ENTSO-E

RDI MONITORING REPORT 2022

RESEARCH, DEVELOPMENT AND INNOVATION PROJECTS

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ENTSO-E Mission Statement

Who we are

ENTSO-E, the European Network of Transmission System Operators for Electricity, is the **association for the cooperation of the European transmission system operators (TSOs)**. The **39 member TSOs**, representing 35 countries, are responsible for the **secure and coordinated operation** of Europe's electricity system, the largest interconnected electrical grid in the world. In addition to its core, historical role in technical cooperation, ENTSO-E is also the common voice of TSOs.

ENTSO-E **brings together the unique expertise of TSOs for the benefit of European citizens** by keeping the lights on, enabling the energy transition, and promoting the completion and optimal functioning of the internal electricity market, including via the fulfilment of the mandates given to ENTSO-E based on EU legislation.

Our mission

ENTSO-E and its members, as the European TSO community, fulfil a common mission: Ensuring the **security of the interconnected power system in all time frames at pan-European level** and the **optimal functioning and development of the European interconnected electricity markets**, while enabling the integration of electricity generated from renewable energy sources and of emerging technologies.

Our vision

ENTSO-E plays a central role in enabling Europe to become the first **climate-neutral continent by 2050** by creating a system that is secure, sustainable and affordable, and that integrates the expected amount of renewable energy, thereby offering an essential contribution to the European Green Deal. This endeavour requires **sector integration** and close cooperation among all actors.

Europe is moving towards a sustainable, digitalised, integrated and electrified energy system with a combination of centralised and distributed resources.

ENTSO-E acts to ensure that this energy system **keeps consumers at its centre** and is operated and developed with **climate objectives** and **social welfare** in mind.

ENTSO-E is committed to use its unique expertise and system-wide view – supported by a responsibility to maintain the system's security – to deliver a comprehensive roadmap of how a climate-neutral Europe looks.

Our values

ENTSO-E acts in **solidarity** as a community of TSOs united by a shared **responsibility.**

As the professional association of independent and neutral regulated entities acting under a clear legal mandate, ENTSO-E serves the interests of society by **optimising social welfare** in its dimensions of safety, economy, environment, and performance.

ENTSO-E is committed to working with the highest technical rigour as well as developing sustainable and **innovative responses to prepare for the future** and overcoming the challenges of keeping the power system secure in a climate-neutral Europe. In all its activities, ENTSO-E acts with **transparency** and in a trustworthy dialogue with legislative and regulatory decision makers and stakeholders.

Our contributions

ENTSO-E supports the cooperation among its members at European and regional levels. Over the past decades, TSOs have undertaken initiatives to increase their cooperation in network planning, operation and market integration, thereby successfully contributing to meeting EU climate and energy targets.

To carry out its **legally mandated tasks**, ENTSO-E's key responsibilities include the following:

- Development and implementation of standards, network codes, platforms and tools to ensure secure system and market operation as well as integration of renewable energy;
- Assessment of the adequacy of the system in different timeframes;
- Coordination of the planning and development of infrastructures at the European level (**Ten-Year Network Development Plans, TYNDPs**);
- Coordination of research, development and innovation activities of TSOs;
- Development of platforms to enable the transparent sharing of data with market participants.

ENTSO-E supports its members in the **implementation and monitoring** of the agreed common rules.

ENTSO-E is the common voice of European TSOs and provides expert contributions and a constructive view to energy debates to support policymakers in making informed decisions.

Contents

Executive Summary

The Research, Development & Innovation (RDI) Monitoring Report 2022 provides a detailed statistical analysis of the current development of the European Transmission System Operators (TSOs') RDI activities and monitors their alignment with the **RDI Roadmap 2020 – 2030 (RDI Roadmap)** and other strategic documents, such as the **RDI Implementation Report 2021 – 2025** and the Acceleration Mission paper, as well as with the business areas in the **ENTSO-E Vision: A Power System for a Carbon Neutral Europe**.

The RDI Roadmap identifies three major RDI Areas / Clusters addressed by six Flagships (Figure 1), setting over 80 milestones which drive the research activities towards a pan-EU energy system with net zero emissions of greenhouse gases in 2050.

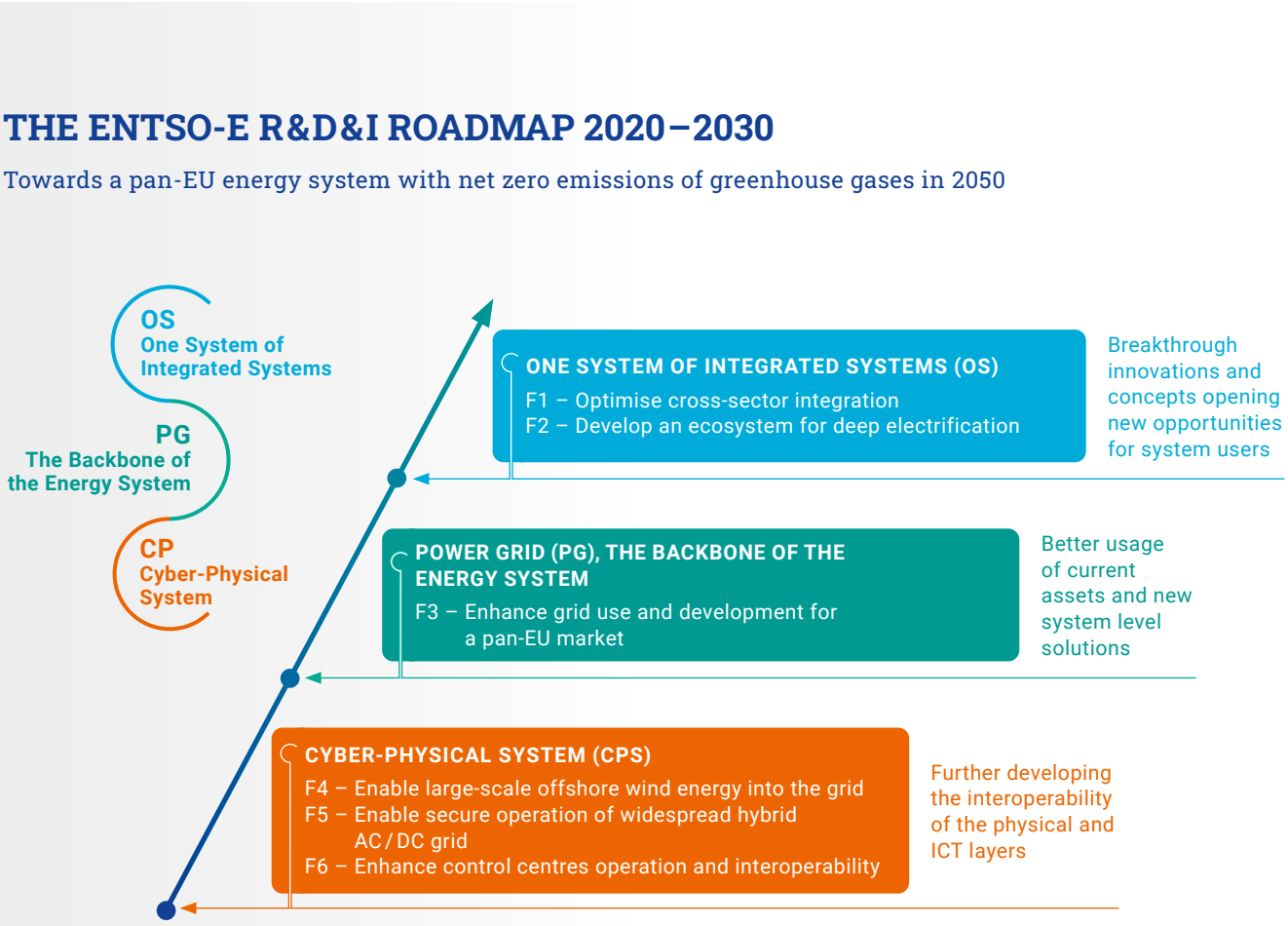

Figure 1: ENTSO-E RDI Roadmap 2020–2030

The information used in this monitoring activity was collected from questionnaires given to ENTSO-E members, and responses were received until April 2022, representing a total of 117 projects. The results show a very good alignment with the milestones from the RDI Roadmap, with over 80 % of these milestones already addressed on different levels by the current RDI efforts, demonstrating a strong commitment from TSOs to deliver the necessary innovations towards carbon neutrality in 2050. Figure 2 summarises the alignment of the current research activities with the RDI Roadmap.

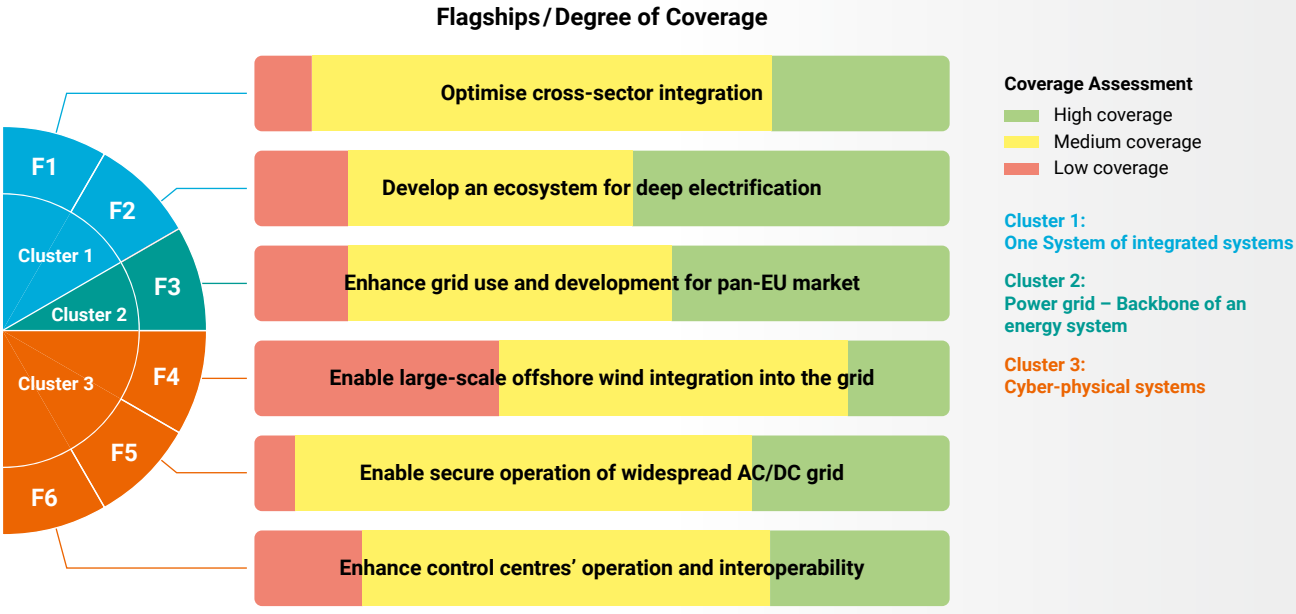

Figure 2: Overview of the alignment between ongoing RDI activities and the ENTSO-E RDI Roadmap

Highlights

- This monitoring report surveyed 117 projects. There is a significant share of projects funded, or co-funded, by the TSOs (51 %), showing that research is already a business support activity in the energy transition.

- Over 80 % of the milestones from the RDI Roadmap are already addressed on different levels by the current research activities, showing the deep commitment of TSOs towards carbon neutrality and the strong alignment with the Green Deal and the REPowerEU action plans.

- Two out of seven focus topics identified by the Acceleration Mission paper to accelerate the energy transition according to the 'Fit for 55' package have a high degree of coverage by the current research efforts. These are the 'Improved modeling and management of extended datasets', and the 'Automated decision support system'. There are still open questions concerning these milestones, such as collaborative network planning and coordinated active system management, as well as the development of vendor independent solutions for automated decision support systems.

- The 117 surveyed research projects declared a total of 192 Key Exploitable Results (KERs). The majority of the results are innovative methodologies (29 %), software tools (28 %) and hardware (15 %), while the most frequent effective use of KERs is public (41 %), followed by collective use (30 %), with a much lower rate of commercial use (4 %).

- Most of the projects' KERs have an expected Technological Readiness Level (TRL) at the end of the project of below TRL 8, but there is a significant concentration at TRL 7 and TRL 9. The most frequent expected time to exploitation of the KERs is less than 5 years. The regulatory framework, followed closely by market conditions, were cited as the most significant barriers to the use of KERs, accounting together for almost 50 % of the responses regarding barriers.

- The fact that the largest share of partnerships is with R&I institutions and universities, and with industry, shows that research projects involving TSOs are a 'hands on' platform for knowledge transfer, serving as a bridge from fundamental research towards technology development and integration.

Key Recommendations

- The increased trend of projects aiming at direct public use should be further maintained and monitored. Such an approach might help to embed outcomes and new competencies within the European electricity industry.

- The increasing pace of electrification of transport needs to be more intensively addressed in the future as a mean of life standard improvement, considering environmental and safety factors. In addition, it is recommended to boost RDI activities towards digitalisation, storage (in particular long duration), power-to-X technologies, CO2 footprint and the assessment methodology and metrics of flexibility needs and value at the pan-EU level as these are key for the timely integration of wind and solar-based electricity in the grid at large scale.

- An emphasis must be placed on accelerating and carrying out the necessary activities to enable large-scale offshore wind energy into the grid as it requires significant advancements and adjustments of the regulatory framework, HVDC modelling tools, technology and materials development followed by system reliability, security and asset management. The development of HVDC multi-vendor & multi-terminal full scale demonstrators remain highly relevant, as well as the development of services and processes to guarantee the stability of the pan-EU grid with the high penetration of power electronic interfaced devices.

- To improve the alignment of topics from Horizon Europe with the RDI Roadmap, the milestones of the RDI Roadmap should become part of the set of outcomes of the research topics of the Horizon Europe and other funding programmes.

- It is necessary to increase cooperation with stakeholders in all sectors, in particular working together with regulatory authorities to dismantle innovation barriers in order to create an environment for innovation uptake, as suggested by the **ENTSO-E paper 'Innovation Uptake through Regulation'**.

1 Introduction

The RDI Monitoring Report provides regular screening of the existing or ready-to-launch, EUfunded regional or national projects involving TSOs participation. As shown in Figure 3, in the current edition, the RDI Monitoring Report assesses the TSOs' RDI activities regarding the milestones and flagships in the RDI Roadmap 2020 – 2030 (hereafter referred to as the RDI Roadmap), the project concepts in the RDI Implementation Report 2021 – 2025 (hereafter referred to as the RDI Implementation Report) and the focus topics in the Acceleration Mission.

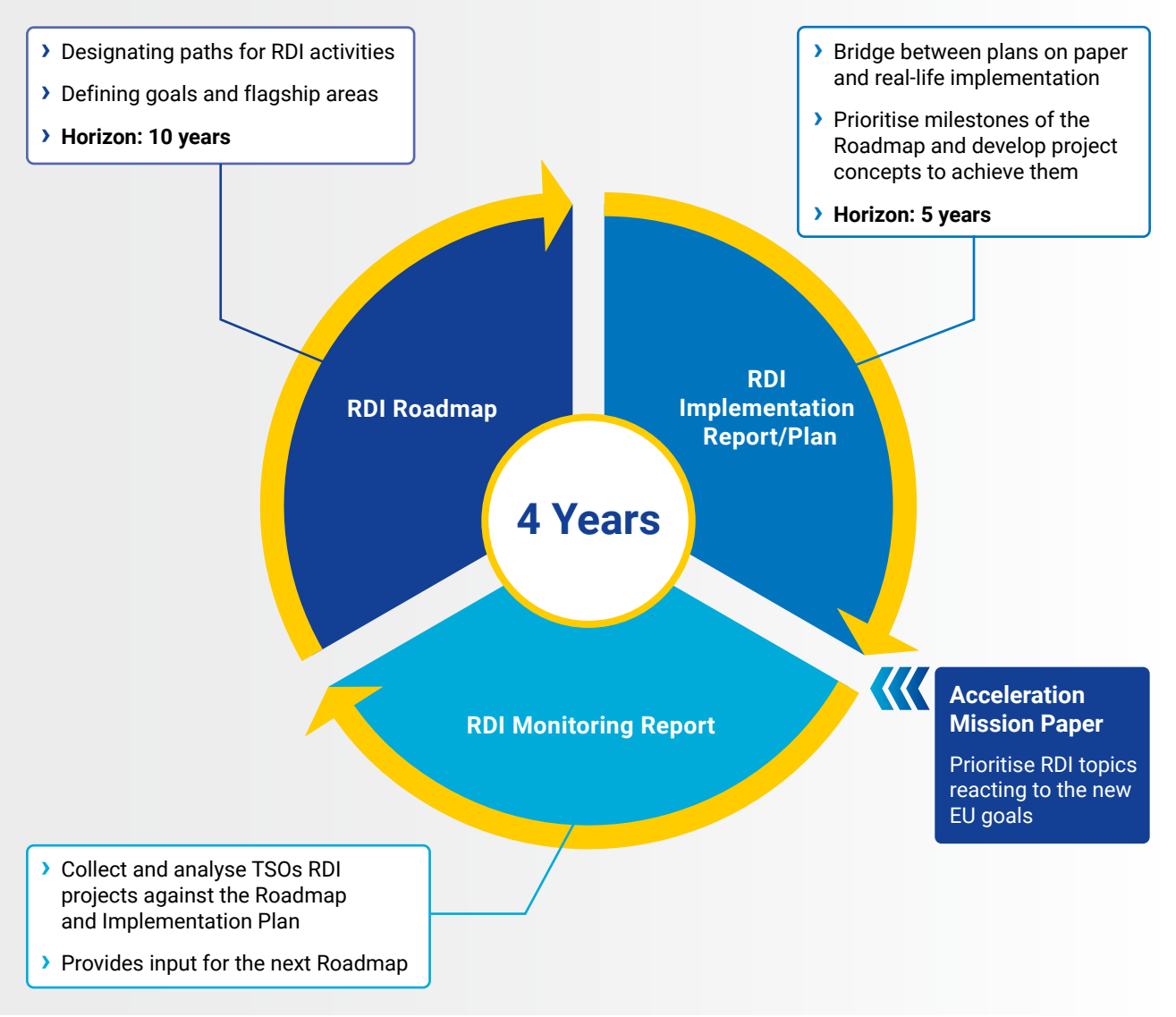

Figure 3: The RDI Roadmap cycle

Hence, the RDI Monitoring Report complements the strategic RDI documents by assessing the alignment of the RDI activities with the strategic directions. The document emphasises the current RDI activities undertaken by the European TSOs, together with other stakeholders, towards developing innovative solutions, as well as their commitment and gaps in the strategic RDI direction to achieve EU energy system goals such as carbon neutrality.

1.1 Structure of the RDI Monitoring Report 2022

The RDI Monitoring Report comprises a main report and one Annex.

The purpose of the main report is to provide a holistic overview of the RDI activities in the electrical energy transmission sector. The analysis focuses on several essential focal points, such as addressed milestones and degree of achievement of the RDI Roadmap flagships, budget issues or project benefits, and key results and partnerships, in addition to funding opportunities to address milestones less covered by the current projects.

Based on the collected TSOs' responses, the Annex provides a summarised characterisation of each of the projects, supporting the analysis presented in the main report.

1.2 Background and motivation

The intensifying of decarbonisation, electrification and digitalisation measures is essential to achieving net zero greenhouse gas emissions by 2050. To achieve this goal, TSOs are required to focus their efforts on developing strategies with policy makers and stakeholders, in order to fast-track the integration of clean energy solutions into the electrical grid. In this context, and acting within its legal mandate according to EU Regulation 2019/943, the ENTSO-E RDI Committee and associated TSOs have developed a Roadmap of RDI activities for 2020–2030.

