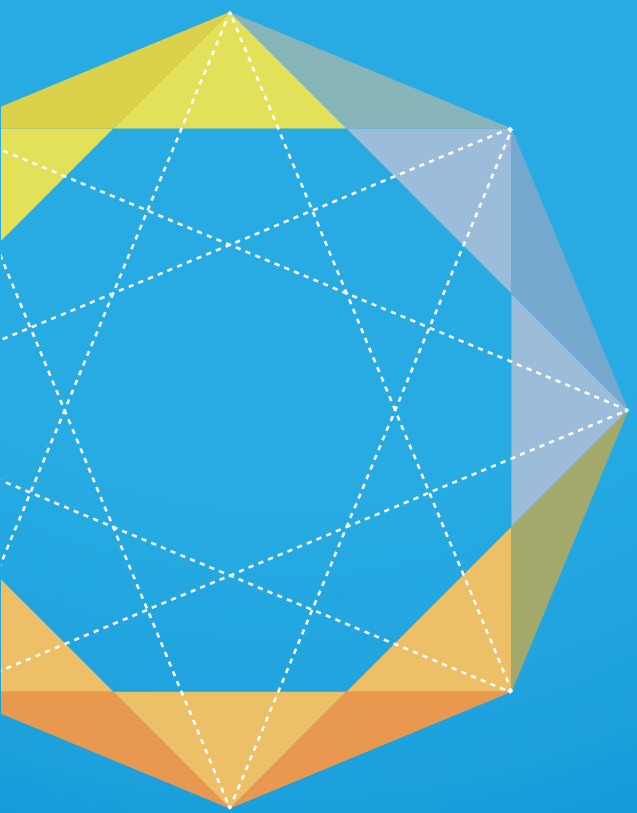
European Commission

Mapping progress in energy systems research and innovation

Update report



ETIP SNET

European Technology and Innovation Platform
Smart Networks for Energy Transition

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EXECUTIVE SUMMARY

This report is the first to provide an update on progress monitoring using the new research methodology with HLUCs[1] and PPCs[2] first introduced in the ETIP SNET[3] 2022-2025 Implementation Plan.

The previous framework looked at research and innovation activities more from an academic R&I (the "R") lens. For that ETIP SNET defined 6 Research Areas which were subdivided into 24 research topics with 90 Research Tasks at the foundation.

The latest framework adds the "I" part of the R&I frameworks to improve practical project comprehension, the latest Implementation Plan 2022-2025 takes a more Use-Case and thus project-oriented approach. It is less granular, with 9 High Level Use Cases (HLUCs) and 31 Priority Projects Concepts (PPCs) to be considered by 2025. At the very bottom and as smallest granularity of the framework, there remain the 90 Research Tasks: The change of frameworks shifts focus from providing insights into research needs to innovation needs for use cases and projects.

Therefore, it was important to ensure that the results of the 1st progress report could be related to the current results. This was ensured by cross-referencing the PPC development scale with progress on the Research Tasks covered in the previous survey. Such a comparison makes it possible to assess whether progress in PPC and HLUC development is being hindered or facilitated by progress in Research Tasks.

In the 2021 survey, respondents selected the most appropriate Research Tasks and assigned TRLs[4] from 1 to 9 associated to these Research Tasks, thus addressing the question what is the reached technology readiness level (TRL) with respect to each of the 90 tasks? There were no restrictions on the number of tasks that could be selected for the respective R&I project. In this 2023 survey, ETIP SNET asked respondents to select a maximum of three HLUCs and any relevant PPCs within those three HLUCs. After selection, ETIP SNET asked to define the phase of technology development - Research (TRL3-5), Demonstration (TRL 6-8) and Deployment (TRL 9) with respect to the PPCs and their associated HLUCs. This initially address the question - what is the technology readiness level (TRL) your project contributes within this PPC? The questions that were asked in the survey can be seen in Table 1.

Section 1 – General information
1. Name and contact details of a respondent
1. Full and short name of a project
2. Start and end dated of the project
3. Contributing organizations (companies, universities, etc.)
4. Source of funds (EU, national, private/ corporate, other)
5. Total project budget (amount received)
Section 2 – HLUC and budget allocation
1. Indicate maximum of 3 HLUCs to which your project contributes the most.
2. In your opinion, what percent of total budget is allocated to selected HLUCs: <25%, <50%, <75%, >75%
Section 3 - TRL levels and KERs for relevant PPCs
1. Choose the Priority Project Concept (PPC) you think your project belongs to and indicate the Development Phase which your project contributes to upon the completion
2. If your project meets TRL8 or TRL9 criteria, describe the product or service that could be commercialized.
3. Indicate up to 3 Key Exploitable Results of your project related to selected HLUC.
4. Indicate the knowledge gaps (if any) that were identified in your project and require further research

Table 1. Questionnaire structure

The survey highlighted the difference between BRIDGE and ERA-NET SES[5] projects. National and regional projects managed under the ERA-NET SES initiative largely contributed to the research phase (TRL 3-5). There are two explanations for this. First, the research agenda of ERA-NET SES is not so much focused on bringing technologies to market but is often directed to supporting academia given the available capacity. Second, the strong contribution to the research phase is due to limited funding opportunities of ERA-NET SES and the need to distribute support equitably. As the contribution of the demonstration and deployment phase requires much more resources, these projects are not sufficiently funded and need to be supported at the EU level.

The survey results indicate that the allocation of the budget among the HLUCs is primarily determined by the BRIDGE projects, as they are more highly funded compared to the ERA-NET SES projects. Therefore, BRIDGE projects are the main tool to steer the R&I agenda, when research gaps are identified in the next progress report or IP plan. At the same time, the importance of ERA-NET SES projects should not be underestimated as contributions of national (regional) projects are crucial, as they provide a large number of focused contributions to the research phase (TRL 3-5) and reveal the national priorities.

The overall coverage of expected outcomes and the number of projects that did not respond to the survey but are expected to contribute can be seen in Figure 1. The bottom graph – PPC coverage based on survey results has been expressed as a percentage and colour coded[6]:

≥ 60% (green) - the PPC is sufficiently covered, perhaps more specific contributions require in future calls
≥40%... < 60% (yellow) - the PPC is partially covered
< 40% (red) - the PPC is not sufficiently covered

As only 55% of the projects completed the questionnaire, the upper chart in Figure 1 shows the number of projects that did not complete the questionnaire but are expected to contribute to the respective PPC. From here and below these projects are referred as "non-surveyed" projects. These figures are based on the analysis of the websites of these projects and their allocation to a maximum of 3 PPCs.

From the perspective of ETIP SNET, strong coordination between

[1] High Level Use Cases
[2] Priority Project Concepts
[3] European Technology and Innovation Platform on Smart Energy Networks for the Energy Transition
[4] Technology Readiness Level
[5] European Research Area Network (ERA-NET) for Smart Energy Systems (SES)
[6] The percentage of completion is calculated based on the assumption that fully covered Expected Outcomes is represented as "1", partially covered is "0.5" and not covered is "0". Full coverage is 100% with all expected outcomes weighted as "1".

national (regional) and EU research is desirable. If this is the case, resources can be allocated appropriately between the research and development phases and among EU member stakeholders. Thus, several national research projects with the same goal can later be combined into one project at EU level, allowing for pooling of resources and expertise.

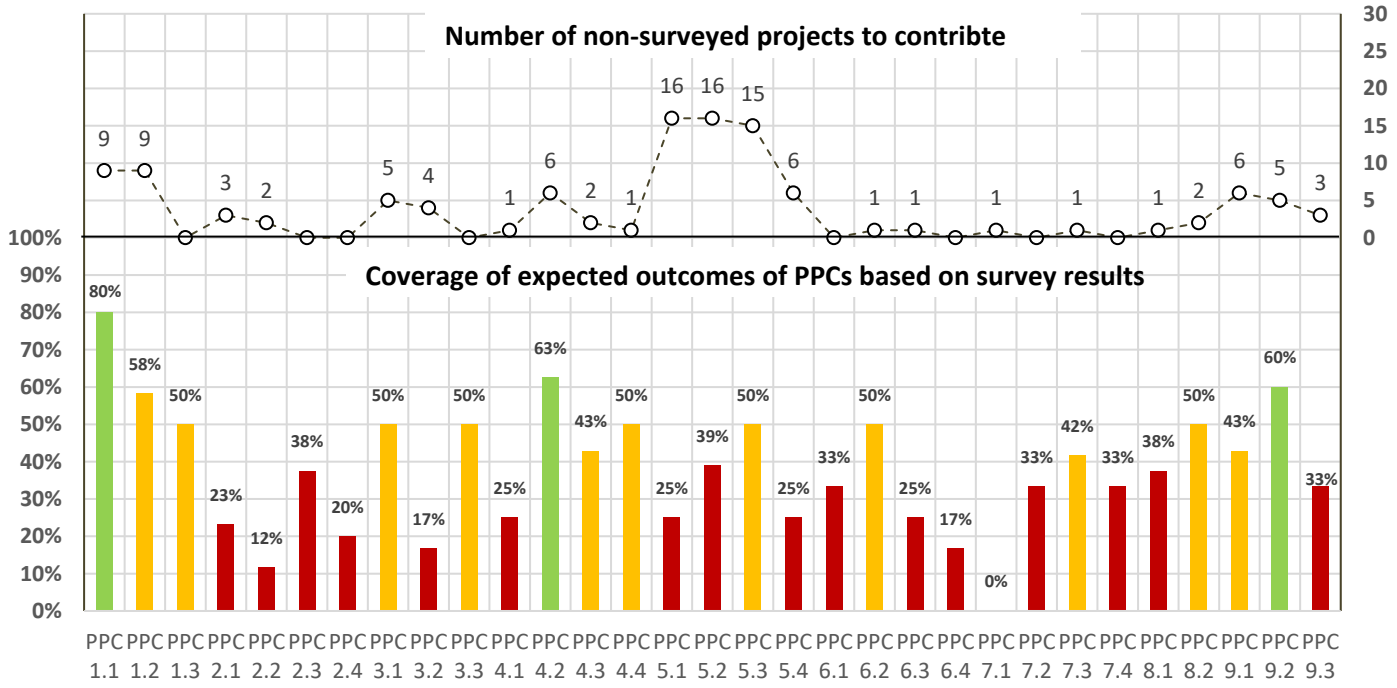


Figure 1. Total indicated and expected contributions to HLUCs

Although this report did not examine private sector funding of Smart Network R&I activities, it found little contribution from private (corporate) funds, with only 11% of respondents mentioning such contributions. There may be four reasons for this. First, despite the strong incentives of the private sector to participate in the projects, it is more interested in shorter term applicable results, thus it prefers to use public funds for projects at early development phases. Second, the private sector is unwilling to invest in R&I of publicly funded projects, because it must share the results and is therefore unable to take ownership of them. Third, most projects are in the research and demonstration phase, so commercial opportunities are not always clear, especially if there are no regulations or business models for commercialization at place. Fourth, private companies have their own research agenda that is not always aligned with public R&I priorities. They develop in-house projects/solutions; therefore, no evidence could be collected since the whole 'ecosystem' is closed.

Nevertheless, both public and private R&I agendas serve the goal of delivering market-ready technologies and appropriate business models and regulations to monetize them. Therefore, strong industry engagement greatly improves the opportunities for successful commercialization. This is particularly important for technologies with high market maturity.

The text below describes the overall progress of each PPC that was observed as a result of this report. The list of key exploitable results and contributions to development phases that laid the foundation for this analysis can be found in the APPENDIX B. Expected contributions to PPCs from not surveyed projects and APPENDIX C. Key Exploitable Results of HLUCs.

PPC 1.1 Value of cross sector integration and storage

Current R&I activities seem likely to make these topics significantly more mature upon completion of the current projects, as the number of projects addressing the concept of cross-sector integration and storage is twice the average. Many of the expected outcomes thus seem to be in reach based on current projects.

The survey showed that the expected outcomes of PPC 1.1 will be achieved through a number of different projects which contribute with both research and demonstration results. It is expected that once these projects are completed, this PPC will be covered holistically and will form the basis for further development of HLUC 1. This observation is consistent with the numerous studies that have been conducted in recent years and that have been increasingly commissioned by the EU and national legislatures. These studies address specific cross-sector planning issues, including holistic energy planning for urban heating and cooling systems, combined hydrogen and electricity system planning, and combined transportation and electricity planning, several of which are getting close to potential commercial application.

Despite numerous ongoing projects, it appears that more attention should be paid to developing market models and regulations to ensure that R&I advances can be commercialized in the near future. This statement is supported by comments of a few respondents which indicated lack of regulations is one of the challenges preventing implementation and scaling of their solutions. Additional results can also be achieved in PPC 3.1, 3.2 and 9 projects that have not been surveyed, i.e. projects that did not complete a questionnaire.

PPC 1.2 Control and operation tools for multi-energy systems

The survey showed that there are several project deliverables that demonstrate control and operation for a multi-energy system. The extensive R&I activities will lead to progress in this area, as some expected outcomes can already be met by the results of the ongoing projects. However, PPC 1.2 would benefit from quite some additional work as current results receive a green assessment only for one out of six expected outcomes. Such development would organize ongoing activities and help channel solutions to the market. This conclusion is in line with the actual operation of multi-energy

systems, as opposed to their planning, having only started developing recently. Additional results can also be achieved under PPC 7.2, 7.3, 7.4 and nine projects that have not been surveyed (did not complete questionnaire).

PPC 1.3 Smart asset management for a circular economy

General asset management methods are evolving greatly, not only at R&I but also in commercial software and platforms. The survey did not indicate extensive research, although the results are more consistent with a demonstration phase. However, establishing circular economy methods for asset management requires further broadening and new goals for asset management, incl. concepts such as Big Data, Artificial Intelligence (AI) and Machine Learning (ML), as well as the use of wearable devices, robotics, drones, etc. No other contributions are expected from non-surveyed projects.

PPC 2.1 Market models and architecture for TSO-DSO-System User interactions

Despite a considerable number of contributions, the surveyed projects only partially meet the expected outcomes of PPC 2.1. It appears that these projects primarily address technical challenges related to the interaction between TSO-DSO and the users. The market models and architectures for the complex interactions between TSOs, DSOs and users have yet to be formulated and agreed upon at the national level, followed by the EU-wide level. Demonstration of self-sufficient demand side participation will also be possible after development of market models that integrate financial and social motives. More demonstration projects in this area need to be conducted to conclude on development of this PPC. The development of this PPC is also linked to the progress of PPC 3.1, 3.2, 5.2 and 5.4, where progress is expected by non-surveyed projects.

PPC 2.2 Control and operation for enhanced TSO-DSO-System User interactions

Despite close to average number of contributions indicated by respondents, the expected outcomes of PPC 2.2 were supported by only a few surveyed projects. The possible explanation is that other projects also explore control and operation of TSO-DSO-User interactions, although it is not explicitly referenced as prime objectives of their work. Moreover, such projects can be ongoing by industry and therefore would not be represented in this report. Further demonstration work is still needed to adjust the control and operations to the continuously evolving market models and architecture to ensure reliability and security of these interactions. Some projects (including two that have not been studied) can demonstrate that they can successfully deliver the required results.

PPC 2.3 Platform Development for TSO-DSO cooperation

The development of PPC 2.3 is closely linked to PPC 2.1 and 2.2 This survey found evidence of platform development that appears to be driven primarily by the development of local market and flexibility platforms. Further results are needed to ensure that these platforms can be used (or extended) for collaboration at TSO-DSO. This will also depend on the development of standards for data exchange and data models. The development of cooperation platforms will depend on clarity on market models and architecture for interaction between TSO-DSO and users, as well as their control and operation, and will therefore need to be found in demonstration projects.

PPC 2.4 Planning tools for TSO-DSO cooperation

Due to advances in heating and transportation electrification, TSO-DSO planning collaboration is becoming much more important than in the past. The report identified results that are consistent with expected outcomes related to TSO and DSO operational planning that can be used for long-term planning. No results were found with respect to joint planning and tools that can ensure overall dynamic stability, especially when it needs to be synchronized with gas TSOs and DSOs. More results are needed to demonstrate the growing efficiency in planning of integrated energy systems.

PPC 3.1 Fundamental market design

The survey showed that this PPC 3.1 is partially covered by ongoing projects. Additionally, only few exploitable results can be linked to the expected outcomes of this PPC. These results partially meet the goal of the PPC and mostly address specific technologies and methodologies, while the outcomes are expected at the fundamental level. This PPC can also be developed through ongoing work covered by PPC 1.1 and 5.4 and the work of 5 non-surveyed projects. Otherwise, additional projects are recommended that can build on work of projects that indicated contribution to this PPC.

PPC 3.2 Regulatory framework and strategic investments

The goal of this PPC is of great importance. Few results were identified in this survey that are related to the expected outcomes of PPC 3.2. This particularly concerns strategic investment decisions that depend on the development of mechanisms of PPA and guarantees of origin which are currently not well enough integrated into the planning processes, and especially at regional and local levels. This is especially crucial in the context of sector coupling of different energy carriers and the Renewable Energy Directive. Some additional results can be obtained in 4 projects that have not been surveyed.

PPC 3.3 IT systems for cross-border trading

Existing IT systems for cross-border trading of electricity and gas may need to be updated to fulfill the requirements of this PPC. Deployment, demonstration, and perhaps research projects will be required if the regulations for trading change significantly or include hydrogen. Given the niche application of the required technologies, development of this PPC may depend on a limited number of projects not covered in this report or currently underway in industry. This PPC may thus depend more than most others on the extent to which regulatory evolution requires research and demonstration on these IT systems. The specific focus should be given to assess how (a variety of) technologies will affect the overall trading capabilities in the context of IT infrastructure and the implication they have on the overall Pan-European network in terms of safety margins and resilience.

PPC 4.1 Technical barriers and technical measures for integration of RES at multiple levels and sector

There are not enough exploitable results that have been indicated by respondents to conclude that the expected outcomes of PPC 4.1 were fully met. This means that the objectives of the surveyed projects do not yet sufficiently address the objectives of this PPC, although some of the outcomes can be used to further develop this area. Based on the indicated KERs, improved modelling and simulation can be associated with the results of only two projects. Also, market design to support RES participation and cross-sector RES participation can be indicated as (partially) covered, as this is the prime objective of many projects. More results are needed for re-dispatch and market dynamic assessments to holistically cover this PPC. These can also be obtained through non-survey projects or ongoing work under HLUC 2 and 6.

PPC 4.2 Control and operation tools for a RES-based energy system

The projects on control and operating tools, both of which become important and difficult with high RES penetration, show that good progress is being made in the research and demonstration phase. This survey showed that many results will be obtained to improve forecasting capabilities, followed by improving efficiency of DER

control in Hybrid Power Systems. No results have been found so far to ensure efficient curtailment mechanisms. Four more outcomes can partially benefit from non-surveyed projects.

PPC 4.3 Infrastructure requirements and network technologies

A number of exploitable results contributed to the development of this PPC, but further investigation of solutions is required that can mitigate lack of inertia in grids (such projects could be part of power electronics under HLUC 6). Additionally, it still needs to be ensured that all the necessary technologies for multi-terminal interconnection design to support offshore wind and optimal flexibility management demonstrated their efficiency. Some contributions can be made in 2 non-surveyed projects conducted within industry.

PPC 4.4 Planning of a resilient system with massive penetration of RES

Expected outcomes of this PPC are partially met with KERs from a number of projects to improve modelling capabilities and enhance operation and planning. Despite the expected progress on this PPC, it should be noted that resilience remains a recent topic with rapidly increasing importance (due to the climate crisis), which means that more results need to be obtained in future. Some contributions can be achieved under PPC 2.4, as well as in one non-surveyed project.

PPC 5.1 Value of Consumer/Customer acceptance and engagement

There are a few results from ongoing projects that can be used as guidelines for prosumer participation in electricity markets. Although attention to this PPC is rising, it needs to increase further because consumer engagement is key to energy transition. There is also need to ensure that relevant guidelines and tools are developed to enable market implementation and the setting of tariffs and prices. The survey did not identify KERs that can explicitly address these outcomes. To date, it seems that most of the results are related to encourage prosumer participation and based on lessons learned in projects developing technical solutions. These aspects are likely covered by 16 non-surveyed projects.

PPC 5.2 Plug and play devices and IoT [Internet of things] including security by design

Several results contribute to this PPC and bring solutions close to market, in part because the smart home / IoT industry is making advances in ICT, somewhat independent of energy system needs. However, the match between advances in commercial ICT products and the needs of the energy system needs further attention. Special attention should be paid to making it easier for customers to access markets and switch energy suppliers. Partially, this can be enabled by efficient data and information management that connects customers to System Operators. Such results are likely to be achieved in 16 non-surveyed projects.

PPC 5.3 Utilisation of Communication Networks including cyber security

The surveyed projects partially covered the expected outcomes of this PPC, however they did not provide explicit results related to communication networks and cybersecurity. However, all expected outcomes need further work in advanced intrusion detection, advanced tools for proactive and anticipatory security strategy and mechanisms of exploitation of common infrastructures, e.g., 5G networks. Development of this PPC can be done in 15 non-surveyed projects, as well as cybersecurity projects that are included in Horizon calls under Cluster 3 (part on Secure Societies) and Cluster 4 (part on Digital and Industry), which are not part of this analysis.

PPC 5.4 Cross-sectorial flexibility use cases

The current projects appear to be focused on practical cases of integration, but achieving the outcomes of this PPC will also require development of a consolidated ICT structure and an integrated framework for developing interoperable systems. The present survey did not identify any KER in this context, although this can be achieved in 6 non-surveyed projects. Since the consumer level is particularly important for flexibilities in the transportation and heating/cooling sectors applied to the power system, further demonstration projects are important.

PPC 6.1 Control solutions for next-generation PV and battery inverters

HLUC 6 (and associated PPCs) development is currently driven by a smaller number of projects, as contributions to these areas were rarely indicated by respondents. Some results can be obtained in the ongoing work of HLUCs 2 and 4. This can be explained by the niche development of power electronics and its applications. To date, the power electronics industry has been dominated by large vendors that often conduct RD&I activities internally and market new solutions through established channels. However, the involvement of academia can be also important to the successful introduction of technologies, as research-driven projects are less focused on short-term returns and can develop solutions for markets that do not yet exist.

PPC 6.2 Hybrid transmission/distribution and hybrid distribution AC/DC grids

This PPC takes a holistic view of future grid concepts that will enable better adoption of RES and efficient energy transfer. Although no exploitable results have been submitted that could be directly linked to the expected outcomes of this PPC 6.2, relevant technologies are currently being explored in PPCs 6.1 and 6.3 and some results can be expected from one non-surveyed project. Some additional evidence is required to ensure development of hybrid AD/DC and energy router concepts.

PPC 6.3 Next generation distribution substation

While the next-generation substations appear to be a commercial issue, non-commercial demonstration projects are needed to prove their capabilities. This survey has identified only one exploitable result that can be linked to the expected outcome of this PPC. This suggests that additional projects are required to research smart transformers for connection between MV and LV AC networks enabling AC and DC microgrids and methods to facilitate distribution grid to work in island mode. However, this PPC can be advanced by one non-surveyed project or by industry.

PPC 6.4 Simulation methods and digital twins at distribution and transmission level for power electronics driven networks

To date, exploitable result from one project has been associated with expected outcome of this PPC. This project is developing a simulation model for a cross-vector energy system for efficient conversion of different forms of energy to ensure rational use of all forms of renewables. To ensure the development of PPC 6.4, more project results are needed that can be directly linked to expected outcomes. These results should be related to IT systems in power electronics and to simulation of behaviour of power electronics at all levels. These could be investigated as part of industrial projects.

PPC 7.1 Next generation of TSO control

This survey has not found any exploitable results that can be directly linked to expected outcomes, although progress is driven by technology vendors. Nonetheless, the solutions created for projects related to HLUC 2 for the collaboration between TSO/DSO can also contribute to the expected outcomes of this PPC.

PPC 7.2 Next generation of DMS

Only one exploitable result associated with sensing technologies is

related to expected outcomes of PPC 7.2. However, there are many projects currently dealing with renewable energy integration and flexibility services at distribution level. Thus, some additional relevant results are obtained under HLUCs 4, 5, and 9, where respondents overall could identify their objectives. Similar to PPC 7.1, significant progress in DSO control rooms and DMS functions is achieved by technology vendors. However, more attention to this PPC is required, especially considering tools to study distribution grids with very low (no) inertia and full LV supervision.

PPC 7.3 Next generation of measurements and GIS for distribution grids

Almost all of the expected outcomes of PPC 7.3 are partially met. Because distribution grid technologies are also mentioned under HLUCs 4, 5, and 9, it is very likely that some projects explicitly report results relevant to PPC7.3 under those HLUCs. Given the extensive research in this area, it is reasonable to assume that PPC 7.3 will be significantly further develop once the current projects are completed. As only one additional non-surveyed project can contribute to this area, Big Data analytics for real-time system operation is an open research field.

PPC 7.4 Wide area monitoring, control and protections

Monitoring, control and protections need to evolve greatly in order to cope with the continued increase in asynchronous generation and decrease in inertia. The results of two projects support the outcome of scalable hierarchical observability methods and systems and regional WAMS applications for TSOs. As no other non-surveyed projects will contribute to this PPC, additional results to support development of on-line dynamic security assessment (voltage, frequency, angle) of interconnected power systems are needed.

PPC 8.1 Technical and economic implication of decarbonisation of transport sector

Most of the surveyed projects focus on the integration and optimisation of EV infrastructure into electricity networks and markets. Given the nature of technical and economic implications of transport sector decarbonization, some results in this category are also obtained under HLUC 1 and HLUC 5. Additional attention needs to be given to the development of decarbonization strategies for the transport sector (based on electricity and hydrogen), especially when it comes to aviation and river and marine transport. One non-surveyed project can also contribute to this PPC.

PPC 8.2 Enhancing effectiveness of energy system operation and resilience with electromobility

Three projects have been identified that partially address the concept of V2X (Grid, Home and/or Business) and energy storage technologies. Given the importance and prevalence of electromobility, PPC 8.2 may require additional results to advance its development, especially focusing on aspects related to security and resilience of energy system. Some contributions can be expected from two projects that are not part of the survey.

PPC 9.1 Value assessment of the integration of buildings, infrastructure and smart communities in a RES based energy system

A large number of ongoing and recent projects in this area already constitute a significant body of research. Although this survey has not confirmed that all expected outcomes are met by the submitted results, it is reasonable to assume that this PPC is adequately covered, as results focus on different types of integration and technical solutions. However, more results to demonstrate the integration of flexibility, ancillary and wholesale markets and methods used in local markets for (pre-) qualification, communication, bid mechanisms are required. This can also be done under HLUC 3 as well as within six non-projects.

PPC 9.2 Control and operation tools for the integration of buildings and smart communities

The expected outcomes of PPC 9.2 appear to be either fully or partially met, given the large number of projects that can be associated with this PPC. More attention needs to be paid to developing resilience support for the grid and systems. This area does not appear to be mature, especially considering that the technologies associated with PPC 9.2 are not yet commercialized, although relevant projects are also developed within HLUC1, HLUC5 and HLUC7. Additional results can be obtained from five projects that have not surveyed.

PPC 9.3 Planning for resilient integration of buildings and infrastructures in an integrated energy system

Although many projects indicated their contribution to PPC 9.3, only two KERs were provided to infer development of this PPC. Results from only one project can be directly associated with net-load and aggregation forecasts. Additional results related to weak grid stabilization, island mode, and black start capability are needed. In particular, the aspects of this PPC that relate to other forms of (non-electric) energy of buildings, infrastructure, and industrial processes require further research and demonstration.

The results of this work are essential for the further planning of the activities of ETIP SNET. To further improve R&I planning and implementation processes, it is suggested that funded projects under Horizon 2020 be contractually obliged to report to the ETIP SNET initiative on project progress and expected results. This should also be reflected in the project budgets and allow for a full understanding of the gaps and constraints that need to be addressed in subsequent calls. In this report, this limitation has been addressed by reviewing the websites of projects that did not respond to the survey (non-surveyed projects) and allocating them to PPCs. This approach has its limitations as the information on the websites may not always be updated or fully presented.

INTRODUCTION

The European Technology and Innovation Platform Smart Networks for Energy Transition (ETIP SNET) aims to guide research, development and innovation to support the energy transition in Europe. This progress monitoring report aims to assess the advancement of European research and innovation (R&I) projects in relation to the ETIP SNET R&I Roadmap and the ETIP SNET Implementation Plans. The current report is a continuation of the previous progress monitoring report published in 2021 and builds on the updated editions of Roadmap 2022-2031 and Implementation Plan 2022-2025 that were published in February 2023 and December 2022 respectively.

The **10-year ETIP SNET R&I Roadmap 2022-2031** provides a system view of the entire energy transition with smart grids as the backbone and includes sector coupling and, electromobility with a focus on integrating all flexibility solutions into the power system, including energy storage technologies.

"The purpose of ETIP SNET R&I Roadmap is to illustrate the view of all energy system stakeholders involved in the ETIP SNET by identifying the range of actions (functionalities) to be addressed during the next decade, with the ultimate goal of reaching the full decarbonisation of the European energy system by 2050." - Guido Guida, ETIP SNET Chairman 2020-2021.

The **4-year ETIP SNET Implementation Plan 2022-2025** prioritizes projects according to their objectives and expected results. This ensures consistency and coordination of ETIP SNET R&I activities and allows projects to build on the results of previous work.

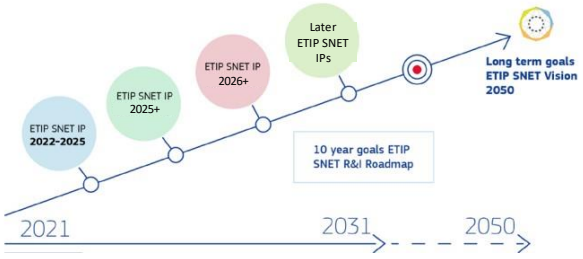


Figure 2. ETIP SNET key steps to achieve 2050 goals

Progress in research and innovation of ETIP SNET is regularly tracked through progress monitoring reports - the most recent reports were published in 2018 and 2021. The objectives of the progress monitoring report are:

- Analyse the state of research and innovation in smart grids and sector coupling for the energy transition in Europe.
- Measure the level of coverage in relation to the ETIP SNET R&I roadmap and identify gaps in R&I that require additional attention or funding to meet the ETIP SNET R&I roadmap and implementation plans towards a successful European energy transition.
- Identify promising technologies and innovations for commercialization within a five-year timeframe.

The progress monitoring activities that led to this report aim to capture recent R&I progress at ETIP SNET, particularly since the last monitoring report published in the end of 2021.
This report analyses the projects that seem to contribute the most to the R&I activities within ETIP SNET. Analysed projects are taken from the Bridge and ERA - Net Smart Energy Systems initiatives (hereafter: ERA-NET SES), the 'coverage' is provided by H2020 and HE R&I programmes.

The BRIDGE initiative of the European Commission brings together projects from the Horizon 2020, Horizon Europe programmes that are active on topics regarding Smart Grid, Energy Storage, Islands and Digitalization. BRIDGE is a European Commission initiative which unites Horizon 2020 and Horizon Europe Smart Grid, Energy Storage, Islands, and Digitalisation Projects to create a structured view of cross-cutting issues which are encountered in the demonstration projects and may constitute an obstacle to innovation. The BRIDGE process fosters continuous knowledge sharing amongst projects thus allowing them to deliver conclusions and recommendations about the future exploitation of the project results.

Data and information for nationally and regionally funded projects are taken from the EXPERA platform of the European ERA-NET SES initiative. The funding organisations of the ERA-NET SES consist of owners and managers of national and regional public funding programs in research, technical development, and demonstration. They provide – together and co-funded with the EU - a platform for financing and developing technologies for smart grids, regional and local energy systems, heating and cooling networks, digital energy and smart services, etc.

Overall, the projects which form parts of these two initiatives (BRIDGE and ERA-NET SES) make up a significant part of all European R&I activities in the scope of the ETIP SNET program at EU, national and regional level.

SURVEY SET UP
Transformation of frameworks

This report is the first to provide progress a monitoring update using the new research framework first introduced in the ETIP SNET Implementation Plan 2022-2025, published one month after the 1st report on mapping progress in late 2021.

Although the goals of ETIP SNET, as defined in its Vision 2050, have not changed, the ETIP SNET IP 2021-2024 and the 1st report on mapping progress provided different perspectives. They looked at research and innovation activities more from an academic R&I (the "R") lens. For that ETIP SNET defined 6 Research Areas which were subdivided into 24 research topics with 90 Research Tasks. To add the "I" part of the R&I frameworks to improve practical project comprehension, the latest Implementation Plan 2022-2025 takes a "Use-Case" and thus, project-oriented approach. It is less granular, with 9 High Level Use Cases (HLUCs) and 31 Priority Projects Concepts (PPCs) to be considered by 2025. At the very bottom and as smallest granularity of the framework, there remain

the 90 Research Task: These Research Tasks are associated to those PPCs where they strongly contribute. The focus shifted from providing insights into research needs to innovation needs for use cases and projects. The Research Tasks appear in both methodologies but have a different weight. The conceptual link between frameworks can be seen in Figure 3 and thoroughly described in the recently published ETIP SNET Roadmap.

This shift does not allow a direct comparison of survey results between the 1st and 2nd surveys, although the key survey questions remained the same - select TRL level and identify key exploitable results from the ongoing R&I projects both of BRIDGE and the ERA-NET SES. In the 2021 survey, respondents selected the most appropriate Research Tasks and assigned TRLs from 1 to 9 associated to these Research Tasks, thus addressing the question what is the reached technology readiness level (TRL) with respect to each of the 90 tasks? There were no restrictions on the number of tasks that could be selected for the respective R&I project. In this 2023 survey, ETIP SNET asked respondents to select a maximum of three HLUCs and any relevant PPCs within those three HLUCs. After selection, ETIP SNET asked to define the phase of technology development - Research (TRL3-5), Demonstration (TRL 6-8) and Deployment (TRL 9) with respect to the PPCs and their associated HLUCs. This initially addresses the question - what is the technology readiness level (TRL) your project contributes within this PPC?

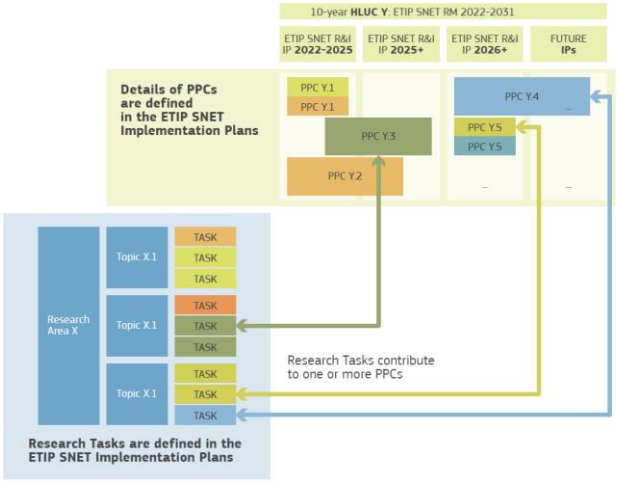


Figure 3. The conceptual link between Research Areas, research topics (and associated lower-level Research Tasks) with PPCs (and associated higher level HLUCs)

Questionnaire

The questionnaire was designed so that respondents could define their project's place within the ETIP SNET HLUC – PPC and to provide insight into the contributing PPCs. With enough data collected, it is possible to define the current state of research of HLUCs and PPCs.

Section 1 – General information
2. Name and contact details of a respondent
6. Full and short name of a project
7. Start and end dated of the project
8. Contributing organizations (companies, universities, etc.)
9. Source of funds (EU, national, private/ corporate, other)
10. Total project budget (amount received)
Section 2 – HLUC and budget allocation
3. Indicate maximum of 3 HLUCs to which your project contributes the most.
4. In your opinion, what percent of total budget is allocated to selected HLUCs: <25%, <50%, <75%, >75%
Section 3 - TRL levels and KERs for relevant PPCs
5. Choose the Priority Project Concept (PPC) you think your project belongs to and indicate the Development Phase which your project contributes to upon the completion
6. If your project meets TRL8 or TRL9 criteria, describe the product or service that could be commercialized.
7. Indicate up to 3 Key Exploitable Results of your project related to selected HLUC.
8. Indicate the knowledge gaps (if any) that were identified in your project and require further research

Table 2. Questionnaire structure

In general, the questionnaire can be divided into three sections: 1. General information about the project and contract details, 2. Selection of relevant HLUCs and approximate budget allocation between them. 3. Indication of TRL levels for relevant PPCs, description of Key Exploitable Results (hereafter: KERs), potentially marketable results and research gaps, if any (see Table 2).

