R&I IMPLEMENTATION PLAN 2017–2019

WITHIN THE FRAMEWORK OF THE RESEARCH, DEVELOPMENT & INNOVATION ROADMAP 2017–2026 JUNE 2017

European Network of
Transmission System Operators
for Electricity

entsoe

CONTENT

EXECUTIVE SUMMARY

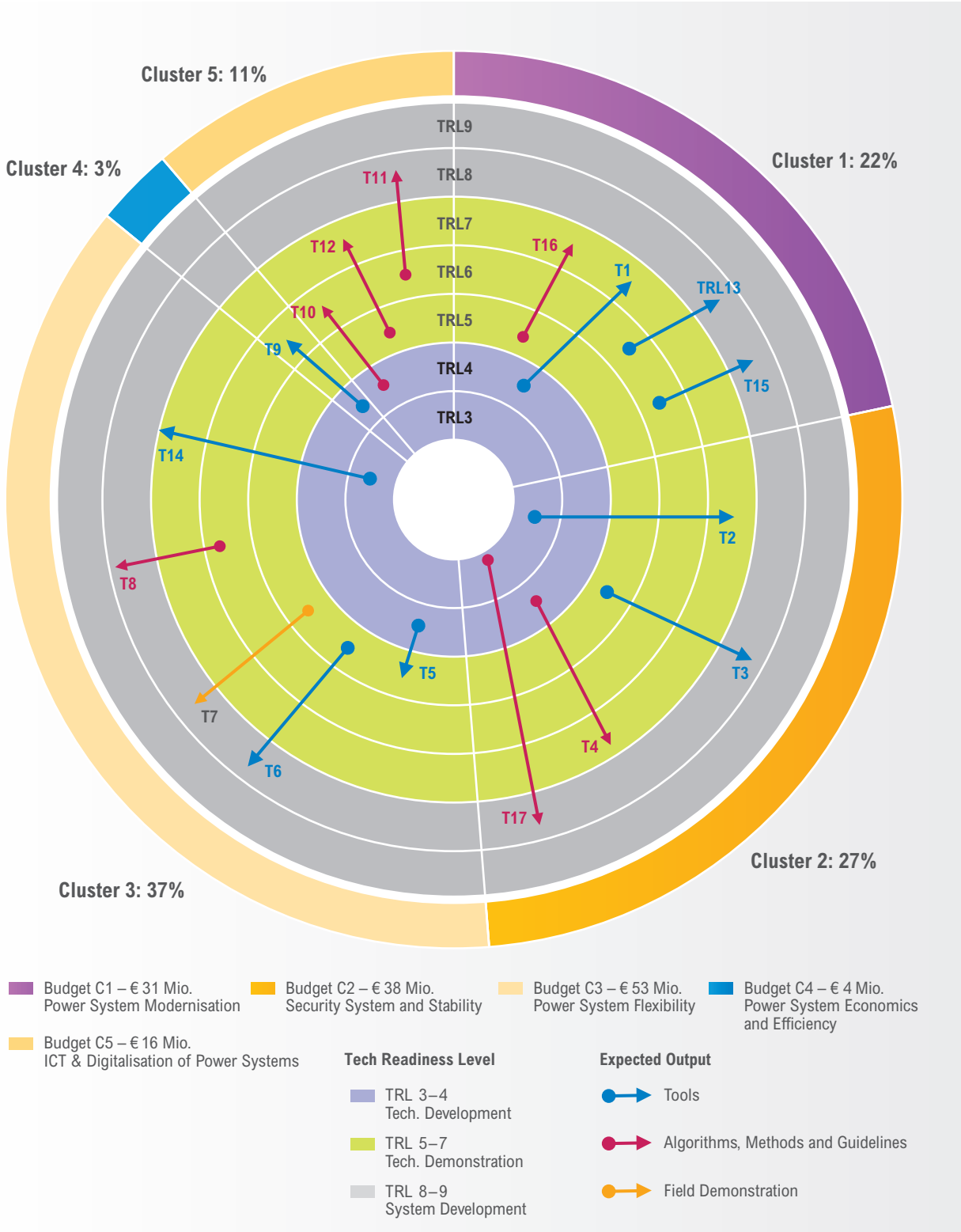

Figure 1: Overview of the topics of the Implementation Plan

WHY A RESEARCH, DEVELOPMENT AND INNOVATION (R&I) IMPLEMENTATION PLAN?

This Implementation Plan is one of the key planning instruments for coordinating TSOs' efforts in R&I with the overarching goal of establishing and maintaining an efficient, cost-effective, reliable, and secure European power system. This document is the fourth edition of the ENTSO-E Implementation Plan (IP) and the first following the revision of the original ENTSO-E R&D Roadmap 2013–2022 into the new ENTSO-E R&I Roadmap 2017–2026.

Looking at the current state of the art and how technology and business are evolving, this Implementation Plan streamlines the R&I topics earmarked to begin in 2017 and outlines topics to be tackled in 2018 and 2019.

The R&I Implementation Plan and the R&I Roadmap are part of ENTSO-E's mission of coordinating TSOs' R&I activities. TSOs' R&I efforts go alongside those of the different stakeholders who interact in the power sector. Because they have a global view of the European power system, from generation to end-consumers, and from long-term planning and adequacy to short-term operational and market issues, TSOs are well placed to foster innovation and progress in the quest for smarter grids. TSOs are also innovation enablers for field testing and deployment of innovative technological components and systems.

HOW HAVE R&I ACTIVITIES BEEN SELECTED?

The R&I topics were identified according to a balanced mix of those originating from addressing EU-funded calls (top-down approach) with topics that were supplied by TSOs (bottom-up approach); such topics will be addressed with international funding programmes as well as with TSO own resources, particularly those characterised as inter-TSO cooperation/knowledge-sharing initiatives among groups of TSOs.

In total, **a set of 23 topics were identified to be commenced over the next three years**, which were then matched with the clusters and functional objectives (FOs) of the ENTSO-E R&I Roadmap for the sake of consistency with the overall planning framework and vision. The list of the identified topics is provided in Section 3 and described in detail in Appendix 1.

The topics were prioritised by applying the following criteria: innovation level expressed through technology readiness level (TRL), applicability/replicability of the expected outcomes, and added value both in terms of economic extent and European footprint.

Figure 1 features an overview of the topics, arranged per the Roadmap cluster to which they belong, with an indication of the guiding budget, the type of expected output (tools, methods/assessment, or field demonstration), and the TRL.

WHAT IS THE BUDGET?

The estimated budget for topics starting in 2017 is approximately 100 million Euros. This is to be intended as a preliminary indication, while a more precise quantification will be possible when the topics are transformed into concrete projects.

Funding comes from the EU, via R&I programmes such as Horizon 2020 (H2020), but also from EU member states, from TSOs themselves, and from private investors.

The coordination of funding and the harmonisation of regulatory treatment within the European jurisdictions are pending certain issues, and ENTSO-E is actively working with the European Commission (EC) and Agency for Cooperation of Energy Regulators (ACER) as interlocutors.

Appendixes 2 and 3 feature, respectively, a summary of the ENTSO-E R&I Roadmap and the outcomes from the public consultation for this IP.

1 INTRODUCTION

1.1 WHAT IS THE ENTSO-E IP?

The ENTSO-E IP is meant to streamline the R&I actions and activities with a European dimension by the TSO community; the framework of the IP 2017–2019 is the ENTSO-E R&I Roadmap 2017–2026, published in mid-2016 and setting the medium-term vision and technological/operational targets of the fast-changing European electricity system.

The deployment of R&I programmes was tabled in the third legislative energy package by Regulation (EC) 714/2009 and was again included in the proposed Regulation of the European Parliament and of the Council on the internal market for electricity (COM(2016)861 final) on 30 November 2016.

1.2 OBJECTIVES AND VISION

The TSO European community is composed of 43 TSOs, and each company is quite active in performing R&I activities. On top of highlighting the added value of R&I carried out by TSOs, the IP emphasises the prioritised subjects that need to be addressed in a broader and more collaborative manner to impact the entire European energy system and contribute to progress in reaching the targets set by the EC at large. Commitment, cooperation and European social economic viewpoints are crucial for success.

The second objective is to contribute with R&I priority inputs to the EC's development of its energy research agenda (European Technology and Innovation Platform Smart Networks for Energy Transition (ETIP-SNET), etc.) and its strategic guidelines described in the Strategic Energy Technology Plan (SET Plan), which will be the basis for corresponding supportive funding schemes, such as H2020 and others. The vision of the IP 2017–2019 is for it to become an instrument for coordinating efforts in R&I in the short-term with the overall goal of establishing and maintaining an interconnected European transmission system that is efficient, cost-effective, and reliable.

ENTSO-E will continue to provide its contribution via the definition and implementation of R&I actions, deriving from its pivotal position in the power system and from the medium-/long-term duties assigned to its member TSOs (grid and system planning, market change enablement) on top of other short-term assignments, such as grid operation and balancing.

1.3 SCOPE AND PROCESS

Reviewing the current state of the art and how technology and business are evolving, the IP 2017–2019 details the topics earmarked for early commencement in 2017 and outlines R&I topics to be tackled in 2018 and 2019.

The contents set forth in the IP reflects the proposals that came directly from the TSOs, following a so-called "bottom-up" approach, complemented with topics stemming from EC guidelines and funding programmes (so-called "top-down" approach); indeed, the EC approach considers a wider perspective, envisaging an integrated energy system encompassing transport, heat, gas, and power-to-X options. In this way, the IP is a means to balance these two approaches pragmatically and concretely while harmonising the visions of different stakeholders.

The IP is updated regularly to keep the planning process aligned with the ever-changing needs of the power system as well to cater to R&I developments by the TSO community at a European level. Therefore, identification, prioritisation, and timing of the topics are fine-tuned or refocused annually after objective consideration by TSOs, outcomes from public consultation, and interaction/feedback from specific stakeholders. Once topics have been identified and prioritised, they are then articulated in specific projects addressing individual R&I targets. The projects are executed by ad hoc consortia that pool the resources from multiple TSOs and other partners. Realisation of R&I projects is then monitored during the lifecycle of the projects and shortly after their completion. The detailed description of each proposed concept and topic is available in Appendix 1.

2 EUROPEAN DIMENSION AND INNOVATION FRAMEWORK

2.1 EVOLUTION OF EUROPEAN R&I FRAMEWORK

The importance of innovation has been stated in the proposal for a regulation of the European Parliament and of the Council on the internal market for electricity of 30 November 2016; in the general rules for the electricity market, it is mentioned that market rules shall allow for progress in R&I to be realised and employed for the benefit of society, concluding that it is a task of ENTSO-E to deploy research programmes addressing overall system needs.

The European R&I framework is an ecosystem undergoing constant evolution and with a huge number of actors in permanent interaction. The main actor is the EC, which has recently set up ETIP-SNET, a widely participated-in platform that pulls together the most representative stakeholders with the aim of elaborating long-term scenarios, the R&I integrated-approach Roadmap and, consequently, the technical basis for the various funding programmes. In Figure 2, a simplified scheme of the main interrelations and information exchange is provided focusing on the TSO pathways leading to the EC regarding R&I issues.

