Strategic Energy Technology Plan

Action 4: Increase the resilience and security of the energy system

Implementation plan

Partial revision 1.1 – October 2021

FOREWORD TO THE FIRST REVISION OF THE IWG4 IMPLEMENTATION PLAN – OCTOBER 2021

The first edition of the Implementation plan of the IWG4 was issued in January 2018 and presented at the Set Plan conference on November 2018.

Confirming the IWG4 targets

The IP is founded on a series of 8 targets, endorsed by the 15 countries participating in the IWG, and more specifically:

- Overarching targets:
    - Establish innovation environments for the development of smart services
        - Provide innovation frameworks to develop attractive services, creating value for the participants in the power system and allowing for participation in pan-European value chains
        - Provide co-creation frameworks to develop attractive services, creating value for the participants in the energy system and allowing for participation in the development of local and regional value chains
- Power grid related targets:
    - Flexibility of the system by 2030:
        - Develop and implement solutions to increase observability and controllability in the energy system.
        - Develop and implement solutions and tools to manage the load profile by demand response and control, in order to optimise use of the grid and defer grid investments.
        - Develop and implement solutions to increase flexibility of all types of generation
    - Economic Efficiency
        - Reduce the cost of all energy storage solutions contributing to the minimization of the overall system costs.
- Integrated, local and regional energy systems targets:
        - Develop heating and cooling systems that are able to locally integrate energy from different sources of different temperature levels
        - Develop innovative mix solutions that will reduce variability by combining multi low carbon solutions

The targets were confirmed by participants in the occasion of two IWG4 meetings on June 2020 and April 2021.

Identifying the needs for an update of the innovation activity fiches

After the publication of the IWG4 IP in 2018, different EU and national initiatives have formulated or updated their research and development agendas (e.g. ETIP SNET has issued in 2018 their Vision2050, in 2020 their Roadmap 2020-2030 and their Implementation plan 2021-2024, the CETP ahs started the preparation work of their Strategic research and innovation agenda in 2020 etc.). The different initiatives have in common the strategic goal to identify R&D pathways towards a resilient and efficient integrated energy system fit for the functionalities requested in 2030, along a pathway of full decarbonization by 2050.

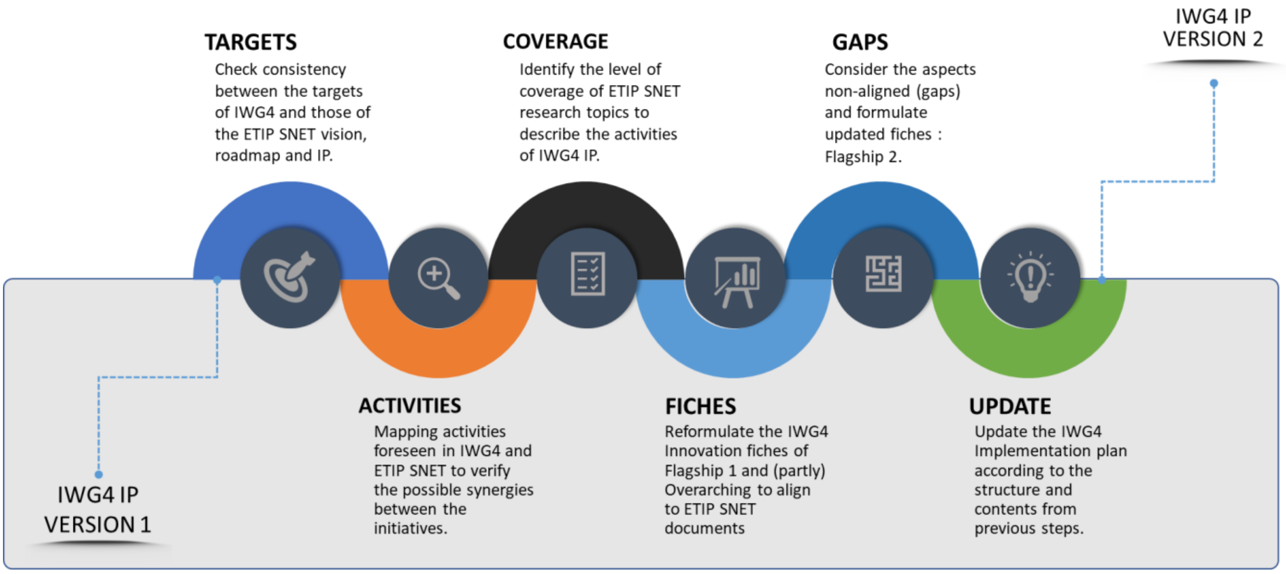
In this framework the IWG4 has worked to identify the most efficient way to align and coordinate the activity plans, so to merge and focus the efforts and the investments on common strategies at national and European level. The following drivers have set the development path:

- Noting that the ETIP SNET maintains a very strategic vision on the energy system development being its main stakeholders regulated bodies having the development of system welfare as common objective, indication was given to revise the IP in such a ways as to adopt a scheme as close as possible to the ETIP SNET Roadmap and Implementation plan;

- Indication was also given to contribute to the drafting process of the CETP SRIA, hence enabling the full consistency of the CETP objectives with the ETIP SNET view;

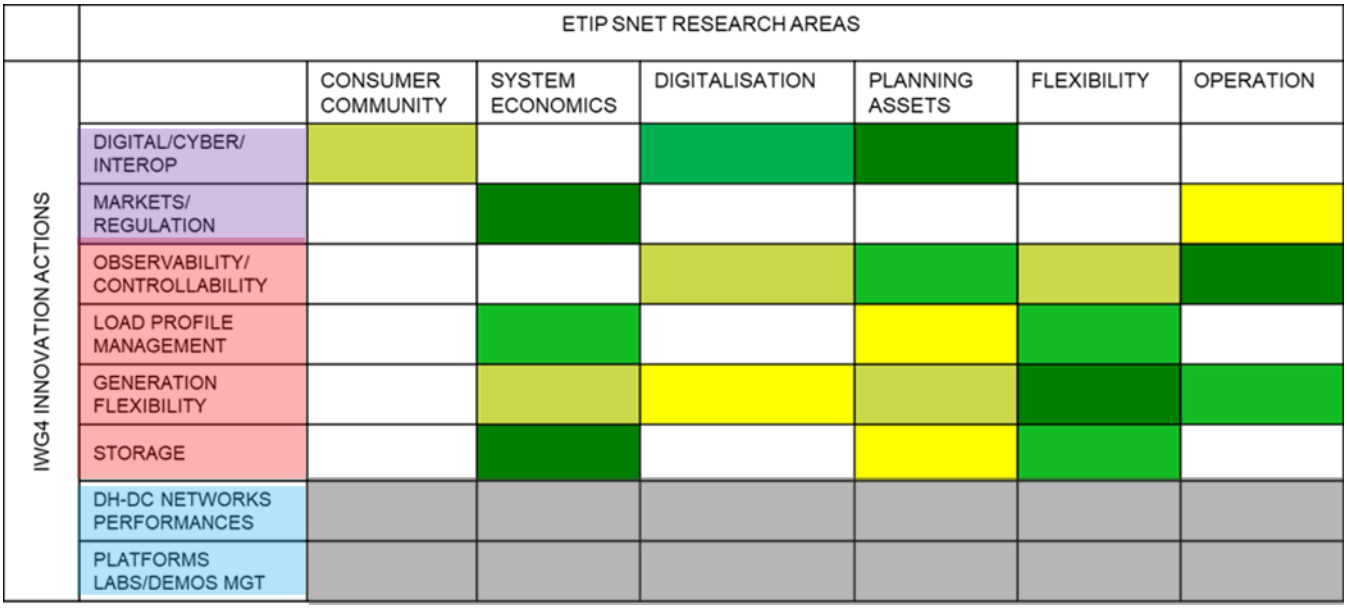
The process followed for the IP update

The process followed for the updating of the IWG4 IP is shown schematically in the following figure, and consists of the following steps:



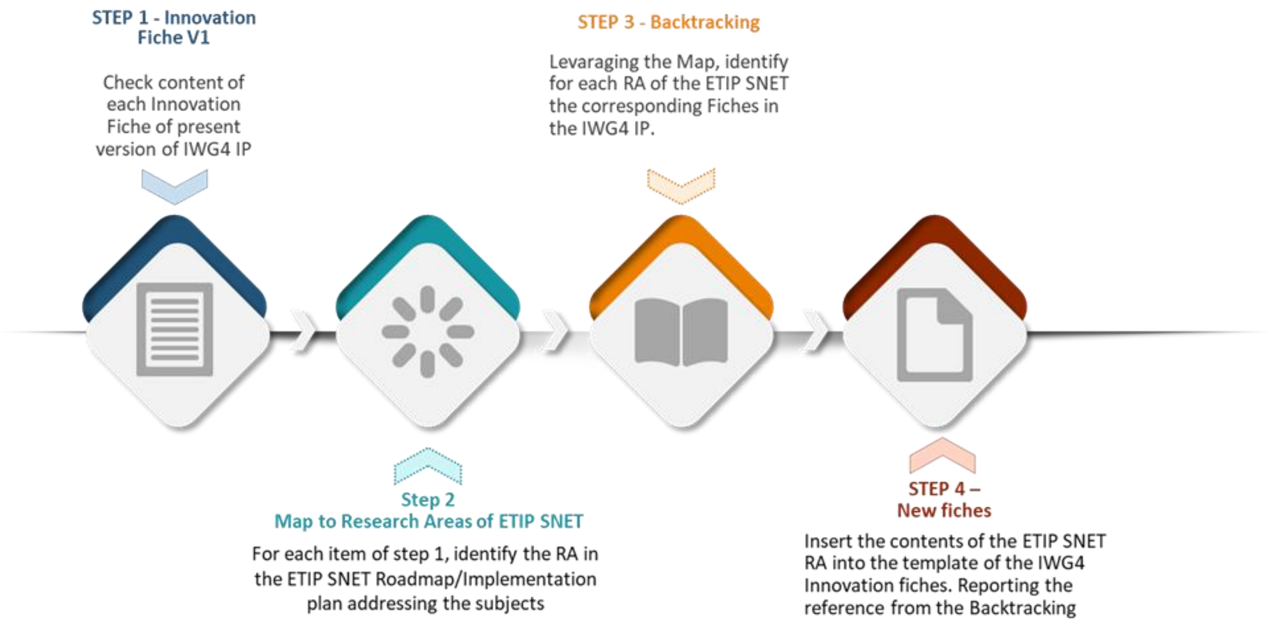
- The targets endorsed by IWG4 were checked for consistency in the documents of the ETIP SNET, to ensure and demonstrate that both initiatives pursue similar objectives.
    - All targets that pertain to IWG4 Flagship 1 were identified as in complete alignment with those of the ETIP SNET.
    - The targets pertaining to Flagship 2 were only partially identified in the ETIP SNET documentation, thus indicating that the alignment for that portion of the IP will not be possible.
- The activities foreseen in the IWG4 IP have been mapped to the Research Areas and Research Topics of the ETIP SNET Roadmap and Implementation plan. The general alignment map is reported in the following figure[1]:

[1] Color code: dark green: complete agreement of approach and activities; light green: general agreement of approach potential synergies in activities, yellow: research topics considered in both documents;

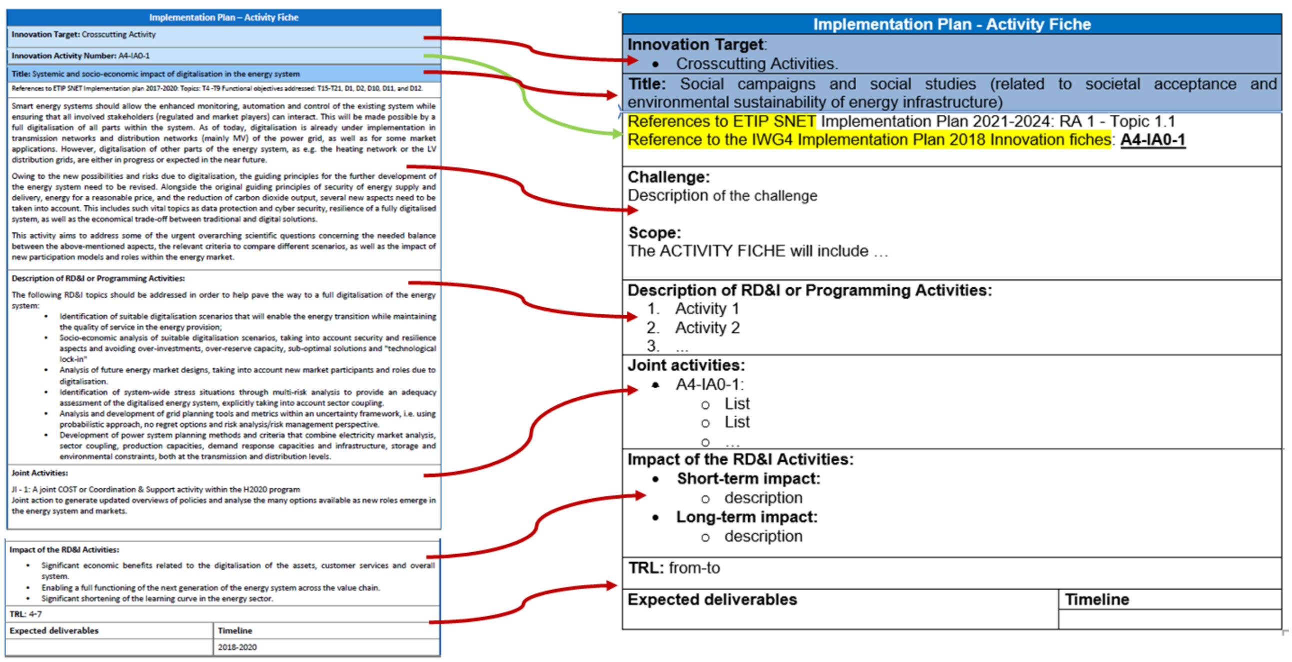


The figure confirms the good alignment between the IWG4 Flagship 1 and the ETIP Roadmap/IP