As part of the survey, respondents were provided with the list of HLUCs (see Table 3) and PPCs that, according to the Implementation Plan, fall within the 2022-2025 period only (APPENDIX A List of PPCs which belong to timeframe 2022-2025). If the proposed PPCs do not fit the project objective, the respondents can indicate the PPCs foreseen by ETIP SNET to begin in later periods until 2031.

List of High-Level Use Cases
HLUC 1: Optimal Cross sector Integration and Grid Scale Storage
HLUC 2: Market-driven TSO–DSO–System User interactions
HLUC 3: Pan European Wholesale Markets, Regional and Local Markets
HLUC 4: Massive Penetration of RES into the transmission and distribution grid
HLUC 5: One stop shop and Digital Technologies for market participation of consumers (citizens) at the center
HLUC 6: Secure operation of widespread use of power electronics at all systems levels
HLUC 7: Enhance System Supervision and Control including Cyber Security
HLUC 8: Transportation Integration & Storage
HLUC 9: Flexibility provision by Building, Districts and Industrial Processes

Table 3. List of High-Level Use Cases

Respondents were not limited to predefined KERs and were allowed to describe the results in an open format. Responses were then categorized by type in accordance with the previous progress monitoring report. The four types of KERs are:

- **Hardware:** a physical device or technology (or set of devices) used in an IT, electrical, control system that enables the efficient generation, storage, transmission, distribution or consumption of electrical energy.

- **Software:** a digital tool, algorithm, simulation, or application that enables optimized data acquisition, processing, interpretation, storage, and access.
- **Methodology:** a theoretical description of methods for designing new rules, energy scenarios, data collection, asset management, monitoring and control, etc.
- **Policy, regulation and market:** business models and recommendations for policy and regulation.

SURVEY RESULTS

The total 2023 survey population consists of 108 projects - 60 BRIDGE and 48 ERA-NET SES projects (see Figure 4). These projects were selected based on their (expected) end date. Projects ending in 2021 or earlier were excluded from the survey, as they are assumed to have been covered already by the previous progress monitoring reports.

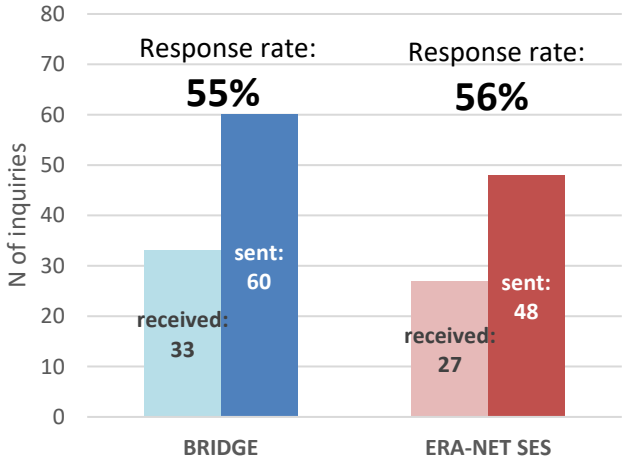


Figure 4. Response rates

A total of 60 responses were received from early December 2022 through the end of January 2023, so the 55% response rate is almost evenly split between BRIDGE and ERA-NET SES projects. This is a higher response rate compared to the 35% rate for the 1st Mapping Progress Report of 2021 (39 responses out of 111 requests). In addition, only 11 projects were covered by both surveys, so 80% of the data is from new R&I projects (see Figure **5**).

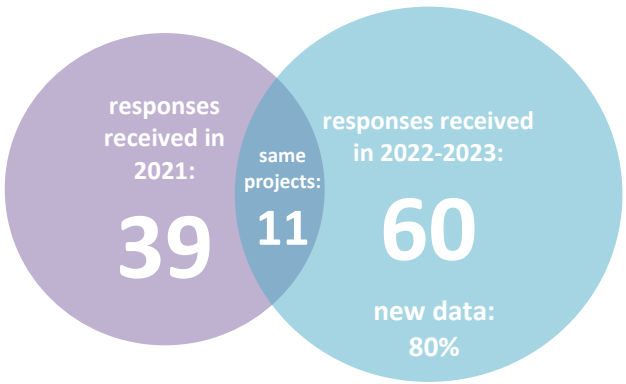


Figure 5. Responses in 2021 and 2023

Despite a nearly equal response rate, BRIDGE projects have a larger share of the total budget contributing to ETIP SNET R&I, as BRIDGE projects on average receive more funding compared to ERA-NET SES projects Figure 6). Most BRIDGE project budgets start from €5 million, while an average ERA-NET SES project is three times smaller and usually does not exceed the €4 million threshold. Consequently, the split between BRIDGE and ERA-NET SES is 76% and 24% budget-wise based on the data collected via survey.

The survey also analysed the source of funding. As expected, most of the funding came from EU funds as BRIDGE projects are mainly funded under the Horizon 2020 framework, Horizon Europe Smart Grid, Energy Storage, Islands, and Digitalization programs (see Figure 7). However, the survey data shows that more than half of the projects both BRIDGE and ERA-NET SES (52%) relied solely on EU funds. A third of projects (34%) received support from national funds in addition to other sources, while only 10% of R&I projects were funded independently of other sources. The survey data also show little contribution from private or corporate funds, as only 11% of projects benefited from additional non-public money.

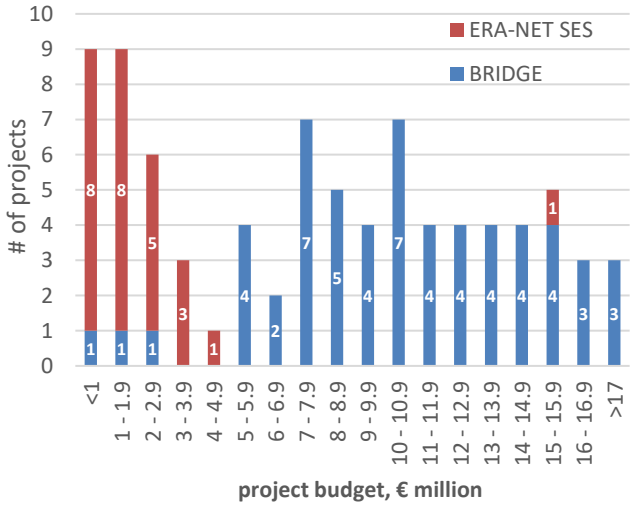


Figure 6. Number of projects per budget size

Apparently, the larger share of public funds can be explained by the survey sample. On the other hand, the observations show that the overall contribution of private funds to smart networks technologies is limited. First, the small share can be explained by the reluctance of industry to commit longer term projects with no immediate commercialization opportunities. Second, it could be due to lack of alignment between the EU or national research agenda and the industry. As a result, there might be a gap in understanding how industry can benefit from ongoing R&I projects. A third, possible explanation is that use of public money requires that the results of the projects are also publicly accessible.

To assess the status of smart energy network development, respondents were asked to select a maximum of 3 HLUCs and corresponding PPCs to which their project contributes the most. Respondents were not limited to the number of PPCs they could select within the HLUC but were required to indicate the stage of development to which their project would contribute upon completion. Consistent with ETIP SNET IP 2022-2025, three development phases are proposed - Research Phase (TRL 3-5), Demonstration Phase (TRL 6-8), and Deployment Phase (TRL 9).

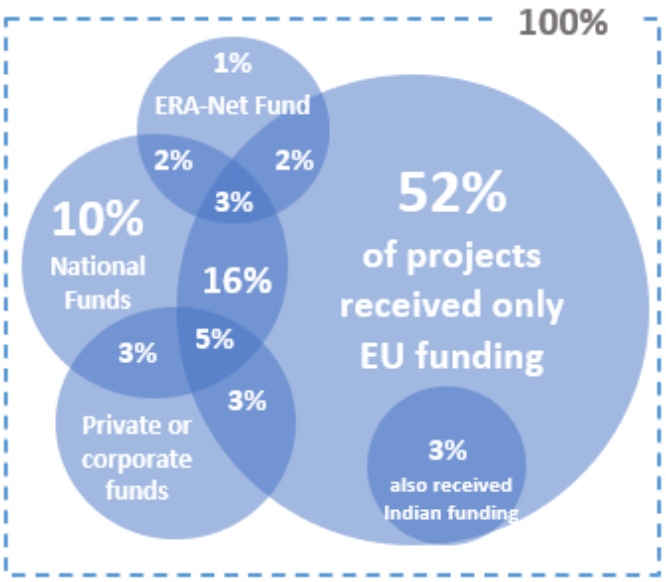


Figure 7. Percentage of projects per funding source

Survey data show that respondents indicated an average of 3 HLUCs (some indicated more than 3 HLUCs, others less) and 5 PPCs (or between 1 or 2 PPCs per HLUC). The results can be seen in Figure 8 and Figure 9. Projects from BRIDGE (Figure 8) predominantly indicated that their project contributes to the demonstration phase (TRL 6-8) of the priority project concepts (76% of responses). The remaining 20% and 4% of responses fell into the research (TRL 3-5) and deployment phase (TRL 9) categories, respectively.

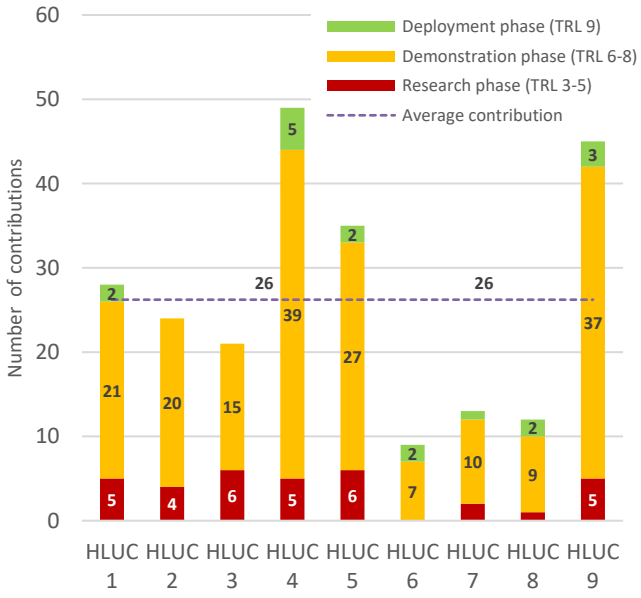


Figure 8. Contributions of BRIDGE projects to HLUCs

In terms of the distribution of responses across HLUCs, the survey results show that respondents from projects covered by BRIDGE are more likely to select "HLUC 4: Massive Penetration of RES in the Transmission and Distribution Grid" than others (23% of responses). HLUC 4 is followed by "HLUC 9: Flexibility provision by Buildings, Districts, and Industrial Processes", which was also selected more often than average by respondents.

In contrast to the BRIDGE projects (see Figure 9)), ERA-NET SES respondents most often select HLUC 1: Optimal Cross-Sector Integration and Grid Scale Storage as their main contribution. HLUC 1 development is also supported by average contributions from BRIDGE projects. Coverage of HLUCs 4, 5, and 9 is consistently supported by BRIDGE and ERA-NET SES projects. Largely, these HLUCs received above-average mentions.

Respondents from BRIDGE and ERA-NET SES selected significantly less than average as their project contributions in:

- HLUC 6: Secure operation of widespread use of power electronics at all systems levels
- HLUC 7: Enhance System Supervision and Control including Cyber Security[7]
- HLUC 8: Transportation Integration & Storage

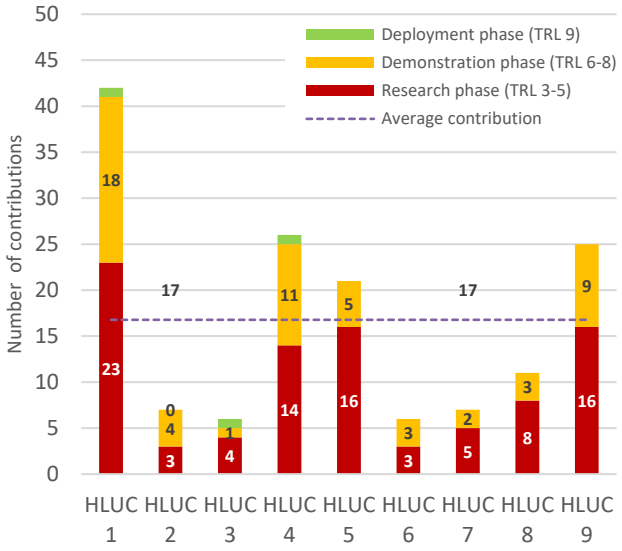


Figure 9. Contributions of ERA-NET SES projects to HLUCs

In contrast to the BRIDGE projects, most ERA-NET SES respondents indicated that their project contributes to the research phase (72%) and least in the demonstration and deployment phases (27% and 1%, respectively). This can be explained by the smaller budget of the ERA-NET SES projects and the research ("R" in R&I) directed agenda at the national and regional level.

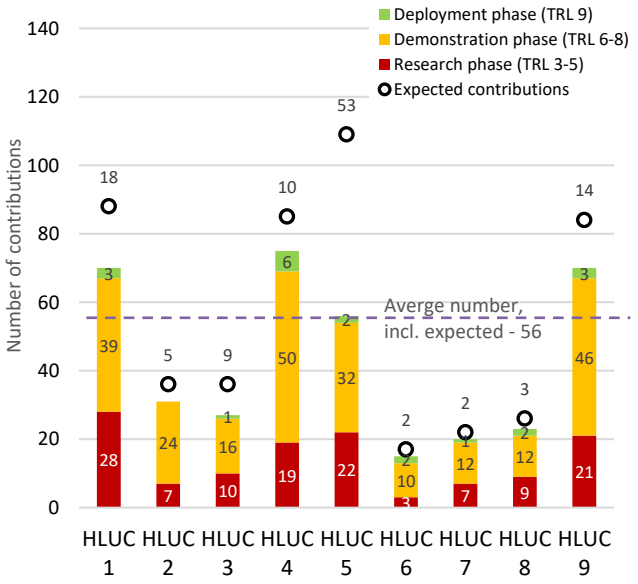


Figure 10. Total indicated and expected contributions to HLUCs

[7] Only projects from Horizon calls Cluster 5 and from ERA-NET SES calls have been analysed. However, some cybersecurity projects are included in Horizon calls under Cluster 3 (part on Secure Societies) and Cluster 4 (part on Digital and Industry), which have not been analysed.

The total number of indicated and expected contributions from both ERA-NET SES and BRIDGE can be seen in Figure 10. The assessment of expected contributions was made by analysing the websites of the projects that did not respond to the survey. The projects' objectives or expected results compared with the PPCs. No more than three PPCs were assigned to a project (see APPENDIX B. Expected contributions to PPCs from not surveyed projects). In line with the results collected via the survey, the additional contributions were in HLUC 1, 4, 5 and 9 and the least in HLUC 6, 7 and 8.

However, the number of contributions does not accurately represent the impact they have on the development of the HLUC. For example, broadly formulated HLUCs were selected more often than the others. The overall impact of the projects on can be also determined by comparing the perceived budget allocation among the HLUCs selected by respondents. These answers can then be compared to the projected budget allocation by IP 2022-2025 According to the questionnaire, the largest shares are allocated to HLUCs 4, 7, 1, and 12, and the least to HLUCs 2 and 3. These HLUCs received either more or less than 11% of the average budget allocation (100% ÷ 9 HLUCs). The main budget contribution according to the survey is attributed to HLUCs 4 and 9 at 20% and 23%, respectively. This also corresponds to the largest selection of the HLUCs by the respondents and probably by the broader perception of the respective HLUCs.

Figure 11 shows the correspondence between the perceived (survey) and planned (IP 2022-2025) budget allocation. The deviation for the HLUCs 1, 2, 3, and 5 is no more than 2%, suggesting efficient implementation of the funding allocation of the IP. A significant discrepancy can be seen in HLUCs 6, 7 and 8. This also corresponds to the small number of contributions from ERA-NET SES and BRIDGE projects, indicating that these projects have a stronger industrial-Utility focus and are better directed at pan-European level, attracting limited local interest.

The survey results indicate that the allocation of the budget among the HLUCs is primarily determined by the BRIDGE projects, as they have higher budgets compared to the ERA-NET SES projects. The share of ERA-NET SES projects per HLUC does not exceed 4% (Figure 4). Therefore, BRIDGE projects are the main instrument to formulate the R&I agenda when research gaps are identified in the next progress report or IP plan. At the same time, the importance of ERA-NET SES projects should not be underestimated. Figure 8 and Figure 9 indicate that the contributions of regional (ERA-NET SES) projects are crucial, as they can provide a large number of contributions to the research phase (TRL 3-5) at a lower cost.

On the other hand, the Smart Networks R&I agenda is strongly driven by the EU because it can fund larger projects of Pan-European interest, including projects in the demonstration phase (TRL 6-8) and therefore advance the state of development towards higher TRL with larger real-world project demonstrations and real-world systemic technology integration solutions and services.

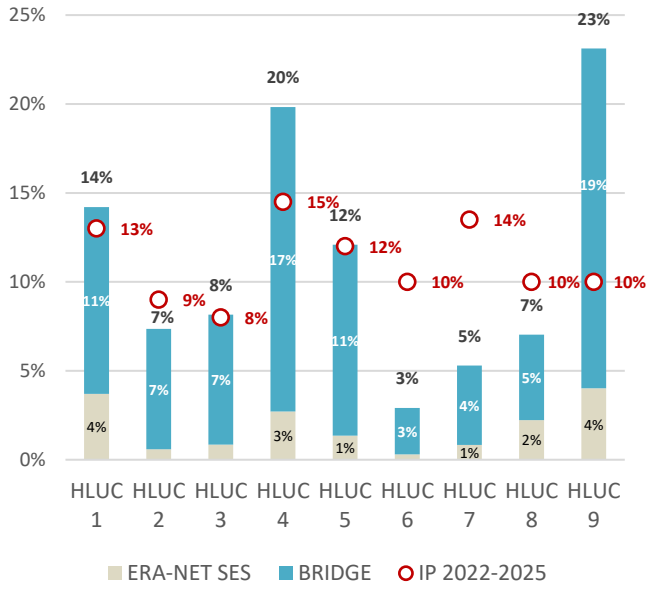


Figure 11. Budget allocation between HLUCs

Key Exploitable Results (KERs) were provided by the majority of respondents. However, because most projects are ongoing or even recently started, not all respondents were able to share KERs in this survey. Also, the KERs should be understood as expected to be achieved when the projects are completed. The full list of KERs can be found in "APPENDIX C. Key Exploitable Results of HLUCs", while the number of KERs per HLUCs is shown in Table 4.
Note that respondents could indicate the same KERs in more than one HLUC, so the total number of unique KERs is lower than can be seen in Table 4.

Consistent with the number of contributions, HLUCs 1, 4, and 9 account for the largest number of KERs (41, 41 and 50, respectively). There is also a dominance of software oriented KERs, while the number of KERs in the hardware category is significantly lower. HLUC 6, HLUC 7 and 8 received the lowest number of KERs (14, 12 and 14 respectively). Given the nature of HLUC 6 (power electronics) this was mostly contributed with hardware contributions than software solutions.

	HLUC 1	HLUC 2	HLUC 3	HLUC 4	HLUC 5	HLUC 6	HLUC 7	HLUC 8	HLUC 9
Software	17	11	9	37	14	0	7	5	28
Hardware	10	0	0	4	1	5	1	3	4
Methodology	11	2	9	5	5	8	2	3	4
Policy, regulation and market	3	9	4	4	5	1	2	3	5
TOTAL KERs	**41**	**22**	**22**	**50**	**25**	**14**	**12**	**14**	**41**

Table 4. KERs per HLUCs

Methodology for progress assessment of PPCs

The next sections focus on the current development of HLUCs. The analysis includes both a quantitative and a qualitative assessment. These two approaches complement each other to provide a comprehensive picture.

The qualitative assessment is based on comparing the key exploitable results (KER, provided in APPENDIX C. Key Exploitable Results of HLUCs) submitted by respondents with the expected outcomes (EO) defined for each PPC in IP 2022-2025. Once the key exploitable results were assessed, each expected outcome (EO) was color-coded to indicate its coverage. The colours represent the following status of EO:

✓	Several KERs can be directly associated with the expected outcome EO.
+	Too few KERs can be associated with EO, or/and KER does not fully match EO.
−	No KERs were provided that can be directly associated with EO

These important analyses are displayed in detailed tables for each HLUC and its PPCs, providing the color-coded evaluations of each expected PPC outcome against current projects key exploitable results. These tables can be found at the end of each HLUC chapter.

The qualitative assessment is complemented by the names of projects whose research falls within the scope of ETIP SNET but who did not respond to the survey, i.e., non-surveyed projects. For each non-surveyed project, no more than three PPCs that best fit the project description on the website were selected (see APPENDIX B. Expected contributions to PPCs from not surveyed projects). This supplementary information should fill the gap in this assessment as not 100% of the projects responded to the survey.

This approach is detailed, strong and concrete but still in one dimension limited because it only allows evaluation of the contributions that were directly indicated by the respondents. However, the PPCs are broader than the collection of their individual expected outcomes; as projects aim to produce applicable results, they must also address and consider issues that do not correspond to main objectives. For example, when developing a platform for P2P trading, projects must also consider regulatory and social issues. Another example: Novel simulation methods for network operations will primarily improve network operations, but the results can also be used for long-term network planning and standards development. This type of additional outcome is difficult to capture because respondents limit their input to our questionnaire to the most important outcomes that align with the project' objectives.

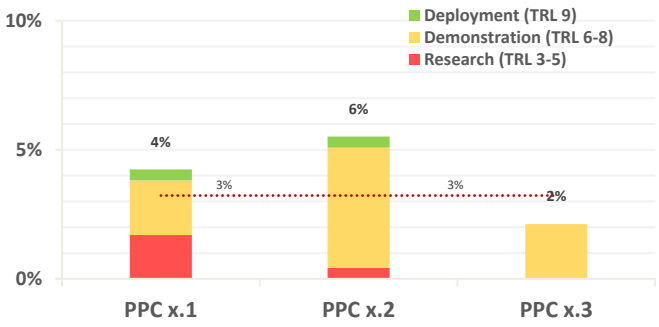


Figure 12. Contributions to PPCs indicated by respondents

A complementary quantitative approach is therefore intended to capture these complementary contributions, which are not part of the main objective of the project. In this survey respondents were also asked to select PPCs and indicate the phase of development in which their project contributed. Such an assessment allows for flexibility, as respondents made their selections based on their own interpretation of the contribution to HLUCs/PPCs. The number of selections was presented as a percentage of contributions, categorized by phase, and color-coded (see Figure 12). The number of responses is compared to the average number of responses per PPC. In the event of even distribution of responses, it can be inferred that each PPC would account for 3% of the total responses (100% ÷ 31 PPCs ~ 3%). However, it is important to understand that selections made by respondents do not always align with expected outcomes of PPC and thus should be understood as general input from a project one can further develop to meet objectives of PPC.

Finally, the relationship and development between the results of the current and the previous survey can be assessed on the basis of such a qualitative assessment. In the previous survey, R&I progress was analysed based on research areas, research topics, and research tasks. The relationship between PPC progress (this survey) and research topics (previous survey) is described below and will also be presented in specific tables in the following analyses of each HLUC and PPC.

The previous survey analysed RD&I progress at the lower level of the framework – the 90 research tasks. Respondents were asked to select the appropriate task and indicate the contribution to the TRL level from 1 to 9. This report looks at a higher level of aggregation of 24 research topics. The TRL levels were also divided into 4 categories: Basic Research (TRL 1-2), Research (TRL 3-5), Demonstration (TRL 6-8), or Deployment (TRL 9) to match PPC scale. These data are presented in the HLUC analysis table (see Figure 13). Area 2.1 contains the list of research topics that serve as building blocks for relevant PPCs. Area 2.2 shows the results of the previous survey - percentage of contributions to each phase of development (color-coded). This should not be taken as the number of contributing projects, as respondents were allowed to indicate more than one research task or topic. The number of responses is compared to the average number of responses per Research Task (100% ÷ 24 ~ 4%).

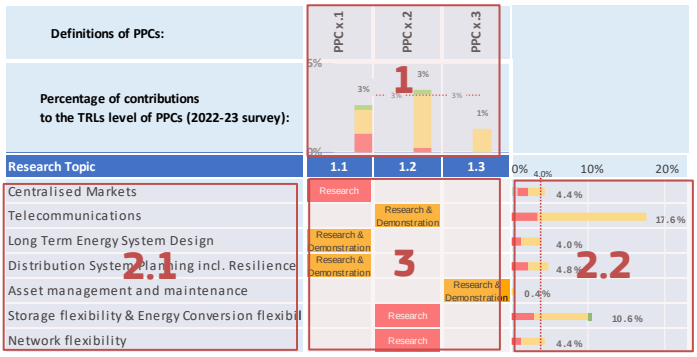


Figure 13. HLUCs analysis table

Thus, the HLUC analysis table (Figure 13) allows us to combine 3 components - 1. current TRL maturity and development phase of PPCs, obtained by the survey for this report, 2. TRL maturity and development phase of research topics according to data from the previous survey (marked with 2.1 and 2.2), and 3. TRL maturity and development phase of PPCs according to data from the last survey. These observations are described in the next sections.

HLUC 1: Optimal Cross-Sector Integration and Grid Scale Storage

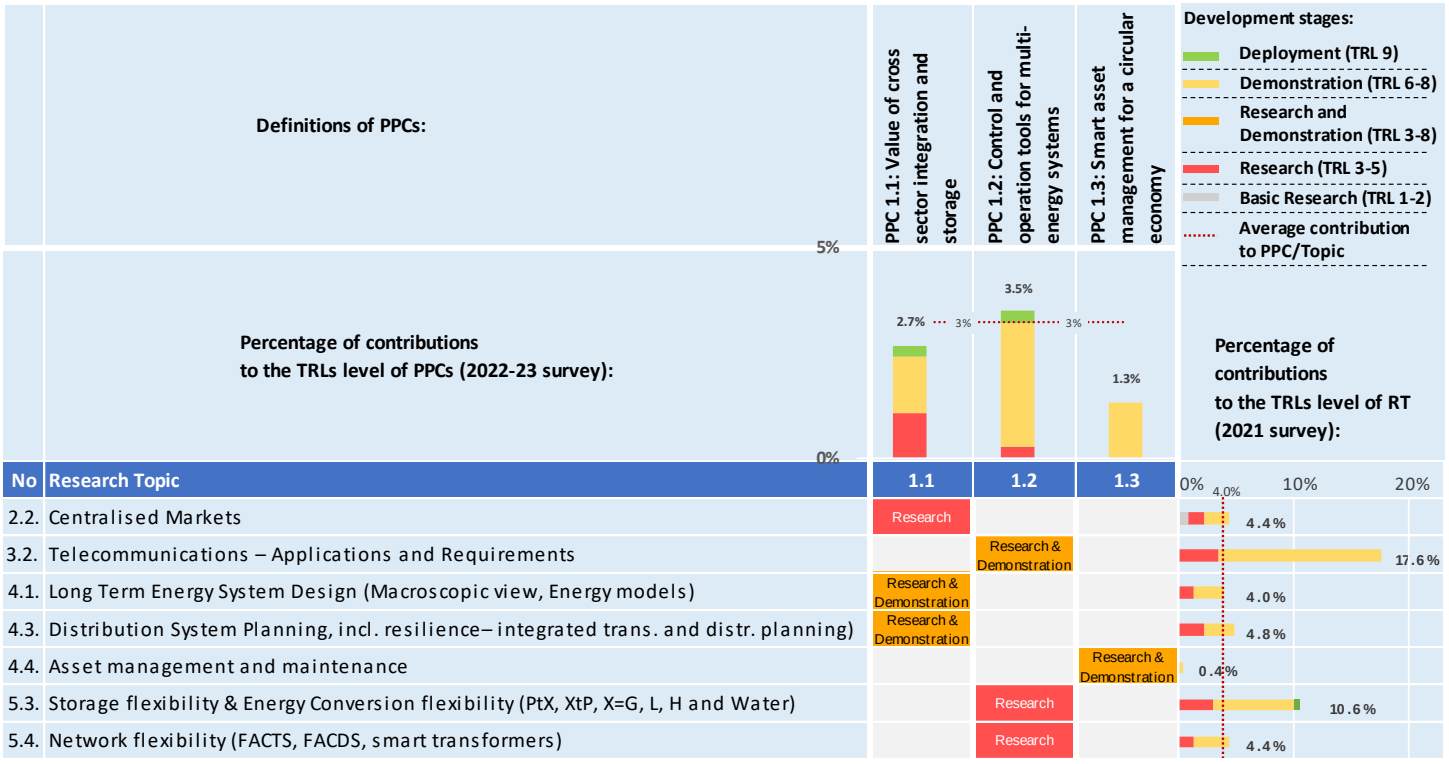


Figure 14. Percentage of contributions to HLUC 1

HLUC 1 Optimal Cross-Sector Integration and Grid Scale Storage addresses the transformation of the traditional energy system into an integrated system of gas transport, heating and cooling systems, EVs, P2X and X2P solutions, and large-scale energy storage. Coupling such complex systems requires new automated services that enable better grid flexibility.

PPC 1.1 Value of cross sector integration and storage

PPC 1.1. builds on key research topics - Centralized markets, Long Term Energy System Design and Distribution System Planning. The current stage of development of related technologies ranges from the research to the demonstration phase. Current R&I activities are in line with the current stage of development of the technologies defined in the IP 2022-2025. They seem likely to make these topics significantly more mature upon completion of the current projects, as the number of projects addressing the concept of cross-sector integration and storage is twice the average. This is seen primarily in Table 5 which relates current projects' key exploitable results to PPC expected outcomes (EO) and shows several green assessments in addition to a couple of orange ones. Many of the expected outcomes thus seem to be in reach based on current projects.

The survey also showed that the expected outcomes of PPC 1.1 will be achieved through a number of different projects which contribute with both research and demonstration results. It is expected that once these projects are completed, this PPC will be covered holistically and will form the basis for further development of HLUC 1. This observation is consistent with the numerous studies that have been conducted in recent years and that have been increasingly commissioned by the EU and national legislatures. These studies address specific cross-sector planning issues, including holistic energy planning for urban heating and cooling systems, combined hydrogen and electricity system planning, and combined transportation and electricity planning, several of which are getting close to potential commercial application.

Despite numerous ongoing projects, it appears that more attention should be paid to developing market models and regulations to ensure that R&I advances can be commercialized in the near future. This statement is supported by comments of a few respondents which indicated lack of regulations is one of the challenges preventing implementation and scaling of their solutions.

PPC 1.2 Control and operation tools for multi-energy systems

PPC 1.2 builds on Telecommunications and Flexibilities of Storages, Conservation Technologies and Networks. The latter categories are likely to be in the research phase, while communications and smart networks include both demonstration and research phase technologies. This year's and the 2021 survey data consistently show that the majority of ongoing projects contribute to the demonstration phase. In addition, the number of projects falling into this category is systematically high (twice the average) across all research topic and PPCs.

The survey showed that there are several project deliverables that demonstrate control and operation for a multi-energy system. The extensive R&I activities will lead to progress in this area, as some expected outcomes can already be met by the results of the ongoing projects (see Table 5). However, PPC 1.2 would benefit from some additional work as current results receive a green assessment for one out of six expected outcomes. Development of this PPC would help to channel solutions to the market. This conclusion is in line with the actual operation of multi-energy systems, as opposed to their planning, having only started developing recently.

PPC 1.3 Smart asset management for a circular economy

is primarily influenced by, but not limited to, the development of the Asset Management and Maintenance research topics. The projects studied contributed at the expected level, with almost equal impact on the research (TRL 3-5) and demonstration (TRL 6-7) phases. However, the results of the previous survey showed that asset management and maintenance was barely addressed in the projects.

Although general asset management methods are evolving greatly at not only at R&I levels but also with commercial software and

platforms, current survey did find many projects that specifically address these issues. Establishing circular economy methods for asset management requires further broadening and new tools for asset management, incl. concepts such as Big data, Artificial Intelligence (AI) and Machine Learning (ML), as well as the use of wearable devices, robotics, drones, etc. (EO 1.3.3 and EO 1.3.4). The relation between EO and KERs is also shows in Table 5.

Expected outcomes	KER of the surveyed projects
PPC 1.1: Value of cross sector integration and storage	
EO 1.1.1: Develop models for optimisation of the operation and planning of the integrated energy systems, in order to facilitate cost effective transition to zero carbon energy future. **EO 1.1.2:** Provide evidence related to the importance of cross-energy vectors coupling that would facilitate integration of large amount of RES and decarbonisation of heat / cooling, transport, industrial sectors. **EO 1.1.3:** Develop a new market, regulatory and policy frameworks for delivering low-emission, low cost, secure, reliable and resilient whole-energy system **EO 1.1.4:** Provides a holistic view and scientific guidance to foster technology and business model innovation to promote sustainable environmental and social circular economy objectives in energy storage and P2X, X2P, X2IndustrialService for an effective decarbonisation of the cross-energy sectors. **EO 1.1.5:** Set targets according to established measurable KPIs for energy storage and P2X, X2P, X2 Industrial Service	The Flexi Grid, X-Flex, LocalRES, TwinERGY, E- LAND, MAGNITUDE, RE-EMPOWERED, DIEGO, DISTRHEAT, SONDER, TOP-UP, and Power-2-Transport projects aim to develop solutions for optimisation of the operation and planning of integrated energy systems (EO 1.1.1) and to demonstrate the benefits (importance) of cross-energy vector coupling (EO 1.1.2). Some of these projects are also relevant to cross-sector coupling at local level, which is a topic covered further in HLUC9. The extensive list of KER can be found in APPENDIX B. Expected contributions to PPCs from not surveyed projects and APPENDIX C. Key exploitable results of HLUCs: HLUC 1: Optimal Cross sector Integration and Grid Scale Storage, while this section describes only selected KERs. The X-Flex project is developing tools for grid and microgrid operators to prevent congestion (voltage and current problems) and power quality issues as the share of intermittent energy increases RES. TwinERGY is developing a demand response solution for residential buildings and models to optimize the operation and planning of integrated energy systems. MAGNITUDE is developing models and software tools for simulating multi-energy systems and optimizing control strategies to maximize flexibility provision. RE-EMPOWERED is working on an EcoEMS tool that supports power system operations by scheduling different energy vectors while meeting a wide range of operational, security, and availability constraints. and prediction methods, ICT architecture support, and digital tools to improve design of PV systems. The DISTRHEAT project is developing an intelligent controller that manages a multi-energy system by exploiting the flexibility of buildings and making it available to the network. The NESOI and BioLens projects are developing methodologies/frameworks to support the development of a resilient energy system (EO 1.1.3). However, NESOI's KERs are limited to coordination and support actions (CSA) to provide technical assistance on clean projects to local authorities of EU islands while BioLens focuses on coordinating biofuel production and use, which is not directly related to smart grids. In addition, some respondents indicated a lack of regulations to enable the deployment and commercialization of their technologies. This may indicate a potential gap that requires further investigation. ZEHTC, USC - Flex Store, DEVISE, GIFT and P2G projects are developing energy storage, P2X / X2P technologies, software, and devices to demonstrate the benefits of cross-energy vector coupling to integrate more RES and decarbonize other resources and industries EO (1.1.4). The ZEHTC research area focuses on hydrogen turbine development, USC-FLEX Store - on underground seasonal storage enabling sector coupling via P2G at the point of storage as a bridge between electricity and gas markets. DEVISE develops and optimizes thermal and hybrid storage solutions. GIFT focuses on reversible electrolyzer technologies and hydrogen bromide flow batteries as a solution for buildings. The P2G project focuses on developing tools to analyse the potential of P2G systems at different levels - regional, national and EU. Although this is the only project that directly addresses EO 1.1.5, it is reasonable to assume that all projects addressing storage and P2X solutions will also shed light on the performance assessment of these technologies. Further results are expected from projects that are not covered by this survey: E-LAND, ROBINSON, ACES, RELflex, AGRO-SOFC, Flexi-Sync, HEATflex, H2CS, HED-LiS.

