European Commission

ETIP SNET

R&I Implementation Plan 2022-2025

ETIP SNET

European Technology and Innovation Platform

Smart Networks for Energy Transition

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CONTENTS

INDEX OF FIGURES

INDEX OF TABLES

1. EXECUTIVE SUMMARY

1.1 Context

By 2050, the extensive electrification in (nearly) all sectors of the energy system, combined with large energy efficiency improvements and CO_2 reductions in all sectors, will lead to a carbon-neutral energy system. It is widely understood that this will rely on:

- The massive use of renewables for electricity and heating & cooling generation;
- Smart Grids technologies (Digitalisation and Smart control of flexible generation and demand, sustainable buildings);
- The combination of the above with sector coupling of all energy carriers via storage (such as batteries, by use of liquids (e.g. hydro pumping), CO_2-neutral or CO_2-free gases) and conversion technologies (for extensive use of carbon neutral gases and green fuels and possibly hydrogen in industry, transport and buildings);
- A widely adopted circular approach of the energy systems, with high recycling rates.

The EU "Green Deal" and related European national requirements set precise targets by 2030 in terms of:

- Decarbonisation of building stock, transport, industry, and energy systems;
- Involvement of consumers and citizen communities in energy systems;
- Digitalisation as an enabler of the environmental transition and participative energy markets;
- Reliability, adaptability and resilience of the integrated energy systems.

In order to show the view of the more than 350 ETIP SNET (European Technology & Innovation Platforms for Smart Networks for Energy Transition) Stakeholders, the ETIP SNET published and updated three types of documents:

- **ETIP SNET VISION 2050** (published 2018) provides a detailed description of this future with a set of goals to reach by 2050.
- The **ETIP SNET R&I Roadmap 2020-2030** describes the 10-year path towards this future. The Roadmap will be updated by the end of 2022.
- The ETIP SNET publishes this **ETIP SNET R&I Implementation Plan 2022-2025** in order to show the details of the most urgent R&I needs for these next four years 2022-2025.

These paths are not linear for each energy system and integration goal defined for 2050. Some of the tasks and associated R&I projects will need to be deployed and implemented before others (prerequisites). Others still, will only need to be prepared or demonstrated later, towards 2030, so that their deployment can be done between 2030 and 2040, for sure before 2050.

In order to meet the EU "Green Deal" and related European national requirements targets listed above, the current R&I Roadmap 2020-2030 translates these requirements into 5 fundamental elements of an integrated energy system - called hereafter **BUILDING BLOCKS**[1]

- **Building Block 1** - Efficient Organisation of Energy Systems;
- **Building Block 2** - Markets as the key enablers of the energy transition;
- **Building Block 3** - Digitalisation enabling new services for integrated energy systems;
- **Building Block 4** - Infrastructure for integrated energy systems;
- **Building Block 5** - Efficient energy use.

In the previous ETIP SNET Roadmap 2020-2030, these 5 building blocks have been broken down into 12 Functionalities which were understood as features of the European Energy system of the year 2030 to be demonstrated and to be realised by concrete R&I projects.

In order to improve the understanding, ***Functionalities have been replaced by the following 9 "High Level Use Cases" (HLUCs).*** The HLUCs – each valid for the next 10 years (until 2031) - are used to structure in this ETIP SNET R&I Implementation Plan 2022-2025 the needed R&I Priority Project Concepts (PPCs).

[1] The five ETIP SNET VISION 2050 BUILDING BLOCKS are described in Chapter I of the ETIP SNET Roadmap 2020-2030.

1.2 Synthesis of R&I High-Level Use Cases with associated budgets for the period 2022-2025

Applying a top-down stakeholder approach combined with a bottom-up analysis of the current EC Horizon Europe budgets yields:

> **R&I Budget Requirements:** For the period 2022-2025, the proposed PPCs (Priority Project Priority Concepts) realising parts of the nine HLUCs (High-Level Use Cases) require together an estimated budget of approx. **1000 M€.**

The budgets for this IP-Period 2022-2025 have been defined by the ETIP SNET stakeholders in a consultative process: they were asked about the budgets on a European level for each of the proposed PPCs. In addition, the ETIP SNET has analysed the budgets proposed by the European Commission in their first work program for Horizon Europe and its Clusters 4 and 5. The combination of both yields robust budgets proposed by the ETIP SNET for the IP-Period 2022-2025.

The following table 1 shows how the expected total budget of 1000 M€ for the period 2022-2025 is allocated among the proposed HLUCs (High Level Use Cases) with their associated PPCs (Priority Project Priority Concepts).

Table 1: The ETIP SNET R&I Implementation Plan - Period 2022-2025 with expected budgets for each HLUC

	HLUC (with specific PPCs during 2022-2025)	Total Budget 1000 M€
	**HLUC 1: Optimal Cross sector Integration and Grid Scale Storage**	130M€
	**HLUC 2: Market-driven TSO–DSO–System User Interactions**	90M€
	**HLUC 3: Pan European Wholesale Markets, Regional and Local Markets**	80M€
	**HLUC 4: Massive Penetration of RES into the transmission and distribution grid**	145M€
	**HLUC 5: One stop shop and Digital Technologies for market participation of consumers (citizens) at the center**	120M€
	**HLUC 6: Secure operation of widespread use of power electronics at all systems levels**	100M€
	**HLUC 7: Enhance System Supervision and Control including Cyber Security**	135M€
	**HLUC 8: Transportation Integration & Storage**	100M€
	**HLUC 9: Flexibility provision by Building, Districts and Industrial Processes**	100M€

A short description of these 9 HLUCs is given in this document. More information will be given in the 10-year context of the next ETIP SNET R&I Roadmap 2022-2031, to be released by the end of the year 2022.

The concept of HLUCs and the associated Priority Project Concepts (PPCs) were selected to communicate to the key audiences of this ETIP SNET R&I Implementation Plan, i.e. the European Commission, the national governments, the associations and the R&I community at Institutes of Technologies, Universities, Research Centres and Labs, etc. By using and defining HLUCs, the ETIP SNET intends to underline the urgency of realising the transformation of today's energy system through concrete R&I projects into the needed (partially) renewable energy system of 2031 and the fully CO_2-neutral energy system of 2050 as the ultimate goal. This is strongly connected with concrete outcomes and scopes for real-world demonstrations.

The R&I Priority Projects Concepts (PPCs) for each of HLUC should cover all integration features of the Future Energy Systems with concrete goals and time schedule.

Each PPC serves as input not only to "Horizon Europe" for work programs and co-funded projects at European level, but also to the transnational, national and regional projects (and preceding national roadmaps, R&I Implementation Plans, work programmes and calls) among and within European countries.

As an overview, the following table contains the PPCs during this IP Period 2022-2025. More details and also PPCs, to be revised and implemented in future IP Periods until 2031, are given in Section 4.

In the following, the numbering of PPCs x.y follows the principle that "x" refers to the HLUC x and y is a consecutive numbering among the PPCs of HLUC x. Further PPCs such as PPCs 1.4 - 1.7 (see chapter 3.2 for complete list of PPCs beyond this IP Period 2022-2025) indicate that these PPCs are proposed by the ETIP SNET to be started in a later IP period (at the earliest 2024) during the 10 years 2022-2031.

Table 2: List of Priority Project Concepts (PPCs) 2022-2025

HLUC 1: Optimal Cross Sector Integration and Grid Scale Storage (PPC 2022-2025)
PPC 1.1: Value of cross sector integration and storage
PPC 1.2: Control and operation tools for multi-energy systems
PPC 1.3 Smart asset management
HLUC 2: Market-driven TSO–DSO– System User Interactions (PPC 2022-2025)
PPC 2.1: Market models and architecture for TSO-DSO-System User interactions
PPC 2.2: Control and operation for enhanced TSO-DSO- System User interactions
PPC 2.3: Platform development for TSO-DSO cooperation
PPC 2.4: Planning tools for TSO-DSO cooperation
HLUC 3: Pan European Wholesale Markets, Regional and Local Markets (PPC 2022-2025)
PPC 3.1: Fundamental market design
PPC 3.2: Regulatory framework and strategic investments
PPC 3.3: IT systems for cross-border trading
HLUC 4: Massive Penetration of RES into the Transmission and Distribution Grid (PPC 2022-2025)
PPC 4.1: Technical barriers and technical measures for integration of RES at multiple levels and sectors
PPC 4.2: Control and operation tools for a RES based energy system
PPC 4.3: Infrastructure requirements and network technologies as solutions for integration of massive RES
PPC 4.4: Planning for a resilient system with massive penetration of RES

HLUC 5: One Stop Shop and Digital Technologies for Market Participation of Consumers (Citizens) at the Center (PPC 2022-2025)
PPC 5.1: Value of consumer/customer acceptance and engagement
PPC 5.2: Plug and play devices and IoT (Internet-of-things) including security by design
PPC 5.3: Utilisation of communication networks including cyber security
PPC 5.4: Cross-sectorial flexibility use cases
HLUC 6: Secure Operation of Widespread Use of Power Electronics at all System Levels (PPC 2022-2025)
PPC 6.1: Control solutions for next generation PV and battery inverters
PPC 6.2: Hybrid transmission/distribution and hybrid distribution AC/DC grids
PPC 6.3: Next generation distribution substation
PPC 6.4: Simulation methods and digital twins at distribution and transmission level for power electronics driven networks
HLUC 7: Enhance System Supervision and Control including Cyber Security (PPC 2022-2025)
PPC 7.1: Next generation of TSO control room
PPC 7.2: Next generation of DMS (Distribution Management Systems)
PPC 7.3: Next generation of measurements and GIS (Geographical Information System) for distribution grids
PPC 7.4: Wide Area monitoring, control and protections
HLUC 8: Transportation Integration & Storage (PPC 2022-2025)
PPC 8.1: Technical and economic implication of decarbonisation of transport sector
PPC 8.2: Enhancing effectiveness of energy system operation and resilience with electromobility
HLUC 9: Flexibility Provision by Building, Districts and Industrial Processes (PPC 2022-2025)
PPC 9.1: Value assessment of the integration of buildings, infrastructure and smart communities in a RES based energy system
PPC 9.2: Control and operation tools for the integration of buildings and smart communities
PPC 9.3: Planning for resilient integration of buildings and infrastructures in an integrated energy system

Details related to desired Outcomes, Scope and associated Research TASKS for each of these PPCs are given in Section 4 of this document. Note that only PPCs related to the IP Period 2022-2025 are included in the work programs of the time period 2022-2025. The next ETIP SNET IP (2024-2027) will provide details for those PPCs to be realised during 2024-2027.

The new term of project-concept oriented HLUC complements the previous concept of “Research Areas”, which are divided in Research Topics, each with a defined number of Research Tasks. A detailed description of Research Areas, Research Topics and Research Tasks can be found in Annex I.

This ETIP SNET R&I Implementation Plan 2022-2025 describes for each PPC to be implemented during this period:

- Type of PPC Action
- PPC Start/End Year
- Indicative PPC Budget
- Expected PPC Outcome
- Scope of PPC
- Research Tasks associated to PPC with short descriptions.

2. POLICY DRIVERS FOR THE ENERGY TRANSITION

With the **European "Green Deal"** released in December 2019, the European Union has taken another considerable step towards the ambition of a climate neutral Europe by 2050. Making it reality will require to achieve some key milestones in terms of:

- Decarbonisation of building stock, transport, industry, and energy systems;
- Involvement of consumers and citizen communities in the energy systems;
- Digitalisation as an enabler of the environmental transition and of participative energy markets;
- Reductions in transport emissions;
- Increased reliability, adaptability and resilience of the integrated energy systems.

On July 14, 2021, the European Commission presented the **"Fit for 55" package** and published 12 proposals to shape EU policies in the areas of climate, energy, land use, transport and taxation in such a way that net greenhouse gas emissions of up to 2030 will be reduced by at least 55 percent compared to 1990 levels. With the submitted plan, the EU Commission is taking a decisive step closer to its goals - **Europe as the first climate-neutral continent in the world by 2050 and the implementation of the European "Green Deal"**. The "Fit for 55" package contains the necessary legal instruments for the realisation of the goals agreed in the European Climate Law and a fundamental reorientation of the economy and society in order to guarantee a fair, "green" and prosperous future.

The ETIP SNET describes here those parts with strong impact on its own scope, mainly related to the **transformation of the electricity system and the changing integration with the other energy carriers and sectors** from now via 2030 towards 2050 when the whole energy system is to be CO_2-neutral.

The energy efficiency directive provides for a binding annual target for reducing energy consumption in the EU. The aim is to **increase the national contributions and to double the energy-saving obligations of the EU member states**. Among other things, the public sector is to renovate 3 percent of its building stock every year, thereby creating new jobs and reducing energy consumption and costs for taxpayers.

In order to counteract CO_2 emissions in road traffic, **all new vehicles registered should be emission-free from 2035**. The CO_2 emission standards for passenger cars and light commercial vehicles intend to accelerate the transition to emission-free mobility, since the average annual emissions of new vehicles must be 55 percent lower from 2030 and 100 percent lower from 2035 than in 2021. Regulation on infrastructure for alternative fuels ensures a reliable and EU-wide network of tank and charging stations for emission-free vehicles. The EU member states are to promote the expansion of charging and refuelling capacities - charging stations for electric vehicles every 60 kilometres and options for refuelling with hydrogen every 150 kilometres.

According to the EU Commission's proposal, **planes and ships in large ports and airports must have access to clean electricity in the future**. As part of the "ReFuelEU Aviation" and "FuelEU Maritime" initiatives, sustainable aviation and marine fuels are to be promoted and an upper limit for the energy consumption of ships calling at European ports is to be set.

The **revised Energy Taxation Directive** aims to reduce the negative effects of energy tax competition; this should help the EU member states to generate income from green electricity. This could promote clean technologies and remove obsolete tax exemptions and reduced tax rates that currently promote the use of fossil fuels.

Clear targets are set for the time horizon 2030, that will require the involvement of all stakeholders of the energy system (end-users; electricity, gas, heat and cooling providers; other market participants; grid operators; governments and regulators). Reaching those targets is not only a matter of changes in technologies and infrastructures, but also in laws and governance processes, and their implementation by regulators at EU and national levels.

The energy system key indicators by 2030 are synthesised below:

- Greenhouse gas emissions are reduced by **55% compared to 1990**; and renewable energy reaches **at least 40% of gross final energy consumption**;
- **Electricity becomes the dominant energy carrier** and its shares in the final energy demand grow steadily from 22% in 2015 to 29% in 2030; the share of renewables in gross electricity generation reaches 57% in 2030;
- **The flexibility of energy systems is increased** (both demand side and generation), **including all forms of storage** (such as thermal, batteries (CO_2-neutral or free), gases, liquids, etc) so that the needed system services for the present, but also upcoming system state (with more RES, more flexible demand, more storage and flexibility markets) can be provided;
- **The share of transport electricity use** (except from trains, tramways) **in total electricity consumption is still limited in 2030**, however, simultaneous charging of EVs may lead to operational challenges, power quality and power system stability issues for electricity distribution grids (temporal overloads and too low voltages); Although investments are necessary to prepare networks for the increasing use of electricity, smart charging provides a complementary solution for such operational challenges;
- **Residential electricity use accounts for 30% of total electricity end use**: this implies an increase in use of electricity for heating and cooling (via heat pumps) considering – by 2030 – only a minor efficiency improvement due to the slow renovation rate of buildings and their insulation;
- **Industrial electricity uses shift towards carbon neutral heat supply**. Electrification, hydrogen or use of green fuels will depend on the heat demand profiles and temperature needs. Electrification is one option;
- **Tertiary sector (services) electricity uses reach up to 25% of total electricity end use** with strong energy efficiency improvements;
- **Household consumers (citizens) become "active consumers"** thanks to new regulations and governance processes facilitating self-consumption, sustainable bioenergy, and Citizen Energy Communities;
- **Distributed renewable energy sources** are stimulated and integrated to buildings and the local environment;
- **The share of nuclear energy in gross inland consumption** (14% in 2015) remains stable;
- **The share of natural gas** (**excluding non-energy uses**) remains stable at approx. 20%.

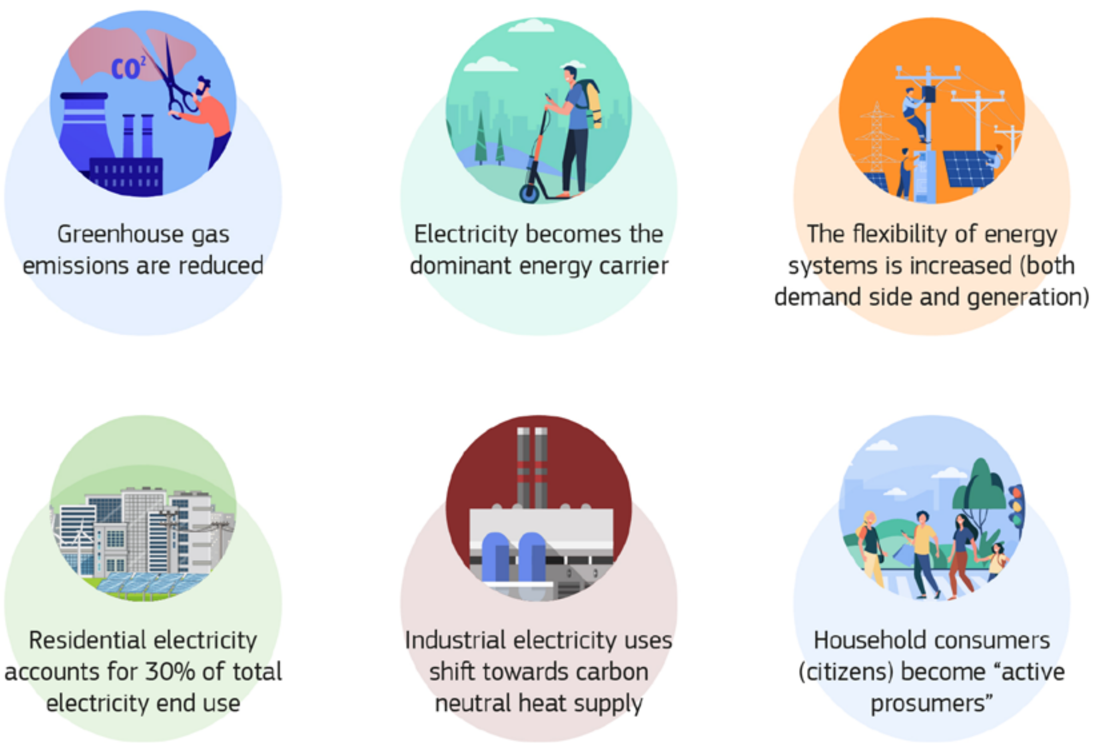

Figure 1: Key indicators for Europe to be achieved by 2030

2.1 Defining R&I needs for the Energy System Transition

This ETIP SNET R&I Implementation Plan 2022-2025 details the Research and Demonstration activities that must be performed in priority. It will be followed by three further ETIP SNET R&I Implementation plans in order to cover all the time periods until 2031.

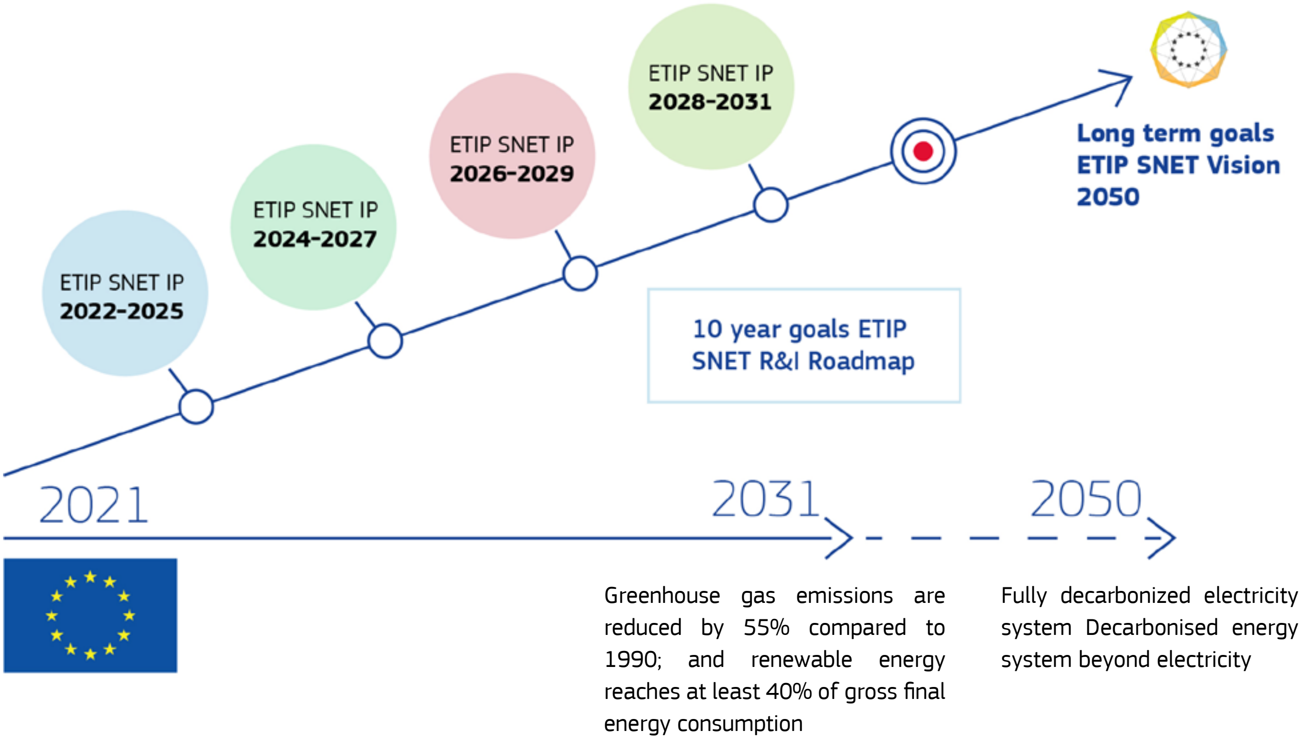

Figure 2: The ETIP SNET key steps from today via the year 2030 towards the achievement of 2050 goals

In this R&I Implementation Plan, the ETIP SNET puts emphasis on the fact that some projects with defined outcomes and goals need to be done before others (as prerequisites), while some others only need to be prepared or demonstrated by 2030, so that their deployment can be done between 2030 and 2040 or later.

The ETIP SNET R&I Implementation Plan 2022-2025 therefore describes the required R&I efforts to be achieved by 2024 by two principals: On one side, it reuses concepts defined in the previous Vision, R&I Roadmaps and R&I Implementation plans, such as Research Areas, Research TOPICS and **Research TASKS** so that researchers are orientated on how to organise the research for the proposed TASKS. On the other side, it is based on the key concept of **High-Level Use Cases (HLUCs)** with associated sets of **Priority Project Concepts (PPCs)** to specify more precisely the practical, including demonstration-related outcome of R&I projects as a whole.

As a consequence, the proposed PPCs serve as a conceptual basis for the (co-funded) R&I projects to be launched in the coming four years. By associating in this R&I Implementation Plan the Research TASKS associated with each PPC, future R&I projects will be able to consider both the practical demonstration aspects through defined outcomes and the fundamental and applied research needed as defined in the TASKS.

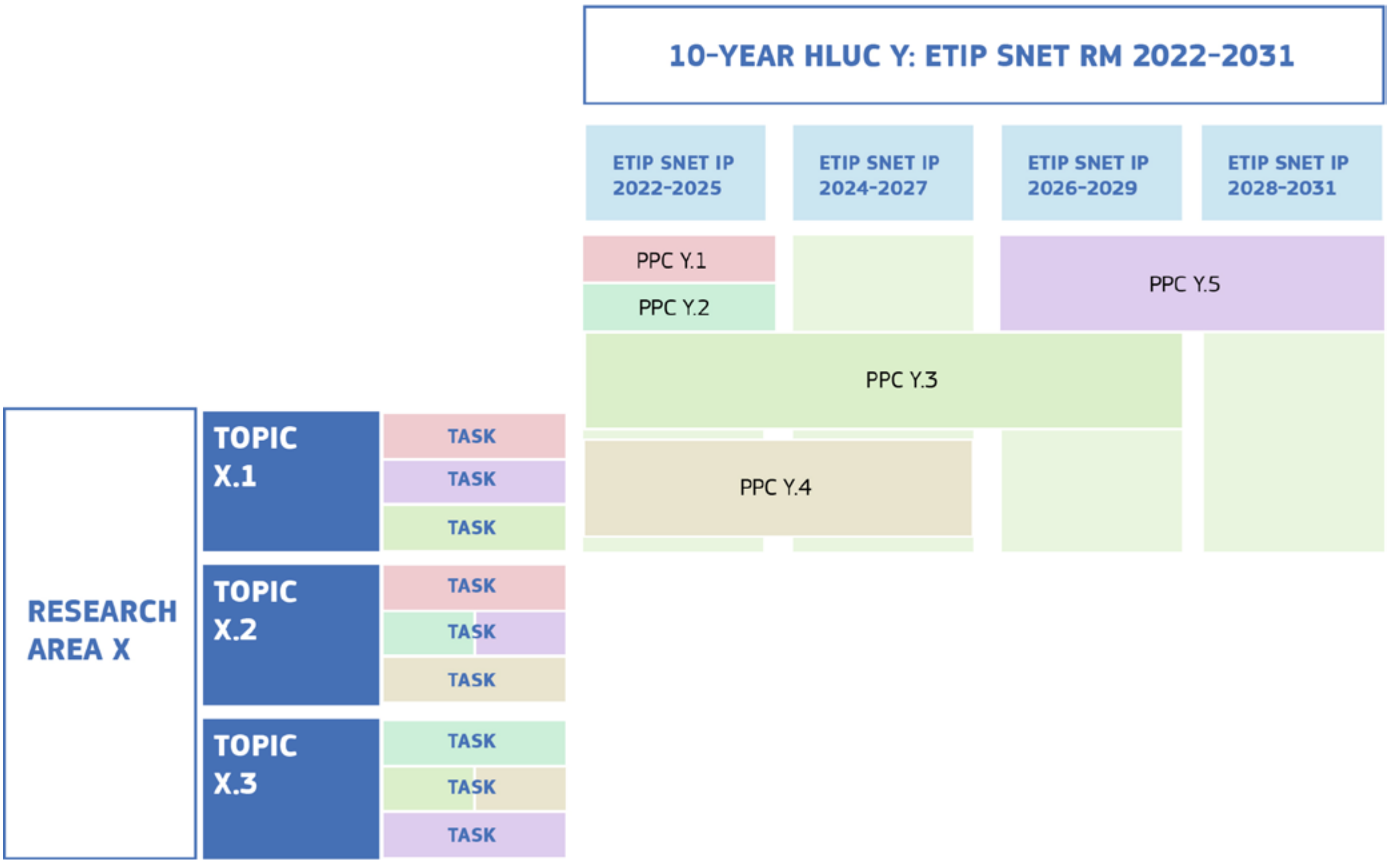

Figure 3: The conceptual link between Research Areas, Research Sub-Areas or TOPICS and PPCs with HLUCs.

2.2 From R&I needs to R&I Project implementation needs: Diversity in European landscapes requires implementation from local to transnational levels

The PPCs and their associated Research Tasks detailed in the next sections and in the Annex I should serve as inputs not only to "Horizon Europe" for work programs and calls for co-funded projects at European level, but also to the transnational, national and regional funding programs (with national roadmaps, R&I Implementation Plans, work programmes and calls) with their R&I projects among and within European countries.

Each PPC begins in a certain R&I Implementation Plan period, and it may need more than one IP (four year) period until it reaches its desired outcomes. On the other side (y-axis in the previous figure), it has a defined set of associated Research TASKS. The ETIP SNET recognises that in order to reach deployment[2], research and above all demonstrations of these tasks are needed not only locally, but also at country, cross-country and pan-European level. It is well recognised that some of the tasks are local and national:

- due to fundamentally different characteristics of weather (temperature, clouds, sunshine, wind, rain, etc.) during each day and seasons of the year;
- due to different energy potentials;
- due to different consumer and prosumer mixes and needs, etc.

As a consequence, different aspects of tasks need to be researched and demonstrated in different types of environments, such as large, medium and small size cities, communities, rural areas, mountain-areas, islands, etc. Some of the tasks can be demonstrated in cross-border, regional or even pan-European R&I projects such as:

- the (EU-) internal electricity market;
- harmonisation and standardisation of the IT;
- flexibility markets;
- sector coupling initiatives;
- industrial applications.

Challenges, such as balancing of variable RES, differ from one environment (e.g. north of Europe with more off-shore wind capacity) to another (e.g. south of Europe with higher PV yield). Across all solutions, however, are principles such as interoperability, Grid-Operator cooperation, system flexibility solutions, smart charging, hierarchical control etc, that urgently require common solutions and knowledge sharing across Europe.

These aspects need also to be balanced when selecting and funding R&I projects in the years to come.

[2] Deployment and Innovation are meant in the same way in the ETIP SNET R&I Roadmap 2020-2030. It is the phase after Research and after Demonstration.

2.3 Collaborative process to build the ETIP SNET R&I Implementation Plan 2022-2025

The ETIP SNET, European Technology & Innovation Platform (ETIP) for Smart Networks for Energy Transition (SNET), has a long tradition to consolidate the views of all stakeholders of the energy sector in view of guiding the Research, Development & Innovation activities required to support Europe's energy transition. It is strongly motivated by the European Commission.

The elaboration of this document has been coordinated by the ETIP SNET Core team (ICCS/NTUA, BACHER, ZABALA, with the support of Guidehouse) in close cooperation with the ETIP SNET energy system stakeholders: Experts, EU associations, the ETIP SNET technical Working Groups (WG1, WG2, WG3, WG4, WG5), BRIDGE initiative leaders and the SET Plan IWG4, Member States representatives, through several consultation rounds in the years 2020 and 2021. The ETIP SNET Governing Board (GB) has been regularly informed about the progress made and validated the new structure adopted.

In 2018, the ETIP SNET published its **VISION 2050** describing a shared view of the energy sector on the requested features of the future European energy system to meet the above-mentioned ambitions.

This vision relies on the key assumption that the extensive electrification in (nearly) all sectors of the energy system, combined with large energy efficiency improvements and CO_2 reductions in all sectors, will allow to reach a carbon-neutral energy system by 2050. It also assumes:

- The massive deployment of renewables for electricity and heating & cooling generation;
- The deployment of Smart Grids technologies (Digitalisation and Smart control of flexible generation, demand and electricity-releasing storage, sustainable buildings and mobility);
- The combination of the above with sector coupling of all energy carriers via multiple types and sizes of storage and conversion technologies (for extensive use of carbon neutral gases and green fuels and possibly hydrogen in industry, transport and buildings);
- A widely adopted circular approach of the energy systems, with high recycling rates.

The ETIP SNET VISION 2050 details specific goals and building blocks, constituting the ground for defining the specifications of further research and innovation activities required to meet the energy transition. In order to meet the EU "Green Deal" and related European national requirements targets listed above, the current R&I Roadmap 2020-2030 translates these requirements into 5 fundamental elements of an integrated energy system - called **BUILDING BLOCKS.**

- **Building Block 1 –** Efficient Organisation of Energy Systems;
- **Building Block 2** - Markets as key enablers of the energy transition;
- **Building Block 3** - Digitalisation enables new services for integrated energy systems;
- **Building Block 4** - Infrastructure for integrated energy systems;
- **Building Block 5** - Efficient energy use.

