacity for the electricity market leading to a more efficient market • Data requirements and software architectures needed for new asset management tools.
Additional Information	The consortium should be led by European TSOs with a strong involvement of universities and research centres
Proposal Duration	3 years
Total Budget	€ 2 million

Topic 3 – 2015	Novel Cross Border Balancing Market Mechanisms and Tools for Ensuring System Reliability
Main Functional Objective	**T10**
Supported Functional Objectives	T11, T9
Motivation	In order to realise an integrated European energy market it is important to facilitate cross-border trading. Moreover, large-scale integration of fluctuating RES generation increases the need for cross-border balancing
Specific challenge	The aim of this project is to design and demonstrate a cross-border balancing market design which fulfils the requirements of the network codes for load-frequency control, reserves and balancing. It should integrate local balancing resources by finding appropriate price signals and increasing system reliability and efficiency. Different balancing process will be investigated with a focus on the frequency restoration process. The optimal allocation of cross-border capacities with respect to security, technical requirements and geographic locations is another important area to be examined. The impact of the resulting market design on the roles and responsibilities of the different market players will be assessed. The market design can also be examined using with a small-scale real-time demonstration project.
Funding Scheme	Collaborative project at a regional scale
Expected Impact	• More efficient balancing markets • Better integration of renewable generation due to greater flexibility • Evolution of control centres and demand-side technology for better system security
Additional Information	The consortium should be led by European TSOs with strong involvement from research centres. Participation of DSOs and balancing service providers could have an added value.
Proposal Duration	3 years
Total Budget	€ 10–20 million

Topic 1 – 2016	Fast storage needed by TSOs
Main Functional Objective	**T3**
Supported Functional Objectives	T7
Specific Challenge	The European electricity systems are challenged by the high penetration of renewable electricity generation with fluctuating feeds. Interconnectors between power systems and market coupling ensure access to Day Ahead resources and demand in neighbouring regions, countries or power systems. Large-scale energy storage such as hydro power or power-to-gas facilities are contributing to the present and future need for storing vast amount of electricity in a comprehensive energy form. There is a growing challenge in balancing the power system in the short term (a few hours) and at a minute base (Intra Hour). Until now, fluctuations from wind turbines or solar units have been balanced by rotating reserves on traditional thermal power plants. These resources will decrease in the years to come while being supplanted by RES at an accelerating rate.
Content / Scope	Activities should focus on storage systems that aim to support the power system with highly responsive power and energy storage. There are technical issues to overcome and many economic, regulatory, market and environmental aspects must be addressed. The primary technical objectives to cover are optimal power-to-power cycles with optimal efficiency and minor losses or integration with other energy systems offering to regenerate losses as valuable energy services such as heat. It might be technically feasible to store electricity by converting it to other forms of energy, but this might not necessarily be desirable if conversion losses are too high or regeneration of electricity for the power system is not significant. Secondary technical objectives are focussed on the need to support the power system with ancillary services and not just ensuring energy flow. Using highly responsive power and energy storage at different voltage levels in the power system calls for novel solutions where ancillary services are included in the storage facility. Swift power response, reactive power, voltage control, short circuit power and inertia should be included in a package of complete solutions from storage services to power systems. Future power systems with large amounts of inverter-based generation at all voltage levels require ancillary services from other sources. The advantage and business opportunities for highly responsive power and energy storage could be significantly higher if system operators would be able to harvest ancillary services from the storing systems, and vice versa if the storage facility needs ancillary services to operate. The third technical objective is to find the optimal size and position of highly responsive power and energy storage for operation in transmission systems as well as in distribution grids. This topic will address regulatory aspects such as: • Who will own and/or operate such highly responsive power and energy storage facilities? • Is the storage facility to be included with system operations or is it a fully market-integrated resource with optimisation potential in different electricity markets? • What are the investment incentives for large storage facilities with only a few hours of operation? • What tariffs should be developed to pay for these services? • How will storage facilities comply with varying national RES feeds? Potentials for servicing the power system with fast responding services should be examined compared with other technical and/or market opportunities.

