Strategic Energy Technology Plan

Implementation Working Group 4

Implementation Plan

24/04/2025

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1. Executive summary

1.1. Introduction to the SET-Plan Implementation Working Group 4: Integrated Energy Systems

The aim of the **Implementation working groups of the SET-Plan** is to contribute to the European Green Deal[1] in which Europe is striving to become the first climate neutral continent and to the European energy system integration strategy[2]. They develop and carry out Implementation Plans and research Roadmaps and strive to facilitate execution of them and share project results.

The aim of the **SET-Plan Implementation Working Group 4**: **Integrated Energy Systems** (IWG4) is to contribute to the fulfilment of the SET-Plan Action 4 resilience and security of energy systems on the member states level.

The overarching goals driving the SET-Plan Implementation plan for Action 4 are the development and operation of energy systems showing an appropriate level of **resilience, reliability, and economic efficiency**, leveraging the use and integration of **all types of bulk and local resources**, with special reference to **integrating variable renewables** at all-time scales. The system **flexibility** is essential to respond to the variability and uncertainty of most renewable generation sources and new stochastic loads (in a short time scale), to the adaptation to different possible energy scenarios (long time scale). This evolution of the energy system requires a very large share of flexibility to ensure the stability of the system. Flexibility can be achieved by means of innovative technologies enhancing **customer participation**, integrating better **storage**, making the best use of **connections between electricity grids** at all voltage levels **and other networks** (e.g. gas, heating and cooling transport) and optimising the use of **flexible sustainable combined power and heat generation**. A further level of flexibilization can be obtained from **centralised and decentralised thermal power generation technologies**, sector **coupling, market design, dynamic pricing, empowerment and integration of end-users, increased connectivity and data accessibility,** etc**.** The implementation of smart and integrated energy systems is not only a technological practice, but also a **societal, cultural, commercial** and **political practice** where cooperation and coordination are pivotal ingredients. It entails a change in the relationship between production, distribution, consumption, and storage, going beyond capacity optimisation.[3]

In 2023 a revamp of the SET Plan took place[4]. The new SET plan expands the current technology scope. For the Energy systems the following topics were highlighted:

- Accelerate the development of innovative and flexible solutions (e.g. demand response, storage);
- Extend its scope to low and medium voltage direct current technologies and help reducing the number of converters.

The activities planned on member state level to fulfil the SET-Plan Action 4 are summarised in this document, the IWG-4's **Implementation Plan.** The document, for an important portion, completes, complements and refers to the ETIP SNET implementation plan and its progressive updates. In fact, this document is intended to be used among member states to coordinate and drive the practical implementation of solutions, while the ETIP-SNET outcomes are intended to be implemented at the EU level.

This Implementation plan consists of a general description, two main priorities (Flagships): Flagship 1 Develop an optimised European power grid and Flagship 2 Develop Integrated Local and Regional Energy Systems), and is complemented with cross-cutting activities, covering aspects such as digitalisation (including cybersecurity), new regulatory and market approaches, field experiments and living labs, test beds and energy communities.

All activities are summarised in the form of activity fiches. These fiches were based on the inputs given by all members of IWG 4 as well as by representatives from ETIP SNET, ETIP RHC and ETIP PV. The fiches are concrete, output based, innovation oriented and technology neutral.

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[1] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en
[2] https://energy.ec.europa.eu/index_en
[3] https://energy.ec.europa.eu/topics/research-and-technology/strategic-energy-technology-plan
[4] Strategic Energy Technology Plan (europa.eu)

Flagship Initiative 1: Develop an Optimised European Power Grid

Develop the appropriate levels of reliability, resilience and economic efficiency, while integrating variable renewables, such as wind and solar generation by providing increased flexibility through innovative technologies to enhance customer participation, integrating better storage, making the best use of connections with other networks (e.g. heat and cold, transport) and optimising the use of flexible sustainable combined power and heat generation.

Flagship Initiative 2: Develop Integrated Local and Regional Energy Systems

Develop Integrated Local and Regional Energy Systems that can efficiently deliver, accommodate, and use high levels of renewables, up to and beyond 100% of local or regional supply by 2030, enabling regions and local communities to achieve their sustainable energy ambitions. They will provide tailor-made solutions that meet the local and regional needs and demand. At the same time, they shall link to a secure and resilient European energy system, enabling the participation in inter-regional exchange of energy as well as in sharing responsibility to maintain the overall system, considering the sustainable use of local and global resources.

This Implementation Plan (IP) gathers the consensus of 15 country representatives (AT, BE, CY, DE, ES, FI, FR, IE, IT, LV, NL, NO, SE, TR, UK), about the R&I actions to be implemented in coordination, in order to achieve the challenging targets set in the Declaration.

Figure 1 Participating Countries IWG-4

The IWG-4 is led by

- **Michael Hübner**, Senior Expert,
  Federal Ministry Republic of Austria Climate Action, Environment, Energy Mobility Innovation and Technology (Michael.Huebner@bmk.gv.at) and by

- **Michele de Nigris**, Director Dept. Sustainable Development and Energy Sources, Ricerca sul Sistema Energetico - RSE S.p.A Italy (Michele.deNigris@rse-web.it)

and is guided by the EC officer responsible

- **Mugurel George Paunescu**, Policy Officer, DG Energy – European Commission

SET Plan countries are committed to using their energy R&I national programmes and policies to implement some of the R&I activities that will be selected and are preferably interested in developing and pursuing joint research with other countries. Country representatives in the IWG-4 are government representatives or nominated persons by their governments.

The Implementation Plan is adapted and renewed on a yearly basis.

2. SET-Plan

The SET Plan has identified 6 priorities to achieve the energy transition and subsequently 10 actions for research and innovation (Table 1). They are based on an assessment of the energy system's needs and on their importance for the energy system transformation and their potential to create growth and jobs in the EU.

6 Priorities of the SET-Plan	10 SET Plan key actions	1 Implementation working groups (IWGs)	
Becoming world number one in renewables	❶ Performant renewable technologies integrated in the system	Offshore wind Photovoltaics Deep geothermal	Ocean energy Concentrated solar power/solar thermal electricity
	❷ Reduce costs for technologies		
Delivering a smart, consumer-centric energy system	❸ New technologies & services for consumers	**Energy systems** Positive energy districts Direct current technologies	
	❹ **Resilience & security of energy system**		
Develop and strengthen energy-efficient systems	❺ New materials & technologies for buildings	Energy efficiency in buildings Energy efficiency in industry	
	❻ Energy efficiency for industry		
Diversify and strengthen energy options for sustainable transport	❼ Competitive in global battery sector and e-mobility	Batteries Renewable fuels and bioenergy	
	❽ Renewable fuels and bioenergy		
Driving ambition in carbon capture, utilisation and storage	❾ Carbon capture storage / use	Carbon capture and storage, carbon capture and utilisation (CCS-CCU)	
Maintain and strengthen safety in the use of nuclear energy	❿ Nuclear safety	Nuclear safety	

Table 1 SET Plan priorities, actions and Implementation Working Groups

In 2023 a **revamp of the SET-Plan** took place in order to make it fully in line with the European Green Deal[5], REPowerEUPlan[6] and the Green Deal Industry Plan[7] (Net-Zero Industry Act[8]). It continues to cover the fifth dimension of the Energy Union: **Research, innovation and competitiveness –** supporting breakthrough solutions in low-carbon and clean energy technologies by prioritising research and innovation to drive the energy transition and improve competitiveness. Additionally, the SET-Plan

[5] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en
[6] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/repowereu-affordable-secure-and-sustainable-energy-europe_en
[7] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/green-deal-industrial-plan_en
[8] https://single-market-economy.ec.europa.eu/industry/sustainability/net-zero-industry-act_en

is fully anchored in the ERA (European Research Area), which has the ambition to create a single borderless market for research, Innovation and technology across the EU[9].

The Implementation Working Group was established to cover Priority 2 on Delivering a smart, consumer-centric energy system and the 4th SET Plan key action: Resilience & security of energy systems.

The revised SET Plan will accelerate the development of innovative and flexible solutions to optimise the existing grid, in particular **demand response and energy storage**, whose use will be supported by the proposed **electricity market design reform**. These solutions will help increase the **share of renewable electricity production integrated into the grid to reach at least 65% by 2030**. The SET Plan will also accelerate the development and use of innovative technologies providing **security, stability and cyber-resilience to the energy system** to help it cope with the increasing likelihood of climate-driven disruption and human-driven external threats.

At **local level**, the new solutions stemming from the revised SET Plan will **support cities in accelerating their green and digital transformation**, contributing to the **Climate-Neutral and Smart Cities Mission** objective of at least 100 climate neutral and smart cities by 2030. The revised SET Plan will also extend its scope to cover **low and medium voltage direct current (LVDC and MVDC) technologies** to take advantage of LVDC microgrids **in buildings, industrial facilities, data centres and electric vehicle charging stations**. This will reduce the number of (AC/DC and DC/AC) converters and improve material and energy efficiency in applications where most electrical equipment runs on direct current.

Furthermore, the following cross-cutting issue of the revised SET Plan is of high importance for IWG-4 cross-cutting activities:

Digitalisation

The revised SET Plan will **support closer cooperation between digital and energy areas** across the entire strategic technology value chains in EU and national R&I programmes. As announced in the **EU action plan for the digitalisation of the energy system**, the Commission will create the '**Gathering Energy and Digital Innovators from across the EU' (GEDI EU) platform** for cooperation between the SET Plan stakeholders and the European Digital Innovation Hubs and the Artificial Intelligence Testing and Experimentation Facilities (AI TEFs) set up under the Digital Europe Programme that focus on energy.

Furthermore, the SET Plan community will assist the Commission in preparing **policy initiatives on the digital and sustainable transformation of the EU's energy system.**

3. Approach and Structure of IWG 4

3.1. Structure of the Implementation Working Group 4

The main aim of the Implementation Working Group 4 is to plan research, innovation and implementation activities that benefit from the cooperation between the member states of the European Union. The IWG-4 is structured into two thematic flagships, led by two chairs. The thematic focuses of the two Flagships are:

Flagship Initiative 1: Develop an Optimised European Power Grid

Chair: Michele de Nigris

Develop the appropriate level of reliability, resilience and economic efficiency, while integrating variable renewables, such as wind and solar generation by providing increased flexibility thanks to innovative technologies enhancing customer participation, integrating better storage, making the best use of connections with other networks (e.g. heat and cold, transport) and optimising the use of flexible sustainable combined power and heat generation.

[9] European research area (europa.eu)

Flagship Initiative 2: Develop Integrated Local and Regional Energy Systems

Chair: Michael Hübner

Develop Integrated Local and Regional Energy Systems that can efficiently deliver, accommodate, and use high levels of renewables, up to and beyond 100% of local or regional supply by 2030, enabling regions and local communities to achieve their sustainable energy ambitions. They will provide tailor-made solutions that meet the local and regional needs and demand. At the same time, they shall link to a secure and resilient European energy system, enabling the participation in inter-regional exchange of energy as well as in sharing responsibility to maintain the overall system, considering the sustainable use of local and global resources.

3.2. An integrative Approach to Innovation

The transition of our energy system requires the further development of clean technologies to convert, store and transport energy. It further requires a clear vision of the future design of our energy systems, in order to make the best use of the new technologies, with their seamless integration into a highly performant and efficient technology service ecosystem. This, however, requires investigation of how different technologies and infrastructure can interoperate seamlessly across single energy vectors and sectors. Moreover, it also requires investigation of how the interplay of the different actors and technologies in the whole network, from production to end-use, can be organised in a way so that the various forms of renewable energy can be combined for a continuous and flexible supply of services and processes. On top of all that, it needs to be considered, how a controlled and well-regulated "Just Transition" from established energy systems to the new, clean energy systems can be facilitated. This concerns organisations and companies as well as individuals, citizens and communities, in short all parts of society. We need to know how the new solutions finally become part of our everyday businesses and lives, how and by whom decisions are taken to adopt a new solution and how we can involve the responsible stakeholders in the innovation process. We also need to keep the implications on nature, ecology and resources in focus, with CO_2 and the climate crisis as a leading motive.

An impact-oriented approach in any case has to have the development of technologies and solutions to their market and societal readiness in mind.

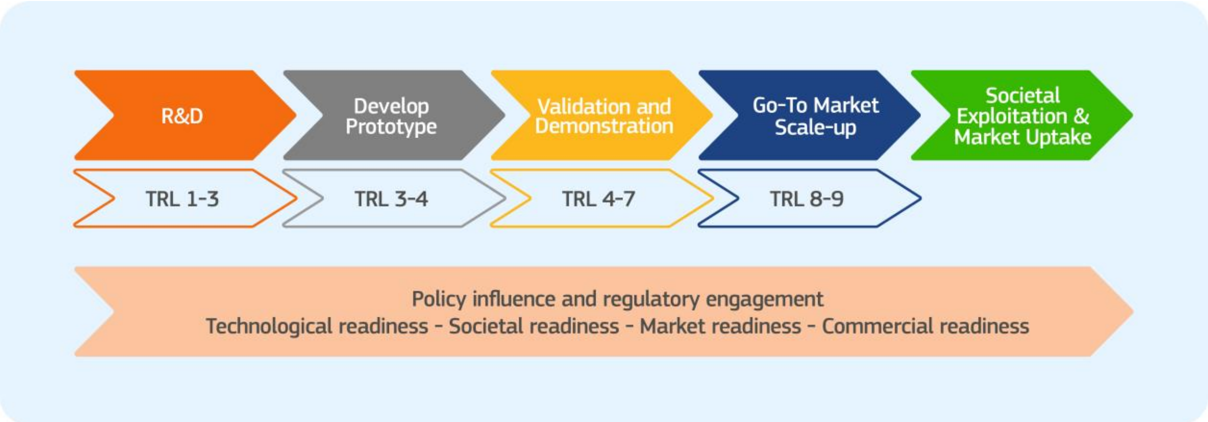


Figure 2 Exploitation pathway – "continuous flow of innovations to market"

Moreover, **an impact-oriented approach that aims to utilise research, technology development and innovation as catalyser and driving force for the energy transition, has to look beyond a simplified linear concept of innovation and transition.** It has to go beyond the adoption of new technologies and additionally consider aspects like the creation of new infrastructure, establishment of new markets, as well as the development of new social preferences and adjustment of user practices. **In such a wider view[10], innovation can be considered as an accelerator that can do much more**

[10] See for example „Sociotechnical transitions for deep decarbonization", Geels et al, Science Vol 357 (6357) (September 22, 2017), pp. 1242-1244; [Sociotechnical Transitions for Deep Decarbonization by Frank Geels, Benjamin K. Sovacool, Tim Schwanen, Steven Robert Sorrell :: SSRN] [https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3447276]

than improve technological price and performance characteristics of low-carbon technologies. It can also help to innovate or even disrupt existing systems, stimulate public enthusiasm around evidence based positive visions and build social and business coalitions that can help to innovate regulations and policies. [11], [12]

In terms of social science[13], such an approach has to consider techno-economic factors like technically feasible least-cost pathways, business and market models, etc. Beyond that, it also has to consider socio- technical aspects like innovation processes and related ecosystems, social acceptance, cultural discourse. The interlinked mix of technologies, infrastructure, organisations, markets and business models, regulations and public policies situated user practices, cultural meanings, etc., that, together, deliver societal functions should be considered as sociotechnical systems. An impact-oriented approach to innovation consequently should address and support iterative interactions of experimentation, learning and validating, in order to build an evidence-based knowledge base for the energy transition. By this, it can also produce outcomes that help the stronger alignment between innovation policy and (energy) sector specific policies. It has to be interesting to facilitate stakeholder involvement, further social acceptance and positive discourses as well as opportunities for new entrants.