3. 10-YEAR R&I NEEDS

3.1 The concept of 10-year High-Level Use Cases (HLUCs) 2022-2031 and 4-year Priority Project Concepts (PPCs)

3.1.1 Explanations

In the ETIP SNET Roadmap 2020-2030, these five building blocks have been broken down into 12 Functionalities which are features of the European Energy system 2030 to be demonstrated and to be realised by concrete R&I projects before 2030. In order to improve comprehension, Functionalities have been replaced by **"High Level Use Cases"** (HLUCs) which are briefly described in this document and will be described in more details and in the 10-year context in the next ETIP SNET R&I Roadmap 2022-2031, to be released by the end of the year 2022.

The concept of HLUCs and the associated **Priority Project Concepts** (PPCs) were selected chosen to be communicated to the key audiences of this ETIP SNET R&I Implementation Plan, i.e. the European Commission, the national governments, the associations and the R&I community at Institutes of Technologies, Universities, Research Centres and Labs, etc. By using and defining HLUCs, the ETIP SNET intends to underline the urgency of realising the transformation of today's energy system through concrete R&I projects into the needed (partially) renewable energy system of 2031 and the fully CO_2-neutral energy system of 2050 as the ultimate goal. This is strongly connected with concrete outcomes and scopes for real-world demonstrations of the HLUCs with their PPCs.

The new definition of project-concept oriented HLUC complements the previous "Research Area" dimension, which is broken down into Research Topics, each with a defined number of Research Tasks.

The R&I Priority Projects Concepts (PPCs) for each of HLUC should cover all integration features of the Future Energy Systems with concrete goals and time schedule. Nine **HLUCs – each valid for the next 10 years (until 2031) - are used to structure** in this ETIP SNET R&I Implementation Plan 2022-2025 the **needed R&I Priority Project Concepts.**

3.1.2 High-Level Use Cases (HLUCs)

The following table describes the titles of the **9 High-Level Use Cases** (HLUCs).

	**HLUC 1: Optimal Cross sector Integration and Grid Scale Storage**
	**HLUC 2: Market-driven TSO–DSO–System User interactions**
	**HLUC 3: Pan European Wholesale Markets, Regional and Local Markets**
	**HLUC 4: Massive Penetration of RES into the transmission and distribution grid**

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

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

HLUC 7: Enhance System Supervision and Control including Cyber Security

HLUC 8: Transportation Integration & Storage

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

3.1.3 Priority Project Concepts (PPCs)

In this ETIP SNET R&I Implementation Plan 2022-2025, in order to describe R&I project families for the concrete realisation of each of the nine HLUCs, the ETIP SNET defines for each HLUC the needed **Priority Project Concepts (PPCs)**. PPCs can be understood as "families for R&I projects" for the next four years 2022-2025. Each PPC is associated to one of the 9 HLUCs.

The ETIP SNET does not intend to define the individual R&I projects for each PPC: This is left to the teams proposing R&I projects to the various funding bodies in Europe (currently mainly Horizon Europe) and in the European countries.

The ETIP SNET introduces with this R&I Implementation Plan the concept **of Priority Project Concepts (PPCs) for each HLUC. The PPCs** defined in this ETIP SNET R&I Implementation Plan 2022-2025 are thought to be reused and applied in the Electricity system and Energy System Integration related European and national R&I Work programs with their R&I project calls.

HLUCs, each with their own PPCs, represent the practical realisation-related dimension to achieve the integrated energy system needs of the year 2031. On the other side, RESEARCH AREAS with their TOPICs and TASKS represent the Researcher-related dimension. TASKS are associated to PPCs to indicate the Research pre-requisites in PPC.

The ETIP SNET recognises that in order to reach deployment, demonstrations within these PPCs are needed not only locally, but also at country, cross-country and pan-European level. It is well recognised that some of the PPCs may vary when being implemented at local or national levels due to varying implementations of European legal directives, different energy system transition stages from fossil to renewable, etc.

As a consequence, different aspects of PPCs need to be demonstrated in different types of environments, such as large, medium and small size cities, communities, rural areas, mountain-areas, islands, etc. Some of the PPCs can be cross-border, regional or even pan-European.

Each PPC serves as input not only to "Horizon Europe" for work programs and co-funded projects at European level, but also to the transnational, national and regional projects (and preceding national roadmaps, R&I Implementation Plans, work programmes and calls) among and within European countries.

This ETIP SNET R&I Implementation Plan 2022-2025 describes for each PPC to be implemented during this period:

- Type of PPC Action
- PPC Start/End Year
- Indicative PPC Budget
- Expected PPC Outcome
- Scope of PPC
- Research Tasks associated to PPC with short descriptions

3.1.4 Research Areas, Topics and Tasks contributing to PPCs

Six Research Areas have already been identified by the ETIP SNET in its previous R&I Roadmap and R&I Implementation Plans. These six Research Areas have been further divided in (currently) **24 TOPICs**, being further detailed by currently **90 Research TASKs** ("TASKS").

The slightly revised and updated Research Areas are synthesised in the next table together with the RESEARCH TOPICs. The list of TOPICS with their TASKS is given in Annex I.

Table 3: Research Areas (RA) and Research TOPICS (TOPICs)

Research Areas (RA)	TOPIC No.	RESEARCH TOPICS
1. CONSUMER, PROSUMER and CITIZEN ENERGY COMMUNITY	1.1	Social campaigns and social studies (related to societal acceptance and environmental sustainability of energy infrastructures)
	1.2	Adaptive consumer/user behaviour incl. energy communities (Interaction, incentives by dynamic tariffs)
2. SYSTEM ECONOMICS	2.1	Business models
	2.2	Centralised Markets
	2.3	Decentralised Markets and flexibility platforms
	2.4	Ancillary Services Markets
3. DIGITALISATION	3.1	Application of Data Analytics and Artificial Intelligence
	3.2	Telecommunications – Applications and Requirements
	3.3	Cybersecurity (vulnerabilities, failures, risks) and privacy
4. PLANNING & RESILIENCE – HOLISTIC ARCHITECTURES and ASSETS	4.1	Long Term Energy System Design (Macroscopic view, Energy models, e.g. PRIMES)
	4.2	Transmission System Planning including Resilience
	4.3	Distribution System Planning including Resilience– Integrated Transmission and Distribution Planning
	4.4	Asset management and maintenance
5. SYSTEM FLEXIBILITY	5.1	Demand flexibility (household and industry related)
	5.2	Generation flexibility (flexible thermal, RES (Hydro, PV and wind generators))
	5.3	Storage flexibility & Energy Conversion flexibility (PtX,XtP, X=G,L,H and Water)
	5.4	Network flexibility (FACTS, FACDS smart transformers and DC networks)
	5.5	Transport flexibility (V2G/EV; railway, trams, trolleybus)
6. SYSTEM OPERATION	6.1	Supervisory control and State estimation
	6.2	Short-term control (Primary, Voltage, Frequency)
	6.3	Medium and long-term control (Forecasting (Load, RES), secondary & tertiary control: LFC, operational planning
	6.4	System Stability analysis
	6.5	Preventive control/restoration (Contingencies, Topology (incl. Switching) optimisation, Protection, Resilience)
	6.6	Control Center technologies (EMS, platforms, Operator training, Coordination among Control Centres)

The complete list of Research TOPICS and their TASKS is described in Annex I.

Individual TASKS shall be part of PPCs in this ETIP SNET IP 2022-2025. This allows the linking of the Research TASK dimension to the Project (PPC) dimension.

For details, what concrete TASKS are to be researched primarily in what PPC, see the details descriptions of PPC in Section.

3.2 ROADMAP 2022-2031 (Overview 10-year ETIP SNET HLUCs and their PPCs)

Due to the new introduction of the HLUC and PPC concept without a preceding 10-year ETIP SNET roadmap, this section provides a short description of the High-Level Use Cases (HLUCs) as well a short description of the Priority Project Concept (PPC) to be implemented within the next 10 years under each HLUC.

This section will be moved to the upcoming (Dec. 2022) ETIP SNET Roadmap 2022-2031 including an update of the PPCs for the upcoming IP Periods beginning in the year 2024 and later.

The following list presents the PPCs to be implemented during the next 10 years. Only a subset of them (**bold**, for details see Section V) is to be implemented in this **ETIP SNET IP Period 2022-2025. This is indicated in the first column.** The other PPCs (such as PPCs 1.4, 1.5, etc.) are to be started in later ETIP SNET IP Periods, beginning in the year 2024.

HLUC 1: Optimal Cross sector Integration and Grid Scale Storage

IP 2022-2025	**PPC 1.1: Value of cross sector integration and storage**
IP 2022-2025	**PPC 1.2: Control and operation tools for multi-energy systems**
IP 2022-2025	**PPC 1.3: Smart asset management**
Later IP	PPC 1.4: Integrating hydrogen and CO_2-neutral gases
Later IP	PPC 1.5: Regulatory framework for cross sector integration
Later IP	PPC 1.6: Cross sector resilience
Later IP	PPC 1.7: Future cross-vector infrastructure design
Later IP	PPC 1.8: Validation/Demonstration

HLUC 2: Market-driven TSO–DSO–Prosumer Interactions

IP 2022-2025	**PPC 2.1: Market models and architecture for TSO-DSO-System User interactions**
IP 2022-2025	**PPC 2.2: Control and operation for enhanced TSO-DSO- System User interactions**
IP 2022-2025	**PPC 2.3: Platform development for TSO-DSO cooperation**
IP 2022-2025	**PPC 2.4: Planning tools for TSO-DSO cooperation**
Later IP	PPC 2.5: Viable business cases through market mechanisms and incentives
Later IP	PPC 2.6: Governance for TSO, DSO and System Users

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

IP 2022-2025	**PPC 3.1: Fundamental market design**
IP 2022-2025	**PPC 3.2: Regulatory framework and strategic investments**
IP 2022-2025	**PPC 3.3: IT systems for cross-border trading**
Later IP	PPC 3.4: Validation of new market concepts
Later IP	PPC 3.5: IT systems for TSO/DSO control to support real time balancing

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

IP 2022-2025	**PPC 4.1: Technical barriers and technical measures for integration of RES at multiple levels and sectors**
IP 2022-2025	**PPC 4.2: Control and operation tools for a RES based energy system**
IP 2022-2025	**PPC 4.3: Infrastructure requirements and network technologies as solutions for integration of massive RES**
IP 2022-2025	**PPC 4.4: Planning for a resilient system with massive penetration of RES**
Later IP	PPC 4.5: Well-functioning markets for a RES based energy system
Later IP	PPC 4.6: Policies and Regulation for a RES based energy system

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

IP 2022-2025	**PPC 5.1: Value of consumer/customer acceptance and engagement**
IP 2022-2025	**PPC 5.2: Plug and play devices and IoT (Internet-of-things) including security by design**
IP 2022-2025	**PPC 5.3: Utilisation of communication networks including cyber security**
IP 2022-2025	**PPC 5.4: Cross-sectorial flexibility use cases**
Later IP	PPC 5.5: Large Scale Demonstration activities
Later IP	PPC 5.6: Creating consensus on consumer solutions

HLUC 6: Secure Operation of Widespread use of Power Electronics at all System Levels

IP 2022-2025	**PPC 6.1: Control solutions for next generation PV and battery inverters**
IP 2022-2025	**PPC 6.2: Hybrid transmission/distribution and hybrid distribution AC/DC grids**
IP 2022-2025	**PPC 6.3: Next generation distribution substation**
IP 2022-2025	**PPC 6.4: Simulation methods and digital twins at distribution and transmission level for power electronics driven networks**
Later IP	PPC 6.5: HVDC interoperability, multi-terminal configurations, meshed grids
Later IP	PPC 6.6: Large scale demonstration activities
Later IP	PPC 6.7: Standardisation activities

HLUC 7: Enhance System Supervision and Control including Cyber Security

IP 2022-2025	**PPC 7.1: Next generation of TSO control room**
IP 2022-2025	**PPC 7.2: Next generation of DMS (Distribution Management Systems)**
IP 2022-2025	**PPC 7.3: Next generation of measurements and GIS (Geographic Information System) for distribution grids**
IP 2022-2025	**PPC 7.4: Wide Area monitoring, control and protections**
Later IP	PPC 7.5: Grid operator of the future
Later IP	PPC 7.6: Human machine interface (HMI)
Later IP	PPC 7.7: Large scale demonstration activities
Later IP	PPC 7.8: Standardisation activities

HLUC 8: Transportation Integration & Storage

IP 2022-2025	**PPC 8.1: Technical and economic implication of decarbonisation of transport sector**
IP 2022-2025	**PPC 8.2: Enhancing effectiveness of energy system operation and resilience with electromobility**
Later IP	PPC 8.3: Demonstration activities
Later IP	PPC 8.4: Policy and market for cost-effective integration of transport and energy sectors
Later IP	PPC 8.5: Interoperable planning of energy and transport sectors

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

IP 2022-2025	**PPC 9.1: Value assessment of the integration of buildings, infrastructure and smart communities in a RES based energy system**
IP 2022-2025	**PPC 9.2: Control and operation tools for the integration of buildings and smart communities**
IP 2022-2025	**PPC 9.3: Planning for resilient integration of buildings and infrastructures in an integrated energy system**
Later IP	PPC 9.4: Well-functioning markets for integrating buildings and community facilities in the energy transition
Later IP	PPC 9.5: Governance for an effective integration of buildings and smart communities

In the following sections, each of the nine HLUCs is briefly described, together with related "ongoing indicative R&I projects" and the scope description of each associated PPC to be done during the 10-year period 2022-2031.

HLUC 1: Optimal Cross sector Integration and Grid Scale Storage

The traditional energy system silos for electricity generation and end-use, for gas transport, for heating & cooling needs and for mobility / transport must be coupled and optimised as one overall, Integrated Energy System considering P2X, X2P and large-scale energy storage technologies in order to achieve the carbon targets at lowest costs. The coupling of such complex systems needs new services based on higher degrees of automated management and control of flexible energy network resources including the conversion between them. Decarbonisation of industrial sector, transport and end use energy demand at the building level, shall be supported by smart coordinated control of the interaction between energy sectors.

PPC 1.1: Value of cross sector integration and storage (IP 2022-2025, Project Start 2022-End 2027[3])

Scope of PPC: Role and value of cross sector Integration and energy storage under different future decarbonisation pathways, assessing the impact on operation and planning of energy infrastructure costs. Assessment of cost and benefits of local versus national and international approach to cross-sector integration. Role of large-scale energy storage (electricity, thermal, synthetic liquids, hydrogen, etc) in supporting cost effective decarbonisation.

Assessment of the benefits of providing system flexibility services by optimal cross-sector integration.

PPC 1.2: Control and operation tools for multi-energy systems (IP 2022-2025, Project Start 2022-End 2027)

Scope of PPC: Development and demonstration of advanced technologies and control concepts /platform tools for multi-energy systems based on appropriate data exchange between different energy sectors in local, national and international regions.

PPC 1.3: Smart asset management (IP 2022-2025, Project Start 2022-End 2027)

Scope of PPC: Advanced management of assets in the energy system along their entire lifecycle, deployment of IoT sensors, communication, data management & analysis and feedback to control systems

PPC 1.4: Integrating hydrogen and CO_2-neutral gases (IP 2024-2027)

Scope of PPC: Development and demonstration sectoral integration of hydrogen and CO_2-neutral gases with electricity system and renewables

[3] In the bracket (.), the first part refers to the IP where the PPC belongs to and – if the PPC is to be done in the period 2022-2025 -. the second part refers to the starting and latest ending year of the projects to be done within the PPC.

PPC 1.5: Regulatory framework for cross sector integration (IP 2024-2027)

Scope of PPC: Design of new market and regulatory frameworks that would provide business cases for cross-sector coupling in low carbon energy future, considering local, regional and international areas.

PPC 1.6: Cross sector resilience (IP 2026-2029)

Scope of PPC: Enhancing Security & Resilience of the energy system through optimal cross sector Integration and long duration energy storage. Enhancing resilience of interconnected regions in EU.

PPC 1.7: Future cross-vector infrastructure design (IP 2026-2029)

Scope of PPC: Development of the new design standards that would enable cross-sector integration and energy storage to be compared with traditional energy infrastructure design approach.

PPC 1.8: Validation/Demonstration (IP 2026-2029)

Scope of PPC: Large scale demonstration projects focused on coordinated operation of cross-sector coupled energy systems, while managing synergies and conflicts between local and national level objectives

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

The recent clean energy legislation requires that system operators must cooperate in planning and operating their networks. This requirement originates from different angles. On one side, there are efficiency gains in planning if information is shared, thus avoiding unnecessary investments or complexities. On the other side, both efficiency gains and increased reliability (risk reduction) can be achieved in the operation process. This cooperation aims in particular at exchange of coordinated balancing and congestion handling services (coming from DER, conventional Power Plants or controlled loads located in their grids). Additionally, sharing of forecasting information benefits a more efficient and secure energy system. System Operators need to reinforce competitive energy markets.

Furthermore, the recent policies and legislation stress the need to involve the consumer (individual, community or organisation) in the energy system, making the prosumer-related processes central in the energy system design and operation. This requires the development of adequate mechanisms for the prosumer to interact with the system operators, to contribute to the energy system operation and to participate in the energy markets. An appropriate design shall achieve both a valuable outcome for the prosumer (either financially, convenience or other) and for the operators, benefiting the energy system as a whole. Innovative tools and solutions shall be developed and tested in order to enable user-friendly interactions (e.g., use of Social Sciences and Humanities (SSH) approaches) among and between prosumers and system operators.

PPC 2.1: Market models and architecture for TSO-DSO-System User interactions (IP 2022-2025, Project Start 2022-End 2027)

Scope of PPC: Definition of suitable market models for the interaction of TSOs and DSOs including interactions between central and local markets and across different time frames. Identification of technical, market and business barriers to the smooth cooperation and interaction between TSOs, DSO and prosumers. Provide evidence related to the benefits of market-driven options and solutions. These cooperations and interactions shall be market-driven and applicable in heterogeneous geographical, social and economic conditions. Planning and operational coordination, and flexibility mechanisms shall be primarily market-based, with appropriate market signals and incentives. Design, development and test of adequate incentives shall be performed to maximise the welfare of the energy transition. The operational and planning arrangements between TSOs and DSOs need to be revised and developed further in order to support a market framework that unlocks the potential of prosumers. Resources should be able to value their potential in the most efficient way.

PPC 2.2: Control and operation for enhanced TSO-DSO-System User interactions (IP 2022-2025, Project Start 2022-End 2029)

Scope of PPC: Design, development and demonstration of effective control mechanisms and technologies for prosumers participation in the market. Optimisation of the operation of the energy system and the provision of Ancillary Services from distributed resources, ensuring resilience contributions from DER. Development and improvement of digital technologies to support customers and distributed energy resources to participate in the operation and market. Use of advanced analytics and big data management for decision-making.

Real time balancing and management of flexibility.

PPC 2.3: Platform Development for TSO-DSO cooperation (IP 2022-2025, Project Start 2022-End 2029)

Scope of PPC: Design and development of platforms for an effective secure and governed information sharing, allowing access and cooperation from multiple energy system players and an efficient organisation of the energy system

PPC 2.4: Planning tools for TSO-DSO cooperation (IP 2022-2025, Project Start 2022-End 2031)

Scope of PPC: Optimise the planning of the energy system. Development of efficient long-term planning and corresponding tools and simulation capabilities, including local and global dimensions and allowing multiple prosumer typologies and aggregations.

PPC 2.5: Viable business cases through market mechanisms and incentives (IP 2026-2029)

Scope of PPC: Design, test and demonstrate market mechanisms and incentives for an open participation of (aggregated) prosumers (system users) and effective cooperation of system operators ensuring viable business cases and positive cost benefit analysis in a sector coupling context. Stimulate Demand Side participation, consumer involvement and Local Energy Communities. Planning and operational coordination, and flexibility mechanisms shall be primarily market-based, with appropriate market signals and incentives.

PPC 2.6: Governance for TSO, DSO and System Users (IP 2026-2029)

Scope of PPC: Enhancing the regulatory and administrative framework for an effective and efficient Energy System Governance. Develop and demonstrate enhanced and robust standards for cooperation and coordination among energy system players. Leverage the use of standards for data exchange of data. Definition of appropriate data models that can represent properly all the TSO-DSO-System User interactions.

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

There is a clear need to design a radically new multi-energy market that would include cross-energy sector coupling, covering all temporal scales (from seconds, minutes, hours, days, months and years) and spatial granularity (from local district to regional and international areas), which will be critical for cost effective transition to a low carbon energy future.

In this context, emerging flexibility technologies and advanced control systems in all energy sectors (electricity, heating and cooling, Gas, transport, hydrogen, etc), would deliver major cost savings, that the new market design needs to address, including:

- savings in system operating costs by the avoided curtailment of zero-carbon renewable generation and providing significantly more cost-efficient provision of the required balancing services across all energy sectors (energy trading and balancing services market)
- savings in capital expenses associated with reinforcing distribution, transmission network assets (both gas and electricity) driven by reduced peak demand levels and the cost-effective management of network constraints (market for network congestion management)
- savings in capital expenses associated with investments in conventional generation, driven by reduced peak demands and support by interconnection (capacity market)
- savings in capital expenses associated with investments in low-carbon generation while meeting the carbon targets, driven by the much more efficient utilisation of lower-cost variable renewable generation (low carbon generation market)

In this context the new legislation asks for enhanced roles of DSOs, particularly in procurement of ancillary services, flexibility, data management, effective integration of heat and transport sectors. Markets must encourage development of flexible technologies and control systems and Member States must eliminate obstacles to market-based pricing. Bidding zones must be reviewed by TSOs, and possible alternative concepts should be proposed. DSOs should align network access and congestion tariffs and charges. Member States should enable scarcity pricing, interconnection, DSR and storage to contribute to capacity market.

PPC 3.1: Fundamental market design (IP 2022-2025, Project Start 2022-End 2029)

Scope of PPC: Development of fundamentally new fully decentralised multi-energy market with appropriate temporal and special spatial granularity to facilitate cost effective transition to low carbon energy future, considering energy balancing, network congestion management services, EU wide capacity market, renewable power purchase agreement.

Development cost effective market mechanism for allocation of costs related to the provision of balancing services, network charging, investment in conventional and low carbon generation

Assessment of the need to coordinate market clearing process for balancing services covering different timescales (second, minutes, hours) while considering the conflicts and synergies between local district and national, international objectives.

In the context of EU wide market, develop appropriate market design that would enable optimal exchange of energy and balancing services by interconnectors.

Energy market design that would recognise option value of flexibility technologies dealing with uncertainties in future deployment of low carbon technologies in local, regional EU wide areas.

Market design that recognises uncertainties in the provision of alternative balancing / ancillary services by different technologies (establishing level-playing approach for the provision of services across different service delivery concepts /technologies).

PPC 3.2: Regulatory framework and strategic investments (IP 2022-2025, Project Start 2022-End 2029)

Scope of PPC: Development of fundamentally new concept for efficient allocation of cost related to the provision of all ancillary / balancing services, network congestion management, provision of security of supply and meeting carbon targets cost effectively.

Market design / regulatory framework for supporting cost effective delivery of security and resilience of supply from local to national / international level

Design of market / regulatory framework that would support strategic investment in energy infrastructure when/where appropriate (e.g. investments in reinforcement of electricity distribution network infrastructure in order to support cost effective and timely electrification of transport sector and DERs, strategic investment in offshore infrastructure to integrate offshore wind, etc).

PPC 3.3: IT systems for cross-border trading (IP 2022-2025, Project Start 2022-End 2029)

Scope of PPC: Demonstration of platforms /IT systems for market-based trading of energy, balancing services across interconnectors and supporting EU wide capacity market.

PPC 3.4: Validation of new market concepts (IP 2026-2029)

Scope of PPC: Development and demonstration of advanced technologies and control concepts /platform tools for

- supporting multi-energy systems market based on appropriate data exchange between different energy sectors in local, national and international regions
- supporting decentralised peer-to-peer trading, (enabling end consumers to trade energy and ancillary services in real time) while supporting market driven system control (e.g. congestion management) and assess the impact on end consumers services quality
- management of uncertainties in the provision of alternative balancing / ancillary services by different technologies (establishing a level-playing field for the provision of services across different service delivery concepts).

PPC 3.5: IT systems for TSO/DSO control to support real time balancing (IP 2026-2029)

Scope of PPC: Demonstration of platforms /IT systems for market driven coordination of trading of energy, balancing services and network congestion management

Demonstration of advanced platforms for coordination of trading of energy, balancing services and network congestion management

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

The EC has set ambitious targets for RES penetration in the European Energy System. This is a key element of both the EU Green Deal package and the Fit for 55 proposals. This includes both large, centralised RES installations at Transmission level and distributed RES at both Transmission and Distribution levels. The massive penetration of RES stresses challenges at multiple levels.

On one side, the operation with less natural inertia and with increased imbalances between generation and load, reinforcing the importance of improved forecast, where sophisticated analytics can play a key role. Still on the technical side, adequate protection mechanisms and control must be in place. Furthermore, adequate global monitoring systems need to be in place to anticipate and correct system stresses. On the other side, market dynamics and new market designs to ensure participation and to reduce risk for vulnerable consumers must be taken into account. Energy System resilience shall be assured in the context of a massive RES penetration, counting with the contribution of storage and flexibility solutions.

PPC 4.1: Technical barriers and technical measures for integration of RES at multiple levels and sectors (IP 2022-2025, Project Start 2022-End 2029)

Scope of PPC: Creating the conditions for the effective participation of industrial, residential actors and energy communities and for deploying corresponding grids leading to an increased share of RES in the energy system

PPC 4.2: Control and operation tools for a RES based energy system (IP 2022-2025, Project Start 2022-End 2027)

Scope of PPC: Design and test advanced technologies and control mechanisms for integrating massive volumes of RES at distribution and transmission level, handling network constraints and providing flexibility needs, ensuring coordination throughout energy sectors.

PPC 4.3: Infrastructure requirements and network technologies as solutions for integration of massive RES (IP 2022-2025, Project Start 2022-End 2029)

Scope of PPC: Ensure the integration of massive RES at multiple voltage levels through advanced networking solutions (e.g., HVDC, FACTS) and increasing flexibility capabilities from RES and grids

Ensure the efficient and reliable connection and integration of large RES generation (e.g., large offshore grids).

PPC 4.4: Planning for a resilient system with massive penetration of RES (IP 2022-2025, Project Start 2022-End 2031)

Scope of PPC: Enhance system resilience in the presence of increased RES penetration at all levels, via sophisticated forecast methods, models and techniques, simulation, restoration mechanisms, ensuring stability of the system and robustness to extreme events

PPC 4.5: Well-functioning markets for a RES based energy system (IP 2026-2029)

Scope of PPC: Ensure appropriate mechanisms for market participation from RES at multiple levels, from local to global scale, and from heterogeneous energy sectors, ensuring viable business cases and backed by supporting regulations

PPC 4.6: Policies and Regulation for a RES based energy system (IP 2026-2029)

Scope of PPC: Providing evidence for an informed design of policies and regulations and decision-making from different stakeholders, and for adequate analysis of market dynamics under massive penetration of RES

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

Consumers - also in the role of prosumers – and citizens have a critical proactive role to play to accelerate the adoptions of new energy services and technologies in their environment as well as for deciding the most suitable options for them to reach the decarbonisation objectives set through the high-level policies. The pace of consumer adoptions will significantly impact the design of Cross sectorial Energy System infrastructures with the acceleration of electrification – particularly to accommodate new heat pumps and electrical vehicle home charging as well as the introduction of new decarbonised heat network and Green Hydrogen in specific sectors. While local solutions may differ country by country, it is necessary that the differences are transparent to the consumers and citizens. IT solutions are needed that facilitate consumer/citizen inclusions and that are independent or abstract from the contingencies of a specific market.

Furthermore, it is necessary to integrate the energy system in the wider picture of the data economy so that consumer/citizen inclusion means also to facilitate use cases that go beyond energy and cross-link to completely new domains.

This HLUC will develop the necessary research and innovation to facilitate one stop shop consumer/citizen participation in the energy system and, correspondingly, inclusion of the energy system in the concept of data economy. This implies several aspects: standard interfaces, communication solutions and even better secure communication solutions.

PPC 5.1 Value of Consumer/Customer acceptance and engagement (IP 2022-2025, Project Start 2022-End 2027)

Scope of PPC: The scope of this PPC is the analysis of the platform requirements that will accelerate the adoption of new energy services and technologies. The access to data and energy services will allow the consumer/citizen to go beyond the electricity sector into a fully integrated energy system.

PPC 5.2: Plug and play devices and IoT (Internet of things) including security by design (IP 2022-2025, Project Start 2022-End 2027)

Scope of PPC: One of the obstacles for consumers to have a more active role in the energy system is the lack of solutions that really support plug and play. Purpose of this PPC is to remove this barrier and develop solutions that facilitate joining any kind of energy market across Europe.

PPC 5.3: Utilisation of Communication Networks including cyber security (IP 2022-2025, Project Start 2022-End 2029)

Scope of PPC: Smart solutions will use a variety of connection solutions. It is critical to facilitate connection while preserving security. This PPC will investigate how security by design can support use of communication networks, including private ones, in energy applications.

PPC 5.4: Cross-sectorial flexibility use cases (IP 2022-2025, Project Start 2022-End 2027)

Scope of PPC: Consumer/citizen are not used with the idea of flexibility, and it can be perceived as a restriction of the private way of living. It is important to redefine access to flexibility by means of use cases that do not target directly energy flexibility but bring flexibility as consequence. Examples can be given by the idea of selling comfort instead of heating, other ideas can emerge from other business sectors such as security or health.

PPC 5.5: Large Scale Demonstration activities (IP 2026-2029)

Scope of PPC: This PPC should take the results of the PPCs 5.1-5.3 and bring them to a new scale thanks to large demonstrators.

PPC 5.6: Creating consensus on consumer solutions (IP 2026-2029)

Scope of PPC: This PPC has the task to transfer the results of all the PPCs from innovation to real life by preparing the conditions for new standards in particular at the level of software API's but also in terms of service definitions (compatible with the results of the projects and the large demontrators).

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

Power electronics driven components are becoming a key asset for modern power grids but there is not yet an overarching concept of how these devices will shape system operation. The more the share of power electronics devices grows, the more there is a need to involve these devices with an active role. This is true at different levels for the grid. Projects considering the transmission system shall consider the evolution of HVDC towards multi-terminal multi-vendors meshed DC grids. These are appearing first of all for off-shore applications but are expected to spread also in on-shore solutions and to move from HV also to MV applications. In particular, the definition of the roles of grid-forming converters is still mostly at research level and a flexible transition between different modes of operation shall be further investigated, including how substations with traditional transformers can be enhanced by power-electronics and how the penetration of smart power routing devices such as FACTS and Solid-State Transformers can be handled.