PPC 1.2: Control and operation tools for multi-energy systems	
EO 1.2.1: Development of the new design standards that would enable cross-sector integration **EO 1.2.2:** Demonstrate the ability of providing real time balancing and management of flexibility by cross-energy vector coordination including various P2X, X2P, grid scale energy storage technologies. **EO 1.2.3:** Tools using multi objective optimisation for the operation of multi-energy systems **EO 1.2.4:** Development and demonstration of advanced technologies and control concepts /platform tools for multi-energy systems based on appropriate data exchange between different energy sectors in local, national and pan EU regions **EO 1.2.5:** Creation of incentives and mechanisms for non-electric sector participants in an integrated energy system **EO 1.2.6:** ICT requirements and standards to collect, deliver and utilise data, including data from different energy sector, to enable efficient flexibility markets.	The results of the MAGNITUDE and P2G projects may support the development of new design standards that would enable multi-sector integration (EO 1.2.1). P2G results enable better evaluation of integrated energy systems. MAGNITUDE aims to develop methods for evaluating the performance of integrated energy systems, while the SP2G project aims to provide tools for P2X / X2P systems assessment. The GIFT, OSMOSE, X- FLEX, E- LAND, SERENE, ZEHTC, HONOR, USC - Flex Store, DEVISE, Power-2-Transport and TOP-UP projects demonstrate the ability to provide real-time balancing and management of flexible assets (EO 1.2.2). OSMOSE the X- FLEX, HONOR, SERENE and E- LAND projects are developing methods, algorithms and software for better integration and coordination of assets. GIFT, the ZEHTC, USC - Flex Store, NewSETS and DEVISE projects aim to develop hardware solutions - energy storage, hydropower solutions and P2X / X2P technologies to support grid flexibility. The RE-EMPOWERED, OSMOSE, DIEGO, DISTRHEAT, and SONDER projects are developing software and hardware tools to optimize the scheduling, operation, and planning of facilities in the multi-energy system (EO 1.2.3). The Interconnect project is developing a platform solution to integrate different types of assets into the energy system using concepts of IoT, blockchain, AI, and data analytics. Although this is the only project that can be associated with EO 1.2.4, it should be noted that it is the most highly funded project, involving 50 stakeholders from 11 countries. Exploitable Results from the GENTE and LocalRES projects can be directly linked to the creation of incentives and mechanisms for non-electric sector participants (EO 1.2.5). The GENTE project is developing a toolbox for communities and managers to optimize resources and join communities. The LocalRES project is developing a planning tool designed to enable citizen participation in RES planning decision-making processes. The survey identified only 2 projects that explicitly address ICT-related requirements for data collection in their projects (EO 1.2.6). The DIEGO project includes ICT architecture support as part of its planning tools, and the E- LAND project is developing a data pre-processing application that detects/corrects missing or erroneous data for further use in forecasting, optimisation and planning. Further results are expected from projects not covered by this survey: E-LAND, ROBINSON, ACES, RELflex, AGRO-SOFC, Flexi-Sync, HEATflex, H2CS, HED-LiS.
PPC 1.3: Smart asset management for a circular economy	
EO 1.3.1: New approaches for managing critical assets based on probabilistic risk assessment and optimisation of maintenance planning. **EO 1.3.2:** Common asset models for interpretation of the huge amount of data available from system monitoring and inspection. **EO 1.3.3:** Techniques and tools to extract the maximum level of information and knowledge out of the data from the field, using advanced analytics, machine learning and Big data technologies, to be applied using equipment ageing and failure models as well as system resilience evaluation tools. **EO 1.3.4:** Solutions based on digital approaches (such as tablets, wearables, robotics, drones and other elements) to support asset management and intelligent management to increase system reliability, reduced the risk for workers, decrease OPEX.	The results of the FlexiGrid project can be linked to EO 1.3.1 to develop new approaches to critical asset management. FlexiGRID is developing advanced management of assets in the power system throughout their lifecycle, enabling optimisation of the electric grid, including demonstration of V2G and optimal loading. In part, the results of the E- LAND project can be linked to common asset models to interpret the vast amount of system monitoring data (EO 1.3.3). The E- LAND project is developing a data pre-processing application to detect/correct missing or corrupt data and use it for forecasting, optimisation, and planning. The survey did not find results that can be directly linked to the development of intelligent asset management (EO 1.3.4).

Table 5. Coverage of expected outcomes of HLUC 1 by projects' results

HLUC 2: Market-Driven TSO–DSO–System User interactions

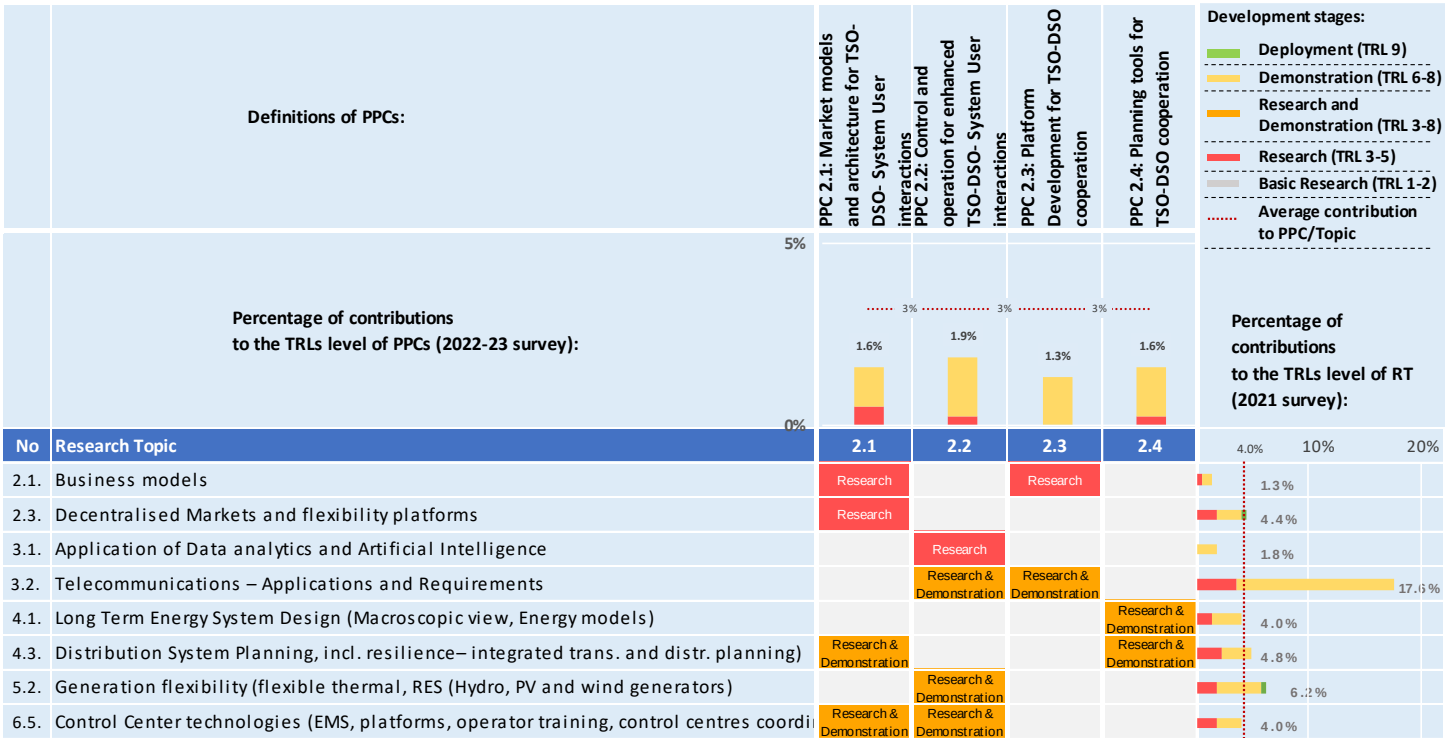


Figure 15. Percentage of contributions to HLUC 2

HLUC 2: Market-Driven TSO–DSO–System User Interactions addresses challenges associated with need for better TSO and DSO interaction. It includes coordinated planning of grid expansion and transformation, joint control and asset management in order to provide better value for local markets and make the most use of flexibility.

PPC 2.1 Market models and architecture for TSO-DSO- System User interactions

PPC 2.1 builds on the following research topics - Business model, Decentralized market and flexibility platform, Distribution system planning, incl. Resilience and Control centre Technologies. Currently, these topics are in the research and demonstration phases. The recent survey shows that this PPC received a close to average number of contributions, with a slightly larger percentage in the development phase than in the research phase. The observations are consistent with the previous survey - related research topics are relatively often included in projects.

Despite the considerable number of contributions (see Figure 15), the surveyed projects only partially meet the expected outcomes of PPC 2.1. It appears that these projects primarily address technical challenges related to the interaction between TSO-DSO and the users. The market models and architectures for the complex interactions between TSOs, DSOs and users have yet to be formulated and agreed upon at the national level, followed by the EU-wide level. Demonstration of self-sufficient demand side participation (EO 2.1.9, see Table 6) will also be possible after development of market models that integrate financial and social motives. More demonstration projects in this area need to be found or conducted to conclude on development of this PPC. This can also be seen in Table 6 where most EOs are assessed orange, i.e., significant R&I work remains before market maturity.

PPC 2.2 Control and operation for enhanced TSO-DSO- System User interactions

Development of PPC 2.2 to some extent depends on the progress of applications of data analytics and AI, Telecommunications, Flexibility of generation and Control centers. This PPC was selected slightly below average with contributions to demonstration phase (exception – OneNet response indicated research phase). Data from previous survey concur, but with a clear emphasis on development of telecommunication technologies.

Despite close to average number of contributions indicated by respondents (see Figure 15), the expected outcomes of PPC 2.2 were supported by only a few surveyed projects. The possible explanation is that control and operation of TSO-DSO-User interactions was not in the prime objectives of the projects Progress in this area can be achieved through projects that can successfully demonstrate the positive results. These types of projects can be developed by industry and therefore would not be represented in this report. Table 6 shows mostly a mix of orange and red assessments, indicating that more progress needs to be pursued. For example, further demonstration work will be needed to adjust the control and operations to the continuously evolving market models and architecture of these interactions to ensure their reliability and security.

PPC 2.3 Platform Development for TSO-DSO cooperation builds on business models and Telecommunication research topic and currently seems to be less covered by the ongoing current projects. However, in line with PPC 2.2, platform technologies for TSO and DSO can be developed up to the demonstration phase but, a holistic view of technology inclusion is recommended.

The development of PPC 2.3 is closely linked to PPC 2.1 and 2.2 This survey found evidence of platform development that appears to be driven primarily by the development of local market and flexibility platforms. Further results are needed to ensure that these platforms can be used (or extended) for TSO-DSO collaboration. This will also depend on the development of standards for data exchange and data

models (EO 2.3.4). This is supported by Table 6 of KERs and EOs which shows orange assessments. The development of cooperation platforms will depend on clarity on market models and architecture for interaction between TSO-DSO and users, as well as their control and operation, and will therefore need to be found in demonstration projects.

PPC 2.4 Planning tools for TSO-DSO cooperation

PPC 2.4 builds on long term energy system design and distribution system planning that were moderately developed according to the previous survey. The recent survey also identified only few projects contributing to this PPC, and the table of KERs and EOs is dominated by orange and red assessments.

Due to advances in heating and transportation electrification, TSO-DSO planning collaboration is becoming much more important than in the past. The report identified results that are consistent with expected outcomes related to TSO and DSO operational planning that can be used for long-term planning. However, no results were found with respect to joint planning and tools that can model and validate overall dynamic stability, especially when it needs to be synchronized with gas TSOs and DSOs (EO 2.4.2-2.4.4). More results need to be obtained or found that demonstrate growing efficiency in planning of integrated energy systems.

Expected outcomes	KER of the surveyed projects
PPC 2.1: Market models and architecture for TSO–DSO–System User interactions	
EO 2.1.1: Market design for DER and VPP participation **EO 2.1.2:** Development and validation of Cost Benefit Analysis for TSO-DSO ancillary services coordination **EO 2.1.3:** Increased participation of consumers and local communities **EO 2.1.4:** Definition of standard pan-European ICT platforms to allow the interaction of the different actors in the process of acquisition of ancillary services (end-users/BSPs, market operators, TSOs, DSOs, aggregators and BRPs) in an integrated and optimised environment. **EO 2.1.5:** Methodologies to optimise provision of Ancillary Services from distributed resources in the distribution network **EO 2.1.6:** Market models for the interaction of TSOs and DSOs including interactions between central and local markets **EO 2.1.7:** Assessment to identify technical, market and business barriers to the smooth cooperation and interaction between TSOs, DSO and consumers **EO 2.1.8:** Assessment of improvement paths in system operation to enable the integration of new services and products in system operation **EO 2.1.9:** Demonstrate Demand Side participation, consumer involvement and Local Energy Communities **EO 2.1.10:** Increase observability in the power system and allow data exchange between the DSOs and TSOs **EO 2.1.11:** Specify appropriate technical characteristics and timeframes to participate in the markets **EO 2.1.12:** Unlock markets of flexibility at every level to address the needs of the SOs. (Standardise balancing market data exchange vertically (across the electricity value chain) and horizontally (across vectors/sectors). **EO 2.1.13:** Creation of incentives and mechanisms for non-electric sector participants in an integrated energy system.	The Coordinet project contributes to TSO-DSO coordination of ancillary services (EO 2.1.2). It does not use cost-benefit analysis but explores best practices of TSO-DSO cooperation through mutual market management and provision of available flexibilities (EO 2.1.1). The Coordinet project is also expected to provide results related to methods for optimizing the provision of ancillary services by distributed resources (EO 2.1.4). First, it provides definitions of standardized products for ancillary services in terms of innovative technical platform solutions. Second, it identifies and evaluates market platform concepts to facilitate extension to the pan-European level. The Coordinet, EUniversal, and HONOR projects contribute to the development of methods for optimizing ancillary services from distributed resources (EO 2.1.5), but with different solutions. Coordinet is developing coordination algorithms to manage the response of different end users. The EUniversal project is developing software to select the best price offer that most efficiently solves the grid constraint problem and is also improving aggregation algorithms for local flexibility markets to aggregate small capacities at end-user locations. The goal is to develop a hybrid model for optimal use of flexibility that allows load shifting and storage charging and discharging based on market incentives. A contribution to market models for the interaction between TSOs and DSOs, including the local market (EO 2.1.6), was indicated by the TwinERGY project. Improving observability in the power system and enabling data exchange between DSOs and TSOs (EO 2.1.10) is being investigated by the OneNet project. Their solutions combine the principles of International Data Spaces with the benefits of the FIWARE ecosystem to provide seamless and secure data exchange in a decentralized end-to-end approach. The results of the Coordinet project can be used to define appropriate technical characteristics and timeframes for participation in the markets (EO 2.2.11). The project defines organizational and administrative solutions for the establishment of a fully automated marketplace with transparent prices for neutral and secure trading with available flexibility through intraday, day-ahead and long-term settlements including payment processes. BeFlexible also improves the availability of flexibility resources for TSOs and DSOs, allowing them to develop markets for flexibility and interact with many distributed resources simultaneously. To some extent, this meets the expected outcome of developing flexibility markets at each level for SO needs (EO 2.1.12). In addition, the BeFlexible project defines new business models for market participants based on energy services and revenue streams for consumers in all energy sectors and beyond, based on the valorization of the flexibility of their energy consumption. This is in line with the expected outcome of creating incentives and mechanisms for participants from the

	non-electric sector in an integrated energy system (EO 2.1.13). Further results are expected from projects that are not covered by this survey: INTERRFACE, SIES2022 and LASAGNE.
PPC 2.2: Control and operation for enhanced TSO–DSO– System User interactions	
⊖ **EO 2.2.1:** Methods and tools for prosumer monitoring and participating in the markets ⊖ **EO 2.2.2:** ICT technologies enabling prosumer participation in the markets ⊖ **EO 2.2.3:** Standardise balancing market data exchange vertically (across the electricity value chain) and horizontally (across vectors/ sectors) ⊕ **PPC 2.2.4:** Design and test efficient optimisation algorithms for near real-time TSO-DSO-Consumer coordination considering grid constraint. ⊖ **EO 2.2.5:** Identify universal devices needs for TSO-DSO information exchange at different time frames ⊖ **EO 2.2.6:** Big data management and advanced algorithms solutions for supporting decision making by System Operators ⊖ **EO 2.2.7:** Improved real-time observability of RES ⊕ **EO 2.2.8:** Develop models for robust net load forecasting and robust forecasting of available flexibility. ⊖ **EO 2.2.9:** Assessment of technical, market and business barriers to the smooth cooperation and interaction between TSOs, DSO and consumers ⊖ **EO 2.2.10:** Ensure resilience contributions from DER (including black start) ⊖ **EO 2.2.11:** Ensure and test overall dynamic stability ⊖ **EO 2.2.12:** Improve/deploy and demonstrate IoT and EMS at System User premises to optimise (self)consumption and market participation according to grid needs and/or market signals (intelligent agents) ⊕ **EO 2.2.13:** Design and test optimal utilisation and control of Demand Side Response by TSOs and DSOs	The expected outcomes of PPC 2.2 were supported by only a few projects studied. However, considering the niche application of DSO-TSO, only little publicly funded research is to be expected in this area. Instead, progress in this area can be achieved through a limited number of projects that can successfully demonstrate the positive results. These types of projects are also expected to happen within industry-internal projects which are outside the scope of this report. Exploitable result from two projects could be explicitly linked to the expected outcome EO 2.2.4 - Design and test efficient optimisation algorithms for near real-time TSO-DSO - Consumer coordination considering grid constraint. The OneNet project software solution provides a coordinated TSO-DSO flexibility market simulator and a market balancing module that ensures that system operators' flexibility requirements are met at the lowest possible cost, while abiding by the network constraints. EUniversal develops a set of tools to select the bid that solves the network constraints most effectively and at the best price. Two projects are contributing to the development of models for - net load forecasts and - forecasts of available flexibility (EO 2.2.8). The REgions project is developing a short-term (intra-hourly) DER forecasting solution to support power system stabilization by enhancing traditional virtual power plants (VPPs) and incorporating regional and interregional services. The EPC4SES project is developing tools to provide load forecasts for DSOs based on CO2 forecasts for buildings. Further results are expected from projects that are not covered by this survey: LASAGNE and SIES2022.
PPC 2.3: Platform development for TSO/DSO cooperation	
⊕ **EO 2.3.1:** Design data exchanges and standard protocols for all players paving the way for a cross-sector approach ⊕ **EO 2.3.2:** Test platforms and mechanisms usage for cooperation (between System Operators, and between SOs and consumers). ⊕ **EO 2.3.3:** Develop and improve digital technologies (e.g., protocols, devices) to support customers and distributed energy resources to participate in the operation and market. ⊖ **EO 2.3.4:** Leverage the use of standards for data exchange (CGMES, CIM, etc). Definition of appropriate data models that can represent properly all the TSO-DSO- System User interactions. ⊕ **EO 2.3.5:** Develop and demonstrate effective and efficient platforms for market-driven interactions between multiple players that are interoperable and that fits the market requirements and have flexible interfaces	The OneNet project is developing two solutions that can be linked to the development of data exchange and standard protocols for all stakeholders for a cross-sector approach (EO 2.3.1). First, the OneNet Connector leverages the principles of International Data Spaces and the FIWARE ecosystem to ensure seamless and secure data exchange in a decentralized end-to-end approach. Second, the cross-platform service catalogue solution enables the definition and description of services and business objectives to enable harmonized data exchange between different platforms and actors. The results of two projects can be related to the development of test platforms and mechanisms for cooperation between System Operators and between System Operators and consumers (EO 2.3.2). The solution from the SYNERGY project is currently being developed to facilitate short-term planning for network operators by leveraging the available flexibility of suppliers. Orchestration Workbench is the component of the OneNet system capable of orchestrating and evaluating the performance of cross-platform services. Each participant in the system will be able to test and evaluate its own service to enable integration into the system. Universal Market Enabling Interface (UMEI) is a solution that is currently developed in the EUniversal project. This solution appears to contribute to EO 2.3.3 and EO 2.3.5 (develop and improve digital technologies (e.g., protocols, devices) and develop and demonstrate effective and efficient platforms for market-driven interactions between multiple actors). UMEI is an open-source market interface that provides a common way for market participants to interact with flexibility markets and each other without requiring intermediary components such as data hubs or platforms to procure system services to operate the distribution network. This is done through a conceptual architecture design and implementation of a standardized, agnostic, adaptable, and modular combination of

	different APIs to connect DSOs and market participants to flexibility market platforms, in coordination with other flexibility users.
PPC 2.4: Planning Tools for TSO-DSO cooperation	
EO 2.4.1: Efficient long-term planning and corresponding tools and simulation capabilities **EO 2.4.2:** Stimulate participation from cross-sector actors Expand TSO-DSO cooperation towards the network planning longer timeframe **EO 2.4.3:** Identify and validate mechanisms for Gas TSO and Gas DSO cooperation in managing pipe pressures and consumer requirements in the context of increasing alternative gases (e.g., hydrogen) **EO 2.4.4:** Ensure and test overall dynamic stability	Exploitable results from two projects can be linked to the expected outcome of developing efficient long-term planning and appropriate tools and simulation capabilities (EO 2.4.1). The BeFlexible project contributes to informed decision making by network operators and national regulators by illustrating the role of flexibility markets and new business models to avoid new investments. The Synergy project develops the software solutions that simulate the operation of the grid and assess the state of the network in terms of reliability, performance and power quality metrics. Another exploitable result obtained in EUniversal can be linked to the simulation of the participation of cross-sector actors (EO 4.2.2). The results allow the selection of the best asset offer that solves the grid constraint most effectively and at the best price based on the set of tools to assess the state of the grid and the exact need for flexibility in terms of quantity, time and location.

Table 6. Coverage of expected outcomes of HLUC 2 by projects' results

HLUC 3: Pan-European Wholesale Markets, Regional and Local Markets

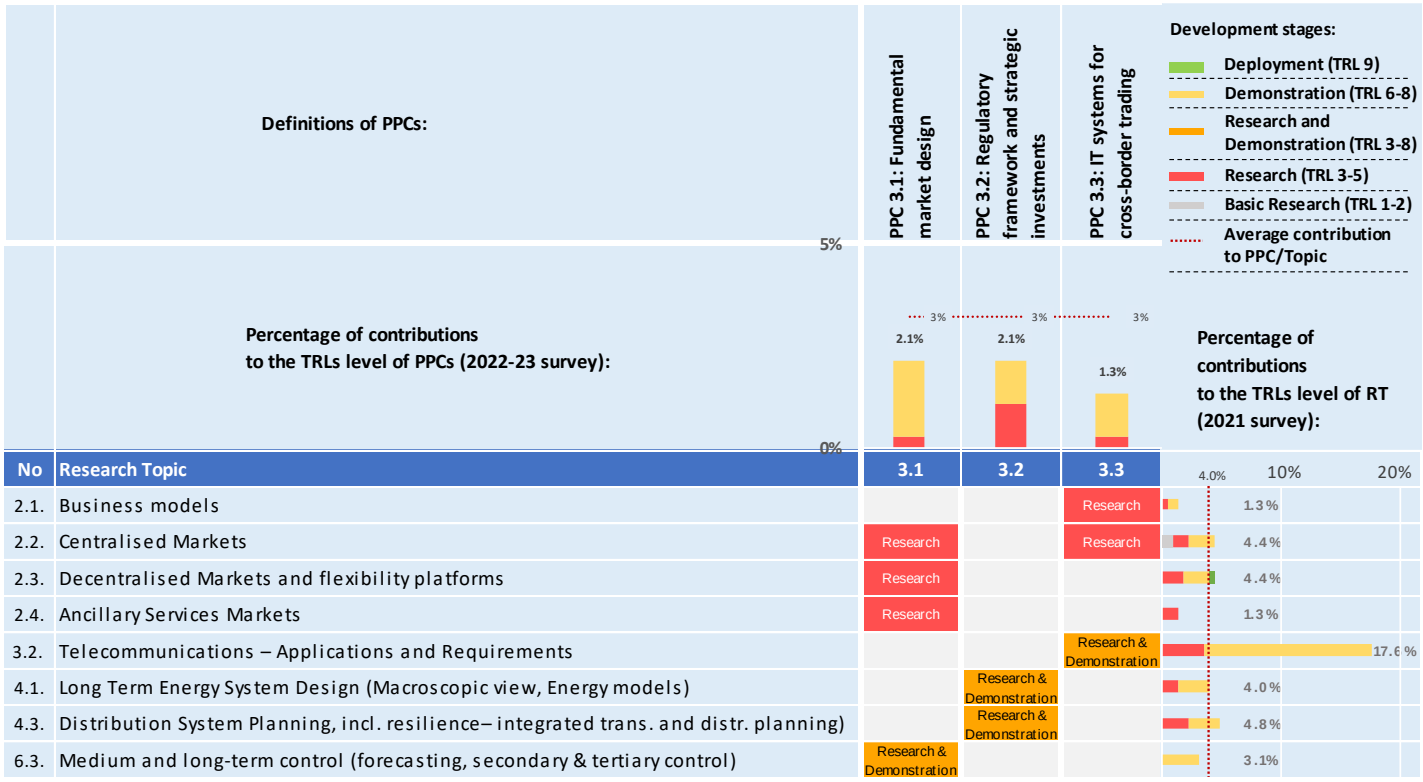


Figure 16. Percentage of contributions to HLUC 3

HLUC 3 Pan European Wholesale, Regional and Local Markets aims to redesign electricity markets design also considering cross-energy coupling, which encompasses temporal (from seconds to years) and spatial (from local to international) dimensions. The key role of technologies and control systems that can exploit the available flexibility should benefit the power system from lower operating costs associated with maintaining and retrofitting existing systems and building new ones. In the context of this HLUC, new legislation should encourage DSOs to take on more responsibility, especially in the procurement of ancillary services, data management, and integrating the heat and transport sectors effectively. Flexible technologies and control systems should be encouraged by markets, and Member States should remove barriers to market-based pricing. DSOs should align network access and congestion tariffs and charges, while Member States should enable scarcity pricing, interconnection, demand-side response (DSR), and storage to contribute to the capacity market.

PPC 3.1: Fundamental market design

PPC 3.1 is based on Centralized markets, Decentralized markets and Flexibility platforms, Ancillary services markets and Medium and long-term control research topics. Almost all research topics are currently in the research phase and according to the previous survey not yet at the demonstration phase. The survey showed that PPC 3.1 is partially covered by ongoing projects, most of which will require demonstration when completed. Additionally, only few exploitable results can be linked to the expected outcomes of this PPC. These results partially meet the goal of the PPC and mostly address specific technologies and methodologies, while the outcomes are expected at the fundamental level. All six expected outcomes are marked orange as only partially met (see Table 7). More results need to be collected to draw a conclusion about the development of this PPC.

PPC 3.2: Regulatory framework and strategic investments

Development of PPC 3.2 includes long term system design and (distribution system) planning, incl. resilience. There is consistency between the two surveys, showing a roughly average level of contribution and an almost even split between research and demonstration phases.

The goal of this PPC is of great importance for the adoption of the technology. Few results were identified in this survey that are related to the expected outcomes of PPC 3.2 and more need to be obtained to ensure the development of this PPC. This particularly concerns strategic investment decisions that will depend on the development of mechanisms of PPA and guarantees of origin which are currently highlighted red and not yet well enough integrated into the planning processes, and especially the regional and local levels (not addressed by the surveyed projects yet; see Table 7). This is especially crucial in the context of sector coupling, different energy carriers and the Renewable Energy Directive.

PPC 3.3: IT systems for cross-border trading

PPC 3.3. includes Business model, Centralized markets and Telecommunication. As noted above, the first two categories are currently in the research phase and not yet at the demonstration phase, while telecommunications are significantly advanced.

There are already IT systems in place for cross-border trading of electricity and gas that may need to be updated. Deployment, demonstration, and perhaps research projects will be required if the regulations for trading change significantly or include hydrogen. Given the niche application of the required technologies, development of this PPC may depend on a limited number of projects not covered in this report or currently underway in industry. This PPC may thus depend more than most others on the extent to which regulatory evolution requires research and demonstration on these IT systems. The specific focus should be given to assess how (a variety of) technologies will affect the overall trading capabilities in the context of IT infrastructure (currently few results observed, marked orange, see Table 7) and the implication they have for overall Pan-European network in terms of safety margins and resilience (no results are observed yet, marked red in Table 7).

Expected outcomes	KER of the surveyed projects
PPC 3.1: Fundamental market design	
EO 3.1.1: Enable development of operation of short term (seconds-minutes-hours) fully decentralised energy markets including stability, balancing and energy exchange, while managing network congestions **EO 3.1.2:** Develop fundamentally new multi-energy market with appropriate temporal and special spatial granularity to facilitate cost effective transition to low carbon energy future. **EO 3.1.3:** Develop cost effective market mechanism for allocation of costs related to the provision of balancing services, network charging, investment in conventional and low carbon generation. **EO 3.1.4:** Demonstrate that the new market will enable flexibility technologies and advanced system control concepts to access revenues associated with all benefits delivered. **EO 3.1.5:** Develop fully decentralised energy markets including peer-to-peer trading of energy and balancing services, while maximising service quality delivered to end consumers	Exploitable results from 2 projects can be related to the expected outcome EO 3.1.1 - Enable development of operation of short-term (seconds-minutes-hours), fully decentralised energy markets, including stability, balancing, and energy exchange, while managing network congestions. The EUniversal project develops a comprehensive methodology for designing dynamic grid tariffs to mitigate both short- and long-term congestions. The REgions interviewee also mentioned that his project is addressing short-term operations issues. The exploitable result of the Magnitude and SP2G projects can be linked to EO 3.1.2. The Magnitude project develops innovative market designs to improve synergies between electricity, gas, and heat energy markets, implemented on a market simulator. It also provides a policy strategy and recommendations in a pan-European perspective. The SP2G project is developing assessment methods of P2G technologies under specific market conditions and thus also can be related to this outcome. The results of the FEVER project can be related to EO 3.1.3 - Development of cost-efficient market mechanisms for the allocation of costs related to the provision of balancing services, network charges, investments in conventional and low-carbon generation. The FEVER project develops market mechanisms for day-ahead and intraday flexibility trading to demonstrate the effectiveness of mitigating distribution system problems. First, the optimisation problem is solved at the transmission level to determine electricity prices and market schedules. Then, at the local level, each DSO solves a local cost minimization subproblem by incorporating the technical constraints of its distribution network and the flexibility offers received from flexibility aggregators. The results of the EUniversal project can be partially related to EO 3.1.4 as they are limited to business model innovation and CBA methodologies and explore approaches to distribution grid planning in Europe, focusing on the trade-off between flexibility and network investment. The results of the FEVER, Interconnect and TwinERGY projects are related to EO 3.1.5 - Development of fully decentralized energy markets including peer-to-peer energy trading and balancing services. FEVER is developing a P2P flexibility trading platform, mainly consisting of distributed applications (DAPPs) enabling P2P trading. The Interconnect project is developing a platform to integrate different types of assets into the energy system using concepts of IoT, blockchain, and AI and data analytics. The TwinERGY project also develops P2P trading solution. Further results are expected from projects that are not covered by this survey: BD4NRG, INTERRFACE, SIES2022, TRINITY and LASAGNE.
PPC 3.2: Regulatory framework and strategic investments	
EO 3.2.1: Develop Market design / regulatory framework for supporting cost effective delivery of security and resilience of supply from local to national / international level. **EO 3.2.2:** Enhance renewable power purchase agreements **EO 3.2.3:** Guarantees of origin are a key tool for consumer information as well as for the further uptake of renewable power purchase agreements.	The results of the EUniversal project can be partially related to EO 3.2.1, as the project proposes regulatory recommendations on how to use six flexibility tools that were developed under this project. In addition, regulatory sandboxes are proposed as a solution to test the impact of different implementation options in practice. To some extent, the results of the FEVER project can also contribute to EO 3.2.1. FEVER is developing market mechanisms for day-ahead and intraday flexibility trading to demonstrate the effectiveness of mitigating distribution system issues through market mechanisms for flexibility trading. - No exploitable results have been collected that can be associated with EO 3.2.2 – 3.2.3. Further results are expected from projects that are not covered by this survey: INSULAE, ISLANDER, MAESHA and TRINITY.

PPC 3.3: IT systems for cross-border trading	
EO 3.3.1: Simulation analysis with new technologies; real-time analysis of new technologies with extensive power electronics; use of HIL (HW in the loop) simulation to validate new technologies; simulation at local level, national level, cross-border level and pan-European effects; preparation for risk-controlled field demonstrations. **EO 3.3.2:** Validated tools and solutions for the management of the Pan-European transmission network, for secure operation of the power system with steadily increasing (beyond 100% of demand during certain intervals) inverter-based RES, through fast real-time and continuous prediction of dynamic stability margins and preventive mechanisms and the market-based activation of cross-border dynamic stability services (such as ancillary services).	The results of the EUniversal project are directly related to EO 3.3.1 The project aims to develop an improved methodology to perform simulation-based quantitative SRA (scalability and replicability analysis) of use cases related to the application of local flexibility markets to prevent or mitigate congestion in the distribution grid. Developments will be made - joint use of active and reactive power, comparison of market clearing through a MO versus DSO-determined flexibility activations (incorporating different grid modeling approaches and jointly solving congestion and voltage problems). The results of FARCROSS project partially meet EO 3.3.2 as the project aim to develop and introduce advance software solutions, including capacity allocation and reserve optimisation tools, as well as an advanced forecasting of energy production and demand response platform, to increase the cross-border capacity and the potential of cross-border grid services.