Funding Scheme	Innovation actions including RD&D activities.
Expected Impact	The proposals are expected to cover the general impacts with focus on: • Feasibility studies of several technologies being able to support the power system with highly responsive power and energy storage • Pilot demonstration of highly responsive power and energy storage integrated at both transmission (HV) and distribution levels (LV) to show potentials for balancing, congestion management and/or support with ancillary services • Analyses and recommendations for regulatory and economic impacts and opportunities for storage facility • Deferred investments for transmission and distribution grids reinforcements and lower social costs associated with high penetration of fluctuating renewable power generation.
Additional Information	The overarching benefit of the project is that it will help to develop a sustainable, efficient, secure and flexible Smart Cities solution with advanced integration of competitive low-carbon and renewable electricity generation.
Proposal Duration	3–4 years
Total Budget	€ 10 million

Topic 2 – 2016	**Control system of the future: real-time tools for control centres**
Main Functional Objective	**T6**
Supported Functional Objectives	T8
Specific Challenge	The rapid evolution of the European power system presents control room operators with new challenges with respect to real-time control of transmission networks. The first challenge is related to the increase in system size to be controlled due to ever more components being connected. This is especially due to distributed production units being installed for the development of renewable production. The European electricity market has also increased cross-border exchanges and operators must now have access to more information on neighbouring systems. The second challenge is related to the increase of complexity with the emergence of active distribution networks, the insertion of new controllable components using power electronic (FACTS, HVDC links, and more) and the fast development of fluctuating generation from RES. This evolution also leads to changes in system dynamics due to additional fast close-loop control and fluctuating systems. A correct level of information synthesis should be given to the operators taking opportunities from new types of user interfaces. This will provide efficient access to more information from new monitoring systems including PMUs, smart meters, dynamic rating systems, local weather condition monitoring, and more. This presents another challenge in defining a new role for operators in the decision loop. We can see a move away from current control systems where operators have more or less direct control of the power system to a future control system that is more or less automatically controlled and highly responsive.

Content / Scope	Activities should focus on developing new real-time tools for control centres (SCADA enabling massive acquisition of information, EMS with advanced functions). The targeted time frame of these systems lies between 30 minutes ahead to real-time. Based on big data and machine learning techniques, development of prototypes of new tools for: • Automatic analysis functions improving the system observability (what is the current state of the system?), detection of security issues, alarms based on synthesis of detailed results from advanced security analysis tools (as proposed in the two ongoing FP7 projects Umbrella and ITesla) ("what if" analysis) providing contextual information and advice (guided analysis). Such analysis should help the operators to focus on critical contingencies or equipment, thus increasing awareness and accelerating decision-making processes. Another important issue is the detection of real-time conditions needing specific attention such as novel conditions (i.e., conditions never before observed) or that were not studied during day-ahead preparations. • Decision support for adaptation of parameters and setting points of the transmission system controls (such as HVDC infrastructures, special protection schemes, voltage controls of SVCs, generator set points, and more). The objective is to help operators to increase or maintain stability in the context of a more complex and dynamic power system. Issues relating to optimal man-machine interfaces (i. e., between operators and transmission grid) are also covered by this topic. Various new technologies are available for synthesising information, easing navigation through huge quantities of information and accelerating the implementation of actions (such as touch-sensitive screens, head-up display, 3D, haptic technology, etc.). A question is raised on how operators can best interact with physical power systems.
Funding Scheme	Innovation actions including RD&D activities.
Expected Impact	The development of more advanced control centre tools will enhance European power system security and allow systems to be operated closer to their limits without increasing risk. The possibility to use more advanced controls will also have a positive impact on the possibilities of incorporating more active and distributed components such as RES generation. Finally, optimal usage of software should reduce the need for additional infrastructure (hardware).
Additional Information	Including RD&D activities with development of prototypes and demonstration in control centres (at least for some of the functions).
Proposal Duration	3–4 years
Total Budget	€ 10–15 million