PPC 6.1: Control solutions for next generation PV and battery inverters (IP 2022-2025, Project Start 2022-End 2029)

Scope of PPC: This PPC will develop control solutions for components such as PV and Battery inverters that can be considered grid friendly, i.e. able to provide a variety of services that can be used at system level. The goals is the facilitation of digitalised plug & play solutions.

PPC 6.2: Hybrid transmission/distribution and hybrid distribution AC/DC grids (IP 2022-2025, Project Start 2022-End 2029)

Scope of PPC: This PPC will develop the necessary control solution that support the development of hybrid AC/DC grids in HV and MV. Goal is not to focus on new topology but on the development of the proper concepts that support interoperability and cooperation between converters operating in the DC and in the AC section of the system.

PPC 6.3: Next generation distribution substation (IP 2022-2025, Project Start 2022-End 2029)

Scope of PPC: This PPC will explore all the possible integration of power electronics in the substation or close to the substation to develop the concept of a flexible and programmable power grid in which the substation is a center of intelligence that facilitate the optimal power routing while ensuring power grid resilience.

PPC 6.4: Simulation methods and digital twins at distribution and transmission level for power electronics driven networks (IP 2022-2025, Project start 2022-End 2029)

Scope of PPC: The growing presence of power electronics is radically modifying the dynamics of the power grids. This PPC will tackle the need of the new simulation tools that go beyond the classical separation between phasor simulation and electromagnetic transient analysis.

PPC 6.5: HVDC interoperability, multi-terminal configurations, meshed grids (IP 2024-2027)

As mentioned in the CIGRE Green Book, the goal of multi-terminal DC transmission systems is to keep the main advantages of point-to-point DC transmission network and maximise the utilisation of the assets. Multi-terminal configurations will improve the investment on assets and the environmental impact of the power system infrastructure. The goal of this PPC is the development of the necessary methodologies, tools and models for the analysis of the operation of such configurations.

PPC 6.6: Large Scale Demonstration activities (IP 2024-2027)

Scope of PPC: This PPC shall take the results of the PPCs 6.1-6.3 and bring them to a new scale thanks to large demonstrators.

PPC 6.7: Standardisation activities (IP 2024-2027)

Scope of PPC: This CSA has the task to transfer the results of all the PPCs of this HLUC from innovation to real life preparing the condition for new standards and grid codes compatible with the results of the projects.

HLUC 7: Enhance System Supervision and Control including Cyber Security

The growing electrification and the more decentralised deployment of renewable power generation will require reinforced and smarter electricity networks, able to accommodate both centralised and decentralised elements and to make the best of RES allocation over the European territory. Pervasive network Digitalisation, supported by high-capacity cyber-secure communication networks, will ensure decentralised monitoring and control. Not only density of the network, but also interconnection capacities –with harmonised security, planning and operation standards- will be needed to match growing RES supply and electricity demand over larger areas, as well as transparency to market participants all over Europe. These changes are calling for a complete reconsideration of the concept of control room both at TSO and DSO level. The change will affect not only the definition of the appropriate functionalities but also the fundamentals of the architectures. While we can still imagine the control room as a centralised place, the intelligence will be more distributed and, for the case of distribution grids, mostly at the edge.

At the same time with introducing significant changes in the concept of operation, there will be a significant impact on the workforce. This impact can be manifested in two directions: needs of new types of Human Machine Interface and need of training to prepare the workforce to operate under the modified conditions.

PPC 7.1: Next Generation of TSO control room (IP 2022-2025, Project Start 2022-End 2029)

Scope of PPC: System level automation is supposed to evolve to cope with the distributed characteristics of the generation and the active role of the loads. This PPC will define new architecture and solutions for the control room of the future. This PPC should also coordinate the work with PPC 7.2 for a coherent TSO-DSO cooperation.

PPC 7.2: Next generation of DMS (Distribution Management Systems) (IP 2022-2025, Project Start 2022-End 2029)

Scope of PPC: With the evolving role of the DSO, also the architecture of the Advanced DMS is supposed to evolve and to consider new services DER integration services and interfaces with both IT and OT solutions. This PPC will investigate new architectures and services for the DSO of the future. This PPC should also coordinate the work with PPC 7.1 for a coherent TSO-DSO cooperation.

PPC 7.3: Next generation of measurements and GIS for distribution grids (IP 2022-2025, Project Start 2022-End 2029)

Scope of PPC: Data fusion is one of the key topics in the process of digitalisation of power grids. This PPC will investigate the new type of data associated to new measurement devices but also to other sources of information such as GIS (Geographic Information System) to improve planning and operation of distribution grids. This PPC will investigate how these different sources of data and asset information can be integrated in a smooth way improving the on-line capability of planning and operating of DSO.

PPC 7.4: Wide area monitoring, control and protections (IP 2022-2025, Project Start 2022-End 2031)

Scope of PPC: While Phasor Measurement Units have already emerged as a key measurement tool both at transmission and distribution level, the application in monitoring, control and protection that fully exploit the capability of the Wide Area approach are still limited. This PPC should develop innovative use cases to fully exploit the potential of the technology.

PPC 7.5: Grid operator of the future (IP 2024-2027)

Scope of PPC: While the tools and the solutions for grid operation are changing, it is critical to prepare also the next generation of workforce. This PPC will work in cooperation with 7.1-3 to define educational needs and solutions for the personnel that will work in the control room of the future.

PPC 7.6: Human machine interface (HMI) (IP 2024-2027)

Scope of PPC: As the automation level grows, more data also become available. The role of the operator in the control room is changing but this means that one needs to rethink also how data is presented and how the HMI drives the possibility of interaction of the operator.

PPC 7.7: Large scale demonstration activities (IP 2026-2029)

Scope of PPC: This PPC shall take the results of the PPCs 7.1-7.3 and bring them to a new scale and contribute to higher impacts thanks to large demonstrators.

PPC 7.8: Standardisation activities (IP 2026-2029)

Scope of PPC: This PPC has the task to transfer the results of all the previous PPCs 7.1-7.7 from innovation to real life preparing the condition for new standards and architectures compatible with the results of the projects.

HLUC 8: Transportation Integration & Storage

The 2016 EU "Low-emissions mobility strategy" and the 2020 "Sustainable and Smart Mobility Strategy" have already shown that an integrated system approach is required to put the transport sector on a sustainable path. Central elements of such approach include actions on overall vehicle efficiency, promoting low- and zero emission vehicles and infrastructure, and the long-term switch to low- and zero-carbon electricity and to alternative and net-zero-carbon fuels for transport, together with further encouraging multi-modal integration and shifts towards more sustainable transport modes. Conditions must ensure the effective deployment of publicly accessible and private recharging points for electric vehicles and the efficient integration of vehicle charging into the system.

With the focus on system implications, different transport sectors will be considered, including:

- Road transport
    - micro mobility (e-bikes, e-scooters)
    - private vehicles
    - taxies and fleet vehicles
    - buses
    - lorries
- Railway transport: Trains
- Waterborne transport: River and sea boats
- Airborne transport: commercial and passenger airplanes

In the context of fuel/energy used, low carbon sources could be electricity and lower carbon fuels (biofuels, hydrogen, ammonia) including a combination of electricity and fuels.

The assessment of the role and value of alternative approaches for the transport sector decarbonisation should be the focus of this work, considering the impact on the future energy system operation and design and benefits of achieving cost effective transition to zero carbon energy future, as the interface between transport and energy sectors is the crucial element for ensuring the successful development for both.

PPC 8.1: Technical and economic implication of decarbonisation of transport sector (IP 2022-2025, Project Start 2022-End 2029)

Scope of PPC: Development of alternative decarbonisation strategies for transport sectors (electricity and hydrogen based) – (a) micro-mobility, public, fleet and private vehicles, (b) long on the ground transport (c) riverboats, sea-boats, (d) aviation.

Assess alternative funding for decarbonisation of different transport sectors.

Assessing the whole-energy system implications of alternative strategies for decarbonisation of transport sectors, including the impact on investment cost of conventional and low carbon generation, network infrastructure reinforcement and system operating costs, while meeting the carbon targets.

Assessment of the system value of smart electro mobility-based powertrain technologies (full electric vehicles, plug-in hybrids and hydrogen fuel cell-based vehicles), in providing control services at the local and national level through coordinated DSO/TSO control.

Assessment of the degradation of EV batteries when providing different V2G based system services and corresponding costs.

Deployment strategies for rapid-charging infrastructure considering the impact on the energy system, including application of energy storage and hydrogen-based resources for electricity production.

Assessment of the end-user perspective for different EV charging strategies, considering the costs and benefits related to provision of system services through smart EV charging and V2G.

Explore the viability of developing offshore charging facilities for sea boats/vessels supplied by offshore wind, considering the energy system impacts.

PPC 8.2: Enhancing effectiveness of energy system operation and resilience with electromobility (IP 2022-2025, Project Start 2022-End 2029)

Scope of PPC: Assessment of the benefits of smart control of different charging infrastructures in providing various system services through connecting EVs to IoT concept.

Incorporation of uncertainties related to the provision of services by transport sector, specifically considering V2G concept from private, fleet and public vehicles.

Assessment of the V2X based enhancement of resilience of supply in local areas, through making use of batteries in busses, taxies and fleet vehicles and energy storage technologies.

Assessment of the benefits of fast-charging stations in providing security services to local district and national infrastructure.

PPC 8.3: Demonstration activities (IP 2026-2029)

Scope of PPC: Development of appropriate IT infrastructure for common management of charging stations supported by appropriate market design to enable information exchange between energy system and charging point operators.

Modify the regulatory framework to enhance TSO–DSO interaction in supporting cost effective integration of transport sector in low carbon energy system.

Providing evidence regarding the changes in design of energy market needed to provide appropriate costs/ revenues related to the operation of the charging infrastructure (e.g. establishment of electro-mobility market for system services).

PPC 8.4: Policy and market for cost-effective integration of transport and energy sectors (IP 2026-2029)

Scope of PPC: Development of appropriate IT infrastructure for common management of charging stations supported by appropriate market design to enable information exchange between energy system and charging point operators.

Modify regulatory framework to enhance TSO–DSO interaction in supporting cost effective integration of transport sector in low carbon energy system.

Providing evidence regarding the changes in design of energy market needed to provide appropriate costs/ revenues related to the operation of the charging infrastructure (e.g. establishment of electro-mobility market for system services).

PPC 8.5: Interoperable planning of energy and transport sectors (IP 2026-2029)

Scope of PPC: Development of novel probabilistic energy system planning strategies incorporating the impact of large-scale deployment of different transport sector decarbonisation concepts and energy storage technologies.

Establish full interoperability between energy and transport sectors through development of common standards, protocols and digital services including connection of EVs to IoT, considering cyber security challenges.

Development of electricity system design standards that include security contribution of smart charging of EV and V2G, considering slow and rapid charging infrastructure for private, fleet and public vehicles.

Assessment of the option value of smart charging and V2G in energy system planning under uncertainties related to deployment of transport infrastructure.

Strategic planning of electricity grids to support timely deployment of EV charging infrastructures, while considering the second life of the EV batteries and ensuring that EV batteries can be recycled efficiently (appropriate standards can be developed).

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

The recent Clean Energy legislation requires that renewable heating and cooling must contribute to the progressive increase of the share of renewable energy. Provisions shall be included, at national, regional and local level, for the integration and deployment of renewable energy, including for renewables self-consumption and renewable energy communities, and the use of unavoidable waste heat and cold when planning, including early spatial planning, designing, building and renovating urban infrastructure, industrial, commercial or residential areas and energy infrastructure, including electricity, district heating and cooling, natural gas and alternative fuel networks.

Furthermore, extrapolating from the building level to a wider neighbourhood, campuses and community level (and even smart cities level), provisions should be included to allow an efficient and effective integration of smart communities in the energy system, addressing connectivity issues, market participation issues, control mechanisms and resilience.

Finally, integration of heating and cooling sector and coupling with the electricity grid is still limited. Rules for effective participation in the market are incipient. Initial control mechanisms and technologies for allowing such sector-coupling integration exist but need further development. Understanding of behavior and impact of buildings, infrastructure and communities in the grids and markets need further analysis and demonstration. Data management and cybersecurity issues still need further development.

PPC 9.1: Value assessment of the integration of buildings, infrastructure and smart communities in a RES based energy system (IP 2022-2025, Project Start 2022-End 2027)

Scope of PPC: Creating the conditions for the effective integration of renewable generation from multiple sectors in buildings and other individual or aggregated infrastructures leading to an increased share of RES in the energy system supported by digitalisation.

PPC 9.2: Control and operation tools for the integration of buildings and smart communities (IP 2022-2025, Project Start 2022-End 2029)

Scope of PPC: Design and test advanced control methods and enabling technologies to integrate multi-sector generation, ensuring the provision of needed flexibility from individual or aggregated heating and cooling devices, buildings, local communities, benefiting from energy system digitalisation.

Demonstrate effective and efficient management (e.g., via HEMS and BMS) of connected and stand-alone (island) buildings, living quarters, businesses and industries, communities supplied by RES, enabling sector coupling and storage components (P2X, X2P).

PPC 9.3: Planning for resilient integration of buildings and infrastructures in an integrated energy system (IP 2022-2025, Project Start 2022-End 2029)

Scope of PPC: Design and test energy models with multi-sector buildings, infrastructures and communities, through enhanced forecasting and analytics techniques and understanding of behaviour of individual and aggregated loads and local generation, ensuring resilient integration of multiple infrastructures, including microgrids, VPPs and VPSs and resulting grid stability.

Enable and demonstrate the contribution of distributed infrastructures and communities to the system resilience, recovery and robustness throughout extreme events, both cyber and physical.

PPC 9.4: Well-functioning markets for integrating buildings and community facilities in the energy transition (IP 2026-2029)

Scope of PPC: Ensure appropriate mechanisms for market participation of buildings and infrastructures with multi-sector RES sectors (e.g., gas-fired, biomass CHP units), making use of digital enabling technologies, ensuring viable business cases, including the provision of ancillary services at different aggregation levels.

PPC 9.5: Governance for an effective integration of buildings and smart communities (IP 2024-2027)

Scope of PPC: Development of new design and standards, with adequate data management, protocols, communication technologies and security and privacy, leading to efficient policies and regulations and coordination mechanisms with system operators and multiple energy stakeholders.

4. THE ETIP SNET R&I IMPLEMENTATION PLAN 2022-2025

This section provides the description of the Priority Project Concepts (PPCs) to be implemented during this R&I Implementation Plan 2022-2025. The descriptions have the following sections:

- Type of PPC Action (IA/RIA)
- PPC Start/End Year
- Indicative PPC Budget
- Expected PPC Outcome
- Scope of PPC
- Research Tasks associated to PPC with short descriptions

The background colours in the following tables indicate the Task-TRL-maturity:

Red	**Research**	- TRL 3-5
Yellow	**Demonstration**	- TRL 6-8
Green	**Deployment**	- TRL 9

PPC 1.1: Value of cross sector integration and storage

Type of Action: RIA

Start/End Year: 2022-2027 **Indicative Budget:** 30M€

Expected Outcome

- Projects should cover basic aspect for the cross-sector integration. Should provide support to EU policy for the following topics
- Develop models for optimisation of the operation and planning of the integrated energy systems, in order to facilitate cost effective transition to zero carbon energy future.
- Provide evidence related to the importance of cross-energy vectors coupling that would facilitate integration of large amount of RES and decarbonisation of heat / cooling, transport, industrial sectors.
- Develop a new market, regulatory and policy frameworks for delivering low-emission, low cost, secure, reliable and resilient whole-energy system
- Provides a holistic view and scientific guidance to foster technology and business model innovation to promote sustainable environmental and social circular economy objectives in energy storage and P2X, X2P, X2IndustrialService for an effective decarbonisation of the cross-energy sectors.
- Set targets according to established measurable KPIs for energy storage and P2X, X2P, X2IndustrialService

Scope

The projects should analyse the following topics:

- Role and value of cross sector Integration and energy storage under different future decarbonisation pathways according to both environmental and social sustainability dimension of the circular economy practices
- Assessment of cost and benefits of local versus national and international approach to cross-sector integration
- Role of large-scale energy storage (electricity, thermal, gas, hydrogen, etc.) in supporting cost effective decarbonisation and enhancing energy supply resilience
- Assessment of the benefits of providing system flexibility services by optimal cross-energy sectors integration according to established measurable KPIs for energy storage and P2X, X2P, X2IndustrialService
- Projects' assessment under dimensions of eco-design, life-time assessment, circular economy, sustainability

Research Task	Description
Market design for system services by other (non-electricity) energy carriers	Market design for large-scale demand response, beyond electricity. Market models expressing the price-sensitive nature of loads obtained by smart metering and metrology methods.
Market design for storage owners and operators	Market design for storage owners and operators, including of EV including thermal storage in electricity and heating markets
Market design for Virtual Power Plants	Market rules and coordination mechanisms for provision of ancillary services by aggregated storage and virtual power plants, comprising RES, flexible thermal generation (small and micro-CHP), heat-pumps, EVs, etc.
Energy models of the whole energy system development	Model of the energy system including all major energy carriers, encompassing the whole energy chain from prosumers, energy communities, e-transportation, distribution and transmission grids (LV, MV, HV), national and regional electrical and gas exchange, with clear boundary interaction Follow-up according to defined KPIs for energy storage and P2X, X2P, X2IndustrialService. Increasing the cross-energy sectors resilience leveraging on both environmental and social sustainability dimension of the circular economy practices
Develop European hydro energy system model	Develop European hydro energy system model based on hydro power data set. Develop European wide reservoir and river inflow data set based on up-to-date climate simulations.
Operational measures to increase network resilience (topology optimisation, DER operation, mobile DER)	Distribution network operational measures, like topology optimisation and DER operational planning for increasing network resilience against natural disasters, terrorism and cyber-attacks.
Pan-European market design concepts	Pan-European market design to foster the integration of large-scale RES, storage, demand response, EVs, etc. in coordination with network operation taking into account uncertainties of production and demand.
Optimally sized and coordinated non-chemical energy storage (gas, thermal, Compressed Air, Flywheel etc.)	Optimally located, sized and coordinated hydro, gas and chemical thermal and chemical storage for seasonal needs.

PPC 1.2: Control and operation tools for multi-energy systems

Type of Action: IA

Start/End Year: 2022-2027 **Indicative Budget:** 60M€

Expected outcome

- Development of the new design standards that would enable cross-sector integration
- Demonstrate the ability of providing real time balancing and management of flexibility by cross-energy vector coordination including various P2X, X2P, grid scale energy storage technologies.
- Tools using multi objective optimisation for the operation of multi-energy systems
- Development and demonstration of advanced technologies and control concepts /platform tools for multi-energy systems based on appropriate data exchange between different energy sectors in local, national and pan EU regions
- Creation of incentives and mechanisms for non-electric sector participants in an integrated energy system
- ICT requirements and standards to collect, deliver and utilise data, including data from different energy sector, to enable efficient flexibility markets.

Scope

Development and demonstration of advanced technologies and control concepts /platform tools for multi-energy systems based on appropriate data exchange between different energy sectors in local, national and international regions

Research Task	Description
Data exchange protocols / interfaces for market actors	Data exchange protocols / interfaces for a well-functioning market between all players. Protocols for stochastic model-based handling of market operations on different timescales. Common, standardised models for encrypted and authenticated market orders
Flexibility potential from aggregated heating (and cooling) storage at household / building / industrial leve	Flexibility potential from aggregated heating (and cooling) storage at household / building / industrial level to provide system services (balancing). Power-to-heat technologies, like heat pumps, heat boilers, etc.
Flexibility potential from power-to-gas application	Dynamics of coupled, integrated energy systems when producing large quantities of methane (power-to-gas) to be injected into the gas system (pipelines and underground storages).

Flexibility potential from Hydrogen integration	With the increasing interest in the Hydrogen economy and the possibility to produce clean and low-cost hydrogen from renewable power, fuel cells technology and affordability could receive a boost. While fuel cells are still not competitive in the car industry and residential sectors, they compete in low- and medium-temperature uses of heat in industry, where they represent an interesting source of both electricity and heat, especially where heat pumps technically struggle to supply the required heat load. Moreover, hybrid fuel cells and battery systems can overcome the shortcomings of the standalone technologies in certain sectors, as already successfully tested for mobility (e.g., Trains running on lines not electrified, buses, heavy-duty vehicles) and other off-grid applications.
Security support by various multi-energy carriers	Security support by various multi-energy carriers in the distribution electricity network (e.g., electric pumps in the district heating and cooling networks, or in the drinking and wastewater networks, as well as electric compressors and control equipment in the gas network).

PPC 1.3: Smart Asset management

Type of Action: IA

Start/End Year: 2022-2027 **Indicative Budget:** 40 M€

Expected Outcome

- New approaches for managing critical assets based on probabilistic risk assessment and optimisation of maintenance planning.
- Common asset models for interpretation of the huge amount of data available from system monitoring and inspection.
- Techniques and tools to extract the maximum level of information and knowledge out of the data from the field, using advanced analytics, machine learning and Big Data technologies, to be applied using equipment ageing and failure models as well as system resilience evaluation tools.
- Solutions based on digital approaches (such as tablets, wearables, robotics, drones and other elements) to support asset management and intelligent management to increase system reliability, reduced the risk for workers, decrease OPEX.

Scope

The PPC addresses the advanced management of assets in the energy system along their entire lifecycle, from the commissioning to the end-of life covering the identification of the degradation phenomena and the indicators of the failure development, the sensors and methods for diagnostic and monitoring, the setting up of maintenance policies and end-of-life decision making at the light of the progressive advancement of data acquisition and management techniques.

Deployment of IoT sensors, communication, data management & analysis and feedback to control systems encompasses a huge number of devices and systems, so high TRL R&I actions are definitely needed.

Research Task	Description
Condition monitoring and Preventive Maintenance	Development of ageing and failure models for condition (risk) in planning LV/MV based maintenance, considering maintenance cycling profiles (including extreme events), different time scales (from operation to planning) both for power system components (lines, substations, transformers, switches, breakers, etc.), ICT infrastructures (sensors, communication infrastructures) and smart meters.
Models and tools for remote maintenance	Tools and methodologies for Remote LV/MV maintenance operations using drones and other monitoring equipment

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

Type of Action: RIA

Start/End Year: 2022-2027 **Indicative Budget:** 20 M€

Expected Outcome

- Market design for DER and VPP participation
- Development and validation of Cost Benefit Analysis for TSO-DSO ancillary services coordination
- Increased participation of consumers and local communities
- Definition of standard pan-European ICT platforms to allow the interaction of the different actors in the process of acquisition of ancillary services (end-users/BSPs, market operators, TSOs, DSOs, aggregators and BRPs) in an integrated and optimised environment.
- Methodologies to optimise provision of Ancillary Services from distributed resources in the distribution network
- Market models for the interaction of TSOs and DSOs including interactions between central and local markets
- Assessment of Identify technical, market and business barriers to the smooth cooperation and interaction between TSOs, DSO and consumers
- Assessment of improvement paths in system operation to enable the integration of new services and products in system operation
- Demonstrate Demand Side participation, consumer involvement and Local Energy Communities
- Increase observability in the power system and allow data exchange between the DSOs and TSOs
- Specify appropriate technical characteristics and timeframes to participate in the markets
- Unlock markets of flexibility at every level to address the needs of the SOs. (Standardise balancing market data exchange vertically (across the electricity value chain) and horizontally (across vectors/sectors)
- Creation of incentives and mechanisms for non-electric sector participants in an integrated energy system

Scope

Definition of suitable market models for the interaction of TSOs and DSOs including interactions between central and local markets and across different time frames. Identification of technical, market and business barriers to the smooth cooperation and interaction between TSOs, DSO and System User. Provide evidence related to the benefits of market-driven options and solutions.

Research Task	Description
Energy Management platforms for TSOs including interaction with local markets	Energy Management platforms for TSOs (with the associated monitoring and control systems) able to interact with local markets and with embedded functionalities such as self-healing capabilities for fault management.
Energy Management Platforms for DSOs for active participation of customers in local energy markets	Energy Management Platforms for DSOs allowing active participation of customers in energy market and in the grid operation optimisation, interoperability with other actors (retailers, aggregators, TSOs) for grid status and data and smart metering data processing. Advanced functionalities for forecasting, protection and optimisation in preventive and corrective way.
Integrated Transmission and Distribution Planning considering Demand Flexibility	Integrated Transmission and Distribution Planning considering Demand Flexibility Coordinated HV (including Ultra-HV) and MV distribution systems. Electricity transmission systems with storage infrastructure and using gas and heat infrastructures and Distribution systems with integrated DER and local flexibilities.
Business models for retailers and aggregators, ESCOs and energy communities	Business models for retailers and aggregators, ESCOs and energy communities, providing energy efficiency at end-user level and participating in the wholesale market
Market design for local markets and their interaction to central markets	Design of local markets and their interaction to central markets. Retail (peer-to-peer) markets including Local Energy Communities with power balancing and coordinated LV/MV technical grid control.

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

Type of Action: IA

Start/End Year: 2022-2029 **Indicative Budget:** 30 M€

Expected Outcome

- Methods and tools for prosumer monitoring and participating in the markets
- ICT technologies enabling prosumer participation in the markets
- Standardise balancing market data exchange vertically (across the electricity value chain) and horizontally (across vectors/sectors
- Design and test efficient optimisation algorithms for near real-time TSO-DSO-Consumer coordination considering grid constraint.
- Identify universal devices needs for TSO-DSO information exchange at different time frames
- Big data management and advanced algorithms solutions for supporting decision making by System Operators
- Improved real-time observability of RES
- Develop models for robust net load forecasting and robust forecasting of available flexibility.
- Assessment of technical, market and business barriers to the smooth cooperation and interaction between TSOs, DSO and consumers
- Ensure resilience contributions from DER (including black start)
- Design and test efficient optimisation algorithms for near real-time TSO-DSO-Consumer coordination considering grid constraint
- Ensure and test overall dynamic stability
- Improve/deploy and demonstrate IoT and EMS at System User premises to optimise (self)consumption and market participation according to grid needs and/or market signals (intelligent agents)
- Design and test optimal utilisation and control of Demand Side Response by TSOs and DSOs

Scope

The projects should analyse the following aspects:

- Design, development and demonstration of effective control mechanisms and technologies for System User participation in the market
- Optimisation of the operation of the energy system and the provision of Ancillary Services from distributed resources, ensuring resilience contributions from DER
- Development and improvement of digital technologies to support customers and distributed energy resources to participate in the operation and market
- Use of advanced analytics and big data management for decision-making
- Real time balancing and management of flexibility

Research Task	Description
Knowledge from Integrated Big data management, including AI techniques	Big data management from different sources: smart-meters, smart-sensors, social media, etc. for their use in planning tools, management tools, market platforms, etc. Data driven tools supported by data analytics, artificial intelligence, development of digital twins, etc.
ICT infrastructure for demand control and aggregation	Communication infrastructures to support demand aggregation and control. M2M or Artificial Intelligence to Artificial Intelligence telecommunication solutions for services required by the energy grid (including AI algorithms for decision-making in device, MEC or cloud level).
ICT infrastructure for monitoring of distributed generation	ICT infrastructure for monitoring and control of distributed generation, e.g. PV systems, including standards and protocols.
Energy Management platforms for TSOs including interaction with local markets	Energy Management platforms for TSOs (with the associated monitoring and control systems) able to interact with local markets and with embedded functionalities such as self-healing capabilities for fault management.
Energy Management Platforms for DSOs for active participation of customers in local energy markets	Energy Management Platforms for DSOs allowing active participation of customers in energy market and in the grid operation optimisation, interoperability with other actors (retailers, aggregators, TSOs) for grid status and data and smart metering data processing. Advanced functionalities for forecasting, protection and optimisation in preventive and corrective way.
Increase operational flexibility of hydropower and pumped storage plants	Increase operational flexibility of hydropower and pumped storage plants, while reducing the negative effects on highly reduced lifetime and security risks from sudden outage.
Contribution of thermal generators to system flexibility (including cogeneration)	Increase the flexibility of thermal generation, i.e., their speed of ramping up and down, start-up/shut down capabilities and minimum loads. Increase efficiency and lower GHG and CO_2-emissions without compromising ability for waste heat recovery (ORC, etc).

PPC 2.3: Platform development for TSO/DSO cooperation

Type of Action: IA

Start/End Year: 2022-2029 **Indicative Budget:** 30 M€

Expected Outcome

- Design data exchanges and standard protocols for all players paving the way for a cross-sector approach
- Test platforms and mechanisms usage for cooperation (between System Operators, and between SOs and consumers).
- Develop and improve digital technologies (e.g., protocols, devices) to support customers and distributed energy resources to participate in the operation and market.
- Leverage the use of standards for data exchange of data (CGMES, CIM, etc). Definition of appropriate data models that can represent properly all the TSO-DSO- System User interactions.
- Develop and demonstrate effective and efficient platforms for market-driven interactions between multiple players that are interoperable and that fits the market requirements and have flexible interfaces

Scope

Design and development of platforms for an effective information sharing, allowing access and cooperation from multiple energy system players and an efficient organisation of the energy system

Research Task	Description
Data exchange protocols / interfaces for market actors	Data exchange protocols / interfaces for a well-functioning market between all players. Protocols for stochastic model-based handling of market operations on different timescales. Common, standardised models for encrypted and authenticated market orders
ICT infrastructure for monitoring of distributed generation	ICT infrastructure for monitoring and control of distributed generation, e.g. PV systems, including standards and protocols.
ICT infrastructure for demand control and aggregation	Communication infrastructures to support demand aggregation and control. M2M or Artificial Intelligence to Artificial Intelligence telecommunication solutions for services required by the energy grid (including AI algorithms for decision-making in device, MEC or cloud level).
Business models for data analysis service and platform providers	Business models for data analysis service and platform providers to energy using large-scale data bases and advanced data-mining techniques

PPC 2.4: Planning Tools for TSO-DSO cooperation

Type of Action: RIA

Start/End Year: 2022-2031 **Indicative Budget:** 10 M€

Expected Outcome

- Efficient long-term planning and corresponding tools and simulation capabilities
- Stimulate participation from cross-sector actors
- Expand TSO-DSO cooperation towards the network planning longer timeframe
- Identify and validate mechanisms for Gas TSO and Gas DSO cooperation in managing pipe pressures and consumer requirements in the context of increasing alternative gases (e.g., hydrogen)
- Ensure and test overall dynamic stability

Scope

Optimise the planning of the energy system. Development of efficient long-term planning and corresponding tools and simulation capabilities, including local and global dimensions and allowing multiple System User typologies and aggregations

Research Task	Description
Integrated Transmission and Distribution Planning considering Demand Flexibility	Integrated Transmission and Distribution Planning considering Demand Flexibility Coordinated HV (including Ultra-HV) and MV distribution systems. Electricity transmission systems with storage infrastructure and using gas and heat infrastructures and Distribution systems with integrated DER and local flexibilities.
Planning distribution networks considering citizen energy communities	Planning distribution networks considering citizen energy community needs. Considering Citizen energy communities, with energy management systems for local multi-energy streams operation, including electrical-storage, P2x generation and storage, and x2P (including CHP based on hydrogen with all different hydrogen technologies).
Optimally located, sized and coordinated electric energy storage	Optimally located, sized and coordinated electric energy storage at different voltage levels in the power system (for fast and slow power response; for future ancillary supplementary services in the storage facility such as inertia support).
Optimally sized and coordinated non-chemical energy storage (hydro, gas, thermal, etc.)	Optimally located, sized and coordinated hydro, gas and chemical thermal and chemical storage for seasonal needs.
Resilience oriented sizing and spatial positioning of assets	Coordinated HV (including Ultra-HV) and MV distribution systems. Electricity transmission systems with storage infrastructure and using gas and heat infrastructures. Resilience oriented sizing and spatial positioning of assets, in order to withstand the impact of extreme weather and grid events.