ENTSO-E RDI Roadmap 2020 – 2030 (RDI Roadmap)

The RDI Roadmap is the major strategic RDI document of ENTSO-E. Aligned with the EU's Green Deal, it defines the main research and innovation directions for the TSOs and strives for the achievement of technical, economical and socially acceptable solutions which increase the use of endogenous and renewable energy resources while keeping the security and quality of electricity supply in the pan-European electricity transmission system.

The RDI Roadmap categorises the RDI activities in three major RDI Clusters, addressed by six flagships and more than 80 milestones. The flagships tackle pressing problems and goals by gathering energy system stakeholders and assembling the necessary expertise and resources to accomplish each step in the RDI Roadmap. Each flagship covers multiple and interdependent topics, which are defined through a set of milestones. These milestones are to be achieved in coordination with numerous stakeholders during the decade.

The ENTSO-E RDI Roadmap calls for the mobilisation of stakeholders from the whole energy value chain. The successful implementation of the RDI Roadmap goals depends on enhanced cooperation with other actors and requires the pooling of different resources, both financial and human capacity, coming from own TSOs' resources, tariffs, and national and pan-European RDI funds.

ENTSO-E RDI Implementation Report 2021 – 2025 (RDI Implementation Report)

The ENTSO-E RDI Implementation Report addresses the RDI activities within individual flagships and respective milestones in detail. The report prioritises some of the milestones outlined in the RDI Roadmap into thirteen project concepts that provide a comprehensive overview of the system challenges that TSOs have identified in the long run, what RDI projects have been recently delivered, and which gaps require urgent addressing. The RDI Implementation Report is the guiding instrument for fostering the collaborative research programmes between TSOs and key stakeholders, policymakers and regulatory authorities in the coming years.

ENTSO-E Acceleration Mission

The RDI Roadmap and RDI Implementation Report were screened in accordance with the new policy package 'Fit for 55' – a follow-up to the EU's Green Deal objectives. The analysis showed that some specific areas manifest critical shortcomings that require urgent improvements. Consequently, ENTSO-E developed a bridging paper titled 'Acceleration Mission'[1]. The document introduces specific Focus Topics, which lead the way for the adaptation of the RDI activities in the next 2 – 3 years regarding anticipation, development and cooperation within TSOs' communities to meet the updated EU policies. The Focus Topics match the milestones from the RDI Roadmap; therefore, they serve as an adjustment measure in the existing structure of the milestones within the defined flagships of the RDI Roadmap.

ENTSO-E Vision: A Power System for a Carbon-Neutral Europe

The objective of the strategic document ENTSO-E Vision: A Power System for a Carbon-Neutral Europe is to present a comprehensive and robust vision from a TSO perspective of a European power system for a carbon-neutral Europe. This vision builds on the findings of the ENTSO-E Vision 2030, the relevant 10-Year Network Development Plan (TYNDP) scenarios and the ENTSO-E RDI Roadmap. The vision of ENTSO-E maintains a strong focus on fossil fuel independency as well as on the overarching political goal of climate neutrality of the whole European economy by 2050 at the latest.

ENTSO-E Vision assumes that in the coming 25 years, electricity will become a dominant energy carrier and that, due to higher efficiency and the maturity of renewable electricity generation technologies, it will play a central role in the achievement of a climate-neutral energy system.

ENTSO-E RDI Monitoring Report 2022

This RDI Monitoring Report assesses the current state and progress of the European TSO-related RDI activities defined in the RDI Roadmap. The results are based on the input collected via dedicated survey and include a total of 117 RDI projects. The data collection process (survey) was designed in such a manner as to provide additional project information regarding the following aspects:

- Funding & budget;
- Multilateral project partnerships (by country and by stakeholder);
- Technologies and services;
- Type of results achieved and consequential benefits for power system stakeholders;
- Technology Readiness Level (TRL) and estimated time-to-market; and
- Next steps for extensive exploitation (further investments, regulatory issues, barriers to deployment).

The outcomes of this RDI Monitoring Report rely on the statistical analysis and gap analysis for each individual flagship. This detailed information is useful for assigning action priorities while updating the ENTSO-E RDI Roadmap strategic goals, as well as for sharing and disseminating new knowledge produced within the framework of RDI activities. With the aid of the identified KERs, the RDI Monitoring Report focuses on the timely deployment and implementation of results.

1 The Acceleration Mission paper was published internally, available only for the members of ENTSO-E in full length. The paper was approved in February 2022 before the REPowerEU plan was published in May 2022.

1.3 Methodology

The methodology adopted for the monitoring activity has been specially designed to enable its implementation in a numerous and diverse set of projects as well as to carry out a systematic assessment by double level analysis. Such a methodology guarantees increased quality and a higher detail level of the monitoring exercise. As shown in Figure 4, the design of the implemented methodology follows a 3-phase structure.

Figure 4: Phases of the Evaluation Methodology

In the first step, a dedicated survey was designed and conducted among all European TSOs associated with ENTSO-E. Due to the special design of the questionnaire, the necessary information on national as well as international TSOs' RDI projects was collected. Subsequently, the collected answers were respectively validated and pre-evaluated. The collected data referred to 93 RDI TSO projects. The list has been extended to include 24 TSOs' EU-funded projects that were not reported but are well documented. The input data corresponds to a total number of 117 RDI TSOs' projects.

Phase 2: 1st Step of Coverage Assessment – Collection, Validation and Evaluation of the Responses

The individual milestones of the RDI Roadmap flagships link the Acceleration Mission and the RDI Implementation Report with the RDI Roadmap. Thus, within the survey conducted, the TSOs were encouraged to link the projects to the RDI Roadmap by assigning their projects to one of the RDI Roadmap clusters and its underlying flagships, as well as selecting the milestones addressed by the specific projects. Moreover, the TSOs were asked to justify their selection based on the KERs for each of the Projects. Accordingly, the TSO's indication was used to evaluate whether and to what extent the collected projects cover the individual milestones of the flagships and, in conclusion, the flagships themselves.

Phase 3: 2nd Step of Coverage Assessment – Coverage Assessment by ENTSO-E's Experts

Based on the evaluation of the TSO responses and the resulting assignment of the TSO projects to the individual milestones, a 2nd level coverage assessment of the ENTSO-E expert panel was performed. The evaluation was based on the ENTSO-E experts' assessment of whether or not the projects meet the declared requirements of the individual milestones. Within this process, ENTSO-E experts choose from the following three options:

Option 1: The coverage of the milestone by the projects is HIGH, when there are 4 or more projects related to this milestone and their objectives are pertinent to it,

Option 2: The coverage of the milestone is MEDIUM, when there are 2 or 3 projects related to this milestone and their objectives are pertinent to it, or

Option 3: The coverage of the milestone by the projects is LOW, when there is at most 1 project related to this milestone and with objectives pertinent to it.

The aggregation of the coverage assessment of each individual milestone results in a coverage assessment of the superordinate flagships. The 2nd level assessment enables efficient further development of the ENTSO-E RDI activities in a targeted manner.

2 Monitoring Activity 2022

The following sections detail the monitoring results. They first present a comprehensive overview of the alignment between the ongoing RDI activities and the ENTSO-E RDI planning, followed by general project statistics related to the technologies and services tackled by the projects, benefits brought by the projects, their KERs, the type of partner organisations and the funding sources.

The ENTSO-E RDI roadmap structure is summarised in Figure 5. It contains three clusters with their flagship projects, namely:

- **Cluster 1:** One system of Integrated Systems – Decentralised generation and increased electrification require TSOs to adapt and support a market expansion with a focus on 'One-System of Integrated Systems' centered around optimised cross-sectoral integration.
- **Cluster 2:** Power Grid, the Backbone of the Energy System. This implies increased grid capacity and optimisation as well as the large-scale deployment of solutions and services with high TRLs.
- **Cluster 3:** Cyber-Physical System. This Cluster focuses on ensuring the technical soundness of the system regarding digitalisation and interoperability, including the integration of power electronics and offshore developments.

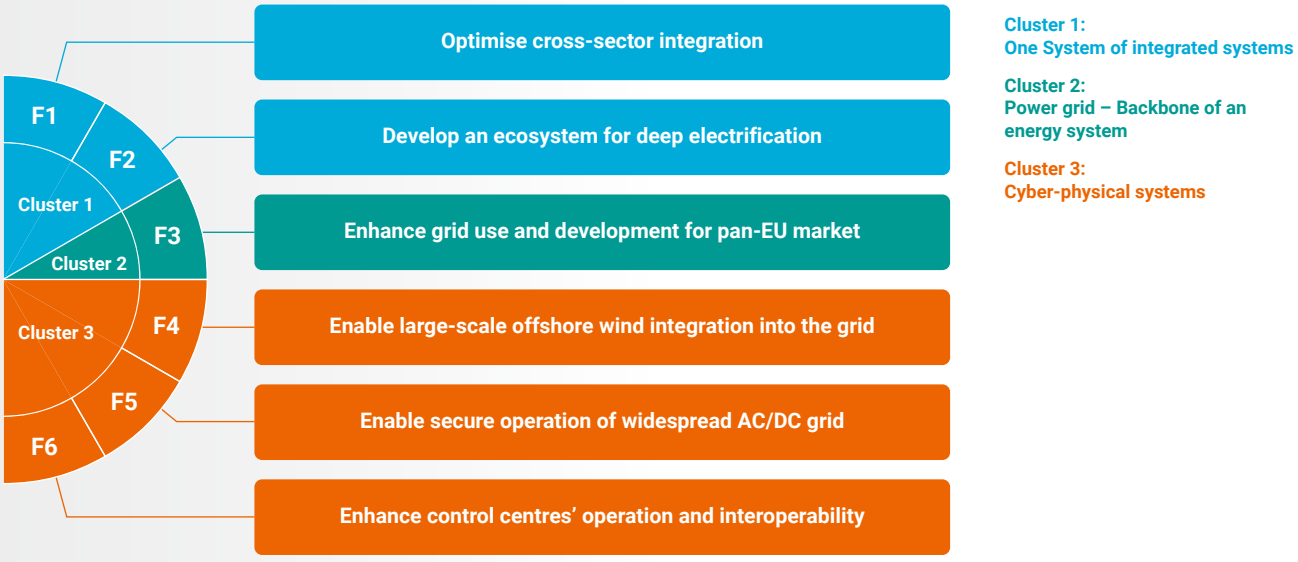

Figure 5: Structure of the RDI Roadmap 2020–2030

The following analysis focus on each flagship, providing a bottom-up assessment of the alignment of the current RDI activities reported in the survey with the RDI planning. This analysis exploits the link between milestones and project concepts in the RDI Implementation Report, the link between milestones and focus topics in the Acceleration Mission, and the link between the milestones and the flagships of the RDI Roadmap.

2.1 Flagship 1: Optimise cross-sector integration

This flagship focuses on significantly improving efficiency and flexibility, as well as the reliability and adequacy of the energy system. In particular, this requires that:

- Markets for cross-sector integration are developed and coupled;
- System operators and market parties have access to planning and optimisation tools to develop and maintain an integrated system; and
- An integrated system of governance is created.

Figure 6 provides a detailed overview od the milestones of Flagship 1 from the RDI Roadmap, as well as showing the interdependency of Flagship 1 with the RDI Implementation Report and Acceleration Mission.

The milestones depicted with an elliptical shape correspond to the focus topics from the Acceleration Mission paper related to this flagship. Flagship 1 addresses two milestones identified in the Acceleration Mission, namely 'Optimal cross-sector planning' and 'Faster electrification of transport'. These milestones are partially addressed by the project in the survey.

The interdependency with the RDI Implementation Report is represented by the colour frame of the milestones. Each colour indicates a different Project Concept. There are five milestones related to project concepts in the RDI Implementation Report. The milestone 'Planning tools to enable sector coupling investments' is one of the objectives of the project concept 'P3 Design of a pan-European cross-sector data model'. This milestone is filled with the red colour, meaning that no RDI activity survey by this monitoring report is addressing this milestone. Also related with the project concept P3 is milestone 'Standards for interoperability and data exchange between sectors'.

This milestone is filled with green, showing that the RDI activities surveyed by this monitoring report are well aligned with this milestone, both by the quantity of projects and by the pertinence of the objectives of these projects in the survey. The milestone 'Scenarios developed in an integrated way considering the whole energy system' is also addressed by the project concept P3. However, the surveyed projects only partially address this milestone, hence it is filled with yellow. The milestone 'Optimisation tools and strategies for operating the integrated energy system' relates to the project concept 'P1 Smart charging for optimal large-scale electromobility integration' and it is partially addressed by the ongoing RDI efforts of the TSOs.

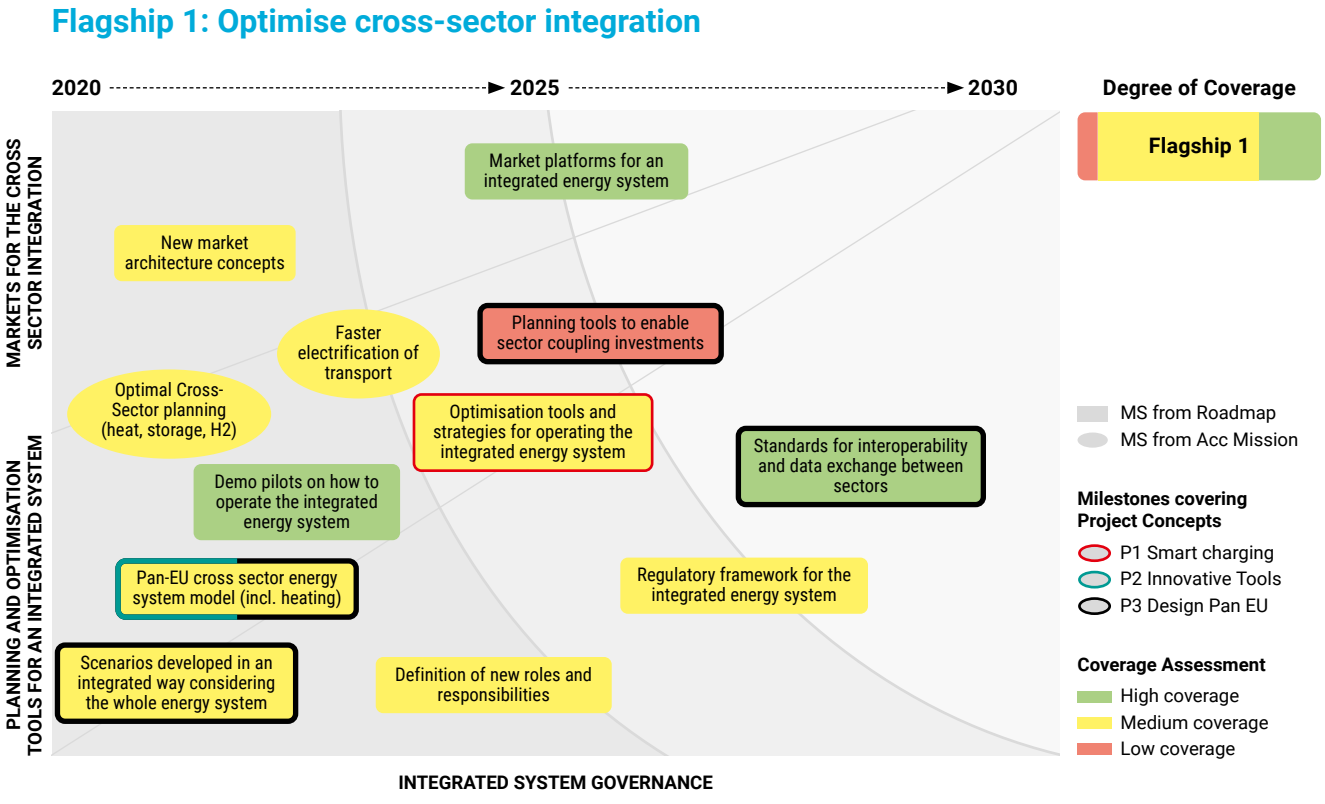

Figure 6: Flagship 1 – Optimise cross-sector integration

The milestones can cover multiple project concepts, which, for example, is the case for 'Pan-EU cross sector energy system model (incl. heating)'. This milestone relates to both 'P2: Innovative models and tools for coordinated multi-sector system operation and planning' and 'P3: Design of a pan-European cross-sector data model', hence the frame contains colours from both project concepts. Current RDI efforts from the TSOs are partially covering this milestone and addressing the objectives of the related project concepts.

By implementing the aforementioned colour scheme, Figure 6 also serves as a tool to visualise the alignment of the ongoing RDI efforts by the TSOs and Flagship 1. This provides the alignment between the current RDI activities and the RDI Roadmap: 8 out of 12 Milestones are partially addressed, including 2 Milestones resulting from the Acceleration Mission and 3 Milestones covering the project concepts. Accordingly, the overall representation of Flagship 1 is dominated by the yellow colour, indicating that this flagship of the RDI Roadmap is mostly partially addressed by the current RDI activities. This summary is depicted in the top-right corner of Figure 6.

2.2 Flagship 2: Develop an ecosystem for deep electrification

This flagship focuses on the deep electrification of energy end uses. It requires:

- A new and comprehensive TSO–DSO interface to provide grid users with the best service;
- New scenarios and modelling techniques; and
- The development of new market concepts and ancillary services to integrate flexible new sources.

Figure 7 provides a detailed overview of the milestones of Flagship 2 from the RDI Roadmap, together with the interdependency with the RDI Implementation Report and the Acceleration Mission.

Flagship 2 has only one milestone identified in the Acceleration Mission, namely the 'Need for flexibility and its value at all timeframes'. The current research work addresses this milestone with a medium degree of coverage because the long term need / value of flexibility and the assessment methodology and metrics of flexibility needs and value at the pan-EU level are not sufficiently addressed.

The milestones 'Assessment of electrification potential in residential, services, industry, heating and cooling, and transports (including load patterns)' is related to the project concept 'P5 Integrating the coordinated flexibility potential into the future energy system of systems' from the RDI Implementation Report. This milestone and the objectives of the project concept are partially addressed by the ongoing research work.

Furthermore, Flagship 2 has only one milestone which relates to P5 and is partially addressed. Overall, 7 out of 15 milestones of Flagship 2 are well covered, 6 milestones have a medium degree of coverage, and 2 milestones are not addressed. Hence, the required work to fulfil this flagship is mostly partially and fully addressed. Figure 7 shows that the ongoing research work is addressing the milestone 'Efficient utilisation of flexibility and demand-side response', which was planned for near-by 2030, rather than the milestone 'Improved CBA considering deep electrification scenarios', which was planned for the short-term. On the one hand, this reflects the ambition to deliver the EU Green Deal and contributes to fulfilling the REPowerEU plan as the increased amount of flexibility and diversification of flexibility sources are of paramount importance for increasing energy independence using renewable energy while securing the supply of electricity. Furthermore, bringing significant demand response to the electricity market contributes to decreasing price spikes. On the other hand, these results from the monitoring activities (along with all flagships) facilitate the adjustment of the RDI Roadmap. The top-right corner of Figure 7 depicts the summary of the coverage degree of this Flagship.

