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1st Report on mapping progress in energy systems research and innovation

ETIP SNET

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1. EXECUTIVE SUMMARY

Progress monitoring of European research and innovation is an essential activity to assess the progress towards a decarbonised energy system and to shape future R&I efforts accordingly. The European Technology & Innovation Platform Smart Networks for Energy Transition (ETIP SNET) aims to guide research, development, and innovation to support Europe's energy transition.

The ETIP SNET Research and Innovation Roadmap presents the framework in which progress monitoring is executed. The framework consists of six Research Areas, 24 Topics (Research sub-Areas) and 120 Tasks. The objective of the progress monitoring activity is to analyse the state of R&I, to identify promising technologies and innovations and to measure the coverage degree of the ETIP SNET R&I Roadmap. The results are to be used in the upcoming ETIP SNET Implementation Plan (2023 - 2026).

1.1. Progress monitoring based on four distinct sources

A methodology is developed, based on four distinct sources of information. Together, these sources cover a broad spectrum of Research and Innovation projects in the European energy transition. These sources are:

- BRIDGE[1] R&I Priorities report
- National R&I reports
- Questionnaire shared with individual R&I projects
- ERA-NET SES Smart Energy Systems[2] project summaries

The **BRIDGE R&I Priorities** report lists achievements and challenges reported by BRIDGE projects. These are mapped towards the ETIP SNET framework of Research Areas, Topics and Tasks. This results in a qualitative overview of the coverage of Topics and Tasks by the contributing projects.

National R&I reports of the Netherlands, Spain, United Kingdom, France, Germany, and Italy are assessed to provide a qualitative overview of the coverage within the ETIP SNET structures. Evidence is gathered whether a particular Research Area is covered by the national research programme(s) of these countries.

A **questionnaire** is developed and distributed to nearly 100 projects across Europe. This is by far the most direct source of information, as project officers are asked to provide input on Key Exploitable Results and contributions to Topics and Tasks. 39 responses are received and collectively assessed on the contributions to Topics and Tasks. The reported Technology Readiness Levels (TRLs) of the participating projects is compared to the target TRL identified in the ETIP SNET Implementation Plan 2021 – 2024.

The fourth source of information are public project summaries of the **ERA-NET SES Smart Energy Systems** funding scheme. 35 projects are assessed, and their Key Exploitable Results are assigned to ETIP SNET Topics.

[1] https://www.h2020-BRIDGE.eu: 'BRIDGE is a European Commission initiative which unites Horizon 2020 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.'
[2] https://www.eranet-smartenergysystems.eu: 'A transnational joint programming platform to initiate co-creation and promote energy system innovation'

1.2. Sufficient coverage of the six Research Areas

All Research Areas are covered to some degree by each of the four sources. However, some Research Areas present a higher level of activity than others. This should be interpreted with care since activities can be categorized in more than one Research Area.

Research Area 1: Consumer, prosumer, and citizen energy community has a high degree of coverage as all sources report contributions to this Research Area. All country R&I reports make mention of activities in this Research Area. The results from the questionnaire show an average level of contributions in terms of project and Key Exploitable Result (KER) contributions, as does the mapping of BRIDGE R&I achievements. ERA-NET SES Smart Energy System projects present a strong focus on this Research Area.

Research Area 2: System economics is well covered in the national R&I reports, the BRIDGE R&I Priorities achievements, and the ERA-NET SES Smart Energy Subsystems project summaries. However, the results from the questionnaire show a lower-than-average level of activity in this Research Area in terms of project and KER contributions.

Research Area 3: Digitalisation is one of the most active R&I fields in Europe. Most country R&I reports indicate contributions to this Research Area. The BRIDGE R&I Priorities achievements and the project contributions (as reported in the questionnaire) show an above average level of activity in this field. However, the ERA-NET SES Smart Energy Systems projects report a below average level of contribution.

Research Area 4: Planning – holistic architectures and assets is one of two Research Areas that is not sufficiently covered by any of the four sources. While most of the country R&I reports indicate contributions in this field, the level of activity reported in the BRIDGE R&I Priorities report, the questionnaire responses and the ERA-NET SES Smart Energy System project summaries is below average. Research areas 4 and 6 mainly comprise topics of interest of Network Operators. The role of these Research Areas in the Energy Transition is critical; however, the number of involved stakeholders is naturally limited. It is clear also that elements of Research Area 5 overlap with Research Areas 4 and 6. The lower level of activity in Research Area 4 (and 6) is therefore accountable. However, additional effort is required to bring the identified Tasks up to the desired level.

Research Area 5: Flexibility enablers and system flexibility is, along with Research Area 3, one of the dominant Research Areas in terms of activity. It is well covered in the country R&I reports. While the ERA-NET SES project summaries indicate a slightly below average level of contribution, the assessment of individual R&I projects showed the highest number of projects and KER's assigned to this Research Area. In addition, Research Area 5 is the dominant field in the BRIDGE R&I Priorities report.

Research Area 6: System operation has a slightly lower level of coverage in the country R&I reports than the other Research Areas. The BRIDGE R&I Priorities report shows several significant achievements in this field, as well as remaining challenges. The assessment of questionnaires shows a relatively low level of coverage by the 39 responsive projects. The same is true for the 35 ERA-NET SES project summaries. The low level of activity can be explained by the fact that system operation mainly concerns Network Operators and the number of involved stakeholders is naturally limited. The same applies to regional/local projects.

1.3. Non-uniform contribution to Topics

The questionnaire assessment, BRIDGE R&I Priorities report mapping and ERA-NET SES project summary analysis results in a view on the contributions to the 24 Topics[3] (Research Subareas). Project officers were asked to indicate Key Exploitable Results within these Topics. Some Research Areas show a high level of activity (many projects contributing to that area), however, that does not necessarily mean that each Topic in that Research Area has many Key Exploitable Results (KER's) attributed to it. The highest number of KER and achievement allocations are found in the Research Areas with the highest coverage ratio:

- Topic 5.3 'Storage flexibility & energy conversion flexibility'
- Topic 3.1 'Protocols, standardisation and interoperability'
- Topic 5.1 'Demand flexibility'

Note that Research Areas 3 and 5 are covered well, but some Topics within those Research Areas have no or few KER's attributed to it. It is advised that the European Commission evaluates the need for more targeted funding for Topics with low levels of contribution according to the required progress within these Topics. The lowest level of KER contributions area found in Research Area 1, 3, 4, 5, and 6:

- Topic 1.3. 'Consumer and prosumer device control'
- Topic 3.4. 'Cybersecurity and privacy'
- Topic 3.5. 'End-to-end architecture'
- Topic 4.3. 'Asset management and maintenance'
- Topic 5.5. 'Transport flexibility'
- Topic 6.5. 'Control Center technologies'

1.4. Subsets of Tasks exceed target TRL

The mapping of BRIDGE R&I achievements shows the level of contribution to each of the 120 Tasks. In the questionnaire, project officers were asked to indicate the expected or target TRL of Tasks the projects contribute to. These two sources are the foundation of the Task progression analysis. Tasks with a high reported TRL (questionnaire) and multiple reported achievements (BRIDGE R&I priorities) are:

- 3.1.2. Standardised communication protocols and ICT infrastructure between devices and networks and between devices and remote management platforms.
- 3.2.1. Demand aggregation and control.
- 3.2.2. Monitoring and control of distributed generation.
- 5.3.1. Storage flexibilities in operation of electrical grids.
- 6.1.2. Observability and state estimation of distribution systems.

The reported TRL of Tasks by the individual R&I projects in the questionnaire are compared to the target TRL formulated in the ETIP SNET Implementation Plan. A Task is said to be on target when the average reported TRL matches or exceeds the target TRL in the Implementation Plan *and* more than five projects report contributions to that Task. The Tasks that match or exceed the target TRL with the highest level of confidence (seven or more projects contributing) are

[3] Note that the term Topics is introduced in the ETIP SNET Implementation Plan, whereas in the ETIP SNET R&I Roadmap these are referred to as Research Subareas.

- 3.1.1. Data exchange protocols / interfaces for a well-functioning market.
- 3.1.2. Standardised communication protocols and ICT infrastructure between devices and networks and between devices and remote management platforms.
- 5.1.1. Optimal utilisation of Demand Side Response (DSR) by TSOs and DSOs.
- 5.2.1. Contributions of wind turbines and solar-PV to system flexibility.
- 5.3.1. Storage flexibilities in operation of electrical grids.
- 6.1.2. Observability and state estimation of distribution systems.

1.5. Concluding remarks

Table 1 shows the level of activity of Topics and the share of Tasks addressed within those Topics. This view is very relevant in drafting the next ETIP SNET Implementation Plan and will help decide which Topics are sufficiently covered and which require additional attention. For Topics that have a high contribution in across the three indicators (project contributions, KERs, and Task coverage), it can be concluded that the Topic is sufficiently covered and requires little to no additional R&I stimulation. In contrast, a Topic that is predominantly yellow or red in this table, additional efforts are required to bring R&I in line with the ETIP SNET R&I Roadmap and Implementation Plan.

Table 1: Coverage of Research Topics in terms of project contributions, KERs, and share of Tasks addressed by all sources. The colour coding indicates the relative level of coverage (legend below each column)

Research Topic	Project contributions	KERs	Task coverage
1.1. Social campaigns and social studies	11	10	3 out of 3 Tasks
1.2. Adaptive consumer/user behaviour including energy communities	11	15	2 out of 2 Tasks
1.3. Consumer and prosumer device control	5	3	2 out of 2 Tasks
2.1. Business models	13	11	3 out of 5 Tasks
2.2. Market design and governance	14	12	6 out of 9 Tasks
3.1. Protocols, standardisation, and interoperability	14	20	4 out of 4 Tasks
3.2. Data Communication (ICT)	14	10	4 out of 4 Tasks
3.3. Data and Information Management	6	5	2 out of 2 Tasks
3.4. Cybersecurity and privacy	5	3	4 out of 4 Tasks
3.5. End-to-end architecture	5	4	3 out of 3 Tasks
4.1. Integrated Energy System Architectures	9	10	6 out of 9 Tasks
4.2. Long-term planning	7	6	3 out of 7 Tasks
4.3. Asset management and maintenance	0	0	0 out of 9 Tasks
4.4. System Stability analysis	6	8	4 out of 7 Tasks
5.1. Demand flexibility	15	18	4 out of 4 Tasks
5.2. Generation flexibility	10	7	5 out of 7 Tasks
5.3. Storage flexibility & Energy Conversion flexibility	18	22	4 out of 5 Tasks
5.4. Network flexibility	9	16	2 out of 4 Tasks
5.5. Transport flexibility	1	1	2 out of 3 Tasks
6.1. Supervisory control and state estimation	9	9	3 out of 3 Tasks
6.2. Short-term control	7	8	2 out of 3 Tasks
6.3. Medium- and long-term control	7	6	5 out of 6 Tasks

Research Topic	Project contributions	KERs	Task coverage
6.4. Preventive control/restoration	3	6	2 out of 8 Tasks
6.5. Control Center technologies	9	8	5 out of 7 Tasks
	≥13 contributions	≥15 KERs	≥67%
	8 – 12 contributions	7 – 14 KERs	33 – 67%
	<8 contributions	<7 KERs	<33%

The goal of this R&I Progress Monitoring Report is to provide insight on the state of European research and innovation for the energy transition, to assess the coverage degree of the ETIP SNET R&I Roadmap and Implementation Plan, and to identify promising technologies and innovations. The observations and findings are to be used in drafting the next Implementation Plan. The coverage degree of Topics and Tasks may lead to a reassessment of priorities within a time horizon of five years. In addition, the assessment of Task progression has shown that some Tasks with low activity are less concrete than or overlap with other Tasks. The Progress Monitoring Report identifies a series of Tasks that are close to commercialisation but need just that final push to be brought into market maturity. Such Tasks and the obstacles towards commercialisation are to be addressed in the R&I Implementation Plan, due towards the end of 2021.

2. Introduction

The European Technology & Innovation Platform Smart Networks for Energy Transition (ETIP SNET) aims to guide research, development, and innovation to support Europe's energy transition. This process 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 follow-up of the previous progress monitoring report published in 2018.

The 10-year ETIP SNET Research & Innovation Roadmap 2020-2030[4] provides the system view to the entire energy transition by addressing a scope with smart electricity grids as its backbone but going beyond: It also encompasses interactions with the gas and heat networks, and with electric mobility, and focuses on integration of all flexibility solutions into the power system, including energy storage technologies (sector coupling).

"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

This progress monitoring report is structured according to the ETIP SNET R&I Roadmap structure, using Research Areas and Functionalities to organise the defined R&I priorities.

2.1. Context

This report is part of the project and progress monitoring activities of ETIP SNET with regards to the ETIP SNET R&I Roadmap and Implementation Plans. The present ETIP SNET R&I Roadmap 2020-2030 addresses the framework in which the European energy

[4] https://www.etip-snet.eu/wp-content/uploads/2020/02/Roadmap-2020-2030_June-UPDT.pdf

system shall develop along the path toward the goal of system decarbonisation by 2050. The ETIP SNET R&I Roadmap will be updated by the end of 2023 and will be valid for a timeframe of approximately 10 years. Details of the immediate four-year R&I activity needs are described in the ETIP SNET Implementation Plans. The ETIP SNET Implementation Plans detail the Research and Demonstration activities that should be performed with priority. The most recent ETIP SNET Implementation plan has been written for 2021 – 2024[5].

The ETIP SNET R&I Roadmap identifies twelve Functionalities to be achieved by 2030. A Functionality is a range of impacts suited to achieve a specific purpose, related to the building blocks of a decarbonised energy system as presented by the ETIP SNET Vision 2050. These Functionalities shall be implemented and be demonstrated by R&I projects with their Use Cases. The related R&I work is described by 120 Tasks, categorised in six Research Areas with 24 Topics (Research Subareas) in total.

The progress monitoring activities of ETIP SNET strive to assess individual R&I projects on their contributions to fulfilling the Tasks that contribute with their integrated implementation and demonstration to the needed Functionalities of the 2030 European power system. The objective of the progress monitoring activities is threefold:

- To analyse the state of research and innovation in the field of smart grids and sector coupling for the energy transition in Europe.
- To measure the coverage degree with regards to the ETIP SNET R&I Roadmap and to identify gaps in R&I that require additional attention or funding to adhere to the ETIP SNET R&I Roadmap and Implementation Plans.
- To identify promising technologies and innovations for commercialisation within a period of five years.

2.2. Approach

The progress monitoring activities that led to this report aim to capture the recent progress of R&I within the ETIP SNET scope made especially over the years since the last monitoring report, i.e. since 2018. The focus is on progress in European R&I, as the legal framework makes this more applicable than R&I progress in other parts of the world, and since in comparison, the European energy transition is further advanced than that in most other regions. A major challenge for the progress monitoring lies in the diversity and number of national projects, bi- or trilateral cooperations between European countries, in addition to the easier-to-monitor projects funded by the European Commission. Therefore, this report is based on four sources of information, ranging from public information to individual project results gathered through questionnaires. The four sources of information are

- BRIDGE R&I Priorities report[6]
- Recent national R&I publications and project summaries from European countries
- A questionnaire specifically developed by this progress monitoring task and distributed to individual R&I projects (analysis split in BRIDGE & non-BRIDGE)
- ERA-NET SES Smart Energy Systems project summaries[7]

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[5] https://www.etip-snet.eu/publications/etip-publications/

[6] See https://www.h2020-bridge.eu/; a cooperation group of Smart Grid, Energy Storage, Islands and Digitalisation H2020 projects funded by the European Commission

[7] See https://www.eranet-smartenergysystems.eu/; a transnational joint programming platform to initiate co-creation and promote energy system innovation

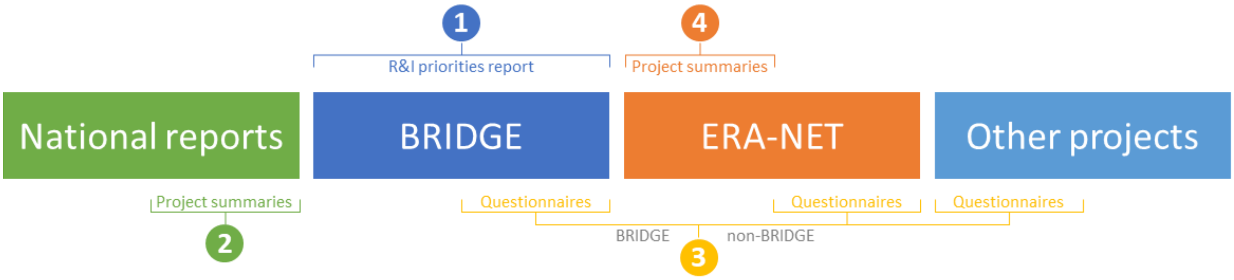

Figure 1: The four sources of information for the progress monitoring report.

The above sources of information, together with the data sources used for each source, are visualised in Figure 1. It should be noted that ERA-NET SES projects that responded to the questionnaires are analysed in source 3, while the projects that did not respond were analysed in source 4. Below, each of the approach and data sources used for each source of information is described in more detail. The detailed methodology for each analysis can be found in Chapter 3.

The **first source of information,** which is an analysis of the recently published **BRIDGE R&I Priorities report**[8]. The reported achievements and remaining challenges in the R&I Priorities report are mapped to the structures defined by ETIP SNET, in terms of Topics and Tasks. It should be noted, however, that BRIDGE reports have reported achievements and remaining challenges, and the mapping towards the ETIP SNET framework of Topics and Tasks is a subjective exercise. From this mapping, qualitative statements are formulated about the contributions to Topics and Tasks to sketch the progress of Research and Innovation provided by the 34 participating BRIDGE projects. Conclusions and recommendations are translated into context and ETIP SNET terminology to remain systematic and to provide a general, comparable view on the state and trends of research and innovation in Europe, related to smart grids, sector coupling and the energy transition in general.

The **second source of information** is **national R&I progress reports** of European countries, which are analysed to assess the progress of individual countries in the ETIP SNET's six Research Areas. The analysis uses aggregate **progress reports**, individual **project summaries** and **funding scheme reports** from each country to identify projects' contribution to the scope of the ETIP SNET. For this progress monitoring report, the following countries have been assessed: Germany, the Netherlands, United Kingdom, France, Spain, and Sweden. The goal of this assessment phase is to provide a clear overview which Research Areas are, or are not, covered by research programmes of individual countries.

The **third source of information** consists of answers to a questionnaire specifically developed for this progress monitoring report. This **questionnaire** has been designed **for individual R&I projects** in which respondents (R&I project coordinators) are asked to answer questions on the Topics covered by their project and to state the Key Exploitable Results and the expected progress on a Task level. The questionnaire is structured in two parts: one relating to general project information and feedback on the call and the second part on the Topics, Tasks and Key Exploitable Results (KERs) of the project. More specifically, project representatives are asked to provide the expected Technology Readiness Level per Task and to elaborate on the project's Key Exploitable Results for each Topic addressed. The responses to the questionnaire are aggregated and assessed at this aggregated level. Questions to be answered in the assessment phase include

[8] BRIDGE R&I Priorities report

- What are the dominant Research Areas and Topics addressed in ongoing research and innovation projects?
- Which Tasks are addressed by the projects that have responded and which Tasks are not addressed?
- What is the number, nature, and TRLs of the Key Exploitable Results?
- What are the constraints (budget or otherwise) that need to be addressed to reach the desired Technology Readiness Level?

The fourth **source of information** are **project factsheets** within **ERA-NET SES Smart Energy Systems**[9]**.** These factsheets are analysed to assess the project contribution to Research Areas, Topics and Tasks based on the reported (and expected) results. The approach is to gather as much detailed information from ERA-NET SES project factsheets and to manually complete the questionnaires. The responses to the questionnaires are then aggregated using the same methodology as for individual R&I projects.

The outcomes of the analysis will be compared to the pathway sketched out in the most recent ETIP SNET R&I Roadmap and Implementation Plan, in which the expected progress of Tasks is described. The mapping of the realised progress of Tasks within projects leads to a clearer view on the state and trends in R&I within the scope of ETIP SNET. In addition, a coverage analysis aims to identify elements of the ETIP SNET R&I Roadmap and Implementation Plan that are insufficiently addressed by the ongoing R&I projects. The findings from the questionnaire and the outcomes of the coverage analysis will feed the next ETIP SNET Implementation Plan.

2.3. Reading Guide

Chapter 3 details the used methodology to analyse the four sources of information. In particular, it elaborates on the methodology to map the BRIDGE R&I Priorities report to the ETIP SNET structure, the analysis process for national reports, the questionnaire development and project selection process to determine which projects to send the questionnaires to, and finally the ERA-NET SES assessment methodology.

Chapter 4 covers information sources 1 and 2. The first part of the chapter covers the BRIDGE R&I priorities report mapped to the ETIP SNET structure (source 1). The second part of the chapter covers the analysis of national progress reports (source 2).

Chapter 5 covers sources of information 3 and 4. The first part of the chapter covers the answers of BRIDGE projects that have responded to the distributed questionnaires, while the second part covers the answers of non-BRIDGE projects that have responded to the distributed questionnaires (source 3). The final part of the chapter covers the ERA-NET SES projects that did not respond to the questionnaires (source 4).

Chapter 5.6 collects the information obtained through the four separate sources of information and provides conclusions and key takeaways.

3. METHODOLOGY

Progress monitoring at individual project level allows for the assessment of the state and trends in R&I within the scope of the ETIP SNET. By analysing a representative sample of R&I projects in Europe, ETIP SNET can identify the status of established research areas and topics and acquire knowledge about promising Key Exploitable Results. In addition, light will be shed upon poorly covered research areas and topics. The methodology for

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[9] https://eranet-smartenergysystems.eu/Projects

progress monitoring is executed through project identification, questionnaire development, questionnaire distribution and recollection and the assessment of responses. In addition, one of the goals of this progress monitoring report covers an analysis of previous work.

3.1. Analysis of BRIDGE R&I Priorities Report

While the progress monitoring exercise of the ETIP SNET is specifically designed to assess the progress along the indicators presented in the ETIP SNET R&I Roadmap and Implementation Plan, a lot of valuable work is also being performed in other EU initiatives such as BRIDGE and EXPERA[10]. BRIDGE is a European Commission initiative which unites Horizon 2020 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[11].

The BRIDGE R&I Priorities Taskforce aims to gather the views from ETIP SNET and BRIDGE communities on research and innovation priorities in flexibility, storage, sector integration and digitalisation. The Taskforce has assessed the achievements of Horizon 2020 projects and highlighted future R&I needs in a report. For this report, the ETIP SNET R&I Roadmap and Implementation Plan, the four BRIDGE permanent Working Groups, the two BRIDGE Topic Workstreams and the other BRIDGE Task Forces were taken into consideration. In addition, a questionnaire was produced with the purpose of identifying achievements and challenges. 29 BRIDGE projects have provided responses to the questionnaire. The questionnaire used in the BRIDGE R&I Priorities Report is structured to conform to the Research Areas and Topics of the ETIP SNET R&I Roadmap and Implementation Plan. For each of the Topics, project coordinators are asked to indicate:

- Project achievements
- Quantitative elements such as KPIs or Key Exploitable Results
- Elements explicitly not covered by the project
- Remaining challenges for future study
- Other observations

The responses to the questionnaire are assessed both individually as well as on an aggregated level. Individual project assessment identifies the achievements and remaining challenges for each of the responding projects. The aggregate analysis is structured into four key dimensions, following the structure of the BRIDGE R&I Priorities report:

- Integrated Energy System, further broken down in three aspects: flexibility resources, energy systems operations and energy systems planning.
- Customer at the Centre
- Market Based Energy System
- Digitalisation

The findings from the BRIDGE R&I Priorities Report are assessed within the ETIP-SNET Framework of Research Areas, Topics and Tasks. The achievements and challenges listed in the BRIDGE R&I Priorities Report are mapped towards ETUP-SNET Research Areas and Topics to obtain a view of BRIDGE project contributions to the ETIP SNET R&I Roadmap.

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[10] Cooperation platform of the ERA-NET SES Smart Energy Systems
[11] https://www.h2020-BRIDGE.eu/

In addition to monitoring at a project level by ETIP SNET, analyses executed by the BRIDGE initiative are studied. Achievements and remaining challenges, as presented by the BRIDGE projects in the report, are translated into the ETIP SNET context and terminology to provide a general view on the state and trends of research and innovation in Europe, related to grid modernisation and the energy transition in general.

3.2. Analysis of National R&I Progress Reports

National R&I progress reports of European countries are analysed to assess the progress of individual countries in the ETIP SNET's six Research Areas. The analysis uses aggregate progress reports, individual project summaries and funding scheme reports from each country to identify projects contribution to the ETIP SNET scope. For this progress monitoring report, the following countries have been assessed: Germany, the Netherlands, United Kingdom, France, Spain, and Sweden. The goal of this assessment phase is to provide a clear overview which Research Areas are, or are not, being covered by the joint effort of all individual countries.

3.3. Individual Project Results

3.3.1. Project Identification

The first step in gathering the required data on a project level is drafting a list of projects which can contribute to providing the necessary information. Previous progress monitoring activities have shown a response rate just below 50%, making it essential to identify sufficient projects that relate to the ETIP SNET's scope for a large enough sample size.

Multiple distinct sources are used to draft a list of projects that are within the ETIP SNET's scope. These sources are the previous ETIP SNET project monitoring report of 2018, projects that are targeted by a comparable BRIDGE initiative on R&I priorities, projects published on the ERA-NET SES Smart Energy Systems (EXPERA) platform and projects that have presented in one of the past ETIP SNET Regional Workshops. Note that efforts have been made to get in touch with nationally funded projects. However, these efforts have not resulted in any additional nationally funded projects responding to the questionnaire. The nature of funding can either be Horizon 2020 (H2020) or a form of national funding, including combined EU and national funding such as done in the ERA-NET SES initiative. Project details (project name, start-date, end-date) are collected from the mentioned sources and stored in a database. Projects ending in 2018 or earlier are assumed to be sufficiently covered in the previous monitoring report. Note that some projects identified through the ETIP SNET 2018 progress monitoring report or the previous regional workshops may also be a subset of BRIDGE or ETIP SNET. Filtering by projects with an end date of 2019 or later results in a list of nearly 100 unique projects.

3.3.2. Questionnaire Development

The purpose of the questionnaire is to receive detailed insight on the qualitative and quantitative details of individual R&I projects. In developing the questionnaire, careful attention is given to the type of question and the phrasing to invite accurate and objective responses. A completed questionnaire must provide the ETIP SNET with knowledge to have a clear view on the Tasks and Functionalities addressed, Research Areas and Topics covered, and the maturity of Key Exploitable Results obtained in the project. Additionally, the questionnaire aims to expose common obstacles towards the implementation of KERs.

The questionnaire is divided in two main sections. Section 1 refers to general project information. Within this section, there are three subsections:

A) Contact details

B) Project details (name, contributors, scope, funding etc.)

C) Feedback on the call for proposals.

The final subsection is optional for respondents, as it is not essential to the progress monitoring activities. However, it can provide valuable feedback to ETIP SNET and the European Commission on the structuring and phrasing of future calls. Figure 2 depicts a snapshot of section 1 of the questionnaire, showing both open-ended questions as well as closed-ended questions on the Research Areas of the project.

A. Contact details

	Response
Name of respondent:	
E-mail address:	
Phone number:	

B. Project Details

	Response	
Project name (acronym, if applicable):		
Project name (long):		
Project contributors:		
Please indicate the relevant Research Area(s) of the project (Yes/No):	1. Consumer, prosumer and citizen energy community	
	2. System economics	
	3. Digitalisation	
	4. Planning – holistic architectures and assets	
	5. Flexibility enablers and system flexibility	
	6. System operation	

Figure 2: Section 1 of the questionnaire: general project information

Section two has only one subsection (D) which refers to the Topics, Tasks and KERs covered by the project. This part of the questionnaire is essential to the progress monitoring activities covered in this report. Respondents are asked to indicate which research areas and topics are addressed within their project. Based on their input, the questionnaire will provide the corresponding tasks as defined in the Implementation Plan 2021 – 2024. Respondents must indicate TRL of each relevant task addressed by the project. Finally, respondents are asked to indicate and elaborate on the KERs, categorised by Topic. Figure 3 presents a snapshot of section 2 of the questionnaire for a project contributing to Research Area 1 and Topic 1.1. Respondents can add as many Topics as relevant to the project, as well as multiple KERs per Topic.

As subsection D is essential for the project monitoring activities, the full set of questions is presented in Table 2 and

Table 3. A complete depiction of the questionnaire can be found in Appendix 1: Questionnaire for individual R&I projects.