PPC 3.1: Fundamental market design

Type of Action: RIA

Start/End Year: 2022-2029 **Indicative Budget:** 25 M€

Expected Outcome

- Enable development of operation of short term (seconds-minutes-hours) fully decentralised energy markets including stability, balancing and energy exchange, while managing network congestions
- Develop fundamentally new multi-energy market with appropriate temporal and special spatial granularity to facilitate cost effective transition to low carbon energy future.
- Develop cost effective market mechanism for allocation of costs related to the provision of balancing services, network charging, investment in conventional and low carbon generation.
- Demonstrate that the new market will enable flexibility technologies and advanced system control concepts to access revenues associated with all benefits delivered.
- Develop fully decentralised energy markets including peer-to-peer trading of energy and balancing services, while maximising service quality delivered to end consumers

Scope

The projects should analyse the following aspect:

- Assessment of the need to coordinate market clearing process for balancing services covering different timescales (second, minutes, hours) while considering the conflicts and synergies between local district and national, international objectives.
- In the context of EU wide market, develop appropriate market design that would enable optimal exchange of energy and balancing services by interconnectors.
- Energy market design that would recognise option value of flexibility technologies dealing with uncertainties in future deployment of low carbon technologies in local, regional EU wide areas.
- Market design that recognises uncertainties in the provision of alternative balancing / ancillary services by different technologies (establishing level playing approach for the provision of services across different service delivery concepts / technologies)
- Assess the value of flexible distributed energy resources, such as demand side response, domestic batteries and batteries in electric vehicles, thermal energy storage etc., in offering flexibility and balancing services to the grid through aggregation

Research Task	Description
Pan-European market design concepts	Pan-European market design to foster the integration of large-scale RES, storage, demand response, EVs, etc. in coordination with network operation taking into account uncertainties of production and demand.
Market design for local markets and their interaction to central markets	Design of local markets and their interaction to central markets. Retail (peer-to-peer) markets including Local Energy Communities with power balancing and coordinated LV/MV technical grid control.
Market design for the provision of ancillary services between DSOs and TSOs	Market rules and coordination mechanisms for provision of ancillary services by aggregated storage and virtual power plants, comprising RES, flexible thermal generation (central power plants, distributed power plants and small and micro-CHP), heat-pumps, thermal storage, EVs, etc.
Optimal Scheduling of generation for balancing in highly uncertain conditions	Optimal scheduling of generation units (unit commitment, economic dispatch), reserve allocation and optimal power flow in highly uncertain conditions.
Market design for storage owners and operators	Market design for storage owners and operators, including of EV including thermal storage in electricity and heating markets
Market design for Virtual Power Plants	Market rules and coordination mechanisms for provision of ancillary services by aggregated storage and virtual power plants, comprising RES, flexible thermal generation (small and micro-CHP), heat-pumps, EVs, etc.

PPC 3.2: Regulatory framework and strategic investments

Type of Action: RIA

Start/End Year: 2022-2029 **Indicative Budget:** 30 M€

Expected Outcome

- Develop Market design / regulatory framework for supporting cost effective delivery of security and resilience of supply from local to national / international level.
- Enhance renewable power purchase agreements
- Guarantees of origin are a key tool for consumer information as well as for the further uptake of renewable power purchase agreements.
- Develop market design / regulatory framework for supporting cost effective delivery of security and resilience of supply from local to national / international level

Scope

The projects should analyse the following topics:

- Development of fundamentally new concept for efficient allocation of cost related to the provision of all ancillary /balancing services, network congestion management, provision of security of supply and meeting carbon targets cost effectively.
- Market design / regulatory framework for supporting cost effective delivery of security and resilience of supply from local to national / international level
- Design of market / regulatory framework that would support strategic investment in energy infrastructure when/where appropriate (e.g. investment in reinforcement of electricity distribution network infrastructure in order to support cost effective and timely electrification of transport sector, strategic investment in offshore infrastructure to integrate offshore wind support system adequacy etc).

Research Task	Description
Resilience oriented sizing and spatial positioning of assets	Coordinated HV (including Ultra-HV) and MV distribution systems. Electricity transmission systems with storage infrastructure and using gas and heat infrastructures. Resilience oriented sizing and spatial positioning of assets, in order to withstand the impact of extreme weather and grid events.
Coordinated investment planning at Regional (neighbouring systems) and EU level	Cost-effective, coordinated investment planning at EU level or neighbouring systems and taking into account the effects of alternative market designs and the requirements for infrastructure development. Consider all flexibility means (demand response, energy storage, generation, transmission), including cross-carrier flexibility.
Integrated Transmission and Distribution Planning considering Demand Flexibility	Integrated Transmission and Distribution Planning considering Demand Flexibility Coordinated HV (including Ultra-HV) and MV distribution systems. Electricity transmission systems with storage infrastructure and using gas and heat infrastructures and Distribution systems with integrated DER and local flexibilities.

PPC 3.3: IT systems for cross-border trading

Type of Action: RIA

Start/End Year: 2022-2029 **Indicative Budget:** 25 M€

Expected Outcome

- Simulation analysis with new technologies; real-time analysis of new technologies with extensive power electronics; use of HIL (HW in the loop) simulation to validate new technologies; simulation at local level, national level, cross-border level and pan-European effects; preparation for risk-controlled field demonstrations.
- Validated tools and solutions for the management of the Pan-European transmission network, for secure operation of the power system with steadily increasing (beyond 100% of demand during certain intervals) inverter-based RES, through fast real-time and continuous prediction of dynamic stability margins and preventive mechanisms and the market-based activation of cross-border dynamic stability services (such as ancillary services)

Scope

An integrated EU energy market needs to be a priority, to ensure secure and affordable energy supplies to European citizens and businesses: therefore, common energy market rules, communication standards and protocols and cross-border infrastructure need to be designed and established.

Research Task	Description
Pan-European market design concepts	Pan-European market design to foster the integration of large-scale RES, storage, demand response, EVs, etc. in coordination with network operation taking into account uncertainties of production and demand.
Market design for TSOs with cross-border coordination	Market design for TSOs with cross-border coordination that involve multiple DSOs and aggregators and multi-operation zones. Market design for cross-border ancillary services (including joint procurement of reserves, sharing of reserves, fast ramping services for frequency response, inertia response, reactive power, voltage control and power flow control)
Data exchange protocols / interfaces for market actors	Data exchange protocols / interfaces for a well-functioning market between all players. Protocols for stochastic model-based handling of market operations on different timescales. Common, standardised models for encrypted and authenticated market orders
ICT infrastructure for demand control and aggregation	Communication infrastructures to support demand aggregation and control. M2M or Artificial Intelligence to Artificial Intelligence telecommunication solutions for services required by the energy grid (including AI algorithms for decision-making in device, MEC or cloud level).
Business models for data analysis service and platform providers	Business models for data analysis service and platform providers to energy using large-scale data bases and advanced data-mining techniques

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

Type of Action: RIA

Start/End Year: 2022-2029 **Indicative Budget:** 20 M€

Expected Outcome

- Analysis of re-dispatch process and efficient market solutions
- Friendly Market design for RES participation (short-term bids)
- Improved modelling and simulation
- Facilitate the participation of cross-sector RES
- Reduce system risks associated with increased fluctuating generation
- Assessment market dynamics

Scope

Creating the conditions for effective participation of industrial, residential, communities from multiple sectors and for deploying of corresponding grids leading to an increased share of RES in the energy system. Ensure the efficient and reliable connection and integration of large RES generation (e.g., large offshore grids).

Identify the technical barriers which may limit the ability of the power systems to accommodate further volumes of variable RES.

Creating the conditions for the effective participation of industrial, residential actors and energy communities and for deploying corresponding grids leading to an increased share of RES in the energy system.

Research Task	Description
Transmission System Planning for large scale offshore wind integration	Probabilistic Transmission planning taking into account the integration of offshore wind generation and other forms of large-scale RES concentrated penetration. Probabilistic planning tools that take into account DER RES stochasticity., i.e., RES, demand response, storage, self-consumption, and their uncertainty including for heating and cooling and the demand for mobility

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

Type of Action: IA

Start/End Year: 2022-2027 **Indicative Budget:** 50 M€

Expected Outcome

- Improved forecast tools
- Transmission Network: Increase RES hosting capacity of Transmission System, expansion of the offshore grid
- Distribution Network: Increase RES hosting capacity of Distribution System
- Technologies for distribution Grid operation exploiting Flexibility and Storage management and corresponding coordination with system operators
- Ensure efficient and effective DER control and Hybrid Power Systems
- Efficient mechanisms reduce system risks associated with increased fluctuating generation
- Efficient digital mechanisms for RES integration and participation (e.g., protocols, platforms
- Efficient curtailment mechanisms, with increased renewables and from multiple sectors

Scope

Design and test advanced technologies and control mechanisms for integrating massive volumes of RES at distribution and transmission level, handling network constraints and providing flexibility needs, ensuring coordination throughout energy sectors

Research Task	Description
Contribution of WTs (Wind turbines) and PVs to system flexibility.	Contribution of WTs (Wind turbines) and PVs to system flexibility. Development of efficient controls for wind turbines and PV MPPT (Maximum Power Point Tracking) to take into account flexibility, reserve sharing, etc.
Real-time observability of RES.	Real-time observability of RES (algorithms and tools) and improved forecasts for operational and planning purposes, including real time balancing
Distribution System Planning for the massive integration of EVs	Develop Methods and tools for Distribution System Planning aiming at the integration of DG and RES. The tools should consider controllable DG and Market Rules
Advanced RES forecasting for network operation	Advanced RES forecasting considering weather forecasts, local ad-hoc models, historical data and on-line measurements. new digitalisation approaches like machine learning based data treatment procedures, AI supported renewable energy generation unit performance analysis and evaluation of existing infrastructure can be considered.
Hydropower forecasting	Hydropower forecasting based on weather, precipitation models and live sensors.

PPC 4.3: Infrastructure requirements and network technologies as solutions for integration of massive RES

Type of Action: IA

Start/End Year: 2022-2029 **Indicative Budget:** 50 M€

Expected Outcome

- Develop advanced network technologies, such as FACTS, WAMS
- Protections and Control
- Solutions to deal with lack of inertia
- Methodologies to manage energy transits in the networks
- Appropriate forecast (load, generation, transits)
- Multinational interconnection design to support offshore wind Optimal Flexibility Management including Demand Response

Scope

Ensure the integration of massive RES at multiple voltage levels through advanced networking solutions (e.g., HVDC, FACTS) and increasing flexibility capabilities from RES and grids

Ensure the efficient and reliable connection and integration of large RES generation (e.g., large offshore grids).

Research Task	Description
Contribution of WTs (Wind turbines) and PVs to system flexibility.	Contribution of WTs (Wind turbines) and PVs to system flexibility. Development of efficient controls for wind turbines and PV MPPT (Maximum Power Point Tracking) to take into account flexibility, reserve sharing, etc.
Flexibility in Transmission and Distribution Networks by Power electronics grid technologies (FACTS, FACDS, HVDC, etc.)	Increasing flexibility in transmission and distribution networks by flexible, power electronics grid technologies, such as FACTS, PSTs and HVDC links, smart transformers (power electronics OLTCs), open soft points, FACDS, and fault current limiters
Advanced RES forecasting for network operation	Advanced RES forecasting considering weather forecasts, local ad-hoc models, historical data and on-line measurements. new digitalisation approaches like machine learning based data treatment procedures, AI supported renewable energy generation unit performance analysis and evaluation of existing infrastructure can be considered.
Hydropower forecasting	Hydropower forecasting based on weather, precipitation models and live sensors.
Condition monitoring and Preventive Maintenance	Development of ageing and failure models for condition (risk) in planning LV/MV based maintenance, considering maintenance cycling profiles (including extreme events), different time scales (from operation to planning) both for power system components (lines, substations, transformers, switches, breakers, etc.), ICT infrastructures (sensors, communication infrastructures) and smart meters. development of tools to be applied in production optimisation, advanced solar tracking algorithms and performance and degradation analysis based on bifacial module technologies

Protection of distribution networks with low fault currents, adaptive protection	Protection of distribution networks with low fault currents due to high penetration of RES interfaced DER

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

Type of Action: RIA

Start/End Year 2022-2031 **Indicative Budget:** 25 M€

Expected Outcome

- Adequate modelling and simulation capabilities.
- Planning and Operating methods that aim at increased RES participation with increased resilience; Improved modelling and simulation

Scope

Enhance system resilience in the presence of increased RES penetration at all levels, via sophisticated forecast methods, models and techniques, simulation, restoration mechanisms, ensuring stability of the system and robustness to extreme events

Research Task	Description
Coordinated LVDC / MVDC and AC distribution network planning.	Planning of LV and MV DC industrial and residential grids. Added value of DC grids in integrating DER, incl. lower costs of BoS (Balance of System). Taking care for safety, especially in homes.
Distribution System Planning for the massive integration of DG	Develop Methods and tools for Distribution System Planning aiming at the integration of DG and RES. The tools should consider controllable DG and Market Rules
Grid stability with large scale penetration of converter interfaced sources	Grid stability support by DER (distributed generation, storage and flexible demand) and by microgrids and nanogrids connected at the distribution networks to the stability and control of the bulk transmission network.
Transmission System Planning for large scale offshore wind integration	Probabilistic Transmission planning taking into account the integration of offshore wind generation and other forms of large-scale RES concentrated penetration. Probabilistic planning tools that take into account DER RES stochasticity., i.e., RES, demand response, storage, self-consumption, and their uncertainty including for heating and cooling and the demand for mobility
Coordinated investment planning at Regional (neighbouring systems) and EU level	Cost-effective, coordinated investment planning at EU level or neighbouring systems and taking into account the effects of alternative market designs and the requirements for infrastructure development. Consider all flexibility means (demand response, energy storage, generation, transmission), including cross-carrier flexibility.
Coordinated HVDC and HVAC network planning.	HVDC meshed grids. Optimisation algorithms for HVDC grids design based on different optimisation criteria (n-1 reliability criterion, loss of infeed risks, economic criteria, etc.) and parallel routing of DC and AC lines on the same tower or parallel paths to utilise existing infrastructure paths.

Planning distribution networks considering citizen energy community needs	Planning distribution networks considering citizen energy community needs. Considering Citizen energy communities, with energy management systems for local multi-energy streams operation, including electrical-storage, P2x generation and storage, and x2P (including CHP based on hydrogen and fuel-cells).

PPC 5.1: Value of consumer/customer acceptance and engagement

Type of Action: IA

Start/End Year: 2022-2027 **Indicative Budget:** 20 M€

Expected Outcome

- Guidelines for the participation of prosumers and energy communities in electricity markets
- Guidelines for the implementation of incentives by dynamic prices, regulated tariffs and other market incentives.
- Software tools to automatically calculate flexibility of different assets and trigger demand response campaigns
- Remuneration software tools, based on energy retail and market prices

Scope

The scope of this PPC is to analyse the requirements of the platform that will accelerate the adoption of new energy services and technologies. The access to data and energy services will allow the customer to go beyond the electricity sector into fully integrated energy system.

Research Task	Description
Increase Customer awareness and acceptance of energy systems	Methods and tools for the effective stakeholder's engagement to increase public acceptance of new energy infrastructures, including transmission lines (overhead lines and underground cables), substations, storage facilities, generation stations (thermal and RES, like hydro, wind, etc.), gas pipelines and conversion stations, etc. (links to Social Science and Humanities)
Studies to reduce or remove the environmental impacts of energy infrastructures (visual, audible, etc.)	Increase consumer understanding and awareness of new electricity/energy systems and particularly the consumer/prosumer central role as active participants in grid operation. Investigate the social and economic impact of the citizen involvement in forming energy communities, including increased system resilience and sustainability.
Methods to support consumers' and prosumers' adaptation of energy behaviour including Energy Communities	Methods and Tools to support consumers' and prosumers' adaptation of energy behaviour, including on-line measurements of electricity consumption and generation, dynamic time-of use tariffs and behavioural studies considering the full environment, such as non-energy benefits, like comfort and security.
Methods and tools to support the industry's consumption adaptation	Methods and tools including campaigns to support the industry's consumption adaptation in order to support the system
Business models for prosumers	Business models for prosumers providing ancillary services, including EV owners with bidirectional capabilities and storage units.

PPC 5.2: Plug and play devices and IoT (Internet of things) including security by design

Type of Action: IA

Start/End Year: 2022-2027 **Indicative Budget:** 30M€

Expected Outcome

- Real plug&play situation for customer assets and data exchange
- Provision of access to the consumer to energy data and advanced services
- Facilitation of customers can easily join and change service providers
- Applications devices for putting the end user in direct contact with supplier, distributor and other involved market stakeholders.
- Availability of software to provide services to increase consumer satisfaction based on IoT.
- Development of robust and low-cost application of digital technology for peer-to-peer interactions (blockchain)
- Implementation of software tools for enhanced cooperative energy services increasing community's resilience and self-sufficiency.
- Design of ICT architectures for mass data communication and processing (Blockchain, Exchange Platforms)
- Design of efficient data and information management mechanisms for platforms integration in the energy system, from consumer related platforms to system operation platforms

Scope

One of the obstacles for customer to have a more active role in the energy system is the lack of solutions that really support plug and play. Purpose of this PPC is to remove this barrier and develop solutions that facilitate joining any kind of energy market across Europe

Research Task	Description
Use of IoT technologies for monitoring and control	Investigate the use of customer data and IoT technologies in TSO and DSO planning, asset management, operational and market activities.
ICT infrastructure for demand control and aggregation	Communication infrastructures to support demand aggregation and control. M2M or Artificial Intelligence to Artificial Intelligence telecommunication solutions for services required by the energy grid (including AI algorithms for decision-making in device, MEC or cloud level).
ICT Technologies for Smart Appliances	Development of tools and interfaces for Smart Appliances: e.g. Wi-Fi enabled Washing Machines, Air conditioners, Dish washers etc. The tools and interfaces should be integrated to platforms for DR

PPC 5.3: Utilisation of communication networks including cyber security

Type of Action: IA

Start/End Year: 2022-2029 **Indicative Budget:** 40M€

Expected Outcome

- Advanced intrusion detection and prevention systems for energy infrastructures using security-related big data and deep learning methods.
- Advanced technologies and tools for the implementation of a proactive and anticipatory security strategy supporting threat hunting in integrated and federated Security Operation Centres (SOCs). New technologies for future SOCs are related to security monitoring, threat detection and response.
- Mechanisms of exploitation of common infrastructures such as 5G networks.

Scope

Smart solutions will use a variety of connection solutions. It is critical to facilitate connection while preserving security. This PPC will investigate how security by design can support use of private networks in energy applications.

Research Task	Description
Risk and vulnerabilities for parallel use of legacy systems	Risk and vulnerabilities for parallel use of legacy SCADA systems (as a traditional means to provide remote supervisory and control)
Data Protection and GDPR-compliant methodologies (privacy)	Data protection and GDPR for activities the manage personal data
Exploitation of concept of network slicing for secure operation within common infrastructures (AM)	Analysing the exploitation of modern solutions such as Network Slicing to integrate secure operation within common communication infrastructures
Advanced definition of the concept of virtual operator (AM)	Facilitate TSO and DSO to operate as virtual operators within public infrastructure combining different telecom providers and also communication media

PPC 5.4: Cross-sectorial flexibility use cases

Type of Action: IA

Start/End Year: 2022-2027 **Indicative Budget:** 30M€

Expected Outcome

- Consolidated ICT vision and strategy for common data acquisition processes for TSO-TSO, TSO-DSO, TSO-BSP (Balancing Service Provider) and TSO-SGU (Significant Grid User) data exchange corresponding to the expected targets for future market design, system development and operation.
- An integrated framework of interoperable systems, fed by multiple data sources from different sectors and with automatised learning and updating processes, implemented in day-by-day TSO processes able to represent near real-time power system status and maintenance and working conditions of the grid assets.
- Methods and algorithms for secure and comprehensive data collection across all energy sectors and for providing a more transparent and timely data access for decision making to all market participants (by exploiting new technologies such as IoT, Big data and AI).
- Design of efficient data and information management mechanisms for platforms integration in the energy system, from consumer related platforms to system operation platforms

Scope

Intrinsic flexibility of the electrical loads is rather limit. Linking different sectors is possible to reach unexplored options. This means not only multi-energy use cases but also links to other sectors not directly related to energy

Research Task	Description
Demand Flexibility provided by the residential sector	Models for demand flexibility provided by residential sectors equipped with smart appliances and storage
Demand Flexibility provided by the industry	Models for demand flexibility provided by integrated energy-intensive industries (e.g. steel production) and bulk energy storage (P2G, CAES, LAES, etc.).
Contribution of thermal generators to system flexibility (including cogeneration)	Increase the flexibility of thermal generation, i.e. their speed of ramping up and down, start-up/shut down capabilities and minimum loads. Increase efficiency and lower GHG and CO_2-emissions without compromising ability for waste heat recovery (ORC, etc).
Flexibility potential from aggregated heating (and cooling) storage at household / building / industrial level	Flexibility potential from aggregated heating (and cooling) storage at household / building / industrial level to provide system services (balancing). Power-to-heat technologies, like heat pumps, heat boilers, etc.

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

Type of Action: IA

Start/End Year: 2022-2029 **Indicative Budget:** 30M€

Expected Outcome

- New control methods are needed to exploit power electronics-based generation to play a central role in the network system
- New modelling methods are needed to better represent the new dynamics while the separation between electromechanical and electromagnetics eigenvalue will not be as clear as today.
- New methods and techniques are required to exploit the flexibility and controllability of these components and a new fundamental approach is needed to define how these devices are part of the system level control.

Scope

This PPC will develop control solutions for components such as PV and Battery inverters that can be considered grid friendly, i.e., able to variety of services that can be used at system level. The goal is standard the interface and deployment of such services to facilitate a future based on plug&play solutions

Research Task	Description
Flexibility potential from battery storage	Development of efficient and advanced controls for battery inverters
Contribution of RES to primary voltage and frequency control in low inertia systems	Contribution of RES to primary voltage and frequency control of power grids (grid forming inverters) with emphasis on weak grids (including islands). Provision of primary reserves by kinetic energy of WT rotors, synthetic inertia by PE interfaced DER, PE based reactive power control, etc.
Contribution of WTs (Wind turbines) and PVs to system flexibility.	Contribution of WTs (Wind turbines) and PVs to system flexibility. Development of efficient controls for wind turbines and PV MPPT (Maximum Power Point Tracking) to take into account flexibility, reserve sharing, etc.

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

Type of Action: IA

Start/End Year: 2022-2029 **Indicative Budget:** 30M€

Expected Outcome

- Deployed holistic architectures which include hybrid AC/DC systems, smart transformers, energy routers and web of cells
- Energy router: Developing innovative and intelligent solutions to enable energy transfer (routing) between various AC and DC networks, also considering energy storage means, in order to increase flexibility, renewable sources (RES) integration and resilience of energy communities.

Scope

This PPC will develop the necessary control solution that support the development of hybrid grids in HV and MV. Goal is not to focus on new topology but on the development of the proper concepts that support interoperability and cooperation between converters operating in the DC and in the AC section of the system

Research Task	Description
Coordinated HVDC and HVAC network planning.	HVDC meshed grids. Optimisation algorithms for HVDC grids design based on different optimisation criteria (n-1 reliability criterion, loss of infeed risks, economic criteria, etc.) and parallel routing of DC and AC lines on the same tower or parallel paths to utilise existing infrastructure paths.
Flexibility in Transmission and Distribution Networks by Power electronics grid technologies (FACTS, FACDS, HVDC, etc.)	Increasing flexibility in transmission and distribution networks by flexible, power electronics grid technologies, such as FACTS, PSTs and HVDC links, smart transformers (power electronics OLTCs), open soft points, FACDS, and fault current limiters
Multi-terminal HVDC networks to coordinate power flows	Standardised HVDC multi-terminal networks to coordinate power flows among different regions and to connect off- and onshore Wind Power plants
Coordinated LVDC / MVDC and AC distribution network planning.	Planning of LV and MV DC industrial and residential grids. Added value of DC grids in integrating DER, incl. lower costs of BoS (Balance of System). Taking care for safety, especially in homes.

PPC 6.3: Next generation distribution substation

Type of Action: IA

Start/End Year: 2022-2029 **Indicative Budget:** 30M€

Expected Outcome

- Smart transformers providing flexible connection between MV and LV AC networks and enabling AC and DC microgrids at LV level
- Methods to facilitate portion of the distribution grid to work in islanding mode coordinated at substation level (AM)

Scope

This PPC will explore all the possible integration of power electronics in the substation or close to the substation to develop the concept of a flexible and programmable power grid in which the substation is a centre of intelligence that facilitate the optimal power routing

Research Task	Description
Protection of distribution networks with low fault currents, adaptive protection	Protection of distribution networks with low fault currents due to high penetration of RES interfaced DER
DC grid protection	DC grid protection, protection relays and breakers, multi-vendor solution with the consideration of interoperability, standardisation
Bottom-up restoration by DER and storage	Bottom-up restoration by DER support and storage including intentional islanding techniques via Microgrids and Web-of Cells approaches. Synchronisation of DER and storage reconnection.
Methods and tools for cyber security protection of grid infrastructures and functions	Methods and tools for cyber security protection of grid infrastructures to avoid injection of false data through physical installations, like primary and secondary substations, MV and LV lines, etc. Cybersecurity strategies for TSOs and DSOs

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

Type of Action: IA

TRL

Start/End Year: 2022-2029

Indicative Budget: 10M€

Expected Outcome

- Simulation analysis with new technologies; real-time analysis of new technologies with extensive power electronics; use of HIL (HW in the loop) simulation to validate new technologies; simulation at local level, national level, cross-border level and pan-European effects; preparation for risk-controlled field demonstrations
- Simulation of DER-provided flexibility for Distribution, under various scenarios, considering Total Expenditure (TOTEX) approach
- Exploring the role and impact of existing and emerging ICT for grid observability and controllability; using co-simulation techniques able to simulate ICT impact in power systems to ensure a reliable digitisation of pan European system

Scope

The growing presence of power electronics is radically modifying the dynamics of the power grids. This PPC will tackle the need of the new simulation tools that go beyond the classical separation between phasor simulation and electromagnetic

Research Task	Description
Advanced Training Simulations for system operators (e.g. Digital Twins)	Advanced Training simulators for DSOs and TSOs (e.g. using Digital Twins) in order to adapt to new Network Energy Management platforms (including multi-energy carrier systems).
Advanced HMI (Human-Machine-Interface)	Advanced MMI (Man-Machine-Interface) for Energy Management System control rooms at all voltage levels, provision of suitable indicators for resilience / vulnerability and other criteria to help network operators to make decisions for preventive and corrective actions. new digitalisation approaches like machine learning based data treatment procedures, AI supported renewable energy generation unit performance analysis and evaluation of existing infrastructure can be considered.
Digital Twin for energy systems	Digital Twin for energy systems development of digital twin based on BIM, including predictive maintenance algorithms through machine learning of the main assets within the different energy systems (primary and secondary substations, heat pumps, hydrogen cells, etc.)
Models and tools for converter driven stability	Models and tools for converter driven stability including fast interaction (dynamic interactions of the control systems of power electronic-based systems, e.g. DGs, HVDC, and FACTS with fast-response components of the power system, such as the transmission network, or other power electronic-based devices) and slow interaction (dynamic interactions with slow-response components, such as the electromechanical dynamics of synchronous generators phenomena.

PPC 7.1: Next generation of TSO control room

Type of Action: IA

Start/End Year: 2022-2029 **Indicative Budget:** 35M€

Expected Outcome

- Innovative sensors for the monitoring of power systems with the aim of an increased observability at all voltage levels.
- Validated prototypes of ICT-platform for real-time communication and data exchange among European TSO's.
- Regional WAMS applications operational in TSO's control rooms
- Validated tools for real-time estimation of intrinsic power system parameters (damping, system inertia, short circuit power in critical nodes…).
- Demonstrated techniques for early identification of critical situations and for the real time stabilisation of interarea oscillations in low inertia systems.
- Integration of distribution grids and dispersed generation data into the set of TSOs observable systems.
- Full observability of the European transmission grid based on phasor measurement linear/hybrid state estimation.
- Scalable hierarchical observability methods and systems enabling the utilisation of monitoring data at different geographical scale in a coordinated manner.
- Consolidated operational ICT-platforms for real-time communication and data exchange among European TSO's

Scope

System level automation is supposed to evolve to cope with the distributed characteristics of the generation and the active role of the loads. This PPC will define new architecture and solutions for the control room of the future. This PPC should also coordinate the work with 7.2 for a coherent TSO-DSO cooperation.

Resilient cyber secure architectures

Research Task	Description
Optimal Load Frequency Control	Optimal Load Frequency Control considering requirements for telecommunication infrastructures, latencies and reliabilities
Contribution of RES to primary voltage and frequency control	Contribution of RES to primary voltage and frequency control of power grids with emphasis on weak grids (including islands). Provision of primary reserves by kinetic energy of WT rotors, synthetic inertia by PE interfaced DER, PE based reactive power control, etc.
Self-healing techniques	Self-healing techniques at distribution level by automatic fault clearing procedures in automatic power system restoration

Load Shedding techniques	Efficient Load Shedding techniques and tools considering reactive power and voltage control
Advanced Training Simulations for system operators (e.g. Digital Twins)	Advanced Training simulators for DSOs and TSOs (e.g. using Digital Twins) in order to adapt to new Network Energy Management platforms (including multi-energy carrier systems).
Advanced MMI (Man-Machine-Interface)	Advanced MMI (Man-Machine-Interface) for Energy Management System control rooms at all voltage levels, provision of suitable indicators for resilience / vulnerability and other criteria to help network operators to make decisions for preventive and corrective actions.
Optimal maintenance scheduling of cross border interconnections	Tools and methodologies to organise the maintenance scheduling of interconnection minimising the impact on market prices
Optimal maintenance scheduling of hydropower and pumped-storage units.	Tools and methodologies to organise the maintenance scheduling of large hydro and pumped-storage units minimising the impact on market prices
Dynamic Line Rating (DLR)	Dynamic Line Rating (DLR) solutions in capacity calculations of transmission and distribution grids.
Equivalent models of aggregated network and system components	Development and validation of equivalent models of aggregated network and system components consisting of multiple technologies and potential energy carriers in different environments for energy system stability.
Methods and tools to analyse large-scale inter-area oscillations	Methods and tools to analyse large-scale inter-area oscillations. Dynamic stability in grids with multiple control systems
Methods and tools for cyber security protection of grid infrastructures and functions	Methods and tools for cyber security protection of grid infrastructures to avoid injection of false data through physical installations, like primary and secondary substations, MV and LV lines, etc. Cybersecurity strategies for TSOs and DSOs
Optimal maintenance scheduling of cross border interconnections	Tools and methodologies to organise the maintenance scheduling of interconnection minimising the impact on market prices

PPC 7.2: Next generation of DMS (Distribution Management Systems)

Type of Action: IA	TRL
Start/End Year: 2022-2029	**Indicative Budget:** 35M€

Expected Outcome

- Sensing technologies, automation and control methods integrated into monitoring, analysis and control architectures.
- Validated tools and software for the study of distribution grids with very low (no) inertia.
- Enhanced MV and LV supervision for distribution grids

Scope

With the evolving role of the DSO, also the architecture of the DMS is supposed to evolve and to consider new services and interfaces. This PPC will investigate new architectures and services for the DSO of the future. This PPC should also coordinate the work with 7.1 for a coherent TSO-DSO cooperation.