The IWG4 therefore follows a holistic, integrated and comprehensive approach to innovation, looking at technology in its socio-economical and socio-technical contexts. This approach is aiming at the use of a broad portfolio of tools, reaching from inter- and transdisciplinary research over the development of technologies and technical systems to the effective innovation of services, processes, interfaces, communication and interaction, business models, markets, etc. The available funding schemes for RTDI projects in the different countries and agencies involved may have limitations. However, the IWG4 intends to go further with its portfolio of measures and concepts this broad spectrum of activities. The reference model as described below is meant as a framework that facilitates a structured approach to fostering different dimensions of innovation in the design and classification of projects and activities.

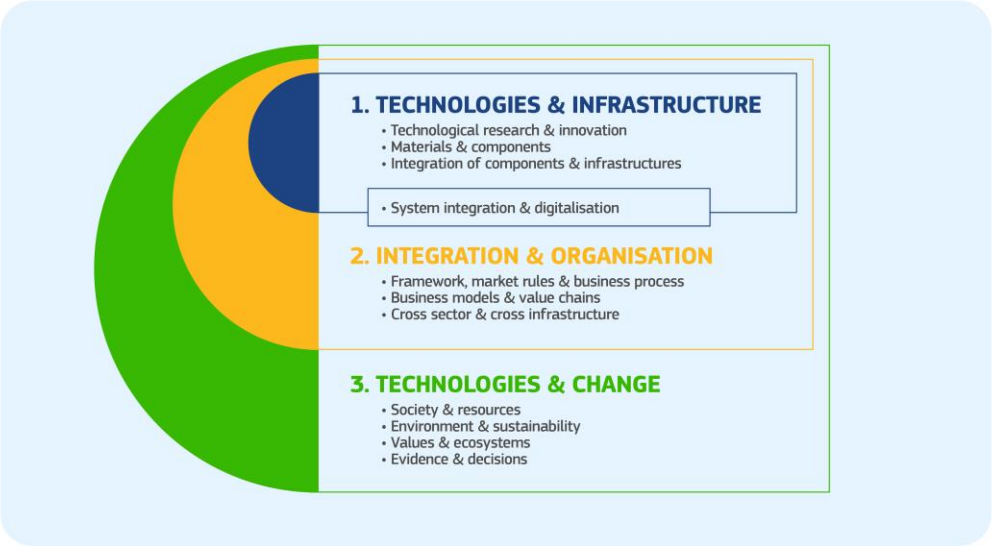


Figure 3 Integrative Innovation Model

1. Technologies & Infrastructure: “How can the necessary new technologies and infrastructure be designed, developed and implemented into effective technical solutions for clean energy?" The focus here is on the design and production of technologies to convert, store and transport clean energy. This includes how different technologies, and infrastructure can technically interoperate seamlessly across single energy vectors and sector, achieving flexibility and sector coupling. It also comprises technical aspects of CO_2 management systems and circularity. Moreover, it concerns aspects of operation and maintenance of infrastructure and components.

[11] See for example “Social Innovation for regional energy transition? An agency perspective on transformative change in non-core regions”, Suitner et al, Regional Studies, 57:8 2023, 1498-1510, DOI: 10.1080/00343404.2022.2053096 Social innovation for regional energy transition? An agency perspective on transformative change in non-core regions (tandfonline.com)

[12] See for example “Understanding innovation”, EPRS | European Parliamentary Research Service, Author: Vincent Reillon, Members' Research Service PE 573.968, European Union 2016; Understanding innovation | Think Tank | European Parliament (europa.eu) [https://www.europarl.europa.eu/thinktank/en/document/EPRS_BRI(2016)573968]

[13] See footnote 2

2. Integration & Organisation: “How can interactions and value exchanges between different sectors and stakeholders be organised to optimise the operation of energy systems?” This concerns, how the interplay of the different actors and their related system elements in the whole network, from production to end use, can be organised so that the various forms of renewable energy can be combined for a continuous and flexible supply of services and processes. This includes aspects of the exchange of value between the actors (with their related system elements) – like market and business models or communities. It also includes aspects of the legal and regulatory framework. Moreover, it also considers the interaction related to CO2 management. Interactions of players to assemble and disassemble the systems are also considered to be part of their operation, including organisational aspects of circularity.

3. Transformation & Change; “How can the change processes for the new energy system be shaped to seamlessly integrate into the daily lives and operations of citizens, businesses, communities, and infrastructure providers?“ This comprises the nurturing and facilitation of innovation ecosystems as well as the design of systems, technologies and services at the human-technology interface. But it also affects the change in companies with their personnel and organisational structures, aspects of social acceptance, the change in values and user behaviour as well as cultural discourse (e.g. spatial planning), and other socio-technical aspects. The sustainable provision of materials, components and systems in global supply chains is an essential prerequisite for the successful energy transition. In the transition, impacts on the climate (with a focus on the CO2 effect and climate crisis as a leading motivation), nature and ecology as well as resources in general must be kept in mind.

B ETIP-SNET Roadmap ([14]) is planned along nine main thematic fields, called High Level Use Cases (Figure 4).

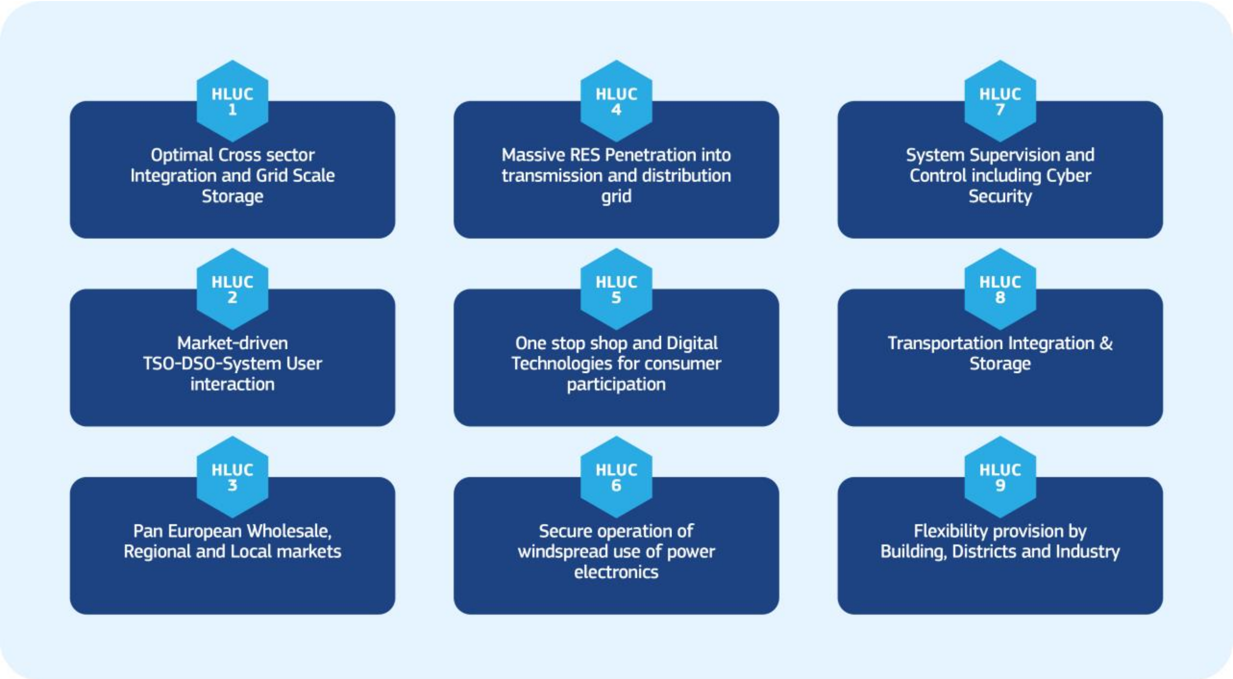


Figure 4 High Level Use Cases of ETIP SNET

Since all activities in Flagship 1 are fully in line with this ETIP-SNET Roadmap no description of the R&D needs is deemed necessary in this document. Flagship 1 mainly covers the overall energy system with a strong focus on the transmission system.

The regional and local aspects planned in the Flagship 2 are generally in line with the High-Level Use Cases of ETIP SNET as well, but specific issues in relation to the regional and local aspects need to be considered separately. Activities for Flagship 2 are described in the form of activity fiches. They were jointly contributed and agreed upon by the members of the IWG-4.

[14] ETIP SNET, R&I Roadmap 2022-2031 - Publications Office of the EU (europa.eu)

In Flagship 2 the following activity fiches have been set out (Table 2) and their detailed description can be found in Chapter 5

Process chain to ensure interoperability for digitalization in the energy system
Digital services for system flexibility
Innovation ecosystems for integrated regional and local energy systems
Heating and cooling systems on regional level
Regional integration of industrial energy systems
Hydrogen production, trading and usage in an integrated regional energy system
Battery energy storage in an integrated regional energy system

Table 2 Activity fiches of Flagship 2

Furthermore, the two flagships are complemented by cross-cutting activities.

3.3. The Innovation Targets

For Flagship 1 four targets were set:

- Observability and controllability:
- Load profile management
- Flexibility increase
- Storage cost reduction

For Flagship 2 the following targets were set:

- Regional RES integration including different energy infrastructure
- Regional system integration of different energy vectors
- Integration of relevant infrastructure into regional energy systems
- Smart services for flexibility to develop local and regional value chains
- Digitalisation as enabler of system connectivity

3.4. Elaboration on Targets

3.4.1.1. Observability and controllability

> Solutions should enable at least the same level of observability and controllability as would be achievable by equipping 80% of the HV and MV substations and 25% of LV substations with remotely accessible monitoring and control devices.

The final target of the RD&I activities is to improve and smarten power system operation at all voltage levels in order to maintain a high level of quality of supply in a more uncertain and more interconnected system. The operation needs to consider variable renewable energy sources (RES), distributed energy resources (DER), demand response (DR) and storage. In addition, it is important to consider new technologies, the interfaces with other energy vectors and the transport/mobility systems, as well as the evolution of the European energy market and new business models. This target requires a stronger controllability of the power system at all geographical scales (from the pan-European level down to the national, regional and local levels) and at all time scales (from the seasonal scale linked with hydroelectricity down to the milliseconds scale linked with the power system stability).

The prerequisite of increased controllability is tightly linked with the capability of a timely observability of the continuously changing conditions of the systems, by means of adequate sensors (from phasor measurement units (PMUs) at transmission and distribution levels down to smart energy meters, equipment conditions and diagnostics, communication system states, including weather forecasts for RES production and resilience etc.). Suitable communication and data exchange protocols and platforms are requested in order to collect and process all data.

3.4.1.2. Load management and demand response

Solutions should have load modulation capabilities equivalent to those that enable a peak load reduction at system level of 25% with respect to the projections in the scenario of the latest TYNDP of ENTSOe [15].

Demand response is potentially one of the most powerful tools for power system flexibility. Load control solutions, such as peak shaving, load profile management, and the related energy savings potential can span the entire range of energy users: from very large-scale industry, to the tertiary sector and single end-consumers. Shaping the demand profile based on the availability of energy in the different regions and at all time scales can be a strong enabler for the integration of RES and DER and a powerful means of system efficiency. Implementing demand response for large numbers of residential and small commercial consumers requires providing end users with information on their consumption and the ability to modify their consumption in response to, for example, time-based price signals and other types of incentives, so as to provide system services for DSOs through new market players such as aggregators and storage operators.

The main targets of the RD&I activities are to address the different aspects of the customer participation at all levels in the evolution of a demand response flexibility model based on a robust market model, and in particular:

- The quantification and assessment of the flexibility and efficiency potentially enabled by demand response;
- the definition and boundaries of a customer-centric model, the role of the different parties and the motivation of the consumers;
- the definition of main focus/market of the business models;
- the analysis of the technologies and solutions that can be applied in this field (e.g. blockchain);
- the forecast of demand (and residual loads) accounting for the new loads and the demand-response activities of new market players;
- the necessity of regulation changes to enable these business models;
- with special reference to the potentially very wide deployment of electric vehicles, the necessity to assess the impact of the charging systems on the grid operation and development and its mitigation through intelligent solutions.

[15] Explore | ENTSO-E TYNDP (entsoe.eu)

3.4.1.3. Flexibility of the generation

Solutions should be equivalent to those providing balancing services, redispatch, contribution to the stability, 'smart' connection with the grid or improving accuracy of forecasting models for aggregated RES plant power production by 10 %.

Solutions should be equivalent to 50% of all thermal power plants fulfilling the following requirements:
- Doubling of average ramping-rates (the speed at which output can be increased or decreased).
- Halving efficiency losses for part-load operations.
- Reducing minimum load by 30% compared to the average of today (avoiding plant switch-off).

With a growing share of renewable power, especially when having priority access to the grid, all types of generation connected to the grid must increase the level of operation flexibility.

Thermal power plants must shift their role from providing base-load power to providing fluctuating back-up power to meet unpredictable and short-notice demand peaks. In this context, flexibility is understood as the ability to complement the variable renewable generation quickly and at lowest emission level, ensuring the necessary reliable electricity and heat/cold supply (start-up/shut down rate, ramp-rate and reduced minimum load). This also includes fuel flexibility (capacity to switch between renewable-based fuel as well as conventional, including different rates of mixtures, reacting to availability of carbon-neutral synthetic fuels like synthetic methanol or methane, hydrogen, ammonia, biomass derived from waste, etc.).