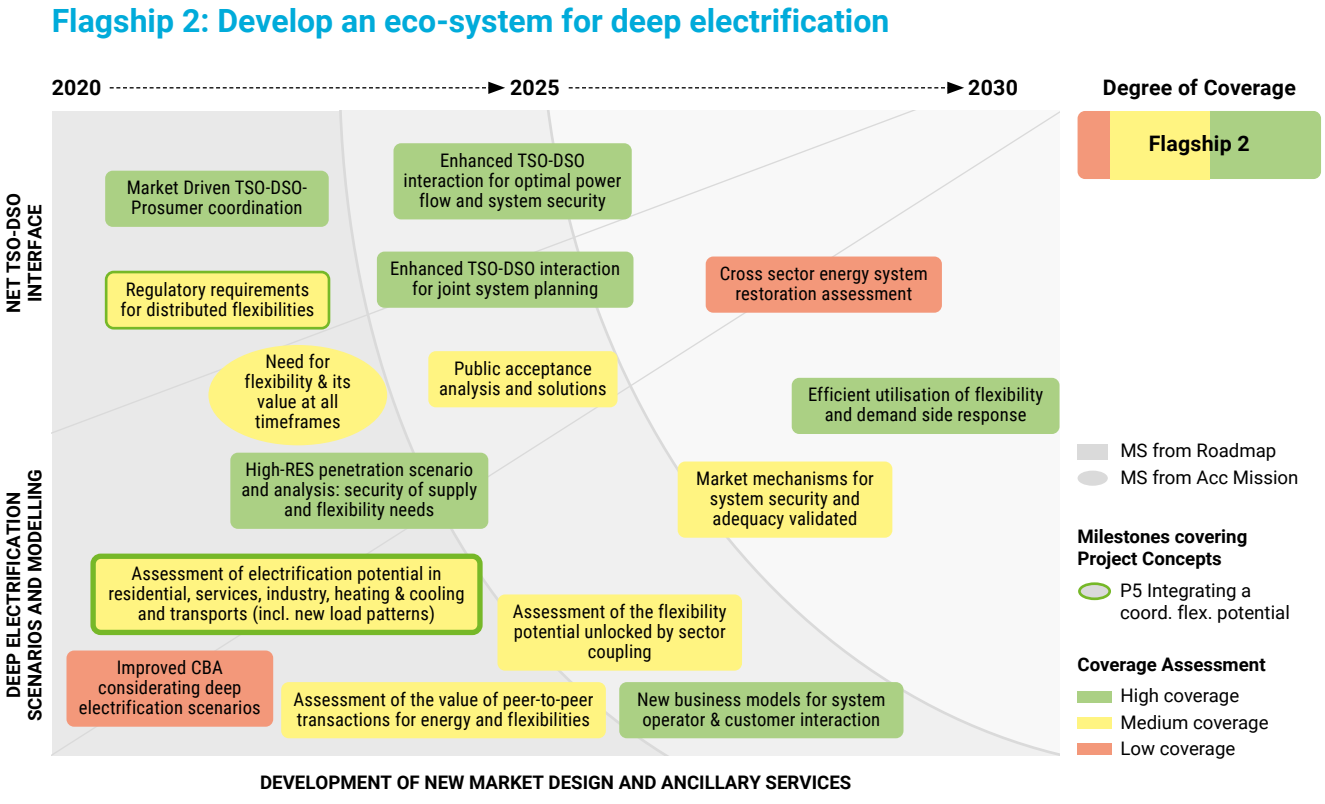

Figure 7: Flagship 2 – Develop an eco-system for deep electrification

2.3 Flagship 3: Enhance grid use and development for the pan-EU market

This flagship focuses on ensuring both horizontal and vertical integration of energy resources through optimisation as new types of services to customers emerge. Tools, algorithms and control systems need to adapt accordingly to:

- Enable enhanced Pan-EU power systems;
- Develop interoperable, integrated and standardised platforms; and
- Find new approaches to grid design and asset management.

Figure 8 provides a detailed overview of the milestones of Flagship 3 from the RDI Roadmap, together with the inter-dependency with the RDI Implementation Report and the Acceleration Mission.

In Flagship 3, the Acceleration Mission identifies the milestone 'Flexible and digital infrastructure to cope with the extended data sets' as a focus topic. The monitoring activity reflects that this milestone is being well addressed by the ongoing research work, both in terms of the quantity of projects addressing it and the specific objectives of such projects towards achieving the milestones. Notwithstanding, the **Digitalising the energy system - EU action plan COM(2022)552** and its goals on increased observability, collaborative network planning and coordinated active system management are some open avenues for innovation related to this milestone.

Concerning the alignment with the RDI Implementation Report, the project concept 'P6 SF6-free alternatives in high-voltage equipment' targets the milestone 'SF6 free solutions' which is at a medium degree of coverage. Furthermore, the monitoring activity shows that the project concept 'P7 Smart asset management for a circular economy' is partially addressed: although the ongoing research work has a low level of coverage of the milestone 'Eco-design and lifecycle management', which is one of the milestones related to P7, the milestone 'New asset management approach and identification of risks associated with production outside EU', also related to P7, has a medium degree of coverage by the current research efforts. Specific attention should be placed in future on developing new asset management procedures that lower the carbon footprint of grid development.

The overall representation of Flagship 3 shows 6 out of 15 milestones with a high degree of coverage, 7 milestones with a medium degree of coverage, and 2 milestones with a low degree of coverage. The latter are planned for near 2025 and near 2030, so while the milestone 'Eco-design and lifecycle management' and the digitalisation of the energy system require a focus in the short-term, overall, the current research works are covering Flagship 3 at a good pace.

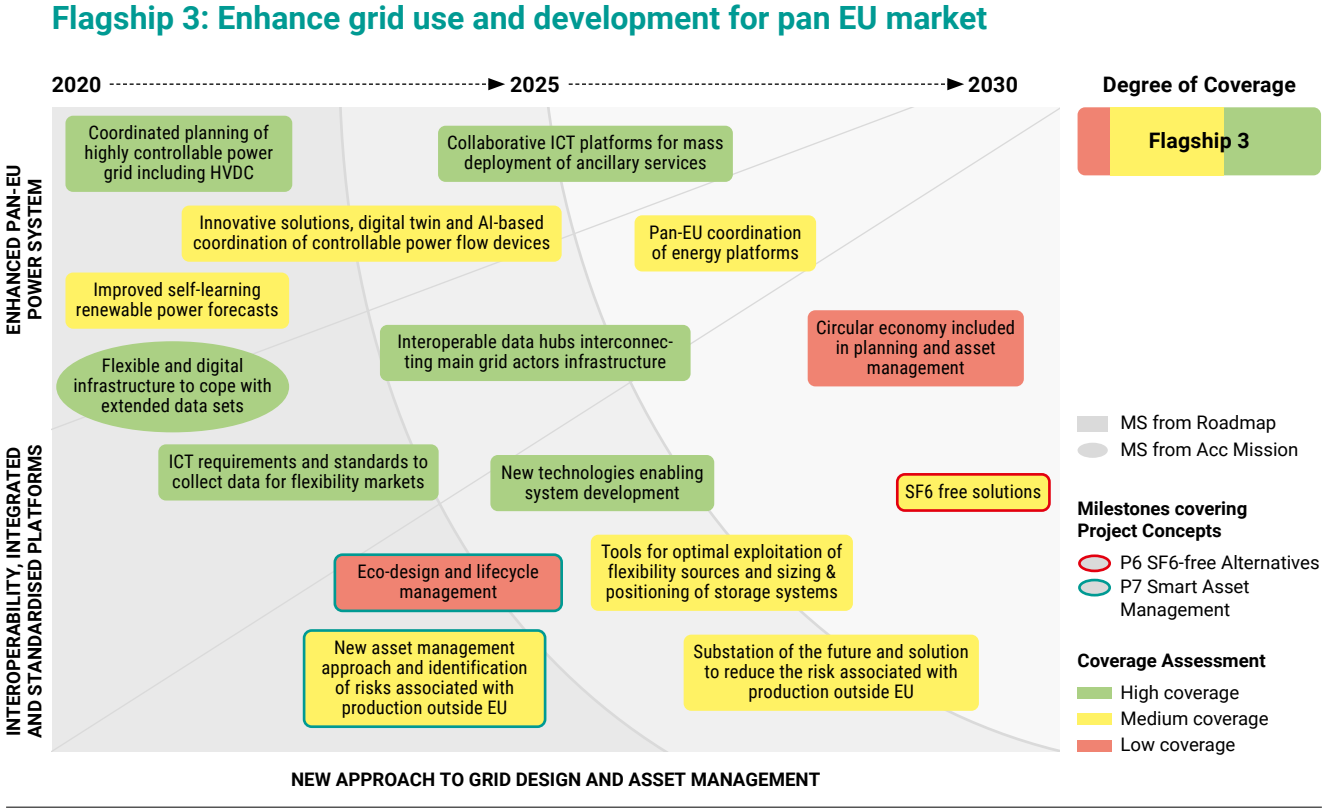

Figure 8: Flagship 3 – Enhance grid use and development for pan EU market

2.4 Flagship 4: Enable large-scale offshore wind integration into the grid

The vast potential of offshore energy sources (e.g. wind) in the North and Baltic Seas is a promising source of renewable energy for Europe. In this context, considerable work has been done by TSOs, research and industry, which has brought Europe to an installed offshore capacity of over 25 GW. Nevertheless, there are still challenges to overcome to fully exploit offshore potential and achieve the EU's climate policy goals, For example, offshore grids and related advanced system models are needed, along with suitable new High Voltage Direct Current (HVDC) connections and improvements in the supply chain to scale up delivery. To meet these goals, the following will be required:

- Thoughtful regulatory guidelines;
- The development of interoperable hardware and software solutions for DC grids and systems; and
- Consistent attention towards developing new HVDC technologies and materials.

Figure 9 provides a detailed overview of the milestones of Flagship 4 from the RDI Roadmap, together with the interdependency with the RDI Implementation Report and the Acceleration Mission.

The coverage assessment of Flagship 4, given in Figure 9, shows that 8 out of 17 milestones have a medium degree of coverage. Furthermore, the milestone 'Standardisation of HVDC models and replicas' has a high degree of coverage from the ongoing research and innovation works. One of the milestones with a medium degree of coverage is the Acceleration Mission topic 'Multi-vendor, multi-terminal offshore solutions', which relates to two project concepts, P8 and P9. It is the only milestone related to P9 within this Flagship, while there are 7 additional milestones which cover P8 in Flagship 4, of which 4 are given a medium level of coverage by the current projects, and 1 has a high degree of coverage.

Figure 9 indicates a medium degree of coverage of the milestones in Flagship 4 at the time of the survey. This result highlights the need to accelerate activities to enable large-scale offshore wind energy into the grid at all levels as it requires significant advancements and adjustments of the regulatory framework, HVDC modelling tools, technology and materials development followed by system reliability, security and asset management. Furthermore, the development of HVDC multi-vendor & multi-terminal full-scale demonstrators remain highly relevant.

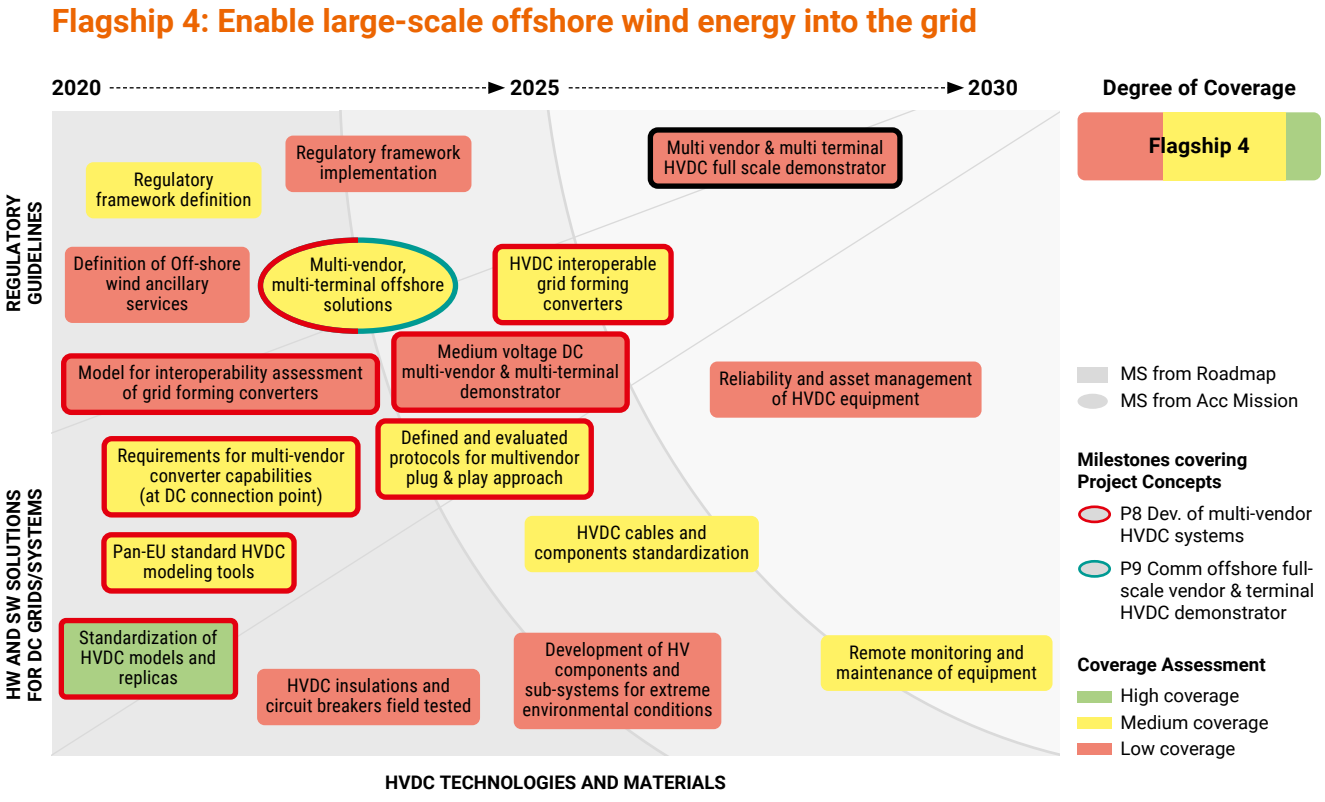

Figure 9: Flagship 4 - Enable large-scale offshore wind energy into the grid

2.5 Flagship 5: Enable the secure operation of widespread AC/DC grid

The development of a strongly interconnected power system with high renewables penetration requires the implementation of advanced solutions by TSOs to overcome the technical challenges associated with the management of hybrid Alternating Current (AC)–Direct Current networks. The following solutions are critical:

- Hybrid AC/DC power flow and system modelling;
- Control, operation and protection of hybrid AC/DC grids; and
- Hybrid AC/DC systems to provide ancillary services.

Figure 10 depicts the milestones of Flagship 5 from the RDI Roadmap, together with the interdependency with the RDI Implementation Report and the Acceleration Mission.

Acceleration Mission identified the Flagship's 5 milestone 'New system stability management approach' as a focus topic, which is at a medium degree of coverage according to the ongoing research efforts and the contributions from this work towards the 'Fit for 55' objectives and, also, to the REPowerEU action plan can be collected progressively and in the short-term. Recent work has highlighted the complexity of the challenges faced regarding stability management, both during the transition period and in the long term. Conventional system development and system operation methods will no longer be sufficient to ensure the system stability. The need for research in the area of stability management is growing and requires significant RDI efforts and stakeholder collaborations to accelerate the uptake of new technologies. Relatively well-known stability phenomena are increasing and, simultaneously, new phenomena are being introduced, such as resonance and converter driven stability.

Project concept 'P10 Stability management in power electronics dominated systems' targets three milestones: two have a high degree of coverage by the ongoing research activities and one is given a medium degree of coverage by the current research projects. However, this research area is expanding and increasing in complexity. The most recent work shows that RDI efforts are still necessary and there are gaps concerning the technology applications ready to manage the stability of the future power electronic dominated systems.

Project concept 'P11 Assessment of a widespread hybrid AC/DC system' targets five milestones of Flagship 5. The current research activities cover to a high degree two, and to a medium degree three of the related milestones. Both projects can be considered partially addressed, in different degrees, by the current ongoing research activities.

Figure 10 indicates that the majority of milestones within this Flagship (11 out of 18) are given a medium degree of coverage by the surveyed projects. There is a total of 6 milestones with high coverage, and only one with low coverage within the scope of Flagship 5. This Flagship mostly has a medium degree of coverage and is highly relevant for addressing power electronic interfaces that increase the availability of renewable energy, storage and demand response in the grid; there are still considerable RDI efforts to be made to tackle both the many and complex stability issues in a timely manner.

Flagship 5: Enable secure operation of widespread AC/DC grids

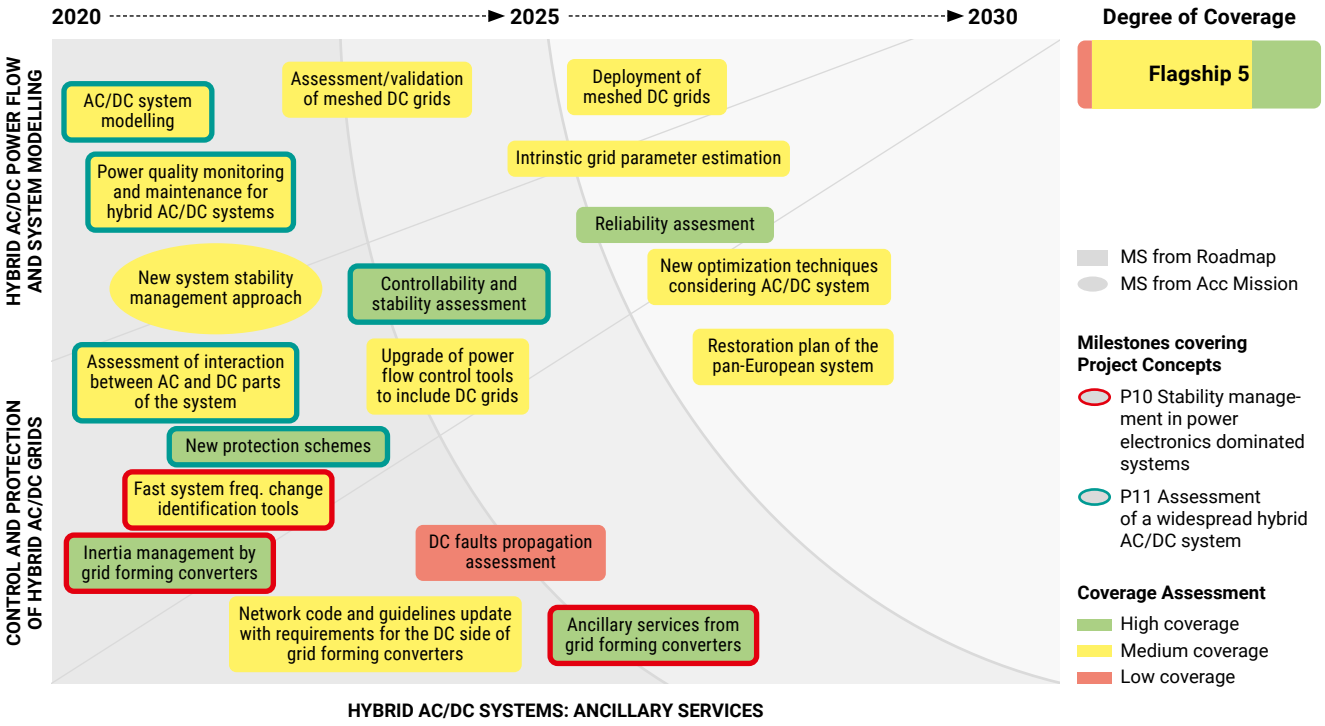

Figure 10: Flagship 5 -Enable secure operation of widespread hybrid AC/DC grids

2.6 Flagship 6: Enhance control centres' operation and interoperability

Due to the coexistence of micro and mega grids, TSOs require new, scalable management tools to cope with increasingly complex systems. Future control centers will rely on improved system monitoring and control capabilities through enhanced information and communications technology (ICT) infrastructure. This requires RDI that focuses on:

- The interoperability of control centers;
- Enhanced control center development and wide-area monitoring; and
- The development of guidelines and tools to manage highly complex interoperated systems.