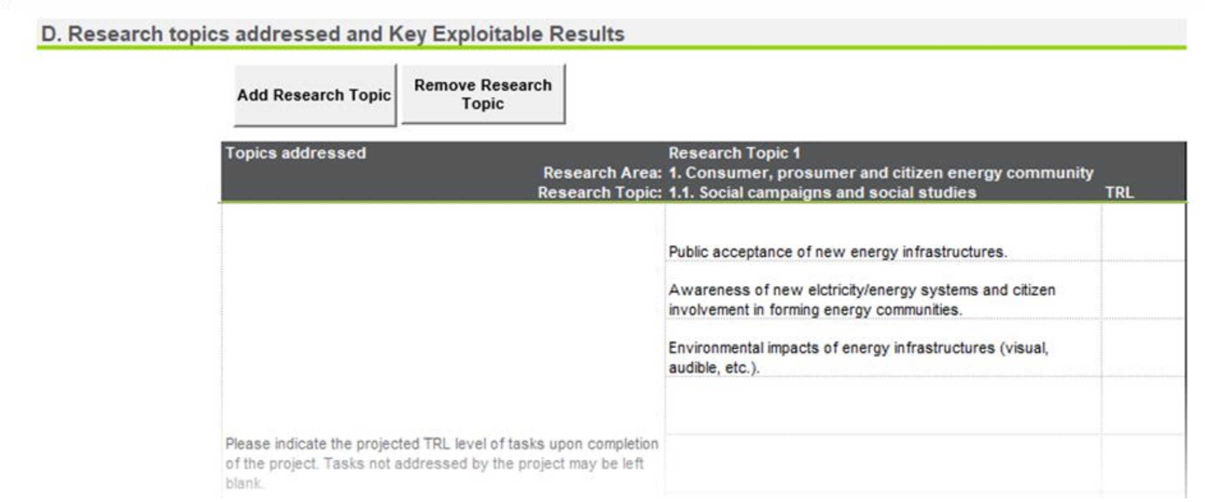

Figure 3: Section 2 of the questionnaire: Topics and KER's

Table 2: Questions in subsection D of the questionnaire on Topics and Tasks

Question	Type of response
Research Area	Drop-down menu with the six Research Areas
Research Topic	Drop-down menu with the Topics corresponding to the Research Area selected
Please indicate the projected TRL level of tasks upon completion of the project. Tasks not addressed by the project may be left blank.	List of tasks corresponding to the Topic selected. Respondents must indicate TRL of 1 – 9 for each task addressed.
If the list of tasks does not properly describe the contributions of your project, use the cell below to list appropriate tasks.	Open-ended question.

Table 3: Questions in subsection D of the questionnaire on Key Exploitable Results

Question	Type of response
Key Exploitable Result (KER)	Description of Key Exploitable Result
Please elaborate on the KER with a quantitative statement:	Quantitative statement substantiating the KER.
What part of the project budget is allocated to this KER (percentage of total budget)?	Open-ended question.
Was the respective part of the budget sufficient?	Closed-ended question.
What was the initial and the target TRL (if applicable)?	Open-ended question.
Please describe the actions taken during the project to reach the desired TRL.	Open-ended question.

Question	Type of response
Which of the actions you have taken to reach the desired TRL have been successful?	Open-ended question.
Upon completion of the project, what further efforts are required and what is the estimated budget for commercialisation?	Open-ended question.
What activities require additional funding (e.g. certification, testing, replicability, business models, etc.)?	Open-ended question.
What was the project management policy (e.g. for software: agile or waterfall method)?	Open-ended question.

3.3.3. Questionnaire Distribution And Collection of Answers

The objective of the questionnaire distribution and collection of answers is to obtain as many responses from individual R&I projects as possible. More contributing projects lead to a more complete view on the state and trends in R&I in Europe and boost confidence in the aggregated results. From the project database created based on previous ETIP SNET, BRIDGE and ERA-NET SES efforts, projects are selected based on the (expected) end date. Projects ending in 2018 or earlier are expected to be sufficiently covered in the previous progress monitoring report. The selected projects are asked to respond to the questionnaire before a given deadline. In addition, ERA-NET SES projects that are not identified in the first iteration are contacted by the consortium partners from BAUM Consult (managing the EXPERA platform). In total, 111 projects have been asked to participate, resulting in 39 complete responses to the questionnaire.

3.3.4. Assessment Of Responses

Completed questionnaires are collected and assessed on their contribution to Functionalities, Research Areas, Topics, and Tasks. The progress of Functionalities and Research Areas is assessed by the number of projects indicating a contribution. For Research Topics, the progress is analysed based on the number of projects contributing and the number of Key Exploitable Results categorised in that Topic.

KERs are categorised by their nature and by their expected TRL upon completion of the project. The five natures of KERs are:

- **Policy, Regulation and Market:** business models and recommendations for policy and regulation.
- **Database:** data collection, aggregation, storage, and access.
- **Hardware:** development or demonstration of a physical piece of equipment.
- **Software:** development or demonstration of a digital tool, algorithm, simulation, or application.
- **Methodology:** a theoretical description of methodologies for designing new rules, energy scenarios, data acquisition, asset management, monitoring and control, etc.

For Tasks, the ETIP SNET Implementation Plan indicates the individual target TRL (in the range of 3 – 5 and 6 – 8). Projects are asked to indicate the expected TRL of relevant Tasks upon completion of the project. The reported range and average TRLs are then compared to the target TRL to assess the progress of the 120 Tasks. In this assessment, a distinction is made between BRIDGE and non-BRIDGE projects.

3.4. ERA-NET SES Assessment

For this Progress Monitoring Report, ERA-NET SES projects ending in 2019 or later have been asked to fill in a questionnaire regarding their research. The results of the projects that have filled in the questionnaire can be found in Chapter 5. Of the projects that have not responded, the questionnaires have been partially filled in using the Project Description and Project Factsheet from the ERA-NET SES Approved Projects website[12]. The ERA-NET SES questionnaires have been partially filled in, based on the publicly available information, not by the researchers of the respective ERA-NET SES projects.

Due to the nature of the literature survey, it has not been possible to determine the Technological Readiness Levels (TRL) for the respective projects with acceptable confidence. Therefore, the reporting is based on the number of projects and their respective budgets, aggregated on the levels of Research Areas, Functionalities and Topics.

4. KEY PUBLICATIONS

The progress monitoring activities described in this report include individual project assessments, aggregated progress analysis and a qualitative assessment of key publications. This chapter focuses on translating the findings of key publications into the ETIP SNET framework of Research Areas, Topics and Tasks. The goal of this chapter is to provide insight in the progress that has been made in research and innovation in the six Research Areas and 24 Topics. The publications considered are BRIDGE R&I Priorities and national progress and funding reports.

The assessment of the BRIDGE publication shows that, while the projects report significant achievements, not all Research Areas are represented evenly. Research Area 3 (Digitalisation) is the most prominent, both in number of achievements as well as in number of Tasks addressed. Research Area 4 (Planning – Holistic Architectures and Assets) has the least reported achievements and Tasks addressed.

The analysis of the national progress reports shows that Research Areas 1 (Consumer, prosumer and citizen energy community), 2 (System economics), 3 (Digitalisation), 5 (Flexibility enablers and system flexibility) and 6 (System operation) are covered by most of the reviewed countries. Research Area 4 (Planning – holistic architectures and assets) is covered to a much lesser degree, reducing the likelihood of significant contributions to those Research Areas by nationally funded research programmes.

4.1. BRIDGE Research and Innovation Priorities

4.1.1. Mapping of BRIDGE Recommendations to ETIP SNET R&I Structures

This section is intended to list the main achievements and remaining challenges within the four key dimensions of the BRIDGE project-related aggregate reporting and translate those findings into the ETIP SNET Implementation Plan 2021-2024 framework of Topics, Tasks and Functionalities.

[12] https://www.eranet-smartenergysystems.eu/Projects

4.1.1.1. First Key Dimension: Integrated Energy System

This dimension consists of three key aspects:

- Flexibility resources
- Integrated system operation and control
- Integrated system planning

The first aspect of the Integrated Energy System, **flexibility resources**, covers:

- Demand flexibility: on the demand side, projects have indicated progress in demand flexibility modelling, demand and supply matching, demand response optimisation, control algorithms, forecasting and aggregation. In addition, the use of commercial and industrial (C&I) customers versus residential customers has been explored. Coordination of TSO and DSO in demand side flexibility use, cybersecurity and data exchange were covered as well. Projects frequently reported flexibility ranges for demand side flexibility of over 20%, strongly depending on the pilot situation.
- Generation flexibility: for generation flexibility, complementarity between different generation sources, forecasting, optimisation, and control has been addressed by the projects.
- Storage flexibility and energy conversion: aspects related to storage flexibility that have been addressed include interoperability between storage and heterogeneous renewable sources, provision of ancillary services, and control of customer-scale batteries. These aspects reportedly led to a wide range of increase of renewables penetration and CO_2 emission reduction.
- Transport flexibility: key topics related to transport-flexibility and other energy-conversion flexibility tackled by the projects include flexibility usage from EVs, public EV charging station networks, office buildings charging stations, control of charging power and vehicle-to-grid and grid-to-vehicle operation.

BRIDGE projects report a significant number of achievements in ETIP SNET Implementation Plan 2021-2024 ***Topic***[13] ***5.1. 'Demand Flexibility'***. ETIP SNET Implementation Plan *Task*[14] *5.1.1 'Optimal utilisation of DR (Demand Response) by TSOs and DSOs* shows three achievements by three projects. These projects report:

- Both upward and downward regulation at the LV and MV level
- Control technologies and aggregation of flexibility services

A remaining challenge for this task includes testing of the services under more realistic market and operational conditions.

In ***Topic 5.3. 'Storage flexibility & Energy Conversion flexibility'***, the BRIDGE projects report several achievements within two tasks. Most notably, *Task 5.3.1 'Storage flexibilities in operation of electrical grids'* contains three achievements by two projects:

- Customer-batteries

[13] The term «Topic» is taken from the ETIP SNET Implementation Plan 2021-2024 and the Roadmap 2020-2030.
[14] The term «Task» is taken from the ETIP SNET Implementation Plan 2021-2024 and the Roadmap 2020-2030.

- Grid-scale batteries operating in the FCR market
- Using batteries to solve local congestion issues

Remaining challenges within this task include full integration of storage and improved coordination, applying storage and power electronics to stabilize weak grids and microgrids, improvements on system aspects and components, and an economical assessment of local storage. *Task 5.3.4 'Power-to-gas applications'* has one achievement:

- A technical feasibility study for power to gas, indicating the economic viability of PEM electrolysis

Four projects report an equal number of achievements in ***Topic 5.5. 'Transport flexibility'***. In *Task 5.5.1 'Efficient management of EV charging'*, achievements include:

- An analysis on the grid impact of smart EV chargers
- Testing of solar based EV charging based on a net metering scheme

Remaining challenges are to further explore the concepts around private charging stations, vehicle-to-grid and other network operators' charging points in the context of grid impact. In *Task 5.5.3 'Electric vehicles with grid to vehicle (G2V) and vehicle to grid (V2G)'*, projects report:

- Vehicle-to-grid using EV batteries as energy
- Vehicle-to-grid and grid-to-vehicle capabilities in distribution net for load flattening and system balancing

A remaining challenge is to increase the number of EV drivers participating in vehicle-to-grid applications.

Topic 5.2. 'Generation flexibility', as well as ***Topic 5.4. 'Network flexibility'*** show no contributions from the BRIDGE projects. In addition, no remaining challenges have been identified at this point.

Table 4: Mapping of the BRIDGE reported achievements for the Integrated Energy System (flexibility resources)

BRIDGE achievement	ETIP SNET Topic	ETIP SNET Task
• **Integration of all flexibility into one platform (INTERRFACE)** • **An Aggregator Control Hub which managed to successfully provide the requested amounts of flexibility to the DSO (INERTIA)** • **Both at LV and MV level, flexibility (downward mainly) was used to solve local congestion issues and voltage problems (InteGrid)**	5.1. Demand Flexibility	5.1.1. Optimal utilisation of DSR by TSOs and DSOs.
• **Using Flexibility of EVs (InterFlex)**	5.1. Demand Flexibility	5.1.2. Direct load control
• **Large-scale battery operating in the FCR market (EU-SysFlex)** • **Customer-scale batteries control testing according to FCR rules (EU-SysFlex)**	5.3. Storage Flexibility	5.3.1. Storage flexibilities in operation of electrical grids.

BRIDGE achievement	ETIP SNET Topic	ETIP SNET Task
• **Using a battery to prevent local congestion (InterFlex)**		
• **Power to gas technical feasibility is analysed and is found that Proton Exchange Membrane Electrolysis Cell (PEMEC) has the lowest investment costs (Store&Go)**	5.3. Storage Flexibility	5.3.4. Power-to-gas applications.
• **Analysis of grid impact of smart EV chargers' integration and development of proper control strategies (INSULAE)** • **Solar based EV charging under a net-metering scheme (TILOS)**	5.5. Transport flexibility	5.5.1. Efficient management of EV charging.
• **V2G using EV batteries as energy buffers (Shar-Q)** • **V2G and G2V capabilities in distribution net for load flattening and system balancing (FlexiGrid)**	5.5. Transport flexibility	5.5.3. Electric vehicles with grid to vehicle (G2V) and vehicle to grid (V2G).

Table 5: Mapping of the BRIDGE remaining challenges for the Integrated Energy System (flexibility resources)

BRIDGE remaining challenge	ETIP SNET Topic	ETIP SNET Task
• **Test an entire process of management of flexibility services. Possibility to establish some pilots with a full involvement of TSO and customers, scoping the test of flexibility market and services management. (EU-SysFlex).** • **Test the flexibility activation under a competitive framework (e.g. market biding) (InteGrid).**	5.1 Demand Flexibility	5.1.1. Optimal utilisation of DSR by TSOs and DSOs.
• **New application of storage systems foreseeing a full integration of these devices; rebound-effect from including storage flexibility; Improved coordination in the use of the storage by the DSO and TSO (EU-SysFlex)** • **Storage and power electronics to stabilize weak grids and micro-grids (INSULAE)** • **Economic assessment of local storage (InterFlex)** • **Improvements on system aspects and components (Shar-Q)**	5.3. Storage flexibility & Energy Conversion flexibility	5.3.1. Storage flexibilities in operation of electrical grids.
• **Further explore private charging stations, V2G and other charging points (EUSysFlex)**	5.5. Transport flexibility	5.5.1. Efficient management of EV charging.
• **Increase share of EV drivers engaging in EV flexibility. (InterFlex)**	5.5. Transport flexibility	5.5.3. Electric vehicles with grid to vehicle (G2V) and vehicle to grid (V2G).

The second aspect of an integrated energy system, **energy system operation**, covers

- State estimation and supervision: projects have reported progress in state estimation and supervision at MV and LV levels. This includes grid monitoring, state estimation algorithms, load allocation, visualisation GIS integration, battery management and EV management. In addition, advanced forecasting and data flow between DSOs and TSOs is developed.
- Short-term control: progress in short term control includes 50% redirection of power flows in short term congestion management. Projects have developed predictive control of flexibility and short-term control strategies to manage storage for congestion relief with power flow controllers.
- Medium- and long-term control: for medium- and long-term control, achievements include multi-period optimal power flow for MV grids, medium term load and renewable energy forecasting, grid balancing and stability and day-ahead topology optimisation. In addition, planning and optimisation of distributed generation and the network were optimised considering flexibility resources such as EVs, storage and residential demand.
- Preventive control and restoration: achievements for preventive control and restoration include adaptive/self-healing control for distribution networks, multi-period optimal power flow to follow the predictive plan and, finally, predictive control of flexibility. In addition, island mode operation, remote shutdown/restart and black-out recovery mechanisms were reported.
- Control centre technologies: projects report achievements in control centre technologies; including TSO/DSO coordination platforms, platforms for virtual power plants, demand response aggregation and cross border aFRR TSO co-optimisation. In addition, integrated LV/MV with LV/MV forecasting was demonstrated.

In **Topic 6.1. 'Supervisory control and state estimation'**, two projects indicate achievements. In Task 6.1.1. 'Steady state and dynamic state estimation of transmission systems using intelligent monitoring devices, state estimation and forecasting tools were developed. Remaining challenges include to further develop state estimation for operational use, and further research on optimisation algorithms.

The improvement of LV and MV grid monitoring was achieved in Task 6.1.2. 'Observability and state estimation of distribution systems.'

Topic 6.2. 'Short term control' is addressed with two achievements from two projects. Achievements in Task 'Contribution of RES to primary voltage and frequency control' include RES control based on real-time network conditions and predictive control of flexibility.

Remaining challenges are the coordination of inverters as well as the electrification of islands focusing on frequency and voltage regulation.

In **Topic 6.4. 'Preventive Control/Restoration'**, two projects indicate achievements in two different tasks. Island operation mode was achieved in Task 6.4.3. 'Topology optimisation for increasing network resilience'.

Remaining challenges include the transition from grid-connected operation to island mode operation with the possibility to improve reliability and resilience of distribution network, and additional information and analyses about the required settings for protection elements in island mode.

In Task 6.4.5. 'Self-healing techniques', multi-period optimal power flow showed its capability to follow the predictive plan or adjust it, if necessary, in one project.

The BRIDGE projects report some achievements in **<u>Task 6.5. 'Control centre technologies.'</u>** In <u>Task 6.5.4. 'Control centre architectures for distributed network control'</u>, projects achieved

- Combined P-Q-optimisation for operational planning
- Demonstration of integrated LV/MV ADMS (Advanced Distribution Management System) solution

Remaining challenges are identified for *<u>Task 6.5.1.'Wide area monitoring and control architecture for transmission systems,'</u>* i.e. developing a detailed view for Demand and Generation in forecasting user interface, and computation of both net (of variable RES) and full load forecasts.

Limited direct achievements or remaining challenges were identified for ***Topic 6.3. 'Medium and long-term control'.*** However, achievements reported in Research Area 5 'Flexibility enablers and system flexibility' are likely to be of importance for medium- and long-term control of the energy system.

Table 6: Mapping of the BRIDGE achievements for the Integrated Energy System (system operation and control)

BRIDGE achievement	ETIP SNET Topic	ETIP SNET Task
• **State Estimation Forecasting Tools (EU-SysFLex)**	6.1. Supervisory control and state estimation	6.1.1. Steady state and dynamic state estimation of transmission systems using intelligent monitoring devices.
• **Improvement of LV and MV grid monitoring (InteGrid)**	6.1. Supervisory control and state estimation	6.1.2. Observability and state estimation of distribution systems.
• **RES control based on real-time network conditions (Compile)** • **Predictive control of flexibility (storage, OLTC, controllable loads, capacitor banks, RES) (InteGrid)**	6.2. Short-term control	6.2.3. Contribution of RES to primary voltage and frequency control.
• **Island mode operation (Compile)**	6.4. Preventive Control/Restoration	6.4.3. Topology optimisation for increasing network resilience.
• **Multi-period optimal power flow showed its capability to follow the predictive plan or adjust it if necessary (InteGrid)**	6.4. Preventive Control/Restoration	6.4.5. Self-healing techniques.
• **Combined P-Q-optimisation for operational planning (real time and schedule-based) (EU-SysFlex)** • **Demonstration of integrated LV/MV ADMS (Advanced Distribution Management System) solution, which included integration of several project developed components: LV/MV forecasting; MPOPF, MVLA and LVSE (InteGrid)**	6.5. Control centre technologies	6.5.4. Control centre architectures for distributed network control.

Table 7: Mapping of the BRIDGE remaining challenges for the Integrated Energy System (system operation and control)

BRIDGE remaining challenge	ETIP SNET Topic	ETIP SNET Task
• **Develop state estimation with little amount of measuring points for operational use (EU-SysFlex)** • **Further research on optimisation algorithms both in aggregator and local hub level (InteGrid)**	6.1. Supervisory control and state estimation	6.1.2. Observability and state estimation of distribution systems.
• **Coordination of inverters (COMPILE)** • **Electrification of island focusing on frequency and voltage regulation (INSULAE)**	6.2. Short-term control	6.2.3. Primary voltage and frequency control of distribution grids.
• **Transitions from grid-connected to island operation with the possibilities to improve reliability and resilience of distribution network by Intended Island Operations (EU-SysFlex)** • **More information/analyses about the needed settings for protection elements when they are operating in island mode. (COMPILE)**	6.4. Preventive Control/Restoration	6.4.3. Topology optimisation for increasing network resilience.
• **Simultaneous detailed view for Demand and Generation in Forecasting UI for long time periods Wind generation forecasting (InteGrid)** • **Compute both net and true load forecast (InteGrid)**	6.5. Control centre technologies	6.5.1. Wide area monitoring and control architecture for transmission systems.

The third aspect of an integrated energy system, **energy system planning**, covers

- Integrated energy system architectures: achievements in integrated energy system architectures include the development of technology for protection of meshed HVDC offshore grids, the development of new DC grids, HVDC circuit breaker, and coupling of the electricity and heating and transport sectors.
- Long term planning: progress in long-term planning includes grid balancing, day-ahead topology optimisation, long term capacity planning based on blockchain technology, and an investment planning tool.
- Asset management and maintenance: asset management achievements reported are weather resilience, de-icing protocols and battery calibration and restoration.
- System stability analysis: achievements for system stability analysis include grid balancing and stability, energy management methods and tools, interoperability between different technologies, increased system resilience and intelligent converters for stability purposes.

Two projects indicate an achievement in ***Topic 4.1. 'Integrated Energy System Architectures.'*** In *Task 4.1.9. 'HVDC meshed grids and parallel routing of DC and AC lines,'* full scale and high power HVDC circuit breaker demonstration was achieved for HVDC offshore grids.

Remaining challenges in *Task 4.1.1. 'Model of the energy system encompassing the while energy chain'* include business models for a unified platform, and the process of transition to DC grids.

In ***Task 4.2. 'Long-term planning,'*** an investment planning tool to support decision makers on the selection and design of cost-effective action plans for island decarbonisation was achieved in *Task 4.2.3. 'Planning for resilience.'*

Taking predictive maintenance from TRL 6 to market remains a challenge in *Task 4.3.3. 'Model-based detection of component failures'* in ***Task 4.3. 'Asset management and maintenance.'***

Table 8: Mapping of the BRIDGE achievements for the Integrated Energy System (system stability analysis)

BRIDGE achievement	ETIP SNET Topic	ETIP SNET Task
• **HVDC circuit breaker full-scale and high-power demonstration for meshed HVDC offshore grids (Promotion)**	4.1. Integrated Energy System Architectures	4.1.9. HVDC meshed grids and parallel routing of DC and AC lines.
• **Investment Planning Tool (IPT) that will support the decision maker on the selection and design of cost-effective Action Plans looking for an island decarbonisation (INSULAE)**	4.2. Long-term planning	4.2.3. Planning for resilience.

Table 9: Mapping of the BRIDGE remaining challenges for the Integrated Energy System (energy system planning)

BRIDGE remaining challenge	ETIP SNET Topic	ETIP SNET Task
• **Business model for a unified platform (InteGridY)** • **Process of transition to DC grids (INSULAE)**	4.1. Integrated Energy System Architectures	4.1.1. Model of the energy system encompassing the whole energy chain.
• **Taking predictive maintenance from TRL 6 to market. Usefulness of fault indicators in major events.**	4.3. Asset management and maintenance	4.3.3. Model-based detection of component failures.

4.1.1.2. Second Key Dimension: Customer at The Centre

Table 10 indicates the achievements of the BRIDGE projects indicated in the BRIDGE TF report on R&I priorities that are related to the different Tasks of the Research Area[15] 1 'Consumer Prosumer and Citizen Energy Community.' The relevant remaining challenges are indicated in

Table 11.

It is evident that the Tasks in **Topic 1.1 'Social campaigns and social studies'** aggregate most of the reported achievements. Five projects indicate achievements related to Task 1.1.2. 'Awareness of new electricity/energy systems and citizen involvement in forming energy communities.' The relevant results concern

- Social awareness campaigns
- Citizen engagement strategies
- Definition of KPIs for customer satisfaction

Moreover, achievements are also reported for:

- Energy communities, with the organisation of the relevant workshops

[15] The term «Research Area» is taken from the ETIP SNET Implementation Plan 2021-2024.

- Processes to get communities involved and retain their interest

The remaining challenges related to this task concern:

- Modification of the developed solutions to include the residential sector
- Development of a multi stakeholder perspective (with a central role of citizen engagement and energy communities)
- Exploitation of energy data for non-energy services

Regarding *Task 1.1.1 'Public acceptance of new energy infrastructures,'* 2 projects report results concerning different technologies to

- Foster Energy Efficiency on Public buildings
- Feedback from battery owners on their experience during demo flexibility activities

Less projects have reported results on the Tasks related to **Topic 1.2 'Adaptive consumer/user behaviour including energy communities.'** Results can be identified for 3 projects concerning Task 1.2.1 'Consumers' and prosumers' adaptation of energy behaviour.' The relevant achievements concern

- Use of IoT technology and monitoring actions to evaluate the thermal and visual comfort of building occupants
- Definition of KPIs for the Self-Consumption Rate
- Definition of a society vector for the quality of life on islands

Remaining challenges have also been reported in this task related to

- Need for testing larger size samples
- Additional data and models for user profiling models
- Evaluation of the behaviour of energy communities (how they emerge, develop and act)
- Need for strategies to support energy communities

A reduced number of projects have reported results related to the tasks of **Topic 1.3. 'Consumer and prosumer device control.'** 2 projects indicate achievements related to Task 1.3.1. 'Wireless technologies for direct control of consumption/generation.' The relevant results concern

- An affordable tool for the flexibility aggregation
- Methods for increasing the self-consumption rate and the flexibility provision to the DSO

The remaining challenges related to this task concern

- The need for a holistic management with applications for end-users of buildings
- New features for the facility managers that include updates on the models of the local hub environment and updates of the applications for the end users of the building

Only one project has indicated achievements related to *Task 1.3.2. 'ICT technologies for smart appliances,'* which concern the automated control of buildings to achieve significant results on energy reduction and flexibility provision. It should be noted however that **Topic 1.3 'Consumer and prosumer device control.'** shows significant overlaps with **Topic 3.2 'Data Communication (ICT)'**, so these findings must be treated considering both tasks combined.

Table 10: Mapping of the BRIDGE achievements for Consumer, Prosumer and Citizen Energy Community

BRIDGE achievement	ETIP SNET Topic	ETIP SNET Task
• **Assessment of different technologies to foster Energy Efficiency on Public buildings (GreenSoul)** • **Positive feedback from the customer-scale battery owners to the questionnaire about their experience during the first flexibility demo phase (EUSysFlex)**	1.1. Social campaigns and social studies	1.1.1. Public acceptance of new energy infrastructures.
• **Social awareness raising campaign (Compile)** • **Citizen engagement strategies and means/tools (Making City)** • **Definition of KPI Customer satisfaction (FlexiGrid)** • **Organisation of workshops for engagement of the local citizens to cleaner energy and creation of energy communities (Insulae)** • **Knowledge on processes on how (and how not) to onboard and retain communities (Integrid)**	1.1. Social campaigns and social studies	1.1.2. Awareness of new electricity/energy systems and citizen involvement in forming energy communities.
• **Definition of a society vector to provide information on the quality of life in islands (Insulae)** • **Definition of KPI Self-Consumption Rate (FlexiGrid)** • **Thermal and visual comfort of building occupants was considered through the use of IoT technology and monitoring control actions (Inertia)**	1.2. Adaptive consumer/user behaviour including energy communities	1.2.1. Consumers' and prosumers' adaptation of energy behaviour.
• **Affordable tool for flexibility aggregation (EUSysFlex)** • **Increase in self-consumption rates & provision of flexibility to DSO (InteGrid)**	1.3. Consumer and prosumer device control	1.3.1. Wireless technologies for direct control of consumption/generation.
• **Automated control of building's assets (HVAC, Lights, Other appliances), achieving significant results in terms of energy reduction and flexibility potential (InteGrid)**	1.3. Consumer and prosumer device control	1.3.2. ICT technologies for smart appliances

Table 11: Mapping of the BRIDGE remaining challenges for Consumer, Prosumer and Citizen Energy Community

BRIDGE remaining challenge	ETIP SNET Topic	ETIP SNET Task
• **How to modify the solutions to cover demand response actions and the residential sector instead of public buildings (GreenSoul)**	1.1. Social campaigns and social studies	1.1.2. Awareness of new electricity/energy systems and citizen involvement in forming energy communities.

BRIDGE remaining challenge	ETIP SNET Topic	ETIP SNET Task
• **Multi stakeholder perspective in which citizen engagement and energy communities take a central stand. (Making City)** • **How to use energy data for non-energy services (Insulae)**		
• **More research effort to how energy communities emerge and develop and act in a multi-stakeholder network, how they can be better supported (Making City)** • **Additional data and models for the extraction accurate user profiling models (Inertia)** • **Testing with larger sample size (more households, wider demographic) for impacts on electricity consumption behaviour (InteGrid)**	1.2. Adaptive consumer/user behaviour including energy communities	1.2.1. Consumers' and prosumers' adaptation of energy behaviour.
• **Applications for the end users of buildings and new features for the facility managers towards the provision of holistic management (Inertia)**	1.3. Consumer and prosumer device control	1.3.1. Wireless technologies for direct control of consumption/ generation.