Resilient cyber secure architectures

Research Task	Description
Optimal distribution network configuration	Optimal distribution network configuration taking into account increased monitoring capabilities at distribution level, automatic LV and MV System Topology identification and day-ahead forecasting.
Risk and vulnerabilities for parallel use of legacy SCADA systems	Risk and vulnerabilities for parallel use of legacy SCADA systems (as a traditional means to provide remote supervisory and control)
Control centre architectures for distributed network control	Control centre architectures for distributed network control (e.g. Web-of-Cells and Microgrids) considering new sensors (e.g. fault detectors, voltage and current sensors in generation, storage, buildings, EVs, industry, etc) and also MV levels with limited bandwidths.
Flexibility provided by distribution network reconfiguration	Develop tools and methods to maximise the impact of Flexibility using distribution network reconfiguration
Optimal reconfiguration of distribution network	Optimal distribution network configuration taking into account increased monitoring capabilities at distribution level, automatic LV and MV System Topology identification and day-ahead forecasting.
Methods and tools for cyber security protection of grid infrastructures and functions	Methods and tools for cyber security protection of grid infrastructures to avoid injection of false data through physical installations, like primary and secondary substations, MV and LV lines, etc. Cybersecurity strategies for TSOs and DSOs

PPC 7.3: Next generation of measurements and GIS (Geographic Information System) for distribution grids

Type of Action: IA

Start/End Year: 2022-2029 **Indicative Budget:** 30M€

Expected Outcome

- Scalable hierarchical observability methods and systems enabling the utilisation of monitoring data at different geographical scale in a coordinated manner.
- Innovative data processing architectures and methods that enable advanced solutions for the increasing complexity of system development and operations.
- Big data analysis functions of real-time data streaming for system operation.
- ICT architectures for mass data communication and processing (Blockchain, Exchange Platforms)
- Use Smart meters for accessing its data directly by multiple actors, while preserving GDPR and contractual clauses
- Test results and proof of concept of AI technologies applied to estimation of indicators and completion of information necessary to operate the system (control systems and interfaces for market participant applications, demand pattern recognition, ...).

Scope

Data fusion is one of the key topics in the process of digitalisation of power grids. This PPC will investigate the new type of data associated to new measurement devices but also to other sources of information such as GIS to improve planning and operation of distribution grids. This PPC will investigate how these different sources of data can be integrated in the processes in a smooth way improving the on-line capability of planning and operating of DSO

Research Task	Description
Communication infrastructures for smart meter data	Communication infrastructures for smart meter data for close to real-time monitoring in critical zones at critical moments (including non-GNSS (Global Navigation Satellite System) systems for time synchronisation and timestamping, consideration of latency, loss of packets, and jitter in end-to-end communications.)
Secure use of public ICT infrastructures and IoT and GIS technologies for smart grid functionalities	Investigate the use of IoT and GIS technologies in TSO and DSO planning, asset management, operational and market activities.
Models and tools for remote maintenance	Tools and methodologies for Remote LV/MV maintenance operations using drones and other monitoring equipment

PPC 7.4: Wide area monitoring, control and protections

Type of Action: IA

Start/End Year: 2022-2031 **Indicative Budget:** 35M€

Expected Outcome

- Scalable hierarchical observability methods and systems enabling the utilisation of monitoring data at different geographical scale in a coordinated manner.
- Regional WAMS applications operational in TSO's control rooms
- On-line dynamic security assessment (voltage, frequency, angle) of interconnected power systems based on active distribution networks, inverter-based generation and loads acting as grid sensors and as integrated part of new network protection schemes

Scope

While Phasor Measurement Units have already emerged as a key measurement tool both at transmission and distribution level, the application in monitoring, control and protection that fully exploit the capability of the Wide Area approach are still limited. This PPC should develop innovative use cases to full exploit the potential of the technology

Research Task	Description
Steady State and Dynamic State Estimation of transmission systems	Steady State and Dynamic State Estimation of transmission systems using intelligent monitoring devices, like PMUs, intelligent sensors and data processing. (Distributed observability of the transmission system)
Increased Observability and State Estimation of distribution systems	Increased Observability and State Estimation of distribution systems (MV and LV) using smart meter consumer data. Advanced forecasting and data flow between DSOs and TSOs
Real-time observability of RES.	Real-time observability of RES (algorithms and tools) and improved forecasts for operational and planning purposes, including real time balancing
Wide Area Monitoring, Control and Protection Architecture for Transmission Systems	Wide Area Monitoring, Control and Protection Architecture for Transmission Systems: High-performance and high-speed communication infrastructure combined with sensing technologies, automation and control methods, also for critical situations.

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

Type of Action: IA

Start/End Year: 2022-2029 **Indicative Budget:** 30M€

Expected Outcome

- Quantify the value of interoperability between energy and transport sectors and develop corresponding strategies for cost effective decarbonisation of both energy and transport sectors
- Development of alternative decarbonisation strategies for transport sectors (electricity and hydrogen based) – (a) micro-mobility, public, fleet and private vehicles, (b) long on the ground transport (c) riverboats, sea-boats, (d) aviation
- Deployment strategies for rapid-charging infrastructure considering the impact on the energy system, including application of energy storage and hydrogen-based resources for electricity production.
- Development of full interoperability between energy and transport sectors through establishment of common standards, protocols and digital services.
- The PPC is expected to contribute to 2Zero Partnership

Scope

Assess alternative policy strategies for providing funding for decarbonisation of different transport sectors

Assessing the whole-energy system implications of alternative strategies for decarbonisation of transport sectors, including the impact on investment cost of conventional and low carbon generation, network infrastructure reinforcement and system operating costs, while meeting the carbon targets.

Assessment of the system value of smart electro mobility-based powertrain technologies (full electric vehicles, plug-in hybrids and hydrogen fuel cell-based vehicles), in providing control services at the local and national level through coordinated DSO/TSO control

Assessment of the degradation of EV batteries when providing different V2G based system services and corresponding costs

Assessment of the end-user perspective for different EV charging strategies, considering the costs and benefits related to provision of system services through smart EV charging and V2G

Explore the viability of developing offshore charging facilities for sea boats/vessels supplied by offshore wind, considering the energy system impacts.

Research Task	Description
Flexibility provided by Energy management of transport electricity networks (railway, metro, tramway, trolleybus, etc)	Methodologies for the optimal utilisation of the Regenerative Braking, the auxiliary consumptions as well electricity storage facilities (e.g. super capacitors)
Flexibility provided by smart EV charging and V2G	Distribution System operation to cater for the integration of massive integration of EVs with fast, very fast, and inductive recharge technologies. (Short-, medium- and long-term scenarios for the implementation of the adequate charging infrastructures, incl. battery swapping infrastructures

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

Type of Action: IA

Start/End Year: 2022-2029 **Indicative Budget:** 70M€

Expected Outcome

- Application of the concept of V2X (Grid, Home and/or Business) and energy storage technologies for enhancing security and resilience of energy system

Scope

Assessment the benefits of smart control of different charging infrastructures in providing various system services through connecting EVs to IoT concept.

Incorporation of uncertainties related to the provision of services by transport sector, specifically considering V2G concept from private, fleet and public vehicles

Assessment of the V2X based enhancement of resilience of supply in local areas, through making use of batteries in busses, taxies and fleet vehicles and energy storage technologies

Assessment of the benefits of fast-charging stations in providing security services to local district and national infrastructure

Research Task	Description
Distribution System Planning for the massive integration of EVs	Develop Methods and tools for Distribution System Planning aiming at the integration of EV. The tools should consider controllable charging process and different types of charging station as well Market Rules
Flexibility provided by Energy management of transport electricity networks (railway, metro, tramway, trolleybus, etc)	Methodologies for the optimal utilisation of the Regenerative Braking, the auxiliary consumptions as well electricity storage facilities (e.g. super capacitors)
Flexibility provided by smart EV charging and V2G	Distribution System operation to cater for the integration of massive integration of EVs with fast, very fast, and inductive recharge technologies. (short-, medium- and long-term scenarios for the implementation of the adequate charging infrastructures, incl. battery swapping infrastructures

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

Type of Action: IA

Start/End Year: 2022-2027 **Indicative Budget:** 20M€

Expected Outcome

- Inclusive market design
- Elaborate energy models and validate economic benefits
- Efficient sector integration
- Effective participation of multi-sector buildings
- Market participation related aspects: (pre-) qualification, communication, bid mechanisms
- Integration of Efficient carbon-neutral buildings
- Integration of building flexibility in distribution network operation
- Integration of Local Energy Communities, Districts and Smart Cities
- Improved flexibility assessment and forecast
- Integration of aggregated demand in the wholesale energy market and in the frequency ancillary services market
- Development of more accurate user profiles for holistic management of buildings
- The PPC is expected to contribute to Built4People Partnership

Scope

Creating the conditions for effective integration of renewable generation from multiple sectors in buildings and other individual or aggregated infrastructures leading to an increased share of RES in the energy system supported on digitalisation

Research Task	Description
Demand Flexibility provided by the residential sector	Models for demand flexibility provided by residential sectors equipped with smart appliances and storage
Business models for prosumers	Business models for prosumers providing ancillary services, including EV owners with bidirectional capabilities and storage units.
Business models for retailers and aggregators, ESCOs and energy communities	Business models for retailers and aggregators, ESCOs and energy communities, providing energy efficiency at end-user level and participating in the wholesale market

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

Type of Action: IA

Start/End Year: 2022-2029 **Indicative Budget:** 50M€

Expected Outcome

- Efficient heating and cooling for buildings, districts and industries
- Efficient Management of Thermal Storage
- Design and test adequate control mechanisms and ICT enables for integration of RES in buildings (namely H&C) and buildings integration in the energy system
- Methods and tools to support prosumers and industries to adapt behaviours (measurements, dynamic tariffs)
- Provision of flexibility from buildings (including thermal storage) and smart communities to system operators
- ICT related aspects: connection of buildings to the power system, communication requirements Integration of heterogeneous flexibility in one platform
- Test flexibility from energy-intensive industries
- Resilience support to the grid and system (e.g., extreme events)
- Microgrid efficient integration
- Develop flexibility mechanisms (support to System Operators) from building level to Community and Smart City level
- Integration of VPP/VPS (logic aggregation of demand/prosumers)
- Use AI and digital twins for demand flexibility assets
- Peer-2-peer mechanisms
- Effective Home Energy Management System (HEMS) – monitoring and control
- Exchange of information with HEMS
- ICT related aspects: connection of buildings to the power system, communication requirements
- Integration of heterogeneous flexibility in one platform
- Device monitoring and control, seamless communication between devices, communications, demand response, data management, security and privacy, consumer interface, EV integration, centralised vs distributed management
- Interfaces with DSO and ESCOs

Scope

Design and test advanced control methods and enabling technologies to integrate multi-sector generation, ensuring the provision of needed flexibility from individual or aggregated heating and cooling networks, buildings, local communities, benefiting from energy system digitalisation

Demonstrate effective and efficient management (e.g., via HEMS and BMS) of connected and stand-alone (island) buildings, living quarters, businesses and industries, communities supplied by RES, enabling sector coupling and storage components (P2X, X2P)

Research Task	Description
Demand Flexibility provided by the residential sector	Models for demand flexibility provided by residential sectors equipped with smart appliances and storage
Demand Flexibility provided by the industry	Models for demand flexibility provided by integrated energy-intensive industries (e.g. steel production) and bulk energy storage (P2G, CAES, LAES, etc.).
Flexibility potential from aggregated heating (and cooling) storage at household / building / industrial level	Flexibility potential from aggregated heating (and cooling) storage at household / building / industrial level to provide system services (balancing). Power-to-heat technologies, like heat pumps, heat boilers, etc.
Methods to support consumers' and prosumers' adaptation of energy behaviour including Energy Communities	Models for demand flexibility provided by residential sectors equipped with smart appliances and storage
Methods and tools to support the industry's consumption adaptation	Models for demand flexibility provided by integrated energy-intensive industries (e.g. steel production) and bulk energy storage (P2G, CAES, LAES, etc.).
Microgrids in islanded mode of operation.	Stability and control of AC, DC and Hybrid Microgrids in islanded mode of operation.

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

Type of Action: IA

Start/End Year: 2022-2029 **Indicative Budget:** 30M€

Expected Outcome

- Stabilisation of weak grids and microgrids
- (Intended) Islanding mode of operation
- Black start capabilities
- Improved forecasting (including behind-the-meter aspects)
- Net load forecasting
- Aggregated forecasting

Scope

Design and test energy models with multi-sector buildings, infrastructures and communities, through enhanced forecasting and analytics techniques and understanding of behaviour of individual and aggregated loads and local generation, ensuring resilient integration of multiple infrastructures, including microgrids, VPPs and VPSs and resulting grid stability

Enable and demonstrate the contribution of distributed infrastructures and communities to the system resilience, recovery and robustness throughout extreme events, both cyber and physical

Research Task	Description
Energy models of the whole energy system development	Model of the energy system including all major energy carriers, encompassing the whole energy chain from prosumers, energy communities, e-transportation, distribution and transmission grids (LV, MV, HV), national and regional electrical and gas exchange, with clear boundary interaction.
Planning distribution networks considering citizen energy community needs	Planning distribution networks considering citizen energy community needs. Considering Citizen energy communities, with energy management systems for local multi-energy streams operation, including electrical-storage, P2x generation and storage, and x2P (including CHP based on hydrogen with all different hydrogen technologies).
Optimally located, sized and coordinated battery energy storage	Optimally located, sized and coordinated electric energy storage at different voltage levels in the power system (for fast and slow power response; for future ancillary supplementary services in the storage facility such as inertia support).
Distribution System Planning for the massive integration of DG	Develop Methods and tools for Distribution System Planning aiming at the integration of DG and RES. The tools should consider controllable DG and Market Rules
Distribution System Planning for the massive integration of EVs	Develop Methods and tools for Distribution System Planning aiming at the integration of EV. The tools should consider controllable charging process and different types of charging station as well Market Rules

5. BUDGET FOR THE ETIP SNET R&I IMPLEMENTATION PLAN 2022-2025

The proposed budget per PPC is presented in the next Figure (in M€). In this figure, "x" refers to the HLUC x. The part of the bars with reference "1" refers to PPC x.1, "2" to PPC x.2, etc.

Budget per PPC (in Million €)

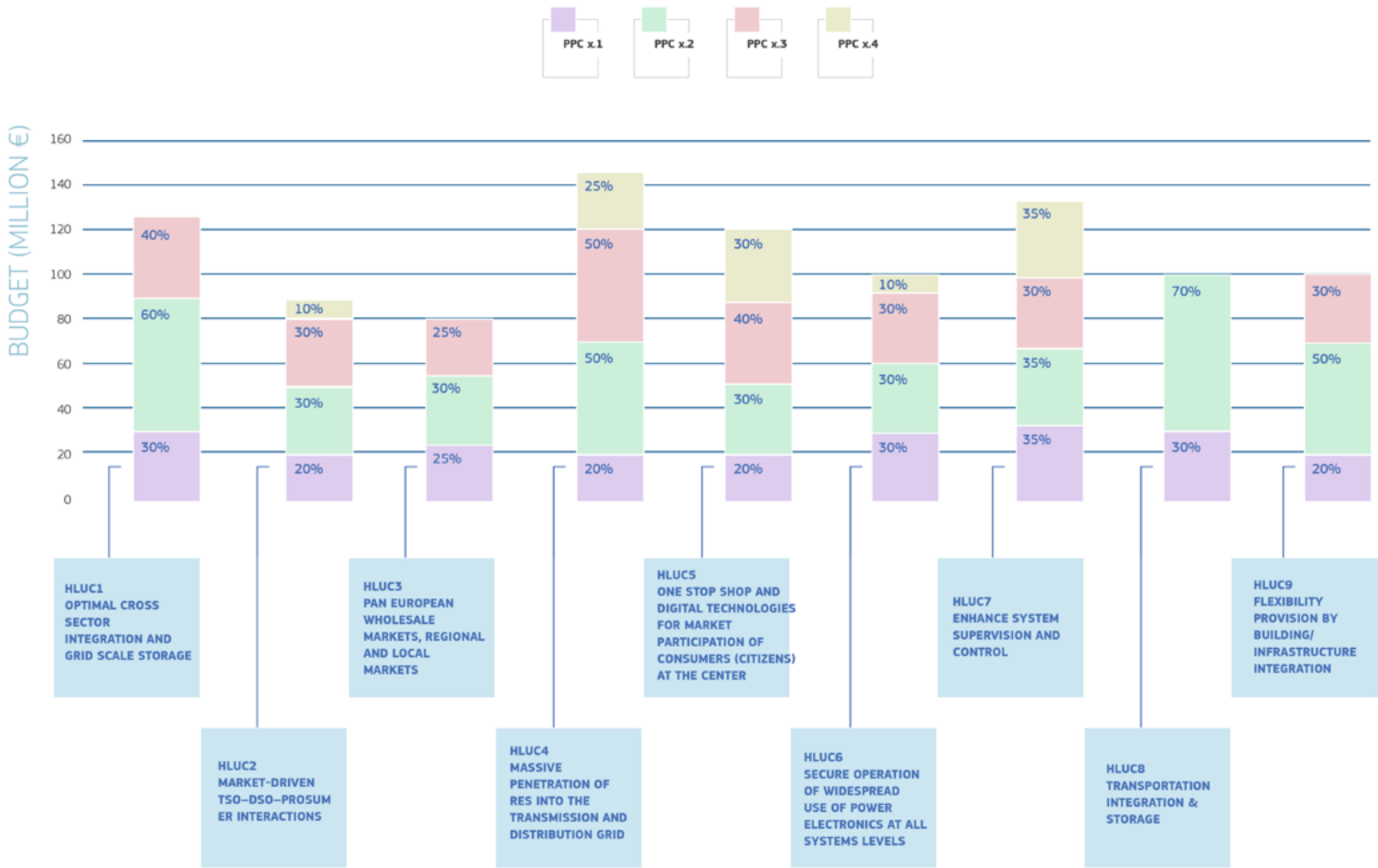

Figure 4: Budget per PPC (in Million €)

An indicative assessment of the budget distribution of Clusters 4 and 5 of the Work Programme 2021-2022 of Horizon Europe to the HLUCs is provided in ANNEX II for comparison.

Budgets for PPC in the period 2022-2025 (in tabular format):

	HLUC 1: Optimal Cross sector Integration and Grid Scale Storage	HLUC 2: Market-driven TSO–DSO–System User interactions	HLUC 3: Pan European Wholesale Markets, Regional and Local Markets	HLUC 4: Massive Penetration of RES into the transmission and distribution grid	HLUC 5: One stop shop and Digital Technologies for market participation of consumers (citizens) at the centre
PPC x.1	40M€	20 M€	25 M€	20 M€	20 M€
PPC x.2	60 M€	30 M€	30 M€	50 M€	30 M€
PPC x.3	30 M€	30 M€	25 M€	50 M€	40 M€
PPC x.4		10 M€		25 M€	30 M€

Budgets for PPC in the period 2022-2025 (in tabular format):

	HLUC 6: Secure operation of widespread use of power electronics at all systems levels	HLUC 7: Enhance System Supervision and Control including Cyber Security	HLUC 8: Transportation Integration & Storage	HLUC 9: Flexibility provision by Building, Districts and Industrial Processes
PPC x.1	30 M€	35 M€	30 M€	20 M€
PPC x.2	30 M€	35 M€	70 M€	50 M€
PPC x.3	30 M€	30 M€		30 M€
PPC x.4	10 M€	35 M€		

GLOSSARY AND ACRONYMS

Active Demand (see Demand Side Response)

Advanced Meter Management (AMM): software that performs long-term data storage and management for the vast quantities of data delivered by smart metering systems.

Advanced Metering Infrastructure (AMI): is an integrated system of smart meters, communications networks, and data management systems that enables two-way communication between utilities and customers.

Aggregator: Data Responsible who aggregates according to a defined set of market rules, e.g. of power generating modules, demand units and/or reserve providing units.

Alternating current (AC): an electric current which periodically reverses direction.

Ancillary services: a service necessary for the operation of an electricity transmission or distribution system to support the electric power from seller to purchaser given the obligations of control areas and to maintain reliable operations of the interconnected electricity system.

Application Program Interface (API): is a set of routines, protocols, and tools for building software applications. Basically, an API specifies how software components should interact. Additionally, APIs are used when programming Graphical User Interface (GUI) components.

Artificial Intelligence (AI):Algorithms emulating the intelligence of human brain

Asset: an asset is something valuable or useful. Tangible assets are fixed such as buildings, equipment etc.; an asset is part of a TSO operator control area or located in a distribution system.

Balance Responsible Party (BRP): means a market participant or its chosen representative responsible for its imbalances in the electricity market.

Balancing Service Providers (BSP): in the European Union Internal Electricity Market, this is a market participant providing balancing services to its Connecting TSO, or in case of the TSO-BSP Model, to its Contracting TSO.

Blockchain: a system in which a record of transactions made in bitcoin, or another cryptocurrency are maintained across several computers that are linked in a peer-to-peer network.

Carbon-neutral: situations where the energy system consumes as much CO_2 as it emits; the CO_2 balance is equal to zero.

Capital Expenditures (CAPEX): budget spent to buy or upgrade fixed assets

Citizen: use for people who value the development of smart grids as an opportunity to realise "We-centred" needs or motivations, e.g. affiliation, self-acceptance or community. Citizens want to help ensure the quality of supply and support environmental preservation and the community.

Cogeneration: simultaneous production of electricity and useful heat. In a regular power plant, the heat produced in the generation of electricity is lost, often through the chimneys. But in a cogeneration plant it is recovered for use in homes, businesses, and industry. A tri-generation plant, or Combined Cooling, Heat and Power (CCHP), produces cooling (air conditioning) as well as heat and electricity.

Combined Heat and Power (CHP): is an energy efficient technology that generates electricity and captures the heat that would otherwise be wasted to provide useful thermal energy—such as steam or hot water—that can be used for space heating, cooling, domestic hot water and industrial processes.

Common information model (CIM): is an open standard that defines how managed elements in an IT environment are represented as a common set of objects and relationships between them.

Consumer: Role of the energy user for electricity, heat and chemical energy (e.g. gas) classified in industrial consumers, consumers providing transport systems, consumers for a commercial entity or commercial building and residential consumers.

Contingency: an event (such as an emergency) that may but is not certain to occur. In power systems, a contingency is when an element such as a transmission line or a generator, or the electric grid fails.

Conversion technology (-ies): any system that converts energy from one form to another (e.g. electricity, heat, work, and motion).

Customer / End-user: an end-user of energy.

Cybersecurity: all mechanisms and processes for guaranteeing the integrity of the operation of computer systems in the event of attacks and malfunctioning.

Demand side flexibility: The capacity to change electricity usage by end-use customers (including residential) from their normal or current consumption patterns in response to market signals, such as time-variable electricity prices or incentive payments, or in response to acceptance of the consumer's bid, alone or through aggregation, to sell demand reduction/increase at a price in organised electricity markets or for internal portfolio optimisation.

Demand Side Response (DSR) / Active Demand: is a change in the power consumption of an electric utility customer to better match the demand for power with the supply. It is the capacity to change electricity usage by end-use customers (including residential) from their normal or current consumption patterns in response to market signals, such as time-variable electricity prices or incentive payments, or in response to acceptance of the consumer's bid, alone or through aggregation, to sell demand reduction/increase at a price in organised electricity markets or for internal portfolio optimisation

Digital twin: refers to a digital replica of physical assets, processes and systems that can be used for various purposes e.g. simulation and modelling. The digital representation provides both the elements and the dynamics of how an Industrial Internet of Things device operates and lives throughout its life cycle including continuous digital predictions through machine learning and artificial intelligence.

Direct current (DC): is the unidirectional flow of electric charge.

Distributed system: systems that are installed at or near the location where the electricity is used, as opposed to central systems that supply electricity to grids. A residential photovoltaic system is a distributed system.

Distribution/Transmission System Operators (DSO/TSO): role for operating distribution/ transmission grids of electricity supply, who plans, builds and maintains distribution/transmission infrastructure responsible for grid access and integration of renewables, grid stability, load balancing and connections to grid users (generators and consumers) at distribution/transmission grid level. Furthermore, a DSO/TSO is responsible for its interconnections with other systems and to ensure the long-term ability of the system to meet reasonable demands for the distribution/transmission of electricity or gas.

Electric Vehicle (EV): A vehicle equipped with electric motor for propulsion.

Electromagnetic Fields (EMF): An electromagnetic field is created by moving electric charges

End-user (see Consumer)

Energy Community / Citizen energy community / Local Energy Community (LEC): a legal entity where citizens, SMEs and local authorities come together, as final users of energy, to cooperate in the generation, consumption distribution, storage (such as batteries, hot water, (CO_2-neutral or free) gases), supply, aggregation of energy from renewable sources, or offer energy efficiency/demand side management services.

Energy Management Systems (EMS): A modular system that manages power stations and the network

Energy storage: system domain for appliances and assets storing energy within the group energy consuming units

Energy systems: electricity, gas, heating and cooling, liquid fuel systems, and other energy carriers (any system or substance that contains energy for conversion as usable energy later) are all considered "energy systems".

European Telecommunications Standards Institute (ETSI) Flexible AC Transmission / Distribution Systems (FACTS/ FACDS): is a system composed of static equipment used for the AC transmission / distribution of electrical energy. It is meant to enhance controllability and increase power transfer / distribution capability of the network. It is generally a power electronics-based system.

Functionality: range of impacts suited to achieve a specific purpose.

Gas to Heat (GtH): combustion of gases to generate heat.

Gas to Power (GtP): combustion of gas to generate electricity.

Gas to Power and Heat (GtP&H): combustion of gases to generate at the same time and with high efficiency electricity and heat.

General Data Protection Regulation GDPR: (EU) 2016/679 (GDPR) is a regulation in EU law on data protection and privacy in the European Union (EU) and the European Economic Area (EEA). It also addresses the transfer of personal data outside the EU and EEA areas.

Green gas: is gas derived from the processing of organic waste or is hydrogen produced by renewable electricity from water.

Geographic Information system (GIS): framework for the management and analysis spatial and geographic data

Grid to vehicle (G2V): smart charging of s (see Smart Charging).

Hierarchical control: is a form of control system in which a set of devices and governing software is arranged in a hierarchical tree.

High Level Use Case (HLUC): A HLUC represents the practical realisation-related dimension to achieve the integrated energy system needs of the year 2031

High voltage (HV): usually considered any AC voltage over approximately 35,000 volts.

Holistic Architecture: Holistic energy system architectures facilitate all processes which are necessary for a reliable, economic and environmentally- friendly operation of integrated smart energy systems with multiple energy carriers, having electricity grids as its backbone.

Information technology (IT): is the use of computers to store, retrieve, transmit, and manipulate data or information.

Institute of Electrical and Electronic Engineers (IEEE): here intended as standardisation body.

International Electrotechnical Commission (IEC): here intended as standardisation body.

Internet of Things (IoT): is a system of interrelated computing devices, mechanical and digital machines provided with Unique Identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.

Interoperability: the ability of two or more networks, systems, devices, applications, or components to interwork, to exchange and use information in order to perform required functions.

Levelised Cost Of Electricity (LCOE): is a measure of a power source that allows comparison of different methods of electricity generation on a consistent basis. The LCOE can also be regarded as the minimum constant price at which electricity must be sold in order to break even over the lifetime of the project.

Liquid to Power (LtP): Combustion of liquid fuel to generate power.

Load Frequency Control (LFC): is used to allow an area to first meet its own load demands, then to assist in returning the steady-state frequency of the system to the nominal value.

Load shifting: shifting large electrical loads from high-demand peak times to times where generation and shifted load match better.

Low-carbon: situation where the CO_2 balance (i.e. emissions vs sinks) is almost zero.

Low voltage (LV): usually refers to AC voltages from 50 volts to below 1,000 volts.

Machine to Machine (M2M): is direct communication between devices; it can include industrial instrumentation, enabling a sensor or meter to communicate the information it records to application software that can use it.

Machine Learning (ML): the scientific study of algorithms and statistical models that computer systems use to perform a specific task.

Medium voltage (MV): usually refers to AC voltages between 1,000 volts to 35,000 volts.

Multi-access Edge Computing (MEC): a network architecture concept that enables cloud computing capabilities and an IT service environment at the edge of the cellular network and, more in general at the edge of any network.

Near Zero Energy Building (NZEB): a building with zero net energy consumption, meaning the total amount of energy used by the building on an annual basis is equal to the amount of renewable energy created on the site or in other definitions by renewable energy sources offsite.

Net Transfer Capacity (NTC): the maximum total exchange program between two adjacent control areas compatible with security standards applicable in all control areas of the synchronous area and taking into account the technical uncertainties on future network conditions.

On load tap changer (OLTC): is a tap changer in applications where a supply interruption during a tap change is unacceptable.

Operational Expenditures (OPEX): OPEX is the cost for operating a product, business, or system

Organic Rankine Cycle (ORC): is a type of power plant using, instead of conventional (water/steam) an organic, high molecular mass fluid with a liquid-vapor phase change, or boiling point, occurring at a lower temperature than the water-steam phase change.

Overhead Transmission (OT): Electric power transmission through overhead power lines

Phasor Measurement Unit (PMU): is a device used to estimate the magnitude and phase angle of an electrical phasor quantity (such as voltage or current) in the electricity grid using a common time source for synchronisation

Phase Shifting Transformer (PST): is a specialised form of transformer used to control the flow of active power on three-phase electric transmission lines.

Point of Common Coupling (PCC): the point at which the interconnection between the public utility's system and the interconnection customer's equipment interface occurs.

Power Electronics (PE): is the application of solid-state electronics to the control and conversion of electric power.

Power Quality (PQ): involves voltage, frequency, and waveform. Good power quality can be defined as a steady supply voltage that stays within the prescribed range, steady AC frequency close to the rated value, and smooth voltage curve waveform (resembles a sine wave).

Power system stability: is the ability of an electric power system, for a given initial operating condition, to regain a state of operating equilibrium after being subjected to a physical disturbance, with most system variables bounded so that practically the entire system remains intact.

Power to Gas (PtG): conversion of electrical power to a gas fuel. As an example of such conversion, electricity is used to split water into hydrogen and oxygen using the electrolysis principle, where hydrogen can then be converted to methane with CO_2 as input.