CHP (combined heat and power) are among the most efficient flexible generation alternatives. However, they are challenged when the need for electricity and heat does not match, reducing their potential application. Using excess renewable energy at times of low demand through the integration of storage – be it electrical, thermal, mechanical or chemical – into thermal power plants can help optimize their operations. Decoupling heat and electricity generation will allow for a more efficient energy use via flexibilization of demand response to the different consumers.

Renewables themselves, when equipped with integrated storage, can make the fluctuating renewable resources a dispatchable, predictable, flexible generation asset, able to provide any generation and network system requirements. The major challenge here is to combine storage with a fluctuating renewable asset (e.g. wind, solar, marine) with a positive business case, including more responsibility in dispatching energy and participating in ancillary services markets.

Power-to-Hydrogen technologies could, in principle, constitute one potential source of flexibility by transforming otherwise curtailed excess renewable generation into hydrogen. However, the effective viability of possible respective electrolyser business cases will ultimately depend on their competitiveness with other sources of flexibility (e. g. batteries). In this context, Power-to-Gas and Power-to-Liquid solutions can produce renewable gases or fuels to be used in, e.g., flexible thermal power plant systems. Moreover, by additionally applying CCU-technologies, synthetic liquid or gaseous fuels can be produced and used in their molecular state to de-fossilise hard-to-abate sectors such as heavy industry or mobility.

The main targets of the RD&I activities are to address the different technological, environmental, economic, and regulatory aspects that will foster the use of flexible generation of all types to enable the most extensive integration of variable renewables in the energy system.

3.4.1.4. Reduction of costs of storage

The range of cost reduction is depending on the specific technologies, covering the whole range including batteries, pumped hydro, the interaction of heat and electricity networks, power-to-heat and power-to-gas/fuel concepts, interaction of gas, heat and electricity networks.
Solutions for **short-term storage** should enable the reduction of the specific storage costs by at least 50% to 70%

Among the various tools system operators can use for real-time balancing of generation and demand, maintaining power quality, and preventing asset overloading, energy storage technologies will play a vital role in supporting system stability.

Energy storage technologies for energy and power applications still seem far from meeting technical and economic targets. For example, while current available storage technology is proving its effectiveness in fast balancing services, there is still a strong need to optimise and demonstrate storage technologies able to cover the intraweek and seasonal modulation needs. Moreover, the total cost of storage systems, including all the subsystem components, installation, and integration costs need to be cost competitive with other non-storage options available to electric utilities.

The principal challenges to be addressed by the RD&I activities are:

- Identify use cases, organisation concepts and business models for energy storage in the various services it may provide to the grid, individually and in multiple or stacked services, where a single storage system has the potential to capture several revenue streams to achieve economic viability while serving different stakeholders (system operators, market participants, prosumers, industry). Consideration of the regulatory framework (limiting the facilitation of energy storage through system operators) is crucial in that regard.

- Investment strategies and business models – Adopting collective investment strategies for the implementation of large-scale energy storage facilities could as well influence overall costs, compared to the traditional approach of investing in numerous smaller storage units. The integration of crowd-investing models and platforms and potential revenue-sharing mechanisms can be additional factors that could contribute to cost efficiency in energy storage projects. Serving different stakeholders (including system operators) has to be considered here as well (see point above).

- Cost competitive energy storage technology – Achievement of this goal requires attention to both cost factors as well as revenue factors. Cost factors include life-cycle cost and performance (round-trip efficiency, energy density, cycle life, degradation, etc.) for energy storage technology. Revenue factors include provision of services to prosumers, system operators and markets in a multifunctional fashion.

- Validated reliability and safety – Validation of the safety, reliability, and performance of energy storage is essential for user confidence.

- Equitable regulatory environment – Value propositions for long-term grid storage depend on reducing institutional and regulatory hurdles to levels comparable with those of other grid resources.

3.4.1.5. Regional RES integration including different energy infrastructures

Regional renewable energy sources (RES) integration involves developing systems that combine various low-carbon energy solutions with other infrastructure and end-use technologies. These integrated systems, supported by smart technologies and energy management tools, aim to optimize local infrastructure use, stabilise energy supply, and connect regional systems to the broader energy grid, enhancing its flexibility and efficiency.

Systems need to be developed that bring together multiple low-carbon solutions (e.g. wind, solar, renewable heat generation, renewable gas, etc.) and combine different energy vectors, technologies and infrastructures.

In a new systemic approach, all the elements (such as electricity, gas, heating and cooling grids, end-use technologies in buildings and other infrastructure (e.g. water supply and sewage systems, transport system etc.), different kinds of end-users and management of energy conversion) will be combined and integrated in an innovative way. Through this, these systems will allow integration of energy supply from various sustainable and variable sources and will secure optimal utilization of the limited local and regional infrastructure and resources. By using energy management, monitoring systems and smart technologies, synergies between different energy vectors and pieces of infrastructure will be used to achieve optimal solutions for the regional or local energy systems. At the same time, the regional and local systems will connect to the overall energy and associated digital system, contributing to its stability, resilience, flexibility and efficiency.

This requires improving the accuracy of generation forecasts, developing technologies, tools and services such as combining local RE generation with storage and/or the injection of electricity into the grid in order to reduce fluctuations in generation and enable RE to act as a market participant and provide services to the grid infrastructure. This includes incentives for self-consumption of locally and regionally generated energy and for flexibility that contributes to the stabilisation of the overall electricity system.

Given the overarching goal of developing integrated, regional and local energy systems, this approach will be transferred to the broader area of multidimensional energy systems, in which the electricity system could play a central role.

3.4.1.6. Regional system integration of different energy vectors

Regional system integration of different energy vectors involves encouraging decentralized renewable energy generation and storage, with consumers playing a key role by adopting flexible technologies like electric vehicles, hybrid storage systems, and district heating/cooling. This approach aims to enhance energy system flexibility through innovations in grid connections, storage integration, and hydrogen utilisation, while addressing the need for viable business models, standardised components, and grid-related measures to ensure both economic viability and supply security.

In its "Clean Energy for all Europeans" package, the European Commission highlights the importance of regional and local energy systems. Consumers should be encouraged to generate and store their own renewable energy, integrating decentralised generation, controllable loads, electric vehicles, and hybrid storage systems.

Flexibility in the electricity sector is key, requiring innovative technologies that change the relationships between generation, distribution, consumption, and storage. This enables greater customer participation, better storage integration, and optimized use of interconnections between electricity grids and other networks (e.g., gas, heating, cooling, transport).

District heating and cooling have proven to have enormous potential for increasing the local flexibility and efficiency of the energy system. Depending on the location of the area (rural/urban, geological conditions, nearby industries or sewers, available land for solar energy, surplus heat from industry or natural cooling, large storage capacities, etc.), different sources of heating and cooling are locally available and can be used. While new grids can be designed from the outset to match the temperature level of the locally available heat source, existing grids require major adjustments. The integration of renewable energies and waste heat sources requires more flexible concepts and solutions.

Renewables themselves, when equipped with integrated storage, can turn fluctuating renewable resources into a predictable, and flexible generation asset capable of meeting all generation and grid system requirements. The biggest challenge is to generate a positive business case and create the framework conditions for taking on more responsibility in dispatching energy and participating in the ancillary services markets.

As part of the current energy transition, hydrogen can play a key role in regional integrated energy systems. Beyond its industrial use, hydrogen's potential in local energy systems needs exploration. Integrating hydrogen with existing gas grids can combine efficient thermal power plant technology with large-scale storage solutions. Innovations in gas grid technology will also support decentralized hydrogen production and efficient feed-in.

R&D&I activities for regional system integration aim to address the technological aspects of improving the flexibility of the energy system and to develop business models that create appropriate incentives for all actors involved, in particular local consumers, commerce and industry and end users. Necessary grid-related measures; the use of standardised, more efficient and more cost-effective components plays an important role. Measures to achieve these targets must consider economic viability and security of supply as key aspects.

3.4.1.7. Regional integration of stakeholders and their relevant infrastructures

Integrating relevant infrastructure into regional energy systems requires incorporating energy grids, buildings, industries, commerce, and households to optimise energy use and support the transition to a low-carbon system. This cross-sector approach, involving renewable energy, waste energy, demand response, and sector coupling (e.g., electric vehicles and thermal storage), promotes flexibility, efficiency, and sustainability, while relying on new technologies, regulatory frameworks, and business models to achieve climate neutrality.

Integrating essential infrastructure into regional energy systems is crucial for achieving balanced energy consumption. Key components of this infrastructure include the energy grid, energy generation facilities, buildings, local industries and commerce, and households. Given the substantial energy demand and CO2 emissions from industry, incorporating industrial sectors into the overall energy system is vital for building a climate-neutral future.

A key aspect of the energy transition involves sustainable integration of industry, buildings, and commerce into local and regional energy plans. This means adapting local communities, municipalities, industries, and businesses to regional conditions, optimising energy use and supporting the transition to a sustainable, low-carbon energy system.

This involves cross-sector integration of renewable energy sources, waste energy, and optimized consumption across various areas. In transport, this includes vehicle-to-grid systems, where electric vehicles both charge and provide storage to stabilise distribution networks. In industry and commerce, facilities like industrial plants, data centres, and large buildings can use electricity, provide waste heat, and leverage thermal storage to balance the grid.

Municipal infrastructure, including heating and cooling networks, water supply, public transport, and street lighting, also contributes to this integration. In agriculture, farms can produce renewable energy, generate fuels, and adjust energy demand to enhance system flexibility. This holistic approach ensures a more efficient and sustainable energy system.

Demand response, such as peak shaving, load profile management and the associated energy saving potential, is potentially one of the most effective tools to increase the flexibility of the electricity system. Demand response can cover the full spectrum of energy consumers: from large-scale industry to the tertiary sector to individual end-users. Shaping the demand profile based on energy availability in the different regions and at all time scales can strongly encourage the integration of renewable energy and be an effective means of increasing system performance. Implementing demand response for a large number of commercial, buildings and industrial consumers requires the provision of information on consumption and the possibility to change their consumption, for example in response to time-based price signals and other types of incentives to provide system services to DSOs by new market entrants such as aggregators and storage operators.

Coupling the thermal and electrical grid and including electric vehicles, energy storage (both thermal and electrical) and residual energy for local activities (industry, agriculture, etc.), can play a role in balancing the electricity market, in addition to providing local energy. Sector coupling, for example, allows surplus electricity or heat to be used to generate heating and cooling for both local buildings and other industries.

To enable this integration of the energy and industry sectors, extensive cross-sectoral cooperation is needed. Building climate neutrality requires the development and deployment of new technologies, new regulatory frameworks and new business models. As a first step, stronger sector coupling within energy (electricity, heat, cooling, gas) is needed. In the long term, the entire energy and industrial system needs to become more flexible and adaptable and the system needs to include new mechanisms for enhanced industrial demand response.

The energy modelling and scenario tools currently in use should comprehensively consider waste heat sources (e.g. industrial processes, cooling of commercial buildings and data centres, electrolysers, urban infrastructure (e.g. sewers) and ambient heat), for example by following a circular economy approach or applying energy saving principles on the end-use side.

3.4.1.8. Smart services for flexibility to develop local and regional value chains

Developing smart services for flexibility in local and regional value chains requires new business models, regulatory frameworks, and partnerships between diverse stakeholders. By fostering cooperation across sectors and enabling the development of scalable, adaptable, and user-friendly solutions, these smart energy systems aim to optimise energy use, enhance flexibility, and accelerate regional energy transitions while integrating various stakeholders.

The development and implementation of smart and integrated energy systems requires not only innovative technologies, but also organisational and regulatory innovations, new business models, new or redesigned value chains, new players in the research and business landscape for energy services and technologies, and better integration of different types of end users into the energy system. For example, local energy communities should be promoted with a view to optimising the overall system. This means that appropriate markets should be developed to facilitate and remunerate the contribution of local energy communities to the security and optimisation of the overall system.

A variety of entrepreneurial initiatives and partnerships between different actors are needed to accelerate the implementation of smart and integrated energy in society. Integrated initiatives are needed to support social, institutional, organisational and market innovations in the energy sector, including the intersections between energy supply, energy efficiency and new user practices. New co-operative approaches will strengthen local and regional transition dynamics and entrepreneurship.

Developers of smart flexibility services, whether for sector-specific or cross-sector solutions, face the problem that ICT solutions for the complex world of energy cannot be developed from scratch. The activities aim to enable key players in the world of smart energy services to develop innovative cross-cutting solutions for flexibility programmes ranging from the regional to the global level, ensuring that the solutions have features such as interoperability, scalability, data protection, replicability, adaptability and extensibility, while being open, possibly as open-source initiatives.

The development of applications should address a wide range of stakeholders with user-friendly services. These include infrastructure operators (transmission/distribution grid operators for electricity, heat/cooling, gas), providers/operators of energy conversion and storage technologies, service providers (e.g. energy suppliers, aggregators), energy communities (electricity-based and cross-sector) and end customers with a focus on industrial customers serving as flexibility providers.

To take a leading role within international developments, European innovation ecosystems should be created around regional and local energy systems, enabling potential buyers, developers and suppliers to work together in co-creation processes to develop attractive services that meet the needs of the various participants and the system as a whole. On a local or regional level, smart energy activities often involve multiple economic sectors.

3.4.1.9. Digitalisation as enabler of system connectivity

> Digitalisation enables system connectivity for facilitating better monitoring, automation, and control of energy systems, allowing stakeholders to interact more effectively. Achieving interoperability across sectors and ensuring seamless data exchange, particularly at regional and cross-border levels, is key to integrating energy systems and overcoming barriers to collaboration, with a focus on harmonised interfaces and a common IT infrastructure.

Smart energy systems should enable better monitoring, automation and control of the existing system while ensuring that all stakeholders (regulators and market participants) can interact. This is made possible by the complete digitalisation of all processes in the system. Today, digitalisation is already being implemented in the transmission and distribution grids (mainly MV) of the electricity grid as well as for some market applications. However, the digitalisation of other processes within the energy system, such as in the heating grid or the low-voltage distribution grid, is either already underway or is expected in the near future. Data exchange between sectors is also becoming increasingly important for integrated energy systems.

The lack of interoperability is a major barrier to progress for the interconnection of energy system actors. Harmonised interfaces facilitate the provision of services that work together within organisations or sectors and across sectors.