4.1.1.3. Third Key Dimension: The Importance of a Market-Based Energy System

The achievements and the remaining challenges that are related to each Task of the Research Area 2 (System Economics) are evident in the following tables.

Most achievements can be related to the tasks of ***Topic 2.1 'Business models.'*** In particular, five projects have indicated achievements related to *Task 2.1.2 'Business models for retailers and aggregators, ESCO's and energy communities.'* The relevant projects' results concern

- The provision of ancillary/balancing/frequency services to System Operators
  - Imbalance Risk Reduction Services
  - Employment of DER flexibilities from the DSO
  - Reactive Power provision to TSO/DSO in a local reactive power market and batteries operating in the FCR market).

Three projects have also identified remaining challenges related to this particular task, concerning

- Real-life Demand Response business models
- Business models based on DER aggregation or behavioural demand

Remaining challenges also concern

- Convergence related issues of the clearing algorithm
- Evaluation of the economic viability of flexibility services provision
- Profitability of the relevant market

Tasks 2.1.1 'Business models for prosumers providing ancillary services' and 2.1.3 'Business models for data analysis service providers' have each been addressed by one project, indicating achievements on

- Exploiting the prosumer flexibility
- Development of a data exchange platform among consumers, the DSO and the retailer

A reduced number of projects have indicated results related to ***Topic 2.2. 'Market design and governance.'*** Two projects have reported results related to *Task 2.2.5 'Design of local markets and their interaction to central markets'*, concerning

- Proof of concept for local reactive power markets
- Cost-benefit analysis of the Home Energy Management System (according to different regulatory frameworks)

Moreover, three projects have identified remaining challenges related to *Task 2.2.3 'Market rules for ancillary services by aggregated storage and virtual power plants.'* These remaining challenges concern

- Regulation barriers to test innovative markets
- Evaluation of the compensation cost for reactive power provision
- Benefits of including active load in the re-dispatch process

Table 12: Mapping of the BRIDGE achievements for System Economics

BRIDGE achievement	ETIP SNET Topic	ETIP SNET Task
• **Utilising Prosumer Flexibility (Inertia)**	2.1. Business models	2.1.1. Business models for prosumers providing ancillary services.
• **Large-scale battery operating in the FCR market, development on-going to include office-scale battery to FCR (EUSysFlex)** • **Provision of reactive power to TSO and DSO with a local reactive power market (EUSysFlex)** • **Offering Ancillary Services to System Operators. (Inertia)** • **Utilizing Portfolio Flexibility for Imbalance Risk Reduction Services (Inertia)** • **DSO using DER flexibilities from different sources. (InteGrid)**	2.1. Business models	2.1.2. Business models for retailers and aggregators, ESCOs and energy communities.
• **Platform enabling data exchange between domestic consumers and the DSO and the retailer (InteGrid)**	2.1. Business models	2.1.3. Business models for data analysis service providers.
• **Technical proof of concept for local reactive power market (EUSysFlex)** • **Cost-benefit analysis of the HEMS considering different types of regulatory frameworks (InteGrid)**	2.2. Market design and governance	2.2.5. Design of local markets and their interaction to central markets.

Table 13: Mapping of the BRIDGE remaining challenges for System Economics

BRIDGE remaining challenge	ETIP SNET Topic	ETIP SNET Task
• **Economic viability of flexibility service provision; Liquidity impact, profitability of participating in such**	2.1. Business models	2.1.2. Business models for retailers and aggregators, ESCOs

BRIDGE remaining challenge	ETIP SNET Topic	ETIP SNET Task
market, need of reactive power capacity mechanisms or connection agreements, and additional issues related with the convergent of the clearing algorithm when grid constraints cannot be guaranteed (EUSysFlex) • **Evaluation of DR Business models: As the implementation of DR strategies is one of the main trends on the deregulated market, it is essential to further examine the potential impact of INERTIA Aggregator platform on real life business models (INERTIA)** • **Business models based on DER aggregation or on behavioural demand response deserve further studies (InteGrid)**		and energy communities.
• **The cost of reactive power compensation provision to the asset owner (the reactive power market concept is not economically feasible in the current situation in some countries) (EUSysFlex)** • **The constraints posed by existing regulation limit the ability to test certain innovative market, tariff or grid operation approaches Barriers to engaging stakeholders of the project may limit the scope of the demonstration activities (Insulae)** • **Identifying of benefit from including load (including energy conversion) in Redispatch process (EUSysFlex)**	2.2. Market design and governance	2.2.3. Market rules for ancillary services by aggregated storage and virtual power plants.

4.1.1.4. Fourth Key Dimension: Digitalisation as a Key Enabling Technology

The following tables indicate a link among the ETIP SNET Tasks, and the Achievements/Remaining Challenges outlined in the BRIDGE Report. A direct link among the relevant achievements and remaining challenges is not always identifiable (additional information is provided in the tables concerning specific tasks). The following tables concern only tentative links among the BRIDGE Report and the ETIP SNET tasks, since the relevant answers received from projects in the before-mentioned BRIDGE report were only distinguished among Topics without reference to relevant tasks.

It shall also be noted that most Tasks are not fully addressed (even when many projects in the BRIDGE report indicate results linked to the relevant tasks). On the contrary, the tables rather indicate work that has been performed concerning the relevant Tasks (or similarly, remaining challenges identified linked to the relevant tasks), indicating aspects of the Tasks to which the projects have contributed.

The following tables indicate the achievements and the remaining challenges as noted in the BRIDGE TF on R&I priorities report. ***Topic 3.1 'Protocols, standardisation and interoperability'*** appears to be the topic in Digitalisation that aggregates most of the projects' results. Most projects have indicated results related to *Task 3.1.1 'Data exchange protocols / interfaces for a well-functioning market.'* In this Task, 9 projects have examined

- Data exchange requirements
- Utilisation of protocols for data buses (a computer subsystem for data transfer) and data exchange
- Interfaces for flexibility exchange
- Sensor/actuator/metering cloud components
- Interoperability issues (among flexibility sources, among the system management and electricity markets, and cross border interoperability)

Interesting remaining challenges are also indicated for this Task:

- Need for cross sectoral data exchange at EU-level
- Real-time markets
- Examination of market hubs at a multi-DSO level

Additional results are indicated for the rest of the Topic 3.1's tasks: 3 projects indicate results for Task 3.1.2 'Standardised communication protocols and ICT infrastructure' and 2 projects for Task 3.1.4 'DSO and TSO information exchanges; decision-making support functions.'

The number of projects indicating results for the Tasks in **Topic 3.2. 'Data Communication (ICT)'** is significantly reduced. One or two projects indicate results for each of the Tasks 3.2.1 'Demand aggregation and control,' 3.2.2 'Monitoring and control of distributed generation' and 3.2.3 'Communication infrastructures for smart metre data.' The results concern

- Communication among assets and the aggregation platform
- Control of hybrid stations
- Energy management control centres
- Communication infrastructures for close to real-time smart metre data

A limited number of projects has also indicated remaining challenges for these tasks. In particular, three projects have indicated

- A need to use the market-hub for "classic" retail market communication (e.g. meter data for billing)
- A need to test the NB-IoT LPWAN radio technology for Smart metering and Demand Side Management

Once again, these results illustrate that Topic 1.3 'Consumer and prosumer device control.' shows significant overlaps with Topic 3.2 'Data Communication (ICT)'.

Only two projects have indicated results on the Tasks of Topic 3.4 'Cybersecurity and privacy.' Projects examined

- Cybersecurity frameworks, while providing improvement recommendations and practices in utilities, related to *Task 3.4.1 'Cyber security protection of grid infrastructures'*
- A need for penetration tests for cyber security as a remaining challenge for this task

Moreover, one project has indicated results related to *Task 3.4.2 'GDPR-compliant methodologies for management of distributed energy resources'* providing risk assessment methods to identify threats and mitigation measures related to GDPR.

No projects have indicated results for ***Topic 3.3 'Data and Information Management'*** or ***Topic 3.5 'End-to-End Architecture.'*** However, two projects have indicated remaining challenges concerning Topic 3.3 and *Task 3.3.2 'IoT technologies in TSO and DSO planning,'* concerning the direct connection of devices at the grid side, since IoT was handled via the demonstrators at demo-sites at the particular project.

Table 14: Mapping of the BRIDGE achievements for Digitalisation

BRIDGE achievement	ETIP SNET Topic	ETIP SNET Task
• **Data exchange requirements between system-services managers and flexibility providers (CoordiNet)** • **Standardised data format and interface for flexibility exchange (InteGrid)** • **Utilisation of MQTTT protocol for data buses and data exchange (SOGNO, Platone, CROSSBOW)** • **Interlink active system management with electricity markets (EUniversal)** • **Interface to all sensor/actuator/metering cloud components. (INERTIA)** • **Interoperability among flexibility sources (MERLON)** • **Cross-border interoperability (EU-SysFlex)**	3.1. Protocols, standardisation and interoperability	3.1.1. Data exchange protocols / interfaces for a well-functioning market.
• **Standardised communication protocols and ICT infrastructure between devices and networks and also between devices and remote management platforms (Flexigrid)** • **Component interoperability at the Hybrid Station and island microgrid level (TILOS)** • **Intelligent controllers- balancing services, DLR, FACTS (FLEXITRANSTORE)**	3.1. Protocols, standardisation and interoperability	3.1.2. Standardised communication protocols and ICT infrastructure between devices and networks and also between devices and remote management platforms.
• **Identifying the data exchange requirements between TSOs, DSOs (CoordiNet)** • **Standardised interface for flexibility exchange in LV and MV grids (Integrid)**	3.1. Protocols, standardisation and interoperability	3.1.4. DSO and TSO information exchanges; decision-making support functions.
• **Communication between assets and aggregation platform (EU-SysFlex, CROSSBOW)**	3.2. Data Communication (ICT)	3.2.1. Demand aggregation and control.
• **Hybrid Station & HL-EMC SCADAs (TILOS)**	3.2. Data Communication (ICT)	3.2.2. Monitoring and control of distributed generation.
• **Communication infrastructures for smart meter data (close to real-time) (Flexigrid)**	3.2. Data Communication (ICT)	3.2.3. Communication infrastructures for smart metre data.
• **Cybersecurity frameworks, improvement recommendations and practices in utilities (CROSSBOW)**	3.4. Cybersecurity and privacy	3.4.1. Cyber security protection of grid infrastructures.

BRIDGE achievement	ETIP SNET Topic	ETIP SNET Task
• **Risk assessment to identify threats and mitigation measures, related to GDPR (InteGrid)**	3.4. Cybersecurity and privacy	3.4.2. GDPR-compliant methodologies for management of distributed energy resources.

Table 15: Mapping of the BRIDGE remaining challenges for Digitalisation

BRIDGE remaining challenge	ETIP SNET Topic	ETIP SNET Task
• **Cross-sectoral data exchange at European level (SHAR-Q)** • **Real time markets (FLEXITRANSTORE)** • **Use of grid/market-hub at a multi-DSO level, instead of a single DSO. (InteGrid)**	3.1. Protocols, standardisation and interoperability	3.1.1 Data exchange protocols / interfaces for a well-functioning market.
• **Readiness level of commercially available aggregation platforms (EU-SysFlex)** • **Interoperability between systems and smart home appliances (*InteGrid*)**	3.1. Protocols, standardisation and interoperability	3.1.2 Standardised communication protocols and ICT infrastructure between devices and networks and also between devices and remote management platforms.
• **Testing of the NB-IoT LPWAN radio technology for the Demand Side Management network (TILOS)**	3.2. Data Communication (ICT)	3.2.1 Demand aggregation and control.
• **Use of the grid/market-hub for "classic" retail market communication (e.g. metre data for billing) (Integrid)** • **Testing of the NB-IoT LPWAN radio technology for Smart metering (TILOS)**	3.2. Data Communication (ICT)	3.2.3. Communication infrastructures for smart metre data.
• **Direct connection with devices at the grid edge (IoT was handled via the demonstrators at demo-sites) (InteGrid)** • **A unique data platform to perform correlation analysis and better target energy choices. (Ebalanceplus)**	3.3. Data and Information Management	3.3.2. IoT technologies in TSO and DSO planning.
• **Penetration tests for cyber security (TILOS)**	3.4. Cybersecurity and privacy	3.4.1. Cyber security protection of grid infrastructures.

4.1.2. Conclusions on BRIDGE Mapping

All six Research Areas of the ETIP SNET have been covered by at least one achievement from BRIDGE projects. Of these Research Areas, most achievements (17) are reported in Research Area 3: Digitalisation. The lowest number of achievements (2) are reported in Research Area 4: Planning – holistic architectures and assets. In total, **31 out of 120 Tasks** have been addressed by at least one achievement. Note that the mapping of achievements is a subjective task, and in case of doubt, the achievement was mapped to the Task with the best fit. However, it is equally important to note that some Tasks have significant areas that overlap between them. As this assessment is qualitative and thus to a certain degree subjective, no precise conclusions can be drawn. However, based on the number of achievements (and Tasks) covered by the BRIDGE projects, it becomes clear that

- Research Area 3: Digitalisation is the most prominent area within BRIDGE, both in number of achievements, as well as number of Tasks addressed. However, with 8 out of 17 Tasks addressed, even this Research Area is not fully covered by the projects.
- Research Area 4: Planning – Holistic Architectures and Planning requires additional steering to achieve the Tasks formulated, as only 2 out of 32 Tasks have been addressed by the projects.
- 89 out of 120 Tasks have not surfaced in the mapping of achievements. These Tasks are either outside the scope of BRIDGE, superfluous due to overlapping with other Tasks, or must be re-evaluated based on the assessment of other sources.

4.2. National Progress Reports

Next to European/multi-national Research Programmes like BRIDGE and ERA-NET SES, most, if not all, European countries have independent National Research Programmes focused on developing expertise within the area of Smart Networks and sector coupling. Those National Research Programmes, while often smaller both in scope and budget than European/multi-national Research Programmes, are tailored to the national requirements, driven by cultural, political, and geographical differences. The projects that fall under these National (or even regional) Research Programmes differ significantly in structure, reporting style and goals, from nation to nation, making an in-depth one-on-one comparison infeasible. One aggregation level higher, i.e. at the level of Research Areas, evidence can be gathered whether a particular Research Area is covered by the National Research Programme(s) of a certain country. The justification for the level of confidence per Research Area per country is described in the sections below. Please note that the overview is not exhaustive in the number of countries, nor in the description of the National Research Programmes, nor the number of projects. A subset of European countries which are at the forefront of the energy transition has been selected; assessing each individual country within the EU is not feasible within the timeframe of this progress monitoring report. Furthermore, when sufficient evidence has been gathered that a Research Area is covered by a country, no further investigation has been conducted for that Research Area for that country.

4.2.1. Germany

Information on Germany's research and innovation projects related to smart energy networks is found in the latest Federal Report on Energy Research from the German Federal Ministry of Economic Affairs and Energy[16]. This document reports on the latest research projects linked with accelerating the energy transition. This report also refers to activities organised formally outside the energy research program and in particular to the very large 4-year SINTEG R&I program (Schaufenster INtelligenTe EnerGie or showcases intelligent energy, comprising five projects performed by large and diverse consortia and covering all regions of Germany with the projects c/sells, DESIGNETZ, enera, NEW4.0 and WindNODE (of these, c/sells is also covered in this report's Chapter 5). These 4-year projects addressed from 2016-20 most Research Areas of the ETIP SNET scope (with perhaps the weakest coverage in Research Area 4 (Planning – holistic architectures and assets). A follow-up synthesis project currently collects the most important results and KERs of all five projects and structures the outcomes in blueprints for future German implementation of smart grids. The synthesis report is due in 2022 and its drafts are foreseen to be covered in the 2022 update of this SPRING Task 3.2 Progress Monitoring Report. The Federal Report on Energy Research has been assessed to see which

[16] https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/bundesbericht-energieforschung-2021.html

Research Areas of the ETIP SNET have been covered by Germany. All Research Areas, except for Research Area 4, show some evidence of coverage by German research entities.

- Research Area 1 (Consumer, prosumer and citizen energy community) is covered by *Benefits* (covers acceleration of the energy transition by involving municipalities and citizens through participation).
- Research Area 2 (System economics) is covered by: *OPTIBIOSY* (analyses the potential and development of an optimisation model for biogas plants in the future electricity system) and *Hysupply* (a market study for hydrogen supply in the energy market).
- Research Area 3 (Digitalisation) is covered by two projects named *ODH @ Julich* (covers open data-based planning tools for cross-sectoral energy supply by means of open, integrated ICT ecosystems) and *DaLion 4.0* (data mining as a basis for cyber-physical Systems in lithium-ion battery cell production).
- Research Area 5 (Flexibility enablers and system flexibility) is covered by multiple projects, including *Arkol* (develops architecturally high integrated facade collectors with heat pipes), *WPUQ – EnEff* (analyses a heat district with renewable energy operated heat pumps to minimise the primary energy demand), and *LEITNING* (research and testing of a power converter for reliable energy supply).
- Research Area 6 (System Operation) is covered by the projects *ReserveBatt* (system services for the safe operation of the energy supply system) and *UNSEEN* (optimalisation models for the energy system).

4.2.2. The Netherlands

The Netherlands has a dedicated National Research Programmes for Smart Grids, reported on by the Topsector Energie (TE), i.e. Top Sector Energy[17]. The TE maintains an up-to-date public overview of projects in The Netherlands working within the field of Smart Grids. This overview provided sufficient confidence that The Netherlands covers each of the six Research Areas.

- Research Area 1 (Consumer, prosumer and citizen energy community) is covered by: *Herman's Smart Grids (*power control supply and demand by BeNeXt); various research projects by *Energieonderzoek Centrum Nederland* (ECN, Dutch Energy Research Centre); *SolarMiles* (by Amelander Energy Cooperation), among others.
- Research Area 2 (System economics) is covered by: *Verosol & MECAL Wind Turbine Design* (Assessing economic viability of a new heating system, using electricity instead of gas); *Cooperative sustainable business models for storage* (by Coöperatieve Vereniging Weerenergie UA); various research projects by *Energieonderzoek Centrum Nederland* (Dutch Energy Research Centre), among others.
- Research Area 3 (Digitalisation) is covered by: *b.Home* (Platform for digitalisation and automatisation of the transition to gas-free neighbourhoods); *Open Real Time Development Platform for Smart Grids* (Locamation, Stedin, and Twente University), among others.
- Research Area 4 (Planning – holistic architectures and assets) is covered by: *Advanced Scenario Management - Phase 2* (Using big data and GIS for designing a tool for designing electricity infrastructure) and *Advanced reservoir simulation workflow for geothermal systems* (simulation framework for the Dutch geothermal sector).

[17] https://www.topsectorenergie.nl/

- Research Area 5 (Flexibility enablers and system flexibility) is covered by: *BlockHeating* (Using data centres for the cooling of gardeners' locations); *Batteries as an Alternative Power Supply at Festivals* (Smart batteries for setting up and operating festivals); *Open local infrastructure network for the supply of heat* (Building district heating network in Asden-Heusden), among others.
- Research Area 6 (System operation) is covered by: *Comfortable natural ventilation and energy reduction in the built environment*. (Pilot for developing a climate control system based on integration of multiple segmented systems combining sun, heat, and more) and *Autonomous smart solar street lighting* (Demonstrating autonomous working traffic lights with dynamic schedules based on traffic and weather information).

4.2.3. United Kingdom

Reporting on smart energy networks in the United Kingdom has been found in the online environment of the Department for Business, Energy & Industrial Strategy (BEIS). This department focuses on tackling climate change, fighting the coronavirus and stimulating innovation for the United Kingdom[18]. The online environment of BEIS provided sufficient confidence that the United Kingdom has been contributing to several research areas[19]. Insufficient evidence has been found to support Research Areas 4 (Planning – holistic architectures and assets) and 6 (System Operation).

- Research area 1 (Consumer, prosumer and citizen energy community) is covered by*: Smarter Tariffs – Smarter Comparisons* (how domestic energy users approach tariff comparisons and switching through consumer research) and *Project InvoLVe* (innovation for low income and vulnerable consumers to identify how future innovation can enable these consumers to benefit from a smart energy system).
- Research Area 2 (System economics) is covered by the *BEIS Flexibility Markets Study competition*. An example of these studies is the *Ipswich Local Supply Community Project* (explore mechanisms to exploit bottom-up flexibility, creating new local partnerships seeking to promote and commoditise flexibility).
- Research area 3 (Digitalisation) is covered by the *Energy Data Visibility project* (increase the visibility of energy system metadata).
- Research area 5 (Flexibility enablers and system flexibility) is covered by *GridIMP* (fully automated self-learning demand side response (DSR) electricity control tool that will balance the need for flexible electricity supply for site specific customer needs) and *Flexitricity* (aggregation smaller HVAC and refrigeration loads to deliver meaningful balancing volumes).

4.2.4. France

France is a country with a dedicated National Research Programme for Smart Grids, governed by the Commission de régulation de l'énergie (CRE), i.e. the Energy Regulatory Commission[20]. The CRE maintains an up-to-date, public overview of projects in France working within the field of Smart Grids[21]. This overview provided sufficient confidence that France covered each of the six Research Areas. Of the six Research Areas covered by France, the lowest confidence is in Research Area 4 (Planning – holistic architectures and assets).

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[18] https://www.gov.uk/government/organisations/department-for-business-energy-and-industrial-strategy
[19] https://www.gov.uk/guidance/funding-for-innovative-smart-energy-systems
[20] https://www.cre.fr/La-CRE/qui-sommes-nous
[21] https://www.smartgrids-cre.fr/projets

- Research Area 1 (Consumer, prosumer and citizen energy community) is covered by: *Saint Nicolas des Glénan-project* (Develop citizen energy communities); *Share* (A pioneering demonstrator for self-consumption); *Island of Sein* (A 100% renewable energy microgrid), among others.
- Research Area 2 (System economics) is covered by: *MHyRABEL* (Adding value to renewable energy production using hydrogen); *STECY* (Valuation of Energy Storage within an islandable hybrid micro-grid), among others.
- Research Area 3 (Digitalisation) is covered by: *SEGA* (A dynamic energy consumption assessment system); *BienVEnu* (optimised management of electric vehicle charging in collective housing); *Liveliness* (Collaborative data management at city-scale), among others.
- Research Area 4 (Planning – holistic architectures and assets) is covered by: *Transform* (The European study of energy planning) and *EnR-Pool* (Promote the development of renewable energies by modulating the consumption of electro-intensive industrialists).
- Research Area 5 (Flexibility enablers and system flexibility) is covered by: *Kaw hybrid power plant* (Ensuring the autonomy of an isolated village thanks to the photovoltaic, thermal and storage installation); *SolarIce* (Tertiary self- consumption with cold storage); *Pegase* (Forecast of renewable energies and active guarantee by energy storage), among others.
- Research Area 6 (System operation) is covered by: *GRHYD* (Converting electricity from renewable sources into hydrogen); *West Grid Synergy* (The first European demonstrator of smart grids for gas); *Jupiter 1000* (Develop Power-to-gas to store surplus renewable electricity), among others.

4.2.5. Spain

The investigation into nationally funded projects in Spain has given the confidence that two entities contribute to smart grids; Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (Center for Energy, Environmental and Technological Research, CIEMAT)[22] and Centro Nacional de Energías Renovables (National Renewable Energy Center, CENER)[23]. CIEMAT is Spain's main body of research for energy and environmental subjects and combines this with technical research. CENER is also a research centre, focused mainly on renewable energy. CIEMAT and CENER provide information on their respective websites about recently finished and ongoing projects. This information provided evidence for Spanish contributions to Research Area 1 (Consumer, prosumer and citizen energy community), Research Area 2 (System economics), Research Area 4 (Planning – holistic architectures and assets) and Research Area 5 (Flexibility enablers and system flexibility).

- Research Area 1 (Consumer, prosumer and citizen energy community), one clear contribution is made by the *CIEMAT* study into the perception of risk, communication and social acceptance of new energy solutions[24].
- Research Area 2 (System economics) is covered by *MUSTEC* (deployment of the solar thermal electricity market through cooperation)
- Research Area 4 (Planning – holistic architectures and assets) is covered by the *ETSAP-TIAM global energy model* within the framework of participation in the IEA ETSAP Technological Collaboration Programme.
- Research Area 5 (Flexibility enablers and system flexibility) is covered by two storage projects that received national or even regional funding: *E-HIERA*

[22] https://www.ciemat.es/
[23] https://www.cener.com/
[24] https://www.ciemat.es/cargarSubLineaInvestigacion.do?identificador=54&idArea=12&idLinea=40

(Distributed storage based on hydraulic pumping for application in microgrids) and HTSTORAGE (Thermal energy storage applications).

4.2.6. Sweden

Sweden has several agencies and funding schemes that contribute to R&I. The most important Swedish entity that funds and administers R&I projects related to the energy transition is Energimyndigheten (Swedish Energy Agency, SEA)[25]. This agency is leading Sweden's transition towards a sustainable energy system. Together with Sweden's big energy companies (Vattenfal, E-on, Hitachi, ABB), Uppsala Universitet (University of Uppsala), and KTH Royal Institute of Technology, SEA founded SWEgrids in 2011. SweGRIDS is the Swedish Centre for Smart Grids and Energy Storage[26]. SEA and SweGRIDS and their respective websites[27,28] provided evidence of Sweden's national R&I contributions to all Research Areas.

- Research Area 1 (Consumer, prosumer and citizen energy community) is covered by *SEA projects 51600-1* (Behavioural Design for energy efficiency between neighbouring properties) and *50343-1* (Electric power grid resilience, the possibility of households and buildings to contribute to a more resilient electric power network).
- Research Area 2 (System economics) has contributions by *SEA projects 50713-1* (How firm internal and external factors combine to contribute to the Energy Transition) and *48527-1* (Innovative business models for a large-scale diffusion of solar PV).
- Research Area 3 (Digitalisation) is covered by *SweGRIDS projects DPS2* (Integration effort prediction for asset management data collection), *CPC5* (Optimal Asset Management Data – System) and *DPS1* (Threat modelling for digitalised power systems).
- Research Area 4 (Planning – holistic architectures and assets) has received contributions from *SEA projects 50538-1* (Electricity transition through intermediaries, Consultants in the smart grid development. Configurations for energy transitions) and *51832-1* (INTERACT, the Interact project is a so-called LINK architecture that optimises the key functions for energy production, energy efficiency and energy flexibility).
- Research Area 5 (Flexibility enablers and system flexibility) received coverage from *SweGRIDS projects FPS3* (The need of energy storage in the future distribution system to ensure a stable operation and a high-power quality) and *CPC1* (Controllable power components for a flexible power system).
- Research Area 6 (System operation) is covered by *FPS1* (The technical power-based challenges of power systems with a major share of power production infeed via power electronics devices), *FPS19* (Improved observability in the power system: Real-time stability monitoring and control), *FPS20* (Improved observability in the power system: Rotor angle measurements and support from faster voltage control) and *CPC17* (Investigation of long-term perspectives of dynamic rating of power lines, underground cables, transformers and substation equipment to promote large-scale Variable Renewable Energy installations).

[25] https://www.energimyndigheten.se/
[26] https://www.kth.se/swegrids
[27] http://www.etk.ee.kth.se/swegrids_projects/
[28] https://www.energimyndigheten.se/forskning-och-innovation/projektdatabas/

4.2.7. Conclusions on National Progress Reports

When aggregating the results from individual countries, it becomes evident that Research Areas 1 (Consumer, prosumer and citizen energy community), 2 (System economics), 3 (Digitalisation), 5 (Flexibility enablers and system flexibility) and 6 (System operation) are at least partially covered by most of the reviewed countries. It is assumed that those Research Areas are covered by enough countries so that a significant contribution can be expected within those Research Areas. Research Area 4 (Planning – holistic architectures and assets) is covered to a much lesser degree, reducing the likelihood of significant contributions to that Research Area since Network Operators are the main stakeholders concerned and as a result, R&I is more targeted. As can be found in Chapter 5, Research Areas 1 (Consumer, prosumer and citizen energy community) and 4 (Planning – holistic architectures and assets) receive relatively little attention from BRIDGE, non-BRIDGE and ERA-NET SES programmes.

5. INDIVIDUAL PROJECT RESULTS

This chapter presents the results of the individual project assessments, based on the questionnaire as described in Chapter 3. The results provide clear insights into the state and progress of Research and Innovation within the scope of the ETIP SNET. This chapter will present an evaluation of recollected questionnaires for both BRIDGE and non-BRIDGE projects, while for ERA-NET SES projects that have not responded to the questionnaires, a separate assessment is done based on manually filled in questionnaires, based on project summaries.