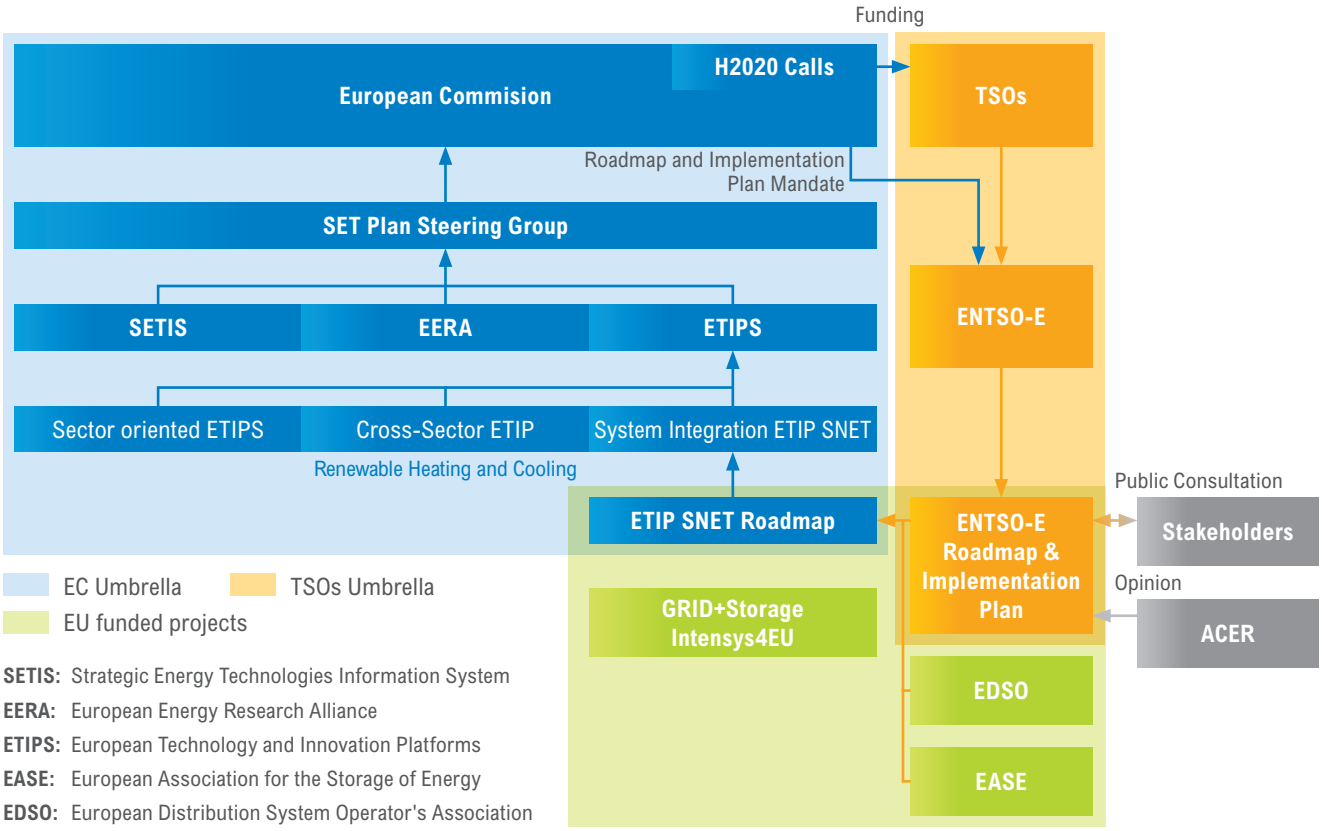

Figure 2: Interrelations between ENTSO-E and other EC Bodies

From Figure 2, several points are worth highlighting:

- The SET Plan Steering Group has 10 fixed key priority actions for Europe and the EC has put in place the ETIP-SNET platform to tackle Priority 4 ("Increase the resilience, security, and smartness of the energy system").

- The SET Plan is based on collaborative work with multiple inputs and contributions from most energy players and bodies as well as research institutions; this work is referenced in the 10-year ETIP-SNET R&I Roadmap covering the period, 2017–2026.

- TSOs are fully committed to assist reaching the targets of the SET Plan, firstly by meeting the EC mandate of the 3rd Energy Climate package – the ENTSO-E Roadmap and the IP – underscoring the work to be carried out from a system perspective to address SET Plan Priority 4. Secondly, ENTSO-E actively participates in several initiatives launched by the EC, in particular the ETIP-SNET platform. Thirdly, ENTSO-E has worked and will continue to work with other stakeholders (Distribution system operators, storage associations) to deliver integrated roadmaps and IPs within the consortium supported by European funding (i. e., Grid+Storage and Intensys4EU projects).

- This process represents a positive circular reference in the sense that projects financed by the H2020 calls have a significant impact on the definition of the short-term set of topics and projects. Activities financed by the H2020 programme address both emerging technologies with medium- to long-term time prospects until deployment in the R&I area and the integration into this technology system, taking into account interoperability and flexibility issues.

The activities supported under the H2020 in 2018–2020 will be structured according to the Energy Union priorities system perspective and SET Plan key actions. Among them, certain cross-cutting issues could be supported by TSO innovation activities, such as those dealing with digitisation, based on the integration of information and communication technology (ICT) and "Big Data".

The ENTSO-E Roadmap (and IP, as well) follows the fast technological changes in the energy sector, evolution of the EC policy framework, and modifications to funding schemes; indeed, funding tools were shifted from a technology-driven approach in the previous funding programme, FP7, to a challenge-driven approach in the current programme, H2020.

2.2 PAVING THE WAY TOWARDS AN ENERGY SYSTEM-INTEGRATED IP

IP 2017–2019 is framed within the challenging environment of the European energy system and the visions set forth by the establishment of the European Energy Union. ENTSO-E has been a dynamic partner in the GRID+Storage project, a consortium appointed by the EC (DG Energy) to foster the development of a European R&I Roadmap, integrating energy storage and other flexibility options into grid activities, both at the electricity transmission and distribution levels. Moreover, ENTSO-E is partaking in the Intensys4EU project, which has the objective of further implementation of innovative solutions in view of hosting up to 45 % of variable renewables sources by the year 2030 while continuing to operate the energy system in a safe, stable, and secure way. In this respect, the core of the ENTSO-E Roadmap, i. e., the list of clusters and FOs, has been included in the integrated Roadmap, and similarly the core of IP (the list of topics) will form a critical component of the integrated IP.

In addition, ENTSO-E is chairing the ETIP-SNET, building upon the consolidated and wide experience of its TSO members in carrying out EU research projects.

2.3 ACER PERSPECTIVE ON ENTSO-E'S R&I ACTIVITIES

As per the EC set of rules and as evident in previous ENTSO-E R&I deliverables, ACER provided its feedback on Roadmap 2017 – 2026, addressing both the methodologies and the contents; ACER's positive opinion encouraged the governance process efforts towards R&I, from identification of needs to deployment of results. The main issues raised and the relevant consequential actions of this IP are summarised hereinafter. R&I funding and regulatory framework issues along with key aspects for ACER intervention are outlined in Section 4.

ACER recommended reporting on the effectiveness and potential for upscaling and widespread deployment of technologies and innovative solutions in TSO daily business in terms of concluded R&I projects with the intent of quantifying their benefits or heir monetisation by potentially utilising "return on research capital"; accordingly, the next ENTSO-E Application Report will take this into consideration.

Regarding dissemination of R&I results, which is already a fundamental duty of individual R&I projects, ENTSO-E is ardently also pursuing dissemination tasks at several levels:

- enacting its role of a natural platform for internal dissemination through regular workshops, conferences, and webinars;
- increasing emphasis on specific inter-TSO initiatives in knowledge sharing and best-practice exchanges;
- dedicating external dissemination efforts and benchmarking them through direct involvement in the most important worldwide arenas – InnoGrid2020+, Cigré General Session, and several international symposia and events that are both sector-specific and broadly innovation-oriented.

2.4 ADDRESSING STAKEHOLDER CONCERNS

ENTSO-E's public consultation strategy has been improved by employing a "pull" (only publishing and announcing the IP on ENTSO-E website for consultation) versus "push" approach (proactively pursuing feedback from particularly relevant stakeholders and collecting significant responses).

To obtain a broad public opinion, the following stakeholders have been involved: market players, consumers, DSOs, ETIP members, research institutions, technology providers, generation companies, associations, and non-governmental organisations (NGOs).

The consultation process, conducted at the beginning of 2017, was performed via questionnaire, which allowed the respondents not only to answer the questions, but also to make comments and propose suggestions to enhance the process of selecting topics and concepts. Suggested changes to the text and structure were carefully evaluated and actions taken accordingly. The comments are summarised in Appendix 3 while further details are published on the ENTSO-E website.

3 R&I ACTIONS

3.1 EVOLUTION FROM PREVIOUS IPs

In the previous years, the focus was on the modernisation of the European electricity network with emphasis on the scenarios and methods for developing a network infrastructure that hosts massive amounts of renewable energy sources. Emphasis had also been placed on the improvement of power technologies, their affordability, and the technical performance of components of emerging technologies that can significantly enhance the operations of the interconnected transmission systems. Still, efforts need to be directed to the demonstration of innovative power technologies and to their integration in processes and the network as a whole.

The main activities for 2017 seek to monitor and control the entire pan-EU grid to improve its flexibility. There is a requirement to assess, measure, and provide flexibility to the system. There is also a focus on the stability of the system, taking into account the great amount of renewable energy sources (RES) in place and the plans for 2030 as well as relevance to the consumer.

Further, the coordination between TSOs and DSOs needs to increase, therefore the IP considers this issue by concentrating on innovation activities with respect to ICT features and data exchange to promote efficient and secure coordination.

RES forecasts, flexibility in all areas (e.g., operation, markets, resources), smart planning approaches, market-grid integration of new technologies, resilience, business models, and smart asset management are also innovations that will have to be covered in the near future.

To meet the challenges of future low carbon energy R&I activities, beyond 2019, there will be emphasis on flexible and smart planning approaches, taking also into consideration resources that are not yet with market integrated but with great potential, such as storage, demand response (prosumers) and cross-border services, which will gain importance in the future. This will lead to innovations in the field of network controllability and observability – bidirectional and loop power flows will be present in the system because of distributed energy resources. For realising these challenges, there is a need to deploy and manage cost-efficient ICT infrastructures for handling and analysing all data. Table 1 shows the priority topics to be developed over the short-term.

3.2 THE IDENTIFIED R&I TOPICS

IP 2017–2019 has the objective of detailing as much as possible the concrete challenges faced with each topic, the state of the art, and the results to be targeted, which improves the quality of the topic description and enables a better comprehension.

The topics are reported in Tables 1 to 3; they have been determined using a mix of those originating from addressing EU programmes and topics related to the inter-TSO cooperation and knowledge-sharing initiative among groups of TSOs. These two pillars aligned with the R&I Roadmap gaps serve as basis for the development of consistent, robust, and exhaustive structure of R&I plans.

More specifically, R&I priorities and topics for 2017–2019 are based on the following:

- R&I Roadmap which serves as a reference and, more specifically, exhibits the relationships of the topics with its clusters and FOs. Topics are in line with Roadmap planning (see Appendix 2).
- EU funding programmes with emphasis on those referring to the transmission system as well as links between transmission and distribution systems to other energy networks.
- Inter-TSO cooperation and knowledge sharing aimed at addressing topics either in the short-term or those not included in the EU-wide system vision, which are still, in any case, deemed very important to improving grid operation and mandated duties of TSOs.

Topic No	Cluster Reference Roadmap 2017–2026	Topics Starting 2017
1	C1/T1	Power system planning for flexible transmission systems
2	C2/T5 & C3/T13	Enhanced grid observability
3	C2/T9	Cross-border use of ancillary and flexibility services
4	C2/T7, T6 & C1/T1	Assessment of pan-European system stability
5	C3/T11, C4/T16 & C5/T19	Coordination of centralised and distributed flexibility
6	C3/T13 & C4/T16	Measuring and forecasting system flexibility
7	C3/T10 & C2/T6	Multiservice storage applications
8	C3/T11 & T19	Demand response engineering
9	C4/T17	Flexible market design
10	C5/T18 & C4/T16	ICT tools for data management
11	C5/T18 & T19	ICT systems and data handling for system control
12	C5/T21	Coordination on cyber-physical security within the energy sector

Table 1: Topics Starting 2017

Table 1 lists the topics for 2017 (coloured in purple) where the projects are more concrete and mature. The proposed R&I topics focus on power system flexibility, security, and stability, storage integration, and digitalisation of the power system.

- **Topic 1-2017:** A comprehensive platform of tools will be developed to study grid storage as a transmission asset and RES forecasting with storage, thus optimising grid flexibility.

- **Topic 2-2017:** Smart control system tools for real-time grid monitoring are to be deployed; these will be evaluated using a new uniform methodology via smart asset management technologies (wide area measurement systems (WAMs), phasor measurement units (PMUs), flexible alternating current transmission systems (FACTs), dynamic line rating (DLR)).

- **Topic 3-2017:** Tools will be deployed to examine the optimal development of flexibility resources and ancillary services with a focus on cross-border coordination; this will be covered at the pan-European level.

- **Topic 4-2017:** Fast real-time predictive and preventive mechanisms are to be formulated for continuous dynamic stability; cross-border responses to dynamic stability issues will be investigated as well as the utilisation of market-based instruments. Stability services provided by all players in the electricity value chain (TSO/DSO/storage/generation/load/cross-border) will be assessed. Tools and mechanisms will also be explored to detect stability margins and predict short-term stability prognoses and optimal predictive responses. In general, optimal asset utilisation and system planning will be compared versus stability limits.