- In terms of coverage, the detailed comparison of activities included in the IWG4 innovation fiches and the Research Topics included in the ETIP SNET Implementation Plan shows the following:
    - Crosscutting activities: the 5 Innovation fiches of the IWG4 include 25 Activities. They are fully aligned with the ETIP SNET RM/IP, except for 1 (regulatory innovation zones); it must be noted that some of the IWG4 crosscutting activities can be harmonized also with the ETIP RHC SRIA (i.e. interoperability IA)
    - Flagship 1 activities: the 12 Innovation fiches of the IWG4 include 84 Activities. They are fully aligned with the ETIP SNET RM/IP, except for 4 (1: Mobility patterns and charging needs of citizens to better understand where to effectively deploy the charging stations; 2: Identification and implementation of strategies for overcoming possible interactions between the different controls; 3: Development of the appropriate testing environments and implementation of advanced testing procedures of PEC's and RFM's grid support/control functions and support to the development of grid codes and standards; 4: Study of the operation data from at least one real-life hybrid plant to validate the proposed strategies)
    - Flagship 2 activities: the 10 innovation fiches of the IWG4 include 47 Activities. Only 8 of them are covered by the ETIP SNET. Additional 16 activities address items that are related to priorities delineated in ETP RHC and its SRIA.
- Observing the close alignment of the Flagship 1 fiches and of the Crosscutting fiches to the ETIP SNET documentation, a first part of the revision of the IWG4 Implementation Plan was focused on these aspects. Flagship 2 requires a complete reshaping the original fiches. This also raises the opportunity to skip some IAs around national programming, currently covered by CETP and results in the reduction/merging of some fiches (following a better efficiency review). 6 new fiches have been developed for this Flagship and represent the second part of the revision of the IWG4 Implementation plan,.
- Now, focusing on the Flagship 1 and Crosscutting, the process for the revision of the innovation fiches is illustrated in the following chart:



- The content of each innovation fiche in the IWG4 IP has been tracked inside the ETIP SNET Roadmap and Implementation plan;
- Once the full coverage of the activities has been assessed, the 12 fiches of flagship 1 and the 5 fiches of crosscutting activities (total 17 fiches) were replaced by 24 new fiches, one for each Research Sub Area of the ETIP SNET Roadmap/Implementation Plan;
- The template of the fiches of the IWG4 IP was maintained and the fields of fiches were filled with the relevant information from the ETIP SNET documents. Cross references were systematically reported to both documents, so as to allow to trace each activity to the previous version of the IWG4 IP and to the related ETIP SNET activity point. The figure here below illustrates the template transformation.



The first update of the IWG4 Implementation plan

The present document is the first partial update of the IWG4 IP.

- For what concerns the Flagship 1 and crosscutting activities, as explained, the 17 innovation fiches have been replaced by 24 fiches in complete alignment with the Research Subareas of the ETIP SNET. This operation allows to enrich the IWG4 IP and has the outstanding advantage of unifying, under the same wording, the strategic research documents of two major European initiatives. It must be noted that this same unifying approach has been adopted in the setting up of the Strategic Research Agenda of the CETP. This part of the revision has been presented and submitted for approval to the IWG4 in April 2021.
- For what concerns the Flagship 2, a complete revision has been carried out and 6 new fiches have been planned and drafted. 4 of them are included in the present document in their draft form. They are reported for reference and discussion only, because they have not yet been discussed with the IWG4 members.

1 Executive summary

1.1 Introduction and process

The present document constitutes the first revision of Implementation Plan (IP) previously issued in 2018 in actuation of the European Stakeholders Declaration for Action 4 “Increase the resilience and security of the energy system" (19 November 2016). It gathers the consensus of 15 country representatives (see Figure on the right) about the R&I actions to be implemented in coordination, in order to achieve the challenging targets set in the Declaration and has been revised to reach the maximum possible alignment to the RD&I priorities identified in the ETP SNET. Based on the mandate given to the Implementation Working Group 4 (IWG4), this IP reconsiders and completes the formulation of the targets aligning them to the Energy Union and SET-Plan goals, and shapes them to be concrete, output based, innovation oriented and technology neutral. Extensive interactions of IWG4 with the main stakeholders of the European energy system (e.g. several ETIPs, associations, experts etc.) resulted in the formulation of two complementary Flagship initiatives, as shown in Figure 1, namely: Flagship 1 “Optimised European power grid” and Flagship 2 “Local and regional energy networks”. With particular reference to Flagship 1, the present revision of the IP formally aligns to the indications of the ETIP SNET Vision, Roadmap and Implementation plan, in such a way as to leverage synergies and efforts among all stakeholders to accelerate the transition toward a decarbonised integrated energy system.

Figure 1: Flagship initiatives for Action 4

The flagship initiatives are complemented by a crosscutting layer, covering enabling aspects such as digitalisation (including cybersecurity), new regulatory and market approaches enhancing the value of field experiments and the concept of living labs. Flagship initiatives have been substantiated into 27 Innovation Fiches (5 crosscutting, 12 on Flagship 1 and 10 on Flagship 2). The revision of the IP has resulted in a reorganisation of the Innovation fiches pertaining to Flagship 1 and Crosscutting, resulting in a total of 24 revised fiches, presented in this document. The flagship 2 needs further elaboration and will be object of a further revision of the IP, expected end 2021. The process undertaken for the setting up of the initial version of the IP is illustrated in Figure 2. The process for revision is described in the Foreword.

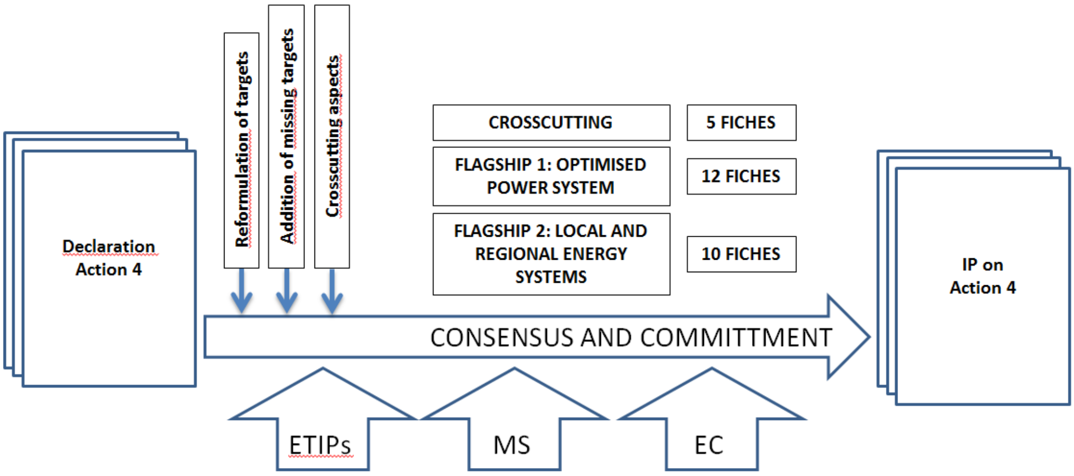


Figure 2: process for the development of the IP for Action 4

1.2 Targets for a resilient and secure European energy system

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, energy 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 variability of renewables, the stochastic nature of loads, the necessity to integrate different energy vectors according to different energy scenarios rise the necessity to develop a strong attribute: FLEXIBILITY. Flexibility in the power sector 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, heat and cold, transport) and optimising the use of flexible sustainable combined power and heat generation. A further level of flexibilisation can be obtained from centralised and decentralised thermal power generation technologies, including for the combined production of heat and power, sector regulation, effective TSO/DSO interaction, market design, dynamic pricing, empowerment and integration of end-users by increasing connectivity and data accessibility. The implementation of smart and integrated energy systems is not only a technological practice, but also a social, 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. For what pertains to local and regional energy systems, innovation targets had to be formulated according to the strategic targets given in the stakeholder declaration, which are referring to the necessary innovation in the heating networks, in order being able to play their role in an integrated regional energy system, further the key issue of developing innovative solutions that make optimal use of a mix of energy sources as well as available technologies and infrastructures, and last but not least the overcoming of innovation barriers by establishing innovation environments to develop smart services for local and regional energy systems. The targets formulated are illustrated in Figure 3. The detailed targets are illustrated in Tables 2 and 3 of the main text.

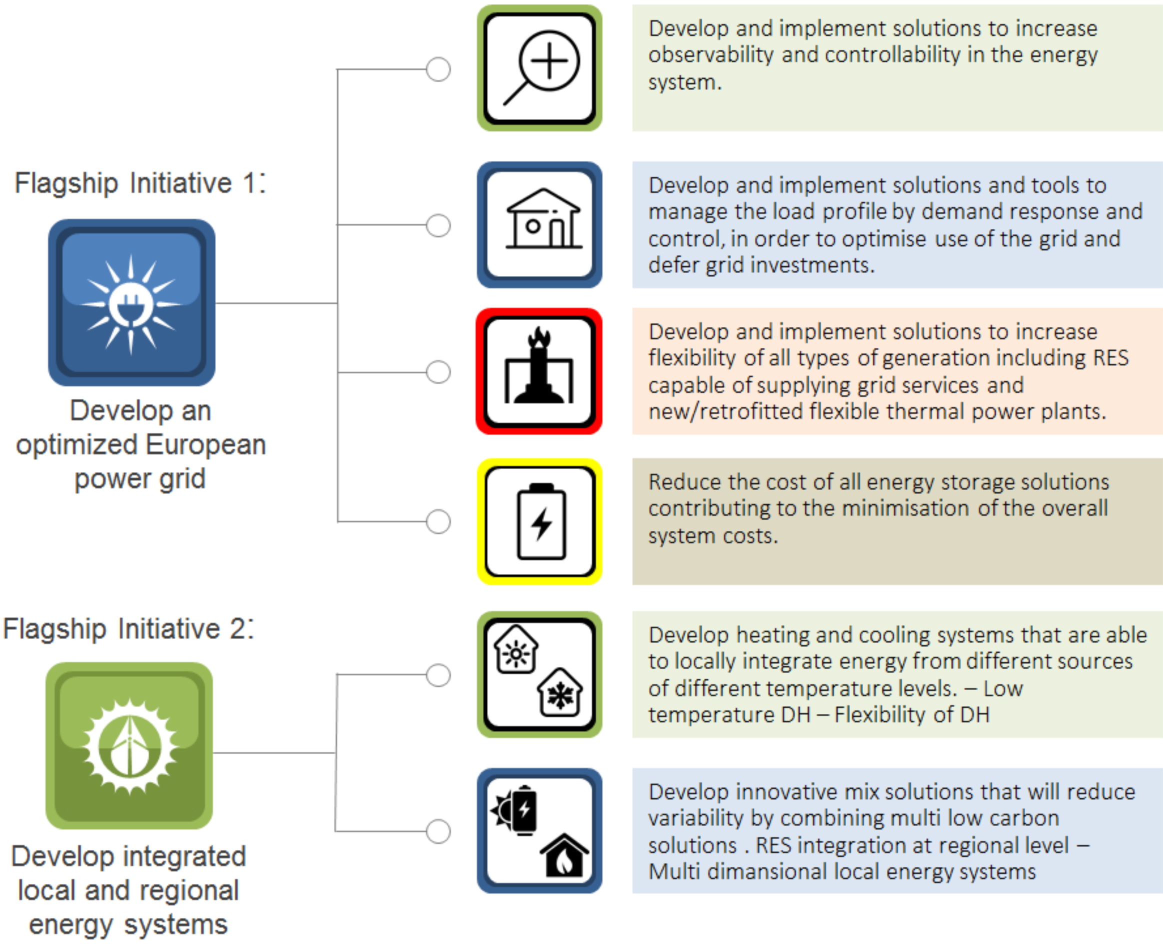


Figure 3: Targets formulated for Action 4 (detailed text in Table 2 and 3 in main text)

1.3 Joint activities and collaboration framework

All IWG A4 members were asked to propose activities contributing to the revised targets from the declaration of intent. Innovation Fiches were proposed by the IWG A4 participants:

- n.5 fiches on the crosscutting activities
- n.12 fiches on Flagship Initiative 1: "Develop an Optimised European Power Grid":

The Innovation activities have been subsequently completely aligned with the ETIP SNET Roadmap 2020-2030 and the ETIP SNET implementation plan 2021-2024. The revision of the IP has resulted in a reorganisation of the Innovation fiches pertaining to Flagship 1 and Crosscutting, resulting in a total of 24 revised fiches, presented in this document. The flagship 2 needs further elaboration and will be object of a further revision of the IP, expected end 2021.

- n.10 fiches on Flagship Initiative 2: "Develop Integrated Local and Regional Energy Systems:

Innovation activities were prepared based on the experience of several of the members, in coordination with representatives from ETIPs (and in particular from ETIP SNET and ETIP RHC) and further external stakeholders

In terms of collaboration frameworks, the following have generally been identified:

- Share results: at this level of collaborations projects share results also using the instruments already in place at European level, i.e the knowledge management platforms EIRIE, BRIDGE, Expera, Mission Innovation SGIA etc.. Participation to related working groups, discussion papers, living documents etc. can also be envisaged

- National projects: at this level the participants intend to launch National call for proposals/projects whose main results can be shared with other stakeholders to increase the speed of network innovation
- Transnational-Europe: at this level the participants intend to organise joint calls, such as those organised in the frame of the ERA-net or joint programming activities such as those active in the frame of EERA
- International: at this level the participants intend to participate in the international context (e.g Mission Innovation) considering a global program setting, together with countries outside Europe
- Horizon Europe complement: at this level, participants foresee the coordination between the national/transnational planning and the European planning e.g. through the HE program or others (e.g. Next Generation EU).

The table 3 reports a preliminary planning of the activities and the collaborative framework. Whenever possible information was taken by the ETIPs activities planning.