The first three sections of this chapter cover the three different types of projects analysed, namely aggregate reporting on BRIDGE projects, aggregate reporting on non-BRIDGE projects and aggregate reporting on ERA-NET SES projects from publicly available project summaries[29]. The fourth section covers the view on the progression of Tasks based on the input from the questionnaire. Finally, conclusions to the individual project assessment are presented.

5.1. Questionnaire Results of BRIDGE projects

Projects that are part of BRIDGE are largely funded by Horizon 2020. The average budget of the responding projects amounts to 11M€, see Figure 4. Given these relatively large project budgets, the responses of such projects carry a different weight than the responses of relatively small projects funded by national or regional institutions. 16 projects within the BRIDGE community have responded, the aggregate results are presented below.

[29] https://www.eranet-smartenergysystems.eu/Projects

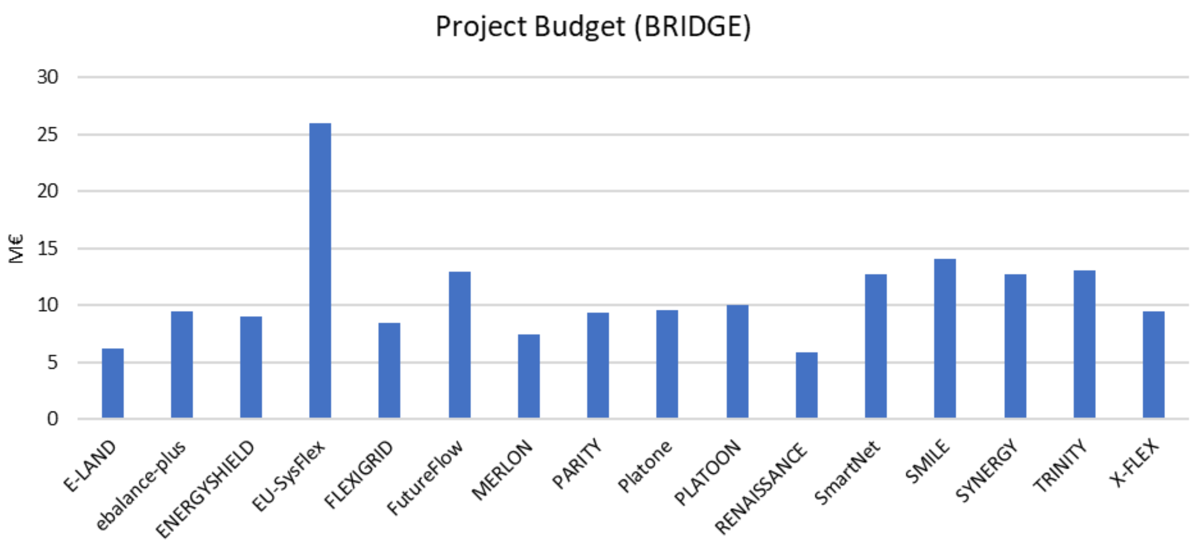


Figure 4: Responsive BRIDGE projects and their budgets

Figure 5 shows the contribution of BRIDGE projects to the twelve Functionalities to be achieved by 2030. As many as 14 projects (88%) indicate a contribution to Functionality 10 (F10: integrating flexibility in generation, demand, conversion, and storage technologies), and 12 projects (75%) indicate a contribution to F6 (Integrating digitalisation services, including data privacy, and cybersecurity), F8 (Energy system business) and F9 (Simulation tools). In contrast, only 2 projects (13%) indicate a contribution to F12 (Efficient carbon-neutral liquid fuels & electricity for transport in view of system integration of flexibilities) and only 4 projects (25%) indicate a contribution to F4 (pan-European wholesale markets).

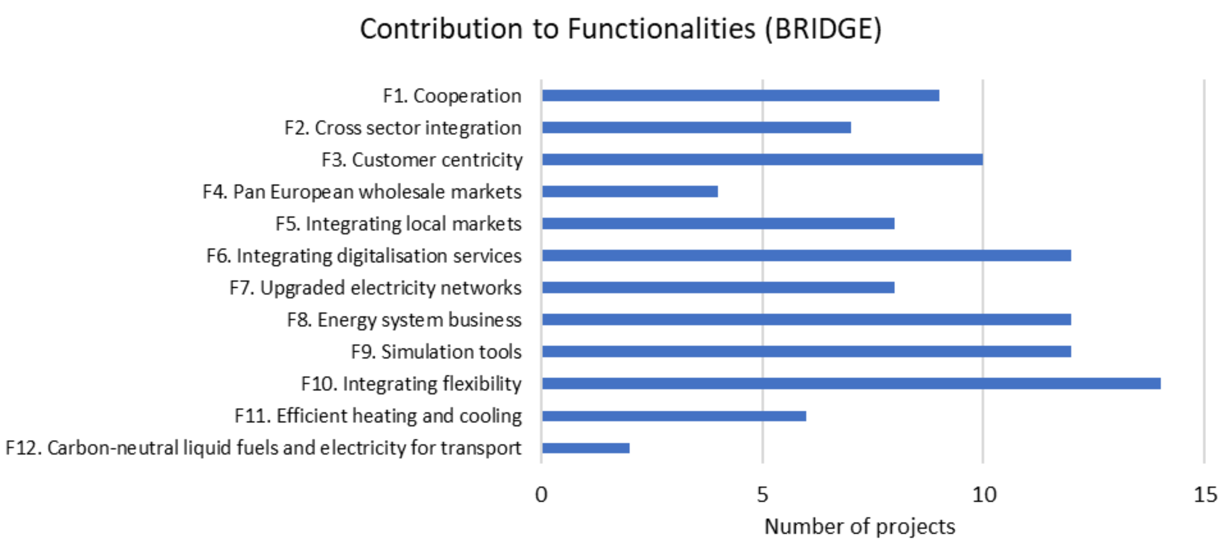


Figure 5: Number of BRIDGE projects reporting contributions to the twelve Functionalities

Figure 6 presents the contribution to the 24 Topics, both in number of contributing projects as well as by number of Key Exploitable Results within those Topics. Note that not all projects that indicate a contribution towards a certain Topic have provided a Key Exploitable Result for that Topic. This is either because the contribution is not large enough to identify a KER, or the project is not mature enough to identify KERs at this point. Topic 5.1 (demand flexibility) shows the highest activity, both in number of projects (8) as well as in number of Key exploitable Results (10). ***Topic 3.1. Protocols, standardisation and interoperability'*** shows the second highest contribution rate in number of Key Exploitable Results (8), but not in number of contributing projects (5). ***Topic 2.2. 'Market design and governance'*** shows contributions from 6 projects and 6 Key Exploitable Results. ***Topic 5.3. 'Storage***

flexibility & Energy Conversion flexibility' shows contributions from 6 projects and 5 Key Exploitable Results. A couple of Research Areas and their Topics show very little contributing projects and KER's, such as ***Topic 4.3. 'Asset management and maintenance'*** with 0 projects and 0 KERs as contributions, ***Topic 6.2. 'Short-term control'*** with only 1 contributing project with 1 KER. ***Topic 3.5. 'End-to-End architecture'*** has been addressed by one of the responsive projects within BRIDGE.

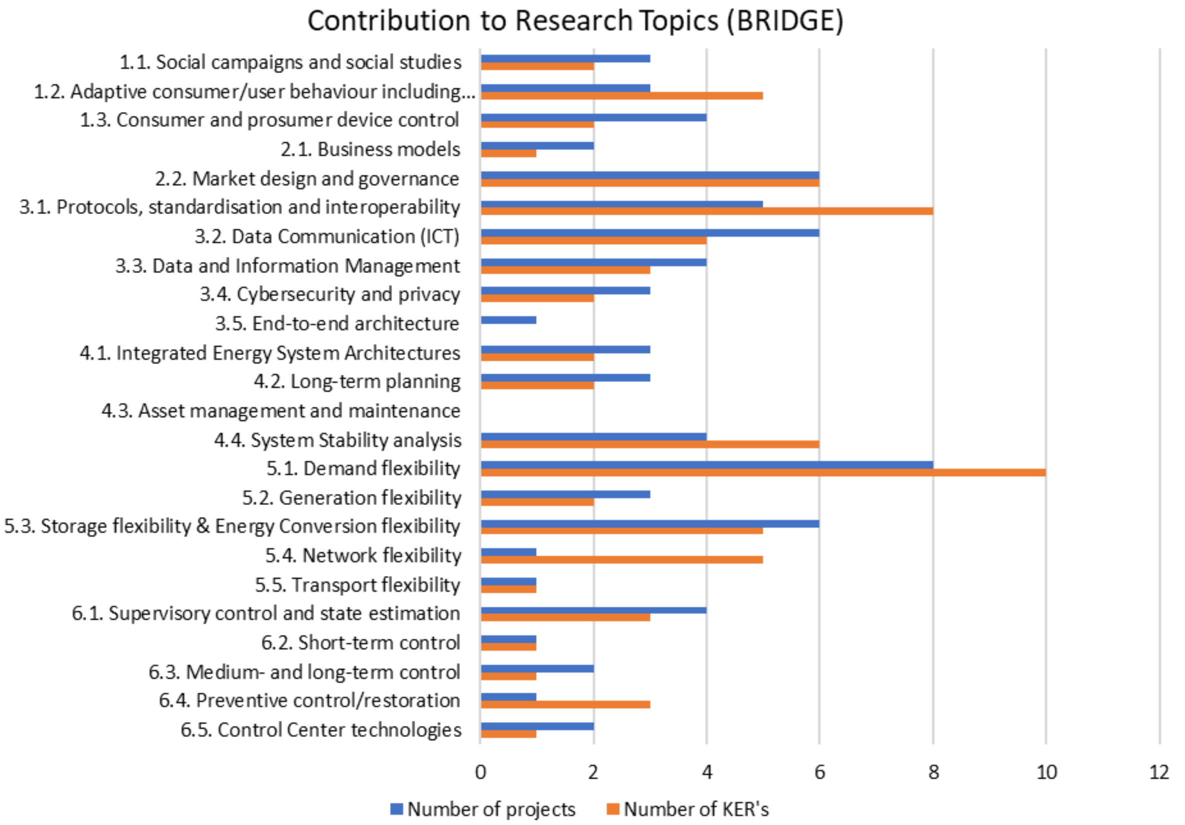


Figure 6: Representation of Topics in BRIDGE projects, in terms of project contributions and KERs

The Key Exploitable Result can be assigned to a single nature, see section 3.3.4. A total of 75 KERs have been identified within the BRIDGE projects. However, 4 KERs were assigned to more than one Topic. In such cases, the KER was still assigned only to one nature. Therefore, Figure 7 shows a total of 71 Key Exploitable Results classified by nature. The most dominant nature is software, with 44 Key Exploitable Results (62%) within this category. This is followed by Hardware and Policy, Regulation and Market, both demonstrating with 8 Key Exploitable Results (11%).

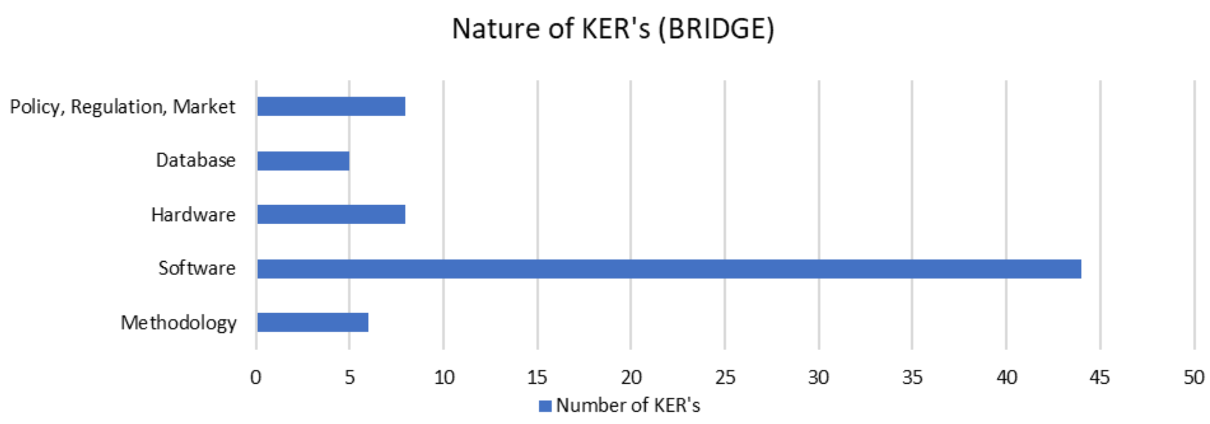


Figure 7: Nature of Key Exploitable Results in the BRIDGE projects

Projects were asked to indicate the projected TRL of the Key Exploitable Results. Note that not all projects were able to indicate the projected TRL of the KER, therefore, Figure 8 shows a total of only 59 KERs, as opposed to Figure 7 with 71 KERs. The Key Exploitable Results reported in BRIDGE projects dominantly have a high target TRL, of TRL 7 (15 KERs) or TRL 8 (41 KERs). Only 3 KERs are reported with a target TRL of 5. See Table 16 for the European Commission's definitions of Technology Readiness Levels.

Table 16: Technology Readiness Levels definition

Technology Readiness Level (TRL)	Description
1	Basic principles observed
2	Technology concept formulated
3	Experimental proof of concept
4	Technology validated in lab
5	Technology validated in relevant environment
6	Technology demonstrated in relevant environment
7	System prototype demonstration in operational environment
8	System complete and qualified
9	Actual system proven in operational environment

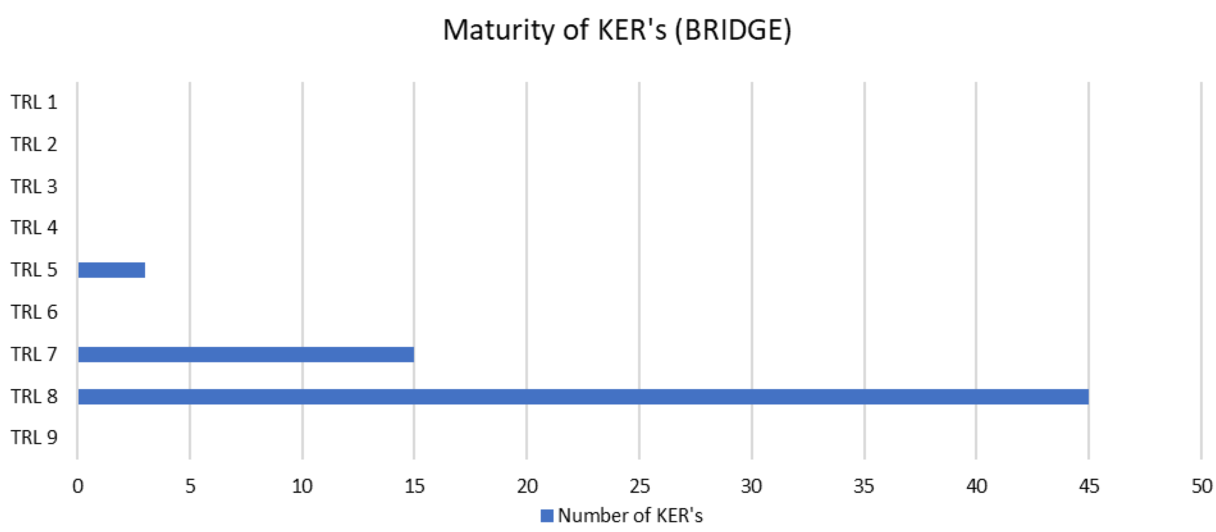


Figure 8: Maturity of Key Exploitable Results in the BRIDGE projects (target TRL upon completion of the project)

5.2. *Questionnaire Results of non-BRIDGE projects*

The questionnaire has been distributed to projects outside of the scope of BRIDGE as well. These non-BRIDGE projects include nationally or regionally funded projects, but also EC co-funded projects not within the content scope of BRIDGE (e.g. ERA-NET SES). An overview of the projects and their respective budgets in M€ is presented in Figure 9. The average budget of the 23 responding projects amounts to 11.81 M€. Note that this image is skewed by the C/Sells project (funded by BMWi) with a total project budget of 90 M€, and the SINCRO.Grid (funded by CINEA) project with a total budget of 88.6 M€. The other projects have an average budget of 4.43 M€. Figure 10 shows the project budgets of the responsive projects, excluding the three largest projects in terms of budget.

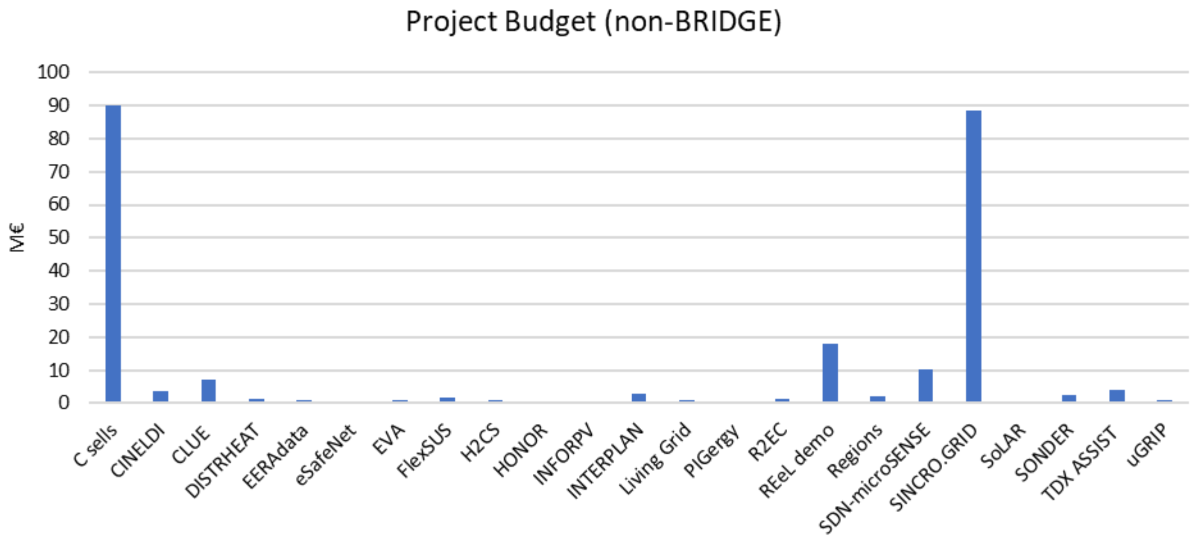


Figure 9: Responsive non-BRIDGE projects and their budget

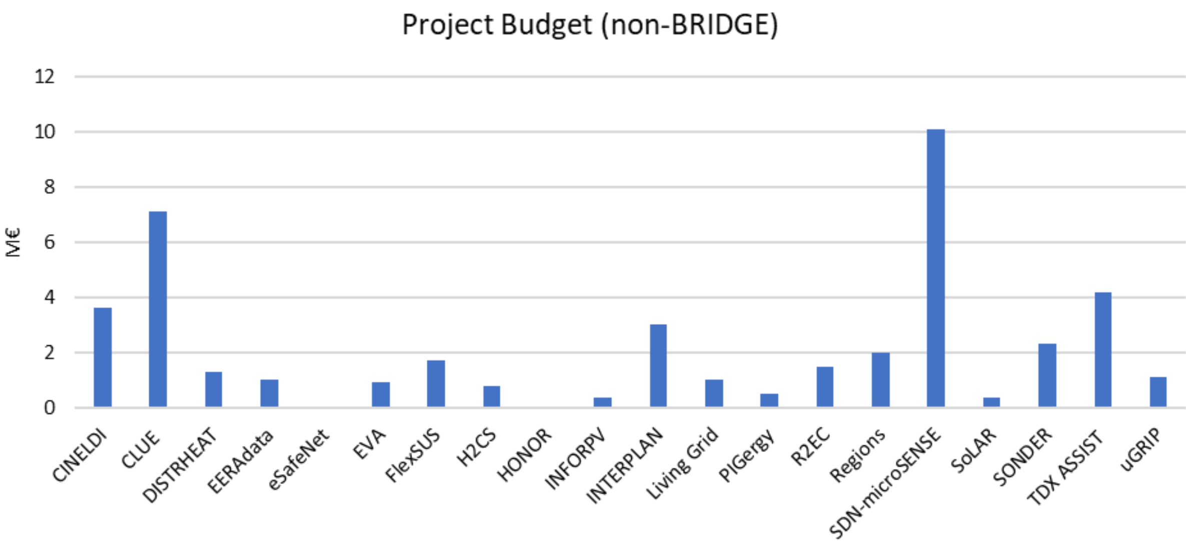


Figure 10: Responsive non-BRIDGE projects and their budget, excluding C/Sells (90 M€), SINCRO.GRID (88 M€) and REel demo (18 M€)

Figure 11 presents the contribution of the non-BRIDGE projects to the twelve Functionalities. 15 projects (65%) indicate a contribution to F10 (integrating flexibility in generation, demand, conversion, and storage technologies). F7 (upgraded electricity networks) is addressed by 14 projects (61%). F9 (simulation tools for electricity and energy systems) and F1 (Cooperation) are both addressed by 12 projects. F4 (pan-European wholesale markets) is addressed by only 2 projects (9%) and F12 (efficient carbon-neutral liquid fuels and electricity for transport in view of system integration of flexibilities) is addressed by 3 projects (13%). The low contribution to F4 can be explained by the fact that these are mainly local projects with limited effect of Pan-European dimensions.

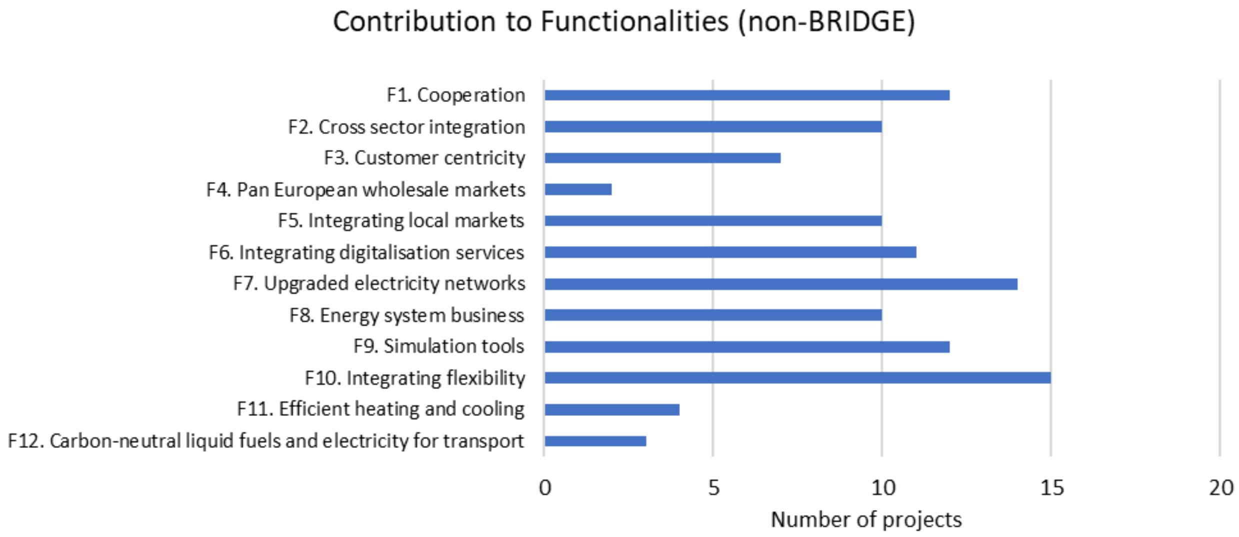


Figure 11: Number of projects reporting contributions to the twelve Functionalities (non-BRIDGE projects)

Figure 12 shows the project and KER contributions to Topics of the non-BRIDGE projects. Note that not all projects that indicate a contribution towards a certain Topic have provided a Key Exploitable Result for that Topic. This is either because the contribution is not large enough to identify a KER, or the project is not mature enough to identify KERs at this point. ***Topic 3.1. 'Protocols, standardisation, and interoperability'*** and ***Topic 5.3. 'Storage flexibility & energy conversion flexibility'*** show the most contributions in terms of number of KERs (10) and a similar number of projects (7 & 8 respectively). ***Topic 5.2. 'Generation flexibility'*** has 7 projects contributing, but these projects report just 5 Key Exploitable Results. ***Topic 4.1. 'Integrated energy system architectures'*** shows 7 KERs within 5 contributing projects. ***Topic 4.3 'Asset management and maintenance'***, ***Topic 5.5. 'Transport flexibility'***, and ***Topic 6.4. 'Preventive control/restoration'*** have no reported contributions by the projects. In general, Research Area 5 and large parts of Research Area 3 and 6 are very well covered by the projects, while the other Research Areas (1, 2 and 4) show low contributions and large gaps.

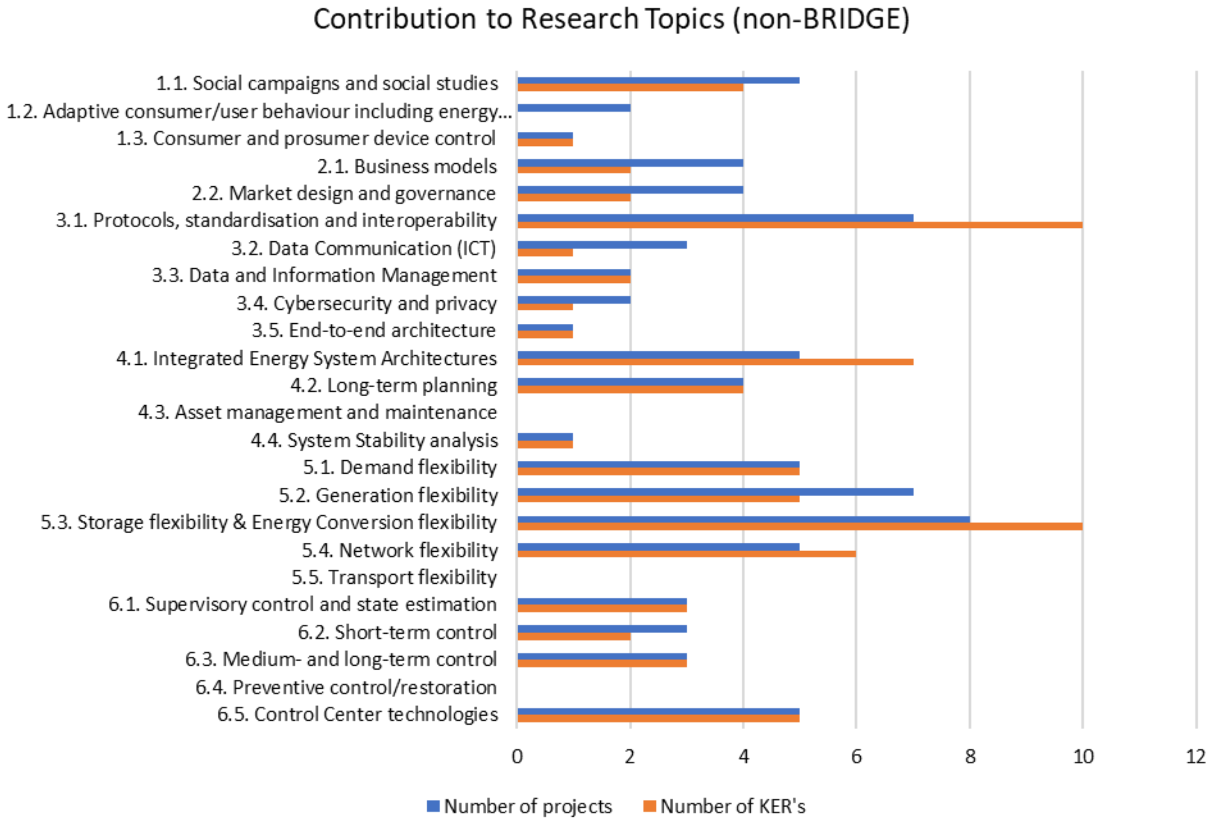


Figure 12: Representation of Topics in the projects, in terms of project contributions and KERs non-BRIDGE projects)

Figure 13 indicates the nature of KERs for the non-BRIDGE projects. Note that a Key Exploitable Result can only be assigned a single nature. A total of 74 KERs have been identified within these projects. However, 1 KER was assigned to more than one Topic. In that case, the KER was still assigned only to one nature. In three other cases, the respondent provided three Key Exploitable Results without any elaboration, therefore these KERs could not be assigned a nature. The most dominant nature is software, with 28 Key Exploitable Results (40%) within this category. This is followed by Methodology, with 22 Key Exploitable Results (31%).