Table 7. Coverage of expected outcomes of HLUC 3 by projects' results

HLUC 4: Massive Penetration of RES into the Transmission and Distribution Grid

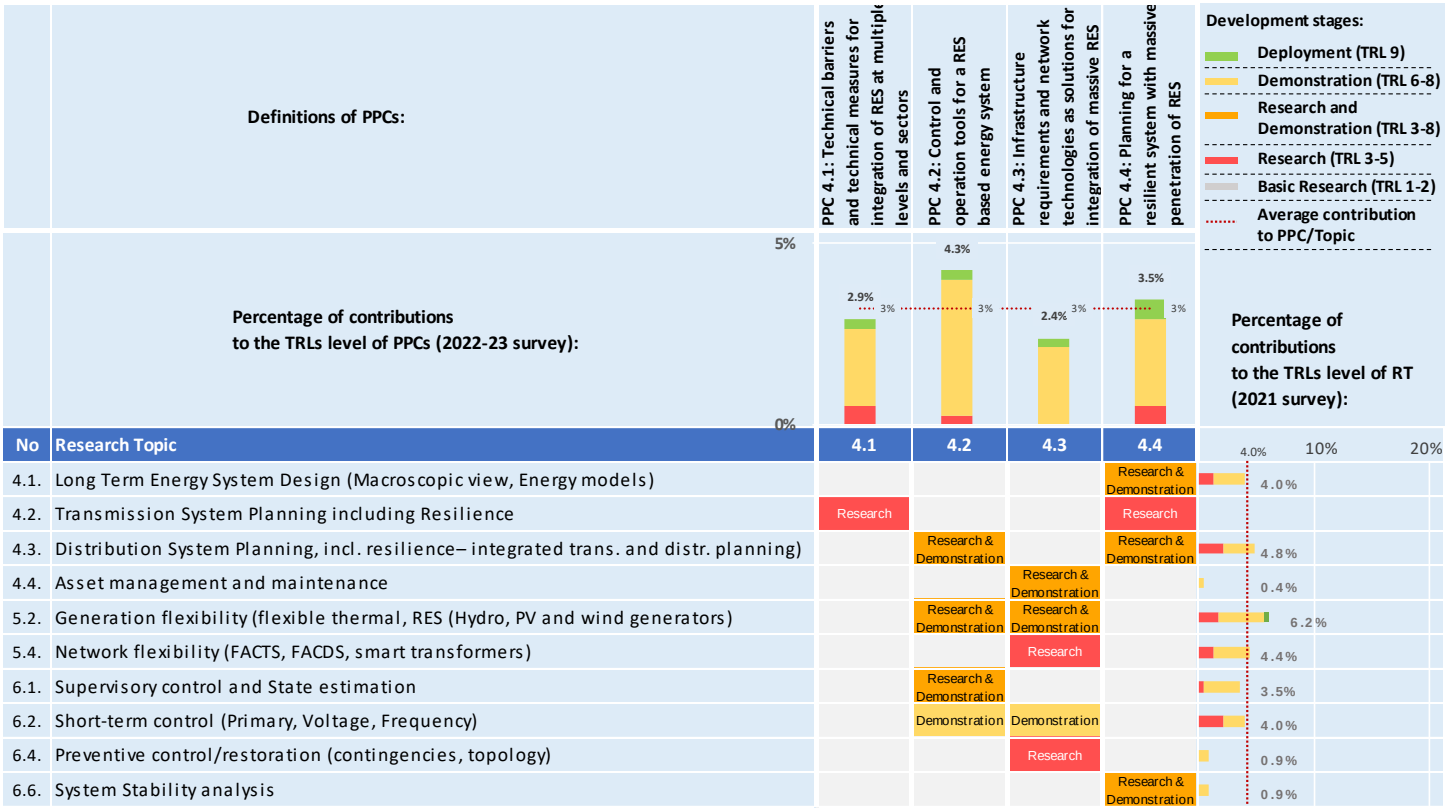


Figure 17. Percentage of contributions to HLUC 4

HLUC 4 Massive Penetration of RES into the Transmission and Distribution grid focuses on the integration of RES at both the transmission and distribution levels. The massive penetration of RES brings challenges at multiple levels. On the one hand, generation-load imbalances will increase, reinforcing the importance of improved forecasting, adequate protection and control mechanisms, and monitoring systems. On the other hand, new market dynamics are required to ensure participation and reduce risk for consumers.

PPC 4.1: Technical barriers and technical measures for integration of RES at multiple levels and sector

PPC 4.1 incorporates Transmission system planning research topic. Although this research topic was not indicated to be covered by the previously surveyed projects, PPC 4.1 has provided significant results based on the current survey data. It is being addressed at a slightly above average level, with projects in the demonstration phase.

However, there are not enough exploitable results that have been indicated by respondents to conclude that the expected outcomes of PPC 4.1 were fully met (three expected outcomes are only partially met while two are not met and indicated red, see Table 8). This means that the objectives of the surveyed projects do not yet sufficiently address the objectives of this PPC although some of the outcomes can be used to further develop this area. Based on the indicated KERs, only Improved modelling and simulation (EO 4.1.3) can be associated with the results of two projects. Also, friendly market design for RES participation (EO 4.1.2) and facilitated participation of cross-sector RES (EO 4.1.4) can be indicated as (partially) covered as this is the prime objective of many projects. More results are needed for re-dispatch (EO 4.1.1) and market dynamic (EO 4.1.6) assessments to holistically cover this PPC.

PPC 4.2: Control and operation tools for a RES-based energy system

PPC 4.2 is based on distribution system planning, generation flexibility, supervisory control and short term control research topics. Currently, these research topics are in the research or demonstration phase, which is also confirmed by the data from the previous survey. Generation flexibility and supervisory control appear to be mainly in the demonstration phase. In the most recent survey, respondents largely indicated that their projects were addressing PPC in the demonstration phase.

The examples of control and operating tools, both of which become important and difficult with high RES penetration, show that good progress is being made in the research and demonstration phase. This survey showed that many results (see Table 8) will be obtained to improve forecasting capabilities (EO 4.2.1), followed by improving efficiency of DER control in Hybrid Power Systems (EO 4.2.5). No results have been found so far to ensure efficient curtailment mechanisms (EO 4.2.8) as well as there are four partially met outcomes that may require further work (see Table 8).

PPC 4.3: Infrastructure requirements and network technologies

PPC 4.3 consists of asset management, generation and flexibility, short-term and preventive control. Progress on these research topics seems to be in line with the current state of development, highlighting that preventive control and asset management seem to be barely covered, while generation flexibility is covered above average in the demonstration phase. This PPC seems reasonably covered with the majority of contributions in the demonstration phase.

Given a significant number of exploitable results that can be linked to the expected outcomes of PPC 4.3, it is likely that this PPC will be able to make significant progress upon completion of projects. Although the survey did not find solutions that can mitigate lack of inertia in

grids (EO 4.3.3, see Table 8), such projects could be part of power electronics and developed under HLUC 6.

It still needs to be ensured that all the necessary technologies for multinational interconnection design to support offshore wind and optimal flexibility management demonstrate their efficiency. There are also reasons to believe that necessary projects are currently conducted within the industry and are not represented in this survey.

PPC 4.4: Planning of a resilient system with massive penetration of RES

PPC 4.4 is based on Long term energy system design, Transmission and Distribution system planning and System stability analysis. According to the previous survey, these research topics were insufficiently addressed. But the recent survey shows that this PPC was selected twice as much as average in both the research and demonstration phases. EOs of this PPC are to be partially met with KERs from a number of projects to improve modelling capabilities and enhance operation and planning (both indicated orange, see Table 8). Despite the expected progress in this PPC, it should be noted that resilience nevertheless remains a relatively young topic with rapidly increasing importance (due to European energy supply disruption), which means that more results need to be obtained in future.

Expected outcomes	KER of the surveyed projects
PPC 4.1: Technical barriers and technical measures for integration of RES at multiple levels and sectors	
EO 4.1.1: Analysis of re-dispatch process and efficient market solutions **EO 4.1.2:** Friendly Market design for RES participation (short-term bids) **EO 4.1.3:** Improved modelling and simulation **EO 4.1.4:** Facilitate the participation of cross-sector RES **EO 4.1.5:** Reduce system risks associated with increased fluctuating generation **EO 4.1.6:** Assessment of market dynamics	Exploitable results of BD4OPEM and SP2G projects are related to EO 4.1.3 - improved modelling and simulation. The BD4OEM project proposes asset and investment planning modelling tool for selecting technologies contributing to grid reinforcement at a given time. Simulations help to understand origins of disturbances in the grid and assess risks to improve the quality of supply. The results of the SP2G project are also related to this expected outcome but are limited to P2G technologies. Friendly market design for RES participation (EO 4.1.2) and facilitated participation of cross-sector RES (EO 4.1.4) can be indicated as (partially) covered as this to be the prime objective of many projects. Further results are expected from R2EC project that is not covered by this survey.
PPC 4.2: Control and operation tools for a RES based energy system	
EO 4.2.1: Improved forecast tools **EO 4.2.2:** Transmission Network: Increase RES hosting capacity of Transmission System, expansion of the offshore grid **EO 4.2.3:** Distribution Network: Increase RES hosting capacity of Distribution System **EO 4.2.4:** Technologies for distribution grid operation exploiting flexibility and storage management and corresponding coordination with system operators. **EO 4.2.5:** Ensure efficient and effective DER control and Hybrid Power Systems **EO 4.2.6:** Efficient mechanisms to reduce system risks associated with increased fluctuating generation **EO 4.2.7:** Efficient digital mechanisms for RES integration and participation (e.g., protocols, platforms) **EO 4.2.8:** Efficient curtailment mechanisms, with increased renewables and from multiple sectors	The results of several projects can be related to EO 4.2.1 - improved forecasting tools. The projects SYNERGY, GIFT, EUniversal, FEVER, ACCEPT, EPC4SES and OSMOSE are developing various solutions to improve forecasting and support operations. Synergy proposes the Operational Scheduler Optimiser to improve forecasts for large PV systems based on climate data predictions. The Gift project is developing a forecasting system (based on a dynamic and mathematical model) for energy supply (renewable and non-renewable) and demand (buildings, transportation, production, etc.). The EUniversal project is developing a set of solutions, including a day-ahead LV congestion forecasting tool. The FEVER project is developing 2 forecasting solutions. The first is a forecasting and decision support solution to support the identification of grid issues and propose a mitigation action plan based on grid flexibility. The second is a short-term (hour-ahead) and medium-term (day-ahead) forecasting method for PV generation that is being developed based on a non-parametric artificial neural network (ANN). The ACCEPT project is developing a digital twin model for consumers to understand, anticipate, and forecast energy/flexibility behavior at the point of grid connection. Another solution from ACCEPT is the District Asset Management component, which accurately predicts the performance of community-level assets and provides a bidirectional interface to those assets to send control commands. The EPC4SES project developed a method to increase renewable energy yields through model predictive control using a digital twin based on energy performance certificate data. Finally, the OSMOSE project conducted a quantified analysis of the impact of more renewables on forecast errors and market operations. These findings can be used to further improve forecasting techniques. Exploitable results from 3 projects can be related to EO 4.2.4 - Technologies for distribution system operation exploiting flexibility and storage management and appropriate coordination with system operators. The system-level assessment framework for quantifying flexibility is being developed as part of the EUniversal project. The solutions from ACCEPT use the energy disaggregation approach in their Non-Intrusive Load Monitoring (NILM) solution. It enables monitoring of residential energy consumption for energy sustainability. AISOP is developing a data-driven dynamic rate design for DERs that indirectly changes consumer and prosumer behavior. This solution supports the operational planning of DSOs. The results of a number of projects can be attributed to EO 4.2.5 - Ensuring Efficient and Effective Control DER and Hybrid Power Systems or EO 4.2.6 - Efficient Digital Mechanisms for RES Integration and Participation. IElectrix does this through an

	energy community management system, a direct load control system, and an energy management system. The GIFT project is developing a VVP solution that uses technologies for automatic trading of energy flexibilities in real time. EUniversal is developing a framework to enable DSOs to procure flexibility services for congestion management and voltage control in the day-ahead market. The project ACCEPT proposes two solutions. First, an on-demand flexibility management module that provides a residential-optimized, intelligent, and predictive integrated energy control system that ensures a comfortable indoor environment and provides schedulable demand/supply flexibility. Second, ACCEPT is developing a component responsible for efficient, reliable, and cost-effective connectivity to the building's physical plant and pre-processing of data for other system components. RE-EMPOWERED is developing an EMS for non-microgrids and microgrids that optimizes the performance of different energy vectors (e.g., water management and cooling systems) while taking into account synergies between them. The IANOS project is developing a VVP solution that allows optimisation and integration of different assets and improved operation, taking into account throttling, voltage control, load profile, etc. Givena sufficient number of projects that have indicated PPC 4.2, there is reason to believe that EO 4.2.3 is also met, as it is not limited to a specific technology, but represents a variety of different approaches. Further results are expected from projects that are not covered by this survey: edgeFLEX, PLATONE, VPP4ISLANDS, SMART-MLA, DiGriFlex and R2EC.
PPC 4.3: Infrastructure requirements and network technologies as solutions for integration of massive RES	
EO 4.3.1: Develop advanced network technologies, such as FACTS, WAMS **EO 4.3.2:** Protection and control **EO 4.3.3:** Solutions to deal with lack of inertia **EO 4.3.4:** Methodologies to manage energy transits in the networks **EO 4.3.5:** Appropriate forecast (load, generation, transits) **EO 4.3.6:** Multinational interconnection design to support offshore wind **EO 4.3.7:** Optimal Flexibility Management including Demand Response	The result of the FARCROSS project can be directly related to EO 4.3.1 - advanced network technologies, such as FACTS, WAMS. The project is developing Wide Area Protection, Automation and Control (WAMPAC) solutions for optimal use of HV transmission lines that investigate the grid stability and security criteria acting as service requirements for a complete WAMPAC solution. The results of three projects can be related to the EO 4.3.2 - Protection and control. The EUniversal project has a number of solutions including data-driven state estimation, data-driven voltage control, day-ahead LV congestion forecasting tool, and Dynamic Line Rating System for OHL operation. FEVER is developing algorithms (based on AI and data-based techniques) for LV grid observability that will enable DSOs to control normally unobservable LV grids. The X- FLEX project is developing a tool for grid and microgrid operators (GridFlex) that aims to avoid congestion (voltage and current problems) and power quality problems with the increasing share of intermittent RES, taking into account extreme climate events. Three exploitable results from the FARCROSS and OSMOSE projects are related to EO 4.3.4 - Methodologies to manage energy transits in the networks. FARCROSS proposes 3 key solutions. First, Dynamic Line Rating (DLR) solutions aiming to establish a grid monitoring system for cross-border power lines. Second, Modular Power Flow Control (MPFC) technology enables an increase in cross-border grid capacity by reducing congestion. Finally, co-optimized cross-border power transmission capacity auction algorithm (OPTIM-CAP) addresses day-ahead capacity allocation for regional cross-border trading by utilizing available transfer capacities for balancing capacity procurement and energy trading. In line with the FARCROSS results, the OSMOSE project has demonstrated near real-time cross-border flexibility exchange between Slovenia and Italy. The results of the project GIFT are directly related to EO 4.3.5 - appropriate forecasts (load, generation, transits). The project is developing a solution that will provide (1) real-time estimation of load of MV /LV substations and LV outgoing lines, (2) real-time estimation of voltage at each meter, (3) prediction of voltage and current loads for the next ten minutes, based on actual grid data. Only one project was identified whose results can be associated with OE 4.3.6 - Multinational interconnection design to support offshore wind Optimal Flexibility Management including Demand Response. The project OSMOSE supports the development of Enhanced Line Dynamic - Thermal Rating, the implementation of Automatic Voltage Control in wind farms (and BESS) and flexibility of large consumers. Although the survey did not find solutions that can mitigate lack of inertia in grids (EO 4.3.3), such projects could be found under HLUC 6.

	Further results are expected from projects that are not covered by this survey: edgeFLEX and DiGriFlex.
PPC 4.4: Planning for a resilient system with massive penetration of RES	
EO 4.4.1: Adequate modelling and simulation capabilities. **EO 4.4.2:** Planning and Operating methods that aim at increased RES participation with increased resilience; Improved modelling and simulation	There are numerous results that can be associated with EO 4.4.1 and EO 4.4.2. The NESOI project proposes an overarching coordination and support action framework aimed at facilitating the transition to clean energy on EU islands. FARCROSS is developing the EUROPAN platform for improved planning, operations, and resource utilization in a TSO. The SYNERGY project provides a set of planning and operation tools for infrastructure sizing and grid planning that simulates grid operations and assesses grid conditions in terms of reliability, performance and power quality metrics. The BD4OPEM project focuses on a modelling tool for asset and investment planning to select technologies that contribute to grid reinforcement at a given point in time. Two solutions are currently being developed as part of the EUniversal project. First, the tool for resilience-informed planning of distribution networks. Second, the MV network maintenance planning tool. The RE-EMPOERERD project is developing the ecoPlanning tool to perform simulations for medium-term planning and expansion of Non-Interconnected Islands (NIIs power systems). The ANM4L project is developing an active network management (ANM) tool that allows the adjustment of safety margins and the use of the full grid capacity in terms of voltage and current limits, limitations in terms of fixed or dynamic ratings, by relying on real-time control. The RESili8 project is developing a set of tools to calculate resilient deployment strategies of software and equipment. By incorporating actual network data, it will be possible to rule out unlikely scenarios in order to improve performance and avoid overprovisioning of resources. Further results are expected from the edgeFLEX project that is not covered by this survey.

Table 8. Coverage of expected outcomes of HLUC 4 by projects' results

HLUC 5: One-Stop Shop and Digital Technologies for Market Participation of Consumers (Citizens) at the Center

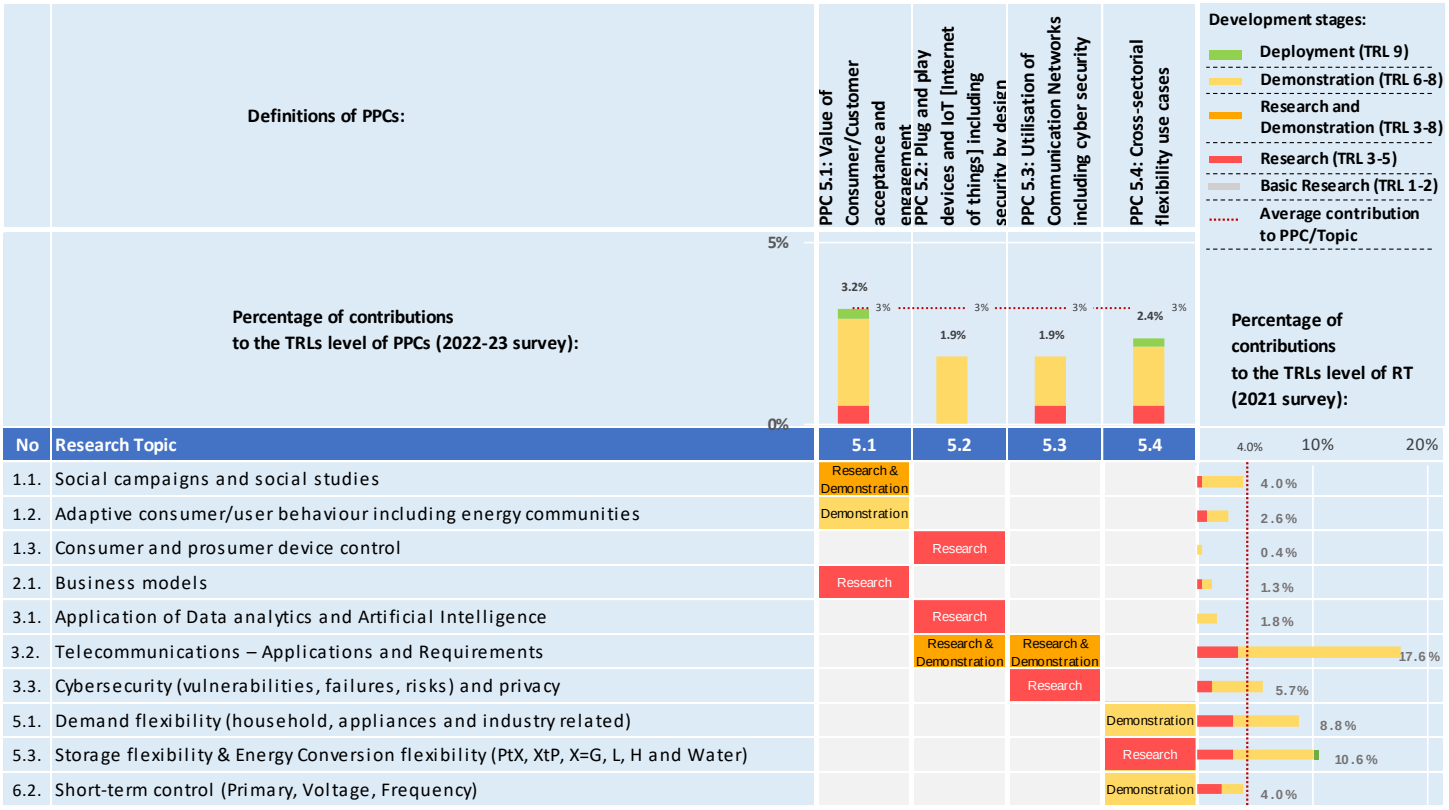


Figure 18. Percentage of contributions to HLUC 5

HLUC 5 One-Stop Shop and Digital Technologies for Market Participation of Consumers (Citizens) at the Center focuses on empowering consumers and citizens to drive the adoption of new energy technologies and services to meet decarbonization goals. The adoption of heat pumps, electric vehicles, decarbonized heat grids, etc. is influencing infrastructure design and the overall pace of electrification. IT Solutions are key to transparency and unification of markets. Integration between the energy system and the data economy will depend heavily on the development and adoption of standard interfaces, communications, and even better cybersecurity solutions.

PPC 5.1: Value of Consumer/Customer acceptance and engagement

PPC 5.1 is based on social campaigns and studies, adaptive consumers behavior and business models as research topics. This is the most frequently selected PPC within this HLUC. Respondents to the last survey were equally likely to indicate that their projects contribute to both research and demonstration, which currently matches the development phase of the relevant research topic.

There are a number of results from ongoing projects that can be used as guidelines for prosumer participation in electricity markets.

Although attention to this PPC is rising, it needs to increase further because consumer support and engagement are key to the success of the energy transition. There is also a need to ensure that relevant guidelines and tools are developed to enable market implementation (EO 5.1.2) and the setting of tariffs and prices (EO 5.1.3 and EO 5.1.4). As can be seen in Table 9, the survey did not identify KERs that can explicitly address these outcomes and thus these EOs are marked red. To date, it seems that most of the results are related to guidance for prosumer participation (EO 5.1.1) and based on lessons learned in projects when they developed technical solutions.

PPC 5.2: Plug and play devices and IoT [Internet of things] including security by design

PPC 5.2 is based on Consumer and prosumer device control, Applications for Data Analytics and Artificial Intelligence and Telecommunications research topics. The former two topics are currently in the research phase and do not appear to be sufficiently covered, while telecommunications are a mix of research and development and is sufficiently covered according to the previous survey. The PPC was selected relatively frequently, with a significant proportion of contributions falling into the demonstration phase.

Several results contribute to this PPC and bring these solutions close to market, in part because the smart home / IoT industry is making advances in ICT somewhat independent of energy system needs. However, the match between advances in commercial ICT products and the needs of the energy system is an aspect that needs further attention in the project. Table 9 shows that special attention should be paid to making it easier for customers to access markets (EO 5.2.3) and switch energy suppliers (EO 5.2.4). Partially, this can be enabled by efficient data and information management that connects customers to SO (EO 5.2.9).

PPC 5.3: Utilisation of communication networks including cyber security

PPC 5.3 builds on Telecommunications and Cybersecurity research topic. Previous survey data indicate that these topics receive a higher than average contribution to the demonstration phase which also largely corresponds to results of this survey showing close to average number of contributions to PPC.

However, the surveyed projects did not provide explicit results related

to communication networks and cybersecurity that can be reconciled with the expected outcomes of this PPC. So far, all three expected outcomes are marked red (see Table 9), indicating need for further work in advanced intrusion detection (EO 5.3.1), advanced tools for proactive and anticipatory security strategy (EO 5.3.2) and mechanisms of exploitation of common infrastructures, e.g., 5G networks (EO 5.3.3). From perspective of energy system resilience, the communications networks as part of this PPC may already be in or near the deployment phase, while the aspect of cybersecurity still requires much attention in the areas of research, demonstration, and deployment.

PPC 5.4: Cross-sectorial flexibility use cases

PPC 5.4 is based on the research topic of demand and storage flexibility and short-term control system. This PPC seems to receive close to average contributions with about 50% contributions to both the research and demonstration phases.

The current projects appear to be focused on practical cases of integration but achieving the outcomes of this PPC will also require development of a consolidated ICT vision (EO 5.4.1) and an integrated framework for developing interoperable systems (EO 5.4.2). As can be seen in Table 9, the present survey did not identify any KER in this context. Since the consumer level is particularly important for flexibilities in the transportation and heating/cooling sectors applied to the power system, further demonstration projects will remain important.

Expected outcomes	KER of the surveyed projects
PPC 5.1: Value of consumer/customer acceptance and engagement	
EO 5.1.1: Guidelines for the participation of prosumers and energy communities in electricity markets **EO 5.1.2:** Guidelines for the implementation of incentives by dynamic prices, regulated tariffs and other market incentives. **EO 5.1.3:** Software tools to automatically calculate flexibility of different assets and trigger demand response campaigns **EO 5.1.4:** Remuneration software tools, based on energy retail and market prices	The results of the various projects can be linked to EO 5.1.1 - Guidelines for the participation of prosumers and energy communities in electricity markets. The BeFlexible project defines new business models for market participants considering services, revenue streams and the valorization of flexibility. The results of the NESOI project go somewhat beyond this expected outcome and include a municipal and national level. The project provides a framework for coordinating and supporting actions (CSA) aimed at facilitating the transition to clean energy in EU islands. The LocalRES project, develops a VPP technology and proposes a methodology for co-design and participatory processes that involves citizens in co-design of solutions (e.g., digital platforms) to maximize their engagement. The TOP-UP project investigates psychological motivations and preferences of end-users when modeling energy systems. The EPC4SES project is developing a collaborative model between building owners and market partners to increase the share of renewable energy in the grid through the application of demand response. The OneNet project aims to create a replicable market architecture that can be deployed in electric systems across the EU. The project defines business cases for all demonstration projects and evaluates against Green Deal priorities and project strategic objectives. The SENDER project is developing a set of solutions for an integrated smart home system that provides the opportunity to build new, inclusive business models. The iFLEX project is developing an intelligent personal assistant (iFLEX Assistant) that helps consumers to manage their flexible assets and participate in demand response. The project applies a user-centered approach to design flexibility management service, paying special attention to the user experience and motivating factors and barriers. One of the results of the SONDER project is a guide for community storage that provides an overview of how to choose the right storage, how to install it, and how to operate it. The GENTE project is developing a toolbox for communities and community managers to optimize resources and community federation. No exploitable results were found that explicitly address guidelines, tools, or software for renumeration, dynamic pricing, rate setting, etc. (EO 5.1.2-5.1.4). Further results are expected from projects that are not covered by this survey: CREATORS, eNeuron, HESTIA, ReDREAM, RenErgetic, DATA CELLAR MERLON, MUSE GRIDS, RENAISSANCE, CLUE, I -Greta, BRIGHT, COMPILE, REACT, SMART-MLA and E-LAND.
PPC 5.2: Plug and play devices and IoT (Internet of things) including security by design	
EO 5.2.1: Real plug & play situation for customer assets and data exchange **EO 5.2.2:** Provision of access to the consumer to energy data and advanced services **EO 5.2.3:** Facilitation of customers can easily join and change service providers **EO 5.2.4:** Applications devices for putting the end user in direct contact with supplier, distributor and other involved market stakeholders.	The results of several projects can be related to EO 5.2.1 and 5.2.2 (plug-and-play and data exchange, and Provision of access to the consumer to energy data and advanced services). IONAS is developing an integrated VPP solution for load profile optimisation, congestion and flexibility management based on forecasts. The iFLEX project is developing an intelligent personal assistant (iFLEX Assistant) to help consumers manage flexible assets and participate in demand response. The project applies a user-cantered approach to design flexibility management service, paying particular attention to the user experience, motivation, and barriers. The RE-EMPOWERED project provides consumers with real-time information on energy consumption and prices

EO 5.2.5: Availability of software to provide services to increase consumer satisfaction based on IoT. **EO 5.2.6:** Development of robust and low-cost application of digital technology for peer-to-peer interactions (blockchain) **EO 5.2.7:** Implementation of software tools for enhanced cooperative energy services increasing community's resilience and self-sufficiency. **EO 5.2.8:** Design of ICT architectures for mass data communication and processing (Blockchain, Exchange Platforms) **EO 5.2.9:** Design of efficient data and information management mechanisms for platforms integration in the energy system, from consumer related platforms to system operation platforms	(ecoCommunity solution). It coordinates residential and community load use based on generation forecasts and bills based on consumption. The EcoDR tool for consumers and utilities measures energy consumption in real time and allows utilities to simultaneously control/limit electricity consumption via energy and load limiters. The BeFlexible project develops various solutions for individual and collective energy optimisation. It also increases the efficiency of energy communities through resource sizing, flexibility potential estimation, billing and invoicing, and smart pairing between consumers and generators. SENDER is developing a smart home solution that includes DR /flexibility, electric vehicle charging, building as battery (thermal storage, hot water boiler optimisation, smart home appliances). FinSESCo is developing an energy contracting platform and XML parser for data from energy performance contracting. The results of the Interconnect project can be linked to EO 5.2.6 - 5.2.9. The solutions developed within Interconnect enable the digitization of homes, buildings and power grids based on an Internet of Things (IoT) architecture. By incorporating digital technologies (artificial intelligence, blockchain, cloud and Big data) based on open standards such as SAREF, interoperability between devices and systems as well as privacy and security of user data is ensured. The solution is composed of several parts: DSO interface, Semantic Interoperability Framework (SIF), Ontology, Service Store, Knowledge Engine, Generic Adapter, Peer-to-peer marketplace. The LocalRES and BeFlexible projects contribute to EO 5.2.7-2.2.9 with solutions for collective energy optimisation. The LocalRES MEVPP product is capable of providing collective self-consumption, local energy market services such as voltage control and congestion management, and energy market services such as ancillary services. The MEVPP also includes model predictive control (MPC algorithm) to manage flexible assets. BeFlexible's solutions also improve the efficiency of energy communities through resource sizing, flexibility potential estimation, billing and invoicing, and smart coupling between consumers and producer. Further results are expected from projects that are not covered by this survey: BRIGHT, BD4NRG, eNeuron, HESTIA, PLATONE, ReDREAM, RenErgetic, VPP4ISLANDS, DATA CELLAR, MERLON, MUSE GRIDS, RENAISSANCE, CLUE, I -Greta, R2EC and SMART-MLA.
PPC 5.3: Utilisation of communication networks including cyber security	
EO 5.3.1: Advanced intrusion detection and prevention systems for energy infrastructures using security-related Big data and deep learning methods. **EO 5.3.2:** Advanced technologies and tools for the implementation of a proactive and anticipatory security strategy supporting threat hunting in integrated and federated Security Operation Centres (SOCs). New technologies for future SOCs are related to security monitoring, threat detection and response. **EO 5.3.3:** Mechanisms of exploitation of common infrastructures such as 5G networks.	The surveyed projects did not provide explicit results related to communication networks and cybersecurity that can be reconciled with the expected outcomes of this PPC. From an energy crisis perspective, the communications networks as part of this PPC may already be in or near the deployment phase, while the aspect of cybersecurity still requires much attention in the areas of research, demonstration, and deployment. Further results are expected from projects that are not covered by this survey: EnergyShield, ELECTRON, SDN-microSENSE, eNeuron, HESTIA, ReDREAM, RenErgetic, DATA CELLAR, COMPILE, MERLON, MUSE GRIDS, REACT, RENAISSANCE, CLUE and I -Greta.
PPC 5.4: Cross-sectorial flexibility use cases	
EO 5.4.1: Consolidated ICT vision and strategy for common data acquisition processes for TSO-TSO, TSO-DSO, TSO-BSP (Balancing Service Provider) and TSO-SGU (Significant Grid User) data exchange corresponding to the expected targets for future market design, system development and operation. **EO 5.4.2:** An integrated framework of interoperable systems, fed by multiple data sources from different sectors and with automatised learning and updating processes, implemented in day-by-day TSO processes able to represent near real-time power system status and maintenance and working conditions of the grid assets. **EO 5.4.3:** Methods and algorithms for secure and comprehensive data collection across all energy sectors and for providing a more transparent and timely data access for	The EO 5.4.2 can be met with the results of the SONDER project. It is developing the Technical Framework for Local Energy Communities (TF-LEC), which is a structured set of informative and normative specifications. The TF-LEC is intended to enable the normalized use and application of existing standards and practices. It intends to enable interoperability between cooperative but independently developed products and systems. The results of the PARITY and OMEGA -X projects can be linked to the expected outcome EO 5.4.3 and EO 5.4.4. PARITY aims to achieve two results. First, a product/service that enables automatic collection and storage of data from buildings/devices and integrates device communication protocols and control software. Second, to achieve secure collection, processing, and storage of data by integrating an IoT gateway with cloud solution. OMEGA -X is developing an Energy Data Space where actors can share data in a trusted, secure and sovereign manner, enabling the deployment of advanced digital services.

decision making to all market participants (by exploiting new technologies such as IoT, Big data and AI). • **EO 5.4.4:** Design of efficient data and information management mechanisms for platforms integration in the energy system, from consumer related platforms to system operation platforms	The results of the BeFlexible project can be related to EO 5.4.4. The cross-sector service solution enables the improvement of flexibility through integration with smart building management systems, EV mobility, and the use of energy data for the provision of health services. Further results are expected from projects that are not covered by this survey: CREATORS, EVCHIP, BRIGHT, PLATONE, VPP4ISLANDS and INTERRFACE.

Table 9. Coverage of expected outcomes of HLUC 5 by projects' results

HLUC 6: Secure Operation of Widespread Use of Power Electronics at All Systems Levels

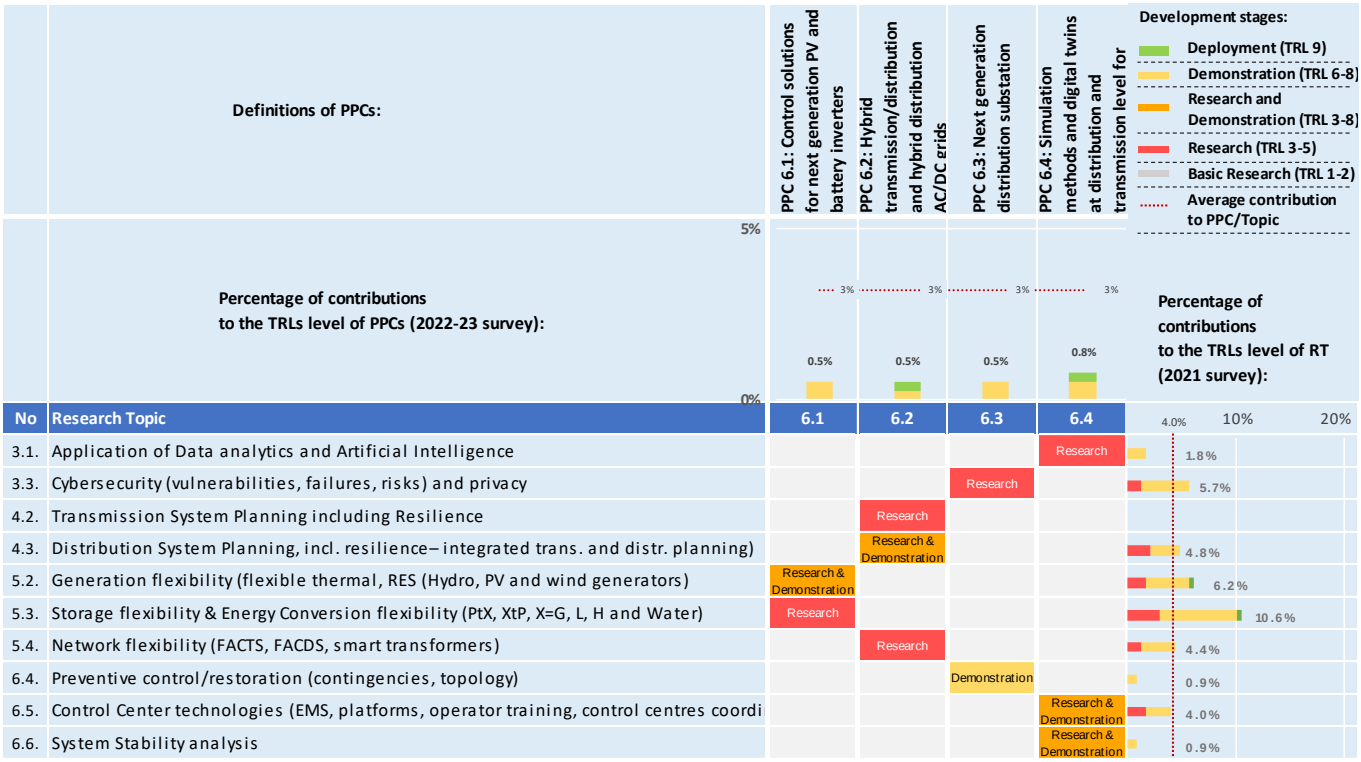


Figure 19. Percentage of contributions to HLUC 6

HLUC 6 Secure operation of widespread use of power electronics at all systems levels addresses the challenges associated with the evolution of power electronics given the need for greater flexibility, growing importance of distribution grids, and the transition to HVDC and MVDC grids. Grid-forming converters are still largely at the research level, and a flexible transition between different modes of operation is to be further explored. This transition includes how substations can be upgraded with power electronics and how to manage the penetration of smart power distribution devices such as FACTS and solid-state transformers.