Figure 11 provides a detailed overview of the milestones of Flagship 6 from the RDI Roadmap, together with the interdependency with the RDI Implementation Report and the Acceleration Mission.

Acceleration Mission identified the milestone 'Automated decision support system' as a focus topic for acceleration in order to deliver the 'Fit for 55' ambitious targets. The current research work is contributing well to this milestone, both in terms of quantity of projects addressing the theme as well as pertinence of the objectives of the ongoing research projects, and it is expected to collect the benefits of this work according to plan. One key open point concerning this milestone is the development and demonstration of vendor independent solutions.

The RDI Implementation Report identified two project concepts within this Flagship, namely 'P12 Cyber resilience in the future control centres' and 'P13 Secure solutions for the future control centres'; both are partially addressed by the current research efforts.

Figure 11 depicts 13 milestones, of which 7 have a medium degree of coverage, 4 have a high degree of coverage and only 2 have a low level of coverage by the surveyed projects. This Flagship contains 7 milestones planned to be achieved before 2025. Among these short-term milestones, 3 are well covered both in terms of the quantity of the research works and the pertinence of the objectives of these research works to achieve the milestones. However, 4 are planned to be delivered before 2025, showing that focused short-term research efforts are required to deliver these milestones according to plan or else, due to limited resources, the plan should be adjusted according to the allocation of available research efforts. The top-right corner of Figure 11 depicts the coverage assessment of Flagship 6.

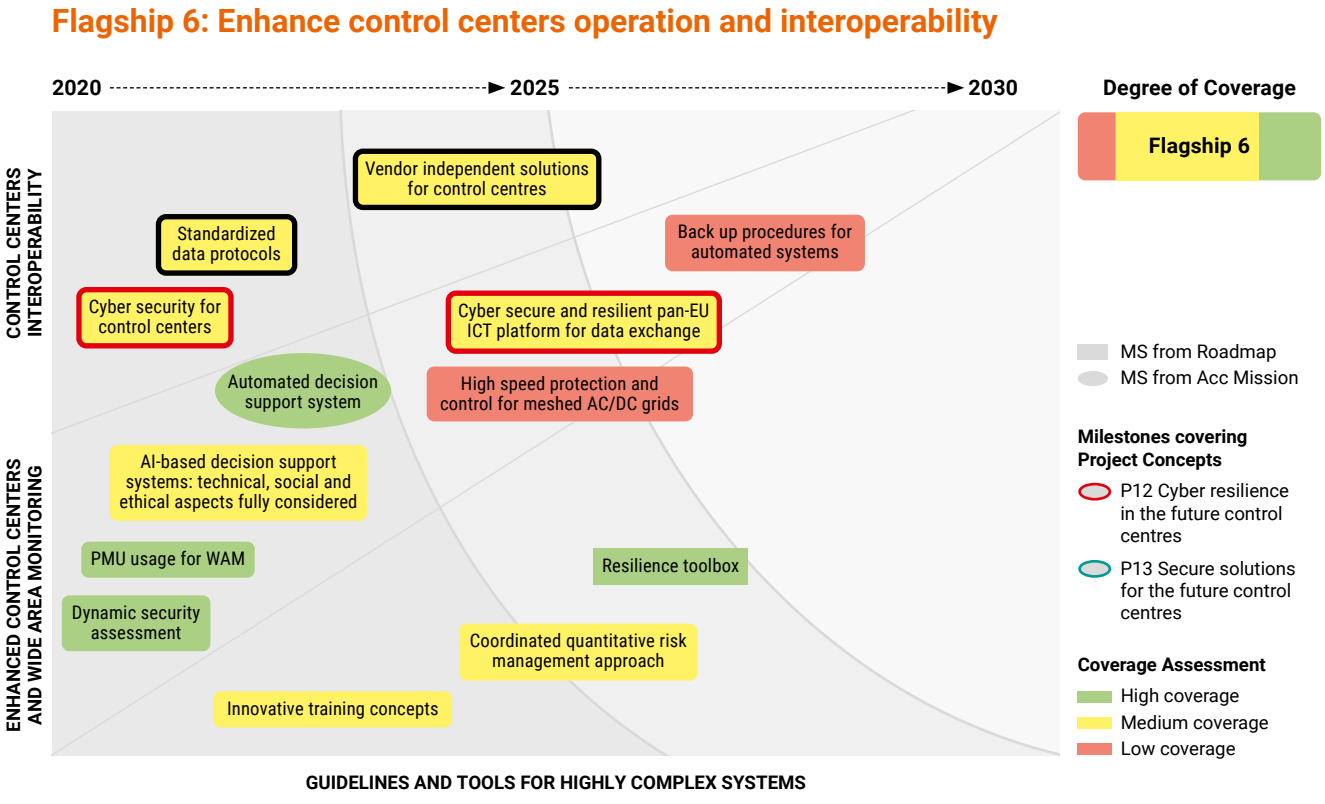

Figure 11: Flagship 6 –Enhance control centres' operation and interoperability

2.7 Statistical analysis of the RDI activities with respect to ENTSO-E RDI planning and ENTSO-E Vision business areas

In total, 117 RDI projects were surveyed by this Monitoring Report. The accumulated data on the set of monitored projects gives valuable insights into TSOs' RDI efforts. This section statistically describes how these activities align with the ENTSO-E RDI planning depicted in the RDI Roadmap, RDI Implementation Report and Acceleration Mission, as well as how the ongoing RDI activities are distribute over the business areas of the ENTSO-E Vision.

Alignment with the RDI Roadmap

Based on the collected responses from the TSOs on the ongoing RDI projects, the degree to which the projects address the milestones and corresponding flagship of the RDI Roadmap was evaluated. One surveyed project can address milestones in different flagships and, therefore, it may cover more than one flagship. The following figure depicts the distribution of projects across the individual flagships (FS).

Cluster 1 'One system of integrated systems' is being addressed by 51 projects and Cluster 2 'Power Grid, the Backbone of the Energy System' is being addressed by 52 projects, while 45 of the surveyed projects are addressing Cluster 3 'Cyber Physical System'. The distribution of projects across the flagships is highly uneven. Based on an evaluation basis, Flagship 3 (Enhance grid use and development for pan-EU market) is by far the most frequently addressed.

In the third phase of the assessment methodology, the ENTSO-E's experts assessed whether the projects' objectives are covering the flagships' milestones at a **high**, **medium** or **low** level. The summarised result of this assessment is displayed in Figure 13.

As evident from the figure, over 80 percent of the milestones from the Roadmap are addressed with different coverage degrees, showing an overall alignment of the ongoing RDI activities with the ENTSO-E planning and a strong commitment towards carbon neutrality, at the latest, in 2050.

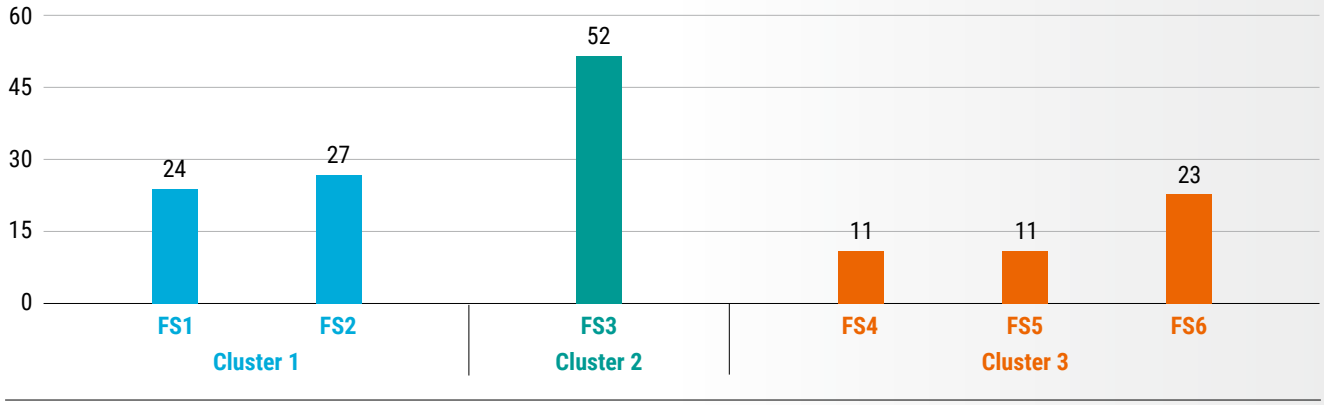

Figure 12: Distribution of projects across the RDI Roadmap flagships*

* It should be noted that a project can address several flagships.

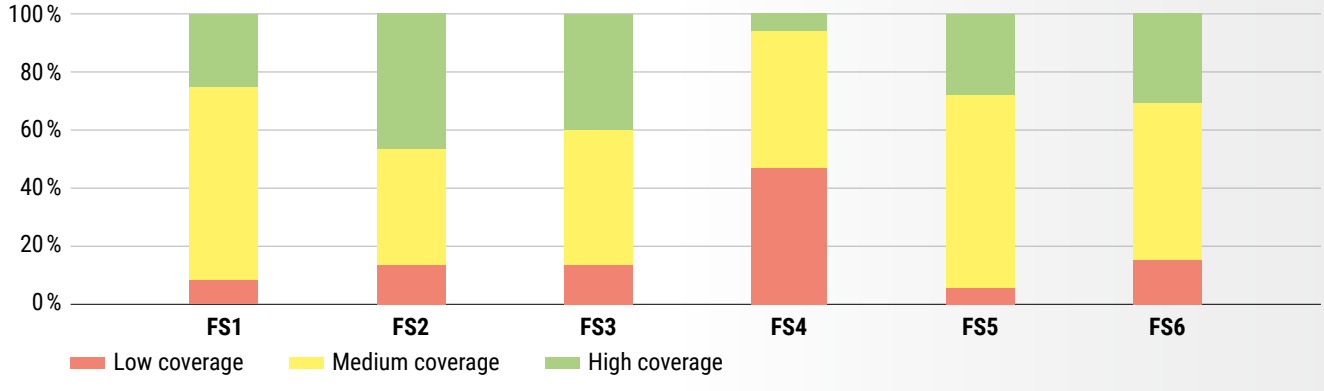

Figure 13: Alignment with the ENTSO-E RDI Roadmap flagships

Alignment with the RDI Implementation Report

Within the RDI Implementation Report, 13 project concepts have been developed. These project concepts prioritise the identified TSO's system challenges in the RDI Roadmap. Each project concepts relates to a set of milestones and thus, to the respective flagships. From the relation between the milestones and the project concepts, the alignment of the ongoing RDI activities with respect to the RDI Implementation Report can be assessed.

The results presented in Figure 14 indicate that the project concepts in the Implementation Report are partially addressed, with 5 out of 13 project concepts related to milestones with a high degree of coverage by the surveyed projects. The results show that acceleration is required to meet the RDI Implementation Report, particularly in the areas of cross-sector integration, asset management and commercial offshore technology, in addition to the case of cyber resilient and open IT solutions. Noticeably, 66 % of the milestones linked to 'P10: Stability management in power electronics dominated systems' have a high degree of coverage when compared to the RDI activities and project concepts. However, recent work shows that this research area is growing in complexity and criticality and still requires considerable RDI efforts to accelerate the uptake of technologies to address the new stability phenomena.

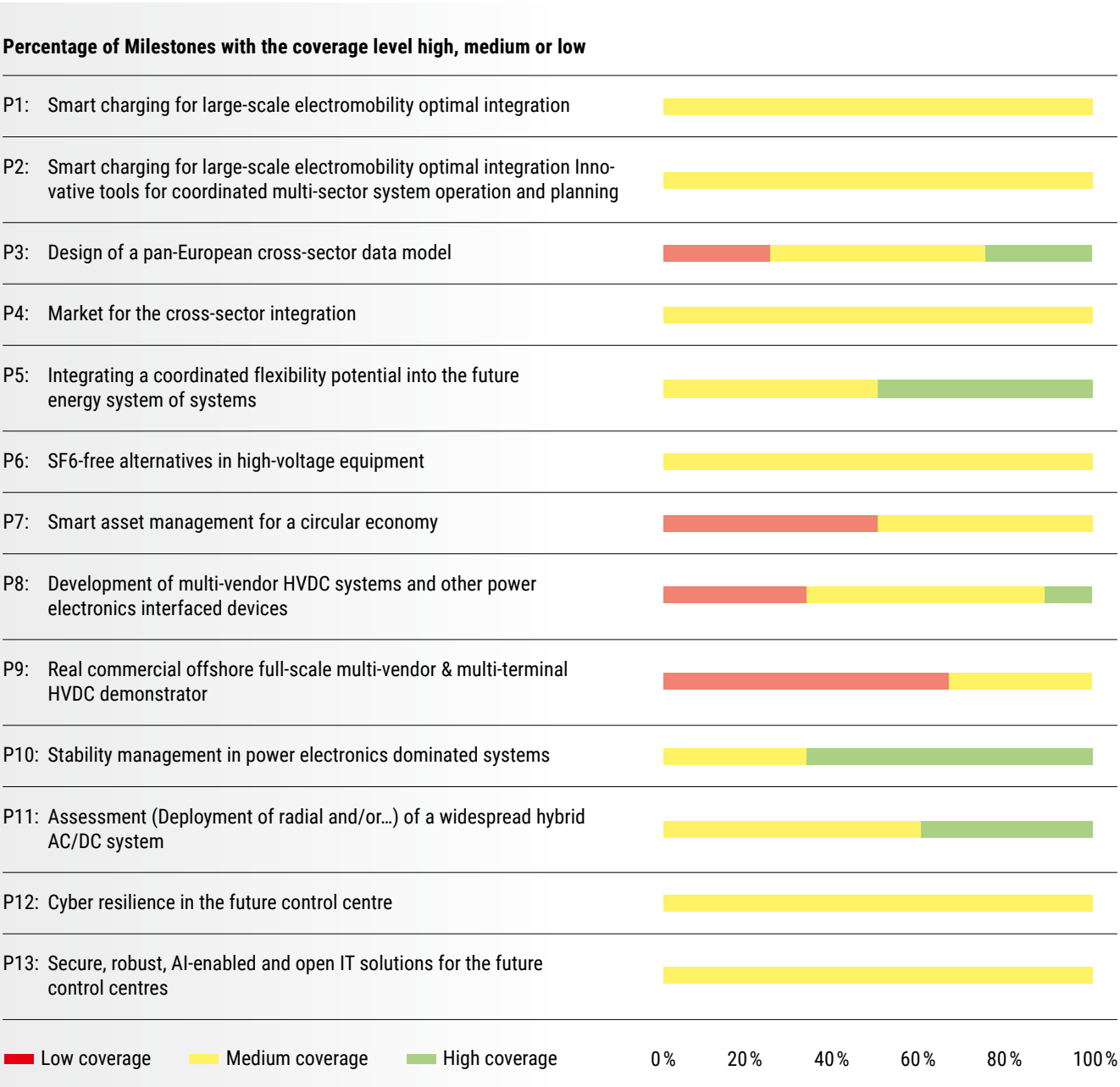

Figure 14: Alignment with the RDI Implementation Report

Alignment with the ENTSO-E RDI Acceleration Mission

The Focus Topics were assigned to the individual flagships as additional milestones and, as such, they were also considered while collecting the data (see Chapter 2.1). By analysing the TSO's input concerning the linkage of the projects to the milestones, the alignment of the Acceleration Mission could be assessed. The results of this assessment are displayed in Figure 15.

Figure 15 illustrates that the topics appointed to accelerate the energy transition all have, at least, a medium degree of coverage, with 2 focus topics which have a high degree of coverage from the current innovation efforts, showing effective commitment from the TSOs to accelerate energy transition.

There are still open questions concerning the milestones with a high degree of coverage, such as collaborative network planning and coordinated active system management, in addition to the development of vendor-independent solutions for automated decision support systems. Furthermore, the 'Need for flexibility and its value at all timeframes' requires acceleration in the development of seasonal flexibility solutions, as well as in the deployment of assessment methodologies and metrics of flexibility needs at EU-level.

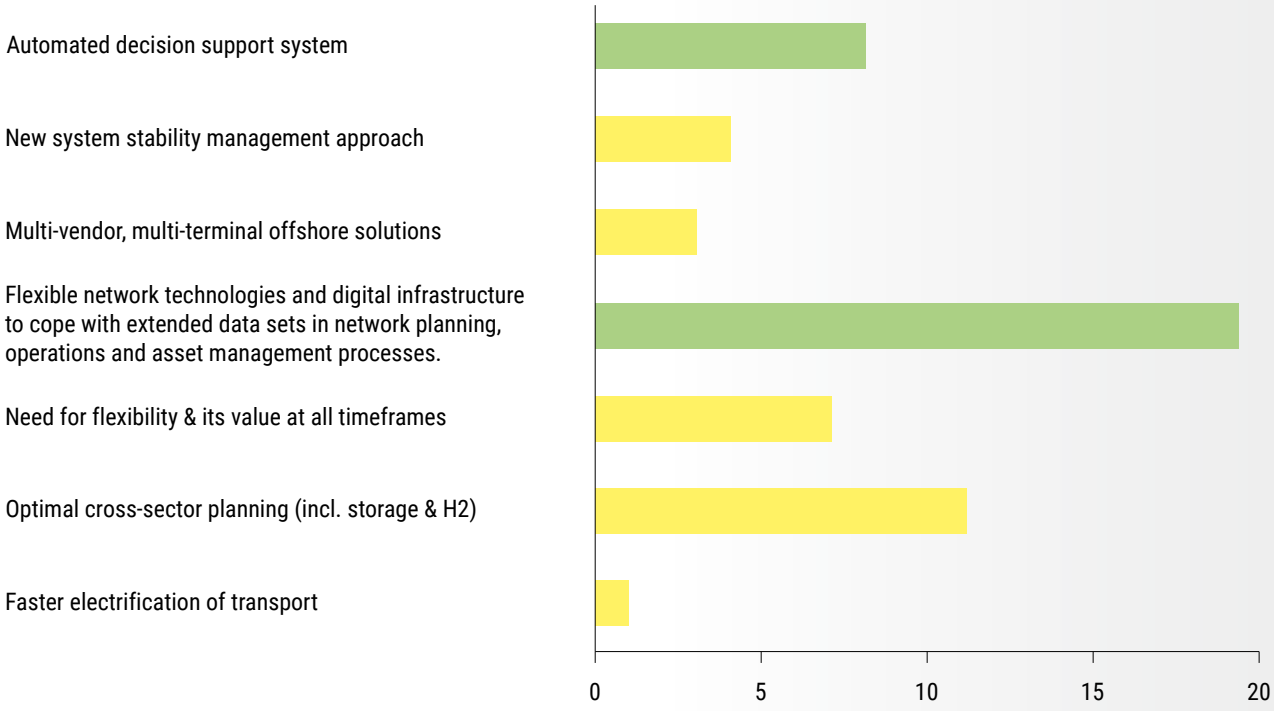

Figure 15: Alignment with the ENTSO-E RDI Acceleration Mission

Alignment with the ENTSO-E Vision: A Power System for a Carbon-Neutral Europe

Within the scope of the survey, the TSOs were asked to assign the projects' KERS to the business areas from the ENTSO-E's Vision, namely:

- **Energy Infrastructure and Investments** – accelerating the development and financing of the future system;
- **Operating Future Grids** – preparing and organising the operation of a carbon-neutral energy system that will be very different from today;
- **Energy System Flexibility** – facilitating the development of adequate flexibility resources to handle the increased complexity of the system and to balance what will become a weather-dependent system; and
- **Market Design for a Carbon-Neutral Power System** – Principles for a new market design fit for a carbon-neutral economy

The results from this analysis are presented in Figure 16:

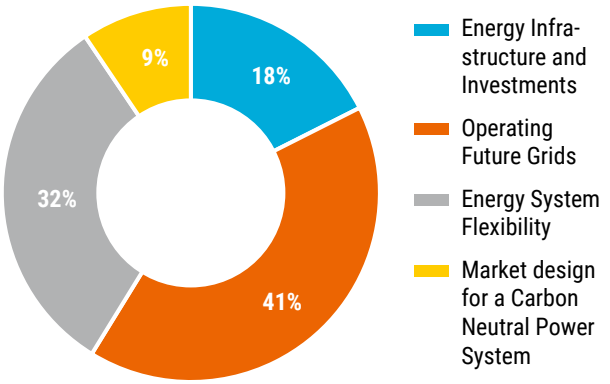

Figure 16: Alignment with the different Business Areas of KERs and the ENTSO-E Vision

The analysis indicates that most of the projects will deliver results oriented with the business areas 'Operating Future Grids' and 'Energy System Flexibility', key to the continuous effort in optimising the system to enable increasing renewable energy integration with high quality and security of supply.