On the one hand, the energy transition will require cross-border data exchange in Europe. This is necessary for operational use cases, such as the provision of flexibility, as well as for business issues and for environmental data monitoring and reporting.

On the other hand, interoperability is crucial for connecting actors in the energy system down to the regional level. Here too, cross-sector data exchange is an important challenge that needs to be solved.

Interoperability, ensured by a common IT infrastructure, is crucial for the creation of European data spaces for energy and cross-sector use cases. A complete process chain to ensure the interoperability of ICT systems provides detailed specification and testing processes as well as the necessary governance for the processes, enabling providers to implement standard-based interoperability of their communication systems.

4. Overview of the Proposed Innovation Activities

The activities in Flagship 1 are planned along the ETIP SNET Roadmap- the activities of Flagship 2 are summarized in the following table:

Activity fiche	Planned activities
Process chain to ensure interoperability for digitalisation in the energy system	• A joint COST or Coordination & Support activity within the HEU program • A joint lighthouse (or research infrastructure) project for an HPCC dedicated to the energy domain • Transnational calls within CETPartnership TRI1 • Setup a joint transnational structure for a European organization 'IES Europe' • Align national, transnational and international activities and funding schemes on interoperability • Further collaboration ideas: Share interoperability profiles, testing and certification procedures on knowledge sharing platforms, development of pan-European network of testing facilities and certification center: e.g. with the ERA Net / CETPartnership working group European Collaboration Network for Interoperability Testing • In cooperation with EC establish interoperability testing in European activities.
Digital Services for system flexibility	• Enable know-how transfer on existing platforms • Provide training and tutorials about existing platforms • Provide hands-on tutorials for integrating smart energy services into exiting platforms • Foster exchange between users of platforms and developers of services to exchange their experiences and to improve the existing systems • Enable close collaboration between different programs aiming to create scalable solutions based on existing platforms. Setup funding frameworks for transnational research and development projects, CETPartnership TRI 1 and TRI 5 • Provide funding (with high funding rates) for multi-domain projects developing, implementing, and demonstrating smart energy services in a real environment • Aiming to achieve high Technology Readiness Level (>=7) • Involve multiple stakeholders from different energy domains
Innovation ecosystems for integrated regional and local energy systems	• Co-operation activities with CETPartnership TRI5 for Integrated Regional Energy Systems, CETPartnership TRI6 Integrated Industrial Energy Systems and CETPartnership WP6 Impact Network such as → *Networking events for the innovation ecosystems, business clusters and Living Labs to share knowledge and connect* → *Support and trainings to strengthen build-up, growth, management and operations* of local *and regional innovation ecosystems, business clusters and Living Labs* • Initiative NoREST from CETPartnership TRI5 to involve need-owners in R&D projects → *Co-creation activities to involve need owners and their requirements in energy concepts for local and regional ecosystems* → *Co-creation activities for new projects, demonstrations, model solutions, challenge camps, market shaping, etc.* • Collaborate with DUT Partnership, ENOLL, INTERREG
Heating and cooling systems on regional level	• Research Programmes (CETPartnership TRI 4) on the technology questions: → *Identify the systemic constraints* → *Realistic mapping* → *Better consideration of waste heat* → *Take into account the different temperature levels* → *Consider different flexibility scales* → *Improve the modelling of seasonal energy storages* → *Geographically differentiated strategies* • Definition and standardization of market models for heating and cooling

Regional integration of industrial energy systems	• Co-operation activities with CETPartnership TRI6 for Integrated Industrial Energy Systems such as → *Thematic workshops and seminars* → *Co-creation of a roadmap for market shaping* → *Identification of potential demonstrations* • Cooperation beyond Europe: Mission Innovation Industry Mission
Hydrogen production, trading and usage in an integrated regional energy system	• A joint technology and system development (or research infrastructure) project for hydrogen production, distribution and storage on a regional level • Government to Government information Exchange on ; Standardization for Products (KPIs) to make them comparable and definition of market and business models • Transnational calls research and studies concerning regional distribution, storage and production options as well as calls for research programmes in order to reduce cost
Battery energy storage in an integrated regional energy system	• Establish a Coordination and Support Action on the Pre-standardization for terminology, core indicators, test procedures (CETPartnership TRI 3) • Provide materials and trainings • Establish a seal of approval (similar to the PV storage efficiency guide), benchmarking, • Develop standardized vendor-independent model calculations, ensure the availability of tools for independent calculations. • Transnational research calls should consider the following research questions: → *Regional business models and technology applications, plant design and deployment strategies.* → *Development of battery storage systems that are easy to implement, safe, easy to scale and expandable over the lifetime.* → *Research projects to increase the resilience of the technology over its entire lifetime, as well as analysis procedures for system evaluation and operational analysis. End-of-life and circular economy*

Table 3 Activities in Flagship 2 fiches

5. Flagship 1

Flagship 1 refers to the R&I Implementation Plan 2025+ of ETIP SNET, the European Technology and Innovation Platform on Smart Networks for Energy Transition. ETIP SNET is a SET Plan organisation that provides R&I roadmaps on integrated energy systems supporting the EU policy and research programs. IWG4 supports R&I programmes at national level ensuring the general alignment among the EU countries and among them and the overall SET Plan Action 4.

Therefore, Flagship 1 targets are aligned with the so-called High Level Use Cases (HLUCs) of ETIP SNET, the main R&I macro-themes identified to coordinate EU R&I programmes on integrated energy systems.

		Flagship 1 Targets			
		Observability & controllability	**Load profile management**	**Flexibility increase**	**Storage cost reduction**
ETIP SNET HLUCs V	**HLUC 1** *Optimal cross-sector integration and grid scale storage*	x		x	x
	HLUC 2 *Market-driven TSO–DSO–system user interactions*	x	x	x	
	HLUC 3 *Pan European wholesale markets, regional and local markets*		x	x	
	HLUC 4 *Massive penetration of RES into the transmission and distribution grid*		x	x	
	HLUC 5 *One stop shop and digital technologies for market participation of consumers (citizens) at the centre*	x	x	x	
	HLUC 6 *Secure operation of widespread use of power electronics at all systems levels*	x			
	HLUC 7 *Enhance system supervision and control including cyber security*	x		x	
	HLUC 8 *Transportation integration and storage*	x		x	
	HLUC 9 *Flexibility provision by building, districts and industrial processes*	x	x	x	

Table 4 Flagship 1 Targets and ETIP SNET High Level Use Cases

5.1. Flagship 1 R&I themes

Flagship 1 R&I themes are meant to guide national R&I programmes on energy systems in line with the four targets and in such a way to foster overall EU R&I Roadmap. The Roadmap and Implementation Plans of the Related ETIP for IWG-4 are structured in High Level Use Cases (HLUCs) and a level more detailed: Priority Project Concepts (PPCs). In the following chapters several references are made to this structure, because Flagship 1 is very much aligned with the structure of ETIP SNET. ETIP SNET HLUCs are kept as terms of reference to ensure activities at national level not only reflect local needs and potential but move in a coordinated EU direction as well.

5.1.1. Activity fiches on Optimal Cross sector Integration and Grid Scale Storage (cfr. HLUC 1)

To develop an energy system fostering high levels of renewable penetration, efficiency, circularity and resilience, different sources, vectors, sectors and technologies need to be integrated, adopting storage, conversion (e.g. P2X, X2P) and load management (e.g. demand response) instruments. On the one hand more renewable and distributed energy production is needed and on the other hand flexibility management across the entire value chain, from generation to load, is necessary, going beyond the boundaries of the energy sector, leveraging the flexibility potential of buildings and industrial processes.

The integration of different sources, vectors, devices and sectors requires solutions to manage technical, economic and commercial aspects, looking respectively to management and control tools and to market frameworks for integration of fostering the participation of stakeholders towards and economically viable energy system.

Looking at the coming years, these are the R&I themes to consider with priority:

- **Integrating hydrogen and CO_2-neutral gases** (PPC 1.4 from IP 2025+): Development and demonstration of sectoral integration of hydrogen and CO2-neutral gases with electricity system and renewables.

- **Regulatory framework for cross sector integration** (PPC 1.5 from IP 2025+): Design of new market and regulatory frameworks that would provide business cases for cross-sector coupling in low carbon energy future, from local to international level.

- **Cross-sector resilience** (PPC 1.6 from IP 2026+): Enhancing security and resilience of the energy system, looking also at interconnected EU regions, through optimal cross-sector integration and long duration energy storage.

- **Standards for cross-sector integration**: Future cross-vector infrastructure design (PPC 1.7 from IP 2026+): Development of new design standards enabling cross-sector integration and energy storage to be compared with traditional energy infrastructure design approach.

- **Demonstration activities**: Validation/Demonstration (PPC 1.8 from IP 2026+): Large scale demonstration projects on coordinated operation of cross-sector coupled energy systems, while managing synergies and conflicts between consumers and actors of the different sectors.

5.1.2. Activity fiches on Market-driven TSO–DSO–System User interactions (cfr. HLUC 2)

It is necessary to prepare to manage the integrated energy system market, with several actors from different sectors, with an increasing importance of prosumers and flexibility services. We need to develop adequate market models and data exchange systems to coordinate both vertical interactions (throughout the value chain) and horizontal ones (among different vectors and sectors) in real time, implementing signals considering grid needs and economic incentives. We need platforms enabling the operation of this new energy market.

R&I institutions and organisations should focus over the coming years on the development of a digital twin of the European power grid enabling new functions in terms of observability and controllability, planning, predictive simulation and maintenance and fostering the study of new interactions among TSOs, DSOs and final users thanks to new regulatory and market frameworks and data exchange standards.

R&I themes on these issues:

- **Development of a Digital Twin of the European Electricity Grid** (PPC 2.5 from IP 2025+): Build a digital twin starting from the activities of innovation projects in five areas: observability and controllability; efficient infrastructure and network planning; operations and simulations for a more resilient grid and improved security of supply; active system management and forecasting to support flexibility and demand response; data exchange between TSOs and DSOs.

- **Viable business cases through market mechanisms and incentives** (PPC 2.6 from IP 2025+): Design, test and demonstrate market mechanisms and incentives for an open participation of (aggregated) prosumers (system users) and effective cooperation of system operators. Ensure viable business cases and perform cost-benefit analysis of different options for coordination schemes.

- **Governance for TSO, DSO and System Users** (PPC 2.7 from IP 2025+): Develop and demonstrate a regulatory and administrative framework for an effective and efficient Energy System Governance, providing robust standards for coordination among energy system players and for data exchange. Definition of appropriate data models that can represent properly all the TSO-DSO-System User Interactions.

5.1.3. Activity fiches on Pan European Wholesale Markets, Regional and Local Markets (cfr. HLUC 3)

The integrated energy system market will need flexibility technologies and advanced control systems in order to be effective enabling different new practices at all levels, from local to regional and pan-European. Among these new practices, we need to demonstrate and validate technologies and control concepts and platform tools enabling markets for energy trading and balancing services, network congestion management, load and capacity management, and efficient low-carbon generation. These tools will also foster a new role mainly for DSOs, which will be the main management bodies for ancillary services, flexibility data management, the integration of heat and transport sectors and for all the above-mentioned practices.

R&I themes on these issues:

- **Tools for multi-energy system market**: Validation of new market concepts (PPC 3.4 from IP 2025+): Development and demonstration of advanced technologies and control concepts/platform tools for supporting multi-energy systems market. These technologies and tools should be based on appropriate data exchange between different energy sectors at all geographical scale (from local to international) and should also enable decentralised, peer-to-peer trading, (enabling end consumers to trade energy and ancillary services in real time), and market driven system control (e.g. congestion management) and assess the impact on end consumers services quality.

- **IT systems for TSO/DSO control** to support real time balancing (PPC 3.5 from IP 2026+): Demonstration of platforms/IT systems for market driven coordination of trading of energy, balancing services and network congestion management from local to international level.

5.1.4. Activity fiches on massive penetration of RES into the transmission and distribution grid (cfr. HLUC 4)

The penetration of variable renewable energy, with the development of both large and centralised plants and distributed ones at transmission and distribution levels, requires improved weather and energy demand forecasting, adequate monitoring, protection and control mechanisms for grid stability. The role of storage and flexibility solutions is crucial for the management of the integrated RES-based energy system for both technical and market aspects.

R&I themes on these issues:

- **Market participation and mechanisms for RES**: Well-functioning markets for a RES based energy system (PPC 4.5 from IP 2025+): Elaborate appropriate mechanisms for market participation from RES from local to global scale and from different energy sectors, ensuring both viable business cases and regulations. Ensure reduced risk for vulnerable consumers and transparency and non-discriminatory requirements under a market design with massive penetration of renewables.

- **Policies and governance for a RES-based energy system** (PPC 4.6 from IP 2025+): Develop tools and mechanisms to support the governance of top-down RES targets with bottom-up private investments in RES, storage and flexibility means. The governance should enable planning for temporal match and adequacy at different time frames.

5.1.5. Activity fiches on one stop shop and digital technologies for market participation of consumers (citizens) at the centre (cfr. HLUC 5)

Consumers will play an important role in the adoption of the solutions at the base of the new integrated energy system. The pace of consumers' adoption of EVs and heat pumps will be relevant for the actual electrification of the energy system. Independently from the country and region-specific characteristics that the energy system will have, consumers should be enabled to take all the advantages of a cleaner and more efficient energy supply provided by a multi-energy integrated system. Education and training will be important but, given consumers cannot become energy experts, user-centred solutions will also need to be developed and validated. The inclusion of people can work only on user-friendly IT solutions able to manage not only consumer energy needs but also their needs related to other services, beyond energy.

The integration of the energy sector in the wider data economy will enable the creation of a one-stop shop for different services (not just energy-related) but requires new developments about standard interfaces and secure communication solutions. These developments become even more crucial given the increasing role of prosumers and flexibility provision from demand side management solutions.

Among tools to be developed there are platforms for the provision of new services, plug & play solutions to enable the citizen participation in the energy system, new smart meters for real-time data management, particularly for flexibility services. “Behind the scenes” all these solutions need a network of decentralised and federated data spaces, ICT infrastructures and skilled workers.

R&I themes on these issues:

- **Platform requirements**: Value of consumer/customer acceptance and engagement (PPC 5.1 from IP 2025+): The requirements of the platforms to be used by consumers to take part to the energy system need to be assessed, in particular the access to the necessary data.

- **Interoperability of plug-and-play devices**: Plug-and-play devices and IoT (Internet of things) including security by design (PPC 5.2 from IP 2025+): All barriers to the use of plug-and-play instruments should be removed focusing on the interoperability of the devices enabling the full access of consumers to the energy markets, in particular the ones related to demand response and flexibility.