- **Topic 5-2017:** Tools are to be developed regarding the cross-border employment of flexibility services and transmission services based on distribution-connected flexibility means, namely demand response and storage.

- **Topic 6-2017:** Real-time tools for measuring grid flexibility with new, consistent methodology encompassing scenarios, social welfare, and stakeholder impact will be developed. This will exploit dynamic line rating and sensors to enhance the absorption of RES power while mitigating new infrastructure needs and costs simultaneously.

- **Topic 7-2017:** Multiservice applications will be tested focusing on the use of storage technologies (e.g., applications of hybrid storage, batteries, flywheel, super capacitors) for providing system services – congestion management, synchronisation, and frequency and voltage control.
- **Topic 8-2017:** Innovative ancillary services will be created provided by large-sized prosumers and by medium-small prosumers connected to the HV, MV and LV grid; advanced management of selected industrial clients based on system-benefits analysis will be explored.
- **Topic 9-2017:** Market simulation tools will be produced and evaluated regarding the integration of distributed flexibility resources into the wholesale market. Additionally, roles of and interactions between regulated and deregulated players will be assessed.
- **Topic 10-2017:** This topic will concentrate on smart data management with suitable ICT tools as value adds for all electricity and system value chains. The assessment and development of ICT architecture, standards, requirements, roles, business models, exchange platforms, and TSO/DSO processes will be also included.
- **Topic 11-2017:** Cloud-based ICT supportive infrastructure will be developed; it will be focused on data monitoring and analysis of control system actions to enhance system performance by improving its predictability and controllability.
- **Topic 12-2017:** This topic will deliver a fully developed framework for the validation of innovative cyber-physical security technologies. Virtual and physical testing will be performed to assess cyber-physical security within the energy sector.

Topic No	Cluster Reference Roadmap 2017–2026	Topics Starting 2018
13	C1/T2	Smart asset management through use of "Big Data"
14	C3/T14	Interaction with other energy systems

Topic No	Cluster Reference Roadmap 2017–2026	Topics Starting 2019
15	C1/T1	Optimal grid design based on the use of most cost-effective solutions/technologies to integrate more flexibility into the system
16	C1/T4	Public acceptance and stakeholder's participation
17	C3/T12	Improve RES forecasting and optimal capacity operation

Table 2: Topics Starting 2018 and 2019

The list of topics for 2018 and 2019 is found in Table 2 (coloured in blue and light yellow):

- **Topic 13-2019:** Smart ICT tools will be developed to integrate new sensors, monitoring devices, and robotics for automated intervention, especially in hostile environments.
- **Topic 14-2018:** Tools and models for the management of balancing and congestion problems will be created as well as platforms to enhance coordination with other energy system players.
- **Topic 15-2019:** This topic will explore new planning methods that combine variable RES and distributed energy resources (DER), production capacities, storage, and environmental constraints at both the transmission and distribution levels. The proposed methodology will also take into account market aspects and coupling with other energy sectors, such as gas, heat, and cold production.
- **Topic 16-2019:** Emphasis on the enhancement of public acceptance considering not only communication to the public, but also technical features; the latter will analyse new technologies that have reduced environmental footprint, like new towers, station designs with less visual impact, audible noise, EMF, etc.
- **Topic 17-2019:** Effective mechanisms, instruments and rules will be validated for the management of variable sources in the system based on RES forecasting with a high level of accuracy.

Topic No	Cluster Reference Roadmap 2017–2026	Topics of Interest for TSOs that are being developed and surveyed under inter-TSO cooperation	Starting
18	C1/T1	Probabilistic methods for generation of adequacy planning	2017
19	C2/T18	High impact of low-probability events	2017
20	C3/T10	Optimal use of storage plants	2017
21	C5/T21	Best practices exchange in cyber-security	2017
22	C1/T3	Partially insulated over head lines (OHL) Conductor	2018
23	C2/T6 & C5/T18	Developing tools for better system awareness based on "Big Data" analysis	2018

Table 3: Inter-TSO Topics

Tabel 3 lists topics that will be addressed under inter-TSO cooperation (coloured in grey).

- **Topic 18:** New methods and tools for adequacy planning based on probabilistic approach.
- **Topic 19:** Tools and methods to evaluate the high impact of low-probability events based on stochastic methods.
- **Topic 20:** This topic will analyse the performance of different storage technologies for ancillary service provision based on scenarios related to storage penetration.
- **Topic 21:** Best practices exchange in cyber-security are to be investigated in terms of standards, security measures, prevention procedures, on-site resolution of attacks, etc.
- **Topic 22:** Partially insulated OHL Conductor will be examined; the main goal is to explore whether a 400 kV circuit can operate on a 110 kV tower.
- **Topic 23:** Methods and tools will be produced so TSOs will fully utilise their data to improve system awareness and operation.

It is also useful to consider how the identified topics address the clusters and FOs of the ENTSO-E Roadmap, which are reported in Tables 4 to 8. For details and full references to the Roadmap, see Appendix 2.

ORGANISATION PER ROADMAP 2017–2026 CLUSTER

Topic No	Cluster Reference Roadmap 2017–2026	Cluster 1: Power System Modernisation	Starting
1	C1/T1	Power system planning for flexible transmission systems	2017
15	C1/T1	Optimal grid design based on the use of the most cost-effective solution / technologies to integrate more flexibility into the system	2019
18	C1/T1	Probabilistic methods for generation of adequacy planning	2017
13	C1/T2	Smart asset management through the use of "Big Data"	2018
22	C1/T3	Partially insulated over head lines (OHL) Conductor	2018
16	C1/T4	Public acceptance and stakeholder participation	2019

Table 4: Topics addressing Cluster 1

Topic No	Cluster Reference Roadmap 2017–2026	Cluster 2: Security and System Stability	Starting
2	C2/T5 & C3/T13	Enhanced grid observability	2017
3	C2/T9	Cross-border use of ancillary and flexibility services	2017
4	C2/T7 , T6 & C1/T1	Assessment of pan-European system stability	2018
23	C2/T6 &C5/T18	Developing tools for better system awareness based on "Big Data" analysis	2018
19	C2/T18	High impact low-probability events	2017

Table 5: Topics addressing Cluster 2

Topic No	Cluster Reference Roadmap 2017–2026	Cluster 3: Power System Flexibility	Starting
20	C3/T10	Optimal use of storage plants	2017
5	C3/T11, C4/T16 & C5/T19	Coordination of centralised and distributed flexibility	2017
6	C3/T13 & C4/T16	Measuring and forecasting the system flexibility	2017
7	C3/T10 & C2/T6	Multiservice storage applications	2017
8	C3/T11 & T19	Demand response engineering	2017
17	C3/T12	Improve RES forecasting and optimal capacity operation	2019
14	C3/T14	Interaction with other energy systems	2018

Table 6: Topics addressing Cluster 3

Topic No	Cluster Reference Roadmap 2017–2026	Cluster 4: Power System Economics and Efficiency	Starting
9	C4/T17	Flexible market design	2017

Table 7: Topics addressing Cluster 4

Topic No	Cluster Reference Roadmap 2017–2026	Cluster 5: ICT and Digitalisation of Power System	Starting
10	C5/T18 & C4/T16	ICT tools for data management	2017
11	C5/T18 & T19	ICT systems and data handling for system control	2017
12	C5/T21	Coordination on cyber-physical security within the energy sector	2017
21	C5/T21	Best practices exchange in cyber-security	2017

Table 8: Topics addressing Cluster 5

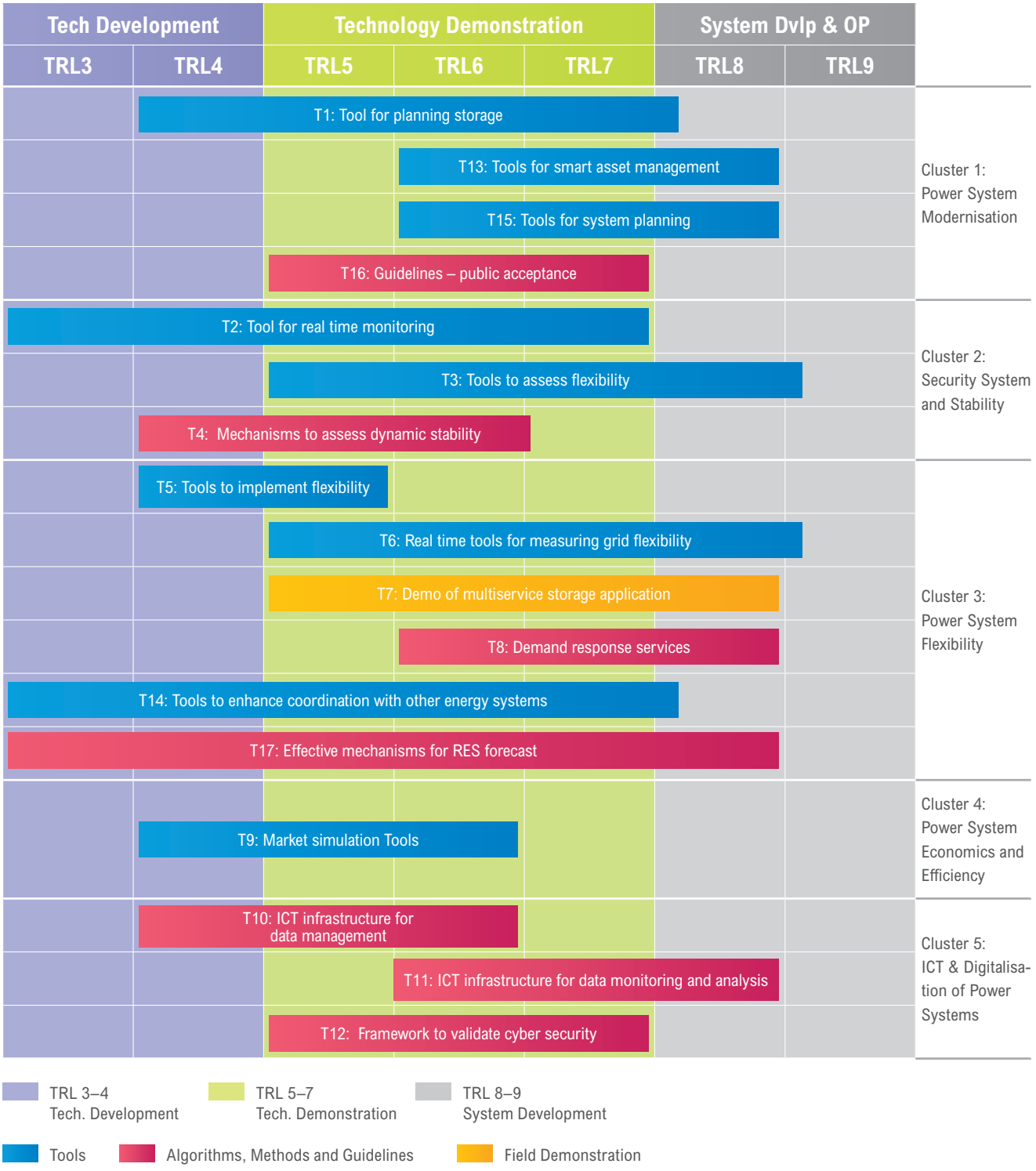

Figure 3: Implementation Plan Topics' Maturity Level

According to the TRL, the method for estimating technological maturity, the proposed topics seek to develop components, models and prototype systems that could be tested in a relevant environment and that are planned to become operational systems (TRL 5 to TRL 8). In Figure 3, the key IP 2017–2019 topics expected outcomes, excluding the inter-TSO cooperation topics, are represented per the TRL. The topics delivering a tool are represented in blue, the topics delivering methodologies, assessment or frameworks are represented in red, and topics with demonstrations in the field are represented in yellow.

3.3 INPUT TO THE ETIP-SNET IP

The set of topics were identified from the perspective of system needs viewed by the central position of TSOs, where the priority was based on: innovation level expressed through TRL, applicability/replicability of the expected outcomes, and added value both in terms of economics and European carbon footprint.