The evaluation of the financing needs and funding sources for the activities included in this IP is very complex. Unlike other technological frameworks, the sector of the energy system involves infrastructures for the delivery of primary public services and regulated players, in addition to research centres and technology and services providers. Based on the indications from the ETIPs involved, the programmes of the recent ERANETs, the benchmarks and planning related to Mission Innovation, the following budgetary indications can be given:

- 100 M€/year for RD&I activities on crosscutting activities
- 350 M€/year for RD&I activities on Flagship Initiative n.1 (electricity and energy networks)
- 250 M€/year for RD&I activities on Flagship Initiative n.2 (local and regional networks)

1.4 Interactions

The IWG A4 interacted with different stakeholder groups to provide scientific and technical soundness, ensure consensus and endorsement and inspiration from the wide experience and already ongoing R&I monitoring, road mapping and prioritisation. In particular the ETIP SNET and its working groups, as constant partners in the development of the IWG A4, work for all aspects pertaining to the power system and its interactions. During the development of specific chapters of the implementation plan, frequent contacts were also ensured with ETIP RHC, ETIP PV, ETIP SNET and other initiatives.

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2 Overarching goals and Flagship Initiatives

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, energy 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 variable renewable generation and new variable loads (in a short time scale), to the adaption to different possible energy scenarios (long time scale). The required 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, heat and cold, transport) and optimising the use of flexible sustainable combined power and heat generation. A further level of flexibilisation can be obtained from centralised and decentralised thermal power generation technologies, including for the combined production of heat and power, sector regulation, effective TSO/DSO interaction, market design, dynamic pricing, empowerment and integration of end-users by increasing connectivity and data accessibility.

The implementation of smart and integrated energy systems is not only a technological practice, but also a social, 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.

The temporary working group on action 4 developed innovation activities in the focus areas identified in the stakeholder declaration. The innovation activities concentrate on two flagship initiatives:

- Flagship Initiative 1: Develop an Optimised European Power Grid

  Enabling 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.
- Flagship Initiative 2: Develop Integrated Local and Regional Energy Systems

  that make it possible to efficiently provide, host and utilise high shares of renewables, up to and beyond 100% in the local or regional supply by 2030, enabling regions and local communities to realise their high sustainable energy ambitions. They shall provide tailor-made solutions that meet the local and regional requirements 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 a sustainable use of local and global resources.

2.1 Develop an optimised European power grid

The European power grid has a central role to play and is seen as the starting point to progress towards an energy system approach. Indeed, today, it integrates already a high share of renewables (26% of renewables in 2013, 10% being variable renewables) with high growth perspectives and offers a number of possibilities to connect to heat and transport networks (e.g. through energy storage or with electric vehicles). The energy transition will be based mainly on dispersed sustainable electricity generation and distributed load controls.

A system approach is therefore needed to guide research and innovation activities in view of designing and developing a portfolio of appropriate solutions. The optimised power system must enable a greater flexibility and effective capacity of the electricity system which, in turn, allows connecting effectively and efficiently an ever-increasing share of variable renewables (wind and solar) and coping with new consumption profiles coming, for instance, from electric vehicles. Conversely, system flexibility can be reached in several ways: Upgrading of the entire electricity value chain (generation, transmission,

distribution and customers, and energy storage), reinforcing / creating new links with other energy networks, via for example power to heat/cold, power to gas / liquid and connections with the electrical components of the transport network and increasing the capabilities of RES through the improvement of their predictability and mechanism development for the future systems network services.
In order to meet the identified challenges in the power system, technologies, systems and services for more flexibility should therefore be developed in the following areas:

- Energy grids and systems (including interconnections),
- Storage, connections with other energy networks
- Demand response, integration of prosumers
- Flexible and sustainable backup and generation
- Optimised integration of renewables

Not only should the flexibility of the system be enhanced but also its economic efficiency.

Flexibility
The power system must be more flexible by enhancing the grid hosting capacity for RES and by responding to variability and uncertainty of operational conditions from short time scale resulting from new variable loads and variable renewable generation to long time scales resulting from a wide range of possible energy scenarios. Enabling the needed flexibility calls for the following:
Grid smartening in the sense of grid observability and controllability, which brings to the system improved forecasting and operation. Benefits will be the potential for less curtailment of distributed generation resources such as photovoltaic or small wind installations, for improved management of distribution losses and voltages, and for reducing negative effects or durations of interruptions due to equipment failure. This requires substations at high, medium and low voltage levels (HV, MV and LV) equipped with remotely accessible monitoring and control devices.
Tools for managing the variability and uncertainty of operational conditions at several timescales. Since distributed generation replaces central generation, self-consumption becomes increasingly important affecting the load profile supplied from the integrated grid. With distributed generation and storage growing in the energy mix and at prosumers' sites, more and more customers can support the paradigm change where loads follow variable generation through demand response, instead of having generation following load as practiced today. Examples of the R&I that can contribute to management of variability and uncertainty include work on transmission and distribution planning under uncertainty, on forecasting methods especially applied on local conditions, on synthetic inertia, or on market design for demand response and for the interaction between different partial markets and different grids.
Increased grid hosting capacity for renewable generation. This acknowledges that the electricity system including especially the grids is, together with Information and Communication Technology (ICT), the platform where the innovations described in this paper come together and create value for customers. The challenge lies to a large extent in the distribution systems where a combination of network reinforcements, congestion management, energy storage, demand response, market and system operational improvements are needed. Finding the right balance for each region between reinforcements and improved market, storage, demand response and operations tools will have significant economic effects. Examples of R&I activities that can contribute to increased use of the grid infrastructure are development of methodologies, software, models for planning, market and network assessment, monitoring schemes to extend the life time of the networks, use of new power technologies, integration of energy storage and the ICT platforms to support all these developments.
A further flexibilisation of centralised and decentralised thermal power generation technologies, including for the combined production of heat and power. Flexibilisation in this sense includes not only the speed to adapt to changes in demand and volatile RES generation, but also the ability to integrate the storage and use of excess energy via power-to-heat and power-to-gas, the further development of hybrid solutions combining vRES with the reliability of dispatchable energy sources, an increased fuel flexibility supporting a

switch from fossil to renewable sources, a better integration of industrial combined production of heat and power into the overall system and an increased used of sustainable combined production of power and heat/cold (e.g. from biomass, solar, waste, geothermal, heat pumps). A key challenge in this is the efficient use of data from the system to run the plants and have them react efficiently and minimising the environmental and climate impact.
Increase the capability of RES to provide services to the energy system. This include improvements in the accuracy of the forecast of production, the development of technologies, tools and services like combining locally RES production with storage or/and power to gas facilities so as to reduce the variability of the production and enable RES to be a market player and to provide services to the grid.

Economic efficiency
Economic efficiency is tied strongly on one hand to technological and cost reduction progress – in particular for technologies such as energy storage and flexible thermal generation which support flexibility – and on the other hand to market design and dynamic pricing. R&I is needed to accompany progress in these fields. At the same time, network operators must face a technology transition in the years to come. Keeping the system reliable, at the likely different levels requested by the different economic agents, means a power system that is observable and controllable while welcoming a growing number of such agents, using dynamic prices and customer-centric market design. The existing power system has been designed by implementing a "cyber ICT layer" on the top of a "hardware (equipment) layer". The future power system's cyber layer will cover the whole continent, and, at the same time, will reach, whenever possible, each agent in order to observe and help them optimising their behaviours. This new cyber layer may also contribute to mitigate/delay infrastructure investments, thanks to integrated intelligent infrastructure monitoring strategies enabling life extension and exploitation.

2.2 Develop integrated local and regional energy systems

Regional and local energy systems and networks are composed of locally and regionally available energy sources, built infrastructure, specific production and consumption characteristics as well as user and consumer structures from different sectors, including the transportation system. They have an important role to play in reaching the Energy Union targets. They are part of the living environment of citizens, including, in some cases, highly ambitious clean energy goals of specific communities and regions. They provide appropriate services to consumers, customers and citizens as well as to the overall European energy system to help ensure the security of supply, maximise the primary energy efficiency and deliver a high share of renewable energy.
Local and regional energy systems will have to cope with a fundamental transformation in the coming years, responding to actual drivers such as the increasing uptake of new and improved technologies for decentralised energy systems, the boosting digitalisation and associated business models as well as current societal trends. In that respect, regional and local innovation ecosystems will be very important 8. Solutions could be tailor made for regions below the size of a NUTS 2 region (which is 800.000 inhabitants and more). It could be the case that a smaller political and planning entity (starting from 150.000 inhabitants. i.e. NUTS 1) will better fit the needs when developing a regional energy system. Especially in rural contexts, smaller regions often allow for better involving the right stakeholders and creating the necessary buy-in.

In its "Clean Energy for All Europeans" legislative proposals (the so called "Winter Package"3, covering energy efficiency, renewable energy, the design of the electricity market, security of electricity supply and governance rules for the Energy Union), the EC particularly highlights specific drivers and elements of regional and local energy systems. Not the least, the EC Winter Package recognises the potential of regional approaches, when it calls for "methodologies to assess security of supply and to identify crisis scenarios in the Member States and on a regional level, to conduct short-term adequacy assessments, to establish risk preparedness plans and to manage crisis situations."

The three dimensions of integration

Implementing smart and integrated energy systems requires not only technological innovation, but also organisational innovation, new business models, new or reconfigured value chains, new actors in the research and business landscape of energy services and technologies as well as a better integration of different types of end-users into the energy system. A variety of entrepreneurial initiatives and partnerships among multiple actors are needed to speed up the implementation of smart and integrated energy in society. Integrated initiatives are needed to support social, institutional, organisational and market innovation in the energy sector including the intersections between energy supply, energy efficiency, and new user practices. Integration can be described along the following three dimensions:

Smart energy system integration. From a technical perspective, new solutions must optimise the integration of renewable energy, provide infrastructure that can host a large number of distributed generation units, increase flexibility by efficiently integrating different energy carriers as well as utilising (local) storage, supply side coordination and demand side response. They should also provide technology service systems that support highly dynamic business processes with a large number of participants enabling the implementation of complex business models serving different market participants such as individual consumers and prosumers or customer groups as well as system operators, facility managers, energy suppliers, service providers and aggregators.

Innovation ecosystem integration (Integration with local & regional development). We need to better understand local and regional processes and the implementation paths of innovative energy systems. Beyond the well-established research and development division (RDD) stakeholders from industry, research institutes and universities, key players of the local and regional energy and innovation eco-system will have to be involved. Supporting new cooperative approaches as well as common standards will not only strengthen local and regional transition dynamics and entrepreneurship, but also enable steps towards EU level solutions in the integration of energy systems. This will help sustain European industrial leadership in sustainable energy solutions worldwide while paving the way to a low-carbon economy.

Cross sectoral integration. On a local or regional level, smart energy activities often involve multiple economic sectors. Particularly that means cross sectoral integration of smart energy systems and energy transition processes with transport (e.g. distribution grids for optimal charging of e-mobility vehicles and using the storage capacities of e-mobile fleets) or industry and trade (e.g. data centres requiring electricity and providing waste heat, enterprises or stores using their large thermal stores for excess electricity and balancing the electricity grid), or municipal infrastructure (e.g. heating and cooling networks, water supply and sanitation, public transport, buildings, street lighting) or agriculture (e.g. farms as facilities to generate or store energy).

3 Innovation Targets

3.1 The principles for the formulation of the final targets

With the mandate given by the SET-Plan Steering Group, the initial work of the TWG A4 was oriented to the re-formulation and completion of the innovation targets from the stakeholder declaration, along the following main lines:

- Referring to Energy Union and SET-Plan goals
- Output based targets – e.g. not the development or implementation of a specific technology is a goal in itself, but the effects that shall be achieved by applying technology
- Innovation oriented targets – research and innovation activities and measures are the primary means to reach the goal

- Technology neutral targets – there is still an open question how technologies and solutions will exactly look like, that will have to be answered by innovation (research and development, technology learning curves, market competition, etc.)
- Concrete targets – the formulation must balance the openness according to the above four high level principles with the fact, that by setting the focus of SET-Plan key action 4, as described in the stakeholder declaration, there is already agreement on some preconditions according to technology and solutions (e.g. the important role of flexibility for the electricity grid, the insight that information flows and communication are important enabler, the way how heating and cooling systems have to be developed further, etc.). In that respect targets shall be as concrete as possible to guide the development in the set direction
- The original quantification of the targets as described in the stakeholder declaration shall serve as a benchmark in the new formulation

The process adopted for the re-formulation of the targets involved the different stakeholders, with special reference to IWG A4 members, ETIP SNET and its working groups, national stakeholders' coordination group, ETIP RHC, ETIP PV and ETIP DG.

3.2 The final Innovation Targets

According to the requirements set by the Set Plan Steering Group, the initial targets were re-evaluated and classified as follows:
- Crosscutting Innovation Targets for Flagship Initiatives 1 & 2;
- Innovation Targets for Flagship Initiative 1: Develop an optimised European power grid;
- Innovation Targets for Flagship Initiative 2: Develop integrated, regional energy systems.

For what pertains to the optimised European power grid, four main priorities were selected, according to the strategic targets "Flexibility by 2030" and "Economic Efficiency" given in the stakeholder declaration, namely:
- Observability and controllability;
- Load management and demand response;
- Flexibility of the generation;
- Reduction of costs of storage.

For each area, output based targets were assessed, giving numerical values in the form of benchmark. The discussion started from the targets formulated in the stakeholder declaration, reflecting and reformulating them in the light of the principles in section 3.1 of this implementation plan. The targets are reported in the table below.
For what pertains to local and regional energy systems, innovation targets had to be formulated according to the strategic targets given in the stakeholder declaration, which are referring to the necessary innovation in the heating networks, in order being able to play their role in an integrated regional energy system, further the key issue of developing innovative solutions that make optimal use of a mix of energy sources as well as available technologies and infrastructures, and last but not least the overcoming of innovation barriers by establishing innovation environments to develop smart services for local and regional energy systems. The following priorities were selected:
- Low temperatures and flexibility for heating grids
- RES integration including different energy vectors
- Multi-dimensional local systems for energy communities
- Smart service co-creation frameworks to develop local and regional value chains

The strategic target regarding smart service development was identified as relevant for both flagship initiatives. Crosscutting targets address therefore the dimension of establishing innovation environments for the development of smart services. According to this, resulting innovation activities make special references to digitalisation (including cybersecurity), new regulatory approaches enhancing the value of field experiments and the concept of living labs.

The following tables give an overview on the formulated innovation targets, according to the strategic targets given in the stakeholder declaration.