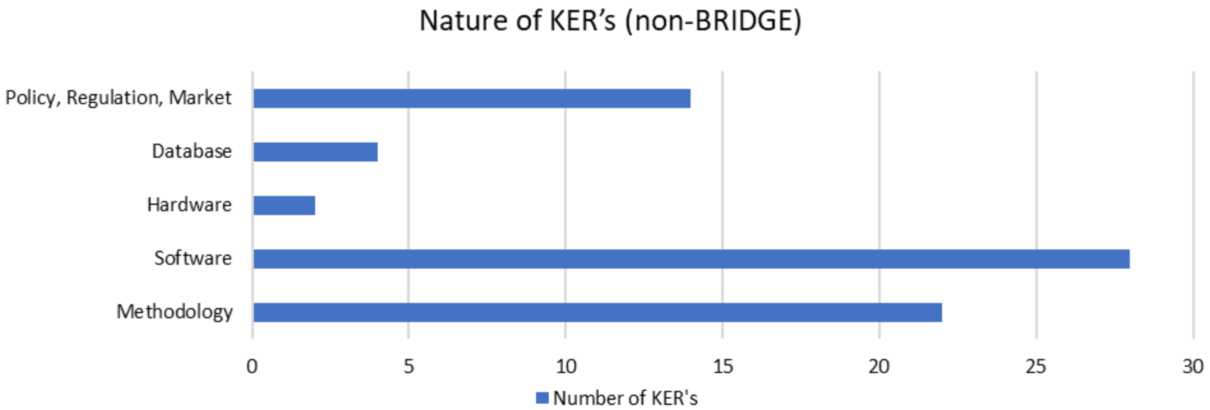


Figure 13: Nature of Key Exploitable Results in the non-BRIDGE projects

Projects were asked to indicate the projected TRL of the Key Exploitable Results. Note that not all projects were able to indicate the projected TRL of the KER, therefore, Figure 14 shows a total of only 48 KERs, as opposed to Figure 13 with 74 KERs. The Key Exploitable Results reported in the non-BRIDGE projects range from TRL 2 to TRL 8, with an average of TRL 5.4. No projects report Key Exploitable Results close to commercialisation or deployment. However, many projects do have KERs in the demonstration phase.

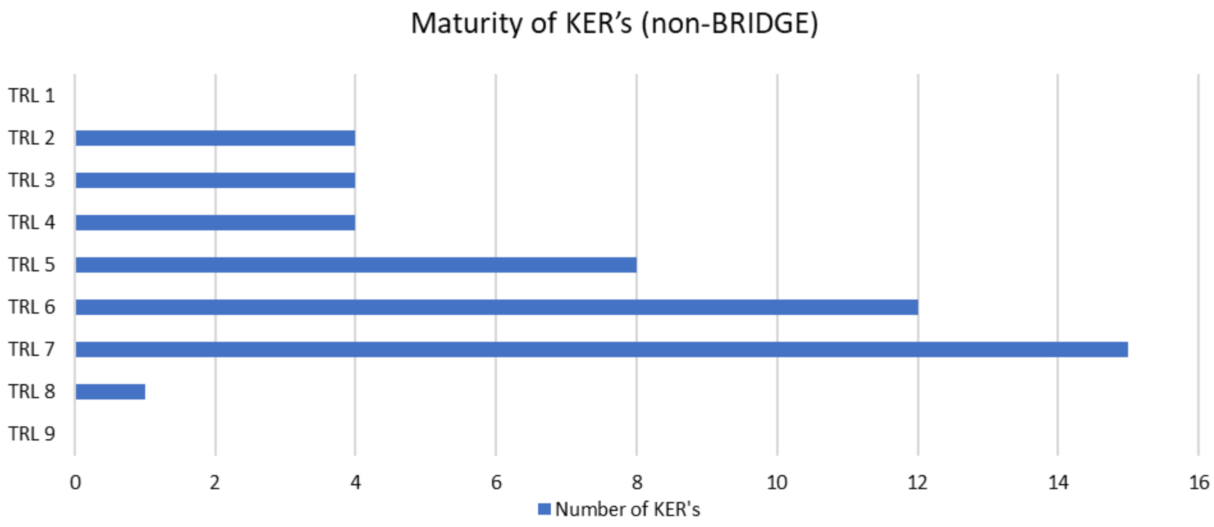


Figure 14: Maturity of Key Exploitable Results in the non-BRIDGE projects (target TRL upon completion of the project)

5.3. ERA-NET SES Project Summary Assessment

The European Research Area Network (ERA-NET SES) is one of the European Commission instruments for research and innovation within the scope of Horizon 2020. The purpose of ERA-NET SES is to coordinate national research programmes between Member States and to stimulate collaboration between national research organisations and research funding organisations in the public sector. Organisations interested in participating in ERA-NET SES research projects can form an international consortium, together with organisations from other participating countries. Such a consortium then submits a project proposal to the relevant ERA-NET SES.

For this Progress Monitoring Report, ERA-NET SES projects ending in 2019 or later have been asked to fill in a questionnaire regarding their research. The results of the projects that have filled in the questionnaire are part of the analysis in section 5.2 For 35 projects that have not responded, the questionnaires have been partially filled in using the Project Description and Project Factsheet from the ERA-NET SES Approved Projects website. The following sections cover only those questionnaires that have been partially filled in, based on the publicly available information, not those filled in by the researchers of the respective ERA-NET SES projects.

Due to the nature of the literature survey, it has not been possible to determine the Technological Readiness Levels (TRL) for the respective projects with acceptable confidence. Therefore, the reporting is based on the number of projects and their respective budgets.

The European Commission has budgeted € 5 million per ERA-NET SES call-for-projects. Member States often double that amount. The European Commission subsidises a maximum of one third of a project. Together with the subsidies of the Member States, approximately 2/3 of a project budget is thus directly related to the ERA-NET SES funding scheme, highlighting its importance in defining and approving novel research within key Research Areas. In this section, project budget refers to the total budget of the project, which includes both the ERA-NET SES funding and other funding sources. Project budgets have not been identified for 2 projects. Of the remaining 33 projects, the funding distribution is shown in Figure 15 and Figure 16, with a total funding of €65.7M. The total budget per project ranged from €0.4M to €5.7M, averaging at €2.1M.

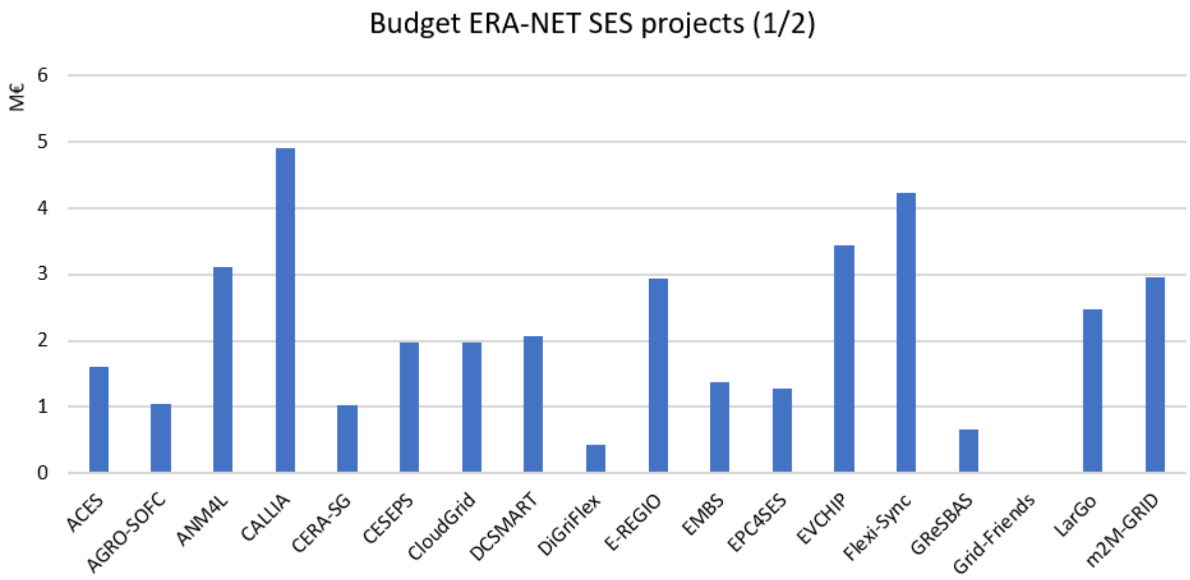


Figure 15: Budget ERA-NET SES projects (1/2)

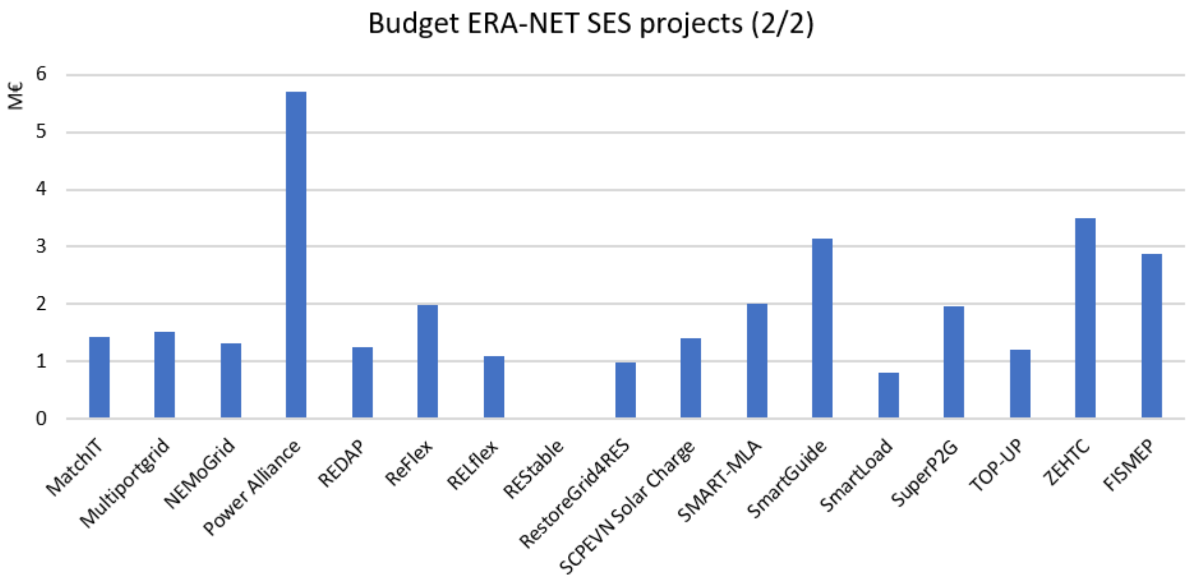


Figure 16: Budget ERA-NET SES projects (2/2)

The distribution of projects over the ETIP-SNET Functionalities is far from uniform, see Figure 17. Please note that a project can contribute to more than one functionality. Functionalities that are a key part of many (15+) projects are F6 (Integrating digitalisation services), F7 (Upgraded electricity networks), F8 (Energy system business) and F10 (Integrating flexibility). Three Functionalities are covered in a lesser extent by the projects: Functionalities F4 (Pan European wholesale markets), F11 (Efficient heating and cooling) and F12 (Carbon-neutral liquid fuels and electricity for transport). The remaining four Functionalities F1 (Cooperation), F3 (Customer centricity), F5 (Integrating local markets), and F9 (Simulation tools) receive moderate attention in the ERA-NET SES projects.

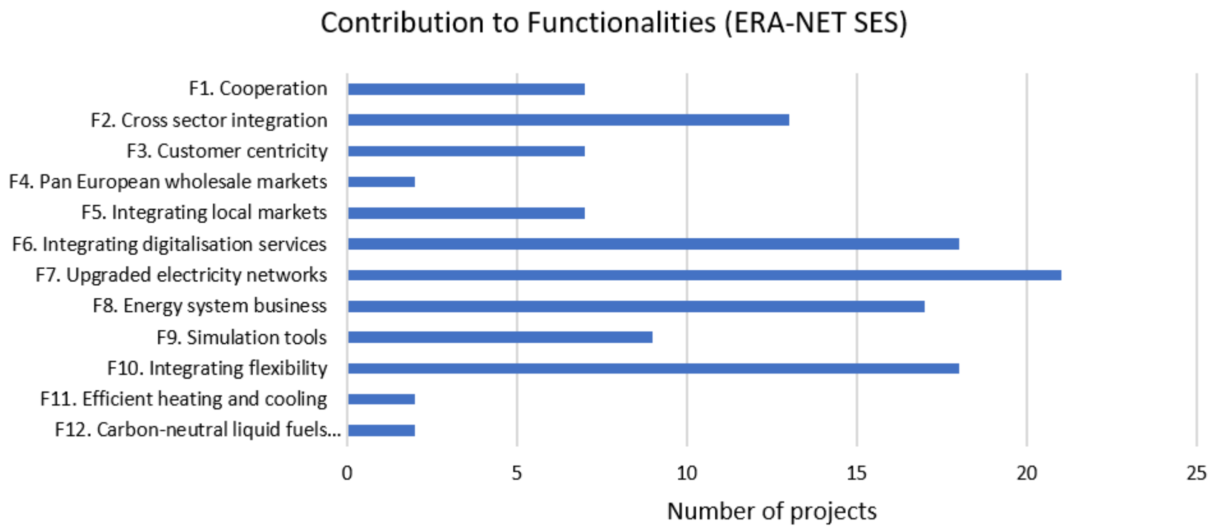


Figure 17: Number of ERA-NET SES projects per Functionality. Note: one project can be in multiple Functionalities.

It is important to note that each Key Exploitable Result (KER) is attributed to only one Research Topic. The Project Description and Project Factsheet from the ERA-NET SES Approved Projects website have been used to decide upon the most relevant Research Area and Topic per KER. For this reason, a KER can only contribute to one research topic, but a project that has multiple KERs can contribute to multiple research topics.

Figure 18 shows the allocation of KERs and projects to the Research Topics. **Topic 1.2. 'Adaptive consumer/user behaviour including energy communities'**, **Topic 2.1. 'Business models'** and **Topic 5.3. 'Storage flexibility & Energy Conversion flexibility'** have comparatively many (6+) KERs. **Topic 1.3. 'Consumer and prosumer device control'**, **Topic '3.3. Data and Information Management'**, **Topic 3.4. 'Cybersecurity and privacy'**, **Topic 4.2. 'Long-term planning'**, **Topic 4.3. 'Asset management and maintenance'**, **Topic 5.2. 'Generation flexibility'** and **Topic 5.5. 'Transport flexibility'** have no contributions by any KER. All other Research Topics have a moderate amount (2-5) of KER contributions.

Figure 18 also shows the difference between the amount of KERs and number of projects contributing to the respective Research Topics. Since each project has at least one KER, the number of KERs per Research Topic is larger than or equal to the number of projects. Research Topics with more KERs than projects naturally have multiple KERs, which indicates more results per project within that Topic. For example: **Topic 1.2. 'Adaptive consumer/user behaviour including energy communities'** has the highest number of KERs, but not the highest number of projects, while **Topic 2.1. 'Business models'** has the second highest number of projects, but only the second highest number of KERs. It should be noted that the same Research Topics that have zero projects associated, logically have no KERs. Research Topics with a moderate number of contributing projects (3-5) and KERs are **Topic 6.2. 'Short-term Control'**, **Topic 1.1. 'Social campaigns and social studies'**, **Topic 2.2. 'Market design and governance'**, **Topic 3.2. 'Data Communication (ICT)'**, **Topic 3.5. 'End-to-end architecture'**, **Topic 5.3. 'Storage flexibility & Energy Conversion flexibility'**, and **Topic 5.4. 'Network flexibility'**. Furthermore, **Topic 6.5. 'Control Center technologies'**, **Topic 6.3. 'Medium- and long-term control'**, **Topic 6.1. 'Supervisory control and state estimation'**, **Topic 5.1. 'Demand flexibility'**, **Topic 4.4. 'System Stability analysis', Topic 4.1. 'Integrated Energy System Architectures'** and **Topic 3.1. 'Protocols, standardisation and interoperability'** all have a low number (1-2) of contributing projects and KERs.

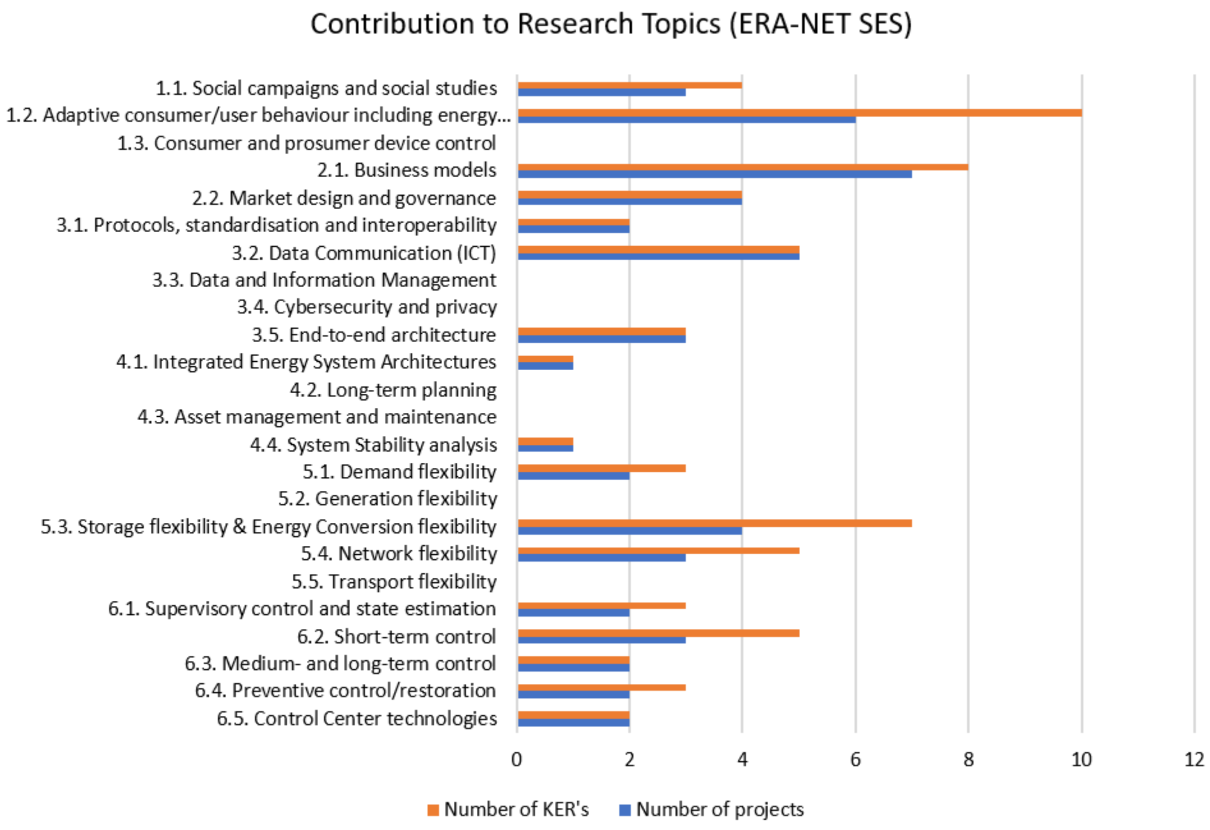


Figure 18: Number of ERA-NET SES projects per research topic. Note: one project can be in multiple research Topics.

ERA-NET SES projects generally focus more on Research Areas 1 (Consumer, prosumer and citizen energy community), 2 (System economics), 5 (Flexibility enablers and system flexibility) and 6 (System operation) and contribute to a lesser extent to Research Areas 3 (Digitalisation) and 4 (Planning – holistic architectures and assets). BRIDGE projects contribute, among others, to a reasonable extent to Research Area 3 (Digitalisation) to fill the gap, and non-BRIDGE projects contribute to fill the gap in Research Area 4 (Planning – holistic architectures and assets). However, specific Topics receive relatively little attention, even when aggregating BRIDGE, non-BRIDGE and ERA-NET SES projects: **Topic 1.3. 'Consumer and prosumer device control'**, **Topic 3.4. 'Cybersecurity and privacy'**, **Topic 3.5. 'End-to-end architecture'**, **Topic 4.3. 'Asset management and maintenance'**, **Topic 5.5. 'Transport flexibility'** and **Topic 6.5. 'Control Center technologies.'**

5.4. Task Progression

The ETIP SNET R&I Roadmap defines 120 tasks within the 24 Topics. The ETIP SNET Implementation Plan has detailed the target TRL for each of these tasks to be achieved by 2030. Based on the responses to the questionnaire, ETIP SNET has assessed the progression of each individual task. In this section, the results of those assessments are presented. In general, a large share of the 120 Tasks has been addressed by at least one project. However, some Topics (e.g*, **4.3. 'Asset management and maintenance'**, and '**6.4. Preventive control and restoration**')* require additional attention to bring the Tasks in line with the target TRL. In addition, reported contributions to Topics do not always translate into contributions to Tasks. This means that the 120 Tasks do not exhaustively describe all R&I activities within the Topics. The analysis is split between BRIDGE and non-BRIDGE projects. One key observation is that the average reported TRL by BRIDGE projects is generally higher than that of non-BRIDGE projects. Note that this analysis is based on the third source of the progress monitoring activities, being the questionnaire distribution and recollection to R&I projects in Europe. ERA-NET SES projects assessed by their project summaries (fourth source of progress monitoring) are not part of the Task progression analysis.

The resulting figures do require some elaboration. Figure 19 for example: this figure shows the result for Research Area 1 (consumer, prosumer, and citizen energy community. The horizontal axis indicates the task number (ranging from 1 in Research Area 1 to 120 in Research Area 6); the vertical axis shows the TRL. The grey shading within the figure illustrates the allocation of task numbers to different Topics (i.e. task number 1, 2, and 3 are part of ***Topic 1.1.***; task number 4 and 5 are part of ***Topic 1.2***.). The green patches indicate the target TRL for each task as reported in the ETIP SNET Implementation Plan. Note that for 2030, the target is either between TRL 3 and TRL 5 or between TRL 6 and TRL 8. Deployment (TRL 9, actual system proven in operational environment) is not expected for any of the 120 tasks. Next, the vertical, dark blue bars indicate the range between minimum and maximum reported TRL by all the projects. Projects with only a single reported TRL (one answer received or all answers indicating the same TRL) do not show a vertical bar. The circular markers with a black edge indicate the average reported TRL of BRIDGE projects, the circular markers with a red edge indicate the average reported TRL of non-BRIDGE projects. The internal colour of the markers indicates the number of projects reporting contributions to the task, both for BRIDGE as well as for non-BRIDGE projects, i.e. the darker the marker, the more projects contributing to that task.

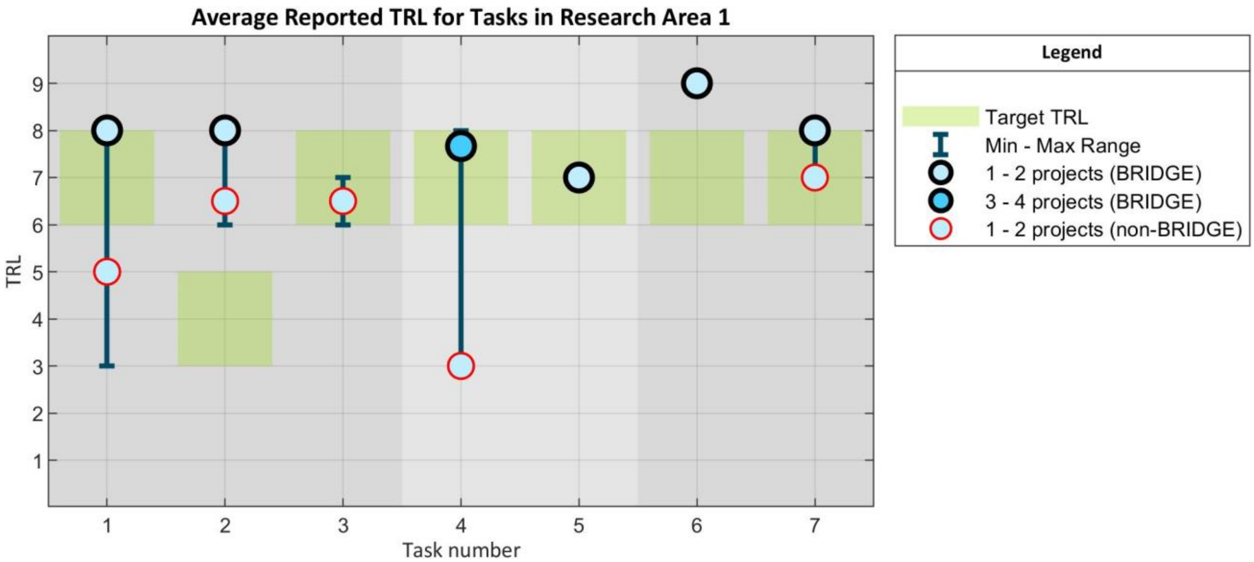


Figure 19: Average reported TRL for Tasks in Research Area 1 (Consumer, prosumer, and citizen energy community)

Table 17: Task number, ID, and description for Research Area 1 (Consumer, prosumer, and citizen energy community)

Task number	Task ID	Task description
1	1.1.1	Public acceptance of new energy infrastructures.
2	1.1.2	Awareness of new electricity/energy systems and citizen involvement in forming energy communities.
3	1.1.3	Environmental impacts of energy infrastructures (visual, audible, etc.).
4	1.2.1	Consumers' and prosumers' adaptation of energy behaviour.
5	1.2.2	Industry's consumption adaptation.
6	1.3.1	Wireless technologies for direct control of consumption/generation.
7	1.3.2	ICT technologies for smart appliances

In Research Area 1 (consumer, prosumer and citizen energy community), all tasks have been addressed by at least one BRIDGE or other project (see Figure 19 and Table 17). Great variance is observed between the minimum and maximum reported TRL in ***Topic 1.1***. '***Social campaigns and social studies,'*** and ***Topic 1.2. Adaptive consumer/user behaviour including energy communities.*'** The average reported TRL for these two Topics is on the low side of the targeted range, while the average reported TRL for ***Topic 1.3. 'Consumer and prosumer device control,'*** is on target or even above target. Note that Task 1.2.1. '*Consumers' and prosumers' adaptation of energy behaviour'* is the only Task that is contributed to by more than four projects. Based on these results and the relatively small portion of projects contributing, Research Area 1 is nearly on target, but must be addressed to avoid falling behind in the ETIP SNET Implementation Plan.

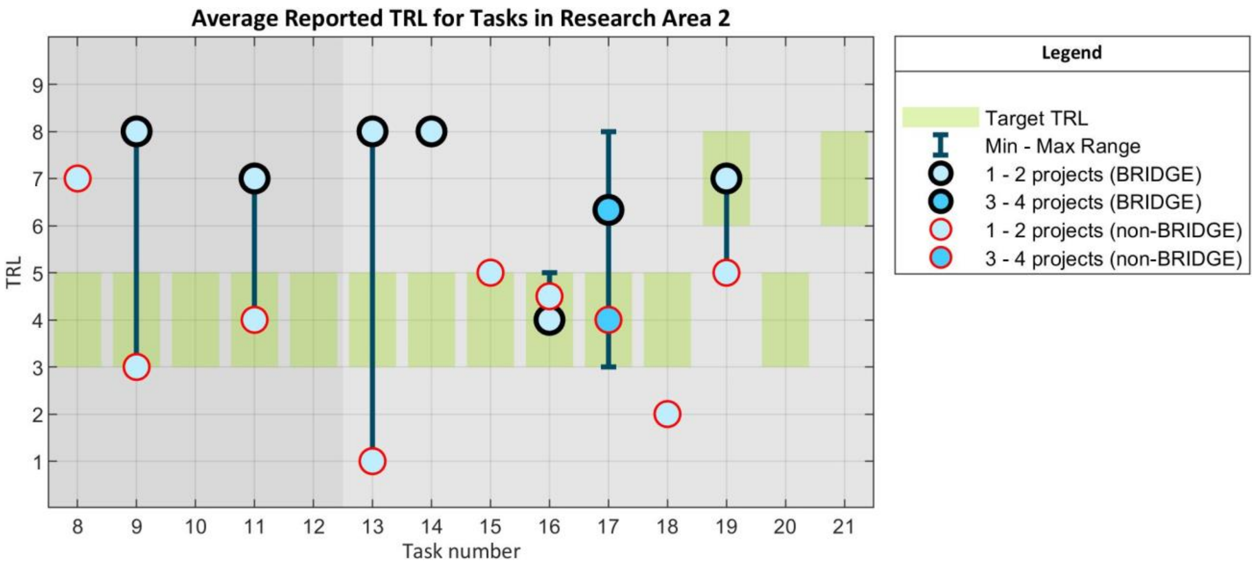


Figure 20: Average reported TRL for Tasks in Research Area 2 (System economics)

Table 18: Task number, ID, and description for Research Area 2 (System economics)

Task Number	Task ID	Task description
8	2.1.1	Business models for prosumers providing ancillary services
9	2.1.2	Business models for retailers and aggregators, ESCOs and energy communities
10	2.1.3	Business models for data analysis service providers
11	2.1.4	Business models for storage in electrical transportation networks
12	2.1.5	Business models for gas-fired or biomass fired CHP units
13	2.2.1	Pan-European market design
14	2.2.2	Market design for TSO cross border coordination
15	2.2.3	Market rules for ancillary services by aggregated storage and virtual power plants
16	2.2.4	Market design for provision of ancillary services between DSOs and TSOs
17	2.2.5	Design of local markets and their interaction to central markets
18	2.2.6	Market design for large-scale demand response, beyond electricity
19	2.2.7	Market design for storage owners and operators
20	2.2.8	Market rules for system services (balancing) by gas networks
21	2.2.9	Market design for water cycle management operators

Figure 20 and Table 18 present the progression of the Tasks in Research Area 2 (system economics). The results resemble the Task progression of Research Area 1, in the sense that the number of responses is relatively low and the fact that not all Tasks are covered. The target TRL of all but two Tasks in ***Topic 2.1. 'Business models,'*** and ***Topic 2.2. 'Market design and governance'*** is between 3 and 5, meaning the technology or solution should at the least be at the level of experimental proof of concept and at most validated in a relevant environment. Given the low level of contributions and the large variety in the reported TRLs, the Tasks in Research Area 2 cannot be said to be in line with the ETIP SNET Implementation Plan and therefore require additional research. Note that BRIDGE projects generally report a higher average TRL than non-BRIDGE projects. In addition, note that BRIDGE projects indicate TRLs higher than the target TRLs of the ETIP SNET Implementation Plan, whereas non-BRIDGE projects mostly report TRLs on or below target.