Topic 3 – 2016	Monitoring & observation tools for power network infrastructures
Main Functional Objective	**T6, T16**
Specific Challenge	The European power system faces major changes mainly associated with the massive integration of distributed and fluctuating RES generation. New types of transmission infrastructures must be added to the system: HVDC links, FACTS, offshore components, underground cables and more. This evolution is taking place on a grid that is already ageing and will require additional expenditures for maintenance and renewal. Sensors are to be used in the transmission grid mainly for real-time measurement of voltage and current. In order to operate the network, there is a need for additional real-time data on the European system that provides dynamic information on a growing number of components. For asset management issues, the classic approach consists in building asset management policies based on laboratory tests and measurements on a few samples of equipment. One challenge is linked with the capacity to use more information coming from equipment in the field. New sensors are needed in order to develop asset management policies based on risk evaluation. This must account for the life status of various equipment (based on previous conditions encountered locally by this equipment) and determine what the consequences for the system would be when a given piece of equipment fails.
Content / Scope	Activities should focus on new components and systems aimed at enhancing TSO awareness of network status either for operational activities (real-time and operational planning) or maintenance and long-term planning activities. "New" sensors are to be developed that allow for different kinds of measurements and applications (video, infra-red imagery, vibration detection, lasers and more). In summary: • Dynamic line-rating equipment including systems for overhead lines, underground or submarine cables • Monitoring systems for substation equipment (transformers, breakers, disconnectors and more) with real-time status and expected lifetime estimates • PMUs and associated local or wide-area monitoring systems • Vegetation monitoring • Presence detection around grid infrastructure (humans, animals, excavators, etc.). The various available communication networks should also be taken into consideration (depending on final applications): centralised vs. local system, cheap communication network with low reliability and low bandwidth vs. expensive communication network with high reliability and high bandwidth. The time synchronisation (acquisition and / or time stamping) requirement must be clarified for each application. This can be critical to finding correlations between different sets of measurement types in large systems. The targeted monitoring and observation tools can be static or mobile through "new" supporting devices (satellites, drones, robots).
Funding Scheme	Innovation actions including RD&D activities.
Expected Impact	Improved real-time monitoring systems together with better knowledge of real constraints seen by components; operation of European system closer to physical limits with no increase in risk. Better knowledge of individual component life status; decisive impact on network performance in terms of power quality and security of supply and consequently on electricity market. This is also a prerequisite for smart asset management policies which will have a positive financial impact on OPEX (i. e., for grid maintenance) and on CAPEX (i. e., for grid renewal).
Proposal Duration	3 years
Total Budget	€ 10 – 20 million

Topic 4 – 2016	Demand-Side Response: load control mechanisms and ancillary services at TSO and DSO levels
Main Functional Objective	**TD2**
Supported Functional Objectives	TD3, T10
Motivation	Integration of high volumes of intermittent generation will necessitate implementation of new technologies to add value to demand response and raise awareness about consumption flexibility and foster active customer participation in the energy market.
Specific Challenge	The main objective is to develop processes, profiles, platforms and standards for commercial actors to generate localised offers that can be activated by the relevant DSO, TSO or market operators. To this purpose, the goals to be achieved by Demand Response (DR) and eventually distributed energy storage must be defined, and joint planning tools and models must be developed. A range of demonstrations must then be performed, with broad coverage, for different loads and different countries, to show the impact of integrating DR on a pan-European level. The impact on system stability and market efficiency can be studied, and the requirements for implementing such programs can be determined. The potential benefits of flexible grids and products are energy savings, enhanced accommodation of RES, lower costs and increased network security through improved cooperation and communications between the participating parties (TSOs, DSOs, distributed generators, end customers, etc.).
Funding Scheme	Innovation action including RD&D activities
Expected Impact	• Load control provided by distributed resources, which allows TSOs and DSOs to plan and operate the network efficiently and economically, and also to reduce grid congestion. • An increased level of flexibility in planning and operation of the network, which will help for enhancement of RES integration at pan-European level while maintaining security of supply.
Additional Information	Main contributors will be: TSOs, DSOs, manufacturers, ICT solution providers, consumers, research institutes, aggregators, renewable generators, energy service providers and regulatory authorities.
Proposal Duration	4 years
Total Budget	€ 60 million

Topic 1 – 2017	Advanced tools for new market models
Main Functional Objective	**T12**
Supported Functional Objectives	TD6
Specific challenge	Pan-European power flows within a free energy market plus massive integration of variable RES resulting in local and regional bottlenecks, necessitating a fair charging mechanism for capacity use.
Content / Scope	The aim is to develop new capacity calculation methods for medium to long-term horizons (week, month, year, multi-year ahead) and congestion management approaches in accordance with a new comprehensive and reliable methodology being developed for the pan-European transmission network. Relevant tools should also be developed to support capacity allocation and congestion management. Stakeholders such as TSOs, market operators, regulators and market players have cooperated in establishing the broad lines of a target model for the European Electricity market. Many details and technical issues need to be further developed particularly for capacity allocation and congestion management. These must account for new approaches of combining preventative and corrective measures for reliability assessment, and allow more precise estimations of the system state due to accurate, wide-area, synchronised and high-sampling rate measurements. The consortium should include a relevant number of TSOs.
Funding Scheme	Collaborative project
Expected Impact	The results of this project should allow correct predictions of available capacities in transmission lines and cross-border interconnections so that they can be efficiently allocated to market actors. The completion of the internal market leads to increasing electricity flows and these are responsible for congestions particularly at cross-border connections. In view of the difficulty of building new lines, it is important to exploit existing connections to the maximum of their physical capacity. Advanced congestion management principles, methods and tools will correctly indicate to the market where true network congestions physically exist and should therefore minimise losses due to limited network capacity.
Additional Information	
Proposal Duration	TBD
Total Budget	TBD