- **Data Spaces** (PPC 5.5 from IP 2025+): At the base of energy system integration to the unique integrated access to energy markets for consumers, there is the development and validation of de-centralised and federated data spaces, enabling data exchange and ensuring security and privacy. Focus both on data sharing mechanisms and business models supporting this data integration.

- **Building skills needed for developers and users of the energy system to accelerate its transition through its digitalisation** (PPC 5.6 from IP 2025+): CSA activities should be organised to assess the gap between the digital skills needed and offered. Education programmes should be updated for workers, university students and general consumers, in order to have the appropriate digital skills for the development of and participation in the integrated energy system.

- **Service management and operations** (PPC 5.7 from IP 2025+): New energy markets open to a major consumers' involvement requires new service management processes.

- **ICT infrastructure funding schemes**: Sharing IT infrastructure investments (PPC 5.8 from IP 2025+): CSA activities should be put in place also for the development of appropriate funding schemes fostering efficient and supporting advanced ICT infrastructures.

- **Large-scale demonstration activities** (PPC 5.9 from IP 2026+): Already developed solutions and analysis tool regarding cross-sectoral flexibility use cases, data spaces, plug and play devices and data management (ETIP SNET Roadmap Implementation Plan 2025+ PPC 5.1-5.5) should be object of large demonstrations to assess their impact.

- **New standards and architectures**: Creating consensus on consumer solutions (PPC 5.10 from IP 2026+): Work on new standards and architectures constituting the conditions for real-life applications of project results.

5.1.6. *Activity fiches on secure operation of widespread use of power electronics at all systems levels (cfr. HLUC 6)*

The penetration of power electronic converter interfaced technologies, (e.g. PV, wind, storage, HVDC, etc.) requires instruments to simulate and manage power system dynamic response. Power grids are growing more dependent on complex fast-response power electronic devices, with a high adoption not only of VRES but also of meshed DC grids at all voltage levels and of hybrid AC/DC grids at both transmission and distribution levels.

R&I themes on these issues:

- **HVDC interoperability, multi-terminal configurations, meshed grids** (PPC 6.5 from IP 2026+): Methodologies and tools for multi-terminal DC configurations: Multi-terminal configurations of DC transmission networks and their operation require new methodologies, tools and models.

- **Large-scale demonstration activities** (PPC 6.6 from IP 2026+): Already developed solutions and analysis tools regarding hybrid AC/DC grids, distribution substations, power electronics-driven networks and multi-terminal DC grids (ETIP SNET Roadmap Implementation Plan 2025+ PPC 6.1-6.5) should be the object of large demonstrations to assess their impact.

- **Standardisation activities** (PPC 6.7 from IP 2026+): Work on new standards and architectures constituting the conditions for project results real life applications.

5.1.7. *Activity fiches on enhancement of system supervision and control including cyber security (cfr. HLUC 7)*

The increase of distributed variable generation and the pervasive adoption of digital devices imply the necessity of improved grid observability, both at transmission and distribution levels, from high to low voltages, in such a way to manage fast dynamics real time. Complexity requires a more distributed grid management, going beyond traditional centralised architecture, balancing automated actions and human operators' interventions and ensuring high cybersecurity levels.

The R&I focus over the next years should be on the control rooms of the future, on the new necessary electronic and ICT expertise and on effective human machine interfaces, adequate to enable the appropriate supervision of automated actions.

R&I themes on these issues:

- **Grid operator of the future** (PPC 7.5 from IP 2025+): Control room workforce preparation: New educational programmes must be designed to prepare future control room operators, focusing on cybersecurity aspects.

- **Grid field workforce of the future** (PPC 7.6 from IP 2025+): New educational programmes have to be designed to prepare the field workforce, that will deal with more electronic devices, more subjects participating to the energy system and more distributed control, with their cybersecurity implications.

- **Human machine interface (HMI)** (PPC 7.7 from IP 2025+): Automated actions must be supervised by human operators, so human machine interfaces should be able to effectively present data and support the interactions of the operators.

- **Cybersecurity of energy networks** (PPC 7.8 from IP 2025+): All ICT systems, services and programs in the energy system should be the object of an appropriate risk assessment in order to identify the most vulnerable ones in terms of cybersecurity criteria.

- **Large-scale demonstration activities** (PPC 7.9 from IP 2026+): Already developed solutions regarding TSO control rooms, DMS and data management and GIS for distribution grids (ETIP SNET Roadmap Implementation Plan 2025+ PPC 7.1-7.3) should be the object of large demonstrations to assess their impact.

- **Standardisation activities** (PPC 7.10 from IP 2026+): Work on new standards and architectures constituting the conditions for project results real life applications.

5.1.8. Activity fiches on Transportation Integration & Storage (cfr. HLUC 8)

Looking beyond energy sector, we have to leverage the opportunities related to the integration of energy and mobility, implementing sector coupling with one of the most energy-consuming human activities: moving by transport. Transitioning from fossil fuel-based fuels to low and zero carbon ones (e.g. electricity, biofuels, hydrogen, ammonia) is just one side of the issue, while sector coupling would align all different means of transport (from vehicles to planes and ships) with the overall energy production system, reaching new levels of efficiency.

The main, but not the only, instrument to couple energy and mobility is smart charging: EVs, when connected to charging points, are not simply charged, they are connected to a system that distributes power among EVs and the grid, enabling flexibility provision from the vehicles to the network. The intensity and pace of charging is managed in such a way to provide both power to the users' EVs and flexibility and balancing services to the grid, enabling an efficient use of local energy resources. This wise energy flow management has to be supported by proper regulation and price signals and by an accessible infrastructure enabling the spread of EVs as well (e.g. charging points).

The benefits for EV owners, in the smart charging system, consist in their remunerated participation to flexibility markets, while the benefits for the grid and the overall energy system consist in peak smoothing and flexibility thanks to flows V2G and G2V.

R&I themes on these issues:

- **Integrated planning of energy and transport sectors** (PPC 8.3 from IP 2025+): Supporting tools and protocol for energy-mobility integration**:** The integration of mobility in the energy system requires the development of probabilistic system planning tools to assess its impacts and to elaborate the best solutions; common standards and protocols to ensure interoperability; proper electricity system design codes to enable secure smart charging.

- **Adapting policy and market for seamless cost-effective merging of transport and energy sectors** (PPC 8.4 from IP 2025+): New policies and market mechanisms for energy-mobility integration: Responsive smart charging and the connection of EVs and the energy system need appropriate market design remunerating the users properly. Also new regulation frameworks should be developed to encourage TSO-DSO interaction to support cost-effective solutions.

- **Demonstration activities** (PPC 8.5 from IP 2025+): Common management of charging stations requires appropriate IT infrastructures to enable the necessary information exchange among energy system and charging points, demonstrating the V2G operations.

5.1.9. Activity fiches on flexibility provision by building, districts and industrial processes (cfr. HLUC 9)

The alignment of energy sector, on the one side, with the energy consumption and production (through plants and waste heat and cold) of industries and the built environment, on the other, can bring sector coupling to a new pervasive dimension, reaching high levels of efficiency and circularity. The integration of industries and buildings in the energy system should go beyond single facility scale, enabling integration at wider levels, from neighbourhoods to smart city levels.

Regulations and control and cybersecurity mechanisms supporting and enabling this integration need further development, like the behaviour and the impact of these facilities in the grids and in the energy markets require more studies and demonstrations.

R&I themes on these issues

- **Governance for an effective integration of buildings and smart energy communities** (PPC 9.4 from IP 2025+): Protocols and rules for the integration of buildings and smart energy communities: It is necessary to elaborate regulations, standards, codes and practices to enable the integration of buildings and smart energy communities in a coordinated way with system operators and all energy stakeholders.

- **Evolved markets for enabling buildings and energy community facilities actively participating in support of the energy transition** (PPC 9.5 from IP 2026+): Market mechanisms for integration with built environment and industries; Market mechanisms, based on digital smart technologies, are fundamental to support the participation of buildings and industries to the energy system.

6. Flagship 2

6.1. Activity fiches

6.1.1. Activity fiches and Targets:

		Activity fiches						
		Process chain to ensure interoperability for digitalisation in the energy system	Digital services for system flexibility	Innovation ecosystems for integrated regional and local energy systems	Heating and cooling systems on regional level	Regional integration of industrial energy systems	Hydrogen production, trading and usage in an integrated regional energy system	Battery energy storage in an integrated regional energy system
Targets	Regional RES integration including different energy infrastructures	x		x	x	x		
	Regional system integration of different energy vectors	x		x	x	x	x	x
	Integration of relevant infrastructures into regional energy systems	x		x	x	x	x	
	Smart services for flexibility to develop local and regional value chains	x	x	x		x		
	Digitalisation as enabler of system connectivity	x	x					

Table 5 Activity fiches and Targets of Flagship 2

6.1.2. Activity fiche 1: Process chain to ensure interoperability for digitalisation of ICT systems

Implementation Plan - Activity fiche
Innovation Target: • Regional RES integration including different energy infrastructures • Regional system integration of different energy vectors • Integration of relevant infrastructures into regional energy systems • Smart services for flexibility to develop local and regional value chains • Digitalisation as enabler of system connectivity
Title: Process chain to ensure interoperability for digitalisation in the energy system
References to ETIP SNET Implementation Plan 2025+: HLUC 3, HLUC 5 and HLUC 9

Challenge

Interoperability of ICT systems is a key factor for the successful transition to digital business. Digital tools are becoming increasingly important in our society and economy. Successful online business (e-business) depends on data that flows seamlessly within and between organisations. The ICT systems must be scalable, both in terms of additional functions and the number of transactions and business partners and suppliers involved.

The "European Interoperability Framework for European public services" recommends "formalizing cooperation arrangements in interoperability agreements", addressing four interoperability layers:

- Legal interoperability: Defines the legal basis for cooperation
- Organisational interoperability: Defines business processes necessary for collaboration
- Semantic Interoperability: Describes the meaning and value of information
- Technical Interoperability: Describes the required technologies and standards

The lack of interoperability is a major obstacle to progress on the digital single market. Using the EIF to steer European interoperability initiatives contributes to a coherent European interoperable environment, and facilitates the delivery of services that work together, within and across organisations or domains.

On one hand, the energy transition will make a cross-border data exchange in Europe necessary. This is required for operational use cases, such as providing flexibility, as well as for business issues and for monitoring and reporting of environmental data.

On the other hand, interoperability is crucial for connecting actors in the energy system down to the regional level. There, the cross-sectorial data exchange is also an important challenge to solve.

Interoperability, ensured by a common IT-infrastructure, is crucial for the establishment of European data spaces for energy and cross-sectoral use cases. An entire process chain to ensure interoperability of ICT-systems offers detailed specification and testing processes as well as the necessary governance for the processes, which enables vendors to implement standards-based interoperability of their communication systems.

Scope

This activity fiche will support a European interoperability initiative, which provides the opportunity to establish developed processes on a European level, thereby linking national and European activities and ensuring an interoperable transition of the energy system in Europe. Interoperability of ICT-systems supports the creation of a cross-sector and cross-border digital single market, as pursued by the European Commission.

Cross-border rules and opportunities for EU data access are fragmented (e.g. smart meter data in the Member States), making use of data collected in Member States particularly difficult.

In this context an IT-Infrastructure which is offering services and functionalities for an EU-wide use of energy data while using the legal basis and possibilities of national authorities can facilitate the access to data sources through common rules, means and procedures. Experience of successful cross-border interoperability in other sectors (e.g., eProcurement, eID, eHealth) can serve as a blueprint for the architecture and services. This will ensure future cross-sector interoperability.

Based on the use cases and relevant standards interoperability profiles will be defined, which specify the requirements for software and communication interfaces and services as part of the digital energy system– for vendors, operators and users of grid-connected devices to ensure the functionality, as well as grid operators to ensure grid stability, reliability and security.

Based on the interoperability profiles, existing testing approaches will be collected, harmonized, and further developed and interoperability certification procedures will be developed. European testing facilities will become interoperability certification centres for smart energy system devices, services, and applications. Qualified centres ensure proper equipment and follow the defined testing and certification procedures.

Description of RD&I or Programming Activities:

Activities should focus on supporting a European interoperability initiative, i.e. by implementing and establishing a process chain, interoperability testing and governance to achieve interoperability of electronic data exchange in the European energy sector.

1. Collect existing standards, use cases, testing approaches in the smart energy domain.
2. Coordinate national stakeholders' participation in transnational governance to ensure the implementation of a process chain to ensure interoperability
3. Support the development of interoperability profiles based on real world use cases and existing standards, which describe the requirements for software and communication interfaces of services, and applications to ensure an interconnected energy system
4. Harmonise and develop interoperability testing approaches
5. Support the establishment of a regular, open and cooperative European test event for interoperability of ICT-systems in the energy sector.
6. Work to increase stakeholders' awareness of competitive advantages of interoperable solutions in smart grid development by applying cross-application, cross-vendor, cross-sector and cross-border dissemination strategies.
7. Offer training sessions to ensure the transfer of knowledge among relevant stakeholders and between the European and the national level.
8. Set out interoperability certification procedures for European testing facilities

Joint activities

- A joint COST or Coordination & Support activity within the HEU programme
- A joint lighthouse (or research infrastructure) project for a high performance computing cluster (HPCC) dedicated to the energy domain
- Transnational calls within CETPartnership
- Set up a joint transnational structure for a European organization ‘IES Europe’
- Align national, transnational and international activities and funding schemes on interoperability
- Further collaboration ideas: Share interoperability profiles, testing and certification procedures on knowledge sharing platforms, development of pan-European network of testing facilities and certification center: e.g. with the ERA Net / CETPartnership working group European Collaboration Network for Interoperability Testing
- In cooperation with EC establish interoperability testing in European activities.

Impact of the RD&I Activities

- **Mid-term impact:**
  - Higher awareness of interoperability among players at an EU level, enabling new digital use cases and services supporting the energy transition.
  - Increased availability of testing procedures and concepts as well as virtual and physical validation environments.