This result is well aligned with the most promising game changers identified in the ENTSO-E Vision, namely *storage* and *deep digitalisation*. Deep digitalisation implies the pervasive modification of most devices, systems and processes. For example, to support the Digitalising the energy system – EU action plan, the ENTSO-E and the EU DSO Entity will kick-start the development of a Digital Twin of the EU-wide electricity grid.

2.7.1 General Projects' Statistics

2.7.1.1 Origin of projects' funding

A total of 117 projects were surveyed, providing information on their main features. Initially, the answers to the survey provide information on the origin of the projects' funding. The results are summarised in Figure 17.

The largest share (40 %) of the collected answers indicate that the respective projects are funded and/or co-funded by TSOs, followed by EU-funded and/or co-funded projects and nationally funded and/or co-funded projects[2]. Only 11 % of the answers considered that the respective projects are funded and/or co-funded by international funds.

Figure 18 illustrates the distribution of the projects' funding over funding programmes. Among the EU funded projects, 37 are co-founded by Horizon programmes – including Horizon2020 and its successor, the Horizon Europe.

The remaining 80 projects are founded through other funding instruments (labelled 'Other Projects'), of which 8 projects are co-founded by EU funds, whereas the remaining 72 projects are nationally, internationally or TSO funded.

The largest share of projects funded by TSOs show that research is already a business support activity, one that is currently neglected by the regulatory incentives[3].

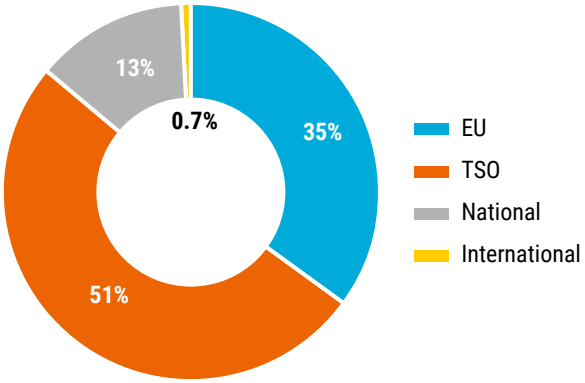

Figure 17: Funding Origin

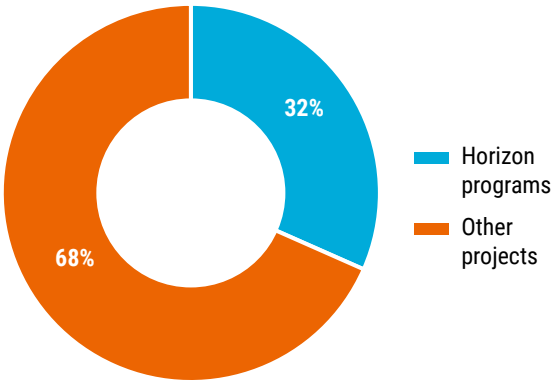

Figure 18: Funding programmes

2 Co-funded projects are defined as projects with several funding sources out of which at least one fits the defined categories (EU, TSO, National & International)

3 **See ENTSO-E Innovation Uptake through Regulation (entsoe.eu)**

2.7.1.2 Technologies and services

A broad range of new technologies and services are being investigated by the projects. These were filtered according to the five main categories:

- **Technologies for consumers**, especially to enable demand response;
- **Grid technologies**, including hardware and software solutions to improve network management.
- **Storage and power-to-X technologies**, connected at transmission or distribution level.
- **Power generation technologies**, including dispatchable and non-dispatchable technologies of all sizes.
- **Market:** electricity market and ancillary services.

Figure 19 and Figure 20 show that the monitored projects address all types of technologies and services in a more balanced manner for the projects funded by the Horizon programmes (with a low coverage of Storage and power-to-X technologies) and with an emphasis on grid technologies for projects funded by other funding programmes (roughly half of the projects).

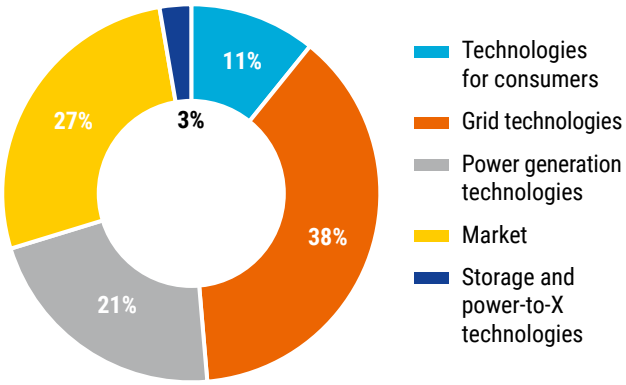

Figure 19: Technologies and Services Tackled (Horizon programmes)

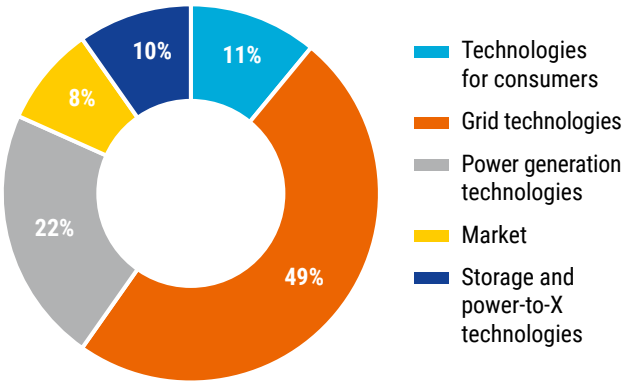

Figure 20: Technologies and Services Tackled (Other Programmes)

2.7.1.3 Benefits brought by the projects

The 117 RDI projects considered offer various contributions for different parties in the energy sector. These contributions have been assessed in a form of benefits, which have been identified within the European project **INTENSYS4EU**[4]:

- **Efficient business models & market designs**, corresponding to projects working on innovative business models or market designs, aiming to bring economic benefits to society;
- **Decreased network costs**, corresponding to a reduction in capital expenditure (CAPEX) and/or operating expenditure (OPEX) of distribution and/or transmission networks;
- **Improved network management**, corresponding to measures which enhance the transmission and distribution network management, for instance congestion reduction, the improvement of grid security and reliability;
- **Decreased carbon emissions**, corresponding to benefits related to the decrease of greenhouse gas (mainly CO2) emissions, for instance due to the increase of renewable penetration;
- **Reduced energy bills** corresponding to benefits linked to the decrease of energy costs for consumers and/or the reduction of energy consumption;
- **Improved social acceptance**, corresponding to measures which foster the acceptance of technologies by society.

Based on this approach, the allocation of the projects' benefits is illustrated in Figure 21. It shows that the top 3 benefits brought by the projects are improved network management (40 %), decreased carbon emissions (21 %) and efficient business models & market designs (16 %). The category least represented is improved social acceptance.

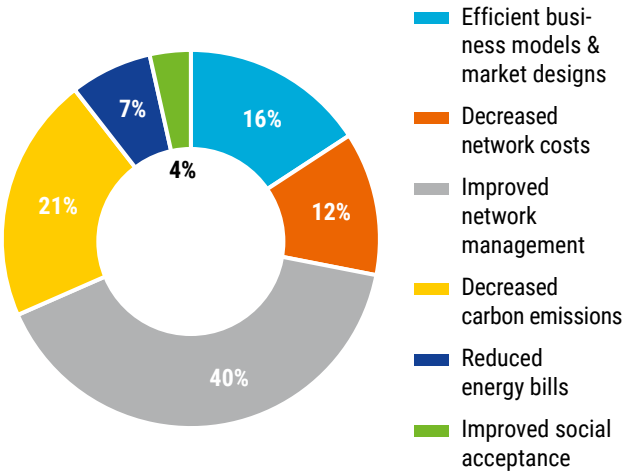

Figure 21: Benefits brought by Projects

4 INTegrated ENergy SYStem, a pathway for Europe

2.7.1.4 Projects' KERs

Within the survey, it was requested to identify up to five project results which are the most relevant for exploitation. A total of 192 KERs have been identified by the projects' coordinators. The displayed data focuses on the description of features and the further steps and barriers before the exploitation of the projects' KERs.

Descriptive features of projects' KERs

Nature of KERs

The results of the survey show the wide nature of the KERs within the listed projects:

- **Methodology:** methodologies for designing new rules, energy scenarios, etc.;
- **Software:** development or demonstration of simulation tools, decision-making support tools, etc.;
- **Hardware:** development or demonstration of pieces of hardware;
- **Database:** quantified scenarios, results of cost–benefit analyses, etc.;
- **Policy & Regulation recommendations; and**
- **New Business Models.**

As shown in Figure 22, the dominant category of the KERs' nature present in the listed projects corresponds to methodologies, software and hardware tools. Policy and regulation recommendations in addition to database are covered by 8 % and 11 % of the projects, respectively. A significant number of KERs (11 %) have a nature which corresponds to new business models.

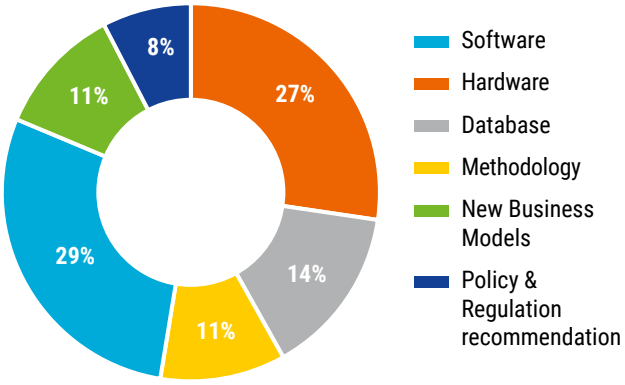

Figure 22: Nature of KERs

Output TRL of KERs

The KERs presented by the projects listed in the survey have also been analysed depending on their aimed output TRL at the end of the project. TRLs are a type of measurement system used to assess the maturity level of a particular technology. There are a total of 9 TRLS, defined as:

- **TRL 1:** basic principles observed;
- **TRL 2:** technology concept formulated;
- **TRL 3:** experimental proof of concept;
- **TRL 4:** technology validated in lab;
- **TRL 5:** technology validated in a relevant environment (industrially relevant environment in the case of key enabling technologies);
- **TRL 6:** technology demonstrated in a relevant environment (industrially relevant environment in the case of key enabling technologies);
- **TRL 7:** system prototype demonstration in an operational environment;
- **TRL 8:** system complete and qualified; and
- **TRL 9:** actual system proven in an operational environment (competitive manufacturing in the case of key enabling technologies).

Figure 23 shows the distribution of KERs by their aimed targeted output – TRL level. It is evident that the TSO's RDI activities span all TRL levels. Considering concentration in individual levels, the largest number of KERs aim for TRL 9 (55 KER) as the expected or targeted TRL output, followed by KERs which expect an output TRL of 7 (52 KER).

Cross-checking the results concerning the nature of the KERs (see above) to the output TRL, it can be seen that the most frequent nature of KERs with a high TRL are the most frequent KERs from the RDI activities, i.e. software and methodology.

Both TRL 7 and TRL 9 are threshold levels for technology development. While the large number of KERs at TRL 9 is aligned with the ENTSO-E RDI Roadmap, as it calls for innovations activities with higher TRLs for the faster deployment and implementation of advanced infrastructures, the accumulated number of KERs aiming at a TRL of up to 7 is larger than the sum of the number of KERs aiming for TRL 8 and TRL 9, i.e. the cumulative distribution shows that the majority of KERs aim for up to TRL 7 at the end of the project.

According to the ENTSO-E paper Innovation Uptake through Regulation[5], activities aiming for levels up to TRL 7 'System prototype demonstration in operational environment' are exploratory and OPEX intensive, with a high risk of 'failure'; however, even 'failure' projects bring additional values through knowledge building, and full cost recovery is needed for these activities, which is currently not the case in the majority of the European regulatory frameworks. Furthermore, mature solutions at TRL 9 'Actual system proven in operational environment' are ready for full-scale deployment, requiring targeted incentives which can rely on Key Performance Indicators.

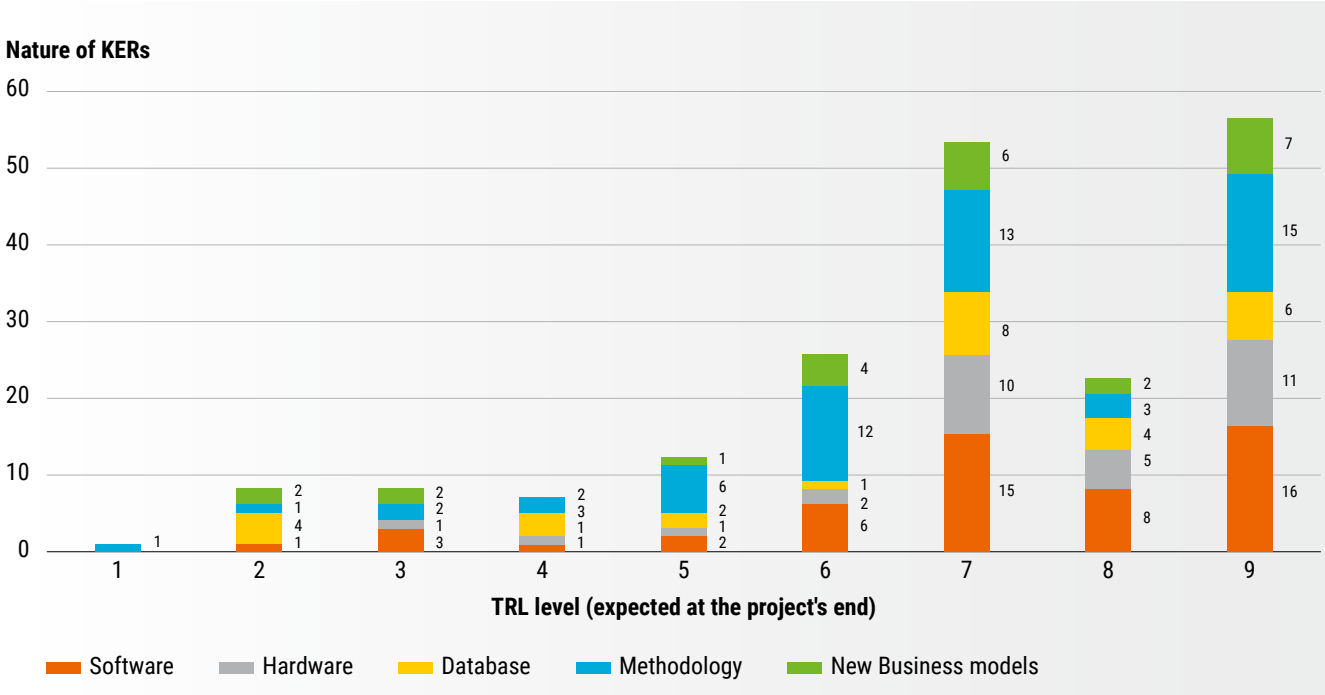

Figure 23: Distribution of the KERs and their nature across their expected TRL at the of the project*

* TRL is not applicable for KERs of policy and regulatory recommendations

5 Innovation Uptake through Regulation (entsoe.eu)

Projective features of Key Exploitable Results

Expected effective use of KERs

The following (non-exclusive) categories have been defined related to the expected effective use of KERs:

- **Private / Internal use**, i. e. by one project's consortium partners
- **Collective use**, i. e. jointly by several project consortium partners
- **Public use**, i. e. open source, open data, open access, public domain
- **Commercial use**, i. e. integration within an educational programme.

Figure 24 displays the distribution of the expected effective use for the KERs, which show mainly an expected public use and on the other hand, the least expected use correspond to commercial use.

Related to the nature of the KERs (Figure 22) and the Business Areas (Figure 16) mostly addressed by the surveyed projects, it can be seen that the TSOs' RDI activities mainly develop innovative methodologies and software, addressing energy system flexibility and the operation of future grid, to improve the public use of the grid. The second largest share is collective use, and we will see from the results on partnerships that these research activities aim for KERs that can be collectively used by several TSOs.

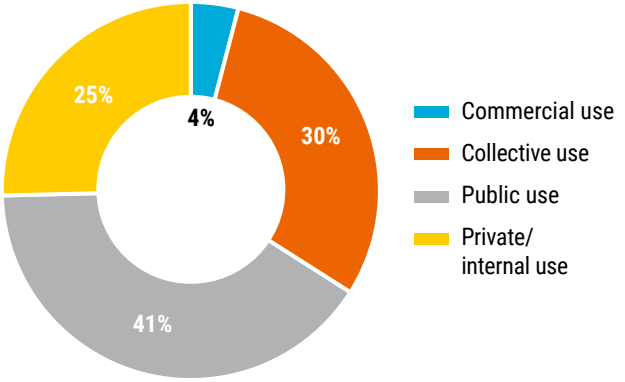

Figure 24: Effective use of KERs

Time to exploitation of KERs

'Time to exploitation' includes 'time-to-market' for commercial products, and 'time-to-operational use' for non-commercial results, i. e. innovations developed within regulated frameworks, starting from the time of answering the survey of each project. Different timeline ranges have been defined to explore the time-to-exploitation of the different KERs:

- The KER is **already in the market**
- KER exploitation is going to start **immediately**
- KER exploitation will start within **less than 2 years**
- KER exploitation will start between **2 and 5 years**
- KER exploitation will start **between 5 and 10 years**
- KER exploitation will start within **more than 10 years**

As can be seen in Figure 25, most KERs are expected to be exploited between 2 and 5 years (57 KERs), whereas only 3 KERs are expected to start with exploitation in a time frame which exceeds 10 years, showing the strong commitment to accelerating the energy transition.