Table 1: Formulated innovation targets, according to the strategic targets given in the stakeholder declaration – Flagship Initiatives 1 and 2

Crosscutting innovation targets for Flagship Initiatives 1 and 2	
Strategic Target	Innovation Target
A4-T1.5 & A4-T2.3: Establish innovation environments for the development of smart services	**A4-T1.5.-1:** Provide innovation frameworks to develop attractive services, creating value for the participants in the **power system** and allowing for **participation in pan-European value chains**. **A4-T2.3.-1:** Provide co-creation frameworks to develop attractive services, creating value for the participants in the **energy system** and allowing for **participation in the development of local and regional value chains** (from investments to customer services) Services have to be scalable, customisable and replicable from a very local to an interregional and global level, leveraging synergies by building on digital platforms. Solution should be able to address customers from small communities up to 100.000 and more (households, commercial, etc.). Services require advanced ICT systems, which have to account for security, privacy requirements and trade-offs.

Table 2: Formulated innovation targets, according to the strategic targets given in the stakeholder declaration – Flagship Initiative 1

Flagship Initiative 1: Develop an optimized European power grid	
Strategic Target	Innovation Target
A4-T1.1: Flexibility of the system by 2030	**A4-T1.1.-1**: Develop and implement solutions to **increase observability and controllability in the energy system.** 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.
	A4-T1.1.-2: Develop and implement solutions and tools to manage the load profile by demand response and control, in order to optimise use of the grid and defer grid investments. 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 TYNDP 2016 of ENTSOe.
	A4-T1.1.-3: Develop and implement solutions to increase flexibility of all types of generation **Sub-Target 1.1.-3.1: Develop and implement solutions to enable Renewable Energy Sources to provide grid services.** Solutions should be equivalent to those providing balancing services, dispatch, contribution to the stability, 'smart' connection with the grid or improving accuracy of forecasting models for aggregated RES plant power production by

	10 %. **Sub-Target A4-T1.1.-3.2:** Develop and implement solutions to **improve the flexibility capabilities for new as well as retrofitted thermal power plants.** 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). • 2) Halving efficiency losses for part-load operations. • 3) Reducing minimum load by 30% compared to the average of today (avoiding plant switch-off).
A4-T1.2: **Economic Efficiency**	**A4-T1.4.-1: Reduce the cost of all energy storage solutions contributing to the minimisation of the overall system costs.** 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. **Sub-Target A4-1.4.-1.1:** Solutions for **short-term storage** should enable the reduction of the specific storage costs by at least 50% to 70%.

Table 3: Formulated Innovation Targets, according to the strategic targets given in the stakeholder declaration – Flagship Initiative 2

Flagship Initiative 2: Develop integrated, local and regional energy systems	
Strategic Target	Innovation Target
A4-T2.1: **Develop heating and cooling systems that are able to locally integrate energy from different sources of different temperature levels**	**A4-T2.1.-1: Low temperatures for the efficient integration of different sources** Develop and/or demonstrate technologies, systems and solutions for matching the system temperatures with local available low-carbon sources, including the set-up of new networks with low (e.g. 35-50°C) and very low (e.g. 10-30°C) supply temperatures and the reduction of the temperatures in existing networks. Solutions should enable buildings to operate with low supply and/or return temperatures in a cost-effective and sustainable manner (for example by improving the building side installations incl. substations and domestic hot water). Further on, the system design/operation should be adapted to the lower temperatures, including the integration of heat pumps, cooling options and storages. Suitable business models involving building owner and end customers should also be addressed. Aim is to develop detailed and replicable concepts and/or implementation projects for decreasing the return temperature by >5°C in significant network sections or for networks low/very low supply temperatures having a return on investment (ROI) of <20 years at minimum influence on the costs and comfort of the end customer.
	A4-T2.1.-2: Flexibility Develop and/or demonstrate technologies, systems and solutions for increasing the short (hours to days) and long (weeks to months) term flexibility of district heating networks. Aim is to minimise the mismatch between the load and supply profiles of alternative heat sources (incl. power-to-heat) and in turn reduce the use of fossil fuels in peak load and winter times and avoid supply competition in summer times.

	Solutions should improve the costs–benefit ratio of storage options and/ or improve the customer side integration in case of building side flexibility options. To develop detailed and replicable concepts and/or implementation projects for cost effective large-scale penetration of flexibility measures (ROI <20 years for long and ROI <5 years for short-term) in a concrete urban DH network, shifting at least 15% of the yearly / 25% of the daily energy demand
A4-T2.2: **Develop innovative mix solutions that will reduce variability** by combining multi low carbon solutions (e.g. wind, solar, renewable heat production combined with energy storage)	**A4-T2.2.-1: RES integration at regional and local levels, including different energy vectors.** Develop and demonstrate technologies, systems and solutions that make it possible to efficiently provide, host and utilise high shares of renewables, up to and beyond 100% in the local or regional supply, by following a holistic view on the energy system, linking different energy domains (electricity, heat/cold, gas, mobility) at different scales while considering system, market and organisational aspects, allowing for making optimal use of renewable energy sources and recovered energy.
	A4-T2.2.-2: Multi-dimensional local energy systems Develop methodologies, tools and technologies that enable local energy communities to operate multi-dimensional energy systems that are optimally integrating regional infrastructures and facilities (swimming pools, greenhouses, steel factory, etc.). These shall also enable local energy communities to actively contribute to the energy markets and to the resilience, stability and flexibility of the overall system. Solutions have to consider the layers: • Technology (physical and digital), • market and adoption in order to increase efficiency above the established European target, • keep quality of supply on established levels.

4 Elaboration on Targets

4.1 Observability and controllability

The final target of the RD&I activities are to upgrade and smarten the power system operation at all voltage levels in order to maintain an adequate quality of supply in a more uncertain and more interconnected system, considering variable RES and DER, demand response, storage and the interface with other energy and transport/mobility networks, new technologies and the evolution of 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 this increased controllability is also tightly linked with the capability of a timely observability of the continuously changing conditions of the systems, by means of adequate sensors (from PMUs at transmission and distribution levels down to electricity demand though smart energy meters, equipment conditions and diagnostics, communication system states, including weather forecasts for RES production and resilience etc.), communication and data exchanges protocols and platforms.

4.2 Load management and demand response

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 over 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 prices 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 potential very wide diffusion 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.

4.3 Flexibility of the generation

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 availabilities 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 of electricity and heat do 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 optimise their operations. Decoupling heat and electricity generation will allow for a more efficient energy use via flexibilisation 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, having more responsibility in dispatching energy and participating in ancillary services markets.

Power-to-Gas and Power-to-Liquid are promising solutions for the future using excess energy at the times of low demand and providing a "green" fuel that can be used in flexible thermal power plant systems. More broadly, synthetic liquid or gaseous fuels can be used in this way to support the synergies between transport and power sector by cycling the CO2 and therefore making CO2 neutral fuels available. The main challenges are the adaptation of the combustion to the new gases as well as the cost-efficiency of the full process chain.

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.

4.4 Reduction of costs of storage

Among the different tools available in the portfolio of network operators for real-time balancing of generation and demand, different technologies of storage will be crucial to support system stability.

Energy storage technologies for energy and power applications seem to be still far to meet technical and economic targets. For example, while current available storage technology is proving their 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 of 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.
- Cost competitive energy storage technology - Achievement of this goal requires attention to factors such as life-cycle cost and performance (round-trip efficiency, energy density, cycle life, degradation, etc.) for energy storage technology as deployed. Long-term success requires both cost reduction and the capacity to realise revenue for all grid services storage provides.
- 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.

4.5 Heating and cooling systems: integration from different sources of different temperature levels

District heating and cooling (DHC) have proven to hold a formidable potential for enhancing the energy system flexibility and efficiency, especially at local level. Depending on the location of the area (country/city, underground condition, nearby industries or sewage water ducts, available areas for solar energy, surplus heat from industry or natural cooling, large storage capacities etc.) different sources for heating and cooling are locally available and can be utilised. The efficient exploitation of locally available resources requires the design of efficient DHC networks (>10% reduction of heat losses compared to standard grids and >80% of utilisation of the sources).

DHC networks traditionally operate with high supply temperatures in order to reduce the investment costs by reaching the required transport capacity with small pipe diameters and using cost effective customer installations. Whereas new networks can be designed for the temperature level of the local available heat source a priori, existing networks require major adaptations. The integration of renewables and waste heat sources require return temperatures at relatively low levels (>5°C).

The RD&I activities aim at addressing the technological aspects of DHC as a means to enhance the flexibility of the energy system as well as elaborating business models generating appropriate incentives for all involved stakeholders, especially building owners and final consumers. Network related actions that are needed; the use of more standardised efficient and cost-effective construction materials and components play an important role (specific numerical target to be added if possible). Measures to achieve these targets need to consider the economic viability and supply security as key aspects.

4.6 RES integration including different energy vectors

Systems need to be developed which bring together multiple low carbon solutions (e.g. wind, solar, renewable heat production combined with energy storage, the transport system, etc.), combining 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 utilisation 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.

4.7 Multi-dimensional local systems for energy communities

In the "Clean Energy for All Europeans" legislative proposals (covering energy efficiency, renewable energy, the design of the electricity market, security of electricity supply and governance rules for the Energy Union), the EC particularly highlights specific drivers and elements of regional and local energy systems. It highlights the fact that solar and wind technology prices have declined respectively by 80% and 30-40% between 2009 and 2015. Such cost-reduction are enabling consumers to produce and store their own renewable energy.

According to the legislative proposal consumers shall benefit from increased allowances to produce their own electricity. They shall be allowed to organise themselves into renewable energy communities to generate, consume, store and sell renewable energy and feed any excess production back to the grid. This includes incentives for self-consumption of locally and regionally produced energy as well as for flexibility to help stabilise the overall electricity system. In the proposal for the internal electricity market9 a specific role is given to "Energy Communities4".'Local energy communities' (LEC) there means "associations, cooperatives, a partnership, a non-profit organisation or other legal entity which is effectively controlled by local shareholders or members….”

According to the proposal, "community energy offers an inclusive option for all consumers to have a direct stake in producing, consuming and or sharing energy between each other within a geographically confined community network …". In the light of the overarching goal to develop integrated, regional and local energy systems, this approach is taken to the wider scope of multi-dimensional energy systems, in which the power system could play a mayor enabling role.

4.8 Smart service co-creation frameworks to develop local and regional value chains

In addition to innovative technologies, developing and implementing smart and integrated energy systems requires organisational and regulatory innovation, new business models, new or reconfigured value chains, new actors in the research and business landscape of energy services and technologies as well as a better integration of different types of end-users into the energy system. (As an example: local energy communities should be encouraged taking into account the overall system optimisation. This means that appropriate markets should be developed to facilitate and remunerate LECs contribution to the overall system security and optimisation.)

A variety of entrepreneurial initiatives and partnerships among multiple actors is needed to speed up the implementation of smart and integrated energy in society. Integrated initiatives are needed to support social, institutional, organisational and market innovation in the energy sector, including the intersections between energy supply, energy efficiency, and new user practices. New cooperative approaches will not only strengthen local and regional transition dynamics and entrepreneurship, but will also develop EU level solutions to the integration of energy systems. This will help sustain European industrial leadership in sustainable energy solutions worldwide while paving the way for a low-carbon economy.

Due to digitisation, enabling an exponential growth in number of active users and participants in the current energy system, the development of related automatized business processes and services is a key requirement in the design of future energy system. While energy management solutions for single family houses or single energy customers are already entering the market, solutions for multifamily buildings, communities and regions still need to be developed.

Their complexity together with the required "service depth" make it difficult for potential providers to see a market and for potential users and buyers to find appropriate development partners. In order to take a leading role within international developments, European innovation ecosystems should be created around the regional and local energy systems that will enable the potential buyers, developers and providers to work together in co-creation processes, to develop attractive services serving the requirements of the different participants and of the overall system. This includes (e.g.):

- Data accessibility for pilot initiatives in cooperation with ICT infrastructure providers,
- Initiation of developer platforms for digital business processes,
- Development of cooperation formats that facilitate the participation of start-ups and SMEs.

5 The new harmonised Innovation Fiches for Flagship 1

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

Implementation Plan - Activity Fiche 1 – Flagship 1
Innovation Target: • Crosscutting Activities
Title: Social campaigns and social studies (related to societal acceptance and environmental sustainability of energy infrastructure)
References to ETIP SNET Implementation Plan 2021-2024: RA 1 - Topic 1.1 Reference to the IWG4 Implementation Plan 2018 Innovation fiches: A4-IA0-1
Challenge: The target of at least 32% of renewable energy in gross final energy consumption in 2030 relies on measures to facilitate the participation of citizens in the energy transition. In the process of acceptance of the integration of variable Renewable Energy Sources (vRES), social and environmental aspects must be considered at all levels. The transition of societal needs from today's energy system towards the future energy system need to be analysed: social studies and communication campaigns are needed to raise awareness with citizens, to build common knowledge and to involve them in the decisions process since the very beginning. In parallel, the current energy infrastructures do not consider yet environmental sustainability such as related to human and animal exposure to EMF and 5G effects. R&I efforts are needed to reduce negative environmental effects from, for example, hydropower plants, windmills, and HV infrastructure. The integration of vRES needs communication campaigns to increase public awareness, acceptance and engagement regarding the building of energy communities and the process of construction of energy infrastructures; the reduction of impacts of the energy infrastructure on the environment and on wildlife; and efforts to put the end-user (customer) at the centre of the energy system. **Scope:** The ACTIVITY FICHE will include, as a basis of further works, social studies fostering societal acceptance and environmental sustainability of energy infrastructure. Social acceptance and environmental sustanaibility are key elements to foster the integration of variable Renewable Energy Sources (vRES). Social studies will be conducted to promote stakeholder engagement and acceptance through the involvement of final users. Specific methodologies will be developed to identify the best practices between the different energy communities, to implement participative decision-making process and support public debates. Studies will also analyse how to minimise the environmental effects of energy infrastructures and harmonise environmental authorisation at EU level. Key indicators will be identified to measure both the degree of social acceptance and environmental impacts. Specific demonstrations will be developed to enhance the microgrid-by-design concept to strengthen Citizen Energy Communities for increased grid stability and reduced energy poverty.
Description of RD&I or Programming Activities: 1. Methods and tools for effective stakeholder engagement to increase public acceptance of new energy infrastructures, including transmission lines (overhead lines and underground cables), sub-stations, storage facilities, generation stations (thermal and RES, like hydro and wind), gas pipelines and conversion stations (links to Social Science and Humanities). 2. Increase consumer understanding and awareness of new electricity/energy systems and particularly the consumer / prosumer central role as active participants in grid operation. Investigate the social and economic impact of the citizen involvement in forming energy communities, including increased

system resilience and sustainability. 3. Studies to reduce or remove the environmental impacts of energy infrastructures (visual and audible) such as for hydropower plants (hydro-peaking effects, better sediment management, fish migration and fish protection, water quality), noise of transformers and transmission lines, more attractive designs for transmission line towers, changed visibility by undergrounding.
Joint activities: • A4-IA0-1: o JI -1: A joint COST or Coordination & Support activity within the H2020 program; o JI -2: A joint light house (or research infrastructure) project for an HPCC dedicated to the energy domain; o JI - 3: Government to Government information exchange; o JI -4: Workshops on GIS interfaces o JI - 5: Transnational calls o Further collaboration ideas (bilateral actions etc…)
Impact of the RD&I Activities: • ***Short-term impact:*** o Reduce the number of infrastructure projects / assets that cannot be realised for public acceptance reasons. o Adopt technical solutions to bring higher socio-economical return for society in general, and that not linked to specific social groups. • ***Long-term impact:*** o From the beginning of any infrastructure project / asset, implement social acceptance interaction to minimise the number of infrastructure projects / assets that cannot be realised for public acceptance reasons. o Reduce time for the realisation of the society accepted technical infrastructures.
TRL: 3-5 / 6-8