- Blue prints for processes to specify interoperability profiles and new testing facilities and certification centers

- **Long-term impact:**
  - System-wide implementation of a standardized and interoperable IT-Infrastructure for energy services and business models.
  - Harmonized and interoperable cross-border and cross sector Energy Data Spaces
  - Fostered participation of new players (SMEs) in the energy markets by easy use of standards and interoperability profiles also for use cases anchored on regional level.
  - European network of testing facilities and certification centers

TRL: 4-7

Expected Deliverables	**Timeline**
• Standardised and interoperable IT-Infrastructure for energy data spaces, services and business models • Information material for SMEs • European network for testing facilities and certification centres	

6.1.3. Activity fiche 2: Digital Services for System Flexibility

Implementation Plan - Activity fiche
Innovation Target • Smart services for flexibility to develop local and regional value chains • Digitalisation as enabler of system connectivity
Title: Fiche 2 Digital services for system flexibility
References to ETIP SNET Implementation Plan 2025+: HLUC5
Challenge Developers of smart flexibility services, whether for domain-specific or multi-domain/cross-domain solutions encounter the problem that ICT solutions for the complex world of energies cannot be developed from scratch. Public funding programmed aimed at to supporting projects for smart service development in the energy sector, risk financing pilots that build on generic technology that are unlikely to achieve the critical mass needed for market compatibility. At the same time, multiple platform solutions are available in the ICT sector to enable the development of technical or business services. These platforms are usually not easily available for project consortia and service developers. The general assumption is that such platforms and development eco-systems have a layered structure with clear interfaces between the layers. **Scope** The scope of this activity is to empower key players in the smart energy services sector to create innovative, cross-domain solutions for flexibility programmes. These solutions should range from regional to global levels and leverage established digital platforms to avoid the development of isolated, fragmented systems. A key focus is ensuring that these solutions are interoperable, scalable, replicable, customisable, and extensible, with an openness that could include open-source initiatives. Security and privacy requirements must also be integral to the design of these services. Additionally, the development of user-friendly applications that cater to a broad range of stakeholders is essential. This includes infrastructure operators (such as transmission and distribution system operators for electricity, heating/cooling, and gas), energy conversion and storage technology providers, service providers (like energy suppliers and aggregators), energy communities, and end customers, particularly industrial users serving as flexibility providers. Ultimately, the goal is to enable collaboration and co-creation networks among solution providers, fostering an environment where innovative energy services can thrive and adapt to diverse needs across the energy landscape.
Description of RD&I or Programming Activities 1. Collaboration with ICT platform providers to establish transnational interoperable environments that support various stakeholders in the energy system in designing, implementing, and testing technical and business services for a multi-domain energy flexibility system, building on established ICT platforms and tools (e.g., leveraging on FIWARE, Gaia-X energy dataspace). 2. Develop multi-domain data-spaces and digital twins with clearly defined accessibility, connectivity, and security parameters tailored for key stakeholders, including sample data for prototyping processes. 3. Develop and integrate AI-based solutions, whether on cloud and/or edge platforms, to support the seamless integration of renewable energy sources while ensuring a resilient system operation. 4. Ensure know-how transfer through the creation and implementation of training courses as well as the provision of tutorials and guidelines on developing and integrating new

flexibility services.
5. Collaborate with ICT infrastructure and platform providers, privacy and security experts, and legal experts to formulate proposals for innovative regulatory environments for the use of data-driven applications. This includes considerations for model-training, data provision and utilisation in both edge and cloud applications, as well as the publication of data and/or trained models.

Joint activities

Enable know-how transfer on existing platforms

- Provide training and tutorials about existing platforms
- Provide hands-on tutorials for integrating smart energy services into exiting platforms
- Foster exchange between users of platforms and developers of services to exchange their experiences and to improve the existing systems

Enable close collaboration between different programmes aimed at creating scalable solutions based on existing platforms.

Setup funding frameworks for transnational research and development projects, CETPartnership TRI 1 and TRI 5

- Provide funding (with high funding rates) for multi-domain projects developing, implementing, and demonstrating smart energy services in a real environment
- Aiming to achieve high Technology Readiness Level (>=7)
- Involve multiple stakeholders from different energy domains

Impact of the RD&I Activities

- **Short-term impact:**
    - Increased knowledge on ICT platforms for digital services (e.g., flexibility services) in regional integrated energy systems by increasing higher-TRL research and implementation programmes
- **Long-term impact:**
    - Empowement of actors in a regional energy system with easy-to-use platforms to provide smart energy services

TRL: 4-7

Expected Deliverables	**Timeline**
• Easy to use platforms for smart energy services • Market-ready smart energy service products • Established communication channels between developers of platforms and their users	

6.1.4. Activity Fiche 3 has already been finalised.

6.1.5. *Activity fiche 4: Innovation ecosystems for integrated regional and local energy systems*

Implementation Plan - Activity fiche

Innovation Target

- Regional RES integration including different energy infrastructures
- Regional system integration of different energy vectors
- Integration of relevant infrastructures into regional energy systems
- Smart services for flexibility to develop local and regional value chains

Title: Innovation ecosystems for integrated regional and local energy systems

References to ETIP SNET Implementation Plan 2025+: HLUC 4

Reference to the SET-Plan 2023 cross-cutting issues

Challenge

Regional ecosystems are interconnected communities focused on transforming local and regional energy systems. These systems include locally available energy sources, infrastructure, and energy production and consumption patterns across various sectors. They play a crucial role in achieving clean energy goals, ensuring energy security, and maximising efficiency.

As new technologies, digitalisation, and sustainable trends reshape the energy landscape, regional ecosystems must adapt. This requires collaboration among local communities, industries, and global players within innovation ecosystems. By involving a wide range of stakeholders, these ecosystems can co-develop new solutions that drive sustainable development.

The goal is to integrate energy transitions into local infrastructure and processes, ensuring that these changes are accepted and supported by communities and industries. This collaborative approach not only strengthens local dynamics but also contributes to the broader European Union energy objectives, helping scale up innovations and develop sustainable energy systems across the region.

Scope

This Activity fiche focuses on building Energy Transition Ecosystems across Europe. It addresses the importance and empowerment of local and regional innovation ecosystems in developing and implementing the best energy solutions and technologies in local communities and regions. Therefore, the role of local living labs as catalysts in creating a shared understanding of local needs and the necessary support for sustainable solutions in local energy communities and systems is emphasized. The intention is to put the need owners of specific regions at the center and to connect them and their regional and local solutions on a European level.

The transnational cooperation of these ecosystems should help foster a deeper understanding of the different infrastructural and socio-economic contexts. Innovation ecosystems at local and regional level can also address the cross-cutting issues of the SET-Plan and find solutions, which in a trans-national approach ensures that learning can be shared and robust transition pathways created across Europe.

Description of RD&I or Programming Activities

1. Identification and engagement of relevant energy-focused local and regional ecosystems and Living Labs in co-operation and co-development
2. Identifying and understanding the requirements of the region's need owners in order to integrate them into a local and regional ecosystem.Support and trainings to strengthen build-up, growth, management and operations of local and regional innovation ecosystems and local Living Labs for sustainable energy.
3. Networking activities for innovation ecosystems and Living Labs for energy to share, connect and co-operate, e.g. organise events, workshops etc.

4. Engagement of regional innovation ecosystems and local Living Labs in co-creation activities for new projects, demonstrations, model solutions, challenge camps, market shaping, etc.

Joint activities

- Co-operation activities with CETPartnership TRI5 for Integrated Regional Energy Systems, CETPartnership TRI6 Integrated Industrial Energy Systems and CETPartnership WP6 Impact Network such as
    - Networking events for the innovation ecosystems, business clusters and Living Labs to share knowledge and connect
    - Support and trainings to strengthen build-up, growth, management and operations of local and regional innovation ecosystems, business clusters and Living Labs
- Initiative NoREST from CETPartnership TRI5 to involve need-owners in R&D projects
    - Co-creation activities to involve need owners and their requirements in energy concepts for local and regional ecosystems
    - Co-creation activities for new projects, demonstrations, model solutions, challenge camps, market shaping, etc.
- Collaborate with DUT Partnership, ENOLL, INTERREG

Impact of the RD&I Activities

- **Short-term impact:**
    - Understanding the requirements of need owners in the regions
        - Find formats for the involvement of local and regional stakeholders within the NoREST initiative and then in R&D projects
        - Work on a joint concept for a local or regional integrated energy system
    - Understanding the markets:
        - Local Living Labs produce knowledge about attitudes and acceptance in local communities towards different energy solutions and create buy-in for sustainable solutions
        - Transnational collaboration will help gain more in-depth understanding of different infrastructural and socio-economic contexts within which the energy transition is taking place across Europe
        - The NoREST initiative can support the implementation of transnational collaboration of European pioneer initiatives
    - Speeding up the learning and the entire energy transition via networking and co-operation:
        - Local Living Labs network, share and collaborate for efficient roll-out of sustainable local energy solutions
        - Empowered innovation ecosystems produce efficiently new sustainable technologies, methodologies and system solutions for local and regional energy communities, and share and co-operate for fast roll-out

- **Long-term impact:**
    - Validated, integrated regional and local energy systems, that make it possible to efficiently provide, host and utilize high shares of renewables
    - Implemented tailor-made solutions that meet the individual regional and local requirements and demand and that enable citizens, companies, communities and other stakeholders to take part in the related value chains and in the exchange of value on different levels
    - Boosting economic growth:
        - Fast growth of solution export to global markets
        - Larger markets for solution providers sooner

TRL: N/A

Expected Deliverables	**Timeline**
• Results from living labs and innovation eco-systems • Information material for local and regional actors of the energy system	

6.1.6. *Activity fiche 5 Heating and Cooling system on regional level*

Implementation Plan - Activity fiche 5
Innovation Target • Regional RES integration including different energy infrastructures • Regional system integration of different energy vectors • Integration of relevant infrastructures into regional energy systems
Title: Fiche 5 Heating and cooling system on regional level
References to ETIP RHC SRIA: 5. Research and innovation priorities for RHC in districts: Topic 2: System Integration. Distinction: ETIP-RHC has a stronger focus on technology developments and implementation; and has a district level focus, whereas this activity fiche focuses on the energy system and grid integration aspects on a political and social, markets and business model as well as the energy system modelling level, considering mainly regional and national aspects. References to ETIP SNET Implementation Plan 2025+: HLUC 9

Challenge

Decarbonising the heating and cooling sector will be key to achieve the European Green Deal goals (European Commission, 2021. 'Fit for 55': delivering the EU's 2030 Climate Target on the way to climate neutrality.) and making Europe a climate-neutral economy by 2050. Some decarbonization strategy tends to emphasise electrification. As a consequence, a dramatic increase in direct electric H&C would require costly upgrades to distribution networks and overshooting renewable capacity deployment. In contrast, solar thermal, geo-thermal, bioenergy, district heating and cooling, and ambient and excess heat recovery – complemented with renewable electricity via heat pumps – could be the backbone of a radically new, user-oriented, carbon-neutral, efficient, reliable, and flexible energy system (https://www.rhc-platform.org/content/uploads/2019/10/RHC-VISION-2050-WEB.pdf). Those RHC technologies are mature, commercial, and market ready today. They will be continuously developed to increase their performance and competitiveness. However, their implementation of such a system faces some systemic challenges:

- **a shift from large gas distribution networks to self-supply and local thermal networks** based on the systematic use of locally available RES. Where viable DHC networks should be the preferred option (high density areas), decentralised solutions should be favored where they are more cost-efficient (low-density areas).
- **the optimisation of energy demand and supply**, through energy storage and smart energy management systems at production, distribution, and consumption levels.
- **a strong integration with the power sector** enabled by the persistent spread of coupling points (e.g. heat pumps and thermal energy storage) together with the wide uptake of smart energy management systems.

Scope

Set up of the basics and foundations for the development plans for boosting the implementation of RHC in a safe way, including suitable transformation strategies for existing energy systems. This focuses on improved flexibility and efficiency of H&C systems for an optimized integration into the regional energy system, including suitable business models.

Description of RD&I or Programming Activities

1. **POLICY AND SOCIAL INNOVATION:**
    a. Various analyses and studies are needed for: a better understanding of the legislation for increasing RE (e.g. EPBD, bans, etc.); European incentive programmes and their results (e.g. cost-efficient subsidy systems with minimal market disturbance), consumer behaviour (e.g. enabling effective marketing, information campaigns and sales tools for people in the RE sales chain); Solutions for large scale RE implementation in energy poverty affected housing
    b. Knowledge transfer and networking between actors including best practice exchange and capacity building and training for local politicians, decision makers, consultancies and advisers; with a focus on political pathways describing precise policy measures on local and regional level to improve regulatory frameworks for DHC; and the introduction of the improved planning methods in the established planning processes of cities and regions
    c. Raising awareness to better integrate waste heat in district heating networks, addressing the development of decarbonisation strategies on a national and European level: The utilisation of the various waste heat sources should be recognized as an important contributor for the decarbonisation of the heating and cooling sector, and at the same time it should support the electricity grid via the smart use of the corresponding heat pumps and storage.
    d. Standardisation and market entry for products/services for enabling an optimised sector integration (e.g. planning tools, smart/ hybrid energy network controller); fostering an increased interoperability of the different systems and technologies as well as ICT security.

2. **MARKETS AND BUSINESS MODELS**
    a. Local energy markets for heating & cooling: development, test-implementation and optimisation of local heating & cooling markets considering private and commercial consumers, producers and prosumers and the interface to electricity markets as well as local storage units. Here, coupling of the thermal and electrical grid and inclusion of EV, energy storage (both thermal and electrical) and residual energy for local activity (industries, agriculture,...) that can provide not just the local energy but also allows to play a role in the electricity market balancing
    b. Development of energy communities centred around renewable heating and cooling; and demonstrating that involving citizens directly translates into high rates of energy savings and catalysing new projects for energy system decarbonisation and sustainability; at the same time, they return profits for the community that can be reinvested into new decarbonisation projects; Initialisation of heat prosumers (pilot demonstration) and funding/market models for local participation in renewable heating and cooling

3. **MODELLING AND OPTIMISATION / INTEGRATING MULTI-ENERGY SYSTEMS:**
    a. Identify the technological and systemic constraints of and thus enable and prioritise prosumer participation in a highly-integrated energy systems. This includes the development and testing of methods for creating cross-sectoral system models and integrated energy network infrastructure plans on a European/national level considering realistic representation of the H&C sector to enable a cross-sectoral and spatial differentiated optimisation of the different energy infrastructure.
    b. Realistic mapping of DHC networks and other H&C systems, including coupling points (CHP, power-to-heat, power-to-gas) and the respective flexibility potentials (especially long-term storage) and efficiency potential (especially temperature levels) as well as consideration of current and future generation potential.
    c. Give better consideration to waste heat in modelling tools: The currently used energy modelling and scenario tools should fully consider waste heat sources (i.e. industrial processes, cooling from commercial buildings and data centres, electrolysers, urban infrastructure (e.g. sewage channels) and ambient heat), e.g. by following a circular economy approach/ applying energy conservation principles at the end use side.
    d. Take into account the different temperature levels of RES heat sources and waste heat, district heating networks and end users in modelling tools. This can allow a cascading approach for optimising the primary energy utilisation, an increased COP of heat pumps and a higher efficiency of heat distribution. Here, reduction strategies for the district heating network temperatures should be taken into account.

e. Consider different flexibility scales (short- to long-term flexibility) of H&C solutions and enabling their efficient utilization. Including the development and implementation of measures for increasing the flexibility, i.e. via the integration of centralised and customer side TES, the utilisation of the DH network as storage and customer side load shifting. These measures are state of the art, their modelling on high-level energy system simulation tools needs to be improved.
f. Improve the modelling of seasonal energy storages. Long term heat storage becomes increasingly important in DH networks, e.g. they can use heat surpluses from summer to provide heat in winter; thereby taking advantage of favourable electricity prices and high air and river temperatures in summer via heat pumps. However, their technical and economic properties need to be better modelled in high-level energy system simulation tools (e.g. costs, availability /location, heat losses, dynamics/ start-up times, temperature mixing).
g. Geographically differentiated strategies: Since heating and cooling in general are a rather local issue, energy strategies should be geographically differentiated. However, long heat transport networks, spanning up to 10 to 100 km should be considered, since they can connect multiple waste heat sources, consumers and storage and thus mitigate the risk of losing one waste heat source.