The prioritisation methodology was considered in several iterations, valuing the metrics of urgency, timeliness for availability and system impact on system planning, as well as operation and maintenance once system integration was successfully carried out.

The second iteration took into consideration the ENTSO-E Roadmap scope, ensuring the coverage of the topics and FOs expected were performed within the IP framework (see Figure 4):

- Power system planning for flexible transmission systems and probabilistic methods for generation of adequacy planning
- Enhanced grid observability and assessment of pan-European system stability
- Cross-border use of ancillary and flexibility services
- Optimal use of storage plants and multiservice storage application
- Demand response engineering
- Measurement and coordination of centralised and distributed flexibility
- Flexible market design
- ICT systems and data handling for system control – TSO and DSO interactions.

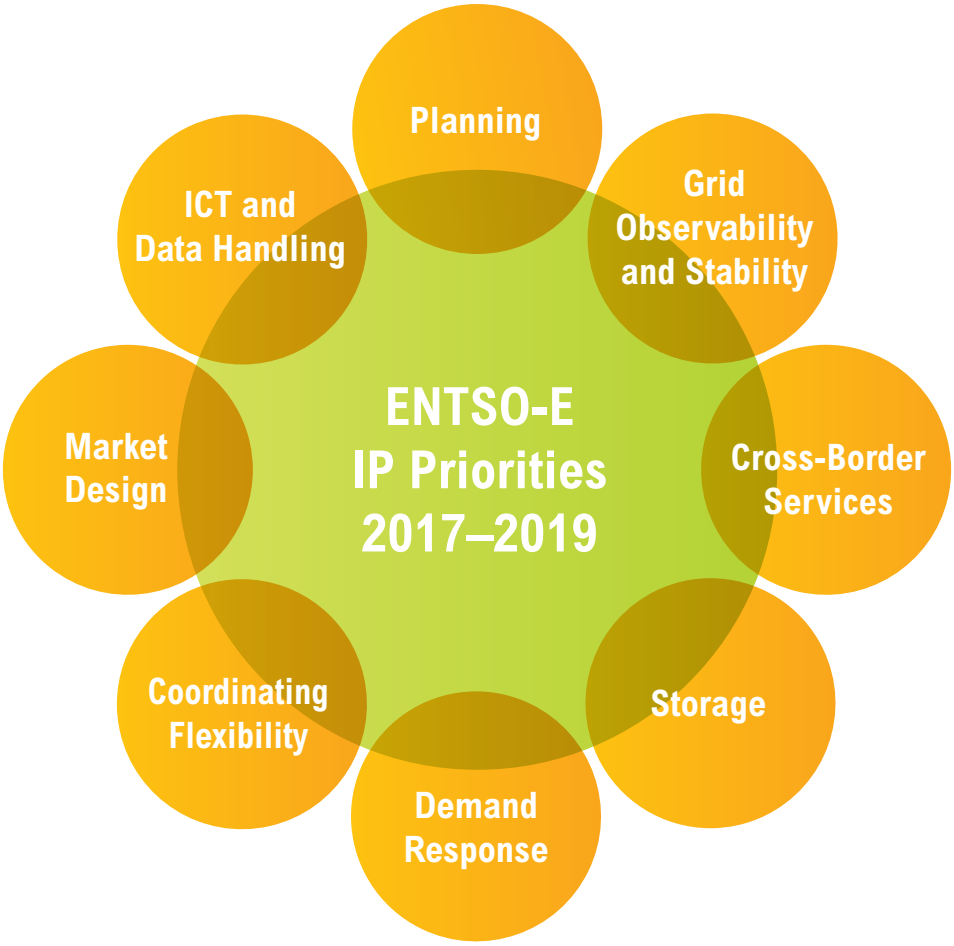

Fig. 4: Implementation Plan Priorities

4 R&I ECONOMICS AND REGULATORY APPROACH

The Third Internal Energy Market Package pushed the national regulatory authorities (NRAs) to support TSOs and DSOs in their R&I efforts (Directive 2009/72/EC, Article 37.8). Despite this provision, only a few EU countries currently account for R&I expenses explicitly through tariff structures. When there is no explicit national regulation for R&I expenses, these financial efforts tend to be considered 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 – paradoxically – to reduce them.

ENTSO-E is working with ACER and the EC to reach common ground regarding the regulation of R&I activities within the TSO community. Recognition from NRAs and ACER/CEER of the need to cover R&I expenses would bring benefits by leveraging TSOs' experience in operating and managing research programmes and disseminating results, therefore promoting a smooth, effective, and efficient implementation of the EU energy strategy.

The estimated budget for topics labelled as to be addressed starting in 2017 is around € 100 million; this is to be intended as a preliminary indication as a more precise quantification will be possible when the topics are transformed into concrete projects. For the projects beyond 2017, the budget estimate is approximately € 40 million, though this will be refined in subsequent IPs. For more data and statistics on dedicated resources, references are found in the ENTSO-E R&I Roadmap, which was published in mid-2016.[1)]

1) https://www.entsoe.eu/publications/research-and-development-reports/rd-roadmap/Pages/default.aspx

APPENDICES

APPENDIX 1
DETAILS OF TOPICS

Topic 1 – 2017	Power system planning for flexible transmission systems
Cluster	C1
Main FO Addressed	T1
Supported FO	T7, T13
Specific Challenge	Different resources, such as intermittent RES, storage, and demand, will play a central role in the future power system. This leads to the challenge of power system planning for flexible transmission systems in order to preserve the same levels of security of supply and power quality within the interconnected pan-European system that will be exposed to a massive amount of uncertainty.
Content / Scope	Develop power system planning tools that optimise transmission grid flexibility according to specific metrics.
Expected Results	Detailed planning methodology that enables and monitors grid flexibility based on specific metrics. Modelling, simulation and decision support tools for optimal grid design with high flexibility potential.
Expected Impact	• System design with major system flexibility, stability, and security. • Promote a strong transmission backbone for liberating the electricity market and develop business opportunities. • Improved and reliable RES penetration.
Additional Information	Partners involved are research institutions, technology providers and TSOs. Outputs will be modelling tools, decision support mechanisms, and use cases.
TRL Range	Initial TRL 4 – Final TRL 7
Proposed Timeline	2017–2020
Estimated Budget	€ 8 million
Funding Scheme	Mainly EC and National Funding Programmes. Type of Project: Research and Innovation Action.
Background / State of the Art	Recent projects that have researched possible scenarios of pan-EU network expansion are: iTesla, Best Paths, Twenties, e-Highway, GridTech, and RealiseGrid. The results could be considered inputs for the development of power system planning. Other EU projects, such as Umbrella, have assessed the effectiveness of control actions that deliver the right level of reliability while facing uncertainties from the large-scale deployment of RES and market integration.

Topic 2 – 2017	Enhanced grid observability
Cluster	C2, C3
Main FO Addressed	T5, T13
Supported FO	T6
Specific Challenge	To achieve a smart control system for real-time grid monitoring, yet to assess, with a new uniform methodology, smart asset management technologies (WAMS, PMUs, FACTS, DLR)
Content / Scope	Develop a methodology that exploits real-time grid monitoring information for system planning, operation and decision support. Specify and implement pilot project with dynamic line rating, FACTS, WAMS, and PMU in order to harness the capacity of the transmission system closer to its limits with high reliability and defer new infrastructure while absorbing more RES power. To explore the role and impact of existing and emerging ICT in terms of grid observability.
Expected Results	• Methodology and use cases for setting up and exploiting real-time monitoring schemes. • Pilot project: specification and deployment of real-time monitoring devices and improvement of grid performance, DSO information exchange and interconnector optimisation.
Expected Impact	Promote the observability of the network. Maintain European leadership in state-of-the-art technology. Reduce the costs of new infrastructure and boost coordination between DSOs and cross-border trading.
Additional Information	Real-time monitoring improves system stability and power quality. Methodologies, simulation tools, use cases, and business models will be the outputs as along with being the laboratory demonstration.
TRL Range	Initial TRL 3 – Final TRL 7
Proposed Timeline	2017– 2020
Estimated Budget	€ 8 –10 million
Funding Scheme	Mainly EC and National Funding Programmes. Type of Project: Research Action.
Background / State of the Art	Indicative list of relative projects: Twenties, BestPaths

Topic 3 – 2017	Cross-border use of ancillary and flexibility services
Cluster	C2
Main FO Addressed	T9
Supported FO	T1, T13
Specific Challenge	TSOs are responsible for the secure and reliable operation of their systems as well as for interconnections with other transmission systems. The challenge then lies in optimising the operation of the system wider than the national level; this is addressed through cross-border utilisation of ancillary and flexibility services.
Content / Scope	Exchange of flexibility resources/ancillary services with a focus on specific service elements and their respective business role models, control mechanisms, responsibilities, and cross-border capacity treatment procedures.
Expected Results	Outputs will be market-design proposals, prototypes, and simulation tools.
Expected Impact	Increased amount of ancillary services and flexibility resources made available across the interconnected borders and market zones. Improved control of RES in the conditions of reduced control reserves from coal-fired and gas-fired production units. Improved security of operation derived from energy-efficient solutions. Avoided or deferred investments into new storage capacities.
Additional Information	Partners involved are research institutions, solution and IT providers, retailers, and TSOs.
TRL Range	Initial TRL 5 – Final TRL 8
Proposed Timeline	2017– 2020
Estimated Budget	€ 10 million
Funding Scheme	EC and National Funding Programmes. Type of Project: Research and Demonstration Action.
Background / State of the Art	Future Flow

Topic 4 – 2017	Assessment of pan-European system stability
Cluster	C1, C2
Main FO Addressed	T6, T7
Supported FO	T1
Specific Challenge	Increasing variable renewable generation significantly influences the dynamics of the grid and poses serious challenges to the stability of power transmission networks. The power system should ride through any single disturbance, event such as failures of generation, load, or transmission lines, and accomplish a new type of operation without impacting customers. However, increasing penetration of renewables and power electronics across Europe means that disturbances can affect the system too rapidly for conventional control and protection approaches to contain the events. Risks of cascading, damage, network separation, loss of voltage or frequency stability, and blackout of large areas may increase unless innovative containment measures can be applied. These risks are not only local phenomena, but they have to be handled across countries, TSOs, and DSOs.
Content / Scope	Develop, build, and demonstrate synchro phasor-based integrated systems for dynamic stability monitoring and responses for the European power system to be able to cope with closer to 100% inverter-based RES, storage systems, and embedded HVDC. For the responsible parties of the European power system, it will be investigated how far the current and the future planned European power system can be pushed with and without advanced dynamic stability mitigation mechanisms in place before it reaches its stability limits. An assessment of new technologies (methods, approaches, and new devices) will be conducted. Assessment of system services available to all players within the power system value chain (TSO / DSO / storage / generation / load / HVDC / etc.). Demonstration of all parts of the monitoring and control chain for future needs for stability control actions in the power system. The overall tasks to take into consideration are: • Monitoring System: Sensors and Observability • Real-Time Analysis, Prediction, Warning, and Guidance • Real-Time Response-Driven Control Processes and Infrastructure • Market Activation and Settlement Using Market-Based Instruments
Expected Results	Novel advanced tools and means, including market-based instruments, for secure operation of the future power system with close to 100 % inverter-based RES: • for optimal system planning and asset utilisation closer to stability limits • For fast real-time and continuous prediction of dynamic stability margins • For fast real-time determination of preventive mechanisms for continuous dynamic stability • For optimal and market-based activation of cross-border dynamic stability services Recommendations and roadmap for utilisation of real-time dynamic stability monitoring and control mechanisms.
Expected Impact	Room for increased integration of renewable generation through optimal system observation and cross-border employment of grid-wide assets to provide new grid services for ensuring continuous stable power system operations.
Additional Information	At the least, following the type of partners is needed for proper coverage of stakeholder interests and competencies relevant for execution of development and demonstration – TSOs, universities, technology providers, etc.
TRL Range	Initial TRL 4 – Final TRL 7
Proposed Timeline	2018 – 2021
Estimated Budget	€ 20 million
Funding Scheme	European Funding. Type of Program: Research and Innovation Action
Background / State of the Art	MIGRATE