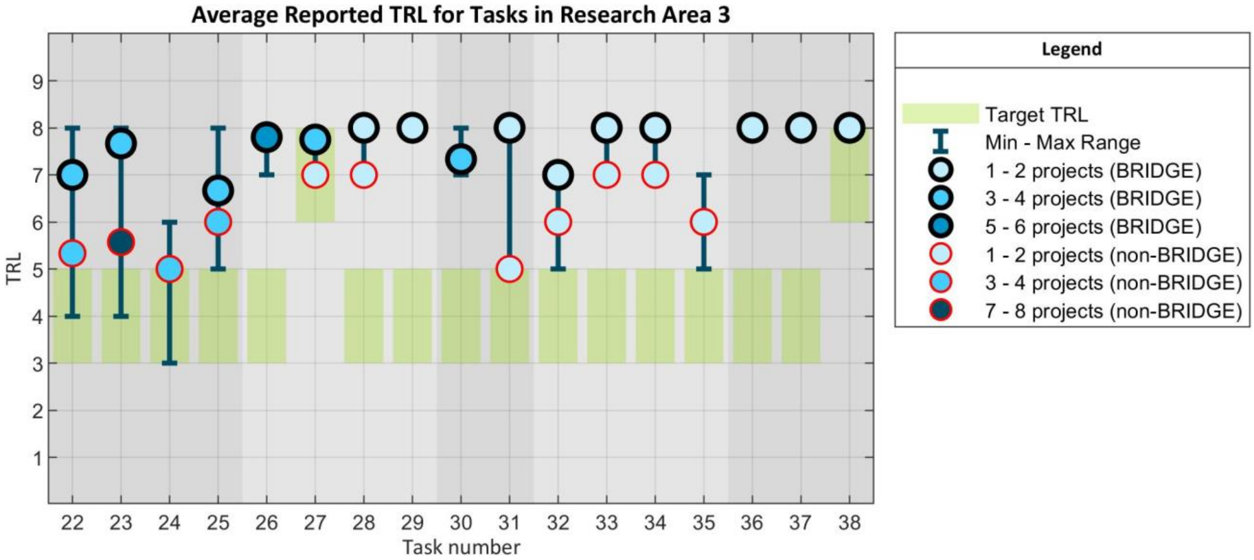


Figure 21: Average reported TRL for Tasks in Research Area 3 (Digitalisation)

Table 19: Task number, ID, and description for Research Area 3 (Digitalisation)

Task Number	Task ID	Task description
22	3.1.1	Data exchange protocols / interfaces for a well-functioning market
23	3.1.2	Standardised communication protocols and ICT infrastructure between devices and networks and also between devices and remote management platforms
24	3.1.3	Communication interfaces of smart substations
25	3.1.4	DSO and TSO information exchanges; decision-making support functions
26	3.2.1	Demand aggregation and control
27	3.2.2	Monitoring and control of distributed generation
28	3.2.3	Communication infrastructures for smart meter data
29	3.2.4	Conditional and risk-based maintenance
30	3.3.1	Big data management
31	3.3.2	IoT technologies in TSO and DSO planning
32	3.4.1	Cyber security protection of grid infrastructures
33	3.4.2	GDPR-compliant methodologies for management of distributed energy resources
34	3.4.3	Parallel use of legacy SCADA systems
35	3.4.4	Public ICT and wireless infrastructures for smart grid functionality
36	3.5.1	Digital twinning of interoperating grid and communication networks

Task Number	Task ID	Task description
37	3.5.2	Data exchange at different system voltage levels
38	3.5.3	Application of advanced ICT-based approaches for data storage

Figure 21: Average reported TRL for Tasks in Research Area 3 (Digitalisation) illustrates the progression of Tasks in Research Area 3 (digitalisation). The contribution rate in ***Topic 3.1. 'Protocols, standardisation, and interoperability'*** and **3.2. 'Da*ta communication (ICT)'*** is higher than what has been seen in the previous Topics. For ***Topic 3.4. 'Cybersecurity and privacy'*** and ***Topic 3.5. 'End-to-end architecture,'*** most Tasks are addressed by just one project. Given the reported average TRL of Tasks in ***Topic 3.1. 'Protocols, standardisation, and interoperability,' Topic 3.2. 'Data communication (ICT),'*** and ***Topic 3.3. 'Data and information management;'*** and given the contribution level in these Topics, it can be concluded that these tasks are well on track. For the remaining Topics (***3.4. 'Cybersecurity and privacy'*** and ***3.5. 'End-to-end architectures'***), additional effort is required to bring this in line with the path set out in the ETIP SNET Implementation Plan.

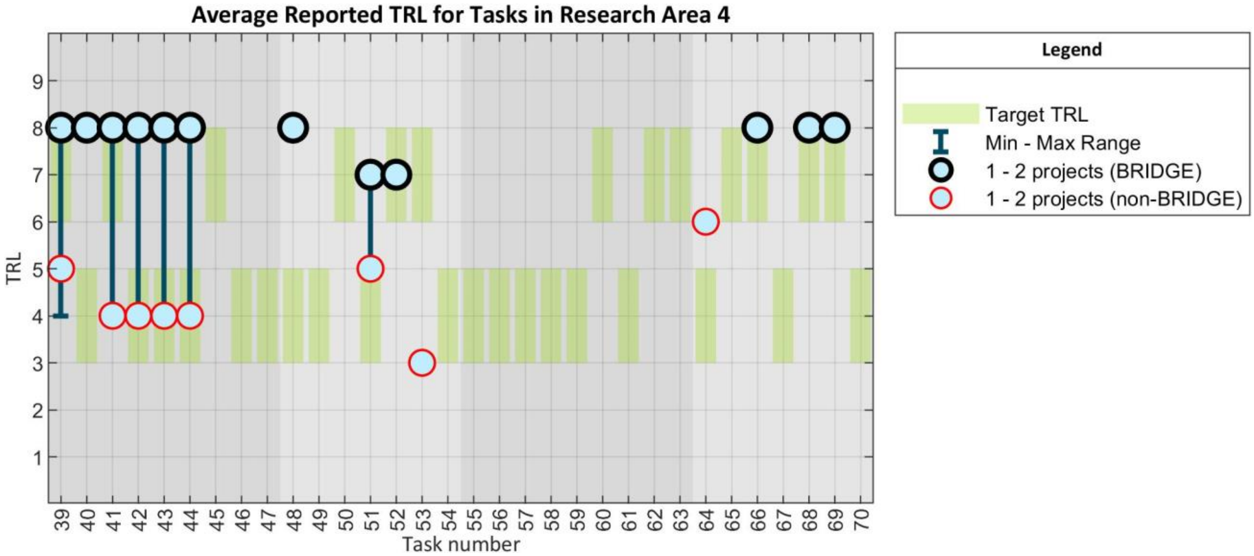


Figure 22: Average reported TRL for Tasks in Research Area 4 (Planning – holistic architectures and assets)

Table 20: Task number, ID, and description for Research Area 4 (Planning – holistic architectures and assets)

Task number	Task ID	Task description
39	4.1.1	Model of the energy system encompassing the whole energy chain
40	4.1.2	Resilience oriented sizing and spatial positioning of assets
41	4.1.3	Local multi-energy streams operation
42	4.1.4	Multicarrier hybrid storage systems
43	4.1.5	Optimally located, sized and coordinated electric energy storage at different voltage levels
44	4.1.6	Optimally located, sized and coordinated storage for seasonal needs
45	4.1.7	Web-of-cells, decentralised, modular control architectures
46	4.1.8	Integrated electricity AC and DC distribution networks
47	4.1.9	HVDC meshed grids and parallel routing of DC and AC lines
48	4.2.1	Planning of integrated (coupled) energy systems

Task number	Task ID	Task description
49	4.2.2	Investment planning in RES at EU level
50	4.2.3	Planning for resilience
51	4.2.4	DER solutions to handle network constraints in planning
52	4.2.5	Probabilistic planning taking into account the DER stochasticity
53	4.2.6	Massive integration of EVs
54	4.2.7	LV and MV DC industrial and residential grids
55	4.3.1	Condition (risk) in planning LV/MV based maintenance
56	4.3.2	State of Health estimates of transmission system components
57	4.3.3	Model-based detection of component failures
58	4.3.4	Remote LV/MV maintenance operations
59	4.3.5	HV and MV-asset management considering resiliency
60	4.3.6	Training of maintenance operators
61	4.3.7	Optimised lifespan of storage systems
62	4.3.8	Optimal maintenance of hydropower and pumped-storage units
63	4.3.9	Improved lifetime of thermal generation
64	4.4.1	Support by DER, microgrids and nano grids
65	4.4.2	Synthetic inertia from power electronic converters
66	4.4.3	Microgrids in islanded mode of operation
67	4.4.4	Converter driven stability
68	4.4.5	Stability of large-scale transmission systems with high penetration of variable RES
69	4.4.6	Equivalent models of aggregated network and system components
70	4.4.7	Large scale inter-area oscillations

The level of contribution in Research Area 4 (Planning – holistic architectures and assets) is low, with only 28 project contributions to the 32 Tasks. In this Research Area, the trend that BRIDGE projects on average report higher TRLs than the non-BRIDGE projects is again confirmed. In addition, the reported TRLs are generally higher than the target TRL in the ETIP SNET Implementation Plan. Note that, while the Tasks in ***Topic 4.3. 'Asset management and maintenance'*** are not covered by any project, one project has indicated contributions to this Topic with a Key Exploitable Result (see section 5.1 and Figure 6). This supports the notion that the 120 Tasks do not exhaustively describe the actions that are in progress. All Topics in this Area require additional efforts to confidently bring the Tasks to the desired TRL. Given the low contribution rate of ***Topic 4.3. 'Asset management and maintenance'*** and ***Topic 4.4. 'System stability analysis,'*** these Topics have a high priority to get in line with the ETIP SNET Implementation Plan.

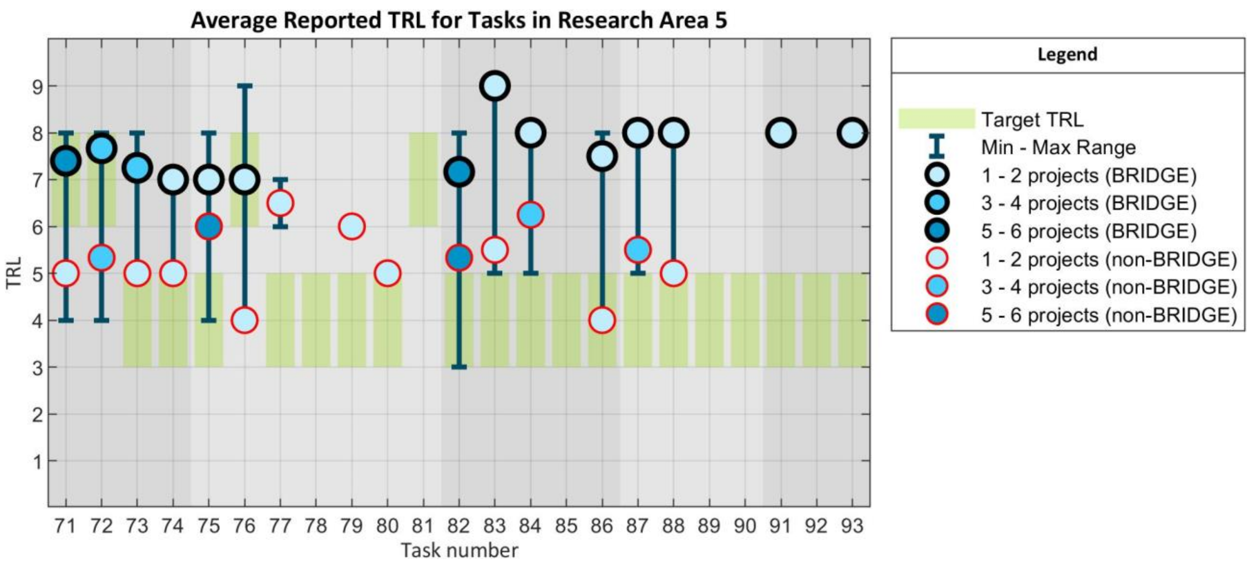


Figure 23: Average reported TRL for Tasks in Research Area 5 (Flexibility enablers and system flexibility)

Table 21: Task number, ID, and description for Research Area 5 (Flexibility enablers and system flexibility)

Task Number	Task ID	Task description
71	5.1.1	Optimal utilisation of DSR by TSOs and DSOs
72	5.1.2	Direct load control
73	5.1.3	Active demand in DSO planning and operation
74	5.1.4	Flexibility by energy-intensive industries and bulk energy storage
75	5.2.1	Contributions of wind turbines and solar-PV to system flexibility
76	5.2.2	Operational flexibility of hydropower and pumped storage plants
77	5.2.3	Flexibility of thermal generation
78	5.2.4	Fuel flexibility of thermal power plants
79	5.2.5	Flexible small and medium scale thermal generation
80	5.2.6	Cogeneration units with decoupled use of heat and power
81	5.2.7	European hydro energy system model
82	5.3.1	Storage flexibilities in operation of electrical grids
83	5.3.2	Energy storage systems with conventional power generators
84	5.3.3	Aggregated heating (and cooling) storage at household/building/industrial level
85	5.3.4	Power-to-gas applications
86	5.3.5	Stand-alone buildings, living quarters and small and medium sized businesses and industries
87	5.4.1	Flexibility in transmission and distribution networks
88	5.4.2	Distribution network reconfiguration
89	5.4.3	HVDC multi-terminal networks to coordinate power flows
90	5.4.4	Dynamic line rating
91	5.5.1	Efficient management of EV charging
92	5.5.2	Energy management in transport electricity networks
93	5.5.3	Electric vehicles with grid to vehicle (G2V) and vehicle to grid (V2G)

Research Area 5 reports the most contributions from projects within the Tasks: a total of 67 contributions spread over 24 Tasks. Figure 23 shows the distribution of those contributions between BRDIGE and non-BRIDGE projects over the different Tasks. Especially **Topic *5.1.***

'Demand flexibility' and ***Topic 5.3. 'Storage flexibility & energy conversion flexibility'*** are well covered by the projects in the assessment. ***Topic 5.2. 'Generation flexibility'*** and ***Topic 5.4. 'Network flexibility'*** have only been partially covered. ***Topic 5.5. 'Transport flexibility***' shows the lowest level of contribution and has not been adequately covered by the responding projects. Note that the average reported TRL of all Tasks with at least one contribution is close to being on target. It is therefore fair to say that bringing the lagging Topics (***5.2., 5.4. & 5.5.***) to the level of the leading Topics is sufficient to adhere to the ETIP SNET Implementation Plan.

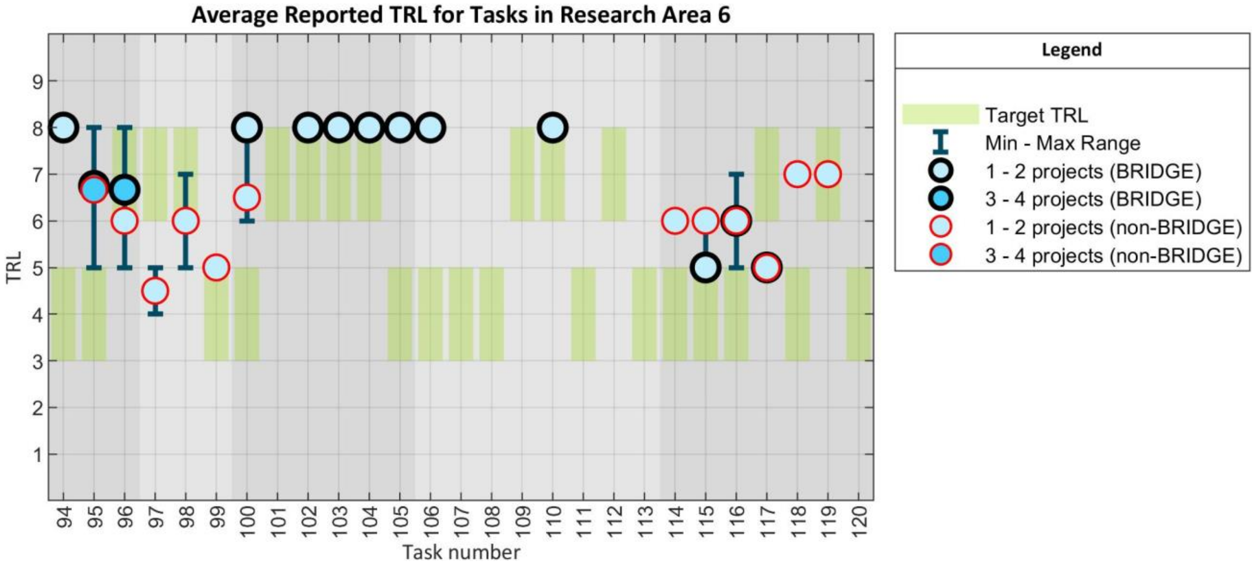


Figure 24: Average reported TRL for Tasks in Research Area 6 (System operation)

Table 22: Task number, ID, and description for Research Area 6 (System operation)

Task Number	Task ID	Task description
94	6.1.1	Steady state and dynamic state estimation of transmission systems using intelligent monitoring devices
95	6.1.2	Observability and state estimation of distribution systems
96	6.1.3	Real-time observability of RES and improved forecasts
97	6.2.1	Load frequency control
98	6.2.2	Contribution of RES to primary voltage and frequency control
99	6.2.3	Primary voltage and frequency control of distribution grids
100	6.3.1	Advanced RES forecasting
101	6.3.2	Hydropower forecasting
102	6.3.3	Solving location-based grid constraints
103	6.3.4	Optimal scheduling in highly uncertain conditions
104	6.3.5	Distribution network configuration
105	6.3.6	Technologies in secondary substations
106	6.4.1	Protection of distribution networks with low fault currents
107	6.4.2	DC grid protection, protection relays and breakers
108	6.4.3	Topology optimisation for increasing network resilience
109	6.4.4	Bottom-up restoration
110	6.4.5	Self-healing techniques
111	6.4.6	Load shedding techniques
112	6.4.7	Security support by various multi-energy carriers
113	6.4.8	Pan-EU or multiregional system restoration
114	6.5.1	Wide area monitoring and control architecture for transmission systems
115	6.5.2	Energy management platforms for TSOs to interact with local markets

Task Number	Task ID	Task description
116	6.5.3	Energy management platforms for DSOs for active participation of customers in energy market
117	6.5.4	Control centre architectures for distributed network control
118	6.5.5	Control of intentional islanding
119	6.5.6	Training simulators for DSOs and TSOs (e.g. using digital twins)
120	6.5.7	Advanced MMI (Man-Machine-Interface)

Task progress in the final Research Area is depicted in Figure 24. The level of contribution to the five Topics is mixed. ***Topic 6.1. 'Supervisory control and state estimation'*** shows 12 contributions to the 3 Tasks within the Topic, all at or above the targeted TRL***. Topic 6.5. 'Control centre technologies'*** shows 10 contributions to the 7 Tasks within the Topic. However, the other three Topics show only 14 contributions to the 17 remaining Tasks. Therefore, Research Area 6.2. *(*Short-term control), 6.3. (Medium- and long-term control), 6.4. (Preventive control and restoration) require additional efforts to bring the Tasks to the desired levels.

5.5. Conclusions Individual Project Results

The assessment of the filled in questionnaires for BRIDGE and non-BRIDGE projects and the qualitative assessment for ERA-NET SES projects that did not respond to the questionnaires, with regards to contributions to Research Areas, Topics and Tasks, results in the following set of conclusions. The qualitatively assessed ERA-NET SES projects generally focus more on Research Areas 1 (Consumer, prosumer and citizen energy community), 2 (System economics), 5 (Flexibility enablers and system flexibility) and 6 (System operation) and contribute to a lesser extent to Research Areas 3 (Digitalisation) and 4 (Planning – holistic architectures and assets). BRIDGE projects contribute, among others, to a reasonable extent to Research Area 3 (Digitalisation) to fill the gap, and non-BRIDGE projects contribute to fill the gap in Research Area 4 (Planning – holistic architectures and assets). However, specific Topics receive relatively little attention even when aggregating BRIDGE, non-BRIDGE and ERA-NET SES assessments: **Topic 1.3. 'Consumer and prosumer device control,' Topic 3.4. 'Cybersecurity and privacy,' Topic 3.5. 'End-to-end architecture,' Topic 4.3. 'Asset management and maintenance,' Topic 5.5. 'Transport flexibility'** and **Topic 6.5. 'Control Center technologies.'** It is advised that the European Commission evaluates the need for more targeted funding for these specific Topics according to the required progress within these Topics.

Table 23 presents the coverage of Research Areas (by Topic), sorted by the number of project and KER contributions in individual R&I projects (questionnaire results) and ERA-NET SES project summaries. The third column presents the number of Tasks per Topic that are on target. The colour code indicates the number of project contributions to Tasks. Focusing on the recollected questionnaires (BRIDGE and non-BRIDGE), it can furthermore be concluded that:

- Research Area 1 (Consumer, prosumer, and citizen energy community), both BRIDGE and non-BRIDGE projects report project or KER contributions to all three Topics. However, the progress on a Task level is not sufficient to conclude that the target TRL has been reached.
- Research Area 2 (System economics) shows higher levels of contributions, both from BRIDGE as well as non-BRIDGE projects. The project and KER contributions are spread evenly over the two Topics. However, the Tasks defined in this Research Area will require additional attention to reach the target TRL for both research Topics.

- Research Area 3 (Digitalisation) shows the second highest level of project and KER contributions. Non-BRIDGE projects report strong efforts and many Key Exploitable Results in ***Topic* 3.1*. ‘Protocols, standardisation and interoperability.’*** All Tasks in this Research Area have been addressed by at least one project, all reporting TRLs on track with the ETIP SNET’s Implementation Plan. However, only ***Topic 3.1.*** shows enough projects contributing to the Tasks to confidently conclude that the target TRL will be satisfied in time.
- Research Area 4 (Planning – holistic architectures and assets) paints a mixed picture. The overall level of contribution in non-BRIDGE projects is relatively high, but no contributions are reported in ***Topic 4.3. ‘Asset management and maintenance.’*** The BRIDGE projects report at least one contribution to each of the Topics. The Tasks in this Research Area are not sufficiently addressed by the projects. The target TRL may be achieved if the BRIDGE projects are indicative, but the non-BRIDGE projects report relatively low TRLs. The Tasks in ***Topic 4.3. ‘Asset management and maintenance’*** are not addressed by any project. However, regarding Topic 4.3, commercial asset management software has made good progress in recent years, the lack of R&I projects could be partly related to a perception that certain asset management R&I objectives have been already realized in software offerings. Nonetheless, this Research Area will require additional focus to update objectives in light of recent software progress and of the state of European companies’ use of such advanced asset management software, and where the software or its application are insufficient, further efforts to achieve the objectives in the ETIP SNET R&I Roadmap and Implementation Plan.
- Research Area 5 (Flexibility enablers and system flexibility) shows the highest level of contributions, both for BRIDGE as well as non-BRIDGE projects. All Topics show contributions by more than one project in both categories (BRIDGE and non-BRIDGE), except for ***Topic 5.5. ‘Transport flexibility.’*** With regards to the Tasks: ***Topic 5.1. ‘Demand flexibility’*** and ***Topic 5.3. ‘Storage flexibility and energy conversion flexibility’*** are almost on Target, except for one Task in ***Topic 5.3.*** The other Topics show lower levels of Task contributions, while the reported TRLs are in line with the ETIP SNET’s Implementation Plan. In this Research Area, ***Topic 5.2., Topic 5.3.,*** and ***Topic 5.5.*** require additional efforts to confirm the achievement of the Target TRL in the ETIP SNET’s Implementation Plan.
- Research Area 6 (system operation) has contributions from at least one project in both categories (BRIDGE and non-BRIDGE), except for ***Topic 6.4. ‘Preventive control/restoration’*** (no contribution by non-BRIDGE projects). The level of contribution is significantly lower than that of Research Area 5. The progress on Task level alternates per Task. The overall level of contribution in ***Topic 6.1. ‘Supervisory control and state estimation’*** is on par, however, not all Tasks are at the level of the Target TRL. The other Topics in this Research Area report low levels of Task contributions: some Tasks are on target, some below target, and some not addressed at all. For this Research Area, targeted efforts on a Task level are required to achieve the objectives of the ETIP SNET’s Implementation Plan.

Table 23: Overview of Research Area and Topic coverage, sorted by highest number of project and KER contributions (BRIDGE, non-BRIDGE, and ERA-NET projects). The colour coding indicates the average number of projects contributing to a Task within the Topic.

Research Topic	Contributions (Projects - KERs)	Task progression (tasks on target/tasks in Topic)	Average task contributions
1.1. Social campaigns and social studies	11 – 10	3/3	3
1.2. Adaptive consumer/user behaviour including energy communities	11 – 15	2/2	3

Research Topic	Contributions (Projects - KERs)	Task progression (tasks on target/tasks in Topic)	Average task contributions
1.3. Consumer and prosumer device control	5 – 3	2/2	2
2.1. Business models	13 – 11	3/5	1
2.2. Market design and governance	14 – 12	6/9	2
3.1. Protocols, standardisation, and interoperability	14 – 20	4/4	7
3.2. Data Communication (ICT)	14 – 10	4/4	4
3.3. Data and Information Management	6 – 5	2/2	3
3.4. Cybersecurity and privacy	5 – 3	4/4	3
3.5. End-to-end architecture	5 – 4	3/3	1
4.1. Integrated Energy System Architectures	9 – 10	6/9	2
4.2. Long-term planning	7 – 6	3/7	1
4.3. Asset management and maintenance	0 – 0	0/9	0
4.4. System Stability analysis	6 – 8	4/7	1
5.1. Demand flexibility	15 – 18	4/4	5
5.2. Generation flexibility	10 – 7	5/7	2
5.3. Storage flexibility & Energy Conversion flexibility	18 – 22	4/5	5
5.4. Network flexibility	9 – 16	2/4	2
5.5. Transport flexibility	1 – 1	2/3	1
6.1. Supervisory control and state estimation	9 – 9	3/3	4
6.2. Short-term control	7 – 8	2/3	2
6.3. Medium- and long-term control	7 – 6	5/6	1
6.4. Preventive control/restoration	3 – 6	2/8	0
6.5. Control Center technologies	9 – 8	5/7	1
			≥ 4 projects
			2 or 3 projects
			≤ 1 project(s)

5.6. Conclusions

In this chapter, insights from the four sources are brought together to describe the overall progress in Research Areas, Topics and Tasks. Finally, concluding remarks on the coverage of Research Areas are presented.