Joint activities

- Research Programmes (CETPartnership TRI 4) on the technology questions:
    - Identify the systemic constraints
    - Realistic mapping
    - Give better consideration to waste heat
    - Take into account the different temperature levels
    - Consider different flexibility scales
    - Improve the modelling of seasonal energy storage.
    - Geographically differentiated strategies:
- Definition and standardisation of market models for heating and cooling

Impact of the RD&I Activities

- **Short-term impact:**
    - Development of standardised markets for heating and cooling
    - Improved knowledge on heating and cooling technologies and market integration variants
- **Long-term impact:**
    - Creation of a new, user-oriented, carbon-neutral, efficient, reliable, and flexible regional energy system by the usage of solar thermal, geo-thermal, bioenergy, district heating and cooling, and ambient and excess heat recovery – complemented with renewable electricity via heat pumps for heating and cooling.
    - Through the proposed activities, better modelling of an integrated energy system can be undertaken and an integrated local green H&C system can be advanced with realistic plans.

TRL: 4-7

Expected deliverables	**Timeline**
• Results of the research activities • Defined markets for heating and cooling	

6.1.7. *Activity fiche 6 Integrated Industrial energy systems*

Implementation Plan - Activity fiche
Innovation Target • Regional RES integration including different energy infrastructures • Regional system integration of different energy vectors • Integration of relevant infrastructures into regional energy systems • Smart services for flexibility to develop local and regional value chains
Title: Fiche 6 Integrated Industrial energy systems
References to ETIP SNET Implementation Plan 2025+
Challenge Due to the significant amounts of difficult-to-avoid CO2 emissions from the energy-intensive industries, building a climate-neutral energy system of the future requires the involvement of these industries. In fact, these industries have to be developed as part of the entire energy system. As process industries are very capital intensive, shifting to innovative technologies and processes and operating them at industrial scale will entail high technological and economic risks due to international competition. While some enabling technologies are advancing well, their integration into the production systems as well as high operating costs still remain a challenge. To establish carbon-neutrality in industrial (energy) systems, both direct renewable heat production (solar thermal) as well as renewable-based electrification of industrial processes are an important innovation challenge. All forms of local renewable power production, e.g., wind and hydropower and solar power, require research and development activities to improve their technological performance for industries in order to tackle different aspects of system integration and to lower the costs. For power provision and distribution at industrial sites, traditional alternate current (AC), direct current (DC) as well as hybrid AC/DC power supply technologies need to be considered. Another important task is to introduce, develop and deploy advanced renewable heating and cooling solutions from industries, which can be used in a regional energy system. The full utilisation of their potential calls for essential developments in regional system integration and sector coupling concepts as well as new innovative combined solutions and use of digital energy management systems. Sector coupling can, for instance, allow surplus electricity or heat to provide heating and cooling for both local demand in buildings and other industries. Extensive cross-sectoral cooperation is needed to facilitate this enormous integration of the energy and industry sectors. Building climate-neutrality will require development and adoption of new regulatory frameworks and business models. As a first step, a greater sector-coupling within energy is needed (electricity, heat, cool, gas). In the long run, regional energy-industry system needs to become more flexible and adaptable and it must involve new mechanisms for extended industrial demand response. **Scope** This activity fiche addresses sector coupling in the industrial context as well as the integration of industrial energy systems with local or regional heat and power networks and systems.
Description of RD&I or Programming Activities: 1. Develop and demonstrate system integration and sector coupling concepts for local symbioses of industrial and municipal energy 2. Develop and demonstrate regionally integrated, renewable-based power systems including energy storage 3. Develop and demonstrate new mechanisms for extended industrial demand response 4. Develop and demonstrate cross-sectoral and cross-industrial energy symbioses

5. Assess barriers and development needs in regulatory frameworks with respect to building local, cross-sectoral and cross-industrial energy symbioses as well as for extended industrial demand response
6. Design new business models to enhance business-driven cross-industry and cross-sector co-operation in energy
7. Electrify industrial processes including power provision via AC, DC and hybrid AC DC grids (in co-operation with IWG6)
8. Develop and demonstrate cost-efficient integrated and/or hybrid solutions for industrial power, heating and cooling (in co-operation with IWG6)

Joint activities

- Co-operation activities with CETPartnership TRI6 for Integrated Industrial Energy Systems such as
    - Thematic workshops and seminars
    - Co-creation of a roadmap for market shaping
    - Identification of potential demonstrations
- Cooperation beyond Europe: Mission Innovation Industry Mission

Impact of the RD&I Activities

- **Short-term impact:**
    - Local symbioses of industrial and municipal energy demands
    - Electrification of industrial processes (together with IWG6)
    - Integrated regional energy solutions including industrial sites (together with IWG6)
- **Long-term impact:**
    - Regionally integrated, renewable-based power systems including energy storage
    - New mechanisms for extended industrial demand response
    - Cross-industry and cross-sectoral energy symbioses on regional level

TRL: TRL 2/4-9

Expected deliverables	**Timeline**
• Market shaping Roadmap in cooperation with CETPartnership TRI 6 • Communication channels between industry and actors of the energy system	

6.1.8. *Activity fiche 7 Hydrogen production, trading and usage in an integrated regional energy system*

Implementation Plan - Activity fiche 7

Innovation Target

- Regional system integration of different energy vectors
- Integration of relevant infrastructures into regional energy systems

Title: Fiche 7: Hydrogen production, trading and usage in an integrated regional energy system

References to ETIP SNET Implementation Plan 2025+: HLUC 1 (PPC 1.4: Integrating hydrogen and CO2-neutral gases; PPC 3.1 Fundamental market design, PPC 3.4. Validation of new market concepts)

Challenge

In the current energy transition hydrogen can play multiple roles in a regional integrated energy system. Considerations around efficiency and reduction of levelized cost of H2 are the drivers of technology development. While currently most of the available hydrogen is required for industry usage, other usage in a local energy system is to be considered.

Scope

The scope of this fiche is to highlight the necessary steps on member-states level for the whole innovation chain of hydrogen.

Description of RD&I or Programming Activities

1. **MARKETS AND BUSINESS MODELS**
   - Production of renewable, regional hydrogen in the context of local supply chains (hydrogen prices regional vs. Import; resilience, subsidies; regional production)
   - Elaboration of local and regional markets for hydrogen

2. **REGIONAL PRODUCTION**
   - Regional holistic concepts including wind, PV and hydropower with electrolysers, hydrogen storage, local gas grid infrastructure considering the limitations of the regional electricity grid

3. **REGIONAL DISTRIBUTION**
   - Investigations about green field gas infrastructure in regions without an existing natural gas grid infrastructure; new thinking / different from classic gas network/ considering gas grids in the regional context including isolated gas grids
   - Developments in technologies and systems for gas grids on different levels to allow for distributed hydrogen production and efficient feed-in to the gas grid
   - Development of regional multi-carrier networks (gas, heat, electricity) as regional energy backbones

4. **REGIONAL STORAGE**
   - Consideration of short-term and long-term gas storage on regional level including underground storage, compressed hydrogen storage or other storage technologies
   - Development of concepts for shared gas storage infrastructure among regional, national and global stakeholders in a regional energy system

5. **INTEGRATING MULTI-ENERGY SYSTEMS:**
   - Development of a regional transport infrastructure including a hydrogen fuelling station network for use in local industry and agriculture
   - Integration with regional biogas and other CO_2 sources to produce hydrocarbons for use in hard-to-abate sectors like chemical industry, steel production, aviation etc.

- Local waste heat utilization of electrolysis for larger customers or district heating systems
- Development of distributed plant concepts to use of Hydrogen as a material for e.g artificial fertilizers
- Development of concepts for the utilisation of oxygen (by-product from electrolysis) in local industry (e.g. waste water treatment)
- Development of regional gas communities and sector coupling energy communities (including gas, heat and electricity)

6. **TECHNOLOGICAL RESEARCH QUESTIONS**
    - Cost reduction, greater efficiency, longer lifetime and greater reliability along the complete supply and demand chain to reduce the levelized cost of H2.
    - Scenario development and concepts for integration of electrolysers in integrated regional energy network

7. **POLICY AND SOCIAL INNOVATION:**
    - Empowerment of local stakeholders to hydrogen producers
    - Development of common KPIs, standards, regulations and processes for a regional hydrogen economy
    - Development of concepts for transition processes and implementation processes of a regional hydrogen community to circumvent the hen-and-egg problem of hydrogen
    - Development of regional mobility concepts with local mobility solutions (interface battery vs. hydrogen); holistic concepts including agriculture, construction vehicles

8. **RE-CONVERSION OF HYDROGEN**
    - In the medium and long term, reconversion of hydrogen to electricity (fuel cells, hydrogen motors and hydrogen turbines) after storage to provide electricity and flexibility also for regional energy communities
    - Usage for flexibility on an interregional and European level

Joint activities: (CETPartnership TRI 3)

- A joint technology and system development (or research infrastructure) project for hydrogen production, distribution and storage on a regional level
- Government to government information exchange on; standardisation for products (KPIs) to make them comparable and definition of market and business models
- Transnational calls research and studies concerning regional distribution, storage and production options as well as calls for research programmes in order to reduce cost

Impact of the RD&I Activities:

- **Short-term impact:**
    - Increase knowledge on technological research questions and political and social innovation topics mentioned above
- **Long-term impact:**
    - Standardised KPIs to empower regional actors to procure hydrogen systems
    - Defined hydrogen markets and business models
    - Integration of hydrogen in a multi-energy system

TRL: 4-7

Expected deliverables	**Timeline**
• Standardized Key Performance Indicators and related information material • Defined market for hydrogen	

6.1.9. Activity fiche 8 Battery energy storage in an integrated regional energy system

Implementation Plan - Activity fiche 8
Innovation Target • Regional system integration of different energy vectors
Title: Fiche 8: Battery energy storage in an integrated regional energy system
References to ETIP SNET Implementation Plan 2025+: HLUC1 PPC 1.1. Value of cross-sector integration and storage

Challenge

The usage of Battery Energy Storage Systems (BESS) in an integrated regional energy system is a prerequisite for the best usage of energy from intermittent renewable energy resources. Lithium-Ion batteries themselves are already very well developed and produced in large volumes in mature manufacturing processes. With the maturation of the technology and the market a whole new set of research topics arise:

1. **Wide-scale empowerment of customers and plant operators**: Prerequisite for the adoption of BESS by a very large number of companies and stakeholders is the development of solutions which allow for an easier entry in the technology.
2. **Technology resilience and interoperability**: However, having lots of BESS on the market from many different manufacturers which do not always stay in the market too long requires norming and standardisation of such systems in order to maintain them, extend them, change parts of them and finally recycle their components in the context of a circular economy. With 10-15 years BESS have a much lower lifetime than usual plants in the power system.
3. **Scaling solutions**: Another challenge for the integration of BESS in integrated regional energy systems is that medium sized BESS are not in an economy of scale yet, like small home-PV BESS already are. Thus, installing BESS for example for Energy Communities is still very costly. Reduction of the specific capacity price for such systems is also necessary.
4. **Technology optimisation & maturation**: Continuous improvement of operation (monitoring, forecasting, etc.) and design, as well as ongoing optimisation of plants, also in the context of regional energy systems.

Scope

The scope of this activity fiche is to set out the next steps towards a robust resilient and safe integration of BESS in regional and local energy systems. Further, a fast integration of new technologies which are currently being developed should be addressed in advance. This ensures fast integration of new technologies and an accelerated usage of BESS.

Currently no comprehensive standardisation of such systems is in place considering all relevant aspects of such a system, starting with a common terminology and specifications. Only with clear and common performance indicators can regional stakeholders be empowered to apply this technology efficiently.

Description of RD&I or Programming Activities:

1. **SYSTEMIC ASPECTS**
   - Integration in regional business models
   - Integration in regional grid controls schemes
   - Operator empowerment

2. **TECHNOLOGICAL ASPECTS**
   - Development and integration of new storage technologies that are suitable for the size needed at the regional level, cost reduction; increase of efficiency
   - all measures that reduce the specific capacity prize

3. **REGULATORY ASPECTS & STANDARDS**
    - Regulation of grid serving batteries
    - Multi-Stakeholder usage of one BESS: clarification of the ownership situation
    - Develop a clear and common terminology and specification of a comprehensive set of key performance indicators for Battery Energy Storage System, their interfaces, all sub systems and components
    - Ensure upgrade / update-ability of systems by norming and standardisation
    - Create and ensure interoperability over the complete operational lifetime of BESS
    - Standardized parameters to ensure comparison of different systems

Joint activities

- Establish a coordination and support action on the pre-standardization for terminology, core indicators, test procedures (CETPartnership TRI 3)
- Provide materials and trainings,
- Establish a seal of approval (similar to the PV storage efficiency guide), benchmarking,
- Develop standardized vendor-independent model calculations, ensure the availability of tools for independent calculations.
- Transnational research calls should consider the following research questions:
    - Regional business models and technology applications, plant design and deployment strategies.
    - Development of battery storage systems that are easy to implement, safe, easy to scale and expandable over the lifetime.
    - Research projects to increase the resilience of the technology over its entire lifetime, as well as analysis procedures for system evaluation and operational analysis. End-of-life and circular economy

Impact of the RD&I Activities

- **Short-term impact:**
    - Coordinated further development and use of the technology
- **Long-term impact:**
    - Robust understanding and use of the technology
    - Acceleration of roll-out and application in regional energy systems

TRL: 4-7

Expected deliverables	**Timeline**
• Standardised battery energy systems to ensure vendor-independent up-scaling and replacement of parts • Information material for users from research and development projects	

7. Budget

Assessing the necessary budget for the tasks of Implementation Working Group 4 is a difficult task. Some general aspects apply for all research projects:

Budgets scale significantly at higher TRLs due to infrastructure, staffing, and real-world testing costs. When it comes to higher TRL levels typically necessary investments become higher in contrast to lower TRLs and basic research.