Topic 2 – 2017	Improved defence and restoration plan
Main Functional Objective	**TD4, TD5**
Supported Functional Objectives	T9, T7, T6
Specific challenge	Need for different types of generation and demand technologies to participate actively in defence and restoration plans, not only centralised generation, but also DER and DR.
Content / Scope	• To develop a methodology of assessing the risk of breakdowns during reconnection, for different kinds of technologies, in order to maintain an appropriate level of security. • To investigate the impact of micro-grids and islanding capabilities into defence and restoration plans. • To investigate the contribution of DER for system restoration and its contribution to immediate power reserves; this is relevant from the TSO perspective (e.g., black start capability and coordination of wind turbine generators). • To develop simulation tools for interactive system restoration including advanced forecast tools developed in TD1 for wind, solar PV and other variable RES. • To propose operational procedures regarding defence and restoration plans with DSOs in the presence of high volumes of DER. • To train operators on the evolution of national regulatory schemes in order to foster coordination efforts. • To address regulatory and technical challenges that implement restoration plans at the pan-European level.
Funding Scheme	Collaborative project
Expected Impact	New operational procedures for improved defence and restoration plans will reduce the economic impact of major disturbances and threats.
Additional Information	Links with Garpur, After, eHighway 2050 and proposals developed under Horizon 2020 call LCE6-2015
Proposal Duration	2 years
Total Budget	€ 20–30 million

Topic 3 – 2017	Market modelling and system adequacy assessment for long-term planning
Main Functional Objective	**T2**
Supported Functional Objectives	T1, T12
Specific challenge	Need for a better approach to address the uncertainties in the future energy mix and market mechanisms for long-term planning purposes
Content / Scope	Based on the outcomes and lessons learned from e-Highway2050 project, a methodology and associated tool is to be developed that integrates long-term market scenarios and simulations for grid planning purposes. The tasks are: • Design and demonstrate new methods, tools and processes for assessing long-term market scenarios and system adequacy. • Build on existing experiences and tools (PSM, SPARK, ANTARES, etc.) to anchor know-how and lessons learned in the business while designing new market models to reflect the future EU market framework for grid planning purposes. • Account for the impact of technologies such as DR, electric vehicles and storage on consumption and generation; to anticipate these during grid planning from a market functionality point of view; develop forecasting techniques including correlation effects (wind, solar, DR, storage, etc.). • Build on these experiences and more specifically deal with the trade off between a bottom-up approach and a top-down approach when identifying gaps and to find the best approach of filling gaps (including the challenges involved in collecting data).
Funding Scheme	Collaborative project
Expected Impact	Methodology and prototype tool for better incorporation of market modelling in long-term planning and decision-making processes
Additional Information	Link with e-Highway 2050
Proposal Duration	4 years
Total Budget	€ 20–30 million

Concept 1 – 2018	Data and information management for system operation and asset management
Main Functional Objective	**T15**
Supported Functional Objectives	T6, T16, T7, T9
Specific challenge	Necessity for a new approach of managing enormous volume of information and data generated throughout the electricity system
Content / Scope	• Set out a methodology for managing the information and data currently available: technical specifications of different assets, lifetime characteristics, maintenance and operational practices, data and information coming from measurements, protection and monitoring devices, as well as from metering devices (generation and demand connection points, measurements on interconnection tie-lines, including metering for contracted and activated reserves). • Data acquisition, data management (updates, storing/archiving and cleaning methodologies, data security) as well as data mining; statistical inference and heuristic algorithms should be investigated so that high-quality data and information can be used for different applications, e.g., for dynamic simulations and security assessments, helping system operators in decision-making processes and for asset management purposes, both at the component and system level. • Experience feedback methods should be proposed in order to learn from best data and information management practices.
Funding Scheme	Collaborative project
Expected Impact	Increase the quality and reliability of the data and information that TSOs use to manage their assets and operate their systems.
Additional Information	Link with iTesla, Umbrella, Garpur
Proposal Duration	4 years
Total Budget	€ 20–40 million

Concept 2 – 2018	Realisation of ultra-high-voltage lines with partial underground cabling
Main Functional Objective	**T14**
Supported Functional Objectives	T2, T3
Specific challenge	TYNDP indicates the urgent necessity of expanding the current pan-EU transmission grid in order to meet European energy policy goals. The main driver of grid expansion is the huge increase in production from RES. Since RES are often situated far away from consumers, this results in large power flows through transmission networks. Furthermore, public acceptance of infrastructural projects is another issue for Member States. This induces public expectance to minimise the visibility of infrastructure. Cable links for EHV/UHV do not yet ensure adequate capacity at a reasonable cost. For the reasons stated above, TSOs require new transmission technologies that: • Can provide greater capacities • Can be easily integrated into existing grids, especially in existing corridors • Can be utilised in densely populated areas

Content / Scope	R&D is necessary to investigate and demonstrate the integration of high-capacity technologies in meshed networks and in densely populated areas. Even though ultra-high voltage AC and DC transmission lines have already been demonstrated around the world, R&D is still necessary to learn how to confront the challenges stated above.
	