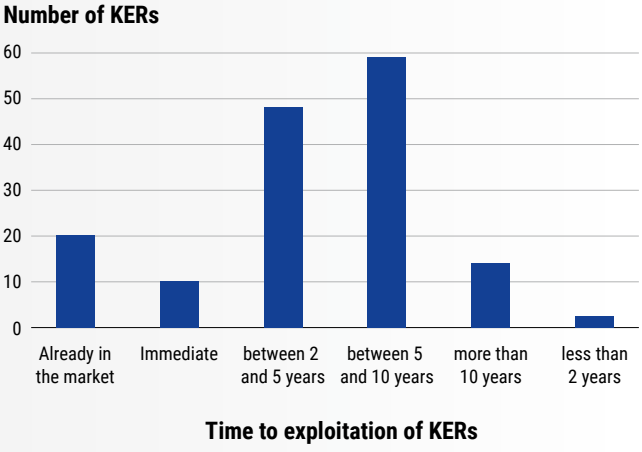

Figure 25: Time until effective use of KERs

Next project steps for the exploitation of KERs

Additional next steps necessary towards the successful exploitation of KERs have been provided by the interviewed parties. The steps can be grouped into 3 main categories:

- Next steps internal to project consortium, such as further testing, further demonstration, internal deployment, etc.
- Next steps involving external stakeholders, such as external certification, external dissemination, etc.
- Next steps involving changes in existing framework, such as regulation, market, etc.

As shown in Figure 25, more than half of the KERs (63 %) considered have identified as main next steps those internal to the project consortium, meaning further testing, further demonstration and internal development is required.

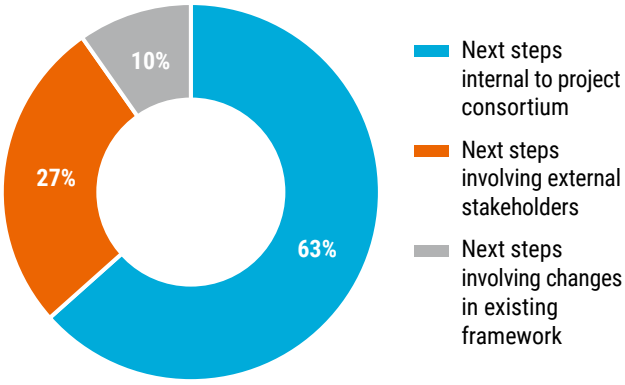

Figure 26: Additional Steps to increase the KER implementation efficiency

Barriers to exploitation of KERs

Surveyed parties have been questioned about barriers to achieving KER exploitation. Different barriers have been identified within the provided data:

- Inadequate regulations;
- Inadequate market conditions;
- Difficulties in scaling-up;
- Further investments needed;
- Data acquisition and management / IT complexity;
- Other; and
- No specific barrier

The results are presented in Figure 27.

More than one quarter of the barriers identified within the projects are related to the regulatory environment (27 %), followed by the barriers related to market conditions (20 %). For 18 % of KERs, scaling up has been identified as a main barrier for their exploitation, followed by data acquisition and management / IT complexity, which were identified as main barriers for the exploitation of 13 % of the KERs.

These results confirm that it is necessary to work together with regulatory authorities in order to create an environment for innovation uptake, as suggested by the ENTSO-E Innovation Uptake through Regulation[6]. Furthermore, the acceleration of the ongoing work on the Digitalising the energy system – EU action plan from the European Commission to which ENTSO-E is actively contributing, will also contribute to overcome the barriers for exploiting innovations in the electricity transmission system.

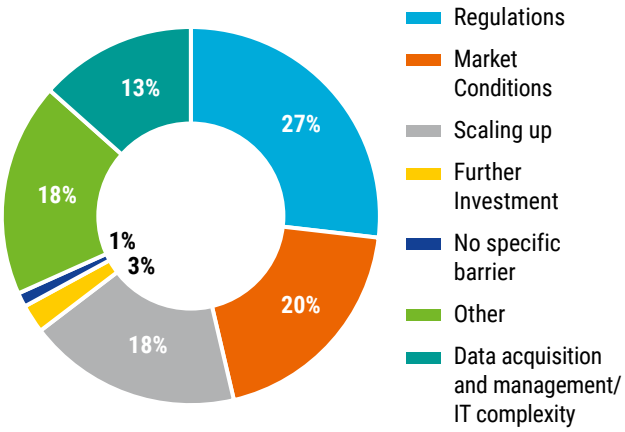

Figure 27: Barriers to exploitation of KERs

6 Innovation Uptake through Regulation (entsoe.eu)

Target group that the KERs have been designed for

It is possible that the projects' KERs target various groups and/or entities. They have been identified as follows:

- System operators;
- Asset managers;
- Energy consumers;
- Energy suppliers and service providers;
- Public authorities;
- Technology / Software developers; and
- Other.

The results of the performed analysis are presented in Figure 28: Target Group of KERs.

More than half of the KERs target system operators and asset management; 8 % of KERs are targeted at energy suppliers and service providers and public authorities, as well as technology / software developers, individually. Energy consumers are targeted by 6 % of each KER. Regarding the effective use of KERs (Figure 28), it can be seen that TSOs' research activities focus on enhancing their business processes to optimise the public use of the grid.

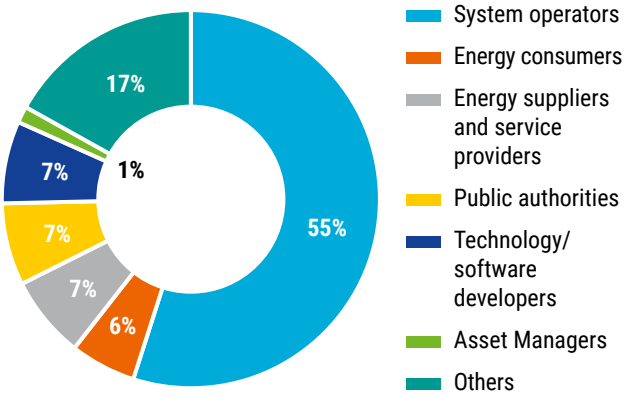

Figure 28: Target Group of KERs

2.7.1.5 Type of partner organisations

The nature of the partner organisations listed for each project have additionally been analysed. Based on their nature, the partner organisations have been categorised as:

- System operators;
- RDI institutions and universities;
- Industrial;
- Energy suppliers;
- Technology and ICT service providers; and
- Others.

The results from this analysis are presented in Figure 29.

Most projects (27 %) are supported by RDI institutions and universities, followed by system operators with 25 %.

Regarding the effective use of KERs (Figure 24) and the target group of KERs (Figure 28), the large share of partnerships between system operators shows that key exploitable results from TSOs' RDI activities are to be used collectively by TSOs to improve the public use of the electricity grid.

The largest share of partnerships with RDI institutions and universities, and with industry, shows that research projects involving TSOs are a 'hands on' platform for knowledge transference, serving as a bridge from fundamental research to technology development and integration.

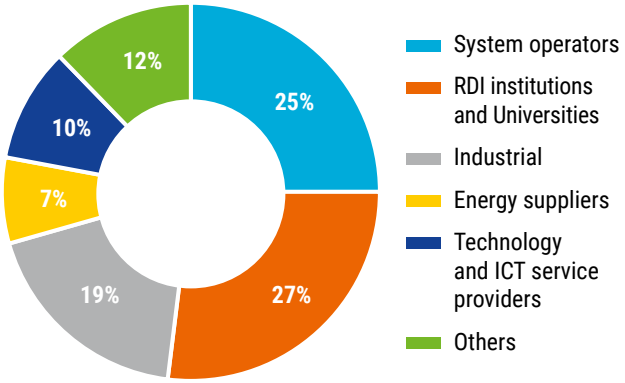

Figure 29: Type of Partner Organisations

2.7.1.6 Budget distribution

Figure 30 shows the different budget ranges for Horizon-funded and non-Horizon funded projects. The projects can be found in all five budget categories. Most of the Horizon-funded projects (roughly 57 %) are within the 10–20 M€ range and higher categories. Twenty-three percent of the Horizon-funded projects have budgets ranging between 5–10 M€, whereas the non-Horizon -funded projects have more dispersed budgets.

Furthermore, it is of interest to analyse the budget range with respect to the origin of the projects' funding. For this purpose, the funding correlation is presented in Figure 31. It can be concluded that the TSO funded projects typically have budgets between 1 M€ and 5 M€ (33 %) or budgets less than 500 k€ (29 %). On the other hand, most projects with EU funding origin (35 %) have budgets ranging from 10 M€ to 20 M€.

Whether the co-funding is an incentive to innovation or not depends on the regulatory system. In view of the necessary acceleration of the energy transition and the REPowerEU action plans, the regulatory authorities and TSOs should work together to find appropriate solutions that are clear incentives to finding innovative solutions, namely for increasing the share of renewable energy in the electricity consumption and, therefore, increasing energy independence, as well as the robustness of the European electricity backbone that is currently ensured by ENTSO-E members.

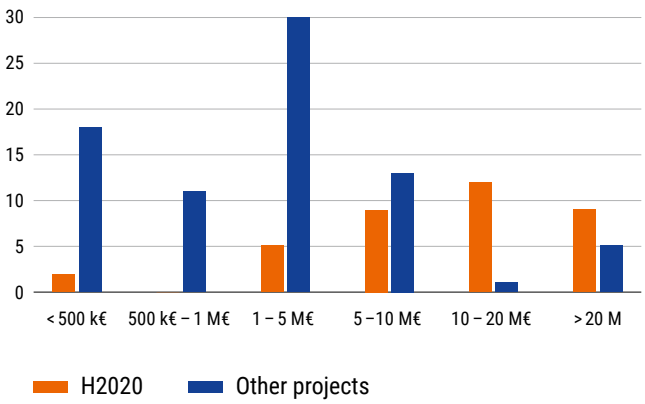

Figure 30: Projects' Budget ranges

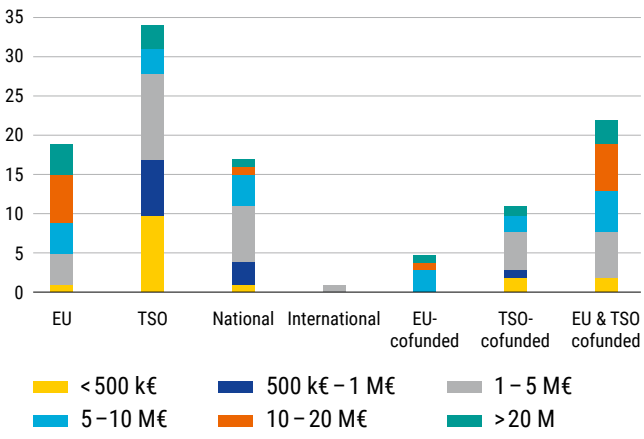

Figure 31: Funding Correlation

3 Horizon Europe Work Programme 2023–2024

The monitoring activity assessed the extent to which the ongoing projects align with the ENTSO-E's RDI Roadmap, Implementation Report and Acceleration Mission, in addition to the benefits of the projects, the nature of the projects' KERs and their use. With the help of this assessment, it was determined which RDI topics are already addressed and in which areas the current RDI activities should be intensified. This chapter subsequently focuses on the milestones of the RDI Roadmap that were not addressed by the surveyed projects and to what extent they can addressed by the new Horizon Europe (HEU) 2023–2024 work programme. With the help of this classification, it is possible to identify potential funding opportunities to address the gaps.

Within the TSO environment, 15 funding calls were identified. The match between the 15 funding calls and the 18 milestones with a low level of coverage by the surveyed RDI activities is visualised in Figure 32. The top row lists the currently not addressed milestones, whereas the column on the left lists the Funding calls and their names. The identified matches are partial, and most milestones in the RDI Roadmap are not in the outcomes of the calls. To improve the alignment of topics from generic research programmes with the RDI Roadmap, milestones of the RDI Roadmap should become part of the outcomes of the research topics in the HEU. For example, the priorities from the milestones with low coverage such as 'Cross sector energy system restoration assessment' needs to be addressed by future RDI efforts. This milestone is partially matched with only 3 topics of the HEU programme, while it is relevant to maintain and improve the energy system resilience amid the challenges brought by energy insecurity in Europe and the necessary acceleration of the energy transition. Hence, a strong alignment between the HEU topics and the milestones of the ENTSO-E Roadmap would benefit all grid users.

Although the alignment of the generic research programmes with the RDI Roadmap is positive, it does not translate automatically into incentives to research by TSOs. The incentive depends on the specific regulatory system in each country. In view of the monitoring activity, the RDI activities mostly funded by TSOs and these activities are already supporting the TSOs to deliver high quality and security of supply through an accelerated energy transition. Incentives, ranging from full recognition of research costs up to regulatory sandboxes, will effectively incentivise the development of innovative solutions towards improving energy independence and sustainability through increasing the use of renewable energy sources and electricity in the final consumption of energy.

	FS 1	FS 2		FS 3		FS 4		
Milestones not adressed / **Funding Calls WP 2023 – 2024**	Planning tools to enable Sector coupling investments	Improved CBA considering deep electrification scenarios	Cross sector energy system restoration assessment	Eco-design and lifecycle management	Circular economy included in planning and asset management	Definition of Offshore wind ancillary services	Regulatory framework implementation	Pan-EU standard HVDC modeling tools
D5-1-1: Static, smart, low-cost pervasive slow charging and bi-directional solutions synergic with the grid for EV mass deployment (2024)								
D5-1-14:Integrated flexible multi-point megawatt charging systems for electric truck mass deployment (2024)								
D3-3-3: System approach for **grid planning** and upgrade in support of a dominant electric mobility (vehicles and vessels) using AI tools (2023)								
D3-3-4: Digital tools for enhancing the uptake of digital services in the energy market (2023)								
D2-1-5: **Hybrid** electric energy storage solutions for **grid support** and charging infrastructure (2023)								
D3-1-12: Energy Management Systems for flexibility services (2024)								
D3-3-5: Creation of an open-source block-chain based default Peer-to-peer platform (2023)								
D3-1-10: Supporting the development of a digital twin to improve management, operations and resilience of the EU Electricity System in support to REPowerEU (2023)								
D3-2-14: Digital twin for forecasting of power production to wind energy demand (2023)								
D3-1-12: Development of MVDC, HVDC and High-Power Transmission systems and components for a resilient grid (2023)								
D3-1-15: HVAC, HVDC and High-Power cable system (2023)								
D3-3-6: Components and interfacing for AC & DC side protection system – AC & DC grid: components and systems for grid optimisation (2023)								
D3-1-17: Development and integration of advanced software tools in SCADA systems for High, Medium and Low voltage AC/DC hybrid systems (2024)								
D3-1-13: DC and AC/DC hybrid transmission and distribution systems (2024)								
D3-2-21: Supporting the green and digital transformation of the energy ecosystem and enhancing its resilience through the development and piloting of AI-, IoT Edge-cloud and platform solutions								

☐ Funding call was linked by an ENTSO-E working group to the specific Flagship
☐ Funding call was not originally linked to this specific Flagship

Figure 32: Linkage between the Horizon Funding Calls of the Work Programme 2023 – 2024 and the Milestones in the Roadmap that are currently not addressed by the surveyed RDI activities

	FS 4							FS 5
Milestones not adressed / **Funding Calls WP 2023 – 2024**	Model for inter-operability assessment of grid forming converters	Medium volt-age DC multi-vendor & multi-terminal demonstrator	Defined and evaluated protocols for multivendor "plug & play" approach	Multi-vendor & multi-terminal HVDC full scale demonstrator	HVDC insula-tions and circuit breakers field tested	Dev. of HV components and sub-systems f. extreme envir. conditions	Reliability and asset management of HVDC equipment	DC faults propagation assessment
D5-1-1: Static, smart, low-cost pervasive slow charging and bi-directional solutions synergic with the grid for EV mass deployment (2024)								
D5-1-14:Integrated flexible multi-point megawatt charging systems for electric truck mass deployment (2024)								
D3-3-3: System approach for **grid planning** and upgrade in support of a dominant electric mobility (vehicles and vessels) using AI tools (2023)								
D3-3-4: Digital tools for enhancing the uptake of digital services in the energy market (2023)								
D2-1-5: **Hybrid** electric energy storage solutions for **grid support** and charging infrastructure (2023)								
D3-1-12: Energy Management Sys-tems for flexibility services (2024)								
D3-3-5: Creation of an open-source block-chain based default Peer-to-peer platform (2023)								
D3-1-10: Supporting the develop-ment of a digital twin to improve management, operations and resil-ience of the EU Electricity System in support to REPowerEU (2023)								
D3-2-14: Digital twin for forecasting of power production to wind energy demand (2023)								
D3-1-12: Development of MVDC, HVDC and High-Power Trans-mission systems and components for a resilient grid (2023)								
D3-1-15: HVAC, HVDC and High-Power cable system (2023)								
D3-3-6: Components and inter-facing for AC & DC side protection system – AC & DC grid: components and systems for grid optimisation (2023)								
D3-1-17: Development and integration of advanced software tools in SCADA systems for High, Medium and Low voltage AC/DC hybrid systems (2024)								
D3-1-13: DC and AC/DC hybrid transmission and distribution systems (2024)								
D3-2-21: Supporting the green and digital transformation of the energy ecosystem and enhancing its resilience through the develop-ment and piloting of AI-, IoT Edge-cloud and platform solutions								

4 Conclusions and Recommendations

The RDI Monitoring Report surveyed 117 research projects involving TSOs. The analysis delved into the alignment of the ongoing research activities with the RDI Roadmap, Implementation Report and Acceleration Mission, as well as understanding the benefits and usage of the KERs of the projects.

The ENTSO-E RDI Roadmap is a research, development and innovation programme for the 2020–2030 period. The results of the current survey show that over 80 % of the milestones of the Flagships are covered at high or medium level by the RDI projects, showing an overall alignment of the ongoing RDI activities with the ENTSO-E planning and a strong commitment towards carbon neutrality by 2050 at the latest. In fact, there is a significant share of projects funded by TSOs (40 %), showing that research is already supporting the activity of TSO in the energy transition.

All the 7 focus topics identified in the Acceleration Mission have, at least, a medium degree of coverage by the ongoing RDI activities, while the current research efforts show high coverage of the 'Automated decision support systems' and 'Flexible network technologies and digital infrastructure'. This high degree of coverage does not preclude the existence of open questions. Therefore, it is recommended to boost RDI activities towards digitalisation and digital twin, and vendor independent solutions for automated decision-making.

The majority of the surveyed projects address the energy system flexibility and the operation of the future grids. The most frequent benefits arising from the innovation projects are improved network management (40 %) and decreased carbon emissions (21 %). To continue to support the Green Deal and the REPowerEU, it is recommended to boost research activities in storage (in particular long duration), Power-to-X technologies (incl. electrification of transport), stability management with high penetration of power electronics in the system, eco-design and the circular economy, and the assessment methodology and metrics of flexibility needs and value at pan-EU level.

The surveyed research projects declared a total of 192 KERs. The majority of KERs are innovative methodologies (29 %) and software tools (28 %), whereas the most frequent effective use of KERs is public use (41 %) followed by collective use (30 %) by the TSOs and other stakeholders to improve the public use of the electricity network. Most KERs are expected to have a TRL of up to 7 at the end of the projects (115 KER), among which 52 are aiming for TRL 7. There is also a high number of KERs aiming at TRL 9 (55 KER) by the end of the project. Most KERs are expected to be exploited within 5 years, but this may be hindered by unsuitable regulatory environments (27 %) or market conditions (20 %), the most frequent barriers for exploitation declared in the survey. These results confirm that it is necessary to work together with regulatory authorities to create an environment for innovation uptake, as suggested by the ENTSO-E paper 'Innovation Uptake through Regulation'.