Power to Heat (PtH): conversion of electrical power into heat/cooling. The conversion can be done for example by using conventional electric heaters or heat pump systems.

Power to Gas and Heat (PtG&H): conversion of electrical power to both gas and heat/cooling at the same time.

Power to Liquid (PtL): process consisting in generating a synthetic liquid fuel by using renewable electricity, carbon dioxide from the atmosphere or other sources, and water.

Power to Water (PtW): use of electrical power to pump water into higher-up hydro reservoirs and hydro dams for energy storage.

Priority Project Concept (PPC): Projects covering all integration features of the Future Energy Systems with concrete goals and time schedule.

Prosumers: consumers of all types (households, tertiary, industry, transport and agriculture sectors) who also produce energy. Prosumers can be active market participants by engaging in the real-time control of their energy-consuming and producing devices.

Reliability: all the measures of the ability of the system, generally given as numerical indices, to deliver electricity to all points of utilisation within acceptable standards and in the amounts desired.

Renewable Energy Sources (RES): energy derived from natural processes that are replenished constantly. In its various forms, it derives directly from the sun, or from heat generated deep within the earth. Included in the definition are electricity and heat generated from solar, wind, ocean, hydropower, biomass, geothermal resources, and biofuels and hydrogen derived from renewable resources.

Resilience: ability of the system with generating sources, transmission and distribution, conversion – to withstand high-impact, low-frequency events. This includes events that are natural, such as hurricanes or ice storms, as well as man-made, such as cyber or physical attacks on e.g. grid infrastructure.

Scalability: capability of being easily expanded as larger service or more powerful product, e.g. to include more participants, a higher load or more RES

Security of Supply: the capability of a power system at a given moment in time to perform its supply function in the case of a fault

Small And Medium size Enterprise (SME): Enterprises with less than 50 employees and less than 50M€ turnover.

Smart Charging: charging system where electric vehicles, charging stations and charging operators share data connections. Through smart charging, the charging stations may monitor, manage, and restrict the use of charging devices to optimise energy consumption.

Smart Grid: an electricity network that can intelligently integrate the actions of all actors connected to it – operators of storage capacity (such as of batteries, (CO_2-neutral or free) gases and liquids), generators and consumers – in order to efficiently deliver sustainable, economic and secure electricity supplies (European Technology Platform SmartGrids, 2010).

Smart Metering: the technology of recording usage in real time from metering devices and providing a two-way communication and/or control path extending from energy network to customer appliances

Smart Transformer / Solid State Transformer / Intelligent Transformer: a power transformer which transfers power between power networks at two voltage levels (usually corresponding to MV and LV levels) by using power electronics ("solid state") and an internal power transformer operating at high frequency; it has usually also internal DC busbars, possible extensions of electrical energy storage and has local control which allows a flexible and smart power exchange between the two power grids. Smart Transformers are considered as an enabling technology in the future distribution grids.

State of Health (SoH): is a figure of merit of the condition of an asset, e.g. a battery (or a cell, or a battery pack), compared to its ideal conditions

Subsidiarity: The subsidiarity principle means that energy systems are operated in such a way that actions are optimised locally (at the most immediate level). Actions that cannot be handled locally are handled at the next level.

System architecture: a set of conventions, rules, and standards employed in a computer system's technical framework, plus customer requirements and specifications, that the system's manufacturer (or a system integrator) follows in designing (or integrating) the system's various components (such as hardware, software and networks).

Ten Years Network Development Plan (TYNDP): provides an overview of the European electricity transmission infrastructure and its future developments and maps the integrated network according to a range of development scenarios.

TOTal EXpenditures (TOTEX): CAPEX (Capital Expenditures) + OPEX (Operational Expenditures)

Transmission System Operators (TSO): see DSO / TSO

Vehicle to grid (V2G): feeding power and energy from the vehicle battery to the grid at the connection point.

Virtual power plant (VPP): is a cloud-based distributed power plant that aggregates the capacities of heterogeneous distributed energy resources (DER) for the purposes of enhancing power generation, as well as trading or selling power on the electricity market.

Vulnerability: the openness to attack or damage.

Water to Power (WtP): is power derived from the energy of falling or fast-running water; in the future also from waves.

Web of cells (energy cell): compound comprehensive smart energy systems with subsidiary structures on the basis of decentralised generation and storage as well as decentralised, automated energy management in autonomously steered energy systems, which are able to run temporarily autarkic, e. g. in the case of failures.

Wide Area Measurement System (WAMS): is technology to improve situational awareness and visibility within power system of today and future grids. It uses real time synchro phasor data to measure the state of grid that enables improvement in stability and reliability of power grid.

ANNEX I - RESEARCH AREAS (RA), RESEARCH TOPICS AND RESEARCH TASKS

This Annex describes an update of each of 24 RESEARCH TOPICs, already presented in the previous ETIP SNET R&I Implementation Plan 2020-2023 and the ETIP SNET R&I Roadmap 2020-2030.

It provides for each TOPIC:

- **CHALLENGE**: WHY is this TOPIC needed, what is lacking today and what is needed.
- **SCOPE**: the extent to which the TOPIC is relevant and what key OUTCOMES shall be produced.
- **The list of research tasks** that shall be investigated in R&I projects.
  - The 1st column indicates the relative number of the task (relative to the TOPIC Number). The background colour of the 1st column indicates the Task-TRL-maturity where:

(red)	**Research**	- TRL 3-5
(yellow)	**Demonstration**	- TRL 6-8
(green)	**Deployment**	- TRL 9

  - The 2nd column describes the task.
  - The 3rd column describes the PPC (Priority Project Concept). The task shall be investigated as a high priority activity in R&I projects belong to this (PPC-based) family of projects.

The following 24 Research TOPICs are organised by 6 Research Areas (RA). Each TOPIC includes several TASKS.

RA 1: CONSUMER, PROSUMER and CITIZEN ENERGY COMMUNITY

TOPIC 1.1: Social campaigns and social studies (related to societal acceptance and environmental sustainability of energy infrastructure)

CHALLENGE

The target of at least 32% of renewable energy in gross final energy consumption in 2030 relies on measures to facilitate the participation of citizen in the energy transition. In the process of acceptance of the integration of variable Renewable Energy Sources (vRES), social and environmental aspects must be considered at all levels.

The transition of societal needs from today's energy system towards the future energy system need to be analysed: Societal studies and social campaigns are needed which include the citizens in the decisions process since their very beginning. In parallel, the current energy infrastructures do not consider yet environmental sustainability such as related to human and animal exposure to EMF and 5G effects. R&I efforts are needed to reduce negative environmental effects e.g. of hydropower plants, windmills, HV infrastructure.

The integration of vRES needs communication campaigns to increase public awareness, acceptance and engagement regarding the building of energy communities and the process of construction of energy infrastructures; the reduction of impacts of the energy infrastructure on the environment and on wildlife; and efforts to put the end-user (customer) at the centre of the energy system.

SCOPE

The TOPIC shall include, as a basis of further works, social studies fostering societal acceptance and environmental sustainability of energy infrastructure.

Social acceptance and environmental sustainability are key elements to foster the integration of variable Renewable Energy Sources (vRES). Some examples are:

- the overhead line of 132 kW design and construction connecting the South of Cyprus to the mountains of Cyprus replacing an older line that has long passed its useful life. The study initiated in 1991 and to this day the line remains incomplete due to public reaction in an area affecting 3 mountain communities. About 80% of the line is complete but in between the two constructed sections there is approximately 20% of the line still pending, and currently operating using the old insecure link running through inhabited areas.
- the delay in the construction of a 400 kV HV line in Southern Greece, necessary to transfer the energy produced by a new natural gas 417 MW thermal station, one of the largest in the country enough to supply 400.000 households. The operation of this modern unit would benefit the Greek economy about € 40 mln annually, i.e. € 110 k daily, thanks to the excellent efficiency rate of the unit and would have important positive environmental effects by avoiding the operation of older, polluting thermal units. The completion of just a few kilometres of the line construction was delayed for several months due to local reactions. The financial losses caused by the delayed operation were more than doubled considering that assets of the €400 mln investment were stranded and the compensations requested by the project contractor.

Social studies shall be conducted to promote stakeholder engagement and acceptance through the involvement of final users. Specific methodologies shall be developed to identify the best practices between the different energy communities, to implement participative decision-making process and support public debates. In parallel, suitable studies shall be set to analyse how to minimise environmental effects of energy infrastructures, harmonise environmental authorisation at EU level, etc. Key indicators shall be identified to measure both the degree of social acceptance and environmental impacts. Specific demonstrations shall be developed to enhance the microgrid-by-design concept to strengthen Citizen Energy Communities for increased grid stability and reduced energy poverty.

The following tasks shall be investigated in R&I projects:

Task No	Tasks	PPC
1	Increase Customer awareness and acceptance of energy systems	5.1
2	Studies to reduce or remove the environmental impacts of energy infrastructures (visual, audible, etc.),	5.1

RA 1: CONSUMER, PROSUMER and CITIZEN ENERGY COMMUNITY

TOPIC 1.2: Adaptive consumer/user behaviour incl. energy communities (Interaction, incentives by dynamic tariffs)

CHALLENGE

In 2030, local and regional demonstrations of Active Demand Response shall be implemented relying on the evolution of the relationship between the consumer and prosumers and the energy system. This change of behaviour is needed to strengthen interactions between citizen energy communities and the energy system. In the process of active participation of the consumer, all means of measurements of electricity and other energy consumptions, user participations and motivations must be explored and evaluated.

The present relationship of the consumer and prosumer with the energy system does not address the integration needs to change society characterised by a progressively increase of environmental and sustainability consciousness that triggers behavioural changes. There is a lack of consideration of sustainable mobility choices, corporate responsibility and transparency, distributed renewables integration, demand response by the user, energy and water conservation measures, neighbourhood comparison and related rewards, etc. In terms of hardware and software answers, there is a lack of solutions that enable consumers, prosumer and communities to make informed and as easy as possible decisions for creating their own comfort, sustainability and security needs, considering budgetary restrictions, market-based prices and regulated tariffs.

The relationship evolution of the consumer and prosumers needs to rely on tools and knowledge for the active participation of prosumers in electricity markets, for the consumer satisfaction by energy services, and for the complete behaviour motivations of the customers to contribute to the functioning of integrated energy systems.

SCOPE

This TOPIC shall include, as a basis for further works, comprehensive guidelines to define the level of interactions between the consumer, prosumer, energy communities and energy system as well as clear incentives by dynamic prices, regulated tariffs and other market incentives.

Interactions between consumers, prosumers and energy communities shall be clearly specified to foster participation in electricity markets. Tools shall be developed for putting the end user in direct contact with supplier, distributor and other involved market stakeholders and to increase consumer satisfaction. Dedicated demonstrations shall be set to demonstrate real-time optimisation of Distributed Energy Resources and to increase the understanding of consumer's behaviour providing direct action on demanding asset in real-time through dynamic energy management mechanisms.

The following tasks shall be investigated in R&I projects:

Task No	Tasks	PPC
1	Methods to support consumers' and prosumers' adaptation of energy behaviour including Energy Communities	5.1, 9.2
2	Methods and tools to support the industry's consumption adaptation	5.1, 9.2

RA 2: SYSTEM ECONOMICS

TOPIC 2.1: Business models (including Aggregators)

CHALLENGE

The value chain of energy production and supply is changing with the entrance of new actors and elements. The new structure should fit with the new demands based of decentralised generation, electric devices and appliances, or storage requirements realised by e.g. batteries, hot water tanks, low-cost containers for CO_2-neutral or free gases and liquids), where both customers and end-users are playing a fundamental role.

New Business models for the different (traditional and new) stakeholders are urgently needed. They must be simulated and analysed. Today's market rules for the transition towards the future energy system should evolve further to enable more effective markets and to enhance the transition to a decarbonised energy system and economy.

Today (2021) - in some European Countries, not all renewable, demand and storage resources are fully enabled to participate in the balancing services market[4].

In some countries in Europe flexibility trading in the true meaning of the function, is still in its infancy. Moreover, smart charging of EVs is not included in market rules and the connected grid is still not smart enough to utilise this huge potential.

The changes in the value chain of energy production and supply, due to the entrance of new actors, technology and elements, needs to be managed, to fit the existing structure to the new demands. Standardised templates and tools to develop CBA in the smart grids' projects need to be developed and extensively used, together with the definition of new regulatory frames, ensuring equitable and fair participation and competition possibilities to all the stakeholders.

[4] the_smarten_map_2020_DIGITAL.pdf

SCOPE

This TOPIC addresses the development and analysis of business models, for the different actors in the energy system playground, namely prosumers, aggregators, DSOs, storage operators (such as of batteries, heating/cooling storage, including EV recharge, EV smart charging) and heating/cooling operators.

Business models shall be developed and analysed for all the different stakeholders of the energy value chain; particular focus shall be devoted to actors in LV/MV systems (e.g. DSO, aggregators and retailers, prosumers), to storage operators and to electric mobility actors, all providing ancillary services to the network, to operators in the energy efficiency sector, to operators in the heating/cooling sector.

The following tasks shall be investigated in R&I projects:

Task No	Tasks	PPC
1	Business models for retailers and aggregators, ESCOs and energy communities	5.1, 9.1
2	Business models for prosumers	2.2, 9.1
3	Business models for data analysis service and platform providers	2.3, 3.3

RA 2: SYSTEM ECONOMICS

TOPIC 2.2: Centralised Markets

CHALLENGE

Increased shares of variable renewable energy, combined with the rise in distributed generation, are profoundly impacting on electricity markets, the demand for system flexibility and the business models of traditional utilities and distribution companies. This requires rethinking of the way power sector markets are designed and operated as well as a timely and efficient adaptation of traditional market and operational mechanisms

The full integration - Europe wide - of intra-day and balancing markets is not yet fully implemented with a swift adaptation of network codes and increased cooperation across national borders. In some cases, demand does not yet have equal market access as supply resources. They lack access to markets (forward, day-ahead, intra-day and balancing markets) to offer their services, provided they fulfil the criteria needed for these sometimes very specific markets. The roles and responsibilities of all market parties are not yet clearly defined for a flexibility market design and for smooth functioning and security of supply.

Prosumers are not yet supported by stable, transparent and enabling regulatory frameworks. They cannot carry responsibilities e.g. for balancing, moreover, they do not yet bear network costs reflecting the services they receive from the public infrastructure, unable to ensure a fair allocation of costs between all consumer groups.

An integrated EU energy market needs to be a priority, it will ensure secure and affordable energy supplies to European citizens and businesses: therefore, common energy market rules, communication standards and protocols and cross-border infrastructure need to be designed and established. Fair competition must be guaranteed to all stakeholder in the energy supply chain, together with provisions to attract investment in resources, like energy storage, not only batteries, but also hot water tanks, containers for CO_2-neutral or free gases and liquids, that can compensate energy production variability. The markets must provide the right incentives to consumers becoming active and to contribute to the stability of the electricity system, as well as fair remuneration of ancillary services.

SCOPE

This TOPIC addresses the tasks needed for the design of energy markets at all time scales and at all geographical scales, from the pan-European cross-border wholesale electricity and gas markets, products, services and businesses, down to local, neighbourhood, aggregated, retail, peer-to-peer market of energy products and services (flexibility, ancillary services, electricity, gas and heating/cooling, etc.).

Detailed analyses and studies shall be conducted of new services which could arise in conjunction with the new aspects introduced by the Clean Energy for All Europeans Package. Standard pan-European ICT platforms shall be defined to allow the interaction of the different actors in the process of acquisition of both local and cross-border ancillary services. Customer's segmentation and clustering shall be carefully analysed, in order to fully unlock the peer-to-peer transactions for energy and flexibilities.

Providing a reference implementation and architecture will facilitate the digitalisation process for all operators. A standard solution will dramatically facilitate the implementation of innovative services for customer involvement.

The market design shall be developed allowing flexible coordination between TSO and DSO, considering physical grid constraints, ancillary services and uncertainties, at the same time addressing the social welfare for the customers and energy communities. Market design shall be extended beyond the electricity sector, and contribute to integration of heating/cooling, thermal storage and batteries, including those of Electric vehicles.

Targeting unhindered electricity market access of coupled sectors and technologies will benefit the liquidity of markets. With about half of EU final energy demand consumed by heating and cooling, and with increased electrification of this sector, the potential market integration in terms of MWh and MW is considerable. In EU households, heating and hot water account for 2.2 PWh/a. In industry, 2.3 PWh/a is used for space and industrial process heating.

Extensive demonstration activities are deemed necessary, especially for higher TRL. Among the issues to be covered, it is worth to include cooperation strategies for TSOs/DSOs to support cross-border AD-based service provisions, innovative market rules and mechanisms for provision of ancillary services by RES, CO_2-neutral thermal generation, virtual power plants and storage systems, integration and proper valorisation of ancillary services provided by EVs and their smart charging, system services brought by gas, heating/cooling and water network operators.

The following tasks shall be investigated in R&I projects:

Task No	Tasks	PPC
1	Pan-European market design concepts	1.1, 3.1, 3.3
2	Market design for TSOs with cross-border coordination	3.1, 2.1, 3.3
3	Market design for system services by other (non-electricity) energy carriers	1.1
4	Market design for storage owners and operators	1.1, 3.1

RA 2: SYSTEM ECONOMICS

TOPIC 2.3: Decentralised Markets and flexibility platforms

CHALLENGE

The role of citizens as active market participants becomes central in the energy transition. This is empowered by the rapid increase in the penetration of Distributed Energy Resources (DER) comprising mainly distributed generators and flexible demand. The way DER will participate in the energy markets is of outmost importance, since this will critically affect the on-going transition of the energy system. Effective participation of DER, as distributed generation or demand flexibility available by customers, can be achieved individually or through aggregation via intermediate entities, like Retailers and Aggregators, Virtual Power Plants, Local Energy Communities and Microgrids, etc. In order to cope with the very large number of DER and to ease the complexity of the large interconnected multi-energy system, the organisation of decentralised markets presents a number of distinct advantages. To this end it is important to:

- Coordinate DER in market terms for having the necessary capacity to meet peak demands (including flexible demand) and energy to meet dispatch requirements
- Remunerate the ancillary services to support the upstream grid including island operation, if needed (Microgrid)

The efficient coordination of decentralised markets with the centralised energy market via aggregators is extremely important to achieve the best utilisation of the local resources, optimise costs for energy supply of citizens and increase the efficiency of the overall system.

Finally, an important goal is to ensure that the flexibility is used at local level to solve local requirements (congestion) but also at pan European level through flexibility platforms for balancing purposes and for having more liquidity in the market

SCOPE

Decentralised market models need to be developed based on decentralised optimisation technologies, e.g. game theory. Local markets should be able to optimise the generation/flexible load offers of its participants together with central energy market prices. A trusted means of settlement is needed. Parties must be assured that the market will work effectively as a means of trade. Development of distributed ledgers, like Blockchain are increasingly developed for distributed and isolated markets.

Prior to full-scale application of new markets, real-life piloting is needed. This requires regulatory sandboxes where innovative solutions can be tested ahead of widespread deployment.

The following tasks shall be investigated in R&I projects

Task No	Tasks	PPC
1	Market design for Virtual Power Plants	1.1, 3.1
2	Market design for local markets and their interaction to central markets	2.1, 3.1

RA 2: SYSTEM ECONOMICS

TOPIC 2.4: Ancillary Services Markets

CHALLENGE

To maintain reliable supply, there are a number of services that are required by the electricity system that need to be funded via the market. These services maintain the strength of the system and used to be provided routinely by synchronous plants. In modern systems, the range of services required is changing due to the increase in intermittent and asynchronous resources in the grid. Funding these services is an essential component of markets. Where possible, these services are incorporated into markets and purchased in conjunction with capacity and energy, ether in parallel with these markets or separately via tenders. Many services, however, are not capable of market provision and have to be purchased through regulatory requirements. The participation of DER connected at the Distribution network to support the operation of the system and the market mechanisms to exploit this flexibility are of particular interest. This requires the close collaboration of DSOs and TSOs supported by the development of appropriate market models. The aggregation of DER in the form of Virtual Power Plants and Microgrids and their efficient coordination in order to participate in ancillary services markets is another critical component for the operation of these markets.

SCOPE

Develop market models for effective remuneration of ancillary service providers.

Efficient models for the collaboration of DSOs and TSOs in order to exploit the capabilities of DER at the distribution level in a most efficient way without causing operating problems (congestions) or out of limits voltages locally.

Efficient aggregation models for the participation of DER

The following tasks shall be investigated in R&I projects:

Task No	Tasks	PPC
1	Market design for the provision of ancillary services between DSOs and TSOs	2.1

RA 3: DIGITALISATION

TOPIC 3.1: Application of Data analytics and Artificial Intelligence

CHALLENGE

Standardisation comprises the establishment of minimum performances for digital equipment and defines a set of rules (e.g. protocols and data models) governing how computer programs, hardware components, etc. interact and exchange information and data for the purposes of the integrated energy system. Standardisation helps devices and systems to interact, using adequate language codes, and to become marketable (ensuring a common base for performances and communication rules) and provide a foundation for certification systems, promoting international trade of uniform high-quality products, thus supporting transfer of expertise from traditional energy systems. Interoperability is needed for integrated energy systems so that products or systems can cooperate with other products or systems to share resources.

The present standardisation and interoperability of digital technologies are not yet able to be the overarching enablers for the functioning of a decarbonised energy system. Stable common modular approaches and standards ensuring the needed data and information flow along the energy system value chain are not yet established and their development represents a key challenge. Equipment and systems used in different European countries and regions and made by different equipment producers are not yet fully interoperable. Providing flexibility within the system accommodating disruptive innovations and addressing the different configurations and layers of the SGAM frameworks requires standards and semantics to be interpreted and managed by Artificial Intelligence, to leverage the potential of these advanced applications.

R&I is needed for the adequate functioning of fully digitalised solutions implemented by network operators, flexibility providers, storage (such as batteries, hot water tanks, cooling systems, storage for CO_2-neutral or free gases and liquids), DER, RES, PV, EV with Smart Charging and V2G services and market operators. There is an urgent need for recommendations regarding communications protocols within the energy network, e.g., the IEC 61850 standard series, IEC 61970 (CIM) standard series, IEC 61968 (CIM) standard series, IEC 62324 (CIM), IEC 61400-24 standard series, ISO/IEC 9594 standard series, ITU-T X500 standard series. There is a strong need for standardisation of encrypted and authenticated market processes considering on different timescales for improved reliability (blockchain) to enhance DSO and TSO information exchange with DER, enabled for third party owned PV and storage from different manufacturers and using different technologies. There is also a strong need for standardisation on physical and cyber security.

SCOPE

The TOPIC shall include, as a basis for further work, comprehensive studies about standardised interfaces of energy operators and users, bulk and aggregated renewable power plants and flexible loads, electric vehicles charging infrastructures and of energy IoT devices. R&I is needed to establish guidelines on interoperability and cyber protection of the grids and assets and their interfaces, and to consider the digital applications enabling markets and user participation. Gaps must be identified to unlock technology applications in view of facilitating data exchange among players of the energy sector (System Operators, market parties and end users). ETSI activities around Common Information Model shall be explored.

Widely recognised international standards from energy sector committees shall be developed to ensure interoperability of IoT devices. Dedicated demonstrations shall be set to implement standardised interfaces among all energy operators and the bulk and aggregated renewable power plants, the electric vehicles charging infrastructures, the final users and their smart home and smart building appliances. Demonstrations shall also consider the standardisation and interoperability for advanced market platforms: e.g. the energy data hubs and tele-control platforms interconnecting Balancing Service Providers-TSO-DSO-SGU (Significant Grid User) infrastructures, the new market platforms with energy management systems etc. Communication and security standards shall be developed in the European Network Codes, while interoperability shall be ensured between TSO-owned digital assets integrated with public telecommunication services. CIM shall be applied for cross-border and cross-sector data exchanges, evaluating the benefits of semantic interoperability.

The following tasks shall be investigated in R&I projects:

Task No	Tasks	PPC
1	Knowledge from Integrated Big data management, including AI techniques	2.2
2	Use of IoT technologies for monitoring and control	5.2
3	Digital Twin for energy systems	6.4

RA 3: DIGITALISATION

TOPIC 3.2: Telecommunications – Applications and Requirements

CHALLENGE

Sensors are electronic devices used to measure physical quantities in networks, in view of the monitoring, control and protection. Smart meters are sensors that record generation and consumption of electric energy and other energy grid-related quantities. The information is communicated from prosumers to dedicated market stakeholders and to the regulated grid operators for monitoring and billing. Communication is typically done in the form of two-way signals between the meter/sensor and the data collection system through wireless, or fixed wired connections. Data communication infrastructures and channels need to link smart meters, allowing market entities to charge different prices for consumption, for production and for grid use according to the state of the integrated energy system.

Wide area monitoring systems are nowadays used in electricity transmission networks. The distribution networks are lack observability, with special reference to the lower voltage levels. In the particular case of the integrated energy system, sensors, data collection systems, metering and control are far beyond the requirements for the full integration of system flexibilities and consideration of physical, thermal and security constraints in the grids through smart and flexible devices and for enabling resilience in scenarios including internet denial-of-service events. Broadband data exchange with all communication systems (and with particular reference to the potential of 5G) are needed. The available technologies for smart metering are not yet used on the widest possible scales and the related market and flexibility services are therefore not yet fully enabled.

Smart metering allows much more than metering of electricity consumed and produced. It represents the observability in detail of the networks including the low voltage parts that normally are quite unknown from the point of view of operation and planning. The functional benefits are far-reaching. For the prosumer, apart from the obvious advantages of more accurate billing, easier procedures to place in service of new connection, easier ways to modify contracted power and improvement of service communications (with DSO), it is and will be fundamental for allowing close to real time market and flexibility options local markets, in these cases through retailers and aggregators. Benefits of massive smart metering implementation are very important for the electricity european market.

There is a need to develop and validate adequate sensors for the optimal performances of a fully integrated energy system, starting from smart metering and ranging across the key physical quantities necessary for system monitoring, automation and control. There is also an urgent need to investigate distributed and/or, meshed communication infrastructure for a system-wide monitoring and control across the entire integrated energy system., using all types, technologies and solutions for telecommunication (with special reference to 5G). Costs analyses of the ICT infrastructure for collecting and processing data to feed the data mining algorithms for system control at all times (from system stability to conditional and risk-based maintenance) need to be carried out.

SCOPE

The TOPIC shall include a proof of concept of new technologies and algorithms (AI/ML) and systems interfaces and systems integration mechanisms to enable joint processing of data from different sources and repositories.

IoT devices shall be developed for system operation and for conditional and risk-based maintenance, enabling advanced solutions for the increasing complexity of system development and operations. Demonstrations shall be implemented and include advanced features for the integrated Energy system such as for ICT infrastructure leveraging 5G, by use of the smart meters and the communication structure for AMM, by use of Smart meters for accessing its data directly by multiple actors, while preserving GDPR and contractual clauses. The resilience of infrastructure and operation management systems shall be investigated including resilient digital (communication) components, thereby considering data communication needs to handle anomalies. The adaptation of grid operation concepts to the new communication and digital environment using secure and broadband data exchange shall be demonstrated as well as the provision of proof of concept of innovative human machine interfaces for system operation, and of AI technologies to estimate indicators and completion of information to operate the system. The development of tools and architectures to manage, large amount of data (also in real time) for mass data communication and processing (Blockchain, Exchange Platforms) including the Integration of sensors and actuators shall be validated. Cost-effective data gateways for RES integration, reliability of “sub-meters” to be usable for different business processes and billing and enhancement of resilience of the ICT architecture (electrical black-out) to ensure the continuity of grid operation services shall be included in the demonstrations.

The following tasks shall be investigated in R&I projects:

Task No	Tasks	PPC
1	Data exchange protocols / interfaces for market actors	2.3, 5.2, 3.3
2	ICT infrastructure for demand control and aggregation	2.2, 2.3
3	ICT infrastructure for monitoring of distributed generation	7.3
4	Communication infrastructures for smart meter data	5.2
5	Exploitation of concept of network slicing for secure operation within common infrastructures (AM)	5.3
6	Advanced definition of the concept of virtual operator (AM)	5.3

RA 3: DIGITALISATION

TOPIC 3.3: Cybersecurity (vulnerabilities, failures, risks) and privacy

CHALLENGE

It is paramount important to define main cyber threats and implement applicable cybersecurity frameworks in the European energy system. For this to happen, energy-focused risks and associated regulatory needs with cost impact must be deeply understood.

Today, there is a lack of an integrated solution for physical and cyber requirements for the integrated energy and communication networks between grid operators, market participants including small prosumers which also require full privacy. There is a lack of cybersecure application of digitised solutions which can support the coordination needs for system operators, the increased use decentralised energy resources. Energy systems include assets with long lifetimes which must be upgraded to interact with cybersecure communication layers. This may expose the system to new threats as it moves towards increased digitalisation of operation. There is a lack of solutions which consider risks and vulnerabilities by use of public ICT and wireless infrastructures for energy systems monitoring and control.

Grid operators need to get physical and cyber security protections to avoid fraudulent or destructive access or injection of e.g. fault data through their physical installations. Grid infrastructures and their ICT must be protected against cyber-attacks, terrorism and extreme weather conditions. There is a strong need for more automatic, but cybersecure control of decentralised resources. The parallel use of IoT-upgraded and legacy SCADA systems must consider risks and vulnerabilities control. Risks and vulnerabilities by using public ICT and wireless infrastructures for smart grid purposes must be understood. Grid operators must be enabled to keep running the grid operation in case of natural catastrophes, terrorism and cyber-attacks. In normal operation, failure modes of ICT including different kinds of sensors must be supported by intrusion prevention and detection systems. Not only electricity systems, but also the whole integrated energy system with other energy carriers and sectors must be transformed to be fully cybersecure.

SCOPE

The TOPIC shall provide support tools (recommendations, guidelines, certifications etc.) to improve practices in cybersecurity (vulnerabilities, failures, risks) and data privacy management.

Tools must be developed for future Security Operation Centres (SOCs) allowing cyber threats detection and response, with anticipative and proactive strategies. Data analytics and deep learning should benefit from the development of new tools for predictive and automated maintenance of TSO's grid assets, and the automation of their data validation processes. Tools shall be developed to ensure full consistency between data privacy compliance and cyber-physical security practices.

Demonstrations shall be done related to dedicated strategies for enhanced cyber security and resilience at DSO and TSO level, including TSO/DSO security data sharing; related to authentication processes for multiple usages, from market mechanisms to system protections and with the involvement of various prosumers, data/service platforms complying with data privacy requirements on one side, and physical-cyber security & resilience of systems on the other. The relevance and impacts of integrating technologies such as blockchain, AI, automation or data analytics for security and maintenance purposes shall be assessed in detail and be demonstrated for system development, operation and asset management.