Four sources of information are used to assess the progress in Research and Innovation projects in relation to the ETIP SNET R&I Roadmap and the Implementation Plans. These sources are the BRIDGE R&I Priorities report, national R&I progress reports, individual project contributions gathered through the distribution and recollection of a questionnaire and, finally, ERA-NET SES project summaries. The highest level of detail is achieved in the assessment of responses to the questionnaire as project officers have provided insight in the contributions to Research Areas, Topics and even Tasks. The BRIDGE R&I Priorities report assessment maps achievements and challenges up to a level of Tasks, without quantifying the progress in terms of TRL. The analysis of ERA-NET SES project summaries results in a view on the progress of R&I at the level of Research Areas and Topics. While the mapping of BRIDGE achievements and challenges is done to the level of Tasks, no quantitative statements can be made on the progression in terms of TRL. Finally, the assessment of national R&I reporting provides insight in the contributions to only Research Areas per country.

Where the previous chapters presented the individual progress for each source, this chapter considers the progress of Topics and Tasks from an aggregate perspective. This chapter is meant to provide insight into the Topics and Tasks that receive sufficient attention to achieve the path set out in the ETIP SNET's Implementation Plan, and those which do not. In addition, Tasks with a high expected TRL are identified.

The assessment of national R&I reports has shown that Research Area 4 is covered to a lesser degree than the other Research Areas. Research Areas 1, 2, 3, 5, and 6 are at least partially covered by most of the reviewed country reports. Note that for the following conclusions on Research Topics and Tasks, the national R&I reports are not considered, given the coarse granularity of the data.

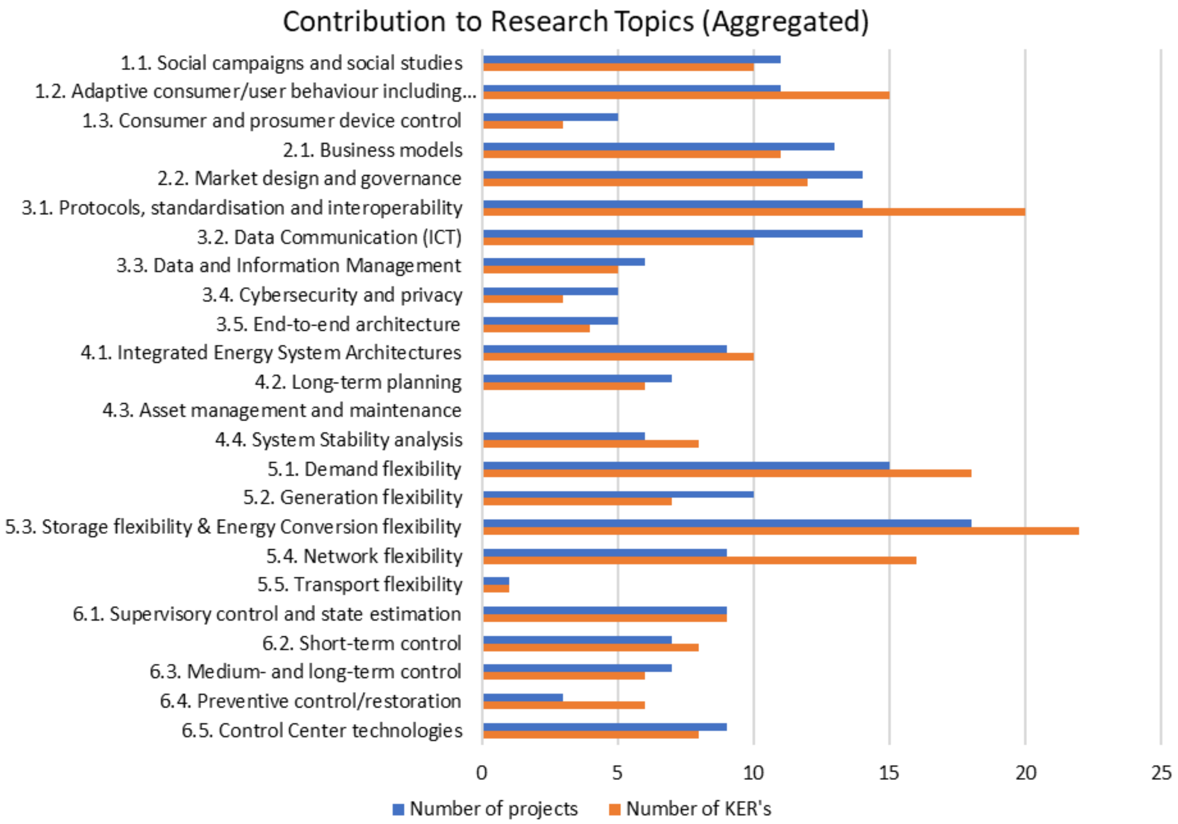


Figure 25: Aggregated project and KER contributions to Research Topics

Tasks with a high level of contribution are identified from the BRIDGE R&I Priorities report and the responses to the questionnaire. Table 24 presents the 13 Tasks with six or more project and achievement contributions. Note that duplicates between the BRIDGE R&I Priorities report and the BRIDGE responsive projects have been removed from this analysis – to avoid double counting project contributions. In addition, a project might have multiple reported achievements in a single Task (BRIDGE R&I Priorities report). These achievements then count as a single project contribution to that Task. It should be noted that these Tasks should be considered with due care, since there are many overlaps and concern various levels of detail/granularity. Therefore, this level of detail can only be indicative.

Table 24: Tasks with a high level of contribution (BRIDGE, non-BRIDGE, ERA-NET)

Task ID	Task	Number of contributions
1.1.1	Business models for retailers and aggregators, ESCO's and energy communities	6
1.1.2	Consumers' and prosumers' adaptation of energy behaviour	8
1.2.1	Wireless technologies for direct control of consumption/generation	7
2.2.5	Business models for prosumers providing ancillary services	7
3.1.1	Public acceptance of new energy infrastructures	12
3.1.2	Awareness of new electricity/energy systems and citizen involvement in forming energy communities	11
3.1.4	Business models for data analysis service providers	6
5.1.1	Industry's consumption adaptation	8
5.1.2	Business models for storage in electrical transportation networks	6
5.2.1	Business models for gas-fired or biomass fired CHP units	6
5.3.1	Environmental impacts of energy infrastructures (visual, audible, etc.)	10
5.3.3	Pan-European market design	6
6.1.2	Market design for TSO cross border coordination	6

In addition, there are 37 Tasks that are not addressed at all by any of the three sources that provide information at Task level. These Tasks are presented in Table 25. Note that some of these Tasks are known to be addressed by at least one project, but this was not apparent from the methodology used in this report. This is partially due to fact that several Tasks display some level of overlap.

Table 25: Tasks with no reported contributions (BRIDGE, non-BRIDGE, ERA-NET)

Task ID	Task
1.2.2	Industry's consumption adaptation
2.1.5	Business models for gas-fired or biomass-fired CHP units
2.2.8	Market rules for system services (balancing) by gas networks
2.2.9	Market design for water cycle management operators
4.1.7	Web-of-cells, decentralised, modular control architectures
4.1.8	Integrated electricity AC and DC distribution networks
4.2.2	Investment planning in RES at EU level
4.2.5	Probabilistic planning taking into account the DER stochasticity
4.2.7	LV and MV DC industrial and residential grids

Task ID	Task
4.3.1	Condition (risk) in planning LV/MV based maintenance
4.3.2	State of Health estimates of transmission system components
4.3.3	Model-based detection of component failures
4.3.4	Remote LV/MV maintenance operations
4.3.5	HV and MV-asset management considering resiliency
4.3.6	Training of maintenance operators
4.3.7	Optimised lifespan of storage systems
4.3.8	Optimal maintenance of hydropower and pumped-storage units
4.3.9	Improved lifetime of thermal generation
4.4.2	Synthetic inertia from power electronic converters
4.4.3	Microgrids in islanded mode of operation
4.4.4	Converter driven stability
4.4.7	Large scale inter-area oscillations
5.2.4	Fuel flexibility of thermal power plants
5.2.7	European hydro energy system model
5.4.3	HVDC multi-terminal networks to coordinate power flows
5.4.4	Dynamic line rating
5.5.2	Energy management in transport electricity networks
6.3.2	Hydropower forecasting
6.3.5	Distribution network configuration
6.3.6	Technologies in secondary substations
6.4.1	Protection of distribution networks with low fault currents
6.4.2	DC grid protection, protection relays and breakers
6.4.4	Bottom-up restoration
6.4.6	Load shedding techniques
6.4.7	Security support by various multi-energy carriers
6.4.8	Pan-EU or multiregional system restoration
6.5.7	Advanced MMI (Man-Machine-Interface)

Finally, Tasks that are close to commercialisation are identified. In this assessment, a Task is close to commercialisation if it has an average reported TRL of 7 (system prototype demonstration in operational environment), 8 (system complete and qualified) or 9 (actual system proven in operational environment). In order to conclude with a certain level of confidence that the average reported TRL is accurate, only Tasks with a contribution level in the 90th percentile are considered. Concretely, this means that Tasks with less than 5 project contributions are not considered. With this definition, seven Tasks are close to commercialisation, as presented in Table 26.

Table 26: Tasks that are close to commercialisation (BRIDGE, non-BRIDGE, ERA-NET)

Task ID	Task	Number of contributions	Weighted average TRL
3.2.1	Demand aggregation and control	5	8
3.2.2	Monitoring and control of distributed generation	6	8
5.1.1	Optimal utilisation of DSR by TSOs and DSOs	7	7
5.1.2	Direct load control	6	7
5.1.3	Active demand in DSO planning and operation	5	7
5.3.3	Aggregated heating (and cooling) storage at building/industrial level	6	7
6.1.2	Observability and state estimation of distribution systems	7	7

Figure 26 presents an overview of the contributions of individual sources to the six Research Areas. The national R&I reports are not accounted for in this figure, as individual project contributions are not extracted from that source. More details are found in appendix 2, in which an overview is presented of the number of contributions to each of the 120 Tasks and the average reported TRL.

Table 27 shows the level of activity of Topics and the share of Tasks addressed within those Topics. This view is very relevant in drafting the next ETIP SNET Implementation Plan and will help decide which Topics are sufficiently covered and which require additional attention. For Topics that have a high contribution in across the three indicators (project contributions, KERs, and Task coverage), it can be concluded that the Topic is sufficiently covered and requires little to no additional R&I stimulation. In contrast, a Topic that is predominantly yellow or red in this table, additional efforts are required to bring R&I in line with the ETIP SNET R&I Roadmap and Implementation Plan.

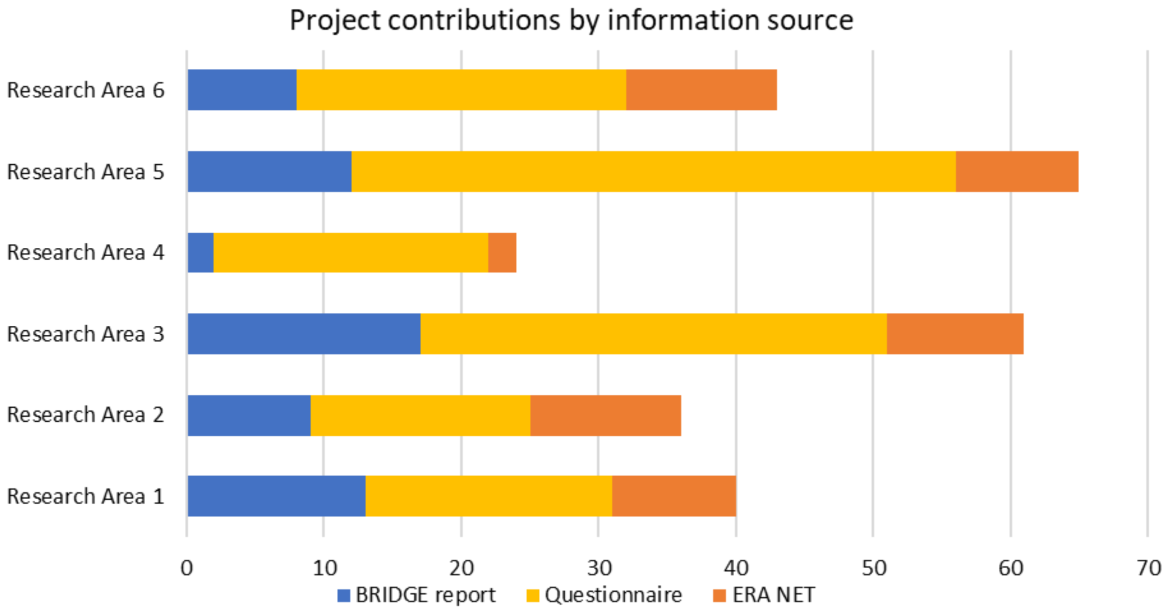


Figure 26: Level of contribution to each Research Area from the BRIDGE R&I Priorities Report, individual project results, and ERA-NET project summaries

Table 27: Coverage of Research Topics in terms of project contributions, KERs, and share of Tasks addressed by all sources. The colour coding indicates the relative level of coverage (legend below each column)

Research Topic	Project contributions	KERs	Task coverage
1.1. Social campaigns and social studies	11	10	3 out of 3 Tasks
1.2. Adaptive consumer/user behaviour including energy communities	11	15	2 out of 2 Tasks
1.3. Consumer and prosumer device control	5	3	2 out of 2 Tasks
2.1. Business models	13	11	3 out of 5 Tasks
2.2. Market design and governance	14	12	6 out of 9 Tasks
3.1. Protocols, standardisation, and interoperability	14	20	4 out of 4 Tasks
3.2. Data Communication (ICT)	14	10	4 out of 4 Tasks
3.3. Data and Information Management	6	5	2 out of 2 Tasks
3.4. Cybersecurity and privacy	5	3	4 out of 4 Tasks
3.5. End-to-end architecture	5	4	3 out of 3 Tasks
4.1. Integrated Energy System Architectures	9	10	6 out of 9 Tasks
4.2. Long-term planning	7	6	3 out of 7 Tasks
4.3. Asset management and maintenance	0	0	0 out of 9 Tasks
4.4. System Stability analysis	6	8	4 out of 7 Tasks
5.1. Demand flexibility	15	18	4 out of 4 Tasks
5.2. Generation flexibility	10	7	5 out of 7 Tasks
5.3. Storage flexibility & Energy Conversion flexibility	18	22	4 out of 5 Tasks
5.4. Network flexibility	9	16	2 out of 4 Tasks
5.5. Transport flexibility	1	1	2 out of 3 Tasks
6.1. Supervisory control and state estimation	9	9	3 out of 3 Tasks
6.2. Short-term control	7	8	2 out of 3 Tasks

Research Topic	Project contributions	KERs	Task coverage
6.3. Medium- and long-term control	7	6	5 out of 6 Tasks
6.4. Preventive control/restoration	3	6	2 out of 8 Tasks
6.5. Control Center technologies	9	8	5 out of 7 Tasks
	≥13 contributions	≥15 KERs	≥67%
	8 – 12 contributions	7 – 14 KERs	33 – 67%
	<8 contributions	<7 KERs	<33%

Below, conclusions are formulated for each individual Research Area. Here, the four sources are used to draw conclusions in order of the level of detail of each source (national R&I reports, BRIDGE R&I Priorities Report, ERA-NET SES project summaries and the questionnaire assessment).

Research Area 1: Consumer, prosumer, and citizen energy community is well covered in research programmes and/or projects in all the country R&I reports assessed. The BRIDGE R&I Priorities report shows achievements in five out of seven Tasks within this Research Area, mostly focused on public acceptance, awareness, and adaptation of energy behaviour. The ERA-NET SES projects whose project summaries are assessed contribute predominantly in Research Area 1, with the highest focus on Adaptive consumer/user behaviour including energy communities. The assessment of the responses to the questionnaires shows that the seven tasks in this Research Area seem to be on target, however, the level of contribution by the responsive projects is relatively low.

Research Area 2: System economics is well covered in research programmes and/or projects in all the country R&I reports. The BRDIGE R&I Priorities report shows achievements in four out of fourteen Tasks within this Research Area, mostly focused on business models. The assessment of ERA-NET SES project summaries shows a decent level of contributions, again with business models being the point of focus. While the projects that participated in the questionnaire indicate a slightly less than average contribution to Research Area 2 in terms of projects and KERs, the contribution to Tasks is very low – with a large uncertainty in the actual TRL progression.

Research Area 3: Digitalisation is covered by research programmes and/or projects in the country R&I reports, except for one. More than half of the Tasks are covered by at least one achievement in the BRIDGE R&I Priorities report, with many projects reporting achievements in data exchange protocols and interfaces for a well-functioning market. ERA-NET SES project summaries indicate project and KER contributions in protocols, standardisation, and interoperability as well as in data communication. Questionnaire respondents report a high level of contribution, especially in the Topic of protocols, standardisation, and interoperability. Research Area 3 shows very promising progression of Tasks, with a high level of contribution across nearly all Tasks.

Research Area 4: Planning – holistic architectures and assets is partially covered by research programmes and/or projects in the country R&I reports, except for one. In the BRIDGE R&I Priorities report, only 2 achievements in 2 tasks (out of 25) are reported. In the questionnaire assessment, non-BRIDGE projects indicate a close-to-average contribution to Topics in Research Area 4, whereas BRIDGE projects report a low level of contribution. The ERA-NET SES project summaries also show a low level of project and KER contributions. The progression of the TRL of Tasks in Research Area 4 cannot unambiguously be concluded based on the questionnaire responses. The level of contribution is low, some Tasks are not covered by any of the respondents, and the uncertainty of other Tasks is high as well.

Research Area 5: Flexibility enablers and system flexibility is well covered by research programmes and/or projects in the country R&I reports. It is also the dominant Research Area in number of achievements in the BRIDGE R&I priorities report, with a significant number of achievements in 6 out of 25 Tasks. ERA-NET SES project summaries show a close-to-average contribution level in this Research Area. The questionnaire assessment shows that many Tasks in Research Area are addressed by at least one project (18 out of 23). Those that are addressed are well on target with the ETIP SNET's Implementation Plan.

Research Area 6: System operation is covered by research programmes and/or the country R&I reports, except for two. 6 out of 27 Tasks have at least one achievement attributed to it in the BRIDGE R&I Priorities report. In the ERA-NET SES project summaries, Research Area 5 shows an average level of contribution by the projects and KERs. The questionnaire assessment shows that 20 out of 28 Tasks in Research Area 6 are covered by at least one project. The Tasks that are reportedly addressed show potential to be on target. The overall uncertainty, though, is relatively high given that 11 Tasks have only one project contribution.

In closing we highlight and summarise again the Tables 23-25 from Section 6.1 above and the related Appendix 2 which lists numbers of contributing projects and achieved TRLs for all 120 Tasks. For the updated ETIP SNET Implementation Plan to be drafted during the remainder of 2021, all analyses reported in the Progress Monitoring Report will provide a strong basis. And for example, Table 23 indicates Tasks which may already have received sufficient attention (depending on the TRLs achieved and the real-world applicability of their KERs). Table 24 on the other hand indicates Tasks which may require increased attention, unless the recent lack of attention might relate to commercialisation, as in the asset management software example, already existing or being imminent. And Table 25 complements Table 23 by indicating Tasks with especially high reported TRLs.

6. APPENDIX 1: QUESTIONNAIRE FOR INDIVIDUAL R&I PROJECTS

A. Contact details

	Response
Name of respondent:	
E-mail address:	
Phone number:	

B. Project Details

	Response	
Project name (acronym, if applicable):		
Project name (long):		
Project contributors:		
Please indicate the relevant Research Area(s) of the project (Yes/No):	1. Consumer, prosumer and citizen energy community	
	2. System economics	
	3. Digitalisation	
	4. Planning – holistic architectures and assets	
	5. Flexibility enablers and system flexibility	
	6. System operation	
To which functionalities does the project contribute? (Yes/No)	F1. Cooperation between system operators	
	F2. Cross sector integration	
	F3. Integrating the subsidiarity principal - the customer at the center, at the heart of the integrated energy system	
	F4. Pan European wholesale markets	
	F5. Integrating local markets	
	F6. Integrating digitalisation services	
	F7. Upgraded electricity networks, integrated components and systems	
	F8. Energy system business	
	F9. Simulation tools for electricity and energy systems	
	F10. Integrating flexibility in generation, demand, conversion and storage technologies	
	F11. Efficient heating and cooling for buildings and industries in view of system integration of flexibilities	
	F12. Efficient carbon-neutral liquid fuels and electricity for transport in view of system integration of flexibilities	
Project start date:		
Project end date:		
Funding agency:		
Budget:		
Which aspects of your project or Key Exploitable Results would benefit from a discussion with peers during Regional Workshops organized by ETIP SNET in the first half of 2021?		

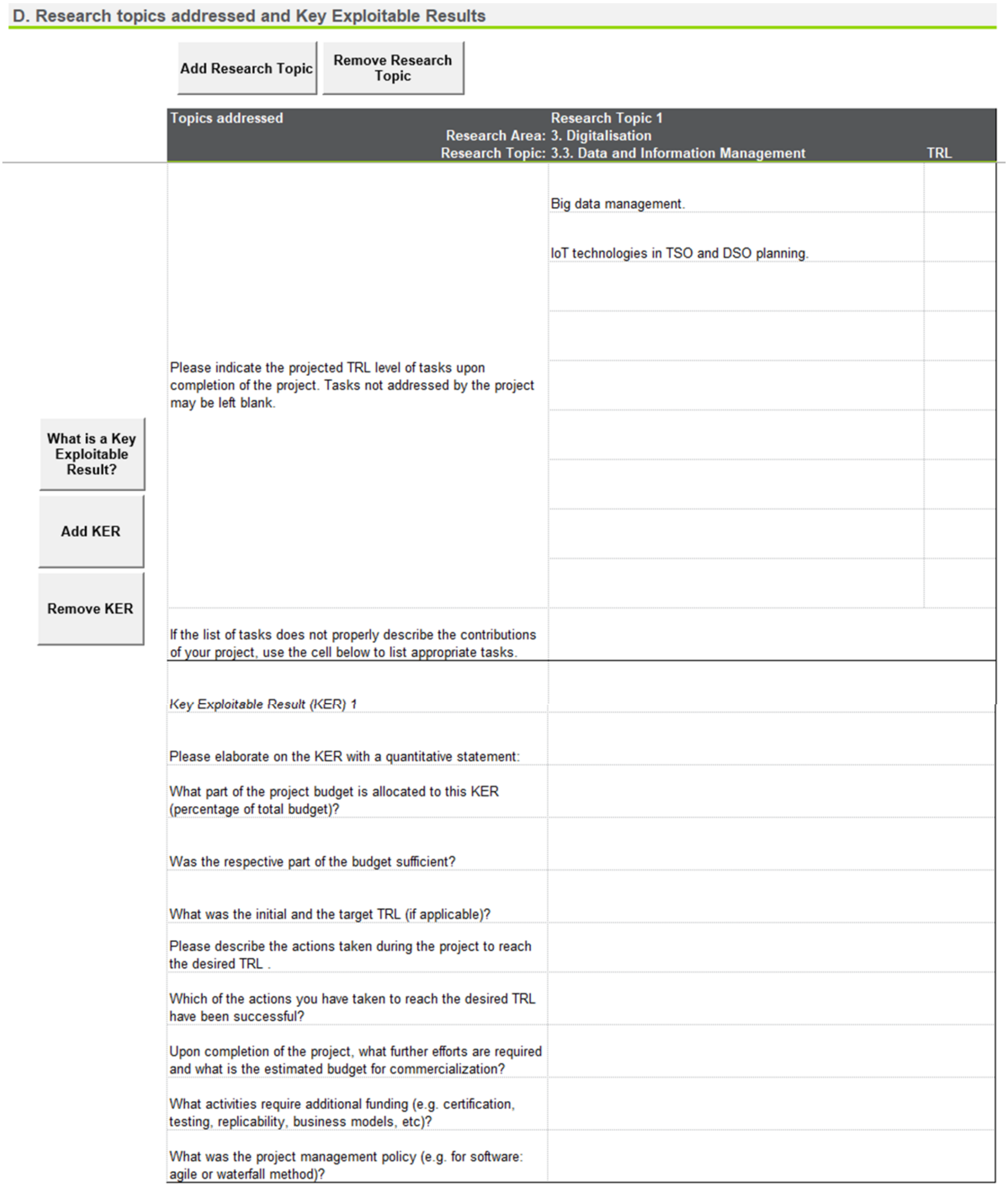
Figure 27: Questionnaire - General Project Information, part A and B

C. Additional questions (optional)

Skip section

Topics addressed	Response
Please list the two most relevant challenges, scope objectives and expected impact of the call that were covered in the proposal or description of work (DoW), using the original terminology of the call.	
Which (maximum two) challenges, scope objectives and expected impacts of the call were omitted in the proposal or DoW? Please use the original terminology of the call.	
For each of the challenge, scope objective, and expected impact of the call listed under question 1, do you think there are aspects not properly covered by your proposal or DoW?	
For each of the challenge, scope objective, and expected impact of the call listed under question 1 and considering the results of your project, do you think that there are new aspects or new goals that need to be included in future calls?	
Which of the challenges, scope objectives, impacts of the call listed under question 1 have been successfully handled at the current status of the project?	
Which of the challenges, scope objectives, impacts of the call listed under question 1 have not yet been successfully handled at the current status of the project?	
What kind of tools are used for the management of the project (e.g. Jira, Trello, TEAMS, Dropbox, etc)?	
How many visitors have you had on the project's LinkedIn, Twitter or Facebook account until now?	

Figure 28: Questionnaire - General Project Information, part C. This part of the questionnaire is optional, meant to provide insight in the coverage degree of Horizon 2020 projects in reference to the call.



D. Research topics addressed and Key Exploitable Results

Add Research Topic | Remove Research Topic

Topics addressed	Research Topic 1	TRL
Research Area:	3. Digitalisation	
Research Topic:	3.3. Data and Information Management	
Please indicate the projected TRL level of tasks upon completion of the project. Tasks not addressed by the project may be left blank.	Big data management.	
	IoT technologies in TSO and DSO planning.	
If the list of tasks does not properly describe the contributions of your project, use the cell below to list appropriate tasks.		
Key Exploitable Result (KER) 1		
Please elaborate on the KER with a quantitative statement:		
What part of the project budget is allocated to this KER (percentage of total budget)?		
Was the respective part of the budget sufficient?		
What was the initial and the target TRL (if applicable)?		
Please describe the actions taken during the project to reach the desired TRL .		
Which of the actions you have taken to reach the desired TRL have been successful?		
Upon completion of the project, what further efforts are required and what is the estimated budget for commercialization?		
What activities require additional funding (e.g. certification, testing, replicability, business models, etc)?		
What was the project management policy (e.g. for software: agile or waterfall method)?		