In the short-term opportunities, 15 topics were identified from the work programme of Horizon Europe for 2023–2024 as being partially aligned with the 18 milestones with low degree of coverage by the current surveyed RDI activities. The identified matches are partial, and most milestones in the ENTSO-E Roadmap are not included in the outcomes of the calls. To improve the alignment of topics from Horizon Europe with the RDI Roadmap, the milestones of the RDI Roadmap should become part of the outcomes of the research topics from the Horizon Europe.

The existence of potential public funding aligned with TSO activities is very positive, but this incentive to research depends on the specific regulatory system of each country. Investment intensive innovation projects, such as the first-in-kind HVDC multi-vendor & multi-terminal full-scale demonstrators, might even require special support to decrease its risks. Given that the TSOs' research activities produce results aiming at all levels of TRL, regulatory incentives, ranging from the full reimbursement of research costs up to regulatory sandboxes and pilot projects, are all necessary. This approach will effectively incentivise the development, deployment and integration into service of innovative solutions towards improving energy independence and sustainability, by increasing the use of renewable energy sources in the final consumption of energy through the increased use of electricity and participation of consumers in the electricity markets.

List of Abbreviations

CAPEX	Capital Expenditure
DSO	Distribution System Operator
ENTSO-E	European Network of Transmission System Operators for Electricity
EU	European Union
H2020	Horizon 2020 funding programme
HEU	Horizon Europe funding programme
HVDC	High-Voltage Direct Current
ICT	Information Communication Technology
KER	Key Exploitable Result
OPEX	Operational Expenditure
RES	Renewable Energy Source
RDI	Research, Development, and Innovation
TRL	Technology Readiness Level
TSO	Transmission System Operator
TYNDP	The 10-year network development plan

Contributors

This Report was conducted by the Working Group Research, Development and Innovation Planning (WG RDIP) under the Research, Development and Innovation Committee of ENTSO-E in support of the engineering consulting company, umlaut SE. The RDI Monitoring Report 2022 was supported by all the thematic working groups of the RDI Committee.

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Appendix

Summary of the reported RDI projects

Project Identification	TSO involved in the project	Country of coordinating organization	Project website	Project objective / description	Funding program
DigiTEL Alba Iulia	C.N.T.E.E. Transelectrica S.A.	Romania	N/A	An expected increase in the operational safety and performance of the National Energy System and standardization of RET asset monitoring solutions. 10 special objective are forseen in the direction of digitalization and optimization of various sectors.	TSO
10.3-0018-SI-W-M-18	ELES, Ltd., Electricity Transmission System Operator	Slovenia	**[Link]**	The project aims at solving network voltage, frequency control and congestion issues and enabling further deployment of renewables (RES) and displacement of conventional generation by integrating new active elements in the transmission and distribution grids into the virtual cross-border control centre based on advanced data management and common system optimisation	EU, TSO
2016-096 NEWEPS – Nordic Early Warning Early Prevention System	Statnett	Norway	NA	The main objective of NEWEPS is to develop and demonstrate technical methods for power system monitoring and control for the Nordic power system- with main focus on Sweden and Norway.	National
2017-093 Avbruddskostnader, hovedprosjekt	Statnett	Norway	NA	Main goal of the project is to estimate the Value of Lost Load based on cost based on sector / extension, frequency and short / long duration, and relate this to the income regulation for grid companies.	National
2017-175 ICEBOX	Statnett	Norway	**[Link]**	Reduced number of disruptions and catastorfic failure of power lines due to icing. Develop tools and measures for dimensioning, monitoring and preventioning of failures related to icing.	EU, National, TSO
2018-116 ECoDiS – Engineering and Condition monitoring in Digital Substation	Statnett	Norway	NA	The main goal is to exploit the full potential inherent in digital substations, in order to increase security-of-supply, safety, observability and reduce costs in a changing energy system.	TSO, EU
2019-054 CybWin	Statnett	Norway	NA	The main delivery is a Cyber Security platform with physical, replicated and simulated components of critical infrastructure, with support for RAMS tools (reliability, availability, maintainability, security), as well as vulnerability assessment, attack simulation, event prediction and response.	National
2019-087 Nye miljørestriksjoners innvirkning på kraftsystem	Statnett	Norway	**[Link]**	The main goal is to quantify the socio-economic impact on the power system of new hydropower environmental restrictions. The impact on avalable power, energy balance, market prices, distributional impact etc. shal be evaluated.	EU
2020-314 ASAP (Advanced System protection schemes Applied in the Power grid)	Statnett	Norway	NA	The primary objective is to build the foundation for the long-term goal of an automatically activated and deactivated System Protection Schemes (SPS) by developing key building blocks, expected to provide highest reliability and utilization of the grid.	National
2020-478 COFACTOR (støtte)	Statnett	Norway	NA	Updated method used to estimate peak load from buildings, given new standards for insulation and smart energy usage. New power factors will impact the dimensioning of distribution grid and reduce investment cost.	EU
5G-VICTORI	IPTO	Germany	**[Link]**	5G-VICTORI will conduct large scale trials for advanced vertical use case verification focusing on Transportation, Energy, Media and Factories of the Future and cross-vertical use cases. It leverages 5G network technologies and exploits extensively existing facilities interconnecting main sites of all ICT-17 infrastructures	EU, International, TSO
A market design which supports the security of supply	Energinet	Denmark	N/A	Analyses show challenges with the security of supply, so therefore market measures should be implemented that make it attraktive for market participants to behave flexible in the system.	TSO

Disclaimer: The projects marked by a star (*) were reported after the survey was closed, therefore they were not taken into account in the statistical analysis of the RDI Monitoring Report 2022, although they are listed in this Annex.

Project Identification	TSO involved in the project	Country of coordinating organization	Project website	Project objective / description	Funding program
ABS4TSO	Austrian Power Grid AG	Austria	**[Link]**	Development of a 1 MW / 500 kWh battery storage system for the purpose of replacing the declining system inertia which is capable of providing highly dynamic system services with specific parameterisation options for the inverter.	National
Advanced decision support for control room	Energinet	Denmark	N/A	Increased use of advanced decision support is necessary for en RES based energy system with a high security of supply as it is needed to help handle the high complexity of the system. The project will build the capability to implement data based decision support in the control centre.	National
ARESS	Amprion	Germany	N/A	ARESS, the first rotating asynchronous phase shifter for a main frequency of 50 Hz, is a holistic solution for grid stabilization. An essential technological component of the asynchronous phase shifter system ARESS is an innovative frequency converter and a new, double-fed asynchronous machine with an optional flywheel.	National, TSO
Asset Management Moonshot	Elia Group	Belgium / Germany	N/A	Through the moonshot demonstrator we aim at giving information on the cause of the OHL incidents and be able to do that in near real time post incident. The demo will be done in a physical test bed where we plan to test different approaches and technologies including existing and new data.	own budget
BD4NERGY	REN, ELES, ENTSO-E	ITALY	**[Link]**	The project considers a set of scientific objectives aiming to devlop a data-driven Reference Architecture for AI-based edge-oriented scalable big data management as well as a semantic and business interoperability framework for cross domain edge-level analytics applications.	EU
CBP	Terna	Italy	N/A	Introduce the CBP in the italian market to support the aggregation pilot projects and to support a set of innovation initiatives aimed at evaluating new participation requirements, new processes, new technologies.	TSO
Coatings	Terna	Italy	N/A	Research and development on the use of new materials with high-level characteristics or performance to coat those normally used. The objective is to increase the resilience and reliability of network components, also with a view to greater environmental sustainability.	TSO
Consumer Centricity Moonshot	Elia Group	Beglium / Germany	**[Link]**	Demonstrate that an EV can be charged with self generated solar energy in a different country taking into account grid constraints.	TSO
Control architecture for hybrid cyber-physical system	RTE	France	**[Link]**	Explore the possibilities offered by a 3 layers control architecture based on decentralized or hybrid Cloud2Edge infrastructure to enable control features necessary to handle the energy transition	TSO
Control Room of the Future (APOGEE)	RTE	France	N/A	Renew the way we operate the system near real time in the new context of energy transition with very high number of interactions.	TSO
CoordiNet	Redeia, Svenska Kraftnat, IPTO	Spain	**[Link]**	Development of a smart and resilient energy system through demonstrating cost-efficient model(s) for electricity grid services that can be scaled up to include grids operated by other TSOs and DSOs, that will be replicable across the EU energy system, and provide the foundations for new network codes, particularly on demand-response.	EU
CPS4EU (internal RTE name NAZA)	RTE	France	**[Link]**	Using Model Predictive Control to manage congestion constraints on an electric network. Moreover, decentralized and self-adaptive IT architecture is suggested in the TSO control architecture.	EU – H2020
CROSSBOW (N. 773430)	Transelectrica, IPTO, ESO, EMS, NOSBiH, HOPS, CGES, MEPSO	Spain	**[Link]**	The objective of the CROSSBOW is to demonstrate a number of different, though complementary, technologies, offering the regional transmission network higher flexibility and robustness.	EU, Consortium partners

Disclaimer: The projects marked by a star (*) were reported after the survey was closed, therefore they were not taken into account in the statistical analysis of the RDI Monitoring Report 2022, although they are listed in this Annex.

Project Identification	TSO involved in the project	Country of coordinating organization	Project website	Project objective / description	Funding program
Cyber security simulation platform	Terna S.p.A.	Italy	N/A	Aims to increase employee awareness of cyber security issues by engaging them in new, innovative and engaging learning experiences. Simulation of the management and coordination of emergencies coming from the cyber-space.	Internally
CyberSEAS	ELES, Transelectrica, HOPS	Italy	**[Link]**	CyberSEAS improves the resilience of energy supply chains, protecting them from disruptions that exploit the enhanced interactions and extended involvement models of stakeholders and consumers in complex attack scenarios, characterised by the presence of legacy systems and the increasing connectivity of data feeds.	International, EU, TSO
DANPAC 2020	Energinet	Denmark	N/A	Safe installation and operation of UGCs on all voltage levels. Development of methods for analysis and design, including any necessary mitigative initiatives for the prevention of destructive impacts on the power quality caused by cable installation in the Danish power system.	TSO
DC corridor A	Amprion GmbH	Germany	**[Link 1]** **[Link 2]** **[Link 3]**	Construction and operation of a multi-terminal HVDC system, which consists of 3 independet bipole converters. The DC link includes both OHL as well as underground cables. Main topics are protection and fault tolerance, the technology of converters and cables as well HVDC reliability.	TSO
DFLEX	ČEPS, a.s.	Czech Republic	N/A	Describe, propose model and set up of independent flexibility aggregator in the Czech Republic focused on balancing services for TSO. Propose a methodology for baseline forecasting and assessment.	National
Digital Substation	MAVIR	Hungary	N/A	Transform secondary systems from analog to digital creating baseline for newly built substations	TSO, EU
DLR Pilot	Litgrid AB	Lithuania	N/A	The DLR pilot project is meant to prove the technology's working principle and to gather sufficient data, so that we could be certain about whether or not this technology could practically help Litgrid to solve current and future congestion problems, integrate additional RES.	TSO
Dynamic Line Rating	MAVIR	Hungary	N/A	Increase the capacity for our transmission lines get information (temp, sag) about TL-s near-real time	National, TSO
Eflex	CEPS	Czechia	**[Link]**	The project is to define options for Battery Energy Storage Systems (BESS) "surplus capacity" utilisation for ancillary services used by CEPS. The BESS concerned are those whose primary purpose are applications such as peak-shaving associated with EV charging or load-shifting at PV plants.	National
Electricity quality monitoring system	Litgrid AB	Lithuania	N/A	Power quality analyzers will be installed in multiple substations, which will connect to a central software. Various parameters will be available real-time, such as harmonics, transient processes, voltage and frequency fluctuations.	TSO
ELECTRON	IPTO, Transelectrica,	Luxembourg	**[Link]**	ELECTRON aims at delivering a new-generation EPES platform, capable of empowering the resilience of energy systems against cyber, privacy, and data attacks through four main pillars	International, EU, TSO
E-mobility Lab	Terna	Italy	**[Link]**	The E-mobility Lab aims at testing technical capabilities of E-mobility technologies (EV, charging stations, aggregation platforms) to provide flexibility services.	TSO
EnergiOprindelse/ Energy origin	Energinet	Denmark	**[Link]**	Defining a new way for energy certification in DK/Europe.	TSO
EnergyShield	ESO	Romania	**[Link]**	The EnergyShield toolkit will combine the latest technologies for vulnerability assessment (automated threat modelling and security behaviour analysis), monitoring & protection (anomaly detection and DDoS mitigation) and learning & sharing (security information and event management).	EU, International, TSO
Entso-E Feasibility of pilot for transmission line monitoring using space based technologies	ENTSO-E, Amprion, IPTO, APG, Elering, Fingrid, Litgrid, Statnett, Swissgrid, Tennet	Belgium, France	N/A	The objective is to combine the know-how still existing for the analysis of satellite images with the needs and KPIs of TSOs across Europe to develop a cost efficient buisness-model for service-providers and ESA that supports the TSOs with another source of reliable data for the operation of their OHLs.	ESA and service providers

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Project Identification	TSO involved in the project	Country of coordinating organization	Project website	Project objective / description	Funding program
ESA satellite imaging	Tennet	Netherlands	N/A	The project is set to develop a web based tool that would provide automated OHL clearance monitoring.	EU
EU-SysFlex	EIRGRID	Ireland	**[Link]**	Meeting EU RES objectives by developing a market design and regulation framework able to foster innovative flexibility approaches in order to address high RES scenario shortfalls of the European system.	EU, Some partners only partially funded by the EU.
EV Grid Integration	Litgrid	Lithuania	N/A	Project aims to assess the technological and economical aspects to smart EV charging, where charging stations would provide system balancing services.	National
FARCROSS	APG, IPTO, ESO, MAVIR, HOPS, OST	Greece	**[Link]**	Promotion of state-of-the art technologies to enhance the exploitation/ capacity/efficiency of transmission grid assets, either on the generation or the transmission level. The hardware and software solutions will increase grid observability.	EU
FESS	Terna	Italy	N/A	Characterization of electro-mechanical storage system (efficiency, CAPEX/ OPEX cost, O&M effort, ecc) Assessment of Flywheel capability and limit in providing grid services. FESS is developed to test ultra power intensive services e.g., contribution to grid inertia.	TSO
FLEXITRANSTORE	IPTO, ESO, REN, OST	Belgium	**[Link]**	FLEXITRANSTORE has identified two main strategic objectives: – To enhance and accelerate the integration of renewables into European Energy systems. – To increase cross-border electricity flows across Europe.	EU
FlexLoF	Amprion GmbH	Germany	N/A	The application of additional power electronic based load flow components (SSSC) in strongly meshed AC system were considered. Their benefits and disadvantages were compared with conventional elements like PST or Shunts in order to identify the need for temporary application of load flow devices.	internal ressources of contributors
Flexplan	Terna	Italy	**[Link]**	The optimal grid planning according to the climate and decarbonization targets for the future decades	EU – H2020
FORESIGHT	ESO	Greece	**[Link]**	The FORESIGHT project aims to develop a federated cyber-range solution to enhance the preparedness of cybersecurity professionals at all levels and advance their skills towards preventing, detecting, reacting and mitigating sophisticated cyber-attacks	EU, International, TSO
Future System Perspective	Energinet	Denmark	N/A	Analyse future energy system configurations and dynamics to identify challenges and support the development of new market concept, infrastructure building plans.	TSO
FutureFlow	ELES, APG, MAVIR, Transelectrica	Slovenia	**[Link]**	Designing a unique regional cooperation scheme between European TSOs associated with power system experts, electricity retailers, IT providers and renewable electricity providers. The scheme aims to open balancing and redispatching markets to new sources of flexibility and supporting such sources to act on such markets competitively.	EU
GG-FG HYGCEL	Fingrid	Finland	N/A	The main goal of the project is to study and create new knowledge about the role and possibilities of energy transmission systems supporting the hydrogen economy and enabling exports.	National, TSO
Green Balance	Energinet	Denmark	N/A	In collaboration with market participants the current market setup for ancillary services is evaluated and new concepts developed and tested in order to increase liquidity especially for new technologies and known technologies that does not participate today.	TSO
Green data	Elia Group	Germany	none	Provide the software developer with the forecast information of available production enabling them to match it with their own consumption needs. Create trust in the legitimacy of the green energy through granular certificates (book and claim) – match green power production/consumption.	TSO, National
GreenLab Skive PtX	Energinet	Denmark	**[Link]**		National

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H2RES	Energinet	Denmark	**[Link]**	Hydrogen production for transportation from offshore wind.	National
HySynergy	Energinet	Denmark	**[Link]**	Operating electrolysers to produce green hydrogen for oil refinery and/or direct use in transport sector	National
I4RD	APG	Austria	https://www.nefi.at/industry4redispatch/	NEFI– New Energy for Industry project that develops innovative grid-supportive solutions enabling the provision of flexibility from demand and supply-side at distribution network level for redispatch and the demonstration of an online, predictive and holistic control concept for industrial energy supply systems.	National
INCIT-EV	ELES	France	**[Link]**	NCIT-EV project objective aims to demonstrate an innovative set of charging infrastructures, technologies and its associated business models, ready to improve the EV users experience by considering their preferences in their design, with the ultimate goal of fostering the EV market share in the EU.	EU
Infra Moonshot	Elia Group	Belgium / Germany	N/A	see above	TSO, TBC if EU funded
InnoSys2030	TenneT, Amprion, 50Hertz, TransnetBW	Germany	**[Link]**	Development of innovative concepts for system operation. This includes especially curative (post-contingency) measures. Based on these concepts, simulations were carried out to evaluate the potential of these curative meausures. Furthermore, the risk for sytem security was assesed and a roadmap was developed.	National, TSO
Integrating new connection and customers to the grid	Energinet	Denmark	N/A	In order to ensure that new installations are geographically placed as optimal as possible in order to utilise the power grid to its full extent a mapping of the available capacity in the system should be constructed to help actors and external communication.	TSO
INTERRFACE	ENTSO-E, AST, ELERING, Fingrid, ESO, Transelectrica, REN	Luxembourg	**[Link]**	New services and products utilized by the TSO and DSO with high level of coordination between the SOs. Enabled TSO-DSO coordination during market process and systems resource qualification. Large field trials of developed IT solutions.	EU, Some partners only partially funded by the EU.
IntNET	ENTSO-E	Germany	N/A	Interoperability as the key enabler for the energy transition > Focus on interoperability in the electricity sector > Fostering multi-level interoperability	International
Inverter integration	Energinet	Denmark	N/A	Increase knowledge and support development to secure the robustness and quality of a power system with a high share of power electronic interfaced devices.	TSO
LIFE DANUBE FREE SKY	SEPS, HOPS, MAVIR	Slovakia	**[Link]**	The project will contribute to implementation of related EU environmental policy and strategies, including EU macro regional strategies for the Danube, Alpine, and Adriatic and Ionian regions.	EU, National, International
LIFE EUROKITE	APG, Amprion	Germany	**[Link]**	The project plans to use telemetry technology to identify and quantify the key reasons behind mortality of birdof prey species in the EU. It will take action to reduce the main human-related causes of death, such as collisions with wind farms, and electricity lines and poles.	International, EU
LINK4S	REN	PORTUGAL	To be done	Develop, test, and implement new generation connectivity systems with a large spectral applicability – namely in mobility and Energy – allowing new business models.	National, International
Lithuanian Offshore Study	Litgrid	Lithuania, Japan	N/A	The purpose of this study is to cooperate in order to compare and specify effective measures technically and economically including specifications and its associated costs for the offshore grid planning and design for the introduction of offshore wind power in Lithuania.	National, TSO
Market & Physics	Energinet	Demark	N/A	Internal congestion is expected to be an increasing problem as a result of fast implementation of large amounts of RES production. The project investigates several possible solutions as alternatives to infrastructure solutions.	TSO