The following tasks shall be investigated in R&I projects:

Task No	Tasks	PPC
1	Methods and tools for cyber security protection of grid infrastructures and functions	6.3, 7.1, 7.2
2	Data Protection and GDPR-compliant methodologies (privacy)	5.3
3	Risk and vulnerabilities for parallel use of legacy systems	5.3, 7.2
4	Secure use of public ICT infrastructures and IoT technologies for smart grid functionalities	7.3

RA 4: PLANNING & RESILIENCE – HOLISTIC ARCHITECTURES and ASSETS

TOPIC 4.1: Long Term Energy System Design (Macroscopic view, Energy models)

CHALLENGE

To enable the integration of renewable energy sources at the penetration rate considered in the fully decarbonised scenarios and to satisfy the energy demand with renewable sources also during winter the electricity system cannot evolve in isolation. Integrated Energy Systems overcoming the silos among energy vectors need to be developed. New architectures encompassing the entire energy system will be needed addressing and optimising the synergies among all energy vectors (i.e. electricity, gas, heating/cooling, mobility, Hydrogen etc.). Specific technologies to enable the implementation of the architectures will be needed, enhancing the system performances, increasing its sustainability and leveraging subsidiarity and circularity.

Today, energy system architectures are not yet based on coherent and convergent approaches, which facilitate all processes necessary for a reliable, economic and environmentally friendly operation of smart integrated energy systems.

Approaches, tools and technologies are needed to plan, analyse and operate the integrated energy system under all scenarios: from scenario setting based on reliable and transparent hypotheses, parameters and relations, to integrated and complete planning tools, addressing holistically an energy system where all vectors interact and foster one another and the development and validation of technologies and solutions that help increasing system performances, environmental friendliness (increased efficiency, reduced footprint, circularity), thus leveraging subsidiarity (e.g. through energy communities/web of cells).

SCOPE

This TOPIC addresses the selection and design of optimal system architectures and key innovative technologies of the integrated energy system covering the different energy vectors, thus overcoming the silos approach and meeting the requirements of efficiency, sustainability and subsidiarity.

The research activities included in this topic shall start from definition and evolution of unified architectures for the integrated energy system, considering better and more advanced planning techniques (probabilistic approaches, dynamic optimisation, integration of Cost Benefits Analysis with Life Cycle Assessment of investments and components, etc.). Key components, solutions and technologies to improve system efficiency and sustainability shall be developed, assessed, validated and demonstrated encompassing all system levels from interoperable HVDC converters such as to smart transformers, energy routers, web of cells, etc. interoperable HVDC converters (“plug and play”), This includes also HVDC grids with multi-terminal HVDC grids and protection, digital equipment for metering, adaptation of conventional equipment to the digital operation (merging units) etc. Innovative materials shall also be developed and tested to increase performances and sustainability such as alternative gases to SF6 for HV and UHV systems, esters to replace mineral oil in power transformers, composite core conductors, superconductors for fault limiters and links, etc.

The following tasks shall be investigated in R&I projects:

Task No	Tasks	PPC
1	Energy models of the whole energy system development	1.1, 9.3
2	Resilience oriented sizing and spatial positioning of assets	2.4, 3.2
3	Coordinated investment planning at Regional (neighbouring systems) and EU level	4.4, 3.2
4	Develop European hydro energy system model	1.1

RA 4: PLANNING – HOLISTIC ARCHITECTURES and ASSETS

TOPIC 4.2: Transmission System Planning including Resilience

CHALLENGE

Planning the energy system towards a deep integration of renewables, while leveraging all flexibility sources mainly by demand response will be a key driver in the process of the decarbonisation. Planning is multifaceted and implies policy strategies, regulatory frameworks, probabilistic analyses considering the variable RES and DER. Planning leverages demand response, storage (such as by batteries or hydro reservoirs) and the interface with other energy and transport/mobility networks and spans through the evolution of known methodologies, considering energy as well as power needs, and the duration and availability of DSR and storage assets. Moreover, driven both by international electricity trade and by renewables with limited capacity factors, the economic benefits from exchanges between different areas or countries become economically more important than the avoidance of equipment overloads. For example, a country with wind resources in the North and strong load in the South might be able to operate securely by curtailing wind energy and running gas-fired plants in the South, but the additional cost of running the gas units – or of foregoing trade between North and South – can be much higher than the cost of additional transmission. Therefore, transmission planning has evolved into a value-based assessment. For example, the security benefits are captured partially through applying reliability criteria (e.g. values of lost load (VOLL)) in a market-related simulation, and partially through AC network simulations; these complement a market simulation with a DC approximation of the network. In the assessment the word “node” is used to mean a region or zone with several or even many nodes within which there is no congestion (e.g. in the European bidding zone approach to ENTSO-E’s Ten-Year Network Development Plans).

Although planning methodologies are rapidly evolving to take into consideration the different types of resources (e.g. RES, DER) and the possible flexibilities (generation, network, demand, storage such as batteries), the approach from the energy vectors point of view still remains essentially deterministic and each energy carrier is dealt with separately, thus missing potential synergies. Combined and fully integrated planning of electricity-gas-heating/cooling and mobility are not yet available for the stakeholders. Another complication comes from the fact that planning methodologies still cannot stochastically optimise decision points for infrastructure projects, i.e. optimise the expected net present value of the lifetime of a project as a function of its installation date and in conjunction with the effects of all other projects. This is partly for reasons of complexity and computation time, and partly because the permitting time for new infrastructure projects continues to be on the order of 5 to 10 years.

Long term planning towards a decarbonised integrated energy system requires the upgrading and smartening of planning procedures to include flexible systems coupling of electricity with other energy vectors such as gas (e.g. synergies of gas network operation in support to electricity flexibility, cost reduction of Power-to-Gas, etc.), heating and cooling (e.g. in presence of district heating networks), liquids, /including transformation processes PtX, XtP. There is a need to apply probabilistic approaches in the planning of the integrated energy systems, considering the stochastic behaviour of demand, RES generation, longer-term climate change effects. The process needs to consider new technologies in the transmission and distribution networks (e.g. hybrid AC/DC systems at energy community/buildings level, microgrids, energy cells and combinations of AC and DC solutions at local level etc.) etc. using eco-design and lifecycle assessment approaches.

SCOPE

This TOPIC addresses the evolution of long-term planning methodologies and tools for the design of the future decarbonised integrated energy system. This evolution shall be multifold, based on probabilistic approaches and shall start from scenarios considering environmental, societal and economic aspects of multi-vectors integrated systems.

The key tool for such analysis is a security-constrained optimal power flow. However, for large networks with several scenarios, these analyses are often solved via security-constrained economic dispatch (SCED) models with DC network approximations due to computational considerations, accompanied by traditional AC security simulations and, if needed dynamic analyses for certain cases. Different scenario representations of load and generation in chronological simulations over the target year and with different weather conditions affecting renewable energy output are analysed. Analyses of the expected nodal price differences are used to determine the value of additional transmission infrastructure between different pairs of nodes. A master program steps through combinations of reinforcement options, and subproblems evaluate equipment overloads and calculate economic benefits from market price differences. AC power flow and dynamic studies complement these economic analyses to indicate technical requirements for new investments. The value estimates from the nodal price studies and the importance of the technically required reinforcements are compared to estimates of the cost of the additional infrastructure. Where benefit/cost ratios are large enough in a relevant majority of scenarios, and where other, non-economic criteria do not reduce benefits strongly, infrastructure investments are decided taking into account public and stakeholder consultations. The research activities included in this topic shall leverage scenario analysis developed in an integrated way spanning across the energy systems, in particular heat and transport, considering environmental, social and economic aspects and the impacts on the grid of high-RES share penetration, electrification of heat and transport sectors, evolution of load profiles and hybridisation of systems. Planning tools shall be developed for modern system requirements (increased variability, flexibility needs, grid constraints, environmental sustainability, climate change issues), and shall include improved CBA (Cost-Benefit-Analysis) as well as CBCA (Cross Border Cost Allocation) for international investments. The tools shall be developed so as to coherently integrate environmental aspects (life-cycle assessment, air quality, visual and noise constraints) into the grid planning procedures.

The following tasks shall be investigated in R&I projects:

Task No	Tasks	PPC
1	Coordinated HVDC and HVAC network planning.	4.4, 6.2
2	Transmission System Planning for large scale offshore wind integration	4.1, 4.4

RA 4: PLANNING – HOLISTIC ARCHITECTURES and ASSETS

TOPIC 4.3: Distribution System Planning including Resilience– Integrated Transmission and Distribution Planning

CHALLENGE

Planning of distribution networks at low and medium voltage, although significantly less meshed than transmission networks, is evolved in analysing combinations of reinforcement options in a master program and evaluating equipment overloads in a subproblem. More advanced approaches evaluate unserved energy and trade off costs of reinforcement, losses and unserved energy, in order to evaluate combinations of reinforcement options both technically and economically. The increasing penetration of distributed energy resources such as batteries, PV, demand response etc., needs also to be taken into account, so that network equipment reinforcements can be traded off against local congestion management. Trade-offs of demand response or customer price elasticity against the cost of generation and network equipment are also central to the planning of microgrids, which aim to be able to operate without connection to a larger distribution and transmission grid, either for standalone applications in remote sites, or for continued service during larger system blackouts. The flexibility of loads may be also prioritised according to their economic value, so that balance can be achieved by adjusting schedules of the available generation sources, any available storage, and the different priorities of loads.

It should be emphasised that the planning for the transmission and distribution systems, which are natural monopolies, requires as input future generation capacities, to include their locations. In an electricity market, the TSO may need to simulate expected or optimal generation additions not because the transmission monopoly would invest in them, but to derive the most realistic assumptions for these important input data to its transmission plan optimisation. Moreover, transmission and distribution planning depend more strongly on each other, as distribution-connected resources tend to account for the majority of the total generation investments in many countries recently, as demand becomes more flexible and responsive to price signals, and as heating and transport are electrified. The EU network codes require intensive data exchange between TSO and DSO about the 110 kV level. Another example of mutual dependency of transmission and distribution planning comes from DC fast charging of EVs, that, when concentrated, would require new substations and probably network reinforcements.

SCOPE

In order to consider system interdependencies, modelling would ideally integrate distribution, transmission, storage, demand flexibility and generation at all voltage levels, with millions of deciders and of decision variables. It would utilise quantities of data several orders of magnitude bigger than in years past, based on smart meters and smart grids. Even for today's powerful computers and algorithms, this is too large to handle with integrated modelling. On the other hand, given the different decisions for which different market parties are responsible (customer vs. network operator vs. generation investor), full integration of modelling should probably not be necessary. According to the basic theory of markets: That many actors, each considering their own limited data and pursuing their own goals based on market price signals, will together make such decisions that the overall results for society are good. With perfect competition, with no externalities, and with good market price signals, economic theory even shows that the outcome for society is optimal. Assuming that market outcomes are optimal for society, appropriate market price signals for the coordination of the many different actors' separate decision-making are required.

The following tasks shall be investigated in R&I projects:

Task No	Tasks	PPC
1	Planning distribution networks considering citizen energy community needs	2.4, 4.4, 9.3
2	Optimally located, sized and coordinated battery energy storage	2.4, 9.3
3	Optimally sized and coordinated non-chemical energy storage (gas, thermal, Compressed Air, Flywheel etc.)	1.1, 2.4
4	Coordinated LVDC / MVDC and AC distribution network planning.	4.4
5	Distribution System Planning for the massive integration of DG	4.4, 9.3
6	Distribution System Planning for the massive integration of EVs	4.2, 8.2, 9.3
7	Integrated Transmission and Distribution Planning considering Demand Flexibility	2.1,.2.4, 3.2

RA 4: PLANNING – HOLISTIC ARCHITECTURES and ASSETS

TOPIC 4.4: Asset management and maintenance

CHALLENGE

The power system will be progressively operating under increasing constraints: managing and balancing the system under the extreme variability linked with the integration of renewables will imply higher frequencies of equipment load cycling, temporary overloads, working conditions closer to the design limits. Moreover climate changes impose increasing mechanical, electrical, thermal, environmental stresses to all system components. Asset management approaches must evolve to ensure the level of reliability of the system.

Asset management is one of the most important chapters in the operation of the energy system. Identifying critical components deserve a specific attention in view of the overall system availability, balancing the necessity to minimise the OPEX and fulfilling the requirements of continuity and quality of supply is an important step towards a reliability or a risk-based operation. Selecting the most adequate monitoring and diagnostic quantities to be used in conjunction with well proven degradation and end-of-life mathematical models is the rationale on which to build the asset management policy: this must be complemented by sensors, monitoring systems, ICT, data, information and knowledge management tools (e.g. data analytics, big data etc.). Critical assets must be managed based on risk and optimisation, to reduce OPEX, while increasing network flexibility and ensuring adequate power quality. Finally, lifetime extension of existing power system components, based on improved monitoring and measurement of their health state and residual lifetime is key to optimise CAPEX.

There is a strong need to develop and validate tools which address the lifecycle management of energy system components. They must span from the study of performance degradation laws to components and systems diagnostics and monitoring. Maintenance approach and residual life evaluation must be addressed at the light of the threats deriving from the radical changes in operation cycles and environmental constraints.

SCOPE

The TOPIC addresses the advanced management of assets in the energy system along their entire lifecycle, from the commissioning to the end-of life covering the identification of the degradation phenomena and the indicators of the failure development, the sensors and methods for diagnostic and monitoring, the setting up of maintenance policies and end-of-life decision making at the light of the progressive advancement of data acquisition and management techniques.

The research activities included in this topic aim at cost-efficient and highly effective probabilistic risk-based approaches for increasing system reliability through enhanced equipment maintenance and lifetime extension of existing power components based on improved monitoring, measurements and models to determine their health and remaining lifetime. The topic shall consider diffused asset monitoring enabled by distributed sensors (IoT technology) for a real–time view of the status of the grid, the identification of grid component anomalies through inspections with minimal human intervention, evidencing use cases for drones, robotics, AR etc. applied to maintenance.

Deployment of IoT sensors, communication, data management & analysis and feedback to control systems encompasses a huge number of devices and systems, so high TRL R&I actions are definitely needed.

With the onset of observability solutions and IoT utilisation, systems and components can be constantly monitored through intelligent systems capable of offering improved operational regimes and advanced sensing capabilities that can offer accurate usage of installed infrastructure. Together with the prespecified capabilities of installed equipment and systems by the manufacturers, maintenance decisions can be more accurate and in time to safeguard flawless operation of the system. This can be of real value to operators and R&I in this direction can offer a family of solutions that can improve operation and maintenance practices.

Acquisition, elaboration and interpretation of the huge amount of data available from system monitoring and inspection shall also be considered leveraging data analytics based on AI, machine learning etc.

The following tasks shall be investigated in R&I projects:

Task No	Tasks	PPC
1	Condition monitoring and Preventive Maintenance	4.3, 1.3
2	Models and tools for remote maintenance	7.3, 1.3
3	Optimal maintenance scheduling of cross border interconnections	7.1
4	Optimal maintenance scheduling of hydropower and pumped-storage units.	7.1

RA 5: SYSTEM FLEXIBILITY

TOPIC 5.1: Demand flexibility (household, appliances and industry related)

CHALLENGE

The progressive decarbonisation of the energy system relies on the deep integration of variable renewable energy sources. A paradigm shift is needed in the management of the energy system in front of all uncertainties, to guarantee the stability and efficiency of the system at all time and geographical scales. All sources of flexibility must be employed along the entire value chain.

The present demand-related technologies, market models and integrated energy system policies do not provide sufficient features and incentives to the customers/prosumers, to engage themselves in DSM and DR programs and market initiatives. There is also a lack of knowledge about customers behaviour and motivation to involve them in the energy markets.

Power systems need to be increasingly flexible to accommodate rising shares of distributed, non-controllable renewable generation. Demand side flexibility in this context refers to enabling final customers/prosumers to become active in the market but also to enable system operators to make best use of flexibility in order to ensure low-carbon, secure, reliable, resilient, accessible, cost-efficient, and market-based system operation at affordable costs. There is a need to assess, in a reliable way, the full potential of flexibility to be addressed in different context and to simulate the effects of different technical and economic measures.

SCOPE

The TOPIC shall include, as a basis for further works, comprehensive studies of consumers on social behaviours and motivation patterns to adapt their consumption profile, aimed –inter alia- to assess the customer's/prosumer's awareness of importance of demand response and design of stimulation packages.

Societal studies shall be conducted to characterise and segment the different types of users (from households to the industry) and to identify the levers (behavioural, societal, economical, technical) to foster their participation into the flexibility arena. Suitable market mechanisms shall be developed and analysed for the exploitation of services based on demand side flexibility, able to support both system adequacy and system security in an integrated and coordinated way. They shall include suitable price signals and/or incentives for leveraging the wide-spread electrification of the economy, e.g. DSR and V2G.

Market models shall be developed and validated, to drive more cost-effective demand-related investments in a coordinated approach including also other energy sectors and vectors, with market mechanisms to facilitate and integrate very large shares of variable RES generation in a cost-effective way as sector coupling, while ensuring the flexibility that is needed to maintain system adequacy and security. Suitable and validated methodologies shall be developed, for evaluating the full potential of optimal utilisation of available flexibilities including technical, economic and regulatory aspects, and taking into account the efficient planning and operation of the power grid using the full potential of demand side flexibility. The design of new architectures for the flexibility markets shall integrate local and European-wide markets in an efficient way and enabling multilateral flexibility where several operators (TSOs and DSOs) may be present at the same time.

The following tasks shall be investigated in R&I projects:

Task No	Tasks	PPC
1	Demand Flexibility provided by the residential sector	5.4, 9.2, 9.1
2	Demand Flexibility provided by the industry	5.4, 9.2

RA 5: SYSTEM FLEXIBILITY

TOPIC 5.2: Generation flexibility (flexible thermal, RES (Hydro, PV and wind generators))

CHALLENGE

The progressive decarbonisation of the energy system relies on the deep integration of variable renewable energy sources. Thermal power generation shall be more and more based on CO_2-neutral fuels, while –at the same time- guaranteeing a higher level of flexibility. This means faster up/down ramping, increased resilience and lower maintenance costs. Hydropower generation, already a major source of flexibility for the electricity system, shall improve its capacity of supporting network balancing needs. Wind turbine and PV MPPT (Maximum Power Point Tracking) controls must take into account flexibility and reserve sharing.

Thermal Power Generation, at all the network levels, lack an integrated coordination with non-programmable RES which needs to be rapid, reliable and efficient and which must guarantee the lowest possible emission level. Fuel flexibility is not realised to its full extend, i.e. the capacity to switch between renewable-based fuel as well as conventional ones, including different rates of mixtures, depending on the availability of carbon-neutral synthetic fuels like synthetic methanol or methane, hydrogen, ammonia, biomass derived from waste, etc. Seasonal storage capabilities of the gas network, via Power-to-gas technologies shall also be developed and extensively used.

Flexible operation could impact negatively on the equipment and components life, with increased maintenance and repair costs; innovative solutions shall, therefore, be developed to reduce out-of-service and failure rates. Power-to-Gas and Power-to-Liquid options are needed to allow increasing synergies between Power and Transport sectors.

SCOPE

The TOPIC addresses the solutions and tools to improve the flexibility of all types of generation technologies to cope with all the uncertainties and variabilities of the progressively integrated energy system.

Suitable tools shall be developed to optimise the different flexibility resources, assessing their availability, the retrofitting technologies, the operating (and external) costs, both under a planning point of view and in a more short-term operational horizon. Improved combustion systems for CO_2-neutral fuels (including renewable “green” hydrogen/natural gas mixtures) shall be demonstrated, with particular attention to efficiency and reliability, as well as faster thermal generation ramping down and up and start-up/shut down. Energy storage systems such as batteries, hydro reservoirs, hot water tanks, cooling systems storage, storage for CO_2-neutral or free gases, etc, integrated with power generation plants, shall be demonstrated via pilot experiences. New technologies and operational methodologies shall be developed and demonstrated to increase hydropower and pumped hydro-storage plants flexibility.

The following tasks shall be investigated in R&I projects:

Task No	Tasks	PPC
1	Contribution of WTs (Wind turbines) and PVs to system flexibility.	4.2, 4.3, 6.1
2	Increase operational flexibility of hydropower and pumped storage plants	2.2
3	Contribution of thermal generators to system flexibility (including cogeneration)	2.2

RA 5: SYSTEM FLEXIBILITY

TOPIC 5.3: Storage flexibility & Energy Conversion flexibility (PtX, XtP, X=G, L, H and Water)

CHALLENGE

The progressive decarbonisation of the energy system relies on the deep integration of variable renewable energy sources. Storage such as batteries appear as the more accessible technological option to guarantee to RES generation the needed flexibility; on the other side, PtX technologies are emerging as a promising option, allowing as well, the desired integration with other "energy-related" networks, i.e. the gas and the heating/cooling ones.

Storage systems and Energy conversion technologies are key factors in ensuring a high degree of flexibility to the energy system as a whole, as well as guaranteeing the deep decarbonisation requested. Storage still lacks a proper valorisation in many scenarios and context, thus limiting the unlocking of its full potential. PtX technologies need extensive R&I activities, followed by the suitable demonstration at different scales.

Storage systems including batteries shall be developed to ensure flexibility and balancing services at all the network levels, at the same time contributing both to the optimal operation of power generation (conventional, fed by CO_2-neutral fuels, and Renewable) and to the DSM (Demand Side Management) at the level of final customers. PtX technologies (the most promising appears to be the Power-to-gas one) shall increase their role and penetration into the energy system. Potential and limits of these technologies need to be carefully assessed, via simulation and demonstration activities; regulatory issues must also be investigated. There is a strong need to assess the costs/benefits ratio of PtX technologies and to understand their effective integration in real scenarios, taking into account realistic synergies with gas, heating/cooling and water networks.

SCOPE

The TOPIC addresses the contribution to flexibility of energy storage integration, together with the advanced conversion technologies, aimed to transform electricity into gas, liquids and water and vice-versa.

Massive and effective storage penetration requires, on one side, mature national legislation fully compatible to the EC regulatory framework and market design (including storage services remuneration), and, on the other, the availability of comprehensive tools to assess cost/benefit balance and –more generally- to evaluate the economics of each initiative (including bankability). Suitable tools and models, to determine optimal size, location and utilisation of storage and PtX technologies and plants, is a pre-condition to ensure their effective deployment.

Demonstration activities shall be undertaken on long term energy storage systems (from advanced pumping hydro to other alternative solutions as PtX), solutions for district heating and cooling as sector integration for flexible operation at different energy levels and carriers, solutions for industry and industrial clusters for integrated flexible generation, consumption and storage.

The following tasks shall be investigated in R&I projects:

Task No	Tasks	PPC
1	Flexibility potential from aggregated heating (and cooling) storage at household / building / industrial level	1.2, 6.1, 9.2
2	Flexibility potential from power-to-gas application	1.2
3	Flexibility potential from battery storage	6.1
4	Flexibility potential from Hydrogen integration	1.2

RA 5: SYSTEM FLEXIBILITY

TOPIC 5.4: Network flexibility (FACTS, FACDS, smart transformers)

CHALLENGE

The progressive decarbonisation of the energy system relies on the deep integration of variable renewable energy sources, requiring the use of all sources of flexibility. A key issue that is becoming more apparent is the increased electricity network observability and controllability, to improve the optimal management of power flows and voltages. Power Electronics has strong potential to increase cost-effective system flexibility at all network levels.

Development and deployment of innovative technologies and tools, to increase network observability and controllability, communication and monitoring, as well as increased interaction and information exchange, are enablers to provide local, regional and system wide flexibility solutions.

Transmission and Distribution networks, HVDC systems and on-shore and off-shore RES generation plants need the development and standardisation of new components and devices, based on power electronics, to ensure full interoperability, optimal flow control, improved grid controllability, thus helping greater flexibility and stability of operation. Extensive demonstration of ready-to-use network flexibility devices is necessary.

SCOPE

The TOPIC addresses the flexibility improvements gained in the T&D networks thanks to the use of advanced Power Electronics.

Standardisation activities shall cover HVDC converter stations, Dynamic Line Rating solutions, and ready-to-use Power Electronics devices and components.

Extensive demonstration activities shall be conducted, focussing on Smart inverters and Smart transformers, providing grid support functions, on full scale interoperability of HVDC Converter stations and on innovative solutions for HVDC multi-terminal networks.

The following tasks shall be investigated in R&I projects:

Task No	Tasks	PPC
1	Flexibility in Transmission and Distribution Networks by Power electronics grid technologies (FACTS, FACDS, HVDC, etc.)	4.3, 6.2
2	Flexibility provided by distribution network reconfiguration	7.2
3	Multi-terminal HVDC networks to coordinate power flows	6.2
4	Dynamic Line Rating (DLR)	7.1

RA 5: SYSTEM FLEXIBILITY

TOPIC 5.5: Transport flexibility (V2G/EV; railway, trams, trolleybus)

CHALLENGE

The progressive decarbonisation of the energy system relies on the deep integration of variable renewable energy sources. All sources of flexibility must be employed along the entire value chain, to guarantee the stability and efficiency of the system at all time and geographical scales. The transport sector, with the growing penetration of electricity, could offer a valuable potential of flexibility to the grid.

There is a lack of charging infrastructures and storage systems, both in urban and extra-urban areas. They should be planned and developed, keeping into account the mobility needs, the impact on network adequacy (especially at the level of Distribution) and the flexibility and balancing potential offered. Suitable market models are missing. They must be developed and tested, where effective price signals could orientate customers in the offer/demand of recharging services (V2G), keeping into due account the peculiarities of mobility services. Electrified public transport (both urban and long-distance) could as well offer flexibility and balancing potential, provided careful planning and operation methodologies to be adopted.

There is a strong need of reliability analysis, quantification and optimisation of the impact (opportunities and constraints) of EV interaction with the grid (Smart Charging and V2G) on urban and transmission grids. Services offered to the distribution and/or transmission network (flexibility and balancing) by electricity penetration in transport sector –both V2G and urban/long-distance public transport- need to be quantified and demonstrated.

SCOPE

The TOPIC addresses the grid flexibility and balancing opportunities offered by electric transport, taking into account both V2G (Vehicle to Grid) and electricity transport networks.

V2G has high potential to support the grid. The flexibility potential of electric transport in the future depends on how rapidly the amount of electric vehicles and machinery increases and this depends heavily on the policy measures. In any case, electrification of the transport sector is expected to proceed rapidly and IEA estimates total electricity consumption for EVs to be at the range of 640 – 1100 TWh in 2030 of which 100-200 TWh in Europe depending on the scenario (IEA Global EV Outlook 2019). A significant portion of the total EV fleet can be utilised to provide flexibility and balancing to the system and, therefore, the potential is high. Typically, V2G shall give the substantial benefit of load shifting, useful for balancing out spikes (both upwards and downwards) in supply and/or demand.

Scenarios shall be determined, and simulations shall be performed, to assess the impact of transport system electrification on distribution grids. Recharging and storage facilities management systems and algorithms are to be developed and tested, enabling integration of V2G into urban distribution grid. Future mixed electric and CO_2-neutral fuels vehicles strategies shall be investigated, to ensure smooth transition to a fully decarbonised mobility.

The following tasks shall be investigated in R&I projects:

Task No	Tasks	PPC
1	Flexibility provided by Energy management of transport electricity networks (railway, metro, tramway, trolleybus, etc)	8.1, 8.2
2	Flexibility provided by smart EV charging and V2G	8.1, 8.2

RA 6: SYSTEM OPERATION

TOPIC 6.1: Supervisory control and State estimation

CHALLENGE

The extensive integration of variable renewables may threaten the continuity and quality of the electricity supply, if adequate mitigation and protection measures are not taken. The delicate internal balance of the electricity system to guarantee its stability requires the real-time knowledge (by measurement and estimation) and control of all critical system parameters.

Supervision and control systems used in most of the present electricity networks have been designed according to the rules of fully controllable generation. The progressive integration of highly variable generation sources such as wind and PV requires a radical change in the ways the systems are managed, starting from the thorough evidence of the trend of the critical system parameters (e.g. frequency, voltage levels and phasors etc.) at all system levels, thus requiring a strong cooperation among system operators.

Adequate and validated tools and systems are needed to foster the observability of the electricity system throughout the different levels (transmission, distribution, delivery). Methods are to be designed for an optimised use of system data in view of state estimation with the adequate time span from stability purposes to energy optimisation and efficiency.

SCOPE

The TOPIC shall consider the entire process of observability and supervision of the electricity system in presence of high variabilities from generation (renewables), network (contingencies) and load and of all flexibility tools adopted (e.g. storage (such as batteries, heating and cooling storage, storage for CO_2-neutral or free gases), VtG etc.).

The research and demonstration activities shall start from the development of adequate sensors, methods and tools (e.g. WAMS, PMUs etc.) for electric system observability, including the advanced algorithms for data elaboration based on the use of deep learning and artificial intelligence, to enhance the estimation of the state of the system (e.g. damping, system inertia, short circuit power in critical nodes…) at all voltage levels, by all network operators (TSO-DSO cooperation) and at all time and geographical scales. Early detection of critical situations or nodes shall be made possible. The activities shall address the ICT infrastructures needed to enable the state estimation and visualisation, as well as the protocols for the adequate cooperation of network operators at all levels.

The following tasks shall be investigated in R&I projects:

Task No	Tasks	PPC
1	Steady State and Dynamic State Estimation of transmission systems	7.4
2	Increased Observability and State Estimation of distribution systems	7.4
3	Real-time observability of RES.	4.2, 7.4

RA 6: SYSTEM OPERATION

TOPIC 6.2: Short-term control (Primary, Voltage, Frequency)

CHALLENGE

The integration of extensive shares of variable renewable energy sources connected to the network via inverters and the use of power electronics (FACTS, smart transformers etc.) throughout the power system requires a rapid evolution of methods and tools adopted to guarantee system stability.

The stability of the present electricity system leverages on the existence of the physical mass of rotating generating machines enabling, through their inertia, the damping of oscillations in front of rapid perturbations, thus allowing the intervention of the primary control systems. The extensive use of power electronics devices, used especially in the connection of variable renewables sources will create issues for the system stability of the power system because of the decrease in physical inertia. Moreover, the adoption of power electronics will substantially change the system protection philosophies.

Systems are needed to control and protect the Pan-European power system in an effective way, by being ready at any time for handling the normal operation as well as different types of contingency system states through preventive and corrective actions based on a system-wide, highly coordinated, fully interoperable grid observability, state estimation, new containment measures and protection criteria, under all scenarios (e.g. weather, failure, attack).

SCOPE

The TOPIC addresses the innovative system operation, focussing on the short-term control techniques, under normal and constrained conditions (such as, under reverse flow conditions from local renewable generation excess, system events under limited inertia conditions, behaviour under extreme meteorological events, etc.) in inverter-dominated grids.

With significant integration of converter interfaced generation (CIGs), loads, and transmission devices, the dynamic response of power systems has progressively become more dependent on (complex) fast-response power electronic devices, thus, altering the power system dynamic behaviour. The time scale related to the controls of CIGs ranges from a few microseconds to several milliseconds, thus encompassing wave and electromagnetic phenomena next to electromechanical phenomena. Considering the proliferation of CIGs, faster dynamics will gain more prominence when analysing future power system dynamic behaviour compared to stability phenomena within the time scale of several milliseconds to minutes of conventional power systems. There is a need therefore to develop models and tools able to extend the bandwidth of the phenomena to be examined and include faster dynamics within electromagnetic time scales when the faster dynamics is of importance and can affect overall system dynamics.