Figure 17 shows that HLUC 6 (and associated PPCs) development is currently driven by a smaller number of projects, as contributions to these areas were rarely indicated by respondents. This can be explained by the niche development of power electronics and its applications. To date, the power electronics industry has been dominated by companies that often conduct R&I activities internally and market new solutions through established channels. However, the involvement of academia is also key to the successful introduction of technologies, as research-driven projects are less focused on short-term returns and can develop solutions for markets that do not yet exist. This is especially true for future energy grids, which are still largely conventional but will need to be rapidly transformed in the coming years.

PPC 6.1: Control solutions for next-generation PV and battery inverters

PPC 6.1 is based on the research topic of generation and storage flexibility, which currently includes technologies in research and demonstration phases. The previous survey showed that these topics were frequently addressed and generally receive demonstration phase contributions. There is also a correlation with PPC development receiving input in the same phase. However, this PPC (and the HLUC 6 in general) does not appear to have been addressed by the projects surveyed recently - only 4 projects reported input on this PPC, which may indicate insufficient coverage of the concept.

As mentioned above, a large number of contributions should not be expected in this niche application topic. The quality of results is key to demonstrate development of this PPC. Two out of three expected outcomes of PPC 6.1 are partially met by the results of the surveyed projects (see Table 10). Given the importance of power electronics in future energy networks this PPC requires further research and demonstration work. Especially, additional results need to be found or obtained to ensure development of new modelling methods to represent the new dynamics (EO 6.1.2) and exploit the flexibility and controllability of these components (EO 6.1.3).

PPC 6.2: Hybrid transmission/distribution and hybrid distribution AC/DC grids

PPC 6.2 builds on Transmission and Distribution system planning and Network flexibility, which are currently in transition between research and development phases. This corresponds to findings from the previous survey. This PPC seems to be little covered by surveyed projects, as only 3 respondents indicated contributions.

This PPC takes a holistic view of future grid concepts that will enable better adoption of RES and efficient energy transfers. Although some relevant technologies are currently being explored in PPCs 6.1 and 6.3, no exploitable results have been submitted that could be directly linked to the expected outcomes of this PPC 6.2 (see Table 10). Some results can be expected from the READY4DC project. Additional evidence is required to ensure development of hybrid AD/DC (EO 6.2.1) and energy router concepts (EO 6.2.2).

PPC 6.3: Next generation distribution substation

PPC 6.3 encompasses Cybersecurity and privacy, and preventive control/restoration. Cybersecurity research shows a fair number of contributions to be considered as of demonstration phase. According to this survey data, there are also not enough contributions to this PPC - only respondents from EUniversal and Tigon selected it.

While the next-generation substations appear to be a commercial issue, non-commercial demonstration projects are needed to prove

their capabilities. This survey has identified only one exploitable result that can be linked to the expected outcome of this PPC (see Table 10). This suggests that additional projects will need to be found or initiated, including smart transformers for connection between MV and LV AC networks enabling AC and DC microgrids (EO 6.3.1) and methods to facilitate distribution grid to work in islanding (EO 6.3.2).

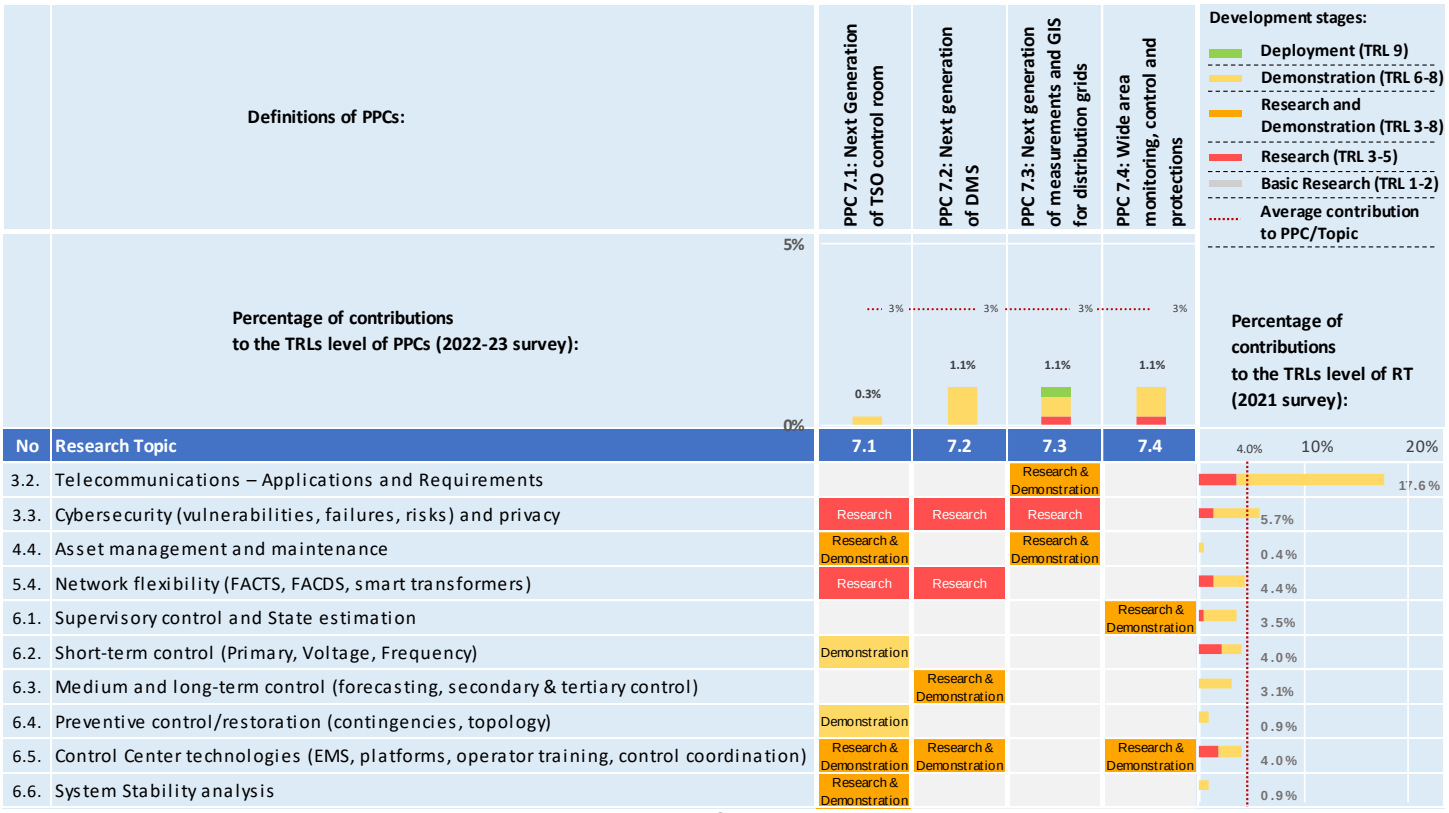
PPC 6.4: Simulation methods and digital twins at distribution and transmission level for power electronics driven networks

PPC 6.4 builds on Application Data Analytics and AI, Control center technologies and System stability research topics. According to the previous survey, these research topics are not sufficiently covered to conclude that they achieve significant development progress. Additionally, exploitable result from one project has been associated with EO 6.4.2 (marked as orange, another two indicated red, see Table 10). The project DEVISE is developing a simulation model for a cross-vector energy system for efficient conversion of different forms of energy to ensure efficient and rational use of all forms of renewables. To ensure the development of PPC 6.4, more project results are needed that can be directly linked to expected outcomes. These results should be related to IT systems in power electronics (EO 6.4.3) and to simulation of behaviour of power electronics at all levels (EO 6.4.1).

Expected outcomes	KER of the surveyed projects
PPC 6.1: Control solutions for next generation PV and battery inverters	
EO 6.1.1: New control methods to exploit power electronics-based generation to play a central role in the network system **EO 6.1.2:** New modelling methods to better represent the new dynamics while the separation between electromechanical and electromagnetics eigenvalue will not be as clear as today **EO 6.1.3:** New methods and techniques to exploit the flexibility and controllability of these components and a new fundamental approach to define how these devices are part of the system level control	Exploitable results from the OSMOSE, DEVISE, TIGON and RE-EMPOWERED projects can be associated with EO 6.1.1 - New control methods for using power electronics-based generation. The OSMOSE project is developing a current limiting method based on threshold virtual impedance (TVI) that maintains voltage source behaviour in the context of grid forming capability (GFM). The DEVISE project stated that a battery bank charge/discharge controller is currently being developed. TIGON is developing the WAMPAC system: a monitoring and protection system whose main purpose is to control the stability and safe operation of the entire system. The RE-EMPOWERED project explores the development of a multi-source microgrid with multiple power electronic modular plug-and-play converters and their control, extracting maximum power from PV panels under partial shading conditions. EO 6.1.2 can be partially met with the results from the OSMOSE project. It develops a quantitative assessment of the use of a grid-forming BESS for frequency regulation based on local grid measurements.
PPC 6.2: Hybrid transmission/distribution and hybrid distribution AC/DC grids	
EO 6.2.1: Deployed holistic architectures which include hybrid AC/DC systems, smart transformers, energy routers and web of cells **EO 6.2.2:** Energy router: Developing innovative and intelligent solutions to enable energy transfer (routing) between various AC and DC networks, also considering energy storage means, in order to increase flexibility, renewable sources (RES) integration and resilience of energy communities.	This PPC takes a holistic view of future grid concepts that will enable better adoption of RES and efficient energy transfer. Although some technologies that constitute this concept are currently being explored in other PPCs of this HLUC, no exploitable results have been submitted that could be directly linked to the expected outcomes of PPC 6.2. Further results are expected from the HYPERRIDE project that is not covered by this survey.
PPC 6.3: Next generation distribution substation	
EO 6.3.1: Smart transformers providing flexible connection between MV and LV AC networks and enabling AC and DC microgrids at LV level. **EO 6.3.2:** Methods to facilitate portion of the distribution grid to work in islanding mode coordinated at substation level (AM).	In part, the results of the EUniversal project can be linked to EO 6.3.1. The project is developing a new intelligent MV / LV substation (Flexible Substation) that will enable advanced monitoring and control of low voltage grids, including photovoltaic (PV), energy storage and charging infrastructure for electric vehicles. Such a solution will lead to the creation of tools for the provision of flexibility services, improve the observability of the grid and avoid unnecessary investments in the LV network. Further results are expected from the HYPERRIDE project that is not covered by this survey.
PPC 6.4: Simulation methods and digital twins at distribution and transmission level for power electronics driven networks	
Simulation analysis with new technologies; real-time analysis of new technologies with extensive power electronics; use of HIL (HW in the loop) simulation to validate new technologies; simulation at local level, national level, cross-border level and pan-European effects; preparation for risk-controlled field demonstrations Simulation of DER-provided flexibility for Distribution, under various scenarios, considering Total Expenditure (TOTEX) approach Exploring the role and impact of existing and emerging ICT for grid observability and controllability; using co-simulation techniques able to simulate ICT impact in power systems to ensure a reliable digitisation of pan European system	To ensure the development of PPC 6.4, more project results are needed that can be directly linked to expected outcomes. Additional projects are needed related to IT systems in power electronics (EO 6.4.3) and on simulating the behaviour of power electronics at all levels (EO 6.4.1). To date, exploitable result from one project has been associated with EO 6.4.2. The project DEVISE is developing a simulation model for a cross-vector energy system for efficient conversion of different forms of energy to ensure efficient and rational use of all forms of renewables.

Table 10. Coverage of expected outcomes of HLUC 6 by projects' results

HLUC 7: Enhance System Supervision and Control including Cyber Security



No	Research Topic	7.1	7.2	7.3	7.4
3.2.	Telecommunications – Applications and Requirements			Research & Demonstration	
3.3.	Cybersecurity (vulnerabilities, failures, risks) and privacy	Research	Research	Research	
4.4.	Asset management and maintenance	Research & Demonstration		Research & Demonstration	
5.4.	Network flexibility (FACTS, FACDS, smart transformers)	Research	Research		
6.1.	Supervisory control and State estimation				Research & Demonstration
6.2.	Short-term control (Primary, Voltage, Frequency)	Demonstration			
6.3.	Medium and long-term control (forecasting, secondary & tertiary control)		Research & Demonstration		
6.4.	Preventive control/restoration (contingencies, topology)	Demonstration			
6.5.	Control Center technologies (EMS, platforms, operator training, control coordination)	Research & Demonstration	Research & Demonstration		Research & Demonstration
6.6.	System Stability analysis	Research & Demonstration			

Figure 20. Percentage of contributions to HLUC 7

HLUC 7 Enhance System Supervision and Control including Cyber Security addresses the challenges associated with the increasing importance of grid supervision and control. Grid expansion and the introduction of a greater number of RES will require the digitization and reinforcement of power grids. Higher density and number of interconnections in the grids will require harmonized security, planning and operation standards.

DSO and TSO control rooms will also need to be rethought due to the changing architecture of networks. Higher levels of intelligence and the technologies of GIS play a key role in this transformation. This requires a better human-machine interface and training to prepare employees to operate under the changed conditions.

PPC 7.1: Next generation of TSO control

PPC 7.1 builds on seven research topics which are largely in the demonstration phase of development. The topics of Network flexibility and cybersecurity are at research phase and received the expected coverage with a high number of contributions to the demonstration phase, according to the previous survey. Despite the progress on the research topics, the PPC is not receiving an impactful number of contributions and is limited to the TIGON and HONOR projects.

With the major transformation of energy networks, TSO control rooms need to undergo modifications as the energy transition and sector coupling move forward rapidly. Although this survey has not found exploitable results that can be directly linked to expected outcomes (see Table 11), progress should be driven by industry and require limited participation from academia. Nonetheless, the solutions created for projects related to HLUC 2 for the collaboration between TSO/DSO (such as Coordinet, OneNET, etc.) can also fulfil the requirements of this PPC. Additionally, projects like FARCROSS and OSMOSE, and the products associated with HLUC 7, are candidate solutions for the TSO's future control room.

PPC 7.2: Next generation of DMS

PPC 7.2 builds on four research topics that appear to be moving toward (or are already in) the demonstration phase. The development of the PPC is also consistent with the development of research topics, but this PPC was not selected by enough projects.

Only one exploitable result associated with sensing technologies (EO 7.2.1) is related to expected outcomes of PPC 7.2 (see Table 11). However, there are many projects that are currently dealing with renewable energy integration and flexibility services. Thus, some additional relevant results are being obtained under HLUCs 4, 5, and 9 where respondents overall found better alignment with their objectives. Similar to the issue for TSOs in PPC 7.1, with the strong evolution which DSO control rooms and DMS need to undergo as the energy transition and sector coupling progress rapidly, more attention to this PPC will still be required, especially considering tools to study of distribution grids with very low (no) inertia (EO 7.2.2) and enhanced MV and LV supervision (EO 7.2.3).

PPC 7.3: Next generation of measurements and GIS for distribution grids

PPC 7.3 depends on the development of telecommunications, cybersecurity, and asset management technologies. The previous survey showed that the first two research topics are moving toward the demonstration phase, while asset management and maintenance are barely within the scope of the projects surveyed.

Almost all of the expected outcomes of PPC 7.3 are partially met based on the data submitted under HLUC 7 (see Table 11). Because distribution grid technologies are also mentioned under HLUCs 4, 5, and 9, it is very likely that some projects selected these HLUCs and did not explicitly report results under HLUC 7. Given the extensive research in this area, it is reasonable to assume that PPC 7.3 will undergo significant further development once the current projects are completed. However, no results were identified that show

development of Big data analysis for real-time system operation (EO 7.3.3).

PPC 7.4: Wide area monitoring, control and protections

PPC 7.4 builds on supervisory control and control centre research topics that are currently a combination of research and demonstration phases. Although there has been progress toward the demonstration phase in these research topics, the PPC as it stands does not show a significant number of contributions or a predominance of demonstration phase projects.

Monitoring, control and protections need to evolve greatly with the continued increase in asynchronous generation and decrease in inertia. The results of 2 projects support the outcome of scalable hierarchical observability methods and systems (EO 7.4.1) and regional WAMS applications for TSOs (EO 7.4.2) which can be indicated orange (see Table 11). The results that support development of on-line dynamic security assessment (voltage, frequency, angle) of interconnected power systems (EO 7.4.3) are yet to be found. Some progress in development of this PPC might also be expected from industry-internal projects.

Expected outcomes	KER of the surveyed projects
PPC 7.1: Next generation of TSO control room	
EO 7.1.1: Innovative sensors for the monitoring of power systems with the aim of an increased observability at all voltage levels. **EO 7.1.2:** Validated prototypes of ICT-platform for real-time communication and data exchange among European TSO's. **EO 7.1.3:** Validated tools for real-time estimation of intrinsic power system parameters (damping, system inertia, short circuit power in critical nodes…). **EO 7.1.4:** Demonstrated techniques for early identification of critical situations and for the real time stabilisation of interarea oscillations in low inertia systems. **EO 7.1.5:** Integration of distribution grids and dispersed generation data into the set of TSOs observable systems. **EO 7.1.6:** Full observability of the European transmission grid based on phasor measurement linear/hybrid state estimation. **EO 7.1.7:** Consolidated operational ICT-platforms for real-time communication and data exchange among European TSO's	With the major transformation of energy networks, TSO control rooms need to undergo modifications as the energy transition and sector coupling move forward rapidly. Although this survey has not found exploitable results that can be directly linked to expected outcomes, progress should be driven by industry and require limited participation from academia. No responses were found regarding the PPC in question. Nonetheless, the solutions created for projects related to HLUC 2 for the collaboration between TSO/DSO (such as Coordinet, OneNET, etc.) are capable of fulfilling the requirements of this PPC automatically. Additionally, projects like FARCROSS and OSMOSE, and the products associated with HLUC 7, are candidate solutions for the TSO's future control room. Further results are expected from the TRINITY project that is not covered by this survey.
PPC 7.2: Next generation of DMS (Distribution Management Systems)	
EO 7.2.1: Sensing technologies, automation and control methods integrated into monitoring, analysis and control architectures. **EO 7.2.2:** Validated tools and software for the study of distribution grids with very low (no) inertia. **EO 7.2.3:** Enhanced MV and LV supervision for distribution grids	Explicitly, only the results of the Resili8 project, mentioned under HLUC 7, can be associated with EO 7.2.1 - sensing technologies. The project is investigating improved mechanisms for identifying and locating faulty or compromised sensor measurements. Furthermore, as previously mentioned, the products included in HLUC 2 have the potential to serve as a solution for the next generation of DMS. Moreover, the solutions for flexibility management that were included in HLUC 5 could also be integrated into the aforementioned DMS related expected outcomes.
PPC 7.3: Next generation of measurements and GIS (Geographic Information System) for distribution grids	
EO 7.3.1: Scalable hierarchical observability methods and systems enabling the utilisation of monitoring data at different geographical scale in a coordinated manner. **EO 7.3.2:** Innovative data processing architectures and methods that enable advanced solutions for the increasing complexity of system development and operations. **EO 7.3.3:** Big data analysis functions of real-time data streaming for system operation. **EO 7.3.4:** ICT architectures for mass data communication and processing (Blockchain, Exchange Platforms) **EO 7.3.5:** Use Smart meters for accessing its data directly by multiple actors, while preserving GDPR and contractual clauses **EO 7.3.6:** Test results and proof of concept of AI technologies applied to estimation of indicators and completion of information necessary to operate the system (control systems and interfaces for market participant applications, demand pattern recognition).	EO 7.3.1 - Scalable hierarchical observability methods are met with results from the PARITY project. It develops a DSO toolset for monitoring, detecting, and resolving congestion and providing appropriate forecasts of network condition. Results of 2 projects are associated with EO 7.3.2 - Innovative data processing architectures and methods. The HONOR project is developing a novel data processing pipeline for automated real-time identification of fast-ramped flexibility activation, enabling DSOs to verify requests. The AISOP project also mentions the development of an innovative data processing architecture but does not specify the solution. Results of the IANOS project contribute to EO 7.3.4 - ICT architectures for mass data communication and processing. Currently, the project is developing a set of services and solutions to improve the efficiency of the iVPP platform. The projects with similar goals can be found under HLUC 1, 4, and 5 and thus also contribute to the fulfilment of this EO. EO 7.3.5 (deployment of smart meters) can be supported by the results of two projects – OMEGA -X and AISOP. The former project is based on the principles of the Energy Data Space, which enables energy stakeholders to share data in a trusted, secure, and sovereign manner.

	The TwinERGY result is related to EO 7.3.6 (Test results and proof of concept of AI technologies). The project is developing advanced training simulators for DSOs and TSOs that use digital twins to adapt to new network energy management platforms. Further results are expected from the BD4NRG project that is not covered by this survey.
PPC 7.4: Wide area monitoring, control and protections	
EO 7.4.1: Scalable hierarchical observability methods and systems enabling the utilisation of monitoring data at different geographical scale in a coordinated manner. **EO 7.4.2:** Regional WAMS applications operational in TSO's control rooms **EO 7.4.3:** On-line dynamic security assessment (voltage, frequency, angle) of interconnected power systems based on active distribution networks, inverter-based generation and loads acting as grid sensors and as integrated part of new network protection schemes	The results of 2 projects relate to EO 7.4.1 - Scalable hierarchical observability methods and systems. The BD4OPEM project is developing two services in this context. First, observability service is a method to determine actual observability in LV network based on smart metering data. Second, topology service - retrieval of LV network topology for estimating network parameters when realistic data is not available. The TIGON project is developing the WAMPAC system to control the stability and safe operation of the whole system based on measurements at different points of the microgrid.

Table 11. Coverage of expected outcomes of HLUC 7 by projects' results

HLUC 8: Transportation Integration & Storage

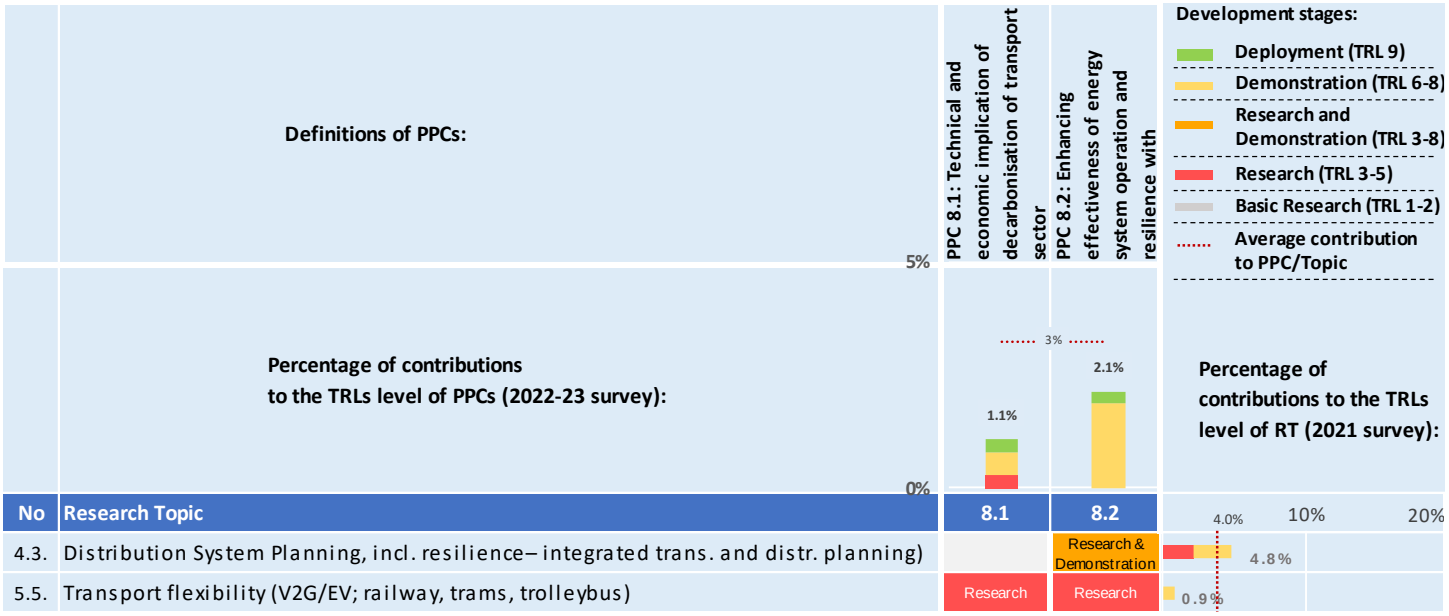


Figure 21. Percentage of contributions to HLUC 8

HLUC 8 Transportation Integration and Storage addressed the transportation sector shift to electrification and other carbon-neutral fuels (hydrogen, ammonia, biofuels). Assessing the role and value of alternative approaches to decarbonizing the transportation sector, implications for future energy system operations and design, as well as benefits of a cost-effective transition to a zero-carbon energy future are in the scope of this HLUC. It also considered conditions that ensure effective deployment of publicly available and private electric vehicle charging stations and the efficient integration of vehicle charging into the system.

PPC 8.1: Technical and economic implication of decarbonisation of transport sector

PPC 8.1. builds on the Transport flexibility research topic which is currently in the research phase of development. This finding is also consistent with recent observations showing that PPC development is driven primarily by contributions to the research phase, in line with the still uncertain future balance of transport decarbonization options incl. e.g., public transport.

From the collected exploitable results, it can be concluded that most of the surveyed projects focus on the integration and optimisation of EV infrastructure into electricity networks and markets (see Table 12). However, given the nature of technical and economic implications of transport sector decarbonization, it is suggested some results in this category can also be obtained under HLUC 1 and HLUC 5. Further, some additional attention can be given to the development of decarbonization strategies for the transport sector (based on electricity and hydrogen), especially when it comes to aviation and river and marine transport (EO 8.1.2).

PPC 8.2: Enhancing effectiveness of energy system operation and resilience with electromobility

PPC 8.2 builds on Distribution system planning, incl. resilience and Transportation flexibility research topics. The previous survey showed insufficient evidence that these research topics are covered to be considered demonstration phase. According to the recent survey, this PPC was mentioned often by respondents and showed better coverage.

This survey has identified 3 projects' results that aim to develop applications partially addressing concepts of V2X (Grid, Home and/or Business) and energy storage technologies (EO 8.2.1, see Table 12).

Given the importance and prevalence of electromobility in the near future (e.g., the 2035 end date for fossil fuel car sales in the EU), despite current progress, PPC 8.2 may require additional projects to advance its development, especially focusing on aspects of security and resilience of energy system.

Expected outcomes	KER of the surveyed projects
PPC 8.1: Technical and economic implication of decarbonisation of transport sector	
EO 8.1.1: Quantify the value of interoperability between energy and transport sectors and develop corresponding strategies for cost-effective decarbonisation of both energy and transport sectors **EO 8.1.2:** Development of alternative decarbonisation strategies for transport sectors (electricity and hydrogen based) – (a) micromobility, public, fleet and private vehicles, (b) long on the ground transport (c) riverboats, sea-boats, (d) aviation **EO 8.1.3:** Deployment strategies for rapid-charging infrastructure considering the impact on the energy system, including application of energy storage and hydrogen-based resources for electricity production. **EO 8.1.4:** Development of full interoperability between energy and transport sectors through establishment of common standards, protocols and digital services.	EO 8.1.3 is supported by the results of the FlexiGrid, OMEGA -X, SERENE and Mulitportgrid projects. The Flexigrid project has two results. First, it evaluates the benefits of smart controls of different charging infrastructures in providing system services. Second, it proposes a change in the regulatory framework to improve the interaction between TSOs and DSOs in supporting the cost-effective integration of the transport sector. The Omega-X project expects results associated with TSO-DSO collaboration for cross-border electric mobility services. The SERENE project is developing an efficient bus charging system based on local storage, including energy management systems. The Multiportgrid project is investigating how converters can be integrated into the charging system to reduce losses in the system and reduce the need for grid reinforcements. EO 8.1.4 (common standards, protocols and digital services for interoperability) is partially met by the results of the FlexiGrid project, which is developing an IT infrastructure for the shared management of charging stations to enable efficient information exchange. Additionally, this EO can also be met with the results of many projects that are focusing on EV-charging technologies and thus should consider IT infrastructure as well. No projects were indicated whose results can be directly linked to EO 8.1.1 and EO 8.1.2. Further results are expected from the REDAP project that are not covered by this survey.
PPC 8.2: Enhancing effectiveness of energy system operation and resilience with electromobility	
EO 8.2.1: Application of the concept of V2X (Grid, Home and/or Business) and energy storage technologies for enhancing security and resilience of energy system	Given the importance and prevalence of electromobility in the near future (e.g., the 2035 end date for fossil fuel car sales in the EU), this PPC may require additional projects to advance its development, despite current progress. In the context of this survey, 3 projects aim to develop results that can be linked to EO 8.2.1 - application of V2G concepts. The IANOS project is developing V2G charging stations to enable power plant operators to fine-tune electric vehicle charging patterns to minimize RES curtailment. The AI-flex project aims to develop and validate an AI-based optimisation interface for energy management of Power-2-Mobility or Vehicle-2-Grid solutions. The EPC5SES project has shown how to achieve resilience by storing energy on the building and vehicle side and optimizing a system that includes heating and charging. Further results are expected from projects that are not covered by this survey: CrossChargePoint and EVCHIP.

Table 12. Coverage of expected outcomes of HLUC 8 by projects' results

HLUC 9: Flexibility Provision by Building, Districts and Industrial Processes

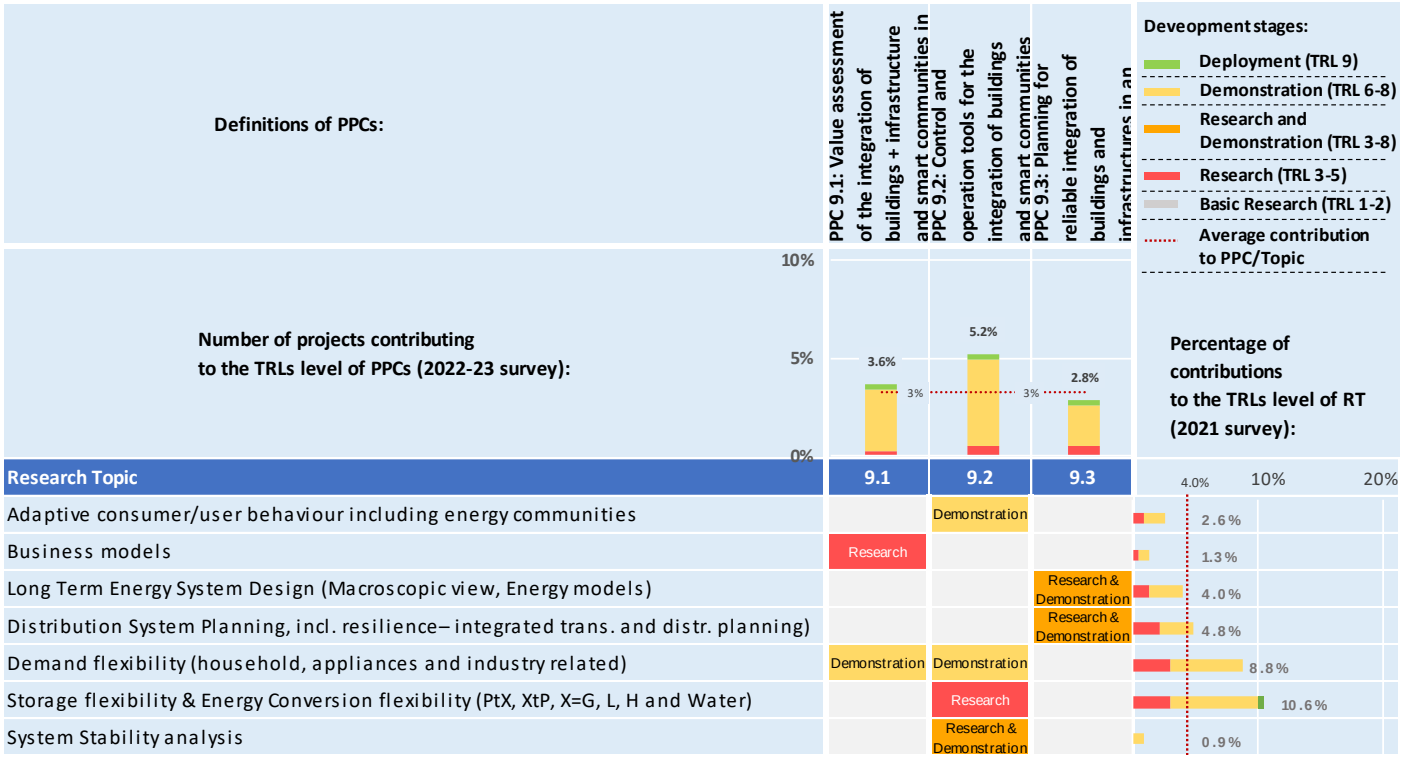


Figure 22. Percentage of contributions to HLUC 9

HLUC 9 Flexibility provision by Building, Districts and Industrial Processes focuses on the integration of renewable heating and cooling systems of buildings, industrial, commercial, and residential areas at the national, regional, and local levels. Such integration should enable efficient and effective integration of smart communities into the energy system, considering issues of connectivity, market participation, control mechanisms, and resilience.

PPC 9.1: Value assessment of the integration of buildings, infrastructure and smart communities in a RES based energy system
PPC 9.1 is based on the business model and demand flexibility research topics. The first topic appears to be in the research phase and was not adequately addressed according to the previous survey. The second topic is in the demonstration phase, which is also reflected in the survey data. The PPC is covered twice more than average, with the most significant contributions being made in the demonstration phase.

A large number of current and recent projects in this area already constitute a significant body of research. Although this survey has not confirmed that all expected outcomes are met by the submitted results, it is reasonable to assume that this PPC is covered, as the results of this PPC focus mainly on presenting different types of integration and technical solutions (see Table 13), rather than solving a specific challenge. However, it is recommended to pursue more results that demonstrate the integration of flexibility, frequency ancillary and wholesale markets (EO 9.1.6) and methods used in local markets for (pre-) qualification, communication, bid mechanisms (EO 9.1.3).

PPC 9.2: Control and operation tools for the integration of buildings and smart communities
PPC 9.2 includes four major research topics. The previous survey did not identify a significant number of projects impacting the Adaptive consumer/user behaviour topic, however, most of them were in the demonstration phase. Demand flexibility research topic is also in the demonstration phase and is twice as much as average addressed by ongoing projects. The same is true for the storage and energy conversion research topic, although it is still in the early development phase. For the System stability analysis research topic, there is a mix of technologies in the research and demonstration phases. However, the previous survey showed that it is difficult to report on progress due to limited coverage by the projects surveyed.

In line with the number of contributions, the expected outcomes of PPC 9.2 appear to be either fully or partially met given the large number of projects that can be associated with HLUC 9 (see Table 13). However, more attention needs to be paid to developing resilience support for the grid and systems. This area does not appear to be mature, especially considering that the technologies associated with PPC 9.2 are not yet commercialized and will need to undergo deployment phase.

PPC 9.3: Planning for resilient integration of buildings and infrastructures in an integrated energy system
PPC 9.3 builds on two important research topics – Long-term energy system design and Distribution system planning. These two topics have both research and demonstration phase technologies and, according to the earlier survey, did not show explicit progress toward the demonstration phase, although this topic is relatively frequently addressed. The most recent survey also showed consistency between the development of the research topics and PPC 9.3, receiving above average contributions that were almost evenly split between the research and demonstration phases.

Although many projects indicated their contribution to PPC 9.3, only two KERs were provided to infer development of this PPC. Only results from the ACCEPT project can be directly associated with EO 9.3.5 and EO 9.3.6 (net-load and aggregation forecasts, see Table 13). Additional results related to weak grid stabilization, island mode, and black start capability are needed (EO 9.3.1- EO 9.3.4). In particular, the aspects of this PPC that relate to the non-electric energy of buildings, infrastructure, and industrial processes will likely require further attention in research and demonstration.