Topic 5 – 2017	Coordination of centralised and distributed flexibility
Cluster	C3, C4, C5
Main FO Addressed	T11, T16, T19
Supported FO	T5, T6
Specific Challenge	The power system has classically relied on a range of services from transmission connected synchronous generators that has maintained the resilience of the power system society has come to expect. These are now being displaced by non-synchronous RES. In the future, many of the resources will be embedded within the distribution networks and will require aggregation. This creates two fundamental issues: • There are barriers (operational and communication) to allowing new technology from providing these to the system (e.g., no grid codes, no scheduling or dispatch tools, no control or observation signals, no access to revenues for services). • The traditional roles and responsibilities do not hold.
Content / Scope	This work should explore the need of the power system with high RES employment and examine new technologies to see how they can provide the needed services. Assessment of roles and interactions of regulated and deregulated players. Integration of distributed flexibility resources into the wholesale market. Design options using "shadow markets" platforms. Cross-border use of flexibility services. Transmission services based on distribution-connected flexibility means, including demand response and storage as well as embedded RES and changing the constitution of demand (electrification and machine-to-machine connections).
Expected Results	Clarity around the barriers and solutions to providing needed services complimentary to high RES policy objectives.
Expected Impact	Materially consider effective integration of embedded capability aligned with facilitating EU Energy Policy.
Additional Information	Research institutions, DSOs, and TSOs
TRL Range	Initial TRL 4 – Final TRL 5
Proposed Timeline	2017– 2021
Estimated Budget	€ 4 million
Funding Scheme	EC and National Funding Programmes.
Background / State of the Art	ANEMOS Plus, MERGE, "From wind power to heat pumps", GridTech, OPTIMATE, Ecogrid EU, Gredor, Cell Controller Pilot Project

Topic 6 – 2017	Measuring and forecasting system flexibility
Cluster	C3, C4
Main FO Addressed	T13, T16
Supported FO	T1, T4
Specific Challenge	Measuring and forecasting grid flexibility with new, consistent methodology encompassing scenarios, social welfare, and stakeholder impact
Content / Scope	According to the European Electricity Grid Initiative (EEGI) (GRID+ KPIs definition), system flexibility is defined as the amount of electrical power that can be modulated based on the needs of system operation within a specific unit of time. This refers mainly to flexible generation and load resources, but also that the grid could become a source of flexibility itself with technologies that have similar effects as the aforementioned to overcome system constraints. Examples of this latter group are basically DLR systems (e.g., sensors and algorithms) as well as different kind of power flow control devices (e.g., phase shifter transformers, HVDC links, FACTS, etc.) To garner as much benefit as possible from these resources, it is essential to count with consistent methodologies and mechanisms not only to measure this flexibility but also to forecast it in order to make proper decisions for day ahead operations and not only in real time (or close to real time). Develop low-cost solutions (sensors) and methodologies for forecasting and real-time measurement of DLR to increase system flexibility while ensuring the current security and stability standards of the network to absorb RES power and mitigate new infrastructure needs and costs (social welfare). It is essential that these solutions can be as affordable as possible (low cost), suitable for use in existing infrastructure with minimum adaptation, and robust (e.g., reliable and minimum maintenance). Develop market mechanisms that integrate new storage technologies, demand-side management resources and DLR to boost the capacity of the network and incentivise new flexibility services for stakeholders, prosumers, TSO/DSO coordination, and cross-border trading.
Expected Results	Methodology and use cases for setting up and exploiting real-time monitoring schemes and best use of power flow control device (PFCDs) for increased flexibility; respective pilot project to implement the method, methodology for market-based mechanisms to remunerate flexibility services, and promotion of new business opportunities for storage and demand-side resource integration, and optimal investments into the network; simulation tools, use cases, and laboratory demonstration.
Expected Impact	• High system flexibility and security with a strong transmission backbone for liberating the electricity market. • Tools and mechanisms for system operation beyond current static ratings while keeping same security allowing for minimising generation re-dispatching costs and RES curtailments. • Develop new business opportunities and remuneration mechanisms for flexibility services that will result in an optimal generation and demand dispatch while boosting socioeconomic benefits for grid users and stakeholders
Additional Information	Promoting real-time monitoring and DLR improves the utilisation of existing grid infrastructure and might defer conventional investment in new OHLs. TSOs, universities/research institutes, and manufacturers. The outputs will be proposed configurations, use cases and pilot projects, and evaluations of results.
TRL Range	Initial TRL 5 – Final TRL 8
Proposed Timeline	2017– 2020
Estimated Budget	€ 8 million
Funding Scheme	Mainly EC and National Funding Programmes. Type of Project: Research Action.
Background / State of the Art	Indicative List of Projects: evolvDSO, Optimate, SEETSOC

Topic 7 – 2017	Multiservice storage applications
Cluster	C2, C3
Main FO Addressed	T6, T10
Supported FO	
Specific Challenge	The European electricity system is challenged by the high penetration of renewable electricity generation with fluctuating feeds. Developments in advanced storage technologies are capable of offering deployment possibilities that support the long-term EU energy policy objectives. Storage technologies can provide several services for both regulated entities and market players: congestion management, synchronisation (grid forming after disconnections/black-outs), frequency and voltage control, and integration of RES into the competitive energy markets. No single service is currently profitable on its own, but the sum of all services provided probably is. The key challenge is to favour a complete integration of storage in the electric system that enables recovering the full value of storage. A coordinated management of these flexibility means is a real challenge for TSOs - it will impact all time horizons, from long-term planning to very short-term stability measures.
Content / Scope	Activities should focus on storage integration within the electric system with the aim of valorising the multiservices offered by storage facilities and to value the grid-connected storage. There are technical issues to overcome and many economic, regulatory, market and environmental aspects must be addressed. From a technical point of view, flexibility can be provided by four distinct players: flexible power plants, demand response, storage, and the network itself (e.g., DLR, topology shifts,). Storage can be used to address a very large range of needs of the system: investment deferrals, congestion management, balancing and stability. From an economic perspective, none of the single services offered by storage is profitable. The key problem is with envisaging a new regulatory framework that enables recovering the full value of storage. This implies a mutualisation between the different services and avoiding a dedicated approach. A holistic approach, instead, should be adopted that encompasses both regulated and deregulated services and all time horizons. This will lead to a new loop between activities and actors that were previously separated.
Expected Results	Recommendations for a new regulatory framework and a novel market design that enables recovering the full value of storage in a cost-effective way. These recommendations should be technologically neutral so that the most efficient flexibility means emerge. Pilot demonstration of highly responsive power and energy storage integrated at both the HV and LV to show potential for balancing, congestion management, ancillary services, and new system services (grid forming) in the context a proliferation of power electronics. Tools for operation that enable mutualising the flexibilities offered by storage facilities and those by the grid itself (e.g., DLR).
Expected Impact	• Enhanced integration of RES owing to the surge in flexibility offered by storage. • Enhanced integration of power electronics into the electric system. • Deferred investments for transmission and distribution grid reinforcement and lower social costs associated with high penetration of fluctuating renewable power generation.
Additional Information	Partners involved are TSOs, universities/research institutes, and manufacturers.
TRL Range	Initial TRL 5 – Final TRL 8
Proposed Timeline	2017 – 2022
Estimated Budget	€ 20 million
Funding Scheme	Type of Project: Research and Innovation Action.
Background / State of the Art	EU-Funded Projects: MIGRATE, e-Highway2050, Optimate

Topic 8 – 2017	Demand response engineering
Cluster	C3
Main FO Addressed	T11, T19
Supported FO	T5, T6, T13, T15, T17, T19.
Specific Challenge	Services provided by large size prosumers and by medium-small prosumers connected to the HV, MV, and LV grid; advanced management of selected industrial clients based on system-benefits analysis.
Content / Scope	Scope is to demonstrate the feasibility of demand-side response (DSR) to provide ancillary services to power systems. This topic seeks to analyse different operation schemes, provide scenario analysis on the feasibility and penetration of DSR techniques and define case studies for real-environment implementation.
Expected Results	Scenario identification of developmental trends of the European electrical system: • Expected evolution of electrical demand • Electrical mobility scenarios and renewables penetration • Electrical market trends An exhaustive identification of the possible services that can be provided with DSR, like FCR, FRR, and congestion management; for each specific function, a comparison with traditional resources should be evaluated. Model for customer behaviours and baseline forecasting. Analysis of key-factors and guidelines for DSR implementation: consumer and producer aggregators, capacity market, advanced dispatching tools, imbalance regulation, and new market schemes. Study on the coordination and interoperability of electrical grid with other networks for DSR implementation: grid to vehicle (G2V), power to water (P2W), and power to gas (P2G). Definition of communication tools, platforms, and devices for increased observability and controllability of resources and measurement acquisitions. Suitable conditions for the settlement of units, especially considering load aggregates, compliant with regulatory framework. Availability assessment of resources pertaining to regulating power. Considering all the deliverables, the implementation of physical demonstrators will prove increased grid flexibility and the possibility of supplying enhanced ancillary services.
Expected Impact	DSR services will provide: • An increase of the available resources for ancillary services, an enhancement of system flexibility, and greater security. • The possibility for electrical consumers to exploit economic advantages associated with service provision.
Additional Information	DSR should be considered in the broader context of more system flexibility (T13). Physical demonstration implementation necessitates a serious improvement in measurement and control (T5 and T6), together with the assessment of standardised communication protocols for unit management (T19). Integration with new market schemes for ancillary services (T15 and T17) will also be a crucial feature. Research centres or academic institutions may be involved in scenario identification; large industrial consumers may contribute to demonstration implementation. Process integrators, electrical distributors, and external suppliers may also be considered.
TRL Range	Initial TRL 6 – Final TRL 8
Proposed Timeline	2017 – 2022
Estimated Budget	€ 4 million
Funding Scheme	EU Funding Programmes. Type of Project: Research and Innovation Action.
Background / State of the Art	According to the Smart Energy Demand Coalition (SEDC; "Mapping Demand Response in Europe Today – 2015"), DSR implementation is different across Europe – most infrastructures are already available and a number of national regulators have just included this service in the market structure. A dissymmetry can still be observed in national authority regulations; this has represented, till now, one of the major barriers to European market uniformity.

Topic 9 – 2017	Flexible market design
Cluster	C4
Main FO Addressed	T17
Supported FO	T15, T16
Specific Challenge	Integration of distributed flexibility resources into the wholesale market and new design options.
Content / Scope	Identify the technical scarcities at high RES and then design products to incentivise these needs in the future. Study the detailed impact of scalable and replicable solutions for RES integration using not only power markets but also system services. Development of tools that involve a global modelling of the major energy carriers able to account for different roles and players involved. Assessment of market developments in terms of grid-connected storage. Studies on tariffs and dynamic pricing.
Expected Results	A simulation toolbox quantifying the economic impact of the different proposed designs. New mechanisms towards optimal investments needs.
Expected Impact	A more efficient internal energy market that considers grid flexibility and an explicit modelling of uncertainties to increase cross-border exchange.
Additional Information	There will be a need to count on other TSOs and research institutes.
TRL Range	Initial TRL 4 – Final TRL 6
Proposed Timeline	2017 – 2021
Estimated Budget	€ 4 million
Funding Scheme	National and EU Funding Programmes. Type of Project: Research and Innovation Action
Background / State of the Art	EU-Funded Projects: Optimate

Topic 10 – 2017	ICT tools for data management
Cluster	C4, C5
Main FO Addressed	T18, T19
Supported FO	T11, T14, T16, T21
Specific Challenge	Using ICT tools for data management that enables smart development of the electricity system and synergies with other sectors (gas, heat, transport, and telecommunication). Assessment and development of ICT architecture, standards, requirements, roles, business models, exchange platforms, TSO / DSO processes, and consumer engagement. Demonstration of cross-border data exchange.
Content / Scope	Defining data-sharing models (architecture, functionalities, and processes). Understanding socioeconomic costs and benefits of different data sharing models. Describe high-level use cases for data services for market participants both at national level and across borders. Options for collecting, storing, and processing massive flows of data – more granular and closer to real-time data. Develop a concept of common interface for the customer considering the differences in data exchange platforms across countries. Applications facilitating TSO / DSO cooperation, e.g., provision of flexibility services. Synergies between metering and operational data. Suitable cyber-security methods and data privacy requirements for data sources. Necessary standards and protocols for data sharing between energy market participants. Testing the cross-border communication between data exchange platforms. Tackle the issue of data ownership and related responsibilities.
Expected Results	• Data sharing models that can be implemented in EU countries with descriptions, including architecture, functionalities, and processes. Demonstration of cross-border data exchange. • Pilot applications targeting different groups (e.g., consumers, network operators). • Data security and privacy requirements and feasible cyber-security methods for data exchange platform. • Suitable standards and protocols for data exchange.
Expected Impact	• Increased energy efficiency. • Smarter, i. e., more efficient asset management and system operation. • RES development. • Development of standards and improved cooperation with standardisation bodies. • Synergies through deeper TSO / DSO cooperation. • New business opportunities for different existing and new stakeholders. • Engagement of active consumer and other flexibility sources.
Additional Information	Partners Involved: TSOs, DSOs, ICT companies, and research institutions.
TRL Range	Initial TRL 4 – Final TRL 6
Proposed Timeline	2017 – 2020
Estimated Budget	€ 4 million
Funding Scheme	Horizon2020. Type of Project: Demonstration, Research and Innovation Action.
Background / State of the Art	Estfeed (www.estfeed.ee), FutureFlow (www.futureflow.eu), SGIH – Smart Grid Innovation Hub (www.eirgridgroup.com)