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MIGRATE	TenneT, Elering, Landsnet, Fingrid, Amprion, Eirgrid, RTE, Eles, Terna, Redeia	Germany	**[Link]**	Address the challenges resulting from high penetrations of PE – interfaced generators such as growing dynamic stability issues, the necessity to upgrade existing protection schemes and measures to mitigate the resulting degradation of power quality due to harmonics propagation.	EU
MultiDC	Svenska kraftnat	Denmark	**[Link]**	Dynamic security – due to increase of PE generation. Optimal operation – significant cost and energy savings. Emergency control – HVDC connections will play a key role in an efficient and secure operation of the future system. Implementation and testing – to analyse the North Sea Wind Power Hub offshore grid stability, and HVDC effective utilization.	National, TSO
NEWEPS	Svenska kraftnät, Statnett	Sweden and Norway	N/A	Develop a system with demonstrators with open interfaces for early warning and early prevention of undesired system states such as instability and system breakdown; Develop specifications for testing the feasibility of the monitoring, assessment, and control applications;	National
Next Inertia	Terna	ITA	N/A	Project focuses on investigating new grid forming capabilities, by an experimental approach. Indeed, with a desk-study, it aims at forecasting the optimal techno-economic mix in future scenarios to guarantee grid stability.	TSO
NSWPH	TenneT	Germany	**[Link]**	In order to integrate large scale offshore wind a large amount of knowledge must be generated in order to succefully harness the RE ressources. This project seeks to generate that knowledge such that Energinet will able to complete this integration.	EU, TSO
ODL	Energinet	Denmark	**[Link]**	The open door lab is an innovation collaboration between Energinet and different actors such as companies where future solutions can be developed.	TSO
Omega-x	Elia Group	Spain	Not yet available	The demonstrator wants to enable the consumer to charge their electric vehicle in Germany at a public charging pole with the solar production in Belgium. The excess of solar production of one country needs to be transferred from one supplier in Belgium to the supplier of the charging pole operator in Germany.	EU, TSO
OneNet (internal name STAR)	ENTSO-E, IPTO, RTE, ELES, REN, AST, Elering, PSE, Fingrid, Litgrid, Cyprus TSO, ESO, CEPS, MAVIR	Germany	**[Link]**	Experimenting with new technological solutions to integrate new flexibility levers to manage congestion on their networks. The use case based on blockchain technology, aims to simplify and optimize the management of renewable production curtailments, by covering the entire life cycle of a flexibility offer.	EU, TSO, International, – H2020
OSMOSE	RTE, Terna, ELES, Elia Group, Redeia, REN	France	**[Link]**	To assess the techno-economic feasibility of new flexibiity sources (from the grid itself with DTR and from other players such as wind farms and industrial DSR)	EU
OSS-GD	Terna	Italy	N/A	The project aims at better estimating the entire distributed generation combining real-time measures of a subset of the power plants, the real-time meteorological data, anagraphic data and historical time series of produced and exchanged power.	TSO
PHOENIX	Transelectrica	France	N/A	PHOENIX aims to offer a cyber-shield armour to European EPES infrastructure enabling cooperative detection of large scale, cyber-human security and privacy incidents and attacks, guarantee the continuity of operations and minimize cascading effects in the infrastructure, the environment, the citizens and the end-users at reasonable cost.	EU, International, TSO
POSYTYF	RTE	France	**[Link]**	The POSYTYF project intends to support the further integration of Renewable Energy Sources (RES) into the power system by developing the Dynamic Virtual Power Plant concept (DVPP).	EU, International, TSO
Power Electronics and DC current	RTE	France	N/A	Feasibility study of a mutualised DC substation and local DC grid to connect different clients to the AC grid.	National
Power to Heat	Litgrid	Lithuania	N/A	Project aims to follow the national energy strategy for maintaining future grid stability through the introduction of a DSR service, based on P2H principle.	National, TSO

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PQ-Test 525-kV	Amprion TenneT, 50Hertz, TransnetBW	Germany	N/A	A German TSOs task force launches a prequalification test for the technical feasibility and capability of EHV DC cable systems with extruded insulation. Scope of investigation were cable systems up to a maximum voltage of 550 kV DC (rated voltage of 525 kV) and a rated current of app. 2000 A.	TSO
Predictive Maintenance	Terna	Italy	N/A	Develop tools and skills for monitoring and maintenance of an increasingly "intelligent" transmission network. The objective is the transition from a maintenance "on condition" to a predictive type with consequent optimization through the interpretation of data and the development of algorithms for prediction.	TSO
Project NEDO	ELES	Slovenia, Japan	**[Link]**	The benefits of the project are in the use of advanced solutions that can respond to the challenges of modern electricity systems. Instead of investing in grid expansion, the use of advanced secondary equipment, information and communication technologies and cloud solutions will enable better exploitation of the existing grid.	International, TSO
PROMOTION	EirGrid, Svenska Kraftnat, RTE, TenneT, Energinet, Scottish Hydro	Netherlands	**[Link]**	Forming the link between technology research, validation (testing) and development of recommendation for meshed offshore grids. These objectives of the project are development of interoperable & reliable network protection, work towards technology interoperability & standardisation.	EU
READY4DC	ENTSO-E, TenneT	Germany	N/A	READY4DC will create the right conditions to establish a community of experts that will discuss all the implications of the process of the case of offshore wind farms both from a technical and a legal perspective	International, EU
REGATRACE	Elering	Italy	**[Link]**	Strong contribution to the uptake of the European common biomethane market. It will be achieved by setting up a European biomethane/renewable gases GoO system, by integrating GoO from different renewable gas technologies with electric and hydrogen GoO systems.	EU, TSO, International
REInvest	Energinet	Denmark	**[Link]**	Design robust, cost-effective investment strategies that will facilitate an efficient transformation towards a 100 % renewable energy system in Europe. A unique transformational approach: a complete redesign of the whole energy system, utilizing the synergies between heat, electricity and transport.	National
RePLANT	REN	PORTUGAL	**[Link]**	Replant project is a collaborative consortium that aims at implementing strategies to tackle forest and wildfire prevention. The project relies on digital technologies, with high degree of innovation, enabling new services, processes, and products regarding risk mitigation and forest management.	National
Robotics for O&M	Terna	Italy	N/A	Implementation of solutions such as robots and drones that aim to promote an increasingly dynamic and innovative network monitoring, guaranteeing the efficiency and safety of the system. This also reduces maintenance costs and the risks associated with the interventions to be carried out.	TSO
Safety and Asset Management solutions	Terna	Italy	N/A	Digitize operational procedures and constitute an advanced support tool for activities related to working methods.	Internally
Satellites	Terna	Italy	N/A	Development of satellite solutions used for centralized data management through which it will be possible to monitor the power grid and make decisions about its development and maintenance.	TSO
SDN-microSENSE	ESO, IPTO	Spain	**[Link]**	SDN-microSENSE intends to provide a set of secure, privacy-enabled and resilient to cyberattacks tools, thus ensuring the normal operation of EPES as well as the integrity and the confidentiality of communications.	EU
SF6 Alternatives	Litgrid AB	Lithuania	N/A	The project aims to assess the SF6-free technologies for circuit breakers and instrument transformers and to demonstrate their operation in two pilot projects.	TSO, EU
SF6 free	Terna	Italy	N/A	One of the fields of research and experimentation is that of isolation and interruption solutions using alternative gases to SF6 in the fluids used, with the aim of reducing SF6 emissions and increasing the environmental sustainability of the network, in line with European directives.	TSO
Smart grid	Montenegrian TSO (CGES)	Montenegro	N/A	The aim of this project is the realization of remote monitoring, management and regulation of new facilities, including them in the new NDC SCADA/EMS system.	TSO

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Smart5Grid	IPTO, ESO	ITALY	**[Link]**	The first global technology standard that will address the variety of future use cases of the energy sector, by ensuring that both the radio and core network performance requirements can be met in terms of end-to-end latency, reliability and availability.	EU
SmartNet	Energinet, Terna	Italy	**[Link]**	Provision of solutions and architecture for optimised interaction betweenT-SOs and DSOs in exchanging information for monitoring and acquisition of ancillary services for local needs and for the whole European system. The project involves distributed generation, demand-side and storage-to-system services.	EU
S-MVDC	Amprion	Germany	N/A	Within the scope of the study, a concept for the application of superconducting medium-voltage cables for use in the transmission grid will be developed and evaluated. This includes both the electrotechnical and constructional aspects as well as topics related to the design of the cooling.	TSO
SOS	Elia Group	Belgium	N/A	Validate and test technology of USV to decrease cost and increase, safety, flexibility, quality and efficency of offshore asset management	TSO
Space Based Application e Space Weather	Terna	Italy	N/A	Study of the origin and effects of the Space Weather phenomena and the possible impacts that such events could have on the assets of the electrical grid. Therefore, a statistical correlation study has been carried out between the measurements of different geomagnetic indices and the number of failures recorded in the last 10 years.	TSO
StoRIES	RTE	Germany	**[Link]**	The project fosters a European ecosystem of industry and research organisations on energy storage technologies aimed at developing novel concepts and technologies.	EU, International, TSO
Strengthening the Transmission Network in the Southeast Region	MEPSO	North Macedonia	**[Link]**	Main objective of the project is secure and reliable integration of planned RES in the southeast region of the country. The project will raise the operation of the transmission grid on higher technical level by the use of smart grid solutions (DLR).	National, WBIF
SYNERGY	IPTO	Spain	**[Link]**	SYNERGY will develop a highly effective a Big Energy Data Platform and AI Analytics Marketplace, accompanied by big data-enabled applications for the totality of electricity value chain stakeholders (altogether integrated in the SYNERGY Big Data-driven EaaS Framework).	EU, International, TSO
TDX-ASSIST	ENTSO-E, REN, ELES	Great Britain	**[Link]**	The TDX-ASSIST project designs and develops novel ICT tools and techniques to facilitate scalable and secure information exchange between the TSOs and DSOs.	EU
TRILATE	Elia Group	Belgium	**[Link]**	Investigation of the energy system requirements for renewable energy carriers including an assessment for the required energy infrastructure. Focus on fundamental modelling of various aspects of the industrial system and a technology study on the future power grid along with feasibility of the energy infrastructure needs for different industrial clusters and regions.	National
TRINITY	ESO, RTE, NOSBiH, MEPSO, EMS	Spain	**[Link]**	Project objectives include enhancment of cross-border trading and balancing energy exchange, ensuring electricity market integration, increased share of RES in SEE, improved security of system operation in the context of increased RES and better coordination, interaction and communication	EU, Consortium partners
Voltage transformer with alternative gas	Amprion	Germany	N/A	Gain experience with new technology, longterm substitution of SF6, development of new standard technology.	TSO
VoltControl	Elia Group	Belgium	N/A	Decision support for voltage	TSO
VSP	Terna	Italy	N/A	Design and development of virtualisation and optimisation alghorithms. Automatitation of batteries testing procedures definition of advdance monitoring strategies and parameters for batteries.	National
WAFB4.0	Amprion	Germany	N/A	The temperature distribution and strain along the optical ground-wires will be measured. These data will be combined with different meteorological modells and measurements. The aim is to develop a methodology to combine different datasets for optimization of real-time monitoring and prognosis of OHL capacity.	National, TSO

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X-FLEX	ESO	Spain	**[Link]**	X-FLEX will propose a new concept that will integrate and create synergies among all energy flexibility sources and technologies, promoting cooperation of all the actors of the smart grid and energy market, in an efficient and cost-effective manner.	EU, International, TSO
RES integration study*	Litgrid AB	Lithuania	N/A	The main objective of the study is to find and evaluate the effect of new and innovative solutions (Dynamic line rating, power flow control schemes, integration of energy storage technologies, FACTS, and others) for greater RES integration into transmission network and to improve grid utilization.	TSO
Relay Protection & Automation Systems digitalization*	Litgrid AB	Lithuania	N/A	The purpose of this project is to move the entire relay protection and automation system data to digital space to faster and more accurately evaluate their selectivity and to improve operation of RPA.	TSO
BESS services capability assessment*	Litgrid AB	Lithuania	**[Link]**	1 MW and 1 MWh battery energy storage system (BESS) was developed and connected to transmission system in Lithuania as a grid component. This project allows to assess possible BESS use cases in Lithuania before and after synchronization with continental Europe's power grid, to analyze different BESS services in real life conditions and according to the test results to prepare technical requirements for such service providers and for connection of batteries energy storage.	TSO
Grid forming control study*	Litgrid AB	Lithuania	N/A	This study aims to assess usage of grid-forming converter-interfaced sources such as battery energy storage systems, renewables and HVDC interconnections in Lithuanian power grid and compare the result with currently used grid-following converter-interfaced sources data.	International, TSOs
Power line scanning and fault detection system*	Litgrid AB	Lithuania	N/A	To automate the power line inspection, Litgrid starts to use lidar scanning and data analyses services. Data base of Lidar scanning and AI methods how to treat the results should be established.	TSO
Open R&D platform using 1 MW BESS*	Litgrid AB	Lithuania	**[Link]**	Litgrid created an open and transparent model for the use of the 1 MW battery for new innovative projects for all electricity market players (producers, consumers, and demand aggregators), developers and/or manufacturers of new battery parks, research organizations and others.	TSO
10.7-0008-SKHU-W-M-20*	SEPS	Slovakia	**[Link]**	The aim of the Danube InGrid (Danube Intelligent Grid) is to integrate more renewables to the distribution grid by the application of smart technologies and manage them in a smarter way along with keeping the security and high quality of supply for the electricity consumers in the CEE region. Project Danube InGrid will adopt smart grid technologies both internally and on cross border level for the evolvement of modern energy infrastructure. It will efficiently integrate the behavior and actions of all market users connected to the electricity network, mainly consumers, prosumers and generators with the goal of integration of large amounts of electricity from renewable and/or distributed energy sources. Gaining and utilising experience in smart technologies in North Western Hungary and Western Slovakia, will be beneficial for electricity system users and distribution and transmission system operators. The second wave of the Danube InGrid project (Danube InGrid 2.0) is smart grid applications related to the design of smart substations, data exchanges, data flow and smart measurement and handling of interactions between TSO and DSO for the safe and efficient operation of future energy systems. The goal of the second wave of the Danube InGrid project is to improve cross-border cooperation at the level of TSO and DSO in coordination of the management of the electricity system with a focus on intelligent data collection and their exchange in order to enable the connection of a larger number of renewable energy producers to the electricity system with an emphasis on ensuring high quality and security of supply for energy consumers in the region of eastern Slovakia, northeastern and central Hungary.	EU, Beneficiaries
PIAF-Pilot Agreggation Flexibility*	SEPS	Slovakia		The project aims to test the concept of aggregating the flexibility of decentralized devices for the purpose of providing ancillary services for the transmission system operator, to identify legislative barriers to the development of this concept and to propose the necessary amendments to the energy legislation. Effective management of flexibility on the consumption side will reduce resource intensity and thus the carbon footprint.	TSO

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HVDC-Wise	TenneT DE, Energinet, Amprion, Statnett	France		HVDC-Wise project explores concepts and proposes solutions to foster the development of large HVDC based transmission grid infrastructures, able to bring benefits in terms of resilience and reliability to the existing electrical system and capable of integrating the forthcoming large amount of renewable energy.	EU
InterOPERA	RTE, TenneT DE, Amprion, Energinet, TenneT NL, Statnett, 50Hertz, Terna	France		InterOPERA project will demonstrate the benefit of multi terminal multi vendor HVDC substation, in order to develop "supergrid" architecture to connect offshore wind farm.The main problem to adress is the interoperability of such substation control (i.e.thus creating a cyber-physical system) where responsabilities are difficult to establish in case of malfunction. Guidelines for standard should emerge at the end of the INTEROPERA project.	EU
C3*	Red Electrica	Spain	NA	Develop a platform (C3)for advanced knowledge in REE to make construction works safer, more efficient and sustainable. C3 will process and exploit the data to improve efficiency and create automation and controls for decision-making	TSO
Use of satellites to estimate photovoltaic potential*	Red Electrica	Spain	NA	Evaluate the feasibility of making an inventory of photovoltaic panels by using very high resolution satellite images and artificial intelligence.	TSO
Partial discharge platform*	Red Electrica	Spain	NA	Improve the estimates required to improve the quality of condition-based maintenance,anticipating faults in assets to avoid them becoming unavailable and the high costs of repairing them. A platform to detect and diagnose partial discharges automatically hsa been developed for such purpose	TSO
Vegetation digitalisation*	Red Electrica	Spain	NA	Deployment of a new model for managing the vegetation growing near power lines. Until now, the plant species were identified manually using photograph interpretation techniques. This project created a series of algorithms to automate the interpretation of photos of tree species and scrubland using satellite images	TSO
Model for preventing occupational hazards*	Red Electrica	Spain	NA	To switch from a reactive/preventive model to a predictive model in the area of occupational health and safety, the project use Artificial Intelligence methods to create a probability indicator of the risk of accidents and issues associated with any maintenance and construction work.	TSO
Dalia*	Red Electrica	Spain	NA	This project strengths and creates efficiencies in the maintenance of overhead power lines by making knowledge systematic and standardising remote detection and classification of possible visual anomalies.	TSO
Newton*	Red Electrica	Spain	NA	Newton is Red Eléctrica's calculation programme easy to extend, integrate and maintain. It is state-of-the-art in power flow, linear calculations and other essential functions. Newton's architecture is designed for the desktop as much as the cloud, capable of massive calculations and integration with AI for the planning and operation of electricity systems	TSO
DLR platform*	Red Electrica	Spain	NA	The project aims to develop a transmission grid based on local and remote monitoring and sensors, operating with transmission categories calculated in real time. These capacities are calculated using a thermal model of the line and data obtained from the monitoring of immediate atmospheric conditions and/or the physical parameters of the installation along its full length.	TSO
Inertia +*	Red Electrica	Spain	NA	Develop and test grid-forming controls in order to evaluate their performance and contribution. A hardware in the loop testbench based on battery and supercapacitors has been used for the implementation and testing.	TSO
RES + *	Red Electrica	Spain	NA	Test and evaluate differnt servies provided by hybrid energy storage devices (battery and supercaapcitors) in order to provide different services to the power system (syntehtic inertia, voltage control power oscillation damping, etc)	TSO
SF6/SO2 sensor*	Red Electrica	Spain	NA	Pilot project for the remote inspection of facilities using artificial vision in different spectrums and the detection of SO2/SF6 gas (indicator of faults in the sub-station and greenhouse gas leakages) both in electricity sub-stations and the channels within them.	TSO

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SF6 recovery system*	Red Electrica	Spain	NA	This solution allows partial recovery of the SF6 leaked from GIS installations using absorbent materials (modified or synthesized commercial compounds).	TSO
Insure*	Red Electrica	Spain	NA	Low-cost IoT devices that are minimally invasive are developed, in order to monitor the dynamic response of safety elements and detect unsafe behaviours when carrying out work on transmission grid elements.	TSO
EPICS*	Red Electrica	Spain	NA	With this project, a software platform executed on diverse hardware, based on concepts of micro-services, will be designed to implement the functions of the sub-station automation system.	TSO
Self consumption platform*	Red Electrica	Spain	NA	This project allows the real-time monitoring of small-scale self-supply by TSO, information not available for the TSO. The data is used to enhance demand forecast.	TSO
Protected Zones*	Red Electrica	Spain	NA	This project ensured the safety of people and facilities during discharge operations, removing situations of risk for operators associated with their work in protected zones and accompanying tasks.	TSO

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