When physical assets like testing facilities, pilot installations, smart meters or control systems are needed costs rise significantly. Furthermore there is also digital infrastructure like cloud platforms, communication networks and SCADA upgrades, that need to be considered. Additional costs for high-TRL projects can also result from contingency and risk-management.

In the Energy Technology and Innovation Platform associated with the Implementation Working Group 4, ETIP-SNET, the necessary European research funds to reach the planned research and innovation was estimated for each High-Level Use Case as shown in Figure 1

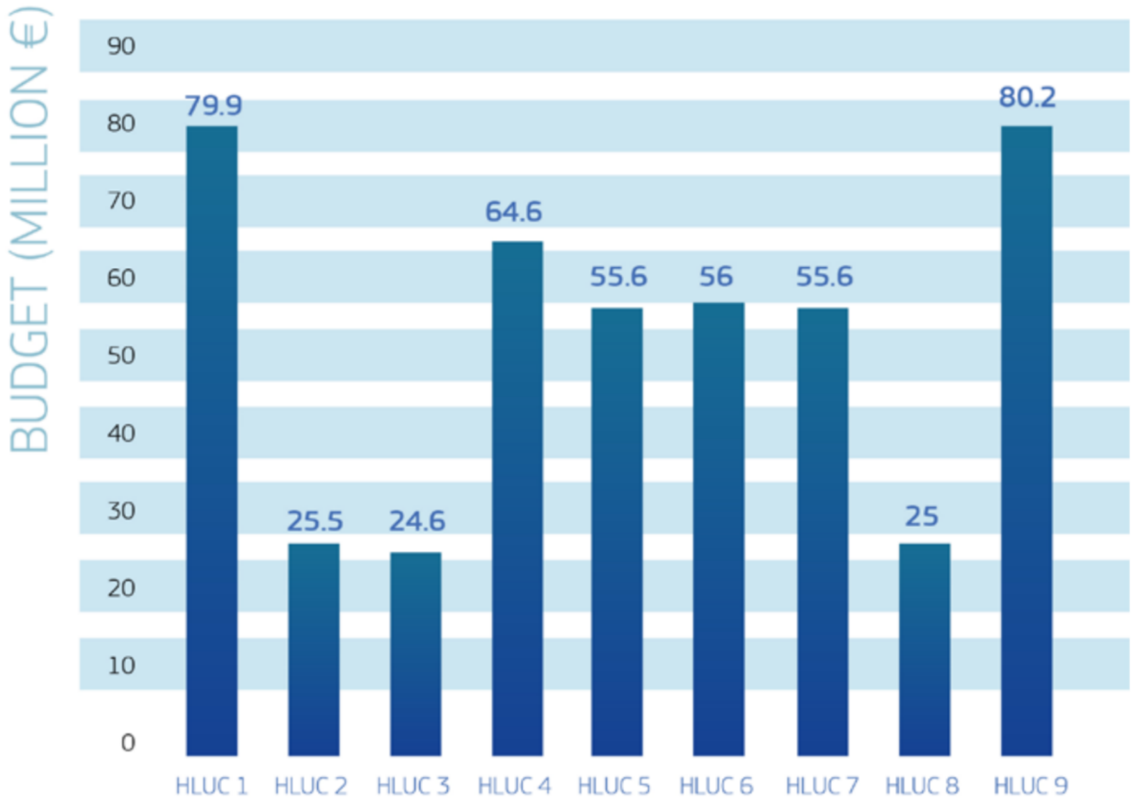


Figure 5: Budget for the HLUCs from the ETIP SNET Implementation Plan 2022-2025 (source https://smart-networks-energy-transition.ec.europa.eu/system/files/2022-06/MJ0122111ENN.en_.pdf)

For the IWG-4 Flagship 1, which is fully aligned with these HLUCs, similar budgets are needed also on a national level.

The current national RD&I budgets of IWG-4 countries consist in principle of three different initiatives:

1) Clean Energy Transmission Partnership:

2) Mission Innovation (mainly green powered future mission)

3) National funding (different types of energy research programmes)

IWG-4 started a process to assess these numbers, but not all data could be collected, yet.

However to describe this methodology, in the following the Italian budget is described in detail.

The Italian budget regarding R&I on IWG-4 topics is managed via these funding programs and initiatives:

1. Ricerca di Sistema (Research on Systems), the Italian national funding program for R&I on energy

2. Mission Innovation

3. Clean Energy Transition Partnership (CETPartnership)

The funding allocated for the scheme “Ricerca di Sistema” for the three-year period 2025-2027 amounts around to 240 M€, nearly evenly distributed between two workstreams, i.e. “Decarbonisation” and “Digitalisation and networks”. The most important themes addressed in the two workstreams, and the related budget fraction are reported in the Figure 6 and Figure 7, referred to Decarbonisation and digitalisatioon respectively.

Figure 6: Ricerca di Sistema 2025-2027 - Distribution of the budget for research projects on Decarbonisation

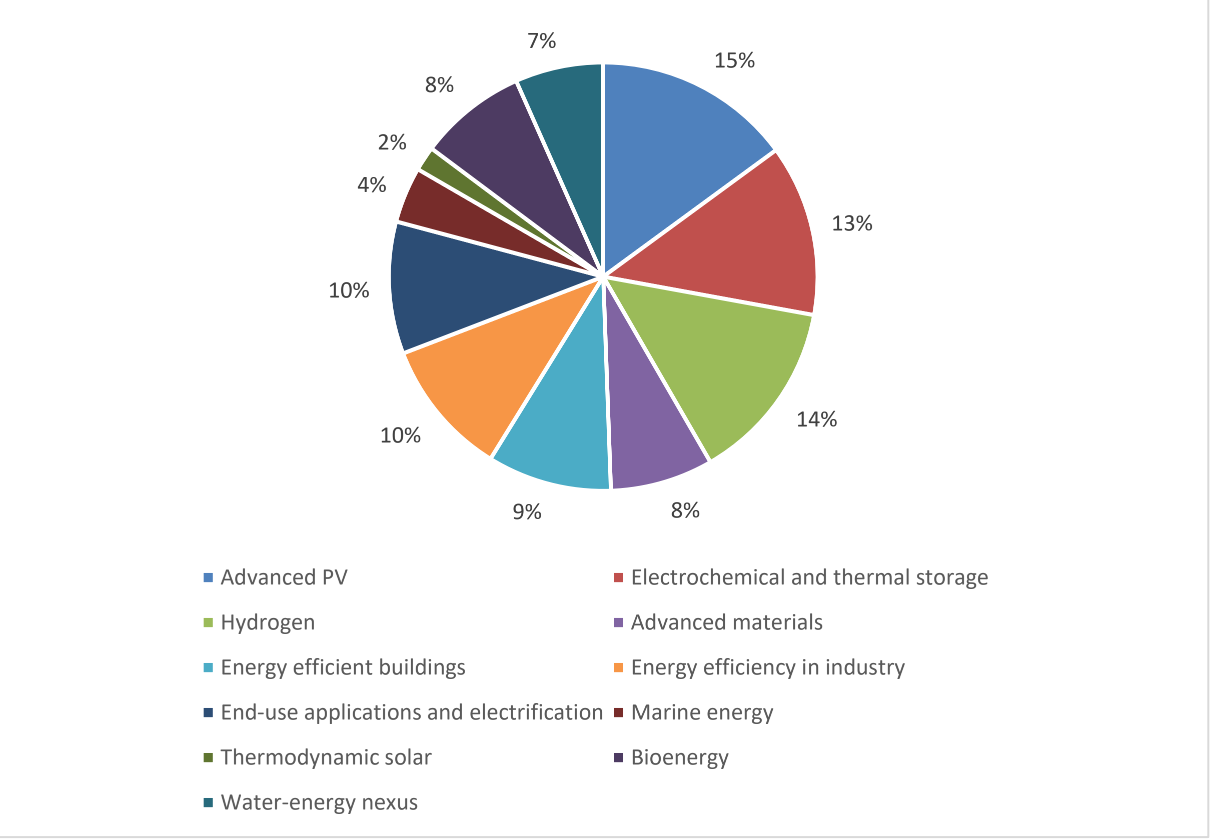
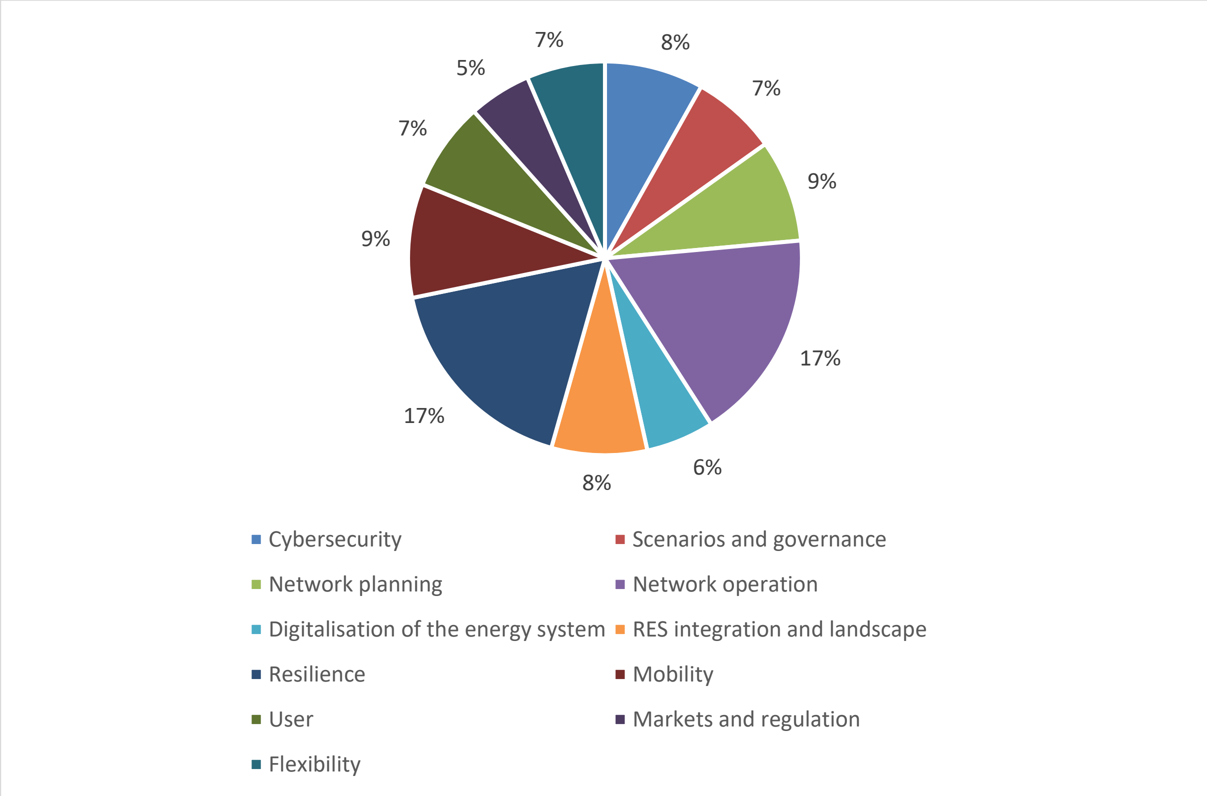
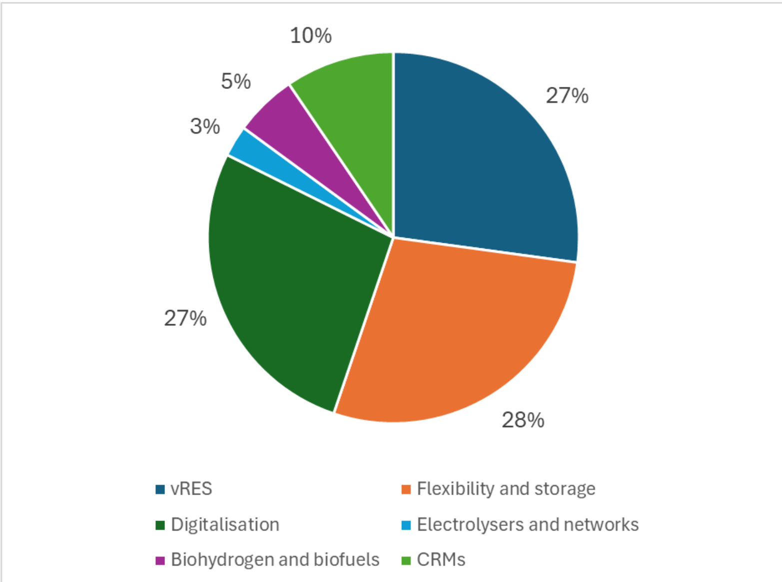


Figure 7: Ricerca di Sistema 2025-2027 - Distribution of the budget for research projects on Digitalisation



The Italian funds dedicated to Mission Innovation related to the three-year period from 2025 to 2027 amount to 221 M€, distributed among different topics (see Figure 8).

Figure 8: Italian budget allocation for Mission Innovation for the three-year period 2025-2027



The Italian contribution to the Clean Energy Transition Partnership (CETPartnership) Joint Call 2024 is provided by the Ministry of University and Research (MUR) and it amounts to 2 M€. Several of the themes financed include: “data spaces and interoperability”, “energy system flexibility” and “clean energy integration in the build environment”, of specific interest for IWG4.

CETPartnership Joint Calls are prepared and published annually, and each year Call Modules change, so do the funding commitments of the different funding organisations (including the Italian ones). Therefore, the budget allocation regarding next CETPartnership Joint Calls will be defined year by year, also depending on the selected projects.