The operator needs to be able to accurately simulate a the dynamic performance of his system in order to ensure that the system can ride through any contingency without losing its angular, voltage or converter driven stability. The main question that the operator needs to answer is if the system will be stable and secure after any credible contingency; to the extent that it is not, what corrective action needs to be taken so that the system becomes operationally feasible.

Dynamic operation, fast response to contingencies, resilience to major disturbances are becoming a paramount challenge for grid operators; security of supply is here at stake, i.e. in case of wide spread blackouts. Therefore the benefits are measured in terms of avoided loss of load hours, where each lost MWh is typically valued at 5 – 30 k€.

Moreover, not just real-time and continuous prediction but also measurement can be devoloped. Critical to get ‘model validation’ right, we see with higher renewables that correlation between reality and models can go down as model complexity increases.

The research and demonstration activities addressed in this TOPIC shall start from the development and validation of models and tools for the investigations of dynamic stability issues for AC and AC/DC hybrid grids, at all voltage levels. Network-based short-term control and protection in presence of high variability conditions (operational, planning) shall use improved data analytics (AI, machine learning…), data collection and processing (e.g. Big Data), also using fast real-time and continuous prediction of dynamic stability margins and preventive mechanisms and the market-based activation of cross-border dynamic stability services (such as ancillary services).

The following tasks shall be investigated in R&I projects:

Task No	Tasks	PPC
1	Optimal Load Frequency Control	7.1
2	Contribution of RES to primary voltage and frequency control in low inertia systems	7.1

RA 6: SYSTEM OPERATION

TOPIC 6.3: Medium and long-term control (Forecasting (Load, RES), secondary & tertiary control: LFC, operational planning: scheduling/ optimisation of active / reactive power, voltage control)

CHALLENGE

In addition to being stable and reliable, the electricity system must be efficient and able to ensure the adequate level of power quality. Measures to reduce internal inefficiencies such as the excessive reactive power flows and the energy imbalances, especially in presence of uncertainties need to be designed and applied.

The evolution of the power system in a resources-constrained context must be ensured minimising stranded assets and prioritising investments. This can be achieved by identifying and implementing medium and long-term control strategies and tools (e.g. reactive power control) and enhancing the performances of forecasting the exogenous parameters influencing the behaviour of the system.

Solutions are needed to optimise the production of renewable energy sources by means of generation forecasting/nowcasting and forecasting and profiling of load and consumer behaviour, as influenced by the variable market conditions and mechanisms. Medium and long-term control strategies and tools are needed to support system operations, effective and sufficient security margins assessment, load sharing between substations, control systems in secondary substations, etc.

SCOPE

The TOPIC addresses the solutions for operational planning of the energy systems, with special reference to resources scheduling (through adequate generation and load forecasting) and optimisation of active/reactive power and voltage control.

The research and demonstration activities shall start from the development of forecasting and monitoring tools for primary energy sources, system behaviour and load dynamics and profiles of real-time tools for improved security analysis and decision making, using probabilistic algorithms, enhanced forecasting of RES integrated in the short-term operational planning optimisation. Validated tools for the dynamic power unit commitment, reserve allocation and optimal power flow for the highest integration of vRES shall also be developed.

The following tasks shall be investigated in R&I projects:

Task No	Tasks	PPC
1	Advanced RES forecasting for network operation	4.2, 4.3
2	Hydropower forecasting	4.2, 4.3
3	Optimal Scheduling of generation (unit commitment) for balancing in highly uncertain conditions	3.1
4	Optimal reconfiguration of distribution network	7.2

RA 6: SYSTEM OPERATION

TOPIC 6.4: Preventive control/restoration (Contingencies, Topology incl. Switching optimisation, Protection, Resilience)

CHALLENGE

Extreme events linked with climate change are increasing in frequency and intensity. Cyber-threats and intentional attacks may be increasingly dangerous for systems relying on extensive digitalisation. The power system is exposed to different types of threats both natural or intentional and needs to increase its level of resilience.

Evaluating and increasing the resilience of the power system starts from the analysis of normal and abnormal operational conditions, identifying threats from external natural and intentional origin, assessing the system responsiveness to contingencies, minimising the risk, determining the right balance between "hardening" the power system infrastructures and smartening the network operation, identifying preventive and curative actions such as, for example, automatic fault clearing procedures and developing system restoration tools.

Solutions are needed to increase the system resilience: i.e. the ability to anticipate and prepare for critical situations, to absorb impacts of hazards, prevent deterioration in service to the point of failure, to respond to and recover rapidly from disruptions, and to make adaptations that strive to provide continued electrical supply under a new condition.

SCOPE

The TOPIC addresses the power system resilience, starting from the evaluation and forecasting of natural and human-related threats, assessing the system and components vulnerabilities, identifying and modelling the contingencies (single and multiple), evaluating the effects of mitigation of the threats through hardware (increasing robustness) or intelligence (smart management) solutions and identifying measures for the rapid restoration of power system performances (even reduced) to progressively restore the adequate level of supply quality.

The research and demonstration activities shall follow the pathway of resilience evaluation and, namely:

- Threats: natural threats, such as natural disasters (earthquakes, tsunami, volcano eruptions etc.), extreme weather events like wind, heavy rains, snowfalls, heat waves, thunderstorms, and their consequences like draughts, floods, terrain drifts shall be studied historically, to assess their return time and project their frequencies along climate changes scenarios and shall be predicted (when applicable) using advanced forecasting methods. Cyberattacks and intentional threats (terrorism) shall also be considered based on technology evolution and geopolitical analysis.
- Vulnerability: the power system vulnerability, intended as composed by the fragility of network components and the system vulnerability in front of different types and combinations of contingencies shall be evaluated, based on equipment tests (e.g. fault ride tests) and system simulation adopting stochastic reliability approaches, thus replacing the current reliability principles.
- Resilience: assessment and validation of self-healing techniques for defence and restoration, probabilistic approaches, and enhanced reliability criteria; general methodological frameworks ("resilience doctrine") to be adopted by network operators to assess and to increase the power system resilience considering all the management phases (planning, operational planning and operation) and possible failures of both physical and digital infrastructures.
- Restoration: identification of pan European and regional system restoration algorithms, procedures and tools taking into consideration the possible contribution of DER/RES and storage systems (such as batteries, hot water tanks, cooling systems storage, storage for CO_2-neutral or free gases), to system restoration and immediate power reserves (e.g. black start capability).

The following tasks shall be investigated in R&I projects:

Task No	Tasks	PPC
1	Protection of distribution networks with low fault currents, adaptive protection	6.3
2	DC grid protection	6.3
3	Operational measures to increase network resilience (topology optimisation, DER operation, mobile DER)	1.1
4	Bottom-up restoration by DER and storage	6.3
5	Self-healing techniques	7.1
6	Load Shedding techniques	7.1
7	Security support by various multi-energy carriers	1.2

RA 6: SYSTEM OPERATION

TOPIC 6.5: Control Center technologies (EMS, platforms, Operator training, Coordination among Control Centres)

CHALLENGE

The management of the integrated energy system under progressively new constrained conditions requires the development of control centre technologies, the associated new skills and the training of operators to cope with the new responsibilities. Decisions on more complex systems shall be taken more rapidly to guarantee the continuity, safety and quality of service.

Innovative training systems are to be made available leveraging the available technologies such as AI and AR to be massively introduced into control rooms and operators training centres.

Automated monitoring and control of networks at all voltage levels (HV, MV and LV), using digital and advanced operators control centres environments are needed to foster decision making, thus enhancing time and quality of reaction; these environments must be complemented and enhanced for the training of operators so as to adapt to Network Energy Management platforms using real-time system implementation (digital twin) to simulate human grid operator roles and intervention.

SCOPE

The TOPIC addresses the necessary network operators control room features as well as the operators' training tools at all levels of the integrated system development, management and operation to ensure adequate level of decision making and the uniform level of skills and approaches.

The research and demonstration activities shall start from the analysis and development of the functions to be implemented for a combined central and decentralised control of energy systems based on advanced smart power systems architectures. The tools developed shall be used also for training network operators based on close-to-real world concepts (e.g. digital twins), able to react to all types of perturbations and system variabilities and events; tools for training of grid maintenance operators, assisted by AI and AR (Augmented Reality) during their interventions, thus facilitating the operators' full adaptation to the new digital environment shall also be considered.

The following tasks shall be investigated in R&I projects:

Task No	Tasks	PPC
1	Wide Area Monitoring and Control Architecture for Transmission Systems	7.4
2	Energy Management platforms for TSOs including interaction with local markets	2.1, 2.2
3	Energy Management Platforms for DSOs for active participation of customers in local energy markets	2.1, 2.2
4	Control center architectures for distributed network control	7.2
5	Advanced Training Simulations for system operators (e.g. Digital Twins)	6.4, 7.1
6	Advanced MMI (Man-Machine-Interface)	6.4, 7.1

RA 6: SYSTEM OPERATION

TOPIC 6.6: System Stability analysis

CHALLENGE

The stability of the electric system may be affected by strong variability situations: this can be caused by the deep integration of renewables, in situations where the intrinsic system inertia is reduced because of the extensive use of inverter-based generation.

The assessment of the electric system stability margins is an important driver for the network operators, especially on the transmission side; the wide development of distributed generation raises the need of advanced tools able to assess the power system stability at local level (i.e. distribution level and/or cell level), to be put in relation to that at pan-European level in presence of large perturbations.

There are urgent needs to develop and validate tools for system stability analysis at all voltage levels. They must be complemented with the setting up of technologies and solutions for synthetic inertia to compensate for this potential weakness.

In the presence of a large number of power electronics connected distributed generators, the number of directly coupled rotating machines in the system will unavoidably be reduced. The reduction in the amount of rotating mass, hence inertia, in the system could lead to a higher rate of change of frequency after a disturbance. This increased rate of change of frequency, may in turn result in a greater frequency excursion (the frequency nadir in the network increases following network disturbances, e.g., conventional generator outage, connection of large load, etc.). The amount of synthetic inertia needed is system specific, it should be high enough to avoid triggering of under-frequency protection devices.

SCOPE

The TOPIC addresses the design and planning of the integrated energy system with special attention to the issue of stability of the power system considering the integration of extensive penetration of variable renewables, in presence of extended inverter-based generation connected to the network.

The research and demonstration activities addressed in this TOPIC shall start from the development and validation of tools and models to assess and enhance the level of power system stability, resilience and reliability in presence of high shares of vRES and include the demonstration of synthetic inertia as substitutes for rotating inertia by power electronics, storage (such as batteries, hot water tanks, cooling systems storage, storage for CO_2-neutral or free gases), variable frequency, and other innovative technologies combined with software and algorithms.

The following tasks shall be investigated in R&I projects:

Task No	Tasks	PPC
1	Grid stability with large scale penetration of converter interfaced sources	4.4
2	Microgrids in islanded mode of operation.	9.2
3	Models and tools for converter driven stability	9.2
4	Equivalent models of aggregated network and system components	7.1
5	Methods and tools to analyse large-scale inter-area oscillations	7.1

ANNEX II - BUDGET ANALYSIS OF THE HORIZON EUROPE WORK PROGRAM 2021-2022 REGARDING HLUCS

Horizon Europe is the European Funding Framework Programme. It runs for seven years from 2021 to 2027 and the total budget set for the programme is 95,500 million €.

The calls of Cluster-5[5] and Cluster-4[6] of the Horizon Europe Work Program (WP) 2021-2022 that fall within the ETIP SNET scope were examined. 26 calls in Cluster-5, were identified to be linked with the ETIP SNET, with a total budget of 428 million € (out of a total budget of 1,216.3 million € for Cluster-5). Only one call in Cluster-4 was identified to be relevant to ETIP-SNET with a budget of 39 million € (out of a total budget of around 520 million € for Cluster-4).

[5] https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/horizon/wp-call/2021-2022/wp-8-climate-energy-and-mobility_horizon-2021-2022_en.pdf

[6] https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/horizon/wp-call/2021-2022/wp-7-digital-industry-and-space_horizon-2021-2022_en.pdf

Table 4: Analysis of budget allocation of the Horizon Europe Calls (HE WP 2021-2022) for the nine ETIP SNET HLUCs

HE Call ID[7]	HLUC1	HLUC2	HLUC3	HLUC4	HLUC5	HLUC6	HLUC7	HLUC8	HLUC9
CL5-20217D5-01-03								100%	
CL5-2021-D3-01-01			30%		70%				
CL5-2021-D3-02-05	70%						30%		
CL5-2021-D3-02-06	40%	60%							
CL5-2021-D3-02-07							100%		
CL5-2021-D3-02-08						80%	20%		
CL5-2021-D3-02-10						100%			
CL5-2021-D3-02-11					100%				
CL5-2022-D3-01-08			50%		50%				
CL5-2022-D3-01-10	20%								80%
CL5-2022-D3-01-11	60%		20%	20%					
CL5-2022-D3-01-13							100%		
CL5-2022-D3-03-08				100%					
CL5-2021-D4-01-03					20%				80%
CL5-2022-D4-01-01									100%
CL5-2022-D4-01-02				30%					70%
CL5-2022-D4-01-03				30%					70%
CL5-2022-D4-02-04							20%		80%
CL5-2021-D3-01-02						100%			
CL5-2021-D3-01-03					100%				
CL5-2021-D3-03-01	100%								
CL5-2022-D3-01-05				20%			80%		
CL5-2022-D3-01-09				20%		60%	20%		

[7] For meaning of HE Call IDs, see list below this table.

HE Call ID[7]	HLUC1	HLUC2	HLUC3	HLUC4	HLUC5	HLUC6	HLUC7	HLUC8	HLUC9
CL5-2022-D3-01-12	70%	30%							
CL5-2022-D3-02-01				40%	60%				
CL5-2022-D3-03-04				100%					
CL4-2021-TWIN-TRANSITION-01-21				20%	20%				60%

The HE call IDs in this table above are associated to the following HE Calls:

- HORIZON-CL5-2021-D3-01-01: Establish the grounds for a common European energy data space (beginning on page 136 of document footnote 5)
- HORIZON-CL5-2021-D3-01-02: Laying down the basis for the demonstration of a Real Time Demonstrator of Multi-Vendor Multi-Terminal HVDC with Grid Forming Capability: Coordinated action (p.138)
- HORIZON-CL5-2021-D3-01-03: Interoperability community (p.139) Cross-cutting issues (p.141)
- HORIZON-CL5-2022-D3-01-05: Demonstration of innovative plug-and play solutions for system management and renewables storage in off-grid applications (p. 205)
- HORIZON-CL5-2022-D3-01-08: Supporting the action of consumers in the energy market and guide them to act as prosumers, communities and other active forms of active participation in the energy activities (p. 209)
- HORIZON-CL5-2022-D3-01-09: Real Time Demonstrator of Multi-Vendor Multi-Terminal VSC-HVDC with Grid Forming Capability (in support of the offshore strategy) (p. 211)
- HORIZON-CL5-2022-D3-01-10: Interoperable solutions for flexibility services using distributed energy storage (p. 213)
- HORIZON-CL5-2022-D3-01-11: Demonstration of innovative forms of storage and their successful operation and integration into innovative energy systems and grid architectures (p. 216)
- HORIZON-CL5-2022-D3-01-12: Replicable solutions for a cross sector compliant energy ecosystem (p. 218)
- HORIZON-CL5-2022-D3-01-13: Energy system modelling, optimisation and planning tools (p. 220)
- HORIZON-CL5-2022-D3-02-01: Digital solutions for defining synergies in international renewable energy value chains (p. 228)
- HORIZON-CL5-2021-D3-02-05: Energy Sector Integration: Integrating and combining energy systems to a cost-optimised and flexible energy system of systems (p. 152)
- HORIZON-CL5-2021-D3-02-06: Increasing energy system flexibility based on sector-integration services to consumers (that benefits system management by DSOs and TSOs) (p. 154)
- HORIZON-CL5-2021-D3-02-07: Reliability and resilience of the grid: Measures for vulnerabilities, failures, risks and privacy (p. 156)
- HORIZON-CL5-2021-D3-02-08: Electricity system reliability and resilience by design: High-Voltage, Direct Current (HVDC)-based systems and solutions (p. 158)
- HORIZON-CL5-2021-D3-02-10: Demonstration of advanced Power Electronics for application in the energy sector (p. 161)
- HORIZON-CL5-2021-D3-02-11: Reinforcing optimisation in related know how of local energy ecosystems (p. 163 Carbon capture, optimisation and storage (CCUS) (p. 164)
- HORIZON-CL5-2021-D3-03-01: AU-EU Water Energy Food Nexus (p. 174)
- HORIZON-CL5-2022-D3-03-04: Integrated wind farm control (p. 242)
- HORIZON-CL5-2022-D3-03-08: Development of digital solutions for existing hydropower operation and maintenance (p. 248)
- HORIZON-CL5-2022-D4-01-01: Demand response in energy-efficient residential buildings (p. 276)
- HORIZON-CL5-2022-D4-01-02: Renewable-intensive, energy positive homes (p. 278)
- HORIZON-CL5-2021-D4-01-03: Advanced data-driven monitoring of building stock energy performance (p. 261) Industrial facilities in the energy transition (p. 264)
- HORIZON-CL5-2022-D4-01-03: Smarter buildings for better energy performance 280 Industrial facilities in the energy transition (p. 281)
- HORIZON-CL5-2022-D4-02-04: Smart-grid ready and smart-network ready buildings, acting as active utility nodes (Built4People) (p. 292)
- HORIZON-CL5-2021-D5-01-03: System approach to achieve optimised Smart EV Charging and V2G flexibility in mass-deployment conditions (2ZERO) (p. 309)
- HORIZON-CL4-2021-TWIN-TRANSITION-01-21: Design and optimisation of energy flexible industrial processes (Processes4Planet Partnership) (IA) (beginning on page 58 of document footnote 6)

In this analysis, each HE call has been thematically linked with relevant High Level Use Case(s) (HLUC(s)). For instance, the call HORIZON-CL5-2021-D5-01-03: '*System approach to achieve optimised Smart EV Charging and V2G flexibility in mass-deployment conditions*' is assumed to be linked only with HLUC 8 (Transportation Integration & Storage), as shown in the previous table.

In case a HE call is related to more than one HLUC, the percentages indicate how the HE call budget is assumed to be allocated to each linked HLUC. For instance, the budget of the HE call HORIZON-CL5-2022-D3-01-05: '*Demonstration of innovative plug-and play solutions for system management and renewables storage in off-grid applications'* is mainly (80%) linked with HLUC 7 (Enhance System Supervision and Control including Cyber Security), as indicated in Figure 1. However, there is also a relation (20%) with HLUC 4 (Massive Penetration of RES into the transmission and distribution grid). In general, each call of the WP 2021-2022 is linked to one or more HLUC(s).

Based on the budgets assigned to each call of Horizon Europe WP 2021-2022 and its relevance to each HLUC, the distribution of HE 2021-2022 funds per HLUC is depicted in Figure 4. In Figure 5 the distribution of the budget per HLUC is indicated as a percentage of the total proposed funding (467 million €) of the calls in the Horizon Europe Work Program 2021-2022 which have a strong relevance to HLUCs. This is compared to the HLUC related distribution of the budgets proposed by the ETIP SNET in this R&I Implementation Plan 2022-2025 as percentage of the total suggested R&I budget of 1000 Million € for R&I projects ongoing between 2022-2025.

Concerning the time-period covered by the (four-year) R&I Implementation Plan 2022-2025, it shall be noted that the EC has provided an amount of funding for the first two years of the period 2022-2025 (i.e. Horizon Europe Work Program 2021-2022), while an additional amount of funding is expected to be provided by EC for the second two years of the IP period 2022-2025 (i.e. Horizon Europe Work Program 2023-2024). Moreover, parts of the R&I budget suggested in the ETIP SNET R&I Implementation Plan 2022-2025 shall come from non-public funding.

HLUC related budget comparison of Horizon Europe WP 2021-2022 and the ETIP SNET IP 2022-25 for HLUCs

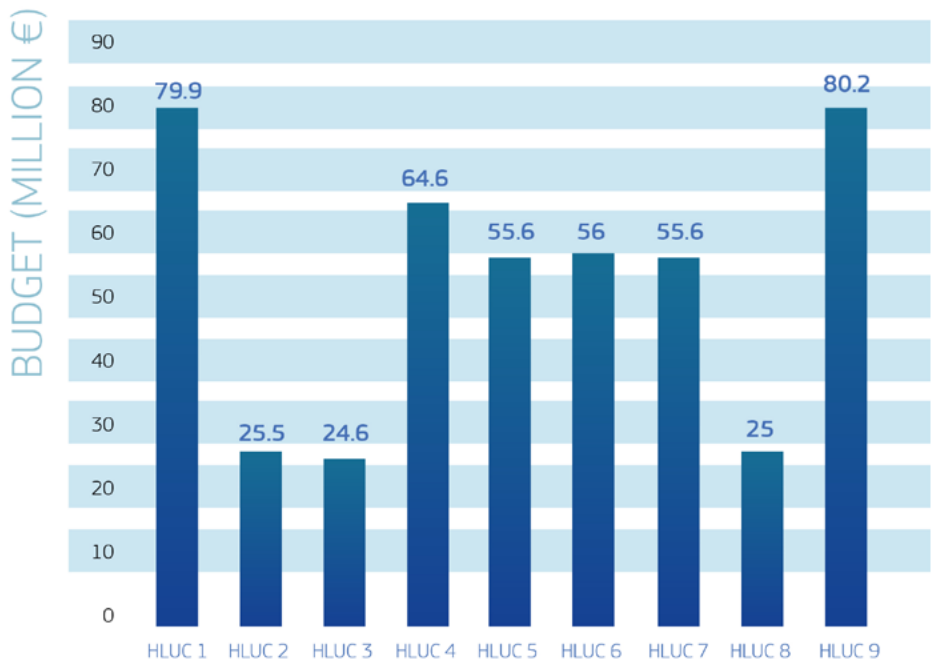

Figure 5: Assumed distribution of 2021-2022 Horizon Europe Call Budgets to the nine HLUCs (with total of 467 million €)

The same figures shown as relative percentages of the totals provide a comparison of the HE proposed budgets for the ETIP SNET HLUCs with those proposed by the ETIP SNET:

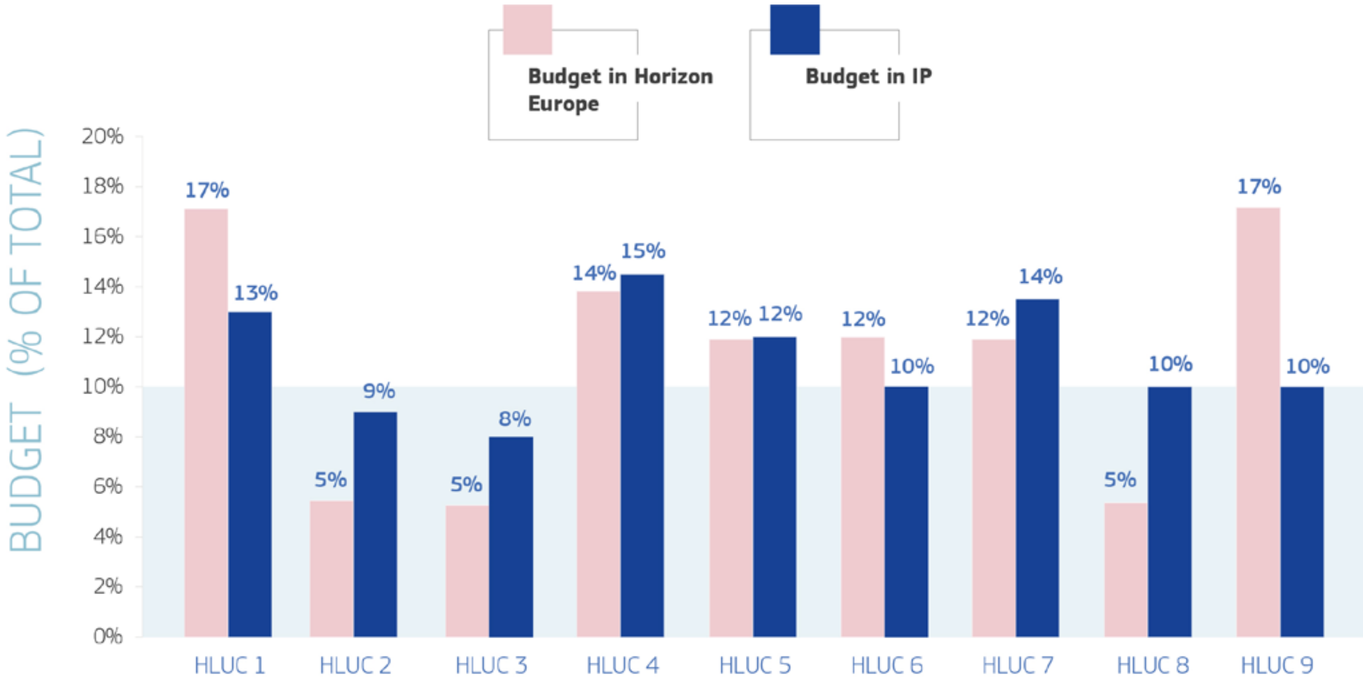

Figure 6: Budgets for HLUCs as a percentage of the HLUC-related Horizon Europe Calls 2021-2022 and as percentage of the total 4-year budget proposed in this ETIP SNET R&I Implementation Plan 2022-2025.

It is evident that the Horizon Europe Call 2021-2022 allocates a significant budget for HLUC 1 (Optimal Cross sector Integration and Grid Scale Storage), with a smaller budget for HLUC 2 (Market-driven TSO–DSO–System User Interactions). On the other hand, the R&I Implementation Plan 2022-2025 suggests a more balanced distribution of research funds between these two HLUCs, still suggesting however that HLUC 1 should be more funded. This is done in recognition of the high importance of cross-sector coupling and storage by the ETIP SNET, but also because large projects have been already funded by previous calls in the TSO-DSO coordination area raising the TRL status of HLUC 2. Moreover, these two HLUCs are highly linked. Thus, if we compare the cumulative funding of HLUC 1 and HLUC 2 in the Horizon Europe and the R&I Implementation Plan, it is evident in Figure 6 that they closely match.

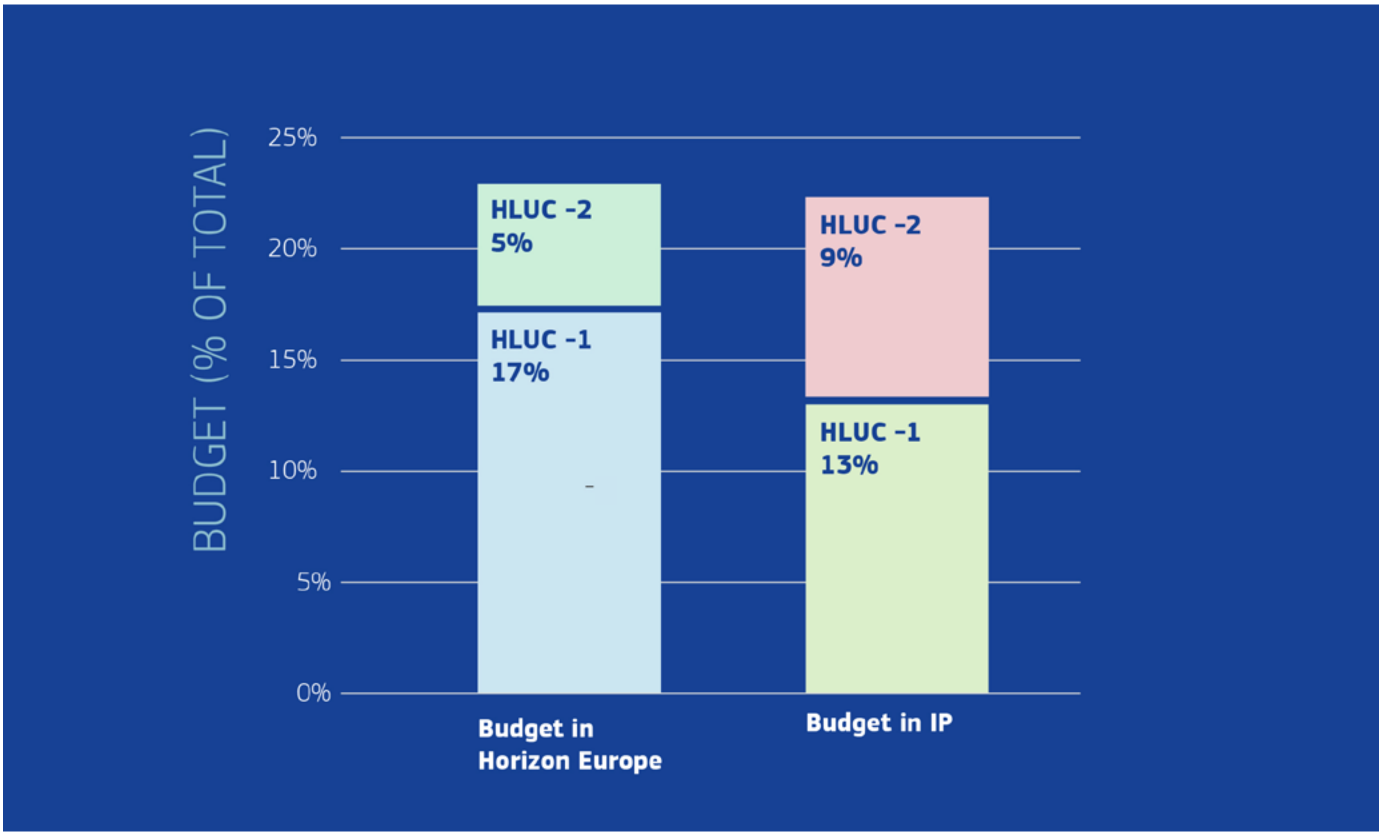

Figure 7: Budget distribution for HLUCs 1 and 2 in the Horizon Europe WP 2021-2022 and the ETIP SNET R&I Implementation Plan 2022-2025

The budget for HLUC 3 (Pan European Wholesale Markets, Regional and Local Markets) appears smaller in the Horizon Europe WP 2021-2022 than in the IP. However, it shall be noted that most calls touch upon market issues, yet not many identify HLUC 3 as the main topic of research. Thus, the budget allocated to HLUC 3 appears smaller in Horizon Europe calls.

The percentages of budget assigned to HLUCs 4, 5, 6 and 7 closely match in the R&I Implementation Plan 2022-2025 and the Horizon Europe WP 2021-2022.

HLUC 8 (Transportation Integration & Storage), appears less funded in the Horizon Europe, however the ETIP SNET highlights the need for additional funding of this area in future calls.

A difference is also noted in HLUC 9 (Flexibility provision by Building, Districts and Industrial Processes). However, it should be noted that some of the calls in Horizon Europe related to HLUC 9, include wider R&I needs, not directly related to the ETIP SNET. For instance, the call HORIZON-CL5-2022-D4-01-02 (Renewable-intensive, energy positive homes), although very relevant to the ETIP-SNET's scope, also concerns issues, like constructions and renovation of buildings, integrated design and construction concepts, etc.

Overall, the relative budget distribution proposed by the ETIP SNET IP 2022-2025 is in satisfactory agreement with the funding allocated by Horizon Europe WP 2020-2021 with few notable differences in areas that have reached a high TRL level and areas where additional funding is recommended by the ETIP SNET.

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