Topic 11 – 2017	ICT systems and data handling for system control
Cluster	C5
Main FO Addressed	T18, T19
Supported FO	C2/T5, T6, T7
Specific Challenge	The future power system will become much more complex and generation will be more uncertain. Generation facilities will be smaller, scattered over larger areas and then aggregated. Demand facilities will become more flexible and responsive to price changes. All in all, a massive communication task is foreseen. The intensive application of converter-based power electronics in generation and demand facilities will continue, e.g., electrical vehicles and storage units will explode. The grid system will be faced with a complex mix of AC and DC interconnectors in order to control the direction of active power flows that will no longer be from high-voltage to low-voltage levels as only generation facilities will be connected at lower-voltage levels. The predictability of system stability as well as stability margins will be tested, and so more advanced control strategies are necessary. The information exchange needs will increase dramatically along with the needs for IT applications to transmit, secure, and process huge amounts of data being a serious driver. Currently, there is a vital requirement for cost-efficient ICT infrastructure to monitor, control, and store real-time information, such as efficient data warehousing solutions, data mining tools to analyse huge volumes of real-time and processed data, and advanced applications to determine preventive control actions for further automation of system controls to maintain the stability of the grid.
Content / Scope	Development of cloud-based ICT supportive infrastructure, data monitoring and analysis of the control chain actions and automation of basic, as well as higher-level control strategies.
Expected Results	• Cost-effective solutions for a modern ICT infrastructure. • Advanced algorithms to implement decision-support applications in grid control centres. • Solutions for integrating automatic control and balancing of the grid system.
Expected Impact	• Improved system performance by increasing stability predictability and controllability based on improvements in observability, serviceability, and user interfaces. • Preservation and improvement of present high-level security of supply. • Pushing for more operator training and initial skills. • Requesting more simulation tools to support greater automation of grid management.
Additional Information	Many conferences have illustrated the needs for improvements and trends in tools and infrastructure solutions. The impact of different state of art and emerging communication technologies in future power system control should also be explored (e.g., 5G) TSOs, DSOs, and IT providers.
TRL Range	Initial TRL 6 – Final TRL 8
Proposed Timeline	2017 – 2021
Estimated Budget	€ 6 million
Funding Scheme	EU Funding Programmes. Type of Project: Research and Innovation Action
Background / State of the Art	Over the last ten years, the outcomes of various EU projects have pinpointed the need for improvements, e.g.: • The EU project, “Twenties”, under the FP7, called for more actions in the ICT arena and information security. • The EU project, “GARPUR”, under the FP7, called for more advanced and improved algorithms for control applications.

Topic 12 – 2017	Coordination of cyber-physical security within the energy sector
Cluster	C5
Main FO Addressed	T21
Supported FO	
Specific Challenge	To overcome existing restraints and provide a coordinated response for improved cyber-physical security within the energy sector.
Content / Scope	Identify, evaluate, and prioritise current and future risks for the European energy system, holistically addressing physical and cyber risks and the combination of both. Iteratively select, test, and validate a set of high-potential innovative technologies in order to deliver a first catalogue of proven innovative security technologies. Deliver the European Energy Security Distributed Assessment Centre (EESDAC), a full-fledged framework for the validation of innovative cyber-physical security technologies. It will consist of virtual and physical testing facilities permitting prequalification and labelling paths aligned with the security scenarios identified in the project. Offer educational capabilities and training opportunities for operators and related stakeholders, along with increasing knowledge and awareness of constantly developing threats and available solutions. Reach out, in Europe and beyond, to energy stakeholders and build a large-scale community of suppliers and users that will support and employ the EESDAC past the end of the project.
Expected Results	Selecting, testing, and validation of innovative technologies. Delivery of a testing facility as well as the development of educational and training capabilities.
Expected Impact	A safe transition towards the digitisation of transmission system operation and asset management.
Additional Information	TSOs, DSOs, research institutes, universities, and security organisations.
TRL Range	Initial TRL 5 – Final TRL 7
Proposed Timeline	2017 – 2020
Estimated Budget	€ 10 million
Funding Scheme	EU Funding Programmes. Type of Project: Research and Innovation Action
Background / State of the Art	EU-Funded critical infrastructure protection projects.

Topic 13 – 2018	Smart asset management through the use of "Big Data"
Cluster	C1
Main FO Addressed	T2
Supported FO	
Specific Challenge	To revisit lifetime-prediction modelling based on extended parameters. To define new and reliable monitoring systems. To specify and develop novel and relevant heuristics and approximations for integrated, realistic, and workable frameworks. To demonstrate how these approaches can be implemented, scaled up, and replicated cost effectively so that the expected benefits are realised.
Content / Scope	To integrate new sensors and equipment-condition monitoring approaches based on distributed technologies. To implement robotics for automated condition monitoring or diagnostic systems for incipient problem detection as well as to intervene in hostile environments and eliminate the need for human maintenance. Live line maintenance and working practises and the use of drones for network monitoring.
Expected Results	New approaches for extending the lifetime of existing power components based on improved monitoring, measurements, and models to determine of their health and remaining lifetime. Novel approaches for managing critical assets based on probabilistic risk assessment and optimisation of maintenance planning that have been shown to reduce operational costs while increasing network flexibility and facilitating adequate power quality.
Expected Impact	Optimised costs for asset maintenance activities while increasing the lifetime of existing assets.
Additional Information	Involved Entities: TSOs, DSOs, IT providers, and security organisations.
TRL Range	Initial TRL 6 – Final TRL 8
Proposed Timeline	2018 – 2022
Estimated Budget	€ 8 million
Funding Scheme	Preferably EC and National Funding (if available).
Background / State of the Art	–

Topic 14 – 2018	Interactions with other energy systems
Cluster	C3
Main FO Addressed	T14
Supported FO	T6, T8, T10, T12
Specific Challenge	Decarbonisation is essential for coping with long-term EU sustainability targets, and electricity is one of the main vectors leading this transition. From the demand-side perspective, electrification of the transport, heating, and cooling sectors provides a pathway to fulfilling this objective. On the generation side, it could be effective for the energy system to coordinate and couple electricity generation with the gas supply for combined cycles.
Content / Scope	The main emphasis will be on enabling energy systems to integrate (very) high shares of renewable generation with conventional generation, smart transmission, and distribution grids and smart storage. This also includes power-to-X, enabler technologies (power electronics), batteries, and other storage systems in order to raise the efficiency of power generation with greater flexibility and resilience. An additional priority will be smart digital management of energy systems to foster well-organised exploitation of combined capacities and flexibilities of the electricity, gas, heating, cooling, water, and transport sectors. Cross-border energy systems will have to be enabled from a technical, economic, regulatory, and legal viewpoint. Developing tools to analyse balancing and congestion issues across the entire energy system and supporting the most efficient technologies in restoration plans will be key. Developing data exchange applications that facilitate system operation, network planning, and flexibility services is essential.
Expected Results	Models and tools to manage balancing and congestion problems. Coordination actions and communication platforms with other system players.
Expected Impact	• Better and more optimal decision-making tools. • Holistic models that make use of the most cost-effective solutions for supplying energy.
Additional Information	Research organisations.
TRL Range	Initial TRL 3 – Final TRL 7
Proposed Timeline	2018 – 2022
Estimated Budget	€ 7 million
Funding Scheme	Mainly EC and National Funding Programmes. Type of Project: Research Action.
Cluster	EU-Funded Projects: Real-Smart, GridTech

Topic 15 – 2019	Optimal grid design based on the use of the most cost-effective solutions / technologies to integrate more flexibility into the system
Cluster	C1
Main FO Addressed	T1
Supported FO	T4, T10, T13
Specific Challenge	Optimal grid design will combine the integration of the uncertainty of variable RES and DER, demand response, storage, as well as the interface with other energy and transport / mobility networks under the scope of cost-effective solutions.
Content / Scope	Planning methods are to be developed based on market analysis, production capacities, DR capacities and infrastructure, and storage and environmental constraints, both at the transmission and distribution levels. Optimal grid design planning will be examined within the uncertainty framework, i. e., probabilistic approaches, no-regret options and risk management. Accounting for coupling with other energy networks, specifically gas but also heat and cold.
Expected Results	Identification of the most cost-effective technologies. Delivery of planning tools for network development, both for cross-border and TSO / DSO system development, considering a broad spectrum of novel technologies.
Expected Impact	Propose a tool to send investment signals to all stakeholders, not only technology developers but also to those accountable for building the infrastructure.
Additional Information	Universities and research centres, software developers, and experts in the field of system operations, planning and markets. It is expected that there will be the development of pilot software, though not at a commercial stage, to demonstrate the concepts.
TRL Range	Initial TRL 6 – Final TRL 8
Proposed Timeline	2019 – 2026
Estimated Budget	€ 10 million
Funding Scheme	Type of Project: Research and Innovation Action.
Background / State of the Art	EU-Funded Projects: e-Highway 2050, Realised Grid, Umbrella, I Tesla, Garpur

Topic 16 – 2019	Public acceptance and stakeholder's participation
Cluster	C1
Main FO Addressed	T4
Supported FO	T1, T2, T3, T14 , T20
Specific Challenge	The manifestation of a secure, sustainable, and competitive European system requires underlying transmission infrastructure. There is a need to enhance public acceptance and stakeholder participation in transmission infrastructure while also reducing environmental impact.
Content / Scope	Increase communication campaigns, develop social impact studies, and raise the involvement of local and territorial bodies during the early stage of planning of the infrastructure. Analyse new technologies that have reduced conductor visibility and propose new towers and station designs with less virtual-visual impact, audible noise, and electromagnetic fields.
Expected Results	Guidelines on best practices to manage projects from the very beginning to minimise their negative effects and promote stakeholder engagement and acceptance (for each situation / kind of project or asset).
Expected Impact	Diminish the number of projects / assets that cannot not be realised because of public acceptance issues. Among those that can be realised: • Adoption of technical solutions which have higher returns in socioeconomical terms with global scope (not linked to specific social groups). • Reduction of the realisation time of selected technical solutions.
Additional Information	–
TRL Range	Initial TRL-5 – Final TRL7
Proposed Timeline	2019 – 2026
Estimated Budget	€ 5 million
Funding Scheme	–
Background / State of the Art	EU-Funded Projects: Best grid, Life ELIA, Twenties (results focused on interconnection links)

Topic 17 – 2019	Improve RES forecasting and optimal capacity operation
Cluster	C2
Main FO Addressed	T12
Supported FO	T7, T10, T11, T13, T15, T16
Specific Challenge	Forecasting the production of RES with a high level of accuracy is key for optimisation of the system, especially in situations of high penetration of variable RES. Better forecasting can be accomplished by improving the quality of meteorological inputs (e.g., wind speed, temperature, irradiation) and utilising hybrid approaches that combine weather forecasts, local ad hoc models, historical data, and on-line measurement.
Content / Scope	The goal is to determine the best method for deploying and demonstrating different concepts using ICT, ancillary services, and models for reliable energy output so that clean energy can be integrated, forecasted, and smartly managed.
Expected Results	Effective mechanisms, instruments, and rules will be validated for the management of variable sources in system operation and power markets. Combining various approaches in the models should merge their strengths.
Expected Impact	More RES will be integrated into the pan-European system without impacting its reliability.
Additional Information	In RES production forecast models, meteorological inputs are those with the most room for improvement. Enhancing meteorological models could have an impact on other forecast models apart from RES production, like demand forecasting, where minor improvements might majorly affect optimisation of system operation.
TRL Range	Initial TRL 3 – Final TRL 8
Proposed Timeline	2019 – 2020
Estimated Budget	€ 10 million
Funding Scheme	Type of Project: Research Action.
Background / State of the Art	EU-Funded Projects: Optimate, Anemos, Safewind, BestPaths, Grid Tech, Realisedgrid, Seetsoc, Windgrid, Ewis.