What is a Key Exploitable Result? | Add KER | Remove KER

Figure 29: Questionnaire - Research Topics and KERs

7. Appendix 2: Contribution of individual projects to 120 Tasks

Table 28: Level of contribution and average reported TRL of the 120 Tasks

Task ID	Task	Number of projects	Average reported TRL
1.1.1	Public acceptance of new energy infrastructures	4	7
1.1.2	Awareness of new electricity/energy systems and citizen involvement in forming energy communities	3	7

Task ID	Task	Number of projects	Average reported TRL
1.1.3	Environmental impacts of energy infrastructures (visual, audible, etc.)	2	7
1.2.1	Consumers' and prosumers' adaptation of energy behaviour	5	6
1.2.2	Industry's consumption adaptation	1	7
1.3.1	Wireless technologies for direct control of consumption/generation	1	9
1.3.2	ICT technologies for smart appliances	3	8
2.1.1	Business models for prosumers providing ancillary services	1	7
2.1.2	Business models for retailers and aggregators, ESCOs and energy communities.	2	6
2.1.3	Business models for data analysis service providers	0	-
2.1.4	Business models for storage in electrical transportation networks	2	6
2.1.5	Business models for gas-fired or biomass fired CHP units	0	-
2.2.1	Pan-European market design	2	5
2.2.2	Market design for TSO cross border coordination	1	8
2.2.3	Market rules for ancillary services by aggregated storage and virtual power plants	1	5
2.2.4	Market design for provision of ancillary services between DSOs and TSOs	3	4
2.2.5	Design of local markets and their interaction to central markets	6	5
2.2.6	Market design for large-scale demand response, beyond electricity	1	2
2.2.7	Market design for storage owners and operators	3	6
2.2.8	Market rules for system services (balancing) by gas networks	0	-
2.2.9	Market design for water cycle management operators	0	-
3.1.1	Data exchange protocols / interfaces for a well-functioning market	7	6
3.1.2	Standardised communication protocols and ICT infrastructure between devices and networks and also between devices and remote management platforms	10	6
3.1.3	Communication interfaces of smart substations	3	5
3.1.4	DSO and TSO information exchanges; decision-making support functions	6	6
3.2.1	Demand aggregation and control	5	8
3.2.2	Monitoring and control of distributed generation	6	8
3.2.3	Communication infrastructures for smart metre data	2	8
3.2.4	Conditional and risk-based maintenance	1	8
3.3.1	Big data management	3	7
3.3.2	IoT technologies in TSO and DSO planning	2	7
3.4.1	Cyber security protection of grid infrastructures	4	7
3.4.2	GDPR-compliant methodologies for management of distributed energy resources	3	8
3.4.3	Parallel use of legacy SCADA systems	2	8
3.4.4	Public ICT and wireless infrastructures for smart grid functionality	2	6
3.5.1	Digital twinning of interoperating grid and communication networks	1	8

Task ID	Task	Number of projects	Average reported TRL
3.5.2	Data exchange at different system voltage levels	1	8
3.5.3	Application of advanced ICT-based approaches for data storage	1	8
4.1.1	Model of the energy system encompassing the whole energy chain	3	6
4.1.2	Resilience oriented sizing and spatial positioning of assets	1	8
4.1.3	Local multi-energy streams operation	4	6
4.1.4	Multicarrier hybrid storage systems	2	6
4.1.5	Optimally located, sized, and coordinated electric energy storage at different voltage levels	2	6
4.1.6	Optimally located, sized, and coordinated storage for seasonal needs	2	6
4.1.7	Web-of-cells, decentralised, modular control architectures	0	-
4.1.8	Integrated electricity AC and DC distribution networks	0	-
4.1.9	HVDC meshed grids and parallel routing of DC and AC lines	0	-
4.2.1	Planning of integrated (coupled) energy systems	1	8
4.2.2	Investment planning in RES at EU level	0	-
4.2.3	Planning for resilience	0	-
4.2.4	DER solutions to handle network constraints in planning	2	6
4.2.5	Probabilistic planning taking into account the DER stochasticity	1	7
4.2.6	Massive integration of EV's	1	3
4.2.7	LV and MV DC industrial and residential grids	0	-
4.3.1	Condition (risk) in planning LV/MV based maintenance	0	-
4.3.2	State of Health estimates of transmission system components	0	-
4.3.3	Model-based detection of component failures	0	-
4.3.4	Remote LV/MV maintenance operations	0	-
4.3.5	HV and MV-asset management considering resiliency	0	-
4.3.6	Training of maintenance operators	0	-
4.3.7	Optimised lifespan of storage systems	0	-
4.3.8	Optimal maintenance of hydropower and pumped-storage units	0	-
4.3.9	Improved lifetime of thermal generation	0	-
4.4.1	Support by DER, microgrids and nanogrids	1	6
4.4.2	Synthetic inertia from power electronic converters	0	-
4.4.3	Microgrids in islanded mode of operation	1	8
4.4.4	Converter driven stability	0	-
4.4.5	Stability of large-scale transmission systems with high penetration of variable RES	1	8
4.4.6	Equivalent models of aggregated network and system components	2	8
4.4.7	Large scale inter-area oscillations	0	-
5.1.1	Optimal utilisation of DSR by TSOs and DSOs	7	7
5.1.2	Direct load control	6	7
5.1.3	Active demand in DSO planning and operation	5	7

Task ID	Task	Number of projects	Average reported TRL
5.1.4	Flexibility by energy-intensive industries and bulk energy storage	2	6
5.2.1	Contributions of wind turbines and solar-PV to system flexibility	7	6
5.2.2	Operational flexibility of hydropower and pumped storage plants	3	6
5.2.3	Flexibility of thermal generation	2	7
5.2.4	Fuel flexibility of thermal power plants	0	-
5.2.5	Flexible small and medium scale thermal generation	1	6
5.2.6	Cogeneration units with decoupled use of heat and power	1	5
5.2.7	European hydro energy system model	0	-
5.3.1	Storage flexibilities in operation of electrical grids	12	6
5.3.2	Energy storage systems with conventional power generators	3	7
5.3.3	Aggregated heating (and cooling) storage at household/building/industrial level	6	7
5.3.4	Power-to-gas applications	0	-
5.3.5	Stand-alone buildings, living quarters and small and medium sized businesses and industries	3	6
5.4.1	Flexibility in transmission and distribution networks	5	6
5.4.2	Distribution network reconfiguration	2	7
5.4.3	HVDC multi-terminal networks to coordinate power flows	0	-
5.4.4	Dynamic line rating	0	-
5.5.1	Efficient management of EV charging	1	8
5.5.2	Energy management in transport electricity networks	0	-
5.5.3	Electric vehicles with grid to vehicle (G2V) and vehicle to grid (V2G)	1	8
6.1.1	Steady state and dynamic state estimation of transmission systems using intelligent monitoring devices	1	8
6.1.2	Observability and state estimation of distribution systems	7	7
6.1.3	Real-time observability of RES and improved forecasts	4	7
6.2.1	Load frequency control	2	5
6.2.2	Contribution of RES to primary voltage and frequency control	2	6
6.2.3	Primary voltage and frequency control of distribution grid	1	5
6.3.1	Advanced RES forecasting	3	7
6.3.2	Hydropower forecasting	0	-
6.3.3	Solving location-based grid constraints	1	8
6.3.4	Optimal scheduling in highly uncertain conditions	1	8
6.3.5	Distribution network configuration	1	8
6.3.6	Technologies in secondary substation	1	8
6.4.1	Protection of distribution networks with low fault currents	1	8
6.4.2	DC grid protection, protection relays and breakers	0	-
6.4.3	Topology optimisation for increasing network resilience	0	-
6.4.4	Bottom-up restoration	0	-
6.4.5	Self-healing techniques	1	8

Task ID	Task	Number of projects	Average reported TRL
6.4.6	Load shedding techniques	0	-
6.4.7	Security support by various multi-energy carriers	0	-
6.4.8	Pan-EU or multiregional system restoration	0	-
6.5.1	Wide area monitoring and control architecture for transmission systems	1	6
6.5.2	Energy management platforms for TSOs to interact with local markets	2	6
6.5.3	Energy management platforms for DSOs for active participation of customers in energy market	3	6
6.5.4	Control centre architectures for distributed network control	2	5
6.5.5	Control of intentional islanding	1	7
6.5.6	Training simulators for DSOs and TSOs (e.g. using digital twins)	1	7
6.5.7	Advanced MMI (Man-Machine-Interface)	0	-

8. Appendix 3: Key Exploitable Results

Table 29 - Table containing all Key Exploitable Results, Natures and Target TRLs. Note that some projects were unable to provide a target TRL for the KER.

Project	Key Exploitable Result	Nature	Research Topics	Target TRL
CLUE	**Identification of several incentives**, which lead to high motivation for participation of citizens (prosumer & consumer) in **Energy Communities**	Policy, regulation, market	1.1	5
CLUE	**Business model:** energy suppliers that are not allowed to participate in renewable energy communities provide services such as billing/accounting or contracting opportunities	Policy, regulation, market	2.1	“High”
CLUE	**The vector integration platform (VIP)** under development in the Scot CLUE project would provide consider optimal flexibility for controlling demand and supply within a web of cells energy assets within the local UK community.	Software	4.1, 5.3	6
CLUE	**Grid Capacity Management (GCM)** - grid optimisation tool to generate optimal setpoints for various controllable devices in the grid.	Software	5.4, 6.4	7
CLUE	**Local peer-to-peer algorithm** will utilise the flexibilities in the distribution grid. This is deployed in the AIT Rapid Deployment Platform.	Software	5.1	7

Project	Key Exploitable Result	Nature	Research Topics	Target TRL
CLUE	**Community storage control for grid support and local energy market** as part of AIT Rapid Deployment Platform and is located inside Grid Capacity Management	Software	5.3	7
CLUE	With the **AIT Rapid Deployment Platform,** it is possible to deploy a running Hardware-in-the-Loop setup (HiL) within 5 days in the field	Software	6.5	7
CLUE	**BIFROST Simulation Platform** developed by Siemens will be further developed to provide community members and stakeholders a simulation tool to visualise a local energy community.	Software	4.2	8
DISTRHEAT	A scale-free approach for **Model Predictive Control development** and application to district heating networks	Methodology	5.2	
DISTRHEAT	The same as for 5.2 because the control system deals with production, distribution and end-users	Methodology	5.3	
E-LAND	The **Common Impact Model** – introducing a standardised set of tools to facilitate and manage social acceptance of energy innovation projects.	Software	1.1	
E-LAND	The **E-LAND business model innovation tool** will be a package of the most successful patterns and a framework to combine such patterns. The tool shall provide reference business models for energy communities, system operators and for seasonal storage.	Software	3.2	8
E-LAND	**The Multi-Vector Simulator (MVS)** performs these pre-feasibility studies by providing the analytical backbone to the **Energy Planning Application (EPA),** which will serve the user as an interface: Provided with the project's specific input data, it can evaluate the performance of the current as well as potential future system configurations	Software	4.1	8

Project	Key Exploitable Result	Nature	Research Topics	Target TRL
E-LAND	**Optimal Scheduler module** provides the scheduling of operating points of **available storage units and flexible loads** (loads that can be rescheduled) that optimise the use of local renewable energy sources.	Software	4.2	8
E-LAND	**Energy forecaster p**rovides forecasting for different energy vectors: electrical and thermal loads; PV and wind generation.	Software	5.3	8
E-LAND	**Data processing app** ensures that gathered data has the best quality detecting and correcting inaccurate/missing records to be exploited by EF.	Software	3.3	8
EERAdata	**EERAdata platform** (**federated database service**) with at least 50 interfaces to other data services, 50 experts in the pool.	Database	3.1	7
Energy Shield	**Integrated EnergyShield Toolkit**	Software	3.4	7
ESAFENET	**Method for Microgrid Black Start -** Performs autonomous black start using only power resources present in microgrid.	Methodology		3
ESAFENET	Method for enduring uninterrupted **machine-type communication during emergencies**	Methodology		3
EU-SysFlex	**Virtual Power Plant (VPP) platform** developed by Siemens and applied with EDP to optimise energy generation and system services provision from the aggregation of wind farms and hydro pumped storage.	Software	5.2	7
EU-SysFlex	**Cross-border interoperability services for consumer portals**, with Elering and Data BRIDGE Alliance. Amongst other demos, a software application facilitating TSO-DSO cooperation will be tested.	Software	3.1	7
EU-SysFlex	**A forecasting tool** is developed and offered to Mitnetz-Strom to manage congestion, while another developed tool helps DN generators determine their redispatch capability.	Software	6.5	7

Project	Key Exploitable Result	Nature	Research Topics	Target TRL
EU-SysFlex	Helen retailer, is testing to manage active power flexibility from **Battery Energy Storage Systems (BESS) and EVs**, connected to the grid of Helen DSO, to support the FCR-N and FCR-D reserve markets.	Methodology	5.3	7
EU-SysFlex	Opening-up of **RR market to DN-units**, combined with a Traffic Light Qualification (TLQ) system, is proposed by InescTec to allow DSOs to validate DN RR bids before they are activated by a TSO.	Policy, Regulation, Market	6.1	7
EVA	Future scenarios about the diffusion of **connected and autonomous vehicles**, particularly under the sharing economy framework, are co-created, focusing on the regions of Bolzano (IT) and Ticino (CH).	Policy, Regulation, Market	4.2	3
EVA	Strategies to **optimise electric vehicle charging infrastructures** and avoid investment in fast obsolescing ones are developed. Guidelines to support regional institutions in the transition towards autonomous mobility are produced and new business models are identified.	Methodology	4.2	
EVA	How to **manage peaks in power demand** due to a wide diffusion of electric autonomous mobility in the smart grid by exploiting vehicle-to-grid (V2G) and vehicle-to-home (V2H) power strategies.	Software	5.3	3
FLexiGrid	**Upgraded Smart Metres** with new automatic learning algorithms capable of proving data to the end-users in real time.	Hardware	5.4	8
FLexiGrid	Energy Box - **a multi-purpose concentrator** for the operation in various scenarios of advanced electrical networks, DER and Smart Grids	Database	5.4	8
FLexiGrid	Self-contained module consisting of a set of **forecasting algorithms**, which allow to accurately predict energy generation, demand and electricity price	Software	5.4	8

Project	Key Exploitable Result	Nature	Research Topics	Target TRL
FLexiGrid	**An updated version of VERD's software** can provide a fully-fledged flexibility modelling and analytics and therefore enable accurate flexibility forecasting and analysis for the definition of optimised control strategies.	Software	5.4	8
FLexiGrid	**CIRCE will develop a machine learning algorithm** for a one-minute forecast combined with a discriminator of the status of the network (with or without network issues like over/under voltage problems or overloaded lines) this will allow sending specific setpoints	Software	5.4	8
FLexiGrid	**Smart secondary substations**: a) with improved structures and advanced IoT integrated communications and b) specially designed for remote isolated areas	Hardware	6.3	8
FLexiGrid	**Innovative protection devices for the MV grid** that will be able to overcome the bidirectional energy flow challenges introduced by the increasing penetration of variable generation in the network	Hardware	6.4	8
FLexiGrid	**Fault detection/location and energy supply restoration** (self-healing) algorithms will be upgraded and included in a software module that will be capable of detecting a fault in the distribution grid.	Software	6.4	8
FLexiGrid	**Fault location prototype** will estimate a distance between the fault point and the place where the locator is installed, using a special approach of time domain reflectometry technique.	Hardware	6.4	7
FLexiGrid	A **software exploiting thermal storage capacity** of existing water heaters and building spaces to dispatch desired amounts of flexibility in a cost-effective manner without compromising occupant comfort or disrupting daily routines and operations.	Software	5.1	8
FLexiGrid	**FLEXIGRID's data platform** provides seamless integration between several energy data sources and the services that exploit that data.	Database	3.1	8

Project	Key Exploitable Result	Nature	Research Topics	Target TRL
FLexiGrid	**Software/web service for calculation of the optimal sizing** (capacity and power) and placement (installation node within the electricity network) as a trade-off between the expected impact on the electricity system and investment/deployment costs.	Software	5.3	7
FutureFlow	The prototype of the **DR&DG Flexibility Aggregation Platform**. This platform represents the link between the smallest control units (individual DR and DGs) and the regional balancing platform managed by the TSOs.	Software	5.1	
FutureFlow	The prototype **Regional Balancing and Redispatching Platforms**. It optimises the use of balancing resources located in different countries and enables the participation of DR&DG sources in cross border real-time balancing processes.	Software	5.1	
FutureFlow	**The Power Flow Colouring (PFC) Method** identifies the components of the power flows in the electricity system (loop flows, internal flows, exchange flows, transit flows, and PST flows).	Methodology	5.1	
FutureFlow	The **DEMOX environment** has been developed as an alternative to the usage of the TSOs Load-Frequency Controllers (LFCs). The DEMOX represents a replica of the real LFC controllers with the integrated real-time Common Activation Function.	Software	5.1	
FutureFlow	The aggregated pool of DR&DGs for the flexibility services.	Database	5.1	
H2CS	LCA on a reversible fuel cell integrated in an energy community	Methodology	1.1	
H2CS	**Risk and Regulatory Study** - Research results provide input and legitimise the action of local members, and vice versa. These barriers must be removed for installation of the fuel cells.	Policy, Regulation, Market	1.1	

Project	Key Exploitable Result	Nature	Research Topics	Target TRL
H2CS	**Sizing tool** - Holistically defines the needs in terms of production, storage and flexibility, providing the possibility to define the economic aspects, and to adapt the business models according to the previous results.	Software	4.1	7
H2CS	**EMS** – Allows for the management of the means of energy production (multiple sources such as solar, wind, geothermal, hydraulic), storage (hydrogen, electric, heat) and flexible loads of the EC dynamically and efficiently. This tool will be based on IoT data and model predictive control (MPC) approach.	Software	6.5	7
HONOR	Full market design for **local/regional flexibility markets**	Policy, Regulation, Market	2.2	
HONOR	Close coordination between TSO and DSO for grid management and the relation to the flexibility market	Policy, Regulation, Market	3.1	
HONOR	**Cyber-security modelling of SCADA** and control system solution	Software	3.4	
HONOR	**Holistic architecture** to enable the flexibility market in a technical environment	Methodology	4.1	
HONOR	The DSOs are able to make use of flexibility from various assets.	Policy, Regulation, Market	5.1, 5.2, 5.3	
HONOR	Flexibility to support grid operation	Policy, Regulation, Market	5.4	
HONOR	Cyber-physical system monitoring, verification and validation	Software	6.1	
HONOR	Integrate a DSO emergency control into the control centre	Methodology	6.5	
INTERPLAN	Methodology/tool (with embedded control functions) for the **operation planning of an integrated grid**	Software	4.2	2
INTERPLAN	Control functions for **exploiting storage flexibility** to solve several network operational planning issues	Methodology	5.3	2

Project	Key Exploitable Result	Nature	Research Topics	Target TRL
INTERPLAN	Control functions to **exploit flexibility coming from DER** in distribution networks to address operation issues at both distribution and transmission levels	Methodology	5.4	2
INTERPLAN	Control functions for: **Coordinated voltage/reactive power control, Provision of frequency tertiary reserve, maintaining frequency stability in low inertia power system, Fast frequency restoration control** by using local DER integrated in the grid	Methodology	6.2	2
INFORPV	High accuracy data-driven **PV production day- and hour-ahead forecasting system** based on machine learning principles	Software	3.1	7
INFORPV	**Unified and scalable distribution energy resource management system (DERMS)** to provide forecast-aided control activities to utility or microgrid operators	Software	3.1	7
LivingGrid	Methodology/tool (with embedded control functions) for the **operation planning of an integrated grid**	Software	4.4	4
LivingGrid	Methodology/tool (with embedded control functions) for the **operation planning of an integrated grid** to evaluate storage flexibility in the operation of grids	Software	5.3	4
MERLON	**Prosumer App** - Interface that facilitates the real-time operation of the ILES in terms of its interaction with the prosumer	Software	1.3	8
MERLON	**Building Flexibility manager** - Performs individual flexibility profiles	Software	5.1	8
MERLON	**Battery Management Module** - Module responsible for monitoring and controlling all sub-systems at the battery plant	Software	5.3	8

Project	Key Exploitable Result	Nature	Research Topics	Target TRL
MERLON	**Interoperability & Data-management platform -** Module that facilitates end-to-end interoperability and information exchange between all components within ILES Energy Management Framework in a standards-based approach and considering all applicable data protection provisions	Software	3.2	8
MERLON	ILESEM platform - **Holistic Energy Management and Optimisation of an Integrated Local Energy System (ILES**)	Software	4.4	8
MERLON	Simulation-based ILES optimised planning and sizing module	Software	4.4	8
PARITY	Smart Contracts Enabled Local Flexibility Market Platform	Policy, Regulation, Market	2.2	8
PARITY	Smart Grid Monitoring & Active Network Management Tool	Software	4.4	8
PARITY	**Storage-as-a-Service (SaaS) framework** efficiently combining Actual Storage (batteries) and Virtual Energy Storage (Power-to-Heat)	Methodology	5.3	8
PARITY	EV profiling and smart charging system	Methodology	5.5	8
PARITY	**IoT Gateway** - Integrates device communication protocols and control software	Software	3.2	8
Platone	Tool to map existing Use Case descriptions produced by commercial tools into a usable, open format	Software	1.2	8
Platone	Open platform for **Distribution Grid Management**	Software	1.2	7
Platone	Platone Market Platform	Software	1.2	8
Platone	**Light Node** - Implements blockchain functionality at smart metre	Software	1.2	8
PLATOON	PLATOON Interoperability framework	Software	3.1	7
PLATOON	Data governance framework	Software	3.1	7

Project	Key Exploitable Result	Nature	Research Topics	Target TRL
REel demo	A **PMU based monitoring system** was deployed for providing our proprietary BESS control algorithm with real-time state estimation	Software	6.1	7
Regions	Participation of **VPPs for reactive power provision** for future (to be established) markets products	Policy, Regulation, Market	5.2	6
Regions	**Irradiance Forecast** based on satellite data, cloud data, solar radiation and technical model data	Software	6.3	6
SmartNet	Elaboration and practical application of a **cost-benefit analysis** to compare the performance of different **TSO-DSO coordination** schemes	Policy, Regulation, Market	2.2	5
SmartNet	Pilot A to analyse **potential for hydro generation** connected to distribution to provide aFRR and reactive support to the system	Methodology	5.2	5
SmartNet	Pilots B and C: **flexibility from thermostatically controlled loads** and from local storage unites of telecommunication radio base stations.	Methodology	5.1	5
R2EC	R2EC will have around 70 survey participants from users of **r2ec's energy cell** about many different social questions	Database	1.1	
R2EC	At the current moment undefinable, a number of **Business models** will be developed for the **usage of flexibility** within an energy cell	Policy, Regulation, Market	2.1	
R2EC	Implementation of an **interoperable communication protocol** between 2 devices in the laboratory application	Software	3.1	
R2EC	Laboratory implementation and monitoring of prototype components	Hardware	3.5	
R2EC	Development of simulation agents for **demand flexibility** (Heat Pump)	Software	5.1	
R2EC	Development of simulation agents for **generation flexibility**	Software	5.2	
R2EC	Development of simulation agents for **storage flexibility**	Software	5.3	

Project	Key Exploitable Result	Nature	Research Topics	Target TRL
R2EC	Development of a forecasting system for **RES**	Software	6.3	
SMILE	**Involvement of end user** in the project demonstrators	Policy, Regulation, Market	1.1	
SMILE	Installation of electricity and temperature **monitoring equipment**	Hardware	1.2	
SMILE	Installation of **electric socket for boats in the touristic harbour**. Each electric socket has a switch and a meter; the consumer switches the socket on from a smartphone	Hardware	1.3	
SMILE	1) In the In the Samsø island demonstrator, **PV plant installed** and put into operation combined with BESS	Hardware	2.1	
SMILE	In the In the Samsø island demonstrator, in the touristic harbour **consumers are billed by their actual consumption**, instead of a fixed lump sum	Policy, Regulation, Market	2.2	
SMILE	Analysis of **regulatory framework related to electricity storage** and Integration of electricity and heat supply systems	Policy, Regulation, Market	2.2	
SMILE	In the In the Samsø island demonstrator, **historical data is collected and processed for future simulations;** real-time data are measured for BESS control	Database	3.2	
SMILE	1) In the Samsø Island demonstrator, **a dashboard** was developed through which data is accessible and downloadable. 2) In the Madeira Island demonstrator, an **Energy Management system** was developed to support the data management of all the pilots of the demonstrator	Software	3.2	
SMILE	1) In the Samsø Island demonstrator, consumers **can pay by credit card via smartphone.** 2) In all the demonstrators, development of **Cybersecurity tools** to identify vulnerability and define protective measures	Policy, Regulation, Market	3.4	

Project	Key Exploitable Result	Nature	Research Topics	Target TRL
SMILE	1) In the Samsø island demonstrator, **Electricity is coupled with heating and transport.** 2) In the Orkney Island demonstrator, **load controller (aggregator platform)** able to control domestic heat installs, EV smart charging and large industrial load	Software	4.1	
SMILE	In the Madeira Island demonstrator, **deployment of cloud-based control of PV-BESS** in local micro-production sites (domestic and commercial)	Software	4.2	
SMILE	In the Madeira Island demonstrator, at the distribution level (sub-station) **the voltage fluctuations were studied**.	Hardware	4.4	
SMILE	1) In the Samsø Island demonstrator, **remote control via Internet.** 2) In the Orkney Island demonstrator, **load controller (aggregator platform) able to control domestic heat** installs, EV smart charging and large industrial load. 3) In the Orkney Island demonstrator, a **DMS system** was installed	Software	5.1	
SMILE	In the In the Samsø Island demonstrator, **forecasts of production and consumption**	Software	6.1	
SMILE	1) In the In the Samsø Island demonstrator, **BESS charges when there is excess PV powe**r, and vice versa 2) In the Madeira Island demonstrator, **development, and deployment of algorithms for load levelling at the substation** level using storage. In the Orkney Island demonstrator, **load controller (aggregator platform) able to control domestic heat installs**, EV smart charging and large industrial load to support the local grid in increasing the demand side management capacity and reduce levels of curtailment.	Software	6.2	
SoLAR	Real demonstration lab (i.e. people live there to use it) - Just **flexibility of heating** allows to increase energy self-consumption by one third (from 50 to 66%)	Methodology	1.3	
SoLAR	**Agents shifting load operation** to optimise value under given use constraints	Software	5.1	

Project	Key Exploitable Result	Nature	Research Topics	Target TRL
SoLAR	First ever implementation of **real time local energy market**	Policy, Regulation, Market	6.2	
SONDER	**AT: IES Integration Profiles** for Energy Communities	Policy, Regulation, Market	3.1	7
SONDER	SE: **Communication Interoperability** in the Energy Community	Policy, Regulation, Market	3.1	5
SONDER	CH: **Huge sensor data collection** and forecasting using graph-based machine learning prediction methods	Database	3.3	6
SONDER	AT: **Common Reference Architecture** for Energy Communities	Methodology	4.1	6
SONDER	AT: **Battery Operator Model** for Community Batteries	Software	4.1	4
SONDER	CH: **Optimal Peak Shaving** on Distribution Network Level Using Stationary Battery Energy Storage Systems.	Methodology	5.3	7
SONDER	SE: Investigating Datacentre as an energy flexibility enabled with UPS	Software	5.3	5
SYNERGY	**SYNERGY Core Big Data Platform** - Big data platform offering 4 main bundles of services for data collection, data security, multi-party data sharing and data matchmaking	Database	3.1	8
SYNERGY	AI **Big Data Analytics Toolkit** and Marketplace	Software	3.1	8
TDX ASSIST	**Fully defined interface specifications for TSO-DSO** information exchange interfaces based on Use Case analysis and IEC 61970/61968/62325 standards to support highly automated information exchange and network analysis.	Methodology	3.1	7

Project	Key Exploitable Result	Nature	Research Topics	Target TRL
TDX ASSIST	**Fully defined interface specifications** for information exchange between DSOs and market participants based on Use Case analysis (using IEC 62559 series, 62913-1 standards) and IEC CIM Model (IEC 61970, IEC 61968, IEC 62325) and IEC 61850 standards to support highly automated information exchanges.	Methodology	3.1	7
TDX ASSIST	**The determination of flexibility areas in the TSO/DSO interface** must consider the discrete controls in the distribution network, namely, transformer taps and capacitor/reactor banks	Hardware	5.4	6
TDX ASSIST	It is recommended that the **flexibility potential** of prosumers in distribution grids is used appropriately to make use of its positive effects on the distribution grid as well as connected ones.	Methodology	5.4	6
TDX ASSIST	Slovenian demonstrator proved that CIM CGMES standards can be used to **exchange data related to long-term network planning** between TSO and DSO.	Methodology	4.1	6
TDX ASSIST	**Evaluating network analysis tools** within Portuguese demonstration activities related to improving the fault location and operational planning coordination. Within this demo, the observability area concept was introduced	Software	4.1	6
TDX ASSIST	Slovenian demonstrator proved that ECCo SP can be used as **efficient and interoperable platform for data exchange** between TSO and DSO in near real-time as well as for static information. Results related to the usage of ECCo SP including measured latency are given in D4.1.	Methodology	6.5	6
TDX ASSIST	The **designed data exchange cloud platform** in WP3 proves scalable, reliable, and secure operation for the data and information exchange regarding the RES and smart metering data	Database	3.2	6

Project	Key Exploitable Result	Nature	Research Topics	Target TRL
TDX ASSIST	Slovenian demonstrator proved that **IoT communication protocol AMQP** can be utilised for the information exchange via ECCo SP platform in near real-time, enabling automation of business processes regarding the balancing market.	Methodology	3.3	5
TRINITY	TRINITY will deliver a **framework to enhance cross-border cooperation** and ensure electricity market integration in SEE.	Policy, Regulation, Market	2.2	8
TRINITY	This platform will serve **to enhance RCC-TSOs cooperation**. The platform will exploit the know-how and lesson learnt by more mature TSOs and regions in Europe – i.e. RTE in France – when structuring cross-border operations.	Software	2.2	8
X-FLEX	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	Software	3.3	8
X-FLEX	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	Software	5.1	8
X-FLEX	This 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.	Software	6.1	8

Project	Key Exploitable Result	Nature	Research Topics	Target TRL
uGRIP	Development of **control strategies that optimise the grid performance on various levels**. Flexibility in generation, storage and consumption is increased because of the introduction of higher degrees of freedom in the system. Namely, advanced control strategies, i.e. Model Predictive Control, enables greater integration of distributed and renewable energy sources.	Methodology	5.2	2
uGRIP	**Improved control strategies are meant to reduce energy consumption**. Controllers implemented in controllable loads act in accordance with price signals and technical constraints of the grid. This reduces energy consumption and energy is used only when is really needed. Because of the optimised behaviour of controllable generators and loads, grid losses are also reduced which is also a way of reducing overall energy consumption.	Methodology	5.1	2
uGRIP	A **structure of the local, distribution-level market is defined and demonstrated** within the project. The complex interactions between the microgrid, distribution network, transmission network, wholesale electricity market and local distribution level market are investigated, and a viable operation mechanism will be proposed.	Policy, Regulation, Market	2.2	2

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