	This concept will provide new knowledge and experience of the advantages offered by new technologies for the densely meshed European transmission system. It will also lead to new and improved equipment for urban applications and demonstrate the benefits of high-capacity corridors from the technical and public acceptance points of view. The potential of bundling with existing infrastructures will also be investigated.
	
	Tasks:
	• Launch the implementation of UHV transmission in Europe (foster political discussion, create public acceptance, trigger necessary legal additions, technical standardisation)
	• Technical development and demonstration of UHV AC solutions (500 kV to 750 kV)
	• Development of new OHL tower designs for UHV applications (flexible for AC/DC and various voltage levels, optimised electro-magnetic fields, compact design etc.)
	• Development of new conductors for UHV applications (in contrast to worldwide applications, special focus shall be placed on noise reduction as well as high capacities)
	• Develop concepts for UHV applications in existing routes
	• Implement demo projects
	• Develop cable solutions for partial cabling in densely populated areas
	  • XLPE cables for DC +/- 500 kV
	  • Reduction of losses
	  • Reduction of trench width to gain space compared to OHL
	  • Technological development to increase reliability and reduce costs
	  • Innovative maintenance concepts for cable with quick reaction times
	• Implementation of AC UHV pilot project in meshed network including maintenance concepts for AC UHV
	• Development of solutions for bundling line routes with existing infrastructure
	  • E.g., using GIL or partial cabling
	  • Demonstrate applicability of new innovative transmission technologies (super-conducting cable etc.)

Funding Scheme	Collaborative project
Expected Impact	Readiness for application solutions with strong energy transmission links useable in meshed networks, densely populated areas, improved public acceptance
Additional Information	Links to other projects with a focus on similar FOs will be considered. The focus will be on innovation and demonstration, i.e., new knowledge and technology.
Proposal Duration	4 years
Total Budget	€ 50 million

ABBREVIATIONS

AC	Alternate Current
ACER	Agency for the Cooperation of Energy Regulators
DC	Direct Current
DER	Distributed Energy Resources
DR	Demand Response
DSO	Distribution System Operator
EEGI	European Electricity Grid Initiative
EHV	Extra-high voltage
ENTSO-E	European Association of Transmission System Operators for Electricity
FO	Functional Objective
GIL	Gas-Insulated Lines
HVDC	high voltage direct current
ICT	Information Communication Technology
OHL	Overhead line
RES	Renewable Energy Source
R&D	Research and Development
SET PLAN	Strategic Energy Technology Plan
TSO	Transmission System Operator
RDC	Research and Development Committee
UHV	Ultra-high voltage
XLPE	Cross-linked polyethylene

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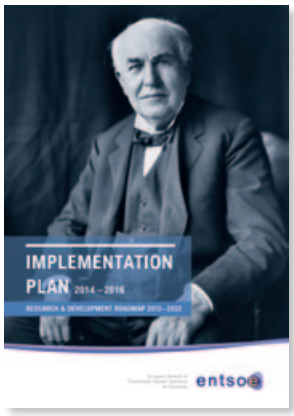
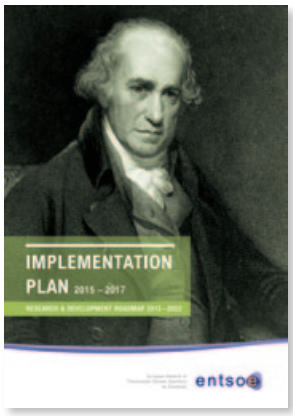
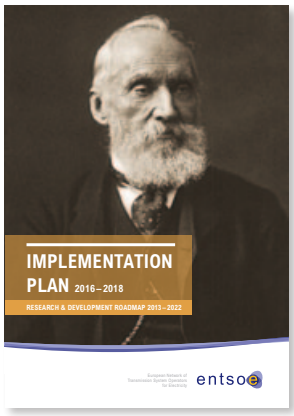
NOTE

This Implementation Plan is issued every year and outlines research and development (R&D) activities for the next three years as stipulated by the ENTSO-E R&D Roadmap 2013–2022.

This is the third Implementation Plan.







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