Expected deliverables: tbd	**Timeline:** tbd

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

Implementation Plan - Activity Fiche 2 – Flagship 1
Innovation Target: • Crosscutting Activities
Title: Adaptive consumer/user behaviour incl. energy communities (Interaction, incentives by dynamic tariffs)
References to ETIP SNET Implementation Plan 2021-2024: RA 1 - Topic 1.2 Reference to the IWG4 Implementation Plan 2018 Innovation fiches: A4-IA0-1
Challenge: In 2030, local and regional demonstrations of Active Demand Response will be implemented relying on the evolution of relations between consumers, prosumers and the energy system. This change of behaviour is needed to strengthen interactions between citizen energy communities and the energy system. In the process of active consumer participation, all means of measuring electricity and other energy consumptions, user participation and motivations must be explored and evaluated. The present relationship of the consumer and prosumer with the energy system does not address the integration needs to change society characterised by a progressive increase of environmental and sustainability consciousness that triggers behavioural changes, such as the current lack of general

consideration for sustainable mobility choices, corporate responsibility and transparency, distributed renewables integration, demand response by the user, energy and water conservation measures, neighbourhood comparison and related rewards. In terms of hardware and software answers, there is a general lack of solutions that enable consumers, prosumers and communities to make informed decisions as easily as possible to create their own comfort, sustainability and security needs, considering budgetary restrictions, market-based prices and regulated tariffs.
The relationship evolution of the consumer and prosumers needs to rely on tools and knowledge for the active participation of prosumers in electricity markets, for the consumer satisfaction by energy services, and for the complete behaviour motivations of the customers to contribute to the functioning of integrated energy systems.

Scope:
This ACTIVITY FICHE will include, as a basis for further works, comprehensive guidelines to define the level of interactions between the consumer, prosumer, energy communities and energy system as well as clear incentives by dynamic prices, regulated tariffs and other market incentives.
Interactions between consumers, prosumers and energy communities will be clearly specified to foster participation in electricity markets. Tools will be developed for putting the end-user in direct contact with supplier, distributor and other involved market stakeholders in order to increase consumer satisfaction. Dedicated demonstrations will show real-time optimisation of Distributed Energy Resources and increase the understanding of consumer behaviour providing direct action on demanding asset in real-time through dynamic energy management mechanisms.

Description of RD&I or Programming Activities:

1. Methods and Tools to support consumer and prosumer adaptation of their energy behaviour, including online measurements of electricity consumption and generation, dynamic time of use tariffs and behavioural studies considering the full environment, such as non-energy benefits, like comfort and security.
2. Methods and tools including campaigns to support the industry’s consumption adaptation in order to support the system.

Joint activities:

- A4-IA0-1:
    - JI -1: A joint COST or Coordination & Support activity within the H2020 program;
    - JI -2: A joint light house (or research infrastructure) project for an HPCC dedicated to the energy domain;
    - JI - 3: Government to Government information exchange;
    - JI -4: Workshops on GIS interfaces
    - JI - 5: Transnational calls
    - Further collaboration ideas (bilateral actions…)

Impact of the RD&I Activities:

- ***Short-term impact:***
    - Intensify behavioural motivations for end-users to become prosumers.

- ***Long-term impact:***
    - Adapt consumer / user behaviour including energy communities for a sustainable, resilient, secure and affordable energy system.

TRL: 6-8

Expected deliverables: tbd	**Timeline: tbd**

5.3 Consumer and Prosumer Device Control

Implementation Plan - Activity Fiche 3 – Flagship 1
Innovation Target: • Manage the load profile by demand response and control: ○ A4-T1.1.-2: Develop and implement solutions and tools to manage the load profile by demand response and control, in order to optimise use of the grid and defer grid investments.
Title: Consumer and Prosumer Device Control
References to ETIP SNET Implementation Plan 2021-2024: RA 1 - Topic 1.3 Reference to the IWG4 Implementation Plan 2018 Innovation fiches: topic not covered by any Innovation fiches in the previous IWG4 IP.
Challenge: In 2030 households actively participate in real-time, automated demand response (electricity, heating and cooling) with connected appliances and equipment. A shift is needed in the relation of the consumer and prosumer with the energy system mainly via technological devices. All control devices to empower the consumer must be considered. The present consumer and prosumer device control tools do not consider enough, in the relationship towards energy system technologies, the experience from digital adopters, the user centredness of technologies, the prosumer device control, market tools. There is a general lack of solutions enabling the consumers to be actors in the energy system (roles and integration of consumer owned DER, smart metering); including local industrial actors with flexibility potential (such as load shifting and Power-to-heat/cooling solutions) to provide a more resilient, clean and self-sufficient energy community system; addressing the market opportunities offered by new digital technologies (peer-to-peer energy markets, flexibility and ancillary services markets). Consumers and prosumers need to have access to technologies and tools to empower them with regards to the energy system in a user-friendly environment. There is a need to develop solutions including storage (such as by batteries, containers for carbon neutral or free gases and liquids), micro CHP, heat pumps, EV with smart charging, smart appliances, incentives, dynamic tariffs. Being active means also the need to connect to flexibility potential with e-mobility smart sector integration, second life EV battery systems; and to consider new digital technologies such as prosumer device control which can be used by energy communities. **Scope:** The ACTIVITY FICHE will include, as a basis for further works, comprehensive documentation on the use of control devices, measurement and visualisation by consumer and prosumer to adapt their behaviour in terms of demand response. Specific guidelines will be specified for the use of smart appliances for measurement and control devices such as smart plugs and voltage clamps, for visualization such as in-home displays, etc. Suitable IT tools will be developed to foster peer to peer interactions, improvement of cooperative energy services; optimisation of energy consumption portfolio; flexibilization of local industrial bodies behaviour. Dedicated demonstration will be set to develop and test standardized devices enabling visualisation and control of electricity consumption/generation and storage (such as by batteries, hot water tanks, containers for CO_2-neutral or free gases and liquids).
Description of RD&I or Programming Activities: 1. Wireless technologies for direct control of prosumers' electricity consumption/generation using low-cost technologies (smart phones). 2. In-home ICT technologies for smart appliances (for example smart load controllers) for direct control of consumer demand, incl. visualization via in-home displays.
Joint activities: //

Impact of the RD&I Activities:
• ***Short-term impact:***
    o Enhanced complex relation of the consumer and prosumer (be it an individual, a community, a commercial user, an industry) with the energy system by development of technologies.
 	
• ***Long-term impact:***
    o Full appropriation of device control by consumer and prosumer.

TRL: 6-8

Expected deliverables: tbd	**Timeline:** tbd

5.4 Business models (including Aggregators)

Implementation Plan - Activity Fiche 4 – Flagship 1

Innovation Target:
• Croscutting activities.
• Manage the load profile by demand response and control
    o A4-T1.1.-2: Develop and implement solutions and tools to manage the load profile by demand response and control, in order to optimise use of the grid and defer grid investments.
• Flexibility of all types of generation
    o A4-T1.1.-3.2: Develop and implement solutions to improve the flexibility capabilities for new as well as retrofitted thermal power plants.

Title: Business models (including Aggregators)
References to ETIP SNET Implementation Plan 2021-2024: RA 2 - Topic 2.1 Reference to the IWG4 Implementation Plan 2018 Innovation fiches: A4-IA0-1; A4-IA1.2-1; A4-IA1.2-3; A4-IA1.3-5
Challenge: The value chain of energy production and supply is changing with the entrance of new actors and elements. The existing structure does not fit with the new demands based of decentralised generation, electric devices and appliances, or storage requirements realised by batteries, hot water tanks, low-cost containers for CO2-neutral or free gases and liquids), where both customers and end-users are playing a fundamental role. Business models for the different (traditional and new) stakeholders are not yet available. They must be simulated and analysed. Today's market rules for the transition towards the future energy system are not yet sufficient to enable more effective markets and to enhance the transition to a de-carbonized energy system and economy. For example, in most of the European Countries, renewable, demand and storage resources (except pumped-storage hydropower plants) are not allowed to participate in the balancing services market. For example, in most of the European Countries, renewable, demand and storage resources (except pumped-storage hydropower plants) are not allowed to participate in the balancing services market. In many countries in Europe flexibility trading in the true meaning of the function, is still in its infancy. Moreover, smart charging of EVs is not included in market rules and the connected grid is still not smart enough to utilise this huge potential. The changes in the value chain of energy production and supply, due to the entrance of new actors, technology and elements, needs to be managed, to fit the existing structure to the new demands. Standardized templates and tools to develop CBA in the smart grids' projects need to be developed and extensively used, together with the definition of new regulatory frames, ensuring equitable and fair

participation and competition possibilities to all the stakeholders.

Scope:
This ACTIVITY FICHE addresses the development and analysis of business models, for the different actors in the energy system playground, namely prosumers, aggregators, DSOs, storage operators (such as of batteries, heating/cooling storage, including EV recharge, EV smart charging) and heating/cooling operators.
Business models will be developed and analysed for all the different stakeholders of the energy value chain; particular focus will be devoted to actors in LV/MV systems (such as DSO, aggregators and retailers, prosumers), to storage operators and to electric mobility actors, all providing ancillary services to the network, to operators in the energy efficiency sector, to operators in the heating/cooling sector.

Description of RD&I or Programming Activities:

1. Business models for prosumers providing ancillary services, including EV owners with bidirectional capabilities and storage units.
2. Business models for retailers and aggregators, ESCOs and energy communities, providing energy efficiency at end-user level.
3. Business models for data analysis service providers to energy using large-scale data bases and advanced data-mining techniques.
4. Business models for storage in electrical transportation networks (such as tramways, trains, buses).
5. Business models for gas-fired or biomass fired CHP units producing heat when residual loads are low, and electricity when residual loads are high or used as thermal storage.

In addition to the RD&I activities included in the ETIP SNET Implementation plan the following activities are considered:

6. Business models for the inclusion of thermal storage into conventional plants
7. Business models for CSP and thermal storage in order to produce a renewable fraction of the total output

Joint activities:

- A4-IA0-1:
  - JI -1: A joint COST or Coordination & Support activity within the H2020 program;
  - JI -2: A joint light house (or research infrastructure) project for an HPCC dedicated to the energy domain;
  - JI - 3: Government to Government information exchange;
  - JI -4: Workshops on GIS interfaces
  - JI - 5: Transnational calls
  - Further collaboration ideas (bilateral actions…)
- A4-IA1.2-1:
  - JI-1: Align national R&I programs to include the above activities
  - JI-2: Share results and best practices
  - JI-3: National, transnational and European calls for RD&I projects on the above given topics
- A4-IA1.2-3:
  - JI-1: National, Transnational and European Calls for RD&I projects on the above given topics.
- A4-IA1.3-5:
  - JA-1: Integration of Storage and vRES
  - JA- 2: integration of different Storage technologies

Impact of the RD&I Activities:	

Impact of the RD&I Activities:
• ***Short-term impact:***
  ○ Support of policy makers in the definition of suitable regulatory measures related to future business during the energy transition (market rules, incentives, prices).
 	
• ***Long-term impact:***
  ○ Robust regulatory measures implemented in EU and national laws and acts to maximise welfare by profitable businesses during the energy transition.	

TRL: 3-5	
Expected deliverables: tbd	**Timeline:** tbd

5.5 Market Design and Governance (Retail, Wholesale; Cross-border; Ancillary services; Flexibility markets)

Implementation Plan - Activity Fiche 5 – Flagship 1

Innovation Target:
• Crosscutting activities.
• Manage the load profile by demand response and control
  ○ A4-T1.1.-2: Develop and implement solutions and tools to manage the load profile by demand response and control, in order to optimise use of the grid and defer grid investments.
• Flexibility of all types of generation
  ○ A4-T1.1.-3: Develop and implement solutions to increase flexibility of all types of generation.
• Reduce the cost of all energy storage solutions
  ○ A4-T1.4.-1: Reduce the cost of all energy storage solutions contributing to the minimisation of the overall system costs.