Expected outcomes	KER of the surveyed projects
PPC 9.1: Value assessment of the integration of buildings, infrastructure and smart communities in a RES based energy system	
EO 9.1.1: Inclusive market design, efficient sector integration, effective participation of multi-sector buildings **EO 9.1.2:** Elaborate energy models and validate economic benefits **EO 9.1.3:** Market participation related aspects: (pre-) qualification, communication, bid mechanisms **EO 9.1.4:** Integration of Local Energy Communities, Districts and Smart Cities **EO 9.1.5:** Improved flexibility assessment and forecast **EO 9.1.6:** Integration of aggregated demand in the wholesale energy market and in the frequency ancillary services market **EO 9.1.7:** Development of more accurate user profiles for holistic management of buildings	EO 9.1.1 can be met with the exploitable results from several projects. Contributions are made by the Interconnect, NESOI, ACCEPT, MAGNITDE, GENTE, and EPC4SES projects. The deliverables are diverse and range from energy community tools to P2P and flexibility platforms. Also, since it is formulated quite broadly, its development can be expected to go beyond the listed projects. The full list of KER can be found in APPENDIX B. Expected contributions to PPCs from not surveyed projects and APPENDIX C. Key exploitable results of HLUCs. Results from the MAGNITUDE and BeFlexible projects could be explicitly linked to the expected outcome EO 9.1.2 (energy models and validation of economic benefits). They conducted a performance evaluation of the integrated system and assessed business models. The SYNERGY project contributes to the development of EO 9.1.5 – Integration of Communities, Districts and Cities. It is developing a solution to visualize building energy performance and analyse districts to improve energy efficiency measures and design urban transformation strategies. The ACCEPT project is developing digital tools for energy communities to evaluate the role of energy communities in the market. Improved flexibility tools and forecasting (EO 9.1.6) are currently being developed by the X-Flex and LocalRES projects. Under the former project, flexibility extraction, profiling, forecasting, classification, clustering, and management tools are being developed to meet various market and grid needs. Under the second project, planning tools will be developed to enable the participation of citizens and local stakeholders in the decision-making processes of local energy system design and planning. Further results are expected from projects that are not covered by this survey: ebalance-plus, REDAP, FlexSUS, OpenGIS4ET, AISTOR and MESH4U.
PPC 9.2: Control and operation tools for the integration of buildings and smart communities	
EO 9.2.1: Efficient heating and cooling for buildings, districts and industries, efficient Management of Thermal Storage **EO 9.2.2:** Design and test adequate control mechanisms and ICT enablers for integration of RES in buildings (namely H&C) and buildings integration in the energy system **EO 9.2.3:** Methods and tools to support prosumers and industries to adapt behaviours (measurements, dynamic tariffs) **EO 9.2.4:** Provision of flexibility from buildings (including thermal storage) and smart communities to system operators **EO 9.2.6:** Resilience support to the grid and system (e.g., extreme events) **EO 9.2.7:** Develop flexibility mechanisms (support to System Operators) from building level to Community and Smart City level **EO 9.2.8:** Integration of VPP/VPS (logic aggregation of demand/ prosumers), integration of heterogeneous flexibility in one platform **EO 9.2.9:** Use of AI and digital twins for demand flexibility assets **EO 9.2.10:** Peer-2-peer mechanisms, integration of heterogeneous flexibility in one platform	The results of the SENDER and DISTRHEAT projects can be linked to EO 9.2.1 and EO 9.2.2. The SENDER project is exploring a concept of using a building as a battery (thermal storage, V2G EV charging, smart water heater) and developing a management system to use the flexibility. DISTRHEAT's work currently includes the development of a smart controller that manages a multi-energy system by harnessing the flexibility of the building and making it available to the network. Future deliverables from the SERENE and DigiCiti projects explicitly correspond to EO 9.2.2 and 9.2.4 (Integration of buildings). The SERENE project is developing a smart energy management system to use the flexibility of heat pumps and car charging stations in local energy systems. One of the expected results of DigiCiti relates to control and operational tools for building and smart community integration (expected to be TRL8 at the end of the project). The results of the iFLEX project' can be related to EO 9.2.3. The focus is on household consumers and demand response to support high penetration of renewables such as solar energy. This EO can also be met with the research that is currently undergo in other projects (e.g., OneNET, Interconnect, FEVER, EUniversal) that are likely also developing advanced solutions to meet their project objective. The PARITY, SYNERGY, and SONDER projects contribute to EO 9.2.7 Flexibility Mechanisms. Parity is developing DERs flexibility management tool for both prosumers and aggregators, SYNERGY is designing a holistic urban planning tool with dynamic simulations, and the SONDER project is developing a two-stage framework for evaluating different control systems that can be used to coordinate mixed energy resources in distribution grids. Projects GIFT, PARITY, FEVER, ACCEPT, IANOS, LocalRES, IANOS, and MAGNITUDE are developing VPP solutions.

	The Interconnect and ACCEPT projects use concepts of Artificial Intelligence and digital twins in their projects, fulfilling the objective of EO 9.2.9. The former project also explicitly mentions the development of P2P mechanisms, which corresponds to EO 9.2.10. Further results are expected from projects that are not covered by this survey: ebalance-plus, FlexSUS, OpenGIS4ET, AISTOR and MESH4U.
PPC 9.3: Planning for resilient integration of buildings and infrastructures in an integrated energy system	
⊖ **EO 9.3.1:** Stabilisation of weak grids and microgrids ⊕ **EO 9.3.2:** (Intended) Islanding mode of operation ⊖ **EO 9.3.3:** Black start capabilities ⊕ **EO 9.3.4:** Improved forecasting (including behind-the-meter aspects) ⊕ **EO 9.3.5:** Net load forecasting ⊕ **EO 9.3.6:** Aggregated forecasting	Although many projects indicated their contribution to PPC 9.3, only two KERs were provided to infer development of this PPC. Only results from the ACCEPT project can be directly associated with EO 9.3.5 and EO 9.3.6 (net-load and aggregation forecasts). Additional results related to weak grid stabilization, island mode, and black start capability are needed (EO 9.3.1- EO 9.3.4). In particular, the aspects of this PPC that relate to the non-electric energy of buildings, infrastructure, and industrial processes will likely require further attention in research and demonstration. Further results are expected from the ebalance-plus project that is not covered by this survey.

Table 13. Coverage of expected outcomes of HLUC 9 by projects' results

Conclusion

This report is the first to provide an update on progress monitoring using the new research methodology with HLUCs and PPCs first introduced in the ETIP SNET 2022-2025 Implementation Plan. Therefore, it was important to ensure that the results of the (previous) 1st progress report could be related to the current results. This was ensured by cross-referencing the PPC development scale with progress on the Research Tasks covered in the previous survey. Such a comparison makes it possible to assess whether progress in PPC and HLUC development is being hindered or facilitated by progress in Research Tasks.

The survey highlighted the difference between BRIDGE and ERA-NET SES projects. National and regional projects managed under the ERA-NET SES initiative largely contributed to the research phase (TRL 3-5). There are two explanations for this. First, the research agenda of ERA-NET SES is not so much focused on bringing technologies to market but is often limited to supporting academia given the available capacity. Second, the strong contribution to the research phase is due to limited funding opportunities of ERA-NET SES and the need to distribute support equitably. As the contribution of the demonstration and deployment phase requires much higher resources, demonstration projects have not been sufficiently funded within the ERA-NET SES and need to be supported at the EU level.

The overall coverage of expected outcomes and the number of projects that did not respond to the survey but are expected to contribute can be seen in **Error! Reference source not found.**. The b ottom graph – PPC coverage based on survey results has been expressed as a percentage and colour coded[8]:

≥ 60% (green) - the PPC is sufficiently covered, perhaps more specific contributions require in future calls
≥40%... < 60% (yellow) - the PPC is partially covered
< 40% (red) - the PPC is not sufficiently covered

As only 55% of the projects completed the questionnaire, the upper chart in **Error! Reference source not found.** shows the number of p rojects that did not complete the questionnaire but are expected to contribute to the respective PPC. From here and below these projects are referred as "non-surveyed" projects. These figures are based on the analysis of the websites of these projects and their allocation to a maximum of 3 PPCs.

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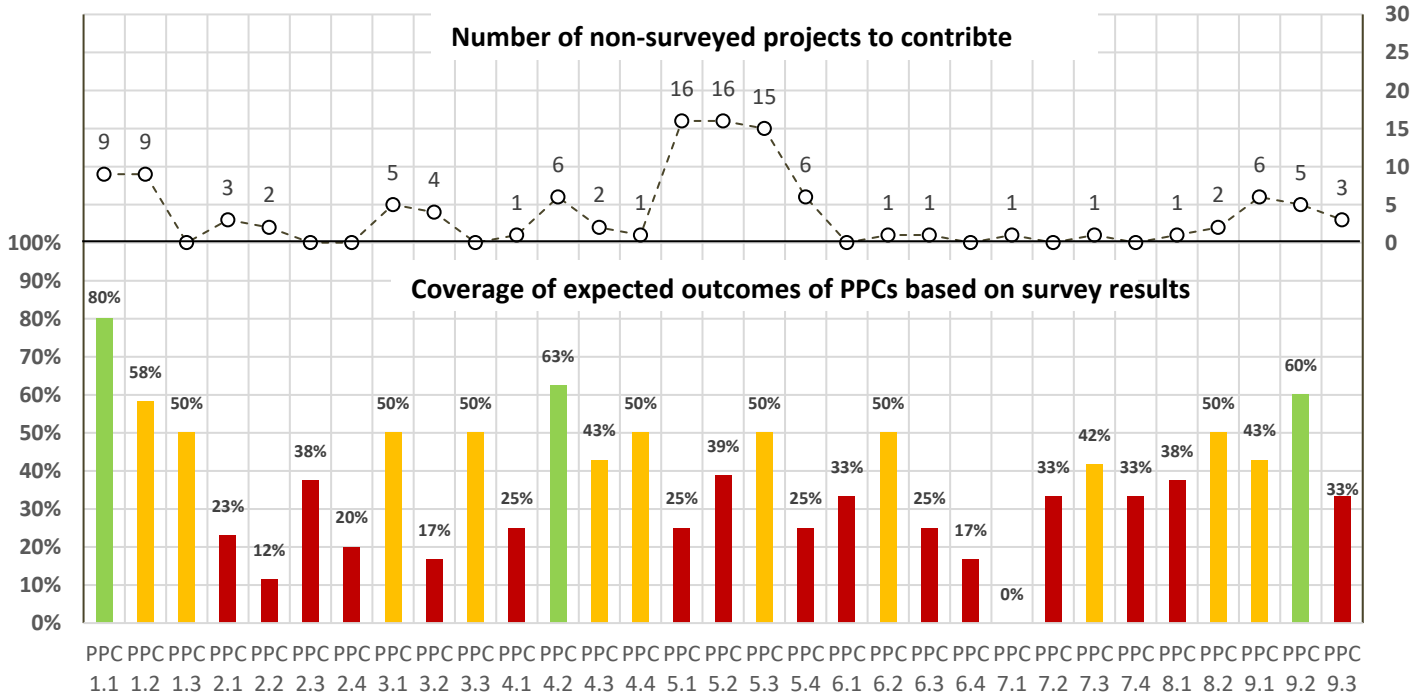

Figure 23. Number of non-surveyed projects and coverage of expected outcomes of PPCs

PPC 1.1 Value of cross sector integration and storage appears seems to be completed with 9 further projects should drive development. Perhaps more attention should be paid to developing market models and regulations to ensure that R&I advances can be commercialised in the near future. These results can also be achieved in PPC 3.1 and 3.2, which are currently not fully covered.

PPC 1.2 Control and operation tools for multi-energy systems would benefit from an additional contribution as the expected results are not fully covered. However, some results can also be achieved under PPC 7.2, 7.3, 7.4 and nine projects that have not been surveyed.

PPC 1.3 Smart asset management for a circular economy requires further expansion and new targets for asset management, including with concepts such as Big Data, Artificial Intelligence (AI) and Machine Learning (ML), as well as the use of wearable devices, robotics, drones, etc. No other contributions are expected from non-surveyed projects.

PPC 2.1 Market models and architecture for TSO-DSO- System User interactions have yet to be formulated and agreed at national level and then at EU level. More demonstration projects need to be

[8] The percentage of completion is calculated based on the assumption that fully covered Expected Outcomes is represented as "1", partially covered is "0.5" and not covered is "0". Full coverage is 100% with all expected outcomes weighted as "1".

developed in this area as only three projects are expected to contribute to this PPC. The development of this PPC is also linked to the progress of PPC 3.1, 3.2, 5.2 and 5.4, where the progress is still expected by non-surveyed projects.

PPC 2.2 Control and operation for enhanced TSO-DSO- System User interactions requires further demonstration to adapt control and operation to evolving market models and architectures and to ensure the reliability and security of these interactions. However, given the niche application of this PPC occupied by industry, extensive research in this area is not expected. Even few projects (including two that have not been studied) can successfully demonstrate that they can deliver the required results and be carried out by industrial actors

PPC 2.3 Platform Development for TSO-DSO cooperation require further results to develop such platforms or to ensure that local market and flexibility platforms can be used (or extended) for collaboration on TSO-DSO. The development of PPC 2.3 is also closely linked to PPC 2.1 and 2.2 so it can be advanced by work that primarily falls in these categories.

PPC 3.1 Fundamental market design is partially covered by ongoing projects, most of which will require demonstration upon completion. This PPC can also be developed through ongoing work covered by PPC 1.1 and 5.4 and the work of 5 non-surveyed projects. Otherwise, additional projects are recommended that can build on the work of projects that have indicated a contribution to this PPC.

PPC 3.2 Regulatory framework and strategic investments has few results with the expected contribution from four non-surveyed projects. The data collected suggests that further R&I activities are needed in relation to the development of mechanisms of PPA and guarantees of origin in the context of strategic investment decisions. This can also be obtained in 4 projects that have not been surveyed.

PPC 3.3 IT systems for cross-border trading needs to be further addressed as no further contributions are expected from non-surveyed projects. The existing IT systems for cross-border trading of electricity and gas may need to be updated to show that they are capable of integrating a variety of technologies into the pan-European market, especially if regulations change significantly or hydrogen is included. One should not expect extensive research in this area, as progress can be made by industry**.**

PPC 4.1 Technical barriers and technical measures for integration of RES at multiple levels and sectors requires more results in terms of re-dispatch and assessment of market dynamics. These can also be obtained through non-survey projects or ongoing work under HLUC 2 and 6.

PPC 4.2 Control and operation tools for a RES -based energy system require further developments in effective curtailment mechanisms which can be made by six non-surveyed projects.

PPC 4.3 Infrastructure requirements and network technologies seems to require further investigation of solutions that can mitigate lack of inertia in grids (also part of HLUC 6). Furthermore, it remains to be ensured that all necessary technologies for multinational grid interconnection design to support offshore wind and optimal flexibility management prove their efficiency. Some results can be achieved in 2 non-surveyed projects as well as in industry.

PPC 4.4 Planning of a resilient system with massive penetration of RES remains a relatively young topic with rapidly growing importance (due to the climate crisis), which means that more results need to be achieved in the future. Some contributions can be achieved under PPC 2.4 as well as in one non-surveyed project**.**

PPC 5.1 Value of Consumer/Customer acceptance and engagement is significantly covered and is likely to be supported by 16 non-surveyed projects. Particular attention is needed to ensure that relevant policies and tools are developed to enable market implementation and tariff and price setting.

PPC 5.2 Plug-and-play devices and IoT [Internet of Things], including security by design, requires additional attention to facilitate customer access to markets and switching energy suppliers. These results can be achieved in 16 non-surveyed projects.

PPC 5.3 Utilisation of Communication Networks including cyber security requires further work on advanced intrusion detection, advanced tools for proactive and anticipatory security strategies, and mechanisms of exploitation of common infrastructures, e.g., 5G networks. The development of this PPC can be done in 15 non-surveyed projects as well as some cybersecurity projects are included in Horizon calls under Cluster 3 (part on Secure Societies) and Cluster 4 (part on Digital and Industry), which are not part of this analysis.

PPC 5.4 Cross-sectorial flexibility use cases may require further development of requirements for a consolidated ICT vision and an integrated framework for the development of interoperable systems. This may be achieved in 6 non-surveyed projects.

PPC 6.1 Control solutions for next- generation PV and battery has been supported from a small number of projects. There are no other non-projects that can contribute to this PPC, but some results can be obtained in the ongoing work of HLUC 2 and 4. This can be explained by the niche development of power electronics and its applications. So far, the power electronics industry has been dominated by large companies that often conduct RD &I activities internally and market new solutions through established channels. Nevertheless, some R&I activities are still needed in this area.

PPC 6.2 Hybrid transmission/distribution and hybrid distribution AC /DC grids require additional evidence to ensure development of hybrid AD /DC and energy router concepts. Some results can be achieved in one non-surveyed project.

PPC 6.3 Next generation distribution substation will benefit from additional projects addressing smart transformers for connection between MV and LV AC networks enabling AC and DC microgrids and methods to facilitate distribution grid to work in island mode. This can be achieved in a one non-surveyed project or in industry.

PPC 6.4 Simulation methods and digital twins at distribution and transmission level for power electronics would benefit from more results related to IT systems in power electronics and simulation of power electronics behaviour at all levels. These could be investigated as part of industrial projects.

PPC 7.1 Next generation of TSO control was not directly supported. Its development may be driven by industry and a project that has not been surveyed. Some results may also be achieved under HLUC 2.

PPC 7.2 Next generation of DMS requires more attention, especially in terms of tools to study distribution grids with very low (no) inertia and enhanced MV and LV supervision. It is not expected that other projects under the ETIP SNET initiative will contribute to this PPC.

PPC 7.3 Next generation of measurements and GIS for distribution grids has several expected outcomes that are partially fulfilled. As only one additional non-surveyed project can contribute to this area, Big Data analytics for real-time system operation is still an open research field.

PPC 7.4 Wide area monitoring, control and protections need to evolve greatly with the continued increase in asynchronous generation and decrease in inertia. As no other non-surveyed projects will contribute to this PPC, further research is recommended in the area of on-line dynamic security assessment (voltage, frequency, angle) of interconnected power systems. Some progress in development of this PPC could also be expected from industry.

PPC 8.1 Technical and economic implication of decarbonisation of transport sector requires further development to assess the technical and economic implications of decarbonising the transport sector. This can also be achieved under HLUC 1 and HLUC 5. Additional attention can be given to the development of strategies to decarbonise aviation and marine transport via electrification or hydrogen. One non-surveyed project can also contribute to this PPC.

PPC 8.2 Enhancing effectiveness of energy system operation and resilience electromobility requires further attention due to the growing importance of electromobility and in the context of system security and resilience. Some contributions can be expected from two projects that are not part of the survey.

PPC 9.1 Value assessment of the integration of buildings, infrastructure and smart communities in a RES based energy system focuses mainly on the presentation of different types of integration and technical solutions. A large number of ongoing and recent projects in this area already represent a significant body of research. However, it is recommended to pursue more results showing the integration of flexibility, axillary and wholesale markets, as well as the methods used in local markets for (pre-)qualification, communication and bidding mechanisms. This can also be done under HLUC 3 as well as within six non-projects.

PPC 9.2 Control and operation tools for the integration of buildings and smart communities has been partially covered. However, more attention needs to be paid to the development of resilience support for the grid and systems. This area does not seem to be mature yet, especially considering that the technologies associated with PPC 9.2 are not yet commercialised and need to go through a deployment phase. Additional results can be obtained from five projects that have not surveyed.

PPC 9.3 Planning for resilient integration of buildings and infrastructures into an integrated energy system requires further attention in research and demonstration related to non-electrical aspects of energy systems of buildings, infrastructures and industrial processes. Some results can be obtained in 3 non-surveyed projects.

The results of this work are essential for the further planning of the activities of ETIP SNET. To further improve R&I planning and implementation processes, it is suggested that funded projects under Horizon 2020 be contractually obliged to report to the ETIP SNET initiative on project progress and expected results. This should also be reflected in projects' budgets and allow for a full understanding of the gaps and constraints that need to be addressed in subsequent calls. In this report, this limitation has been addressed by reviewing the websites of projects that did not respond to the survey (non-surveyed projects) and allocating them to PPCs. This approach has its limitations as the information on the websites may not always be updated or fully presented.

Although this report did not examine private sector funding of Energy System Integration and Smart Network R&I activities, it found little contribution from private (corporate) funds, with only 11% of respondents mentioning such contributions. There may be four reasons for this. First, the private sector has strong incentives to participate in the projects but prefers to use public funds at early development phases. Second, the private sector is unwilling to invest in R&I of publicly funded projects because it must disclose the results and is therefore unable to take ownership of a result. Third, most projects are in the research and demonstration phase, so commercial opportunities are not always clear, especially if there are no regulations or business models for commercialization at place. Fourth, private companies have their own research agenda that is not fully aligned with the public R&I approach.

Despite the intrinsic reason for low industry funding contributions, both public and private R&I agendas serve the goal of delivering market-ready technologies and appropriate business models and regulations to monetize them. Therefore, strong industry engagement greatly improves the chances for successful commercialization. This is particularly important for technologies with high market maturity. As the ETIP SNET R&I agenda progresses, greater industry involvement is desired.

APPENDIX A. List of PPCs which belong to timeframe 2022-2025

HLUC 1: Optimal Cross sector Integration and Grid Scale Storage
PPC 1.1: Value of cross sector integration and storage
PPC 1.2: Control and operation tools for multi-energy systems
PPC 1.3: Smart asset management for a circular economy
HLUC 2: Market-driven TSO–DSO–System User interactions
PPC 2.1: Market models and architecture for TSO-DSO- System User interactions
PPC 2.2: Control and operation for enhanced TSO-DSO- System User interactions
PPC 2.3: Platform Development for TSO-DSO cooperation
PPC 2.4: Planning tools for TSO-DSO cooperation
HLUC 3: Pan European Wholesale Markets, Regional and Local Markets
PPC 3.1: Fundamental market design
PPC 3.2: Regulatory framework and strategic investments
PPC 3.3: IT systems for cross-border trading
HLUC 4: Massive Penetration of RES into the transmission and distribution grid
PPC 4.1: Technical barriers and technical measures for integration of RES at multiple levels and sectors
PPC 4.2: Control and operation tools for a RES based energy system
PPC 4.3: Infrastructure requirements and network technologies as solutions for integration of massive RES
PPC 4.4: Planning for a resilient system with massive penetration of RES
HLUC 5: One stop shop and Digital Technologies for market participation of consumers (citizens) at the center
PPC 5.1: Value of Consumer/Customer acceptance and engagement
PPC 5.2: Plug and play devices and IoT [Internet of things] including security by design
PPC 5.3: Utilisation of Communication Networks including cyber security
PPC 5.4: Cross-sectorial flexibility use cases
HLUC 6: Secure operation of widespread use of power electronics at all systems levels
PPC 6.1: Control solutions for next generation PV and battery inverters
PPC 6.2: Hybrid transmission/distribution and hybrid distribution AC/DC grids
PPC 6.3: Next generation distribution substation
PPC 6.4: Simulation methods and digital twins at distribution and transmission level for power electronics driven networks
HLUC 7: Enhance System Supervision and Control including Cyber Security
PPC 7.1: Next Generation of TSO control room
PPC 7.2: Next generation of DMS
PPC 7.3: Next generation of measurements and GIS for distribution grids
PPC 7.4: Wide area monitoring, control and protections
HLUC 8: Transportation Integration & Storage
PPC 8.1: Technical and economic implication of decarbonisation of transport sector
PPC 8.2: Enhancing effectiveness of energy system operation and resilience with electromobility
HLUC 9: Flexibility provision by Building, Districts and Industrial Processes
PPC 9.1: Value assessment of the integration of buildings + infrastructure and smart communities in a RES based energy system
PPC 9.2: Control and operation tools for the integration of buildings and smart communities
PPC 9.3: Planning for reliable integration of buildings and infrastructures in an integrated energy system

APPENDIX B. Expected contributions to PPCs from not surveyed projects

PLATFORM	PROJECT NAME	Expected PPC contribution	Expected PPC contribution	Expected PPC contribution
BRIDGE	BD4NRG	3.1	5.2	7.3
BRIDGE	BRIGHT	5.2	5.1	5.4
BRIDGE	CREATORS	5.1	5.4	
BRIDGE	ebalance-plus	9.1	9.2	9.3
BRIDGE	edgeFLEX	4.2	4.3	4.4
BRIDGE	E-LAND	1.1	1.2	5.1
BRIDGE	EnergyShield	5.3		
BRIDGE	eNeuron	5.1	5.2	5.3
BRIDGE	HESTIA	5.1	5.2	5.3
BRIDGE	HYPERRIDE	6.2	6.3	
BRIDGE	INSULAE	3.2		
BRIDGE	ISLANDER	3.2		
BRIDGE	MAESHA	3.2		
BRIDGE	PLATONE	4.2	5.2	5.4
BRIDGE	ReDREAM	5.1	5.2	5.3
BRIDGE	RenErgetic	5.1	5.2	5.3
BRIDGE	ROBINSON	1.1	1.2	
BRIDGE	TRINITY	7.1	3.2	3.1
BRIDGE	VPP4ISLANDS	4.2	5.2	5.4
BRIDGE	ELECTRON	5.3		
BRIDGE	DATA CELLAR	5.1	5.2	5.3
BRIDGE	COMPILE	9.3	5.1	5.3
BRIDGE	INTERRFACE	3.1	2.1	5.4
BRIDGE	MERLON	5.1	5.2	5.3
BRIDGE	MUSE GRIDS	5.1	5.2	5.3
BRIDGE	REACT	9.3	5.1	5.3
BRIDGE	RENAISSANCE	5.1	5.2	5.3
BRIDGE	SDN-microSENSE	5.3		
ERA-NET SES	ACES	1.1	1.2	
ERA-NET SES	RELflex	1.1	1.2	
ERA-NET SES	REDAP	9.1	8.1	
ERA-NET SES	AGRO-SOFC	1.1	1.2	
ERA-NET SES	Flexi-Sync	1.1	1.2	
ERA-NET SES	HEATflex	1.1	1.2	
ERA-NET SES	CLUE	5.1	5.2	5.3
ERA-NET SES	R2EC	4.1	4.2	5.2
ERA-NET SES	FlexSUS	9.1	9.2	
ERA-NET SES	H2CS	1.1	1.2	
ERA-NET SES	SMART-MLA	4.2	5.1	5.2
ERA-NET SES	HED-LiS	1.1	1.2	
ERA-NET SES	SIES2022	3.1	2.1	2.2
ERA-NET SES	CrossChargePoint	8.2		
ERA-NET SES	OpenGIS4ET	9.1	9.2	
ERA-NET SES	LASAGNE	2.2	2.1	3.1
ERA-NET SES	AISTOR	9.1	9.2	
ERA-NET SES	BIO NRG STORE	-	-	-
ERA-NET SES	I -Greta	5.1	5.2	5.3
ERA-NET SES	MESH4U	9.1	9.2	
ERA-NET SES	DiGriFlex	4.2	4.3	
ERA-NET SES	EVCHIP	8.2	5.4	
ERA-NET SES	PIGergy	-	-	-

APPENDIX C. Key Exploitable Results of HLUCs

1.1 HLUC 1: Optimal Cross sector Integration and Grid Scale Storage

Project Name	PPC 1.1	PPC 1.2	PPC 1.3	Key Exploitable Results
Interconnect		TRL 6-8	TRL 6-8	**Software** [9,10] The solutions developed within the scope of Interconnect will allow a digitalization of homes, buildings and electric grids based on an Internet of Things (IoT) architecture. By including digital technologies (Artificial Intelligence, Blockchain, Cloud and Big data) based on open standards, such as SAREF, it will guarantee the interoperability between equipment, systems and privacy/cybersecurity of user data. The solution is comprised of several parts: DSO Interface, Semantic Interoperability Framework (SIF), Ontology, Service Store, Knowledge Engine, Generic Adapter, Peer to Peer Marketplace.
OSMOSE	TRL 9	TRL 6-8		**Hardware** [11] Development and integration of Hybrid Flexibility Device that able to provide multiple flexibility services to the transmission system. This hybrid flexibility device integrates containers with STATCOM and supercapacitors and container with a high-voltage lithium-ion battery system and a DC-DC converter. **Methodology** [12] Algorithm for optimal coordination and control of the hybrid flexibility devices allows for coordinating the different flexibility devices at power system level, accounting for the features of each device (size, performance requirements, operation strategies and controls at system level), as well as the most significant simulation results. **Software** [13] A complete scenario dataset related to an open-source tool. Probabilistic hourly dispatch of the European power systems on a country level taking into account new flexibilities sources (battery, P2X, electric vehicles, demand and needs (evolution of demand and reserves requirements. Analysis of the simulations highlight the evolution of the flexibility needs and the contribution of the different system elements.
NESOI		TRL 9		**Policy, regulation and market** [14] A coordination & support action framework aiming at facilitating the clean energy transition on EU islands and going one step forward by providing islands with training, technical support, cooperation opportunities and robust funding opportunities to concretely convert Island Sustainable Energy Action Plans into Renewable Energy Sources (RES plants, building and energy infrastructure retrofitting, energy bill reduction, local job creation, etc.).
GIFT	TRL 6-8	TRL 6-8		**Hardware** [15,16] A reversible electrolyzer, bringing new functionalities: (i) it works as an electrolyzer to store excess of electricity in the form of hydrogen, and (ii) as a fuel cell to produce electricity and heat from that same hydrogen - or alternatively from (bio)-gas. **Hardware** [17,18] Hydrogen bromide (HBr) flow battery allows for safety of storage of hydrogen to use in buildings and mitigates degradation of cell stacks (related to HBr humidity issue inside).
FlexiGrid	TRL 6-8		TRL 6-8	**Software (can be commercialized)** Advanced management of assets in the energy system along their entire lifecycle, deployment of IoT sensors, communication, data management & analysis and feedback to control systems services based on higher degrees of automated management and control of flexible energy network resources. Optimisation of the electric grid, including demonstration of V2G and optimal loading. Development and demonstration of advanced technologies and control concepts /platform tools for enabling flexibility. Assessment of the benefits and possibilities of providing system flexibility services.
SUSTENANCE		TRL 6-8		**Methodology**

[9] https://gitlab.inesctec.pt/groups/interconnect-public/-/wikis/home
[10] https://interconnectproject.eu/about/#results
[11] https://www.osmose-h2020.eu/wp-content/uploads/2022/04/D4.3-Hybrid-Flexibility-Device-Implementation-1.pdf
[12] https://www.osmose-h2020.eu/wp-content/uploads/2022/01/OSMOSE-D4.4-Master_Control_Strategies_vF-1.pdf
[13] https://www.osmose-h2020.eu/wp-content/uploads/2022/04/D1.3-Optimal-Mix-of-Flexibility-1.pdf
[14] https://www.nesoi.eu/system/files/private/nesoi_-_scgm_nakou_-_z-173-compressed.pdf
[15] https://sylfen.com/en/technology/
[16] https://www.gift-h2020.eu/delivrables/
[17] https://www.elestor.nl/technology-the-elestor-solution/fundamentals/
[18] https://www.gift-h2020.eu/delivrables/

				Intelligent control system for energy management at different level for cross-sectorial systems.
X-FLEX	TRL 6-8	TRL 6-8	TRL 6-8	**Software** The tool for grid and microgrid operators that prevents congestion (voltage and current issues) and power quality problems with the increasing share of intermittent RES, giving special attention to the potential grid problems due to the impact of extreme climate events. The tool will use flexibility as an alternative to network reinforcement when it is more cost-efficient than traditional reinforcement of the network.
LocalRES	TRL 3-5	TRL 6-8	TRL 6-8	**Software** a planning tool oriented to enable citizen participation in the REC planning decision-making processes, and a Multi-Energy Virtual Power Plant (MEVPP) approach to optimize in real time different energy vectors and different energy and flexibility services provided by the REC according to their community preferences.
TwinERGY	TRL 6-8			**Methodology** Digital Twin for optimising demand response for residential buildings while having a positive impact on the well-being of consumers and on their ordinary activities. **Methodology** Models for optimisation of the operation and planning of the integrated energy systems to facilitate cost effective transition to zero carbon energy future.
E-LAND	TRL 6-8	TRL 6-8	TRL 6-8	**Software (can be commercialized)** [19] The Optimal Scheduler tool provides an hourly scheduling of storage (when store or consume) and controllable assets (when switch on/off) in order to maximize the use of renewable energy resources. It is based on the forecast production/consumption in the Local Energy System (LES). The application is fully integrable in the Energy Management System. **Software** [20] The Data Pre-Processing Application is a tool that detects/corrects missing, corrupt or inaccurate (outliers) data, re-samples them, if needed, and gets energy load profiles (daily, weekly). This is a necessity to exploit this information by other tools (forecasting, optimisation, planning). **Software** [21] The tool provides forecasting for different energy vectors: electrical and thermal loads; Photovoltaic and wind generation. The Energy Forecaster tool provides hourly forecasting of electrical/loads and Photovoltaic/wind generation in two forecasting horizons: intra-day and day-ahead. Forecasts are based on weather data, characteristics of generation assets, and contextual information and possibly occupancy.
SERENE		TRL 6-8		**Software (can be commercialized)** Control system for flexible control of heat-pumps and car charging in local energy systems. Control system for heat pumps to provide flexibility services to the grid Energy management system for local storage battery systems.
NewSETS	TRL 6-8			**Hardware (can be commercialized)** Seasonal sand-based heat storage provided by Polar Night Energy Oy, a commercial plant running in Finland. The solution uses sand as a storage medium, excess of electricity is used for heating up the sand to a high temperature. The stored energy can be used as heat for industrial needs to district heating. **Hardware (can be commercialized)** Pumped Hydro Storage is a technology to enable reservoirs to be constructed underground in mines (UPHS). Through the solution, mines can instead become assets for large-scale energy storage.