Topic 18 – 2017	Probabilistic methods for generation of adequacy planning
Cluster	C1, C2, C3 (Inter-TSO Cooperation)
Main FO Addressed	T1, T8, T13
Supported FO	T10, T11, T12
Specific Challenge	An increasing share of variable renewable energy in the system is a precondition for critical situations in the future and requires improvement of the current methods for assessing risk in generation adequacy, not only in terms of peak load, but considering changing climate conditions (Pan-European Climate Database (PECD) to 35 climatic years), available balancing reserves, demand-side management potential, etc. All these combinations of circumstances call for the need for probabilistic methods that will assist the computation and assessment of the risks and will exhibit the potential weak spots, resulting in possible solutions for operational and long-term planning.
Content / Scope	Using probabilistic simulation methods to identify different combinations of uncertainties in the power system on average and critical conditions (e.g., stress situations, situations of scarcity of power generation, weather conditions). Based on the ENTSO-E Mid-Term Adequacy Forecast (MAF) report for 2016, there is a need for continued development of the modelling tools and a revision of the data assumptions for more accurate assessment of generation adequacy in the future. [1]
Expected Results	Expected results are new and improved methods and tools for adequacy analysis that incorporate: • Overview and updated data for decommissioning of power plants complying European rules and regulations • Use of the PECD to 35 climatic years • Modelling of demand-side response • Utility of flow-based market methodology • Elaboration of cross-border interconnector assumptions and sensible assessment of cross-board support.
Expected Impact	• Improving and applying the methodologies used by ENTSO-E for assessment of generation adequacy at the national, regional and pan-European level. • Robust planning for and assessing operational reserve adequacy and load shedding risks will negate overinvestment in the network and will assist flexibility. • Enhancing the current methods for evaluating generation adequacy will supply higher quality information on generation reserves for operational planning and long-term planning and will bolster reliability and security at the national and pan-European levels.
Additional Information	Research questions could include, e.g.: • how to take demand response and short-term energy storage into account during adequacy analysis • how to consider the correlation between short-term and seasonal weather variations and fault frequencies of different power system components • how to manage the computational effort required by different calculation methods (e.g., Monte Carlo simulations).
TRL Range	
Proposed Timeline	2017 – Onwards
Estimated Budget	
Funding Scheme	
Background / State of the Art	All the listed recommendations are based on and in line with results of ENTSO-E MAF Report for 2016.

Topic 19 – 2017	High impact of low-probability events
Cluster	High impact of low-probability events
Main FO Addressed	
Supported FO	
Specific Challenge	The complexity and uncertainties of the power system have been ever-increasing since its creation, a trend that will continue with the introduction of more smart devices, new technologies, renewables and distributed energy resources, and more extreme weather. Even in the present power system, the mechanisms behind extraordinary events are not well understood. Regardless of the root cause of such occurrences, the resulting consequences will be of such a magnitude that society will incur great losses. As such, both the TSOs as well as society needs more knowledge and methods for assessing extraordinary events.
Content / Scope	Develop methods and tools for analysing risk and vulnerability related to extraordinary events in the power system, including: 1. Qualitative framework for analysing extraordinary events 2. Quantitative methodology for assessing extraordinary events 3. Methodologies for quantification and interpretation of uncertainties related to extraordinary events. Make certain that the developed methodologies are applicable to real systems through case studies conducted on real transmission systems in collaboration with TSO partners.
Expected Results	The anticipated results will be methodologies and prototyped tools for analysing extraordinary events.
Expected Impact	The primary objectives of evaluating the reliability of electricity supply is to provide decision support for the TSOs to aid them in arriving at a reasonable trade-off between reliability and investment costs. The methodologies developed within this project will generate value for the participating TSOs through improved system reliability and knowledge base with respect to extraordinary events.
Additional Information	The project has been granted support from the Norwegian Research Council as a "Knowledge-Building Project for the Industry".
TRL Range	Initial TRL 2 – Final TRL 5
Proposed Timeline	2017 – Onwards
Estimated Budget	€ 1 – 3 million
Funding Scheme	National Funding Programme.
Background / State of the Art	Extraordinary events comprise complex mechanisms involving various parts of the power system, requiring knowledge of many disciplines within the field of power system studies. The consequences of power system events are traditionally estimated through contingency analyses. In general, relevant contingencies have been selected by experts or by screening techniques utilising approximate power flow techniques. In recent years, probabilistic techniques employing fault and event trees have been proposed. Studying extraordinary events requires more than merely running a power-flow calculation. For instance, there are many complex chains of events that should be correctly modelled to be able to estimate consequences accurately. In this regard, there has, in latter years, been progress in modelling of cascading outages. Important factors involved in cascading failures include dependent faults, hidden faults, and corrective actions. The effect on reliability by taking the probability of unsuccessful corrective actions into account is among the aspects investigated in the GARPUR project. To capture the dynamics of a blackout, detailed dynamic data may also be needed.

Topic 20 – 2017	Optimal use of storage plants
Cluster	C3 (Inter-TSO Cooperation)
Main FO Addressed	T10
Supported FO	T8, T9, T13
Specific Challenge	Use of existing storage laboratory facilities for demonstration of typologies and determining added value from storage technologies.
Content / Scope	The integration of storage facilities into transmission systems is a promising solution for advanced grid services implementation as well as an effective means to increase system flexibility. The scope of the topic is to analyse the performances of different storage technologies for ancillary service provision.
Expected Results	• Scenario identification related to storage penetration: – Evolution of distributed storage in the European network considering e-Mobility development, renewables integration, and plug-and-play architectures diffusion. – Large-scale storage development in transmission and distribution systems for regulation services. • A review of the state-of-the art and a critical comparison between the available storage technologies (battery energy storage systems, compressed air energy storage systems, flywheels, super-capacitors). • An exhaustive analysis of possible services obtainable with storage technologies: – Fast frequency regulation services, FCR, FRR, or congestion management – RES curtailment reduction – System security increase: integration of storage systems into TSOs restoration plans during blackouts and for the black-start of traditional generating groups. • Aging model definitions for several technologies per the operating conditions and required regulation services. • Identification of certain key factors that would determine a broader penetration of storage in electrical systems. • Definition of communication tools, platforms, and devices for increased observability / controllability of resources and measurement acquisition. • Virtual storage implementation – technological and regulatory conditions. • Impact of the cloud-storage model on power system management. • Characterisations of specific regulatory frameworks that would enhance storage distribution.
Expected Impact	Large storage projects would have the following positive impacts: • Provide a significant flexibility to TSOs that will grant the possibility of exploiting innovative ancillary services and higher availability of resources • Push national authorities towards new regulatory frameworks • Development of new business models related to dispatching services provision for electrical market operators.
Additional Information	Owing to the possibility of providing enhanced ancillary services (T9) and increased reliability (T8), large-scale storage development can be considered in the broader perspective of flexible grid use (T13).
TRL Range	Initial TRL 7 – Final TRL 8
Proposed Timeline	Ongoing
Estimated Budget	
Funding Scheme	TSOs' own resources
Background / State of the Art	Per Bloomberg's Global Energy Storage Forecast, between 2016 and 2024, the storage market will experience an exponential increase in its volume, both considering large-scale applications for system operators and domestic distributed storage facilities. Terna (IT) has installed 35 MW of energy-intensive storage for congestion management and a storage laboratory for the evaluation of battery technologies and aging model definitions under different operating conditions.

Topic 21 – 2017	Best practices exchange in cyber-security
Cluster	C5 (Inter-TSO Cooperation)
Main FO Addressed	T21
Supported FO	C5/T18
Specific Challenge	Ensure company IT system security, including protection of: • hardware from theft or damage • software from contamination and malfunctioning • data from undue access and misuse • entire system from disruption or misdirection. Controlling physical access to the hardware as well as protecting against harm that may arrive via network access, data and code injection, and malpractice by operators, whether intentional, accidental, or because of being tricked into deviating from secure procedures. This field is of growing importance because of the ever-increasing reliance on computer systems in most industrial sectors and societies. Computer systems now include a wide variety of "smart" devices, including smartphones, televisions, and tiny devices, as part of the internet of things (IoT), and networks include the internet and private data networks.
Content / Scope	• ITC security standards and architecture. • Security measures, monitoring, detection, and reactions. • Organisation of security and governance models. • External threats and risk-level analysis. • Real case examples and scenarios for fast resolution. • Security agenda and security initiatives - periodical and on-demand. • Prevention procedures and employee education and behaviour. • Early spotting and identifying threats. • On-site resolution of attacks.
Expected Results	Exchange of experiences, case studies, risk-analysis models, ITC disaster recovery procedures, cyber-security strategies, ITC defence plans, and data protection systems.
Expected Impact	Elevated safety and security of IT systems and therefore of all company processes and technical operations.
Additional Information	Topic addressed multilaterally or bilaterally under the inter-TSO cooperation pillar of the ENTSO-E Roadmap.
TRL Range	N/A
Proposed Timeline	2017 – Onwards
Estimated Budget	–
Funding Scheme	TSOs' own resources and EU Funding
Background / State of the Art	Starting point is, for each TSO, its own security systems, to be benchmarked against European peers.

Topic 22 – 2018	Partially insulated OHL conductor
Cluster	C1 (Inter-TSO Cooperation)
Main FO Addressed	T3
Supported FO	
Specific Challenge	Partially insulated OHL Conductor – operate a 400 kV circuit on a 110 kV tower.
Content / Scope	To engineer, set up, and test the optimal insulation level to cater to utilisation of 110 kV infrastructure at 400 kV. To generalise the use case, identify the optimal upgrade rate for voltage levels, and define the criteria for possible voltage upgrade cases of different OHLs.
Expected Results	Demonstrate the viability of such an original scheme and assess the achievable savings, transformation costs, advantages, and drawbacks.
Expected Impact	Avoid or delay new investments in OHL lines. Reduce CapEx for attaining higher transmission capacities. Increase public acceptance of more powerful corridors.
Additional Information	
TRL Range	Initial TRL 7 – Final TRL 9
Proposed Timeline	2018 – 2029
Estimated Budget	€ 1 million
Funding Scheme	TSO's own resources
Background / State of the Art	N/A (Original Research Topic)

Topic 23 – 2018	Developing tools for better system awareness based on "Big Data" analysis
Cluster	Inter-TSO cooperation
Main FO Addressed	T18
Supported FO	
Specific Challenge	Inadequate use of already existing "Big Data"-measurements from power system (from PMUs, AMR devices and sensors), weather forecasts (temperature, wind solar and rain), electricity market data (volumes and prices) etc.
Content / Scope	Exploring the capabilities of "Big Data" for performing/improving risk analysis and system operation.
Expected Results	Methods and tools applicable for TSOs to fully utilise their data for better trending and power system state awareness, in general.
Expected Impact	• Enhanced system awareness enables actions (planning and operation) in real time. • Real-time awareness for control and quantitative information on long-term trends in power system changes (planning).
Additional Information	External specialists required (e.g., mathematicians that understand data-mining techniques)
TRL Range	Initial TRL 4 – Final TRL 6
Proposed Timeline	2018 – 2021
Estimated Budget	€ 2 million
Funding Scheme	TSO's own resources
Background / State of the Art	N/A (Original Research Topic)

APPENDIX 2
ENTSO-E R&I ROADMAP 2017 – 2026

In the revised R&I Roadmap 2017–2026, ENTSO-E strategically repositioned R&I, bridging a potential gap between TSOs' R&I priorities and EC funding policy, which could lead to the situation that topics of interest for TSOs would not be properly covered in the EC calls, the latter of those being of a more integrated nature. In the revised Roadmap, ENTSO-E strategy is based on the two main pillars:

- EC-driven projects, where ENTSO-E has a central aggregation and coordination role,
- Inter-TSO approach, where TSOs may execute projects within a lighter framework than that provided by the EC and on topics not addressed by EC calls.