Title: Market Design and Governance (Retail, Wholesale; Cross-border; Ancillary services; Flexibility markets)
References to ETIP SNET Implementation Plan 2021-2024: RA 2 - Topic 2.2 Reference to the IWG4 Implementation Plan 2018 Innovation fiches: A4-IA0-1; A4-IA0-3; A4-IA1.2-1; A4-IA1.2-2; A4-IA1.2-3; A4-IA1.3-1; A4-IA1.4-1;
Challenge: Increased shares of variable renewable energy, combined with the rise in distributed generation, are profoundly impacting on electricity markets, the demand for system flexibility and the business models of traditional utilities and distribution companies. This requires a rethinking of the way power sector markets are designed and operated as well as a timely and efficient adaptation of traditional market and operational mechanisms The integration of European intra-day and balancing markets is not yet ready to be accelerated with a swift implementation of the network codes and increased dialogues and cooperation across national borders. Demand does not yet have equal market access as supply resources. They lack access to markets (forward, day-ahead, intra-day and balancing markets) to offer their services, provided they fulfill the criteria needed for these sometimes very specific markets. The roles and responsibilities of all market parties are not yet clearly defined for a flexibility market design and for smooth functioning and security of supply. Prior to full-scale application of new markets real-life piloting is needed. This requires regulatory sandboxes where innovative solutions can be tested ahead of widespread deployment. Roles clarification through R&I might be useful for the definition of local flexibility markets, as there may not always be enough market players to constitute a market, as well as for a common description of flexibility products . Prosumers are not yet supported by stable, transparent and enabling regulatory frameworks. They cannot

carry responsibilities e.g. for balancing according to their means; moreover, they do not yet bear network costs reflecting the services they receive from the public infrastructure, unable to ensure a fair allocation of costs between all consumer groups.
An integrated EU energy market needs to be a priority, to ensure secure and affordable energy supplies to European citizens and businesses: therefore, common energy market rules, communication standards and protocols and cross-border infrastructure need to be designed and established. Fair competition must be guaranteed to all the stakeholder in the energy supply chain, together with provisions to attract investment in the resources, like energy storage such as by batteries, hot water tanks, containers for CO2-neutral or free gases and liquids, that can compensate for variable energy production. The markets must provide the right incentives for consumers to become more active and to contribute to keeping the electricity system stable, as well as allowing ancillary services being fairly remunerated providing essential data, together with the possibility of integration of different network.

Scope:
This ACTIVITY FICHE addresses the design of energy markets at all time scales and at all geographical scales, from the pan-European cross-border wholesale electricity and gas markets, products, services and businesses, down to local, neighbourhood, aggregated, retail, peer-to-peer market of energy products and services (flexibility, ancillary services, electricity, gas and heating/cooling).
Detailed analyses and studies will be conducted of new services which could arise in conjunction with the new aspects introduced by the Clean Energy for All Europeans Package. Standard pan-European ICT platforms will be defined to allow the interaction of the different actors in the process of acquisition of both local and cross-border ancillary services. Customers segmentation and clustering will be carefully analysed, in order to fully unlock the peer-to-peer transactions for energy and flexibilities.
Providing a reference implementation and architecture will facilitate the digitalization process for all operators. A standard solution will dramatically facilitate the implementation of innovative services for customer involvement.
The market design will be developed allowing flexible coordination between TSO and DSO, considering physical grid constraints, ancillary services and uncertainties, at the same time addressing the social welfare for the customers and energy communities. Market design will be extended beyond the electricity sector, and contribute to integration of heating/cooling, thermal storage and batteries, including those of Electric vehicles.
Targeting unhindered electricity market access of coupled sectors and technologies will benefit the liquidity of markets. With about half of EU final energy demand consumed by heating and cooling, and with increased electrification of this sector, the potential market integration in terms of MWh and MW is considerable. In EU households, heating and hot water account for 2.2 PWh/a. In industry, 2.3 PWh/a is used for space and industrial process heating.
Extensive demonstration activities are deemed necessary, especially for higher TRL. Among the issues to be covered, it is worth to include cooperation strategies for TSOs/DSOs to support cross-border AD-based service provisions, innovative market rules and mechanisms for provision of ancillary services by RES, CO2-neutral thermal generation, virtual power plants and storage systems, integration and proper valorisation of ancillary services provided by EVs and their smart charging, system services brought by gas, heating/cooling and water network operators.

Description of RD&I or Programming Activities:

1. Pan-European market design to foster the integration of large scale RES, storage, demand response, EVs, etc. in coordination with network operation taking into account uncertainties of production and demand.
2. Market design for TSOs with cross-border coordination that involve multiple DSOs and aggregators and multi-operation zones. Market design for cross-border ancillary services (including joint procurement of reserves, sharing of reserves, fast ramping services for frequency response, inertia response, reactive power, voltage control and power flow control).
3. Market rules and coordination mechanisms for provision of ancillary services by aggregated storage and virtual power plants, comprising RES, flexible thermal generation (small and micro-CHP), heat-pumps, EVs, etc.
4. Market design and cost benefit analysis for the provision of ancillary services between DSOs and TSOs through coordinated communications, coordinated smart metering and platforms, and considering physical grid constraints.
5. Design of local markets and their interaction to central markets. Retail (peer-to-peer) markets for Local Energy Communities with power balancing and coordinated LV/MV technical grid control.
6. Market design for large-scale demand response, beyond electricity. Market models expressing the price-sensitive nature of loads obtained by smart metering and metrology methods.
7. Market design for storage owners and operators, including of EV. Market design for thermal storage in electricity and heating markets.
8. Market rules for the provision of system services (balancing) by gas networks in case of low (or negative) residual loads when producing and storing chemical energy.
9. Market design for system services (balancing) by water cycle management operators.

Joint activities:
• A4-IA0-1:
  ○ JI -1: A joint COST or Coordination & Support activity within the H2020 program;
  ○ JI -2: A joint light house (or research infrastructure) project for an HPCC dedicated to the energy domain;
  ○ JI - 3: Government to Government information exchange;
  ○ JI -4: Workshops on GIS interfaces
  ○ JI - 5: Transnational calls
  ○ Further collaboration ideas (bilateral actions etc…)
• A4-IA0-3:
  ○ JI-1 Transnational Calls
  ○ Further collaboration (Promotion of forum for discussion taking into account all relevant stakeholders: Network operators, market operators, retailers and aggregators, generators, equipment manufacturers, ICT solution providers, regulatory bodies, R&D institutes, end-user associations, organisation promoting standard.)
• A4-IA1.2-1:
  ○ JI-1: Align national R&I programs to include the above activities
  ○ JI-2: Share results and best practices
  ○ JI-3: National, transnational and European calls for RD&I projects on the above given topics
• A4-IA1.2-2:
  ○ JI-1 National, Transnational and European Calls for RD&I projects on the above given topics.
• A4-IA1.2-3:
  ○ JI-1: National, Transnational and European Calls for RD&I projects on the above given topics.
• A4-IA1.3-1:
  ○ JI-1: Align national, transnational and international RD&I programmes
  ○ JI-2: Share results and best practices
  ○ JI-3: National, Transnational and European calls for RD&I projects on the above given topics.
• A4-IA1.4-1:
  ○ JI-1: Align national, transnational and international RD&I programmes
  ○ 2: Share results and best practices
  ○ JI-3: National, Transnational and European calls for RD&I projects on the above given topics.

Impact of the RD&I Activities:
• ***Short-term impact***:
  ○ Enabled new market roles, market participants and energy communities
  ○ Enabled flexibility markets by from increasingly more variable RES, storage and conversion using hybridization of technologies and better forecasting tools
  ○ Enabled residential DR (Demand Response)
  ○ Freedom of choice for prosumers (selecting its own preferred energy suppliers, flexibility providers, aggregators)
 	
• ***Long-term impact:***
  ○ Enabled new market roles, market participants and energy communities
  ○ Enabled flexibility markets by from increasingly more variable RES, storage and conversion using hybridization of technologies and better forecasting tools
  ○ Enabled residential DR (Demand Response)
  ○ Freedom of choice for prosumers (selecting its own preferred energy suppliers, flexibility providers, aggregators)

TRL: 3-5 / 6-8

Expected deliverables: tbd	**Timeline:** tbd

5.6 *Protocols, standardisation and interoperability (IEC, CIM, Information models)*

Implementation Plan - Activity Fiche 6 – Flagship 1

Innovation Target:
• Croscutting activities.
• Increase observability and controllability
  ○ A4-T1.1.-1: Develop and implement solutions to increase observability and controllability in the energy system
• Flexibility of all types of generation
  ○ A4-T1.1.-3: Develop and implement solutions to increase flexibility of all types of generation.

Title: Protocols, standardisation and interoperability (IEC, CIM, Information models)
References to ETIP SNET Implementation Plan 2021-2024: RA 3 - Topic 3.1 Reference to the IWG4 Implementation Plan 2018 Innovation fiches: A4-IA0-1; A4-IA0-5; A4-IA1.1-1; A4-IA1.1-2; A4-IA1.3-1;
Challenge: Standardisation comprises the establishment of minimum performances for digital equipment and defines a set of rules (e.g. protocols and data models) governing how computer programs, hardware components, etc. interact and exchange information and data for the purposes of the integrated energy system. Standardization helps devices and systems to interact, using adequate language codes, and to become marketable (ensuring a common base for performances and communication rules) and provide a foundation for certification systems, promoting international trade of uniform high-quality products, thus supporting transfer of expertise from traditional energy systems. Interoperability is needed for integrated energy systems so that products or systems can cooperate with other products or systems to share resources. The present standardisation and interoperability of digital technologies are not yet able to be the overarching enablers for the functioning of a decarbonized energy system. Stable common modular approaches and standards ensuring the needed data and information flow along the energy system value chain are not yet established and their development represents a key challenge. Equipment and systems used in different European countries and regions and made by different equipment producers are not yet fully interoperable. Providing flexibility within the system accommodating disruptive innovations and addressing the different configurations and layers of the SGAM frameworks requires standards and semantics to be interpreted and managed by Artificial Intelligence, to leverage the potential of these advanced applications. R&I is needed for the adequate functioning of fully digitalised solutions implemented by network operators, flexibility providers, storage (such as batteries, hot water tanks, cooling systems, storage for CO_2-neutral or free gases and liquids), DER, RES, PV, EV with Smart Charging and V2G services and market operators. There is an urgent need for recommendations regarding communications protocols within the energy network, e.g., the IEC 61850 standard series, IEC 61970 (CIM) standard series, IEC 61968 (CIM) standard series, IEC 62324 (CIM), IEC 61400-24 standard series, ISO/IEC 9594 standard series, ITU-T X500 standard series. There is a strong need for standardisation of encrypted and authenticated market processes considering on different timescales for improved reliability (blockchain) to enhance DSO and TSO information exchange with DER, enabled for third party owned PV and storage from different manufacturers and using different technologies. There is also a strong need for standardisation on physical and cyber security. **Scope:**

This ACTIVITY FICHE will include, as a basis for further work, comprehensive studies about standardised interfaces of energy operators and users, bulk and aggregated renewable power plants and flexible loads, electric vehicles charging infrastructures and of energy IoT devices. R&I is needed to establish guidelines on interoperability and cyber protection of the grids and assets and their interfaces, and to consider the digital applications enabling markets and user participation. Gaps must be identified to unlock technology applications in view of facilitating data exchange among players of the energy sector (System Operators, market parties and end users). ETSI activities around Common Information Model will be explored.
Widely recognised international standards from energy sector committees will be developed to ensure interoperability of IoT devices. Dedicated demonstrations will be set to implement standardised interfaces among all energy operators and the bulk and aggregated renewable power plants, the electric vehicles charging infrastructures, the final users and their smart home and smart building appliances. Demonstrations will also consider the standardisation and interoperability for advanced market platforms: for example the energy data hubs and tele-control platforms interconnecting Balancing Service Providers-TSO-DSO-SGU (Significant Grid User) infrastructures, the new market platforms with energy management systems etc. Communication and security standards will be developed in the European Network Codes, while interoperability will be ensured between TSO-owned digital assets integrated with public telecommunication services. CIM will be applied for cross-border and cross-sector data exchanges, evaluating the benefits of semantic interoperability.

Description of RD&I or Programming Activities:

1. Data exchange protocols / interfaces for a well-functioning market between all players. Protocols for stochastic model-based handling of market operations on different timescales. Common, standardised models for encrypted and authenticated market orders.
2. Standardized communication protocols and ICT infrastructure between devices and networks and also between devices and remote management platforms to meet requirements of network operators, retailers and aggregators. Interoperability for devices and actors of the integrated energy system (e.g. prosumers, connected buildings, DSO, storage, RES, PV, EV) etc.
3. Communication interfaces of smart substations, especially on LV secondary substation level (interfaces for internal substation components and between substation with upper level and information systems, like EMS, SCADAS, legacy systems, etc.).
4. Universal device interfaces and protocols to enable DSO and TSO information exchanges. Data interfaces for utility business models and decision-making support functions.

Joint activities:

- A4-IA0-1:
  - JI -1: A joint COST or Coordination & Support activity within the H2020 program;
  - JI -2: A joint light house (or research infrastructure) project for an HPCC dedicated to the energy domain;
  - JI - 3: Government to Government information exchange;
  - JI -4: Workshops on GIS interfaces
  - JI - 5: Transnational calls
  - Further collaboration ideas (bilateral actions…)
- A4-IA0-5:
  - JI-1: Setup a joint transnational structure for a European organisation 'IES Europe'
  - JI-2: Align national, transnational and international activities and funding schemes on interoperability
  - Further Collaboration ideas: Share results on a knowledge sharing platform i.e. Expera and in the framework of national stakeholder meetings, e.g. at ETIP SNET National Stakeholder Coordination Group meetings
- A4-IA1.1-1:
  - JI-1: Align national, transnational and international RD&I programmes
  - JI-2: Share results and best practices

- JI-3: Further collaboration ideas
- A4-IA1.1-2
  - JI-1: Align national, transnational and international RD&I programmes
  - JI-2: Share results and best practices
  - JI-3: Further collaboration ideas
- A4-IA1.3-1:
  - JI-1: Align national, transnational and international RD&I programmes
  - JI-2: Share results and best practices
  - JI-3: National, Transnational and European calls for RD&I projects on the above given topics.

Impact of the RD&I Activities:

- ***Short-term impact:***
  - Enabled efficient functioning of energy markets at local and European levels, in view of delivering the adequate quality of services.
  - Higher degree of interoperability among players and (cyber) security at an EU level, enabling new Digital Use Cases and Services supporting the energy transition.
  - Increased availability of validating laboratory environments of the Quality of Service (QoS) for communication and security protocols for energy applications.
  - More Open-Source advanced market platforms.