[19] https://elandh2020.eu/wp-content/uploads/2021/06/OS-Tool-5.pdf
[20] https://elandh2020.eu/wp-content/uploads/2021/06/DPA-Tool-4.pdf
[21] https://elandh2020.eu/wp-content/uploads/2021/06/EF-Tool-5.pdf

MAGNITUDE	TRL 3-5	TRL 3-5		**Software** Models and software tools for the simulation of multi-energy systems and the optimisation of control strategies to maximize flexibility provision. **Software** Aggregation platform for pooling the flexibilities of decentralized multi-energy systems and trading on the electricity markets. **Methodology** Performance assessment of the integrated system (multi-energy systems optimisation, aggregation platform, and market platform on the real-life case studies. **Policy, regulation and market** Business models evaluation for the multi-energy systems and the aggregator.
ZEHTC	TRL 6-8	TRL 6-8	TRL 6-8	**Hardware (can be commercialized)** [22] Hydrogen storage and re-electrification in gas turbines to support grids with high renewables content.
HONOR	TRL 6-8	TRL 6-8	TRL 3-5	**Methodology** [23] A flexibility service mechanism was developed and demonstrated that determines curative congestion management measures using flexible generators and loads.
RE-EMPOWERED	TRL 3-5	TRL 6-8		**Software** EcoEMS tool assists to operate the Power System economically by scheduling different energy vectors while satisfying the wide range of operational, security and availability constraints. The algorithm permits the deployment of different scales of power systems, and cooperates with other ecoTools, while considering forecasting, both for load and RES generation. The flexibility of different energy vectors like cooling, heating and electric vehicles are incorporated to be scheduled in the most efficient and economic operation.
DIEGO	TRL 6-8	TRL 3-5	TRL 6-8	**Software** Planning and future operation tool for industrial parks and infrastructures, incl., software components for multi-energy grids across multiple sectors and diverse types, optimisation algorithms and prediction methods for real-time energy balancing, ICT architecture supporting (near-) deterministic data exchange, digital tools for enhancing the design of photovoltaic cells.
SP2G	TRL 3-5	TRL 3-5	TRL 3-5	**Software** The 5 tools that were developed analyse the potential of P2G systems on different levels. These levels split up in regional focus, national focus and EU focus. Those tools were developed in cooperation with need owners and by the end of the project will be made accessible to the broader public to lower the barriers for P2G systems being installed which contributes to the over-all efficiency and balancing of the energy system with energy storage and transfer of green energy to end use sectors.
DISTRHEAT	TRL 3-5	TRL 6-8		**Hardware** [24,25] A smart controller that manages a multi-energy system by exploiting building flexibility and by providing it to the network. The Model Predictive Control mechanism needs some preparatory work, but this can be speed up by developing standardized architectures.
USC - Flex Store	TRL 6-8			**Hardware** Underground Sun Conversion allows for sector coupling via Power to Gas at point of storage as bridge between electricity and gas markets. Unlocks a large-scale seasonal energy storage.
SONDER	TRL 3-5	TRL 3-5		**Software** The BESS operation allows for day-ahead load prediction, the transformer measurement, and the peak power of the previous timesteps of the month. The relative savings from peak shaving can increase year by year ranging from 48% in 2019 to 78% in 2022 compared to the theoretical optimum with perfect forecast. The proposed control algorithm does not also cause negative effects on the costs related to energy procurement and network usage fees.
GENTE		TRL 6-8		**Methodology** A toolbox for communities and community managers for resource optimisation and community federation

[22] www.zehtc.org
[23] https://honor-project.eu/wp-content/uploads/2022/03/20211213_OK_D5-2.pdf
[24] https://www.distrheat.eu/download/18.3637497618094a0d39e4043e/1653402251016/DISTRHEAT_D2.3.pdf
[25] https://www.distrheat.eu/distrheat/news/webinar-from-distrheat

DEVISE	TRL 6-8	TRL 3-5		**Hardware (can be commercialized)** Thermal portable energy storage via thermic fluid (temperature: 150-200 degrees C, Capacity: 3-4 KWh, thermal Load: Space/Water Heating) **Hardware (can be commercialized)** Hybrid storage for electrical energy in the LMLA and Li-on types of batteries. Development of chargers to control the charging of parallelly connected batteries.
BioLens	TRL 6-8	TRL 9	TRL 3-5	**Software (can be commercialized)** A system that allows for fast and easy mass balance generation at Biomethane production facilities. Additionally, the platform will generate the necessary Proof of Sustainability (PoS) document packages that are mandatory to follow all biomethane production to ensure sustainability and document GHG reduction by use of the fuel. **Policy, regulation and markets** A new market, regulatory and policy frameworks for delivering low-emission, low-cost, secure, reliable, and resilient whole-energy systems. The project will increase data security compared, low the operation costs of biomethane production by automating the processes. **Methodology** Creating a foundation for the implementation of a forecasting model that will help operators at biomethane production facilities to avoid process breakdowns, through that increase and optimize the production of biomethane.
Power-2-Transport	TRL 3-5	TRL 3-5	TRL 3-5	**Methodology**[26] Methodology to investigate whether synthetic CH4 could be a feasible alternative for buses currently powered by fossil fuels, a dynamic model was built for discrete-event simulations of PtG technology integrated into an urban AD plant designed to supply biomethane as fuel for bus fleets.
TOP-UP	TRL 3-5	TRL 3-5		**Software**[27] An R package for adaptive and recursive online forecasting for e.g., control or energy trading systems **Methodology**[28] An automatic, data-driven methodology for clustering commercial and industrial load patterns for long-term energy planning those accounts for heterogeneity in electricity consumers' load profiles using unsupervised learning. It ensures reliable load profile forecasts for long-term energy planning. **Methodology**[29] Air temperature modeling per room for buildings connected to the local district heating networks. Proposed non-linear autoregressive models with exogenous inputs for room air temperature modelling.

1.2 HLUC 2: Market-driven TSO–DSO–System User interactions

Project Name	PPC 2.1	PPC 2.2	PPC 2.3	PPC 2.4	Key Exploitable Results
OneNet	TRL 3-5	TRL 3-5	TRL 6-8		**Software** Coordinated TSO-DSO Flexibility Market Simulator and Market Clearing Module ensures the flexibility needs of the system operators are met at the minimum possible cost while abiding by the grid constraints of all the systems involved, as well as the technical constraints of the bids. **Software** The OneNet Connector combines the International Data Spaces principles with the advantages of the FIWARE ecosystem ensuring a seamless and secure data exchange in a completely end-to-end decentralized approach. It is ready-to-go for being deployed and integrated in any already existing platform and offers user-friendly interfaces (both as REST

[26] https://www.sciencedirect.com/science/article/pii/S0196890422003703
[27] https://arxiv.org/abs/2109.12915
[28] https://www.sciencedirect.com/science/article/pii/S2666955221000101
[29] https://www.sciencedirect.com/science/article/pii/S2666546822000222

					APIs and GUI) enabling users and platforms to exchange data. **Methodology** Cross-Platform-Services Catalogue is a methodology and tool to define and describe Cross-Platform-Services in the electricity domain and their underlying Business Objects that enables the harmonised data exchange between different platforms and actors. **Methodology** Orchestration Workbench is the component able to orchestrate and evaluate the performance and scalability of the cross-platform services that will be integrated and implemented in the OneNet System. Any OneNet Participant will be able to test and evaluate its own service exploiting the OneNet Orchestration Workbench, that allows to integrate data coming from the OneNet Middleware and to implement a data pipeline orchestration.
Coordinet	TRL 6-8	TRL 6-8	TRL 6-8	TRL 6-8	**Policy, regulation and markets**[30] Exemplifications of good practices in collaboration between TSOs and DSOs through mutual market management and prioritizing available flexibilities to avoid sub-optimisation. Definition of market design options compatible with the collaboration good practice of mutual market management between TSOs and DSOs capable of valuating sources of flexibility connected to the transmission and/or the distribution grid compatible with EU Internal Energy Market. **Policy, regulation and markets**[31] Aggregation algorithms and platforms to coordinate the response of diverse end-users. Recommendations for an open and integrated market for local and regional flexibility providers such as aggregators, generators, consumers and energy storage for ancillary services for congestion management (it could take the form of different platform). **Policy, regulation and markets** Definitions of standardized products for ancillary services in terms of innovative technical platform solutions and novel concepts for payment processes and market agreements but also for market management and organisation, including the interrelations among different products at TSO and DSO levels. Definitions of building blocks of tools for TSO and DSOs to be used in each demonstration. **Policy, regulation and markets**[31] Organisational and managerial solutions for establishing a fully automated marketplace with transparent pricing for neutral and secure trading of available flexibility by intraday, day-ahead and long-term settlements including payment processes. **Policy, regulation and markets**[31] Identifications of a market platform concept to facilitate expansion to pan-European utilisation. Specifications of market platforms requirements and procurement schemes from demonstrations campaigns according to the proposed KPIs. Recommendations for long term solutions and platform algorithms that can be applied in other contexts beyond temporary capacity constraints.
BeFlexible	TRL 6-8	TRL 6-8	TRL 6-8		**Policy, regulation and markets** New business models for market parties based on energy services and revenue streams for consumers (across energy sectors and beyond, based on valorisation of the flexibility in their energy consumption) **Policy, regulation and markets** Increased availability of flexibility sources for TSOs and DSOs and enable them to develop markets for flexibility and interact with many distributed resources at the same time (via intermediaries such as energy suppliers or aggregators based on seamless and secure data exchange and interoperability) **Policy, regulation and markets** Contribution to better informed investment decisions by network operators and tariff setting models by NRAs, as flexibility markets and new business models can postpone or avoid new investments making better use of existing assets
SYNERGY			TRL 6-8	TRL 6-8	**Software** The Infrastructure Sizing and Grid Planning Application simulates the operation of the network and assesses the state of the network in terms of reliability, performance and power

[30] https://coordinet-project.eu/publications/deliverables
[31] https://coordinet-project.eu/publications/deliverables

					quality metrics. **Software**[32] The flexibility-based Network Management and DSO-TSO common operational scheduling Application facilitates network operators to perform short-term planning scheduling by leveraging the available flexibility from providers and network operators.
EUniversal	TRL 6-8	TRL 6-8		TRL 6-8	**Software (can be commercialized)**[33] UMEI - Universal market enabling interface (open-source Flexibility market mechanisms, products and platforms (nodes, n-side, centrica). It ensures a common way for market actors to interact with the flexibility markets, and amongst themselves, without the need of mediator components, such as data hubs or platforms, to procure system services for the distribution grid operation. This is done through a conceptual architecture design and the implementation of a standard, agnostic, adaptable, and modular combination of different APIs to link DSOs and market parties with flexibility market platforms, in coordination with other flexibility users. **Software** Select the asset offer that most effectively solves the grid constraint at the best price. Based on the set of tools to assess the state of the grid and the exact need of flexibility correctly and precisely in terms of quantity, time and location. Includes the combination of the cost-based redispatch approach (Redispatch 2.0) with the market-based approach in terms of daily operations, technical requirements and energy infrastructure as well as the effectiveness to solve grid constraints with the available resources at a reasonable price. **Software** Improved aggregation algorithms for local flexibility markets to aggregate small volumes of flexibility located in LV and MV grid to provide services for DSO. This small volume of flexibility is located at end-users premises. This aggregated flexibility will be offered to DSO via a flexible market operator (FMO).
TwinERGY	TRL 6-8	TRL 6-8	TRL 6-8	TRL 6-8	**Policy, regulation and markets** Market models for the interaction of TSOs and DSOs including interactions between central and local markets. Demonstrate Demand Side participation, consumer involvement and Local Energy Communities
SERENE		TRL 6-8		TRL 3-5	**Software (can be commercialized)** A control system for heat-pumps to provide ancillary services for enhancing distribution grid capacity or for flexibility provision to the overall balancing of the power system.
REgions		TRL 6-8			**Software (can be commercialized)** Short Term (intra hour) DER Forecasting solution to support the stabilisation of the energy system by improving traditional Virtual Power Plants (VPPs) and including regional and inter-regional services and further improving the participation on the markets.
HONOR	TRL 3-5	TRL 6-8	TRL 3-5	TRL 3-5	**Software**[34] A hybrid AC/DC-OPF model for optimal use of flexibility assets by shifting the load and charging and discharging storages based on market incentives. The model could be utilized as a flexibility market tool.
EPC4SES	TRL 6-8				**Software** DSOs receive load prognosis from buildings based on the CO2 prognosis. The project has sketched the collaboration using the transparent smart meter gateway, for demand responsive action. Data exchange is validated via GET/SOAP.

1.3 HLUC 3: Pan European Wholesale Markets, Regional and Local Markets

Project name	PPC 3.1	PPC 3.2	PPC 3.3	Key Exploitable Results
OneNet	TRL 6-8	TRL 6-8	TRL 6-8	**Software** Coordinated TSO-DSO Flexibility Market Simulator and Market Clearing Module ensures the flexibility needs of the system operators are met at the minimum possible cost while abiding by the grid

[32] https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5df29b2f4&appId=PPGMS
[33] https://euniversal.eu/wp-content/uploads/2022/08/EUniversal_D2.6_UMEI.pdf
[34] https://doi.org/10.1109/SEST50973.2021.9543104

				constraints of all the systems involved, as well as the technical constraints of the bids. **Software** The OneNet Connector combines the International Data Spaces principles with the advantages of the FIWARE ecosystem ensuring a seamless and secure data exchange in a completely end-to-end decentralized approach. It is ready-to-go for being deployed and integrated in any already existing platform and offers user-friendly interfaces (both as REST APIs and GUI) enabling users and platforms to exchange data. **Methodology** Cross-Platform-Services Catalogue is a methodology and tool to define and describe Cross-Platform-Services in the electricity domain and their underlying Business Objects that enables the harmonised data exchange between different platforms and actors.
Coordinet	TRL 6-8	TRL 6-8	TRL 6-8	**Methodology** Definition of market design options compatible with the collaboration good practice of mutual market management between TSOS and DSOs capable of valuating sources of flexibility connected to the transmission and/or the distribution grid compatible with EU Internal Energy Market **Methodology** Definitions of standardized products for ancillary services in terms of innovative technical platform solutions and novel concepts for payment processes and market agreements but also for market management and **Methodology** Presentations of organisational and managerial solutions for establishing a fully automated marketplace with transparent pricing for neutral and secure trading of available flexibility by intraday, day-ahead and long-term settlements including payment processes
BD4OPEM	TRL 6-8	TRL 6-8	TRL 6-8	**Software** Flexibility aggregated service - use of algorithms to support decision making based on technic and economic criteria. **Software** Observability service - process to determine the actual observability LV network based on fact (smart metering). Topology service - retrieval of LV network topology and estimate grid parameters when no/no realistic data is available. Together with validated revenue stream models they both showcase a strong potential to generate a positive NPV value over a five year time period.
EUniversal	TRL 6-8	TRL 3-5		**Policy, regulation and markets**[35] The regulatory recommendations include explanation how six different flexibility tools flexibility can be combined and discusses and why regulatory sandboxes and market power remedies can be important for the optimal implementation of the mechanisms. Regulatory sandboxes are proposed as a solution for regulators to test the impact of different implementation options in practice. **Methodology**[36] Business model innovation and CBA methodologies defines the business models of the EUniversal demos and examines distribution planning methodologies in Europe. The business models are built using Osterwalder's business model canvas. Second, the deliverable describes the evaluation of distribution planning methodologies in Europe, with a focus on the trade-off between flexibility and network investments. **Methodology** [37] A comprehensive methodology for the design of (dynamic grid tariffs able to mitigate both short-term and long-term congestions. The qualitative analysis incorporates the conceptual framework of establishing grid tariff designs which includes the different design dimensions, provides a review of dynamic tariff design methodologies and best practices and studies the congestion needs that have to be addressed. A simulation environment is used to assess the impact of the different tariff designs identified in the qualitative assessment on end-consumers on the one hand and on the overall power system on the other hand, assessing the effects of the introduced tariffs on alleviating network congestions and voltage issues. **Methodology** An improved methodology to perform a simulation-based quantitative SRA (scalability and replicability analysis) of use cases related to applying local flexibility markets to prevent or alleviate

[35] https://euniversal.eu/wp-content/uploads/2022/01/EUniversal_D10.3_Regulatory-recommendations-for-flexibility-options-and-markets.pdf
[36] https://euniversal.eu/wp-content/uploads/2021/08/EUniversal_D10.1_Business-model-canvas-and-comparison-of-CBA-methodologies.pdf
[37] https://euniversal.eu/wp-content/uploads/2022/08/EUniversal_D5.2_Methodology-for-dynamic-distribution-grid-tariffs-.pdf

				distribution grid constraints. New modelling capabilities will be developed to enable a more efficient use of flexibility and the analysis of additional use cases. The following developments are being made: joint use of active and reactive power, comparison of market-clearing by a MO vs. DSO determined flexibility activations (involving different grid-modelling approaches, and solving jointly congestions and voltage problems).
FEVER	TRL 6-8	TRL 3-5	TRL 3-5	**Policy, regulation and markets**[38] The market mechanisms for day-ahead and intra-day flexibility trading are intended to demonstrate the effectiveness of mitigating issues of the distribution grid with flexibility trading market mechanisms. The target is to deliver scalable operational mechanisms compatible with EU electricity markets. The proposed day-ahead market mechanism consists of a two-level iterative mechanism. First the master social welfare optimisation problem is solved on the Transmission level, determining the electricity prices and market schedules. Then, at local level, each DSO solves a local cost minimization sub-problem, introducing the technical constraints of their distribution grid and the flexibility offers they have gathered by Flexibility Aggregators. The updated market schedules will be resubmitted to the Market Operator in order to rerun the market and produce the final prices and market schedules. **Software**[38] The Intraday Market Application is a web application related to the intraday market mechanism implemented in FEVER. The intraday market is a market positioned at the level of distribution market that operates via a continuous trading mechanism. It is complemented with a power flow simulator and a grid disturbance simulator that enable testing/validation of the solution. The Intraday Market Application provides functionality related to the realization of test related to intraday market operation. It also acts as a prototype for a real-world application. The target TRL at the end of the project will be 4. **Software**[38] The P2P-Flexibility trading Platform mainly consists of distributed applications (DAPPs) enabling P2P trading: the Community Management DAPP, the FlexCoin DAPP, and the FlexTrading DAPP. The FlexTrading of P2P-FTP is a distributed application (DAPP) delivering a blockchain-based marketplace, where its participants (peers) are able to trade flexibility/energy products without an intermediary. It allows configuring trading parameters (contracts), monitoring and tracking statuses, histories, and states of several parallel P2P markets and individual peers, offering options for connecting third-party trading agents of market participants – for submitting or revoking bids automatically. It is planned to raise TRL from 1 to 8.
X-FLEX	TRL 6-8	TRL 6-8	TRL 6-8	**Software** Market flex tool enables final consumers and prosumers to access and participate, individually or through an intermediate party, on different energy markets, such as wholesale market, local energy market or ancillary services market for TSO or DSO.
TwinERGY		TRL 3-5		**Software** A fully decentralised energy markets including peer-to-peer trading of energy and balancing services, while maximising service quality delivered to end consumers.
MAGNITUDE	TRL 3-5 (only partially related to this PPC)			**Policy, regulation and markets** Innovative market designs to enhance synergies between electricity, gas and heat energy markets, implemented on a market simulator. Policy strategy and recommendations in a pan-European perspective
SP2G		TRL 3-5		**Methodology**[39] Several studies were conducted that applied the tools form the SP2G toolbox to analyse for instance the potential of P2G technology to provide flexibility under certain market conditions.
BioLens			TRL 9	**Software (can be commercialized)** A system that allows for fast and easy mass balance generation at Biomethane production facilities. Additionally, the platform will generate the necessary Proof of Sustainability (PoS) document packages that are mandatory to follow all biomethane production to ensure sustainability and document GHG reduction by use of the fuel. **Policy, regulation and markets** A new market, regulatory and policy frameworks for delivering low-emission, low-cost, secure, reliable, and resilient whole-energy systems.

[38] https://fever-h2020.eu/data/deliverables/FEVER_D8.5_-_Report_on_business_models_assessment_market_analysis_regulatory_context_assessment_and_preliminary_exploitation_assessment_.pdf
[39] https://superp2g.eu/value-of-power-to-gas-as-a-flexibility-option-in-integrated-electricity-and-hydrogen-markets/

				The project will increase data security compared, low the operation costs of biomethane production by automating the processes.
REgions	TRL 3-5			**Methodology**[40] Enable development of operation of short term (seconds-minutes-hours) fully decentralized energy markets including stability, balancing and energy exchange, while managing network congestions

1.4 HLUC 4: Massive Penetration of RES into the transmission and distribution grid

project name	PPC 4.1	PPC 4.2	PPC 4.3	PPC 4.4	Key Exploitable Results
OSMOSE		TRL 6-8	TRL 6-8		**Software**[41] Demonstration of close to real time cross border flexibility exchanges between Slovenia and Italy. **Software**[42] - Enhanced Line Dynamic – Thermal Rating - Implementation of Automatic Voltage Control on Wind farm + BESS. - Flexibility by large scale consumers. **Software**[43] Quantified analysis of the impact of more renewable on forecast errors and market operation
IElectrix		TRL 6-8	TRL 6-8	TRL 6-8	**Software (can be commercialized)** Energy Management System for Energy Communities., SCADA system, Direct Load Control system, Power Management System
NESOI	TRL 9	TRL 9		TRL 9	**Policy, regulation and market**[44,45,46] A coordination & support action framework aiming at facilitating the clean energy transition on EU islands and going one step forward by providing islands with training, technical support, cooperation opportunities and robust funding opportunities to concretely convert Island Sustainable Energy Action Plans into Renewable Energy Sources (RES plants, building and energy infrastructure retrofitting, energy bill reduction, local job creation, etc.).
FARCROSS	TRL 6-8	TRL 6-8	TRL 6-8	TRL 6-8	**Software** Dynamic Line Rating (DLR) solutions for the optimal exploitation of Cross – Border transmission lines aim is to build up a grid monitoring system on cross-border power lines, and then to verify their operational benefits in terms of increased grid capacity and equipment health monitoring tracking, thus achieving a higher level of resilience and security **Software** Modular Power Flow Control (MPFC) Technology is focused on increasing cross-border network capacity in the SEE region. The aim is to deploy MPFC technology at an optimal location on the network to reduce congestion and unlock more capacity on the existing network. The operational, cost, and societal benefits will be evaluated over the project, including impact on congestion, network capacity, and renewable integration. **Software** Co-optimized cross-border power transmission capacity auction algorithm (OPTIM-CAP) deals with day-ahead capacity allocation for regional cross– border trading, by utilizing available transfer capacities for balancing capacity procurement and for energy trading, simultaneously. It extends current, energyonly transfer capacity auction algorithms, thus assuring broader system security and the more effective and valuable allocation of the grid capacity.

[40] https://www.regions-project.info/results/
[41] https://www.osmose-h2020.eu/wp-content/uploads/2022/04/OSMOSE-D6.5-Demonstration-tests_20220427_V1.pdf
[42] https://www.osmose-h2020.eu/wp-content/uploads/2022/04/OSMOSE-D5.6-Final-report-summarizing-main-demo-results_20220427_V1.pdf
[43] https://www.osmose-h2020.eu/wp-content/uploads/2022/04/D2.4-Quantitative-analysis-of-selected-market-designs-based-on-simulations-3.pdf
[44] https://www.nesoi.eu/system/files/private/nesoi/Brochures/nesoi_-_hps-_z-114_c.pdf
[45] https://www.nesoi.eu/system/files/private/nesoi/Brochures/nesoi_-_wire-k_-_z-177-compressed.pdf
[46] https://www.nesoi.eu/system/files/private/nesoi/Brochures/nesoi_-_arindec-grancanaria_-_z-176_-_final_en.pdf

					Software EUROPAN platform for improved planning, operation and resource utilization on a TSO level outlines the architecture and development of EUROPAN, a forecasting platform that TSOs can utilize for more efficient, secure and sustainable operation of their assets. Through extensive data acquisition and analysis, EUROPAN will upgrade the existing coordination and communication schemes employed, achieving flexible and sustainable performance. **Software** Wide Area Protection, Automation and Control (WAMPAC) solutions for the optimal exploitation HV transmission lines investigates the grid stability and security criteria that will act as service requirements for a complete WAMPAC solution. A detailed software architecture is then configured, aiming at improved control and monitoring of the Greek HV Transmission assets while strengthening the system's resilience to transient stability.
SYNERGY		TRL 6-8		TRL 6-8	**Software**[47] For PPC4.2 - RES Operators and Aggregators Toolset - The Operational Scheduling Optimiser (OSO Application will be responsible for providing the forecasting the energy production analytics for different time horizons for large PV plants using climatic data forecast. This will allow the characterisation of the energy production profile within a certain time range in advance using the pre-trained machine learning model. **Software**[47] For PPC4.4 - Network Management Platform KER - The Infrastructure Sizing and Grid Planning Application simulates the operation of the network and assesses the state of the network in terms of reliability, performance and power quality metrics.
BD4OPEM		TRL 6-8		TRL 6-8	**Software** Asset and investment planning modelling tool for selecting technologies contributing to grid reinforcement at any given time. Grid disturbance simulations understands origins of disturbances in the grid and evaluate risks to improve supply quality. Together with validated revenue stream models, and they both showcase a strong potential to generate a positive NPV value over a five year time period.
GIFT	TRL 6-8				**Software**[48,49] Virtual Power System will utilise advanced technologies for automatic trading of energy flexibilities in real time. It uses Flexible Energy Management System and Flex Agents installed at DR provider. **Software**[48] Prediction System is a dynamics and mathematic model for the energy supply (renewable and non-renewable) and demand (building, transport, production, etc.) **Software**[48, 50] Based on actual data measured on the network, the service offers: (1) a real-time estimate of the load of MV/LV substations and LV outgoing lines, (2) a real-time estimate of the voltage at each meter, (3) a prediction of voltage and current stresses for the next ten minutes
EUniversal		TRL 6-8		TRL 6-8	**Software (can be commercialized)** Smart grid tools to improved observability and control, operation and planning strategies: optimal flexibility bid recommender (by N-side), resilience-informed planning of distribution networks (by University Cyprus), Data-driven State estimation (DdSE by INESC-TEC), Data-driven voltage control (DdVC by INESC-TEC), Day-ahead LV congestion Forecasting tool (by Vito), Dynamic Line Rating System for OHL operation (DLR4OHL by IEN) **Methodology (can be commercialized)** System-level assessment framework for flexibility quantification (by ENGIE), impact LV phase and topology mapping tool (by INESC-TEC), MV network maintenance planning tool (by INESC-TEC), LV flexibility needs assessment (by KU Leuven), phase identification under low observability (by KU Leuven). **Methodology** The multi-level preventive management framework enables DSO procurement of day-ahead market-based flexibility services for congestion management and voltage control. An iterative procedure is adopted for enabling LV flexible resources to help solving technical

[47] https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5df29b2f4&appId=PPGMS
[48] https://www.gift-h2020.eu/delivrables/
[49] https://www.inea.si/en/resitve/demand-side-management/
[50] https://odit-e.com/solutions/

					constraints in the MV network, while ensuring that no further technical problems result from flexibility provision. It enables the selection of flexibility bids also considering the impact of flexibility mobilization in both LV and MV network. It includes the validation of the selected bids by the DSO. This framework is compatible with different market designs, both continuous or auction based, with day-ahead and/or intraday activity.
OMEGA-X		TRL 6-8			**Methodology** The expected KER is advanced multi-stakeholder services for Solar plant management, involving PV panel manufacturers, inverter manufacturers, plant operators and DSOs.
FEVER	TRL 3-5	TRL 6-8	TRL 6-8	TRL 3-5	**Software (can be commercialized)** [51] The DSO Toolbox is an overaching application incorporating forecasting and decision support algorithm, providing a user interface for distribution grid operator. It's aim is to support the identification of grid issues (i.e. faults, violation of thermal limits or voltage level in short-term/medium term and suggest a mitigation action plan based on grid flexibility. In case no violations are detected, grid flexibility is leveraged for minimizing grid losses. **Software** [51] The algorithms for LV grid observability (or Local Observability Services (LOS)) enable the DSO to control normally un-observable LV grids. The tool leverages AI and data-based techniques to carry out the grid monitoring task through the estimation of the network state. It is planned to raise the TRL from 5 to 7. **Software** [51] A short-term (hour-ahead) and medium-term (day-ahead) PV generation forecasting methodology was developed based on a non-parametric artificial neural network (ANN) model. The ANN model was optimized according to the input and output parameters (TRL 6). Additionally, the optimized model was evaluated against data sets from the outdoor testing facility (OTF) of the University of Cyprus (UCY) and also by providing PV production forecasts for evaluation to utilities and PV plants (TRL 7). The fully optimized solution will be used as a service by utilities and other stakeholder to derive hour-ahead and day-ahead PV production forecasts (TRL 8).
ACCEPT	TRL 6-8				**Software (can be commercialized)** Energy community tools (digital tools for assisting energy communities in assuming energy market roles, such as the role of the aggregator, the retailer and the ESCo, as well as offer services to their community members. **Software (can be commercialized)** Consumer Digital Twin which delivers a unified modelling approach that enables the causal correlation of consumer behaviour, energy assets and vectors that relate to common building amenities via a building/resident-specific calibrated model that allow a market actor to understand, anticipate and forecast energy/flexibility behaviour at the connection point to the grid. **Software (can be commercialized)** The On-Demand Flexibility Management module which delivers a resident optimized, intelligent and predictive integrated energy control system that guarantees a healthy and comfortable indoor environment while offering dispatchable demand/supply flexibility to the energy community. It will support several objectives and constraints introduced by present and forecasted weather conditions and consequent RES fluctuation, energy demand, building occupancy and activity patterns, human comfort preferences, building thermal inertia, energy prices, overall energy storage capabilities (actual and virtual energy storage as well as building devices operational constraints and shifting/curtailing capabilities. **Software (can be commercialized)** The District Asset Management component that will be able to accurately forecast the performance of community-level assets and also bi-directionally interface with them for sending control commands. **Software (can be commercialized)** The ACCEPT Building Information Management Layer which is the component responsible for

[51] https://fever-h2020.eu/data/deliverables/FEVER_D8.5_-_Report_on_business_models_assessment_market_analysis_regulatory_context_assessment_and_preliminary_exploitation_assessment_.pdf

					interfacing with the physical, real-world assets of the building in a secure, efficient, reliable and cost-effective manner and collecting the information and pre-processing it for other system components. **Software (can be commercialized)** The ACCEPT Non-Intrusive Load Monitoring (NILM – embedded in the Building Information Management Layer – which is an innovative framework that enables residential energy monitoring towards energy sustainability. This method is also known as energy disaggregation, as single-point sensing is utilised in order to extract appliance level energy consumption. **Software and data base (can be commercialized)** The ACCEPT citizen application that allows citizens to access energy and non-energy services through their smart phones, participate in energy demand response schemes, monitor their energy performance and facilitates citizen engagement.
X-FLEX	TRL 6-8	TRL 6-8	TRL 6-8	TRL 6-8	**Software (can be commercialized)** GridFlex tool for grid and microgrid operators aims to prevent congestion (voltage and current issues) and power quality problems with the increasing share of intermittent RES, giving special attention to the potential grid problems due to the impact of extreme climate events. The tool will use flexibility as an alternative to network reinforcement when it is more cost-efficient than traditional reinforcement of the network.
IANOS	TRL 3-5	TRL 6-8	TRL 6-8	TRL 3-5	**Policy, regulation and market** [52] Commercial uptake of heat batteries, smart building control equipment, intelligent control of multi-protocol field level equipment, rollout of V2G chargers, innovative systems from local Aggregators/ VPP integrators, intelligent aggregation clustering and behind the meter assets scheduler. Commercial uptake and promotion of community owned solar farms, in parallel with developing crowdfunding-based business models, development of an exploitable business concept for community owned hybrid solar – fuel cell solutions **Policy, regulation and market** [52] Novel services on optimising response times for voltage and frequency control from variable-scale storage assets; new services on advancing and commercialising the iVPP platform to optimise the use of the electricity grid and provide ancillary services; solar farms connected to industrial batteries, that saves on grid connection and profile costs, able to provide ancillary services- combining the innovative elements above will increase financial attractiveness. Development of the EMS, creating new revenues streams for the owners, increase self-consumption and alleviate grid challenges for the DSO; develop energy flexibility services; and implement secure IT platforms; Provide Ancillary services to the TSO using a VPP with several RES and storage options **Hardware** [52] iVPP DSM module (implemented within the behind-the-meter assets scheduler; HEMS/BEMS that allow the centralized operation of all grid assets (small or big scale by the VPP, to optimize their load profiles considering the forecasts with the goal of minimizing RES curtailment; Congestion management from DSM and smart grid elements can be used by DSO's on energy islands or other locations with a weak grid/ grid-connection; The VPP framework can also use the available flexibility to prevent congestion on the mainland and optimize the revenue streams of the owner's flexibility. **Software** [52] V2G charging stations providing VPP operators the opportunity to fine tune the EV charging pattern therefore minimizing RES curtailment and being able to provide services to the grid. VPP operator use of smart charging and V2G to optimize the energy consumption and storage in the VPP framework, increasing e-vehicle owners who can choose smart charging to maximize RE usage, paying a lower fee to the owner of the station and subsequently the owner of RES.
TIGON	TRL 6-8	TRL 6-8	TRL 6-8	TRL 6-8	**Policy, regulation and market** Project objectives are: (1) to contribute to the creation of a structured view of obstacles to innovation for the deployment of DC grids, (2) to benefit from the continuous knowledge sharing among projects and (3) to participate in the delivery of conclusions and recommendation for the common voice of the sector.
NewSETS	TRL 6-8			TRL 3-5	**Hardware (can be commercialized)** Seasonal sand-based heat storage provided by Polar Night Energy Oy, a commercial plant running in Finland. The solution uses sand as a storage medium, excess of electricity is used

[52] https://ianos.eu/results/

					for heating up the sand to a high temperature. The stored energy can be used as heat for industrial needs to district heating. **Hardware (can be commercialized)** Pumped Hydro Storage is a technology to enable reservoirs to be constructed underground in mines (UPHS). Through the solution, mines can instead become assets for large-scale energy storage.
ZEHTC	TRL 9	TRL 6-8		TRL 6-8	**Hardware (can be commercialized)** [53] Hydrogen storage and re-electrification in gas turbines to support grids with high renewables content. **Hardware**[53] Gas-turbines are matured, and technical barriers are removed to enable operation with climate neutral fuels. This is demonstrated for hydrogen and also other green fuels. Gas turbines shall be 100% hydrogen capable by 2025. The solution is shown to be attractive for electrical grids with high RES content to allow for resilience and stability.
RE-EMPOWERED		TRL 6-8		TRL 9	**Software** ecoPlanning is a tool that supports performing simulations for assisting the decision maker for the mid-term planning and expansion of Non-Interconnected Islands (NIIs power systems. To this purpose, ecoPlanning performs four types of simulations-studies: 7-Year Energy Planning for assessing the adequacy of the generation units for serving the electrical load, RES Hosting Capacity for assessing the hosting capacity of Renewable Energy Sources (RES production units, Monthly Energy Balance for assessing the satisfaction of a specific load timeseries energy balance equation, Interconnections for assessing the implementation of interconnections with other power systems. The innovation of the KER lies in expanding tools functionalities throughout the RE-EMPOWERED project, by considering the flexibility provided by demand response (DR and other energy carriers, such as cooling, and updating the exported reports and optimize the interconnection study for multi power system cooperation. The Demand Response Functionality of ecoPlanning offers Peak Shaving, Increasing the RES penetration, Exploiting the flexibility of EV charging, Application of a demand response scheme according to the user's preferences. **Software** ecoEMS tool assists to operate the Power System economically by scheduling different energy vectors while satisfying the wide range of operational, security and availability constraints. The flexibility of different energy vectors like cooling, heating and electric vehicles are incorporated to be scheduled in the most efficient and economic operation **Software** ecoMicrogrid is an EMS for microgrids where synergies with different energy vectors like water management and cooling systems will be considered by the advanced management algorithms deployed targeting to optimize the performance. All the components of the microgrid will be monitored by the ecoMicrogrid, addressing the required actions (load shedding, diesel generator start-up/shutdown, RES power curtailment to achieve the desired optimisation goals.
SP2G	TRL 3-5	TRL 3-5	TRL 3-5	TRL 3-5	**Software** The 5 tools that were developed analyse the potential of P2G systems on different levels. These levels split up in regional focus, national focus and EU focus. Those tools were developed in cooperation with need owners and by the end of the project will be made accessible to the broader public to lower the barriers for P2G systems being installed which contributes to the over-all efficiency and balancing of the energy system with energy storage and transfer of green energy to end use sectors.
AISOP		TRL 3-5		TRL 3-5	**Software** Data-driven dynamic tariff setting for distributed energy resources for DSO operational planning to indirectly change the behavior of consumers and prosumers **Software** Integrated congestion detection and forecasting (local generation and electrified demand such as EV charging approach) into DSO operational planning **Software** Integrated anomaly detection (e.g., equipment failure, grid faults) as part of risk analysis to DSO operational planning

[53] www.zehtc.org

ANM4L	TRL 6-8			TRL 3-5	**Software**[54] ANM brings a paradigm shift regarding risk considerations for operation and planning of distribution grids, going into full utilization of grid capacity by removing safety margins. ANM enables use of the full grid capacity with respect to voltage limits and current limitations in terms of fixed or dynamic ratings, by relying on real-time control. Thus, from the grid operator perspective the amount of RES that can be safely connected is unlimited, where the operational risk for damaging limit violations is zero. However, relying on curtailment or other flexibility increases the financial risk. As more RES is connected, the need for temporary curtailment or flexibility services rises, and with this the uncertainty of costs for procuring flexibility in the long-term.
RESili8				TRL 3-5	**Software** RESili8 will develop novel tools for computing resilient deployment strategies of software and devices. Previous deployment strategies based on physics-based models alone assume worst-case behavior of all devices to ensure safety during reconfiguration. By incorporating actual network data, it will be possible to exclude very improbable scenarios to improve performance and avoid overprovisioning of resources.
Power-2-Transport	TRL 3-5	TRL 3-5			**Methodology**[55] Methodology to investigate whether synthetic CH4 could be a feasible alternative for buses currently powered by fossil fuels, a dynamic model was built for discrete-event simulations of PtG technology integrated into an urban AD plant designed to supply biomethane as fuel for bus fleets.
EPC4SES		TRL 6-8		TRL 6-8	**Methodology** The project has worked out a methodology to increase the yield for renewable energy using model predictive control employing a digital twin based on data from the energy performance certification.