Clusters	Functional Objectives	FO Content
C1 Power System Modernisation	T1 Optimal grid design	Optimal grid design: planning, adequacy, tools
	T2 Smart Asset Management	Smart Asset Management; predictive and on-condition maintenance; capex optimisation
	T3 New materials & technologies	Use of new materials and power technologies; new construction and maintenance methods
	T4 Environmental challenges & stakeholders	Environmental impact, public acceptance, stakeholders participation
C2 Security and System Stability	T5 Grid observability	Observability of the grid: PMUs, WAM, Sensors, DSO information exchange
	T6 Grid controllability	Controllability of the grid: frequency and voltage stability, power quality, synthetic inertia
	T7 Expert systems and tools	Decision support tools, automatic control and expert systems
	T8 Reliability and resilience	Reliability and resilience: defense and restauration plans, probabilistic approach, risk assessment, self healing
	T9 Enhanced ancillary services	Enhanced ancillary services for network operation; cross-border supply of services
C3 Power System Flexibility	T10 Storage integration	Storage integration, definition and use of storage services; system added value from storage
	T11 Demand Response	Demand Response, tools to use DSR; Load profile, EV impact
	T12 RES forecast	Improved RES forecast and optimal capacity operation
	T13 Flexible grid use	Flexible grid use: dynamic rating equipment, power electronic devices; use of interconnectors
	T14 Interaction with non electrical energy networks	Interaction/coordination with other energy networks (gas, heat, transport)
C4 Power System Economics & Efficiency	T15 Market – grid integration	Integration of market and grid operation across timeframes (up to real time)
	T16 Business models	Business models (for storage, grid extension, distributed generation) for optimal investments in the network
	T17 Flexible market design	Market design for adequacy, flexibility use, cross border exchanges, rationale use of RES, demand management
C5 ICT & Digitalisation of Power System	T18 Big data	Big data, data mining, data management
	T19 Standardisation & data exchange	Standardisation, protocols for communications and data exchange with DSOs and other grid operators
	T20 Internet of Things	New communication technologies, Internet of Things
	T21 Cybersecurity	Cybersecurity

Table 9: List of Clusters and FOs of the ENTSO-E R&I Roadmap 2017–2026

The first pillar denotes interactions and formal collaborations also with associations of DSOs (EDSO for Smart Grids), storage operators (EASE), and research institutes (EERA) in the spirit of the Europe-wide integrated approach advocated by the EC, whilst the second pillar will enable TSOs to cope with challenges not covered by EU funding schemes and also secure funds for issues close to the TSO core business.

The adopted strategy has implied a structural change in the Roadmap, reflecting transformation of the European energy system into one that is integrated and emphasising strong links between the electricity, gas, heat, and transport sectors. Hence, the new Roadmap anticipates the integration of different technologies within the European market framework.

The revised ENTSO-E R&I Roadmap 2017–2026 features five Clusters, where each cluster comprises several FOs as depicted in Table 9. The clusters and FOs are greatly interdependent, meaning that each cluster (or FO) addresses at least one task or duty that is relevant for all TSOs - network operation, asset management, network planning, market, or duties stemming from societal and stakeholder needs. Likewise, each task or duty of a TSO may be assigned to more than one cluster. The interested reader of the ENTSO-E R&I Roadmap 2017–2026 is referred to the official ENTSO-E website[1)].

Roadmap timeline is laid out in Figure 5.

1) http://riroadmap.entsoe.eu/

Clusters	Functional Objectives	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
C1 Power System Modernisation	T1 Optimal grid design										
	T2 Smart Asset Management										
	T3 New materials & technologies										
	T4 Environmental challenges & stakeholders										
C2 Security and System Stability	T5 Grid observability										
	T6 Grid controllability										
	T7 Expert systems and tools										
	T8 Reliability and resilience										
	T9 Enhanced ancillary services										
C3 Power System Flexibility	T10 Storage integration										
	T11 Demand Response										
	T12 RES forecast										
	T13 Flexible grid use										
	T14 Interaction with non-electrical energy networks										
C4 Power System Economics & Efficiency	T15 Market – grid integration										
	T16 Business models										
	T17 Flexible market design										
C5 ICT & Digitalisation of Power System	T18 "Big Data"										
	T19 Standardisation & data exchange										
	T20 Internet of Things										
	T21 Cybersecurity										

Figure 5: Timeline of the ENTSO-E R&I Roadmap 2017–2026

APPENDIX 3 CONSULTATION PROCESS AND OUTCOME

The public consultation for the IP 2017–2019 was carried out in February and March 2017, both through announcement on the ENTSO-E website and via direct contact (e-mail request) with relevant stakeholders, such as ETIP-SNET, EERA Joint Programmes on Smart Grids, EWEA, EASE, EDSO4SG, CORESO, EURELECTRIC, INEA, T&D Europe, Greenpeace, etc.

Stakeholders were invited to:

a) identify missing topics within the current IP;

b) rank the IP topics. The respondents were asked to rank topics from 1 to the number of topics in each cluster (Table 9). For example, there are 6 topics pertaining Cluster 1, and so the topics could be ranked from 1 to 6, where 1 was the highest priority/rank and 6 was the lowest priority/rank;

c) express general comments about each Cluster.

Cluster	Topics	Total Number of Topics in Cluster
C1	T1, T13, T15, T16, T18, T22	6
C2	T2, T3, T4, T19, T23	5
C3	T5, T6, T7, T8, T14, T17, T20	7
C4	T9	1
C5	T11, T12, T10, T21	4

Table 10: Topics in Clusters

ENTSO-E welcomed all comments that were received and is grateful for the contributions of the participants: ABB, Intracom, CORESO, Open Energi, AESTechnologies OU, University Stuttgart together with VGB PowerTech, University Belgrade, Sintef Eneryg, and ElaadNL.

All comments were addressed and the present IP was accordingly updated. Full information on the received comments and reactions is found on the ENTSO-E website.

In addition, a graphical representation has been produced to show the stakeholder preferences. The methodology applied for this representation adopts the following logic:

- all the ranks, from all respondents for each topic, was summed up;
- reciprocal values were determined;
- ranks were multiplied by 100 and rounded to the nearest one decimal digit.

Following this logic, the highest possible value that could be assigned to a topic, if all respondents ranked it "1", was 10. This was the case for Cluster 4, where there was only one topic associated with it. When there were more options to rank, the variance of the obtained rank increased and the values of the rank were reduced.

The following figures report the rankings identified by the respondents for each Cluster except C4. The full list of comments received, together with ENTSO-E comments and the description of the actions taken, is published on ENTSO-E website. Modifications, clarifications, and additions to the topics and their characteristics, which were accepted, are included in the descriptions of Annex 1.

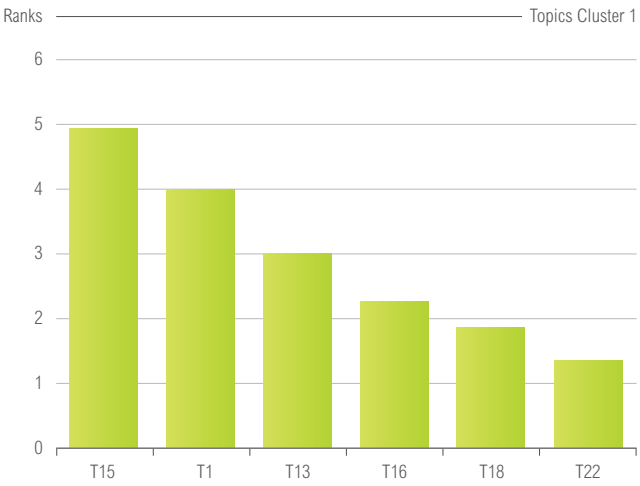

Figure 6: Rankings identified by the respondents for Cluster 1

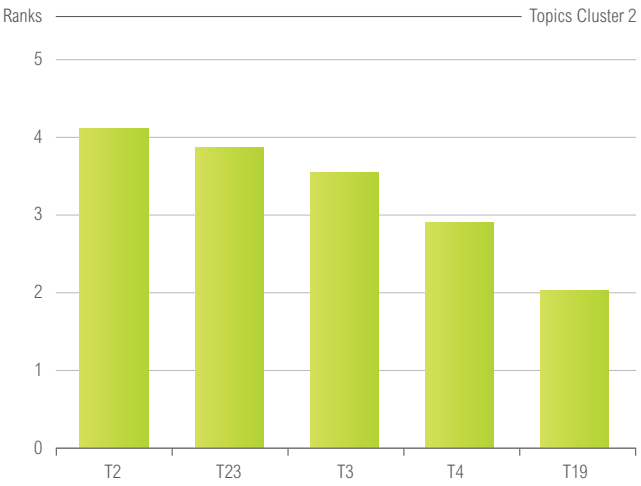

Figure 7: Rankings identified by the respondents for Cluster 2

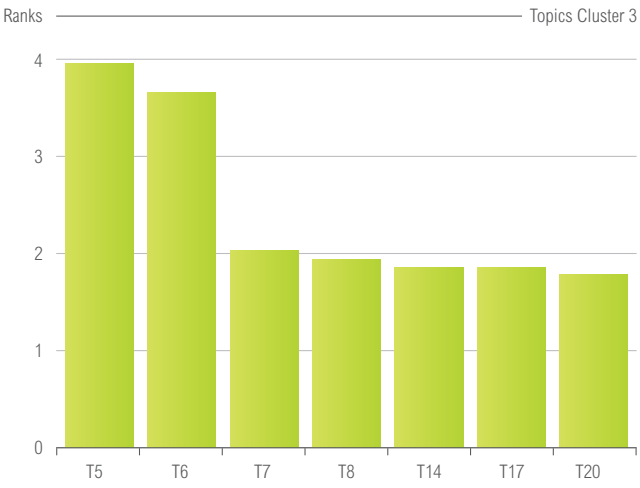

Figure 8: Rankings identified by the respondents for Cluster 3

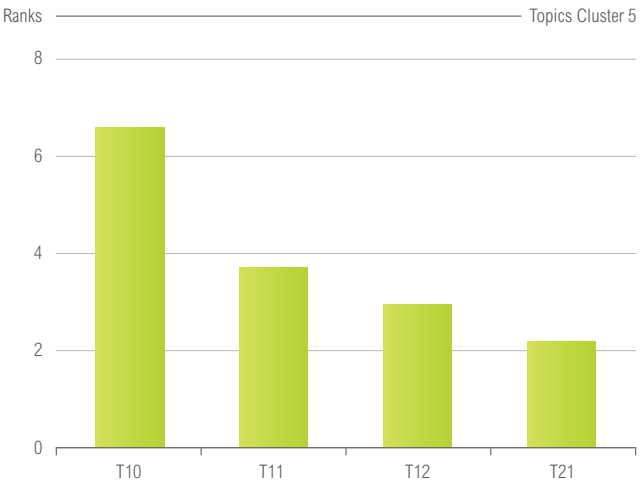

Figure 9: Rankings identified by the respondents for Cluster 5

ABBREVIATIONS

ACER	Agency for the Cooperation of Energy Regulators
DER	Distributed Energy Resources
DSO	Distribution System Operator
EASE	European Association for the Storage of Energy
EC	European Commission
EEGI	European Electricity Grid Initiative
EERA	European Energy Research Alliance
EII	European Industrial Initiative
ENTSO-E	European Network of Transmission System Operators for Electricity
ETIP	European Technology and Innovation Platform
ETIP-SNET	European Technology and Innovation Platform – Smart Networks for Energy Transition
FACTs	Flexible Alternating Current Transmission Systems
FO	Functional Objective
FCR	Frequency Containment Reserve
FRR	Frequency Restoration Reserve
H2020	Horizon 2020 (EU Research and Innovation Programme 2014–2020)
ICT	Information and Communication Technology
IP	Implementation Plan
NGO	Non-Governmental Organisations
NRA	National Regulatory Authority
PMU	Phasor Measurement Unit
PECD	Pan-European Climate Database
R&I	Research, Development and Innovation (sometimes also referred to as R&D or RD&I)
RES	Renewable Energy Sources
RIA	Research and Innovation Actions
SET Plan	Strategic Energy Technology Plan
SETIS	Strategic Energy Technologies Information System
SNET	Smart Network for Energy Transition
TRL	Technology Readiness Level
TSO	Transmission System Operator
WAM	Wide Area Measurement System

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