- ***Long-term impact:***
  - System-wide implementation of standardized and interoperable energy services and business models.
  - Fostered participation of new players (SMEs) in the energy markets by easy use of standards and interoperability.
  - Fully interoperable energy data hubs and tele-control platforms interconnecting Balancing Service Providers-TSO-DSO-SGU (Significant Grid User) infrastructures based on communication and security international standards validated in pilot projects.
  - Full application of communication and security standards in the implementation of European Network Codes.
  - Full interoperability between new market platforms with energy management systems.

TRL: 3-5

Expected deliverables: tbd	**Timeline:** tbd

5.7 Data Communication (ICT) (Data acquisition, Smart Meter, Sensors (monitoring), AMR, AMM, smart devices)

Implementation Plan - Activity Fiche 7 – Flagship 1

Innovation Target:

- Crosscutting activities.
- Increase observability and controllability
  - A4-T1.1.-1: Develop and implement solutions to increase observability and controllability in the energy system.
- Flexibility of all types of generation
  - A4-T1.1.-3: Develop and implement solutions to increase flexibility of all types of generation

Title: Data Communication (ICT) (Data acquisition, Smart Meter, Sensors (monitoring), AMR, AMM, smart devices)

References to ETIP SNET Implementation Plan 2021-2024: RA 3 - Topic 3.2
Reference to the IWG4 Implementation Plan 2018 Innovation fiches: A4-IA0-1; A4-IA1.1-1; A4-IA1.1-2; A4-IA1.3-1;

Challenge:

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

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

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

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

Scope:

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

IoT devices will be developed for system operation and for conditional and risk-based maintenance, enabling advanced solutions for the increasing complexity of system development and operations. Demonstrations will be implemented and include advanced features for the integrated Energy system such as for ICT infrastructure leveraging 5G, by use of the smart meters and the communication structure for AMM, by use of Smart meters for accessing its data directly by multiple actors, while preserving GDPR and contractual clauses. The resilience of infrastructure and operation management systems will be investigated including resilient digital (communication) components, thereby considering data communication needs to handle anomalies. The adaptation of grid operation concepts to the new

communication and digital environment using secure and broadband data exchange will be demonstrated as well as the provision of proof of concept of innovative human machine interfaces for system operation, and of AI technologies to estimate indicators and completion of information to operate the system. The development of tools and architectures to manage, large amount of data (also in real time) for mass data communication and processing (Blockchain, Exchange Platforms) including the Integration of sensors and actuators will be validated. Cost-effective data gateways for RES integration, reliability of "sub-meters" to be usable for different business processes and billing and enhancement of resilience of the ICT architecture (electrical black-out) to ensure the continuity of grid operation services will be included in the demonstrations.
Description of RD&I or Programming Activities: 1. Communication infrastructures to support demand aggregation and control. M2M or Artificial Intelligence to Artificial Intelligence, telecommunication solutions for services required by the energy grid (including AI algorithms for decision-making in device, MEC or cloud level). 2. ICT infrastructure for monitoring and control of distributed generation, e.g. PV systems, including standards and protocols. 3. Communication infrastructures for smart meter data for close to real-time monitoring in critical zones at critical moments (including non-GNSS (Global Navigation Satellite System) systems for time synchronisation and timestamping, consideration of latency, loss of packets, and jitter in end-to-end communications.) 4. Optimise installation of ICT infrastructure, including costs, accuracy, redundancy, etc. for data collection and processing used for conditional and risk-based maintenance.
Joint activities: • A4-IA0-1: o JI -1: A joint COST or Coordination & Support activity within the H2020 program; o JI -2: A joint light house (or research infrastructure) project for an HPCC dedicated to the energy domain; o JI - 3: Government to Government information exchange; o JI -4: Workshops on GIS interfaces o JI - 5: Transnational calls o Further collaboration ideas (bilateral actions…) • A4-IA1.1-1: o JI-1: Align national, transnational and international RD&I programmes o JI-2: Share results and best practices o JI-3: Further collaboration ideas • A4-IA1.1-2 o JI-1: Align national, transnational and international RD&I programmes o JI-2: Share results and best practices o JI-3: Further collaboration ideas • A4-IA1.3-1: o JI-1: Align national, transnational and international RD&I programmes o JI-2: Share results and best practices o JI-3: National, Transnational and European calls for RD&I projects on the above given topics.
Impact of the RD&I Activities: • Short-term impact: o ICT is more and more security integrated into upgraded energy systems, particularly in distribution systems. • Long-term impact: o Seamless integration of all types of variable resources into the system adequately managed through digitalisation along the entire value chain.

TRL: 3-5 / 6-8	
Expected deliverables	Timeline

5.8 *Data and Information Management (Platforms, Big Data, Software, IoT)*

Implementation Plan - Activity Fiche 8 – Flagship 1
Innovation Target: • Increase observability and controllability o A4-T1.1.-1: Develop and implement solutions to increase observability and controllability in the energy system
Title: Data and Information Management (Platforms, Big Data, Software, IoT)
References to ETIP SNET Implementation Plan 2021-2024: RA 3 - Topic 3.3 Reference to the IWG4 Implementation Plan 2018 Innovation fiches: A4-IA1.1-2;
Challenge: Data and information management platforms need to connect to the cloud and remotely access energy-system and user-related devices (sensors, controllers, etc.). Due to the expected masses of such devices, IoT platforms must provide seamless integration of various hardware through interfaces, communication protocols, network topologies, as well as data storage, processing and data mining. At present, there is a lack for integrating new, not yet proven IoT technology in society-critical TSO and DSO activities, for merging and managing big data coming from different sources (e.g. by applying standards, interoperability) and for ensuring the proper integration of different platforms into the energy technical and value chain. There is a strong need to manage big data from different sources which include planning tools, management tools, market platforms, smart-meters, social medias, etc. (infrastructures or tools). This management includes needs to apply data analytics, applications of artificial intelligence, digital twins, etc. TSO and DSO need to understand the implications of applying massive IoT in their activities including both benefits and risks. R&I must contribute to use IoT in TSO and DSO planning, asset management and operational activities and interfaces to market activities. **Scope:** This ACTIVITY FICHE will provide a consolidated ICT vision and strategy for common data acquisition processes for TSO-TSO, TSO-DSO, TSO-BSP (Balancing Service Provider) and TSO-SGU (Significant Grid User) data exchange; identify business opportunities, capturing aggregation and analysis of the operational data collected by distributed systems; identify digital issues and market opportunities related to big data and IoT and the energy system; and leverage the potential of IoT, digital technologies and solution and advanced data management for all users. There is probably no need for a common data acquisition strategy, however the interoperability of data and architectures has to be ensured. Data sets need to be identfied. The main goal is to ensure that the flexibility is used at local level to solve local requirements (congestion) but also at pan European level through flexibility platforms for balancing purposes and for having more liquidity in the market. Software, algorithms and tools will be developed for the security of data collection and digital applications across the energy sectors; for data flexibility management (data mining, control, aggregation, trading, integration into system planning, etc.); for data communication; for platform integration in the energy system; for providing an easy access to data for all citizens and stakeholders; for exploring the benefits, etc of data hubs in the system operation and for cross-border and cross-sector data exchanges. Specific demonstrations will be implemented to validate: advanced features for the integrated Energy

system; best practices to scale up individual TSOs flexibility platforms; case studies dealing with common Data hub and Grid hub architectures; implementation of a framework of data exchange between Data Hubs, Grid hubs and other platforms; the operation of a pan-European data hub interconnecting all TSOs and across market players (customers, generators, DSOs, etc.); the massive Big data, IoT, IIoT and interface technologies, enabling full functioning of the system and for enhanced grid operation and planning; platforms and architectures for cross-sector data exchange; cross-border exchange of private data and the wide use of ontologies. To validate efficient data and information management mechanisms for platforms integration in the energy system, from consumer related platforms to system operation platforms including community platforms, provenance platforms, and access platforms.
Description of RD&I or Programming Activities: 1. Big data management from different sources: smart-meters, smart-sensors, social media for their use in planning tools, management tools, market platforms, data-driven tools supported by data analytics, artificial intelligence, and the development of digital twins. 2. Investigate the use of IoT technologies in TSO and DSO planning, asset management, operational and market activities.

Joint activities:
• A4-IA1.1-2
  o JI-1: Align national, transnational and international RD&I programmes
  o JI-2: Share results and best practices
  o JI-3: Further collaboration ideas

Impact of the RD&I Activities:
• Short-term impact:
  o Lower cost-based, monitoring and control of a massive number of devices relevant for the integrated energy system
 	
• Long-term impact:
  o Fully and efficiently managed complexity of IoT data coming from a variety of streamlined, partially disorganised sources

TRL: 3-5

Expected deliverables: tbd	**Timeline:** tbd

5.9 Cybersecurity (vulnerabilities, failures, risks) and privacy

Implementation Plan - Activity Fiche 9 – Flagship 1
Innovation Target: • Croscutting activities.
Title: Cybersecurity (vulnerabilities, failures, risks) and privacy
References to ETIP SNET Implementation Plan 2021-2024: RA 3 - Topic 3.4 Reference to the IWG4 Implementation Plan 2018 Innovation fiches: A4-IA0-1; A4-IA0-2;
Challenge: It is paramount important to define main cyber threats and implement applicable cybersecurity frameworks in the European energy system. For this to happen, energy-focused risks and associated regulatory needs with cost impact must be deeply understood. Today, there is a lack of an integrated solution for physical and cyber requirements for the integrated energy and communication networks between grid operators, market participants including small prosumers which also require full privacy. There is a lack of cybersecure application of digitised solutions which can support the coordination needs for system operators, the increased use decentralised energy

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

Scope:
This ACTIVITY FICHE will provide support tools (such as recommendations, guidelines, certifications) to improve practices in cybersecurity (vulnerabilities, failures, risks) and data privacy management.
Tools must be developed for future Security Operation Centres (SOCs) allowing cyber threats detection and response, with anticipative and proactive strategies. Data analytics and deep learning should benefit from the development of new tools for predictive and automated maintenance of TSO's grid assets, and the automation of their data validation processes. Tools will be developed to ensure full consistency between data privacy compliance and cyber-physical security practices.
Demonstrations will be done related to dedicated strategies for enhanced cyber security and resilience at DSO and TSO level, including TSO/DSO security data sharing; related to authentication processes for multiple usages, from market mechanisms to system protections and with the involvement of various prosumers, data/service platforms complying with data privacy requirements on one side, and physical-cyber security & resilience of systems on the other. The relevance and impacts of integrating technologies such as blockchain, AI, automation or data analytics for security and maintenance purposes will be assessed in detail and be demonstrated for system development, operation and asset management.

Description of RD&I or Programming Activities:

1. Methods and tools for cyber security protection of grid infrastructures to avoid injection of false data through physical installations, like primary and secondary substations, MV and LV lines, Cybersecurity strategies for TSOs and DSOs.
2. Data protection for management of distributed energy resources, including decentralized storage.
3. Risk and vulnerabilities for parallel use of legacy SCADA systems (as a traditional means to provide remote supervisory and control).
4. Risks and vulnerabilities of using public ICT and wireless infrastructures for smart grid functionalities, e.g. connection with smart meters and energy boxes

Joint activities:

- A4-IA0-1:
  - JI -1: A joint COST or Coordination & Support activity within the H2020 program;
  - JI -2: A joint light house (or research infrastructure) project for an HPCC dedicated to the energy domain;
  - JI - 3: Government to Government information exchange;
  - JI -4: Workshops on GIS interfaces
  - JI - 5: Transnational calls
  - Further collaboration ideas (bilateral actions…)
- A4-IA0-2:
  - n/a

Impact of the RD&I Activities:
• ***Short-term impact:***
  ○ Preventing damages for energy system related businesses by a lack of focus on cyber security
  ○ Minimising the direct economic cost of cyber attacks to the business, including for theft of corporate information, disruption to trading or having to repair affected systems all resulting in financial loss
 	
• ***Long-term impact:***
  ○ By design, fully cyber-secure ICT systems enabling fully integrated energy systems.

TRL: 3-5	
Expected deliverables: tbd	**Timeline:** tbd

5.10 End-to-End Architecture (integrating market, automation, control, data acquisition, digital twin, end-users)

Implementation Plan - Activity Fiche 10 – Flagship 1
Innovation Target: • Increase observability and controllability   ○ A4-T1.1.-1: Develop and implement solutions to increase observability and controllability in the energy system
Title: End-to-End Architecture (integrating market, automation, control, data acquisition, digital twin, end-users)
References to ETIP SNET Implementation Plan 2021-2024: RA 3 - Topic 3.5 Reference to the IWG4 Implementation Plan 2018 Innovation fiches: A4-IA1.1-2
Challenge: Digital twins transform the way companies perform predictive maintenance of technologies and assets in the energy systems. Embedded sensors feed performance data into a digital twin in real time, making it possible not only to identify and address malfunctions before they happen but to tailor market services to better meet unique prosumer needs. Digital twins may be able to control and steer automated processes of the integrated energy system with less or even without human intervention. Integrated end-to-end architecture of digital twins will enable the integrated energy system to evolve on its own, for example by making predictions more accurate and enabling coordinated control of the massive number of devices. The present solution does not yet providing a single unified architecture for Telecommunication and Control for various IEC and CIM standards. There is a lack of bringing together grid data storage and computing on new architectural schemes. MV and LV remote monitoring and control architectures are not yet fully automated in an integrated way. There is a lack of multi-agent systems for the management of LV/MV networks with large amounts of RES. Cyber physical systems concepts and tools from other industrial sectors are not yet applied and adapted to energy systems. There is a need to increase the level of robustness of the future LV/MV grids and systems infrastructures by creation of digital twins of interoperating grid and communication networks among other to resolve performance problems and recovery from abnormal events. An enhanced architecture design for data exchange at the different system voltage levels, in different time frames with enhanced TSO/DSO communication interfaces is needed. There is urgency to demonstrate LV and MV telecommunication and control architectures including information models and their conformance to IEC 61850, IEC 61970, IEC 61968, IEC 62324, and CIM standards to support integration. Advanced ICT-based approaches for both grid data storage and computing on new architectural schemes must be demonstrated. There is a need to analyse middleware layers (with multi-agent systems) as a possible alternative for the management of

LV/MV networks hosting large shares of renewables (including storage such as batteries, hot water tanks, for CO2-neutral or free gases and liquids). New concepts for distributed online analytical data streaming and processing must be investigated. There is a need for pre-integrated architectures, open source frameworks and tools from other industrial sectors which also apply cyber physical systems concepts, methods and tools to energy systems.