1.5 HLUC 5: One stop shop and Digital Technologies for market participation of consumers (citizens) at the center

Project name	PPC 5.1	PPC 5.2	PPC 5.3	PPC 5.4	Key Exploitable Result
InterConnect	TRL 6-8	TRL 6-8	TRL 6-8	TRL 6-8	**Software** [56,57] The solutions developed within the scope of Interconnect will allow a digitalization of homes, buildings and electric grids based on an Internet of Things (IoT) architecture. By including digital technologies (Artificial Intelligence, Blockchain, Cloud and Big data) based on open standards, such as SAREF, it will guarantee the interoperability between equipment, systems and privacy/cybersecurity of user data. The solution is comprised of several parts: DSO Interface, Semantic Interoperability Framework (SIF), Ontology, Service Store, Knowledge Engine, Generic Adapter, Peer to Peer Marketplace.
OneNet	TRL 3-5			TRL 3-5	**Policy, regulation and markets** Defined Business Use Cases for all demonstrators in the four clusters (Northern, Southern, Western, Eastern) and to evaluate them to ensure that are well-positioned and linked with the priorities set by the Green Deal and respectively with the project's strategic objectives.
BeFlexible	TRL 6-8	TRL 6-8	TRL 6-8	TRL 6-8	**Software (can be commercialized)** Energy and Value-Added Services: • CC-E-BE Basic Energy Services: a) Individual optimisation, including energy efficiency packages, energy consumption optimisation based on tariffs, peak shaving, storage optimisation, individual self-consumption (SC optimisation). b) Collective self-consumption and operation optimisation for local energy and commercial flexibility sharing/trading, including energy sharing mechanisms, energy management systems for energy communities, local energy markets, energy community flexibility aggregation, market access services • CC-E-AE Advanced Energy Services for Energy Communities: a) Resources and community sizing b) Estimation of the flexibility surplus in flexibility markets c) Billing and invoicing within the community and collective benefits sharing d) Shared ownership business models

[54] https://anm4l.eu/wp-content/uploads/2022/11/ANM4L-Key-messages-2p.pdf
[55] https://www.sciencedirect.com/science/article/pii/S0196890422003703
[56] https://gitlab.inesctec.pt/groups/interconnect-public/-/wikis/home
[57] https://interconnectproject.eu/about/#results

					e) Intelligent pairing between consumers and producers f) Crowd charging g) Maintenance services for community assets • CC-E-FX Flexibility optimisation for grid services: Flexibility assessment and flexibility provision tools for DSO and TSO grid services, estimation of the elasticity of consumers to enhance demand response programs, aggregation (VPP of DER for BRP balancing. **Software (can be commercialized)** • Cross-Sector Services (CC-CS) a) CC-CSHC Smart buildings and heating/cooling: power and heat and cooling smart management systems coupling for flexibility b) CC-CSMO Mobility: power and EV mobility coupling for flexibility c) CC-CSHE Health & Safety: exploiting energy data for the provision of health services **Software (can be commercialized)** • Customer enablement Services (CC-CE) a) CC-CEDM Data Market: data marketplaces for energy data monetisation for energy and cross-sector services b) CC-CEGM Gamification: gamification strategies for customers engagement in energy efficiency and flexibility provision c) CC-CETR Energy Traceability: flows tracing systems for real-time assessment of the origin of electricity for a specific end use **Policy, regulation and markets** New business models for market parties based on energy services and revenue streams for consumers (across energy sectors and beyond, based on valorisation of the flexibility in their energy consumption. Increased application of digital technologies to support consumers and market parties to market their flexibility. Increased consumer engagement and acceptance
NESOI	TRL 9			TRL 9	**Policy, regulation and market**[58,59] A coordination & support action framework aiming at facilitating the clean energy transition on EU islands and going one step forward by providing islands with training, technical support, cooperation opportunities and robust funding opportunities to concretely convert Island Sustainable Energy Action Plans into Renewable Energy Sources (RES plants, building and energy infrastructure retrofitting, energy bill reduction, local job creation, etc.).
PARITY		TRL 6-8			**Software (can be commercialized)** The product/service allows to automatically collect and store data from buildings/devices and it integrates device communication protocols and control software **Software** IoT Gateway combined with the use of IML Cloud and the LEM/LFM Repository software for secure collection, processing and storage of measurements, flexibility data.
OMEGA-X	TRL 6-8		TRL 6-8	TRL 6-8	**Software** The expected KER is Energy Data Space where energy stakeholders will be able to share data in a trusted, secure and sovereign way, allowing the deployment of advanced digital services.
LocalRES	TRL 6-8		TRL 3-5	TRL 6-8	**Software** MEVPP capable of providing services including collective services such as collective self-consumption, local energy market services such as voltage control and congestion management, and energy market services such as ancillary services. The MEVPP also includes a model predictive control (MPC algorithm) to manage flexible assets. **Methodology** Methodology for co-design and participatory processes, aiming at promoting the involvement of citizens in the co-design of solutions (e.g. digital platforms and therefore maximizing their engagement).
IANOS	TRL 6-8	TRL 6-8	TRL 6-8	TRL 6-8	**Policy, regulation and market** Commercial uptake of heat batteries, smart building control equipment, intelligent control of multi-protocol field level equipment, rollout of V2G chargers, innovative systems from local Aggregators/ VPP integrators, intelligent aggregation clustering and behind the meter assets scheduler. Commercial uptake and promotion of community owned solar farms, in parallel with developing crowdfunding-based business models, development of an exploitable business concept for community owned hybrid solar – fuel cell solutions.

[58] https://www.nesoi.eu/system/files/private/nesoi/Brochures/nesoi_-_e-lafiti-_z-091_compressed.pdf
[59] https://www.nesoi.eu/system/files/private/nesoi/Brochures/nesoi_-_save_-_z-056_c.pdf

					Hardware[60] iVPP DSM module (implemented within the behind-the-meter assets scheduler; HEMS/BEMS that allow the centralized operation of all grid assets (small or big scale by the VPP, to optimize their load profiles considering the forecasts with the goal of minimizing RES curtailment; Congestion management from DSM and smart grid elements can be used by DSO's on energy islands or other locations with a weak grid/ grid-connection; The VPP framework can also use the available flexibility to prevent congestion on the mainland and optimize the revenue streams of the owner's flexibility.
SENDER	TRL 6-8				**Software (can be commercialized)** A smart home solution that covers DR/flexibility, EV charging, building as a battery (thermal storage, hot water boiler optimisation, smart home appliances) **Policy, regulation and market** An integrated smart home system that goes beyond energy services and offers the opportunity to build new, integrative business models.
TwinERGY	TRL 6-8	TRL 6-8	TRL 6-8	TRL 6-8	**Methodology** Guidelines for the participation of prosumers and energy communities in electricity markets. Guidelines for the implementation of incentives by dynamic prices, regulated tariffs and other market incentives. 9 Software tools to automatically calculate flexibility of different assets and trigger demand response campaigns
iFLEX	TRL 6-8			TRL 3-5	**Software** An intelligent personal assistant (iFLEX Assistant) to support the consumer in managing when and how to be flexible and participate in demand response. The assistant is a software agent which handles all the complexity of the system interactions, and which optimises the comfort, energy cost and environmental footprint on behalf of the consumer and according to consumer wishes. While the consumer has full control of the flexibility, the operation can be fully automated so that the consumer does not have to do anything on a daily basis. Since the consumer is a determining factor in the creation of sustainable demand response, the project applies a user-centred approach, engaging the consumer in the design of the flexibility management service with special focus on the user experience, covering not only usability aspects but also analysing the motivational drivers and barriers.
RE-EMPOWERED	TRL 6-8	TRL 6-8			**Software** ecoDR is a tool for the consumers and energy distributors to measure the energy consumption in real time and enables energy distributors to control/limit the consumption of electricity. The key innovation is the existence of both energy and load limiter simultaneously, two output ports (critical and non-critical for enabling controlled consumption of electricity, variable cut-off delay time between two successive overload events and visible indicator for poor power factor. **Software** ecoCommunity provides: Information on real-time energy consumption and energy pricing to the consumers. Coordination of private and communal load usage based of generation forecast. Generation and payment of consumption bills. Platform for reporting problems faced by consumers and share experiences. Access to help and support materials for the use and maintenance of ecoTools sets.
SONDER	TRL 3-5	TRL 3-5		TRL 3-5	**Methodology**[61] The Technical Framework on Local Energy Communities (TF-LEC) is a structured compilation of informative and normative specifications compiled according to the IES (Integrating the Energy System. The TF-LEC shall enable the normalised use and application of existing standards and practices. Thereby, and in particular because this document is public, interoperability among cooperative but independently developed products and systems shall be enabled. **Methodology** A guide regarding community storage for energy communities was created, which provides with an overview on community storage and relevant aspects, such as choosing the right storage, the installation and the operation. Furthermore, it includes experiences from the installation of battery storage, such as the most common problems or difficulties during installation and how these can be counteracted. The guide focuses on the situation in Austria but may contain relevant information for parties from other countries as well.
GENTE	TRL 3-5	TRL 6-8		TRL 6-8	**Software** A goal is to develop a toolbox for communities and community managers for resource optimisation and community federation.
TOP-UP	TRL 3-5				**Methodology** Integrating the (psychological motivations and preferences of end users into energy systems modelling (in the form of self-transcendence and self-enhancement values) has important

[60] https://ianos.eu/results/
[61] www.iesaustria.at

					implications for the control of the system. Namely, there is a big discrepancy between the technical potential of a control scheme (i.e., what is possible) if flexibility is fully adopted and what is psycho-socially feasible (i.e., what is possible) when considering user preferences and motives. Our results show the importance of considering the (psychological) motivations and preferences of end users when modelling energy systems.
FinSESCo	TRL 3-5		TRL 3-5	TRL 3-5	**Software** Energy Contracting Platform and XML Parser for data from Energy Performance Contracting
EPC4SES	TRL 3-5			TRL 3-5	**Policy, regulation and market** The project has worked out a collaboration model between building owners and market partners, allowing to increase the share of renewable energy in the grid/network by applying demand response.

1.6 HLUC 6: Secure operation of widespread use of power electronics at all systems levels

Project name	PPC 6.1	PPC 6.2	PPC 6.3	PPC 6.4	Key Exploitable Results
OSMOSE	TRL 6-8				**Methodology** [62] Performance assessment of grid-forming converters through simulations and demonstration. **Methodology** [63] Quantitative assessment of the advantages of using a grid forming BESS for providing frequency regulation based on the local grid measurements. Experimental results are obtained with a 720 kVA/500 kWh BESS connected to the 20 kV distribution grid of the EPFL campus. **Methodology** [64] Definition of a suitable test matrix, compliance criteria and a power hardware in the loop test bench for the RTE-Ingeteam demonstrator Factory Acceptance Test, validated with experimental results. **Methodology** [65] Stable association of the grid-forming control with different DC side power sharing and energy management strategies for a hybrid energy storage system. **Methodology** [66] A new current limiting method based on the well-known threshold virtual impedance (TVI that keeps the voltage source behaviour associated to the grid forming (GFM capability, even when the current limit is reached, while reducing the voltage unbalance according to user-defined settings.
EUniversal			TRL 6-8		**Hardware (can be commercialized)**[67] New intelligent MV / LV substation (Flexible Substation) will ensure advanced monitoring and control of low voltage grids, autonomous control and monitoring of photovoltaic (PV) generation, energy storage and electric vehicle charging infrastructure, faster failure detection, as well as maintaining the grid voltage within acceptable limits, especially with high PV saturation. Such a solution leads to the creation of tools enabling the future provision of flexibility services, improve grid observability and avoid unnecessary investments in the LV network.
IANOS				TRL 6-8	**Policy, regulation and market** [68] Commercial uptake of heat batteries, smart building control equipment, intelligent control of multi-protocol field level equipment, rollout of V2G chargers, innovative systems from local Aggregators/ VPP integrators, intelligent aggregation clustering and behind the meter assets scheduler. Commercial uptake and promotion of community owned solar farms, in parallel with developing crowdfunding-based business models, development of an

[62] https://arxiv.org/abs/2106.03536
[63] https://arxiv.org/abs/2110.05392
[64] https://www.researchgate.net/publication/348818638_OSMOSE_WP3_Factory_Acceptance_Test_of_the_grid_forming_demonstrator
[65] https://www.researchgate.net/publication/337561687_Upgrade_of_a_grid-connected_storage_solution_with_grid-forming_function
[66] https://www.mdpi.com/1996-1073/14/19/6168
[67] https://euniversal.eu/poland/
[68] https://ianos.eu/results/

					exploitable business concept for community owned hybrid solar – fuel cell solutions **Hardware**[68] iVPP DSM module (implemented within the behind-the-meter assets scheduler; HEMS/BEMS that allow the centralized operation of all grid assets (small or big scale by the VPP, to optimize their load profiles considering the forecasts with the goal of minimizing RES curtailment; Congestion management from DSM and smart grid elements can be used by DSO's on energy islands or other locations with a weak grid/ grid-connection; The VPP framework can also use the available flexibility to prevent congestion on the mainland and optimize the revenue streams of the owner's flexibility.
TIGON	TRL 6-8	TRL 6-8	TRL 6-8	TRL 6-8	**Hardware (can be commercialized)** WAMPAC system: Monitoring and Protection system whose main purpose is to control the stability and safe operation of the whole system thanks to measurements gathered from different points of the micro-grid. CIRCE will fully own the algorithms and strategy developed for the definition of the WAMPAC. They will make use of know-how as IPR protection strategy.
RE-EMPOWERED	TRL 6-8				**Hardware** ecoConverter deals with the development of several power electronic converters and their control to form a multi-source microgrid. In the scope of this tool a power quality conditioner (STATCOM, a load flow controller, a SiC based DC/DC converter, a DC/AC inverter, a DC/DC partial power converter (PPC for multi-string PV architecture, and an FPGA based digital control platform will be developed. The purpose of these converters is to form a local microgrid and extract the maximum power from PV panels under partial shading conditions. The converters will be modular, plug-and-play, reliable and compact with functions like built-in communication, protection, remote control, and display option.
AISOP				TRL 3-5	**Methodology** Definition and requirements for a digital twin including not only the models for simulations but also operational planning tasks and processes that can be automated **Methodology** A data ingestion and processing framework to extract meaningful knowledge for DSO operational planning fusing data from heterogeneous data sources: weather data, grid sensor data, smart meter data, etc.
DEVISE	TRL 6-8			TRL 3-5	**Hardware** Controller for charging/discharging of battery bank **Methodology** Simulation Model of Inter vector energy system: An innovative strategy for efficient conversion of energy forms as secondary sources would be developed to ensure efficient and rational utilization of all forms of renewable energy based on applications such as building heating/cooling, and cooking.

1.7 HLUC 7: Enhance System Supervision and Control including Cyber Security

Project name	PPC 7.1	PPC 7.2	PPC 7.3	PPC 7.4	Key Exploitable Results
BD4OPEM		TRL 6-8	TRL 9	TRL 6-8	**Software (can be commercialized)** Observability service - process to determine the actual observability LV network based on fact (smart metering). Topology service - retrieval of LV network topology and estimate grid parameters when no/no realistic data is available. Together with validated revenue stream models they both showcase a strong potential to generate a positive NPV value over a five-year time period.
PARITY			TRL 6-8		**Software (can be commercialized)** The DSO Toolset is a software component for Smart Grid Monitoring and Management. It is able to monitor, detect and solve congestions, and provide forecasts of the grid state according to the Traffic Light Concept. It includes a web-based UI with GIS related information to the user. It provides related information that can be utilised by an Aggregator.
OMEGA-X					**Software** The expected KER is Energy Data Space where energy stakeholders will be able to share data in a trusted, secure and sovereign way, allowing the deployment of advanced digital services.

IANOS		TRL 6-8	TRL 3-5	TRL 6-8	**Policy, regulation and market** [69] Commercial uptake of heat batteries, smart building control equipment, intelligent control of multi-protocol field level equipment, rollout of V2G chargers, innovative systems from local Aggregators/ VPP integrators, intelligent aggregation clustering and behind the meter assets scheduler. Commercial uptake and promotion of community owned solar farms, in parallel with developing crowdfunding-based business models, development of an exploitable business concept for community owned hybrid solar – fuel cell solutions **Policy, regulation and market** [69] Novel services on optimising response times for voltage and frequency control from variable-scale storage assets; new services on advancing and commercialising the iVPP platform to optimise the use of the electricity grid and provide ancillary services; solar farms connected to industrial batteries, that saves on grid connection and profile costs, able to provide ancillary services- combining the innovative elements above will increase financial attractiveness. Development of the EMS, creating new revenues streams for the owners, increase self-consumption and alleviate grid challenges for the DSO; develop energy flexibility services; and implement secure IT platforms; Provide Ancillary services to the TSO using a VPP with several RES and storage options **Hardware** [69] iVPP DSM module (implemented within the behind-the-meter assets scheduler; HEMS/BEMS that allow the centralized operation of all grid assets (small or big scale by the VPP, to optimize their load profiles considering the forecasts with the goal of minimizing RES curtailment; Congestion management from DSM and smart grid elements can be used by DSO's on energy islands or other locations with a weak grid/ grid-connection; The VPP framework can also use the available flexibility to prevent congestion on the mainland and optimize the revenue streams of the owner's flexibility.
TwinERGY		TRL 6-8			**Methodology** Advanced Training simulators for DSOs and TSOs using Digital Twins in order to adapt to new Network Energy Management platforms.
HONOR	TRL 6-8	TRL 6-8	TRL 3-5		**Software** [70] A novel data processing pipeline for automated real-time identification of fast-ramped flexibility activation events was developed. It can detect potentially critical flexibility activations originating from electricity markets at an early stage, and let the operator verify successful activation of DSO-requested flexibility. In both cases the increased awareness would allow the DSO to take counteractions to avoid potentially critical grid situations.
AISOP			TRL 3-5	TRL 3-5	**Software** Innovative data processing architectures and methods that enable advanced solutions for the increasing complexity of system development and operations. **Methodology** Use Smart meters for accessing its data directly by multiple actors, while preserving GDPR and contractual clauses
RESili8			TRL 3-5		**Software** Consolidation of sensor data: In RESili8 we investigate new, and faster, mechanisms to identify faulty or attacked sensor measurements in a radial power distribution grid. By computing the median of state estimates based on disjoint sets of sensor measurements, we can quickly find anomalous sensor values, if there is majority of healthy sensors.
EPC4SES				TRL 3-5	**Software** The set-up of digital twins for buildings in a central system or the collection of forecast data from buildings both allow to better control the network/grid.

[69] https://ianos.eu/results/
[70] https://arxiv.org/abs/2110.04174

1.8 HLUC 8: Transportation Integration & Storage

Project name	PPC 8.1	PPC 8.2	Key Exploitable Results
NESOI	TRL 9	TRL 9	**Policy, regulation and market**[71,72] A coordination & support action framework aiming at facilitating the clean energy transition on EU islands and going one step forward by providing islands with training, technical support, cooperation opportunities and robust funding opportunities to concretely convert Island Sustainable Energy Action Plans into Renewable Energy Sources (RES plants, building and energy infrastructure retrofitting, energy bill reduction, local job creation, etc.).
EV4EU	TRL 6-8	TRL 6-8	**Policy, regulation and market** New business models related with mobility **Hardware** New charging station solution
FlexiGrid		TRL 6-8	**Policy, regulation and market** Assessment of the benefits of smart control of different charging infrastructures in providing various system services through connecting EVs to IoT concept. Incorporation of uncertainties related to the provision of services by transport sector, specifically considering V2G. Modifying the regulatory framework to enhance TSO–DSO interaction in supporting cost effective integration of transport sector in low carbon energy system **Software** Development of appropriate IT infrastructure for common management of charging stations supported by appropriate market design to enable information exchange between energy system and charging point operators.
OMEGA-X		TRL 6-8	**Methodology** Expected KER is a TSO-DSO collaboration for the purpose of cross-border electromobility services, but not materialized yet, so no KER available
IANOS	TRL 3-5	TRL 6-8	**Software**[52] V2G charging stations providing VPP operators the opportunity to fine tune the EV charging pattern therefore minimizing RES curtailment and being able to provide services to the grid. VPP operator use of smart charging and V2G to optimize the energy consumption and storage in the VPP framework, increasing e-vehicle owners who can choose smart charging to maximize RE usage, paying a lower fee to the owner of the station and subsequently the owner of RES.
TIGON	TRL 6-8	TRL 6-8	**Software** Energy Management System: Operation modes and strategies integrated into a control software able to manage hybrid grids, optimize their energy flows and maximize the efficiency of the system. CEA and CIEMAT will protect the results through know-how.
SERENE		TRL 6-8	**Hardware (can be commercialized)** Bus charging system based on local storage. **Software** Energy management system for energy storage for bus charging. Efficient energy management system for bus charging.
Multiportgrid	TRL 3-5		**Hardware** How a multiport converter could be integrated in the charging system to reduce the losses in the system and reduce the need for grid reinforcements.
AI-flex		TRL 3-5	**Software** The aim is to develop and validate an AI-based optimiser interface for optimised energy management of Power-2-Mobility or Vehicle-2-Grid solutions. Based on a simulated integration of P2M and V2G storage, i.e. electric vehicles, into the energy system, suitable AI/ML methods are combined and further developed to obtain an efficient control algorithm for electric vehicles integrated into a cellular energy system as P2M and V2G storage.
Power-2-Transport	TRL 3-5	TRL 3-5	**Methodology**[73] Methodology to investigate whether synthetic CH4 could be a feasible alternative for buses currently powered by fossil fuels, a dynamic model was built for discrete-event simulations of PtG technology integrated into an urban AD plant designed to supply biomethane as fuel for bus fleets
EPC4SES	TRL 6-8	TRL 6-8	**Methodology** The project demonstrated how resilience can be achieved via storage on the building and vehicle side and optimisation of a system including heating and charging.

[71] https://www.nesoi.eu/system/files/private/nesoi/Brochures/nesoi_-_e-lafiti-_z-091_compressed.pdf
[72] https://www.nesoi.eu/system/files/private/nesoi/Brochures/nesoi_-_save_-_z-056_c.pdf
[73] https://www.sciencedirect.com/science/article/pii/S0196890422003703

1.9 HLUC 9: Flexibility provision by Building, Districts and Industrial Processes

Project name	PPC 9.1	PPC 9.2	PPC 9.3	Key Exploitable Results
Interconnect	TRL 6-8	TRL 6-8		**Software** [74,75] The solutions developed within the scope of Interconnect will allow a digitalization of homes, buildings and electric grids based on an Internet of Things (IoT) architecture. By including digital technologies (Artificial Intelligence, Blockchain, Cloud and Big data) based on open standards, such as SAREF, it will guarantee the interoperability between equipment, systems and privacy/cybersecurity of user data. The solution is comprised of several parts: DSO Interface, Semantic Interoperability Framework (SIF), Ontology, Service Store, Knowledge Engine, Generic Adapter, Peer to Peer Marketplace.
BeFlexible	TRL 6-8	TRL 6-8		**Policy, regulation and markets** Increased availability of flexibility sources for TSOs and DSOs and enable them to develop markets for flexibility and interact with many distributed resources at the same time (via intermediaries such as energy suppliers or aggregators based on seamless and secure data exchange and interoperability) **Policy, regulation and markets** New business models for market parties based on energy services and revenue streams for consumers (across energy sectors and beyond, based on valorisation of the flexibility in their energy consumption)
NESOI	TRL 9	TRL 9	TRL 9	**Policy, regulation and market**[76,77] A coordination & support action framework aiming at facilitating the clean energy transition on EU islands and going one step forward by providing islands with training, technical support, cooperation opportunities and robust funding opportunities to concretely convert Island Sustainable Energy Action Plans into Renewable Energy Sources (RES plants, building and energy infrastructure retrofitting, energy bill reduction, local job creation, etc.).
SYNERGY	TRL 6-8	TRL 6-8	TRL 6-8	**Software**[78] Visualize energy performance of buildings and analyse energy performance of whole districts. Integration of resulted energy efficiency measures and indicators with tools currently used by city planners. **Software** [7878] Holistic city planning with dynamic simulations with alternate scenarios for selected cases. **Methodology** [78] Design alternative urban transformation strategies to reach SECAP tracking for city authorities KPI's
GIFT		TRL 6-8		**Software**[79,80] Virtual Power System will utilise advanced technologies for automatic trading of energy flexibilities in real time. It uses Flexible Energy Management System and Flex Agents installed at DR provider.
PARITY		TRL 6-8	TRL 6-8	**Software (can be commercialised)** DERs flexibility management tool both on prosumer level and on aggregated level. It provides services to individual prosumers in the portfolio, and to the DSO in order to solve congestions. **Software** The Aggregator Toolset including the Prosumer Flexibility Manager, is the software component for calculation and automated aggregation of flexibility. It creates dynamic VPPs to enable response to DSO demands and trading of energy/flexibility in ancillary services markets & wholesale markets in an optimized manner.
EV4EU	TRL 6-8	TRL 3-5	TRL 6-8	**Software** Energy management system for buildings considering V2X management
OMEGA-X		TRL 6-8		**Software** The expected KER is an advanced flexibility services both for Energy Communities and for at City level

[74] https://gitlab.inesctec.pt/groups/interconnect-public/-/wikis/home
[75] https://interconnectproject.eu/about/#results
[76] https://www.nesoi.eu/system/files/private/nesoi/Brochures/nesoi_-_e-lafiti-_z-091_compressed.pdf
[77] https://www.nesoi.eu/system/files/private/nesoi/Brochures/nesoi_-_save_-_z-056_c.pdf
[78] https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5df29b2f4&appId=PPGMS
[79] https://www.gift-h2020.eu/delivrables/
[80] https://www.inea.si/en/resitve/demand-side-management/

FEVER	TRL 6-8	TRL 6-8	TRL 3-5	**Software** [81] The P2P-Flexibility trading Platform is mainly consists of distributed applications (DAPPs) enabling P2P trading: the Community Management DAPP, the FlexCoin DAPP, and the FlexTrading DAPP. The FlexTrading of P2P-FTP is a distributed application (DAPP) delivering a blockchain-based marketplace, where its participants (peers) are able to trade flexibility/energy products without an intermediary. It allows configuring trading parameters (contracts), monitoring and tracking statuses, histories, and states of several parallel P2P markets and individual peers, offering options for connecting third-party trading agents of market participants – for submitting or revoking bids automatically. It is planned to raise TRL from 1 to 8. **Software** [81] The Flexibility Management System (FMS) is a part of the Aggregator-as-a-Service Platform (AaaS Platform) which serves as an overarching platform for using these tools in an integrated fashion in enduser applications. As for FEVER, the most relevant functionality is the FMS part of the AaaS Platform, the following parts focus on the flexibility management service. Generally, FMS is a software solution that: (1) Allows managing large pool of prosumers with different types of flexibility. (2) Aggregates different prosumer's flexibility assets, while considering location of these assets. (3) Disaggregates demand and supply schedules of these assets. (4) Make aggregated flexibility assets available for trading on FTP. **Software**[82] The Factory Energy Management System (FEMS) is a monitoring and control tool intended for larger industrial customers or commercial buildings to collect and monitor the energy consumption data and control the appliances. It is used to control production loads or energy production units in factories or commercial buildings of various industrial branches. It incorporates algorithms enabling simultaneous load control to achieve optimal consumption, peak levelling, external automatic demand response control or any other energy/cost saving goal. The initial TRL level is 7 and it targets 8 at the end of the project.
SUSTENANCE	TRL 6-8	TRL 6-8	TRL 6-8	**Hardware (can be commercialized)** Battery management system for batteries for active local communities
ACCEPT	TRL 6-8	TRL 6-8	TRL 6-8	**Software (can be commercialized)** Energy community tools (digital tools for assisting energy communities in assuming energy market roles, such as the role of the aggregator, the retailer and the ESCo, as well as offer services to their community members. **Software (can be commercialized)** Consumer Digital Twin which delivers a unified modelling approach that enables the causal correlation of consumer behaviour, energy assets and vectors that relate to common building amenities via a building/resident-specific calibrated model that allow a market actor to understand, anticipate and forecast energy/flexibility behaviour at the connection point to the grid. **Software (can be commercialized)** The On-Demand Flexibility Management module which delivers a resident optimized, intelligent and predictive integrated energy control system that guarantees a healthy and comfortable indoor environment while offering dispatchable demand/supply flexibility to the energy community. It will support several objectives and constraints introduced by present and forecasted weather conditions and consequent RES fluctuation, energy demand, building occupancy and activity patterns, human comfort preferences, building thermal inertia, energy prices, overall energy storage capabilities (actual and virtual energy storage as well as building devices operational constraints and shifting/curtailing capabilities. **Software (can be commercialized)** The District Asset Management component will be able to accurately forecast the performance of community-level assets and also bi-directionally interface with them for sending control commands. **Software (can be commercialized)** The ACCEPT Building Information Management Layer which is the component responsible for interfacing with the physical, real-world assets of the building in a secure, efficient, reliable and cost-effective manner and collecting the information and pre-processing it for other system components. **Software (can be commercialized)**

[81] https://fever-h2020.eu/data/deliverables/FEVER_D8.5_-_Report_on_business_models_assessment_market_analysis_regulatory_context_assessment_and_preliminary_exploitation_assessment_.pdf

[82] https://fever-h2020.eu/data/deliverables/FEVER_D8.5_-_Report_on_business_models_assessment_market_analysis_regulatory_context_assessment_and_preliminary_exploitation_assessment_.pdf

				The ACCEPT Non-Intrusive Load Monitoring (NILM – embedded in the Building Information Management Layer – which is an innovative framework that enables residential energy monitoring towards energy sustainability. This method is also known as energy disaggregation, as single-point sensing is utilised in order to extract appliance level energy consumption.
X-FLEX	TRL 6-8	TRL 6-8		**Software** The tool for flexibility managers to take advantage of the value of energy storage along with other demand flexibility resources towards the establishment of a holistic framework for flexibility extraction, profiling, forecasting, classification, clustering and management to serve different market and grid needs.
LocalRES	TRL 6-8	TRL 6-8	TRL 6-8	**Software** MEVPP capable of providing services including collective services such as collective self-consumption, local energy market services such as voltage control and congestion management, and energy market services such as ancillary services. The MEVPP also includes a model predictive control (MPC algorithm) to manage flexible assets. **Software** Planning Tool to enable the participation of citizens and local actors in the decision-making processes associated to the design and planning of the local energy system, with a special focus on energy communities, and accessible for expert and no-expert users, promoting their understanding about energy systems and the feasibility of alternative scenarios.
IANOS	TRL 3-5	TRL 6-8	TRL 3-5	**Policy, regulation and market** [83] Commercial uptake of heat batteries, smart building control equipment, intelligent control of multi-protocol field level equipment, rollout of V2G chargers, innovative systems from local Aggregators/ VPP integrators, intelligent aggregation clustering and behind the meter assets scheduler. Commercial uptake and promotion of community owned solar farms, in parallel with developing crowdfunding-based business models, development of an exploitable business concept for community owned hybrid solar – fuel cell solutions. **Hardware** [84] iVPP DSM module (implemented within the behind-the-meter assets scheduler; HEMS/BEMS that allow the centralized operation of all grid assets (small or big scale by the VPP, to optimize their load profiles considering the forecasts with the goal of minimizing RES curtailment; Congestion management from DSM and smart grid elements can be used by DSO's on energy islands or other locations with a weak grid/ grid-connection; The VPP framework can also use the available flexibility to prevent congestion on the mainland and optimize the revenue streams of the owner's flexibility.
SENDER		TRL 6-8		**Hardware** Building as a battery (thermal storage, V2G EV-charging, Intelligent hot water boilers **Software** Integrated building management system that uses flexibility from HVAC, local charging stations, water heating
SERENE		TRL 6-8	TRL 6-8	**Software and data base** Smart energy management system for gaining flexibility from heat-pumps and car charging in local energy systems. control system for heat-pump for provision of flexibility to the local grid and the overall balancing of the grid. Smart energy management system for gaining flexibility from heat-pumps and car charging in local energy systems. not defined yet, but is an on-going activity using the horizon booster service. Smart system for controlling both heat-pumps and car charging flexible according to local production and hosting capacity
iFLEX		TRL 6-8		**Methodology** iFLEX framework will make easier for energy consumers to be part of energy solutions that focus on demand response, in which energy consumption (demand) is adjusted in response to price signals or incentives coming from an energy actor. It's focus is on household consumers and demand response for supporting high penetration of renewable energy such as solar power.
MAGNITUDE		TRL 3-5		**Software** Aggregation platform for pooling the flexibilities of decentralized multi-energy systems and trading on the electricity markets. **Methodology** Performance assessment of the integrated system (multi-energy systems optimisation, aggregation platform, and market platform on the real-life case studies.

[83] https://ianos.eu/results/
[84] https://ianos.eu/results/

				Policy, regulation and market Business models evaluation for the multi-energy systems and the aggregator.
DISTRHEAT		TRL 6-8		**Hardware** [85,86] A smart controller that manages a multi-energy system by exploiting building flexibility and by providing it to the network. The Model Predictive Control mechanism needs some preparatory work, but this can be speed up by developing standardized architectures.
SONDER	TRL 3-5	TRL 3-5	TRL 3-5	**Hardware** A bi-level framework consisting of two controllers was developed with the upper-level controller for peak shaving at the transformer level and the lower level controller for both peak shaving and self-consumption at the energy community level. The focus was the evaluation of various control schemes that can be used for the coordination of mixed energy resources integrated in distribution networks. **Software** Deep learning predictors represent the current state of the art for load forecasting at various levels of aggregation (they can model non-linear functional dependencies, outperforming traditional AR linear models. Recurrent Neural Networks (RNNs) with Gated Recurrent Unit (GRU) were used as the core of the developed prediction system. When multiple load signals are present, the best strategy is to keep them separate and predict them jointly using a graph-based model that learns dependencies between the multiple signals (GNNs). In case of too many signals, clustering can be performed to obtain an intermediate level of aggregation. In our case, we went from 10k to around 50 signals to validate our approach. Predicting only the peak aggregated load with a GRU-RNN model was the best strategy for practical applications, due to the simpler data collection for both training and inference. This model was used to provide input forecasts to the BESS control algorithm for peak shaving at the Arbon MV Transformer. **Software** A new concept, which is based on the automated generation of a digital twin system, directly from its schematic representation was used to create a digital twin of a datacentre. The designed digital twin "clone" of the datacentre consists of the SIMULINK model of the electrical system plus the automatically generated control application (based on the IEC 61499 standard. By utilizing collected from a real datacentre, parameters of the building blocks were adjusted so that the model represents the datacentre most accurately. The developed model provides the basis for utilization of flexibility provided by the datacentre.
GENTE		TRL 6-8		**Methodology** GENTE aims to deliver as a final KER a toolbox for communities and community managers for resource optimisation and community federation.
DigiCiti	TRL 6-8	TRL 6-8	TRL 3-5	**Software** The expected results related to control and operation tools for the integration of buildings and smart communities will be at TRL8 at the end of the project.
EPC4SES	TRL 3-5	TRL 6-8	TRL 3-5	**Software** Detailed simulation and optimisation was set up to assess flexibility provision via model predictive control. The actors include thermal activation of building masses, DHW storage, central buffer tanks, the thermal grid.

[85] https://www.distrheat.eu/download/18.3637497618094a0d39e4043e/1653402251016/DISTRHEAT_D2.3.pdf
[86] https://www.distrheat.eu/distrheat/news/webinar-from-distrheat

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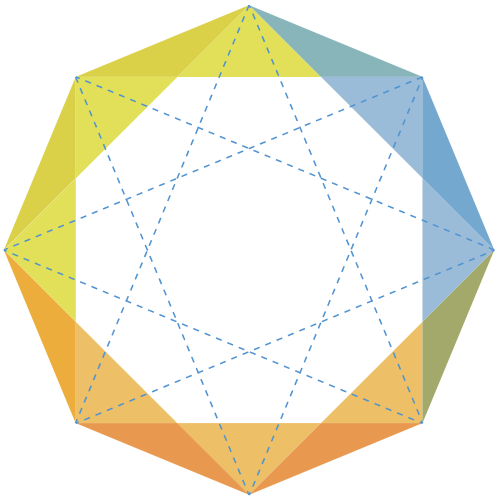

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