Scope:

This ACTIVITY FICHE will include principles for integrated communication design and architectures allowing data exchange between distribution and transmission levels. Sharable support tools (software, guidelines, trainings) will be developed for the upskilling of competences in view of improving the robustness, cybersecurity and resilience of systems. Risk management tools will be developed to assess and mitigate hazards on cyber-power systems.

Specific demonstrators will address operational end-to-end architectures and digital twins of interoperating grid and communication networks. Demonstration activities will also target the real-life market implementation of different types of flexibilities (loads, DER, storage like batteries, hot water tanks, cooling systems, for CO2-neutral or free gases and liquids) down to the household level. Tools for an integrated approach to cyber risk management and cyber resilience will also be demonstrated. TSOs must demonstrate new practices in digital assets' management, leading to clear improvements in their operational processes, and increased participation of customers.

By digital management of assets, utilities can postpone or avoid new investments making better use of existing assets. They can better organize predictive maintenance increasing the reliability of operation and drastically reducing costs. Predictive maintenance can reduce maintenance related costs up to 50% and extend asset life by up to 60%.

Description of RD&I or Programming Activities:

1. Digitalization of distribution and transmission networks. Creation of a digital twin of interoperating grid and communication networks to resolve performance problems and recovery from abnormal events.
2. Enhanced architecture design for data exchange at different system voltage levels, at different time frames with enhanced TSO/DSO communication interfaces.
3. Application of advanced ICT-based approaches (IoT, edge computing, cloud computing, cyber-security, blockchain, etc) for data storage and computing on new (Hardware & Software) architectural schemes.

Joint activities:

- A4-IA1.1-2
  - JI-1: Align national, transnational and international RD&I programmes
  - JI-2: Share results and best practices
  - JI-3: Further collaboration ideas

Impact of the RD&I Activities:

- ***Short-term impact:***
  - Fostered active System Management
  - Fostered real time monitoring
  - Facilitated participation from players of the energy sector
  - Facilitated involvement and increased confidence of the end user
  - Higher flexibility investments for business in electricity sector to other energy vectors and their networks and businesses.
  - allowing new service portfolio for the whole energy system beyond electricity

- ***Long-term impact:***
  - Seamless integration of all types of variable resources into the system adequately managed through market mechanisms and adequate tools and business processes
  - Fully standardized flexibility products and services
  - Fully deployed market architecture for EU-wide sector coupling

TRL: 3-5 / 6-8	
Expected deliverables: tbd	**Timeline:** tbd

5.11 *Integrated Energy system Architectures (design including new materials and hybrid AC/DC grids)*

Implementation Plan - Activity Fiche 11 – Flagship 1

Innovation Target:

- Manage the load profile by demand response and control,
  - A4-T1.1.-2: Develop and implement solutions and tools to manage the load profile by demand response and control, in order to optimise use of the grid and defer grid investments.
- Flexibility of all types of generation
  - A4-T1.1.-3: Develop and implement solutions to increase flexibility of all types of generation
  - A4-T1.1.-3.2: Develop and implement solutions to improve the flexibility capabilities for new as well as retrofitted thermal power plants

Title: Integrated Energy system Architectures (design including new materials and hybrid AC/DC grids)

References to ETIP SNET Implementation Plan 2021-2024: RA 4 - Topic 4.1
Reference to the IWG4 Implementation Plan 2018 Innovation fiches: A4-IA1.2-1; A4-IA1.3-2; A4-IA1.3-5;

Challenge:
To enable the integration of renewable energy sources at the penetration rate considered in the fully decarbonised scenarios and to satisfy the energy demand with renewable sources also during winter the electricity system cannot evolve in isolation. Integrated Energy Systems overcoming the silos among energy vectors need to be developed. New architectures encompassing the entire energy system will be needed addressing and optimising the synergies among all energy vectors (i.e. electricity, gas, heating/cooling, mobility, Hydrogen etc.). Specific technologies to enable the implementation of the architectures will be needed, enhancing the system performances, increasing its sustainability and leveraging subsidiarity and circularity.
Today, energy system architectures are not yet based on coherent and convergent approaches, which facilitate all processes necessary for a reliable, economic and environmentally friendly operation of smart integrated energy systems.
Approaches, tools and technologies are needed to plan, analyse and operate the integrated energy system under all scenarios: from scenario setting based on reliable and transparent hypotheses, parameters and relations, to integrated and complete planning tools, addressing holistically an energy system where all vectors interact and foster one another and the development and validation of technologies and solutions that help increasing system performances, environmental friendliness (increased efficiency, reduced footprint, circularity), thus leveraging subsidiarity (for example through energy communities/web of cells).

Scope:
This ACTIVITY FICHE addresses the selection and design of optimal system architectures and key innovative technologies of the integrated energy system covering the different energy vectors, thus overcoming the silos approach and meeting the requirements of efficiency, sustainability and subsidiarity.
The research activities included in this topic will start from definition and evolution of unified architectures for the integrated energy system, considering better and more advanced planning techniques (probabilistic approaches, dynamic optimisation, integration of Cost Benefits Analysis with Life Cycle Assessment of investments and components). Key components, solutions and technologies to improve system efficiency and sustainability will be developed, assessed, validated and demonstrated such as smart transformers, energy routers, web of cells, interoperable HVDC converters ("plug-and-play"), HVDC grids with multi-terminal and protection, digital equipment for metering, adaptation of conventional equipment to the

digital operation (merging units) etc. Innovative materials will also be developed and tested to increase performances and sustainability such as alternative gases to SF6 for HV and UHV systems, esters to replace mineral oil in power transformers, composite core conductors, superconductors for fault limiters and links.

In addition to the ETIP SNET implementation plan, reference is made here to the important role of massive thermal storage, as an important to foster to limit curtailments of RES power.

Description of RD&I or Programming Activities:

1. Model of the energy system including all major energy carriers, encompassing the whole energy chain from prosumers, energy communities, e-transportation, distribution and transmission grids (LV, MV, HV), national and regional electrical and gas exchange, with clear boundary interaction.
2. Coordinated HV (including Ultra-HV) and MV distribution systems. Electricity transmission systems with storage infrastructure and using gas and heat infrastructures. Resilience oriented sizing and spatial positioning of assets, in order to withstand the impact of extreme weather and grid events.
3. Citizen energy communities, with energy management systems for local multi-energy streams operation, including electrical-storage, P2x generation and storage, and x2P (including CHP based on hydrogen and fuel-cells).
4. Multicarrier hybrid storage systems, including their economic benefits in comparison to single storage units, their application to Power2Heat for balancing and storage, dynamic interaction between heat and electricity, their application at building level, dynamics of the coupled energy system considering the inertia of thermal loads (electricity-heating-buildings).
5. Optimally located, sized and coordinated electric energy storage at different voltage levels in the power system (for fast and slow power response; for future ancillary supplementary services in the storage facility such as inertia support).
6. Optimally located, sized and coordinated hydro, gas and chemical thermal and chemical storage for seasonal needs.
7. Web-of-Cells, decentralised, modular control architectures for real-time voltage and frequency control (including AC, AC/DC hybrid and DC microgrids, local storage, smart transformers) utilizing flexibility from all energy carrier systems.
8. Integrated electricity AC and DC distribution networks including large-scale electrification of heating, domestic and commercial heat pumps, EV charging stations, etc. DC and hybrid AC/DC networks connected to AC through FACDS (Flexible Alternating Current Distribution System), Smart transformers, MV/LV DC, etc. AC, AC/DC hybrid and DC microgrids and local storage for providing locally flexibility.
9. HVDC meshed grids. Optimization algorithms for HVDC grids design based on different optimization criteria (n-1 reliability criterion, loss of infeed risks, economic criteria, etc.) and parallel routing of DC and AC lines on the same tower or parallel paths to utilise existing infrastructure paths.

Joint activities:

- A4-IA1.2-1
  - JI-1: Align national R&I programs to include the above activities
  - JI-2: Share results and best practices
  - JI-3: National, transnational and European calls for RD&I projects on the above given topics
- A4-IA1.3-2
  - JI-1: Align national, transnational and international RD&I programmes
  - JI-2: Share results and best practices
  - JI-3: National, Transnational and European calls for RD&I projects on the above given topics.
- A4-IA1.3-5
  - JA-1: Integration of Storage and vRES
  - JA- 2: integration of different Storage technologies

Impact of the RD&I Activities:
• ***Short-term impact:***
  ○ Improved system performance by increasing stability, predictability and controllability based on higher observability.
  ○ Enhanced system controllability and stability, thus enabling the integration of higher shares of non-synchronous renewable generation
  ○ Increased resilience in case of natural disasters
  ○ More secure frequency (balancing) and voltage control in the future power system.
  ○ Better use of network capacities
  ○ Demonstrated innovative solutions to counteract the decrease of short circuit current and increased voltage/frequency interactions resulting from the increased penetration of PE-connected generation
  ○ Deployed power electronics based “synthetic inertia” services with positive impact on stability, assessed at system level.
  ○ Deployed holistic architectures which include hybrid AC/DC systems, smart transformers, energy routers and web of cells
  ○ Applied techniques to detect cascading mechanisms possibly triggered by multiple contingencies or interarea oscillations.
  ○ Proven wide area defense systems aimed to limit the extension and consequences of disturbances, also resorting to islanding, reconnection and grid formation capabilities by power electronics connected generators.
 	
• ***Long-term impact:***
  ○ Fully integrated energy system services: full DER integration, regionally beyond 100% demand.
  ○ Tested and proven mature technological solutions for the provision of large-scale controllability and flexibility on both TSO and DSO voltage levels.
  ○ Grid resilience by design.
  ○ Minimized stranded assets and infrastructure with cost savings.
  ○ Assessed impact of network controllability (achieved by methods and tools for optimal and coordinated use of flexibility resources) on the global social welfare and ancillary services sharing.

TRL: 3-5 / 6-8

Expected deliverables: tbd	**Timeline:** tbd

5.12 Long-Term Planning (System Development)

Implementation Plan - Activity Fiche 12 – Flagship 1

Innovation Target:
• Croscutting activities
• Increase observability and controllability
  ○ A4-T1.1.-1: Develop and implement solutions to increase observability and controllability in the energy system
• Manage the load profile by demand response and control
  ○ A4-T1.1.-2: Develop and implement solutions and tools to manage the load profile by demand response and control, in order to optimise use of the grid and defer grid investments.
• Flexibility of all types of generation
  ○ A4-T1.1.-3: Develop and implement solutions to increase flexibility of all types of generation
  ○ A4-T1.1.-3.2: Develop and implement solutions to improve the flexibility capabilities for new as

well as retrofitted thermal power plants

- Reduce the cost of all energy storage solutions
    - A4-T1.4.-1: Reduce the cost of all energy storage solutions contributing to the minimisation of the overall system costs

Title: Long-Term Planning (System Development)

References to ETIP SNET Implementation Plan 2021-2024: RA 4 - Topic 4.2
Reference to the IWG4 Implementation Plan 2018 Innovation fiches: A4-IA0-1; A4-IA1.1-2; A4-IA1.2-1; A4-IA1.2-2; A4-IA1.3-2; A4-IA1.3-5; A4-IA1.4-2;

Challenge:

Planning the energy system towards a deep integration of renewables, while leveraging all flexibility sources will be a key driver in the process of the decarbonisation. Planning is multifaceted and implies policy strategies, regulatory frameworks, probabilistic analyses considering the variable RES and DER. Planning leverages demand response, storage (such as by batteries or hydro reservoirs) and the interface with other energy and transport/mobility networks and spans through the evolution of known methodologies, considering energy as well as power needs, and the duration and availability of DSR and storage assets.

Although planning methodologies are rapidly evolving to take into consideration the different types of resources (RES, DER) and the possible flexibilities (generation, network, demand, storage such as batteries), the approach from the energy vectors point of view still remains essentially deterministic and each energy carrier is dealt with separately, thus missing potential synergies. Combined and fully integrated planning of electricity-gas-heating/cooling and mobility are not yet available for the stakeholders.

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

Scope:

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

The research activities included in this topic will leverage scenario analysis developed in an integrated way spanning across the energy systems, in particular heat and transport, considering environmental, social and economic aspects and the impacts on the grid of high RES share penetration, electrification of heat and transport sectors, evolution of load profiles and hybridization of systems. Planning tools will be developed for modern system requirements (increased variability, flexibility needs, grid constraints, environmental sustainability, climate change issues), and will include improved CBA (Cost-Benefit-Analysis) as well as CBCA (Cross Border Cost Allocation) for international investments. The tools will be developed so as to coherently integrate environmental aspects (life-cycle assessment, air quality, visual and noise constraints) into the grid planning procedures.

Any full life cycle cost and environmental impact optimization of assets starts at the planning stage, where the careful selection of the most adequate materials, components and production methods, - also in consideration of “green” criteria such as expected maintenance frequency, degree of inherent resilience,

asset life duration and feasibility of reuse of materials at life end; will allow to opt for the most sustainable technical solutions. Benefits should be assessed on the basis of full life cycle costs and environmental impacts.
Description of RD&I or Programming Activities: 1. Planning of integrated (coupled) energy systems (heat and cooling, gas, electricity networks with an extension to water -waste and drinking- and public transport networks in urban areas). Planning tools to optimize the development of the electricity networks taking into account energy efficiency policies at the urban/ city but also rural scale (interaction with other energy network, spatial planning). 2. Cost-effective, coordinated investment planning in RES at EU level (covers all time horizons and markets (from investment planning until real-time) and taking into account the effects of alternative market designs and the requirements for infrastructure development. Consider all flexibility means (demand response, energy storage, generation, transmission), including cross-carrier flexibility. 3. Electricity System Planning for resilience, including Grid designs, PV, Wind and Hydropower generation, storage and demand flexibilities against natural disasters (storms, floods, wildfires, etc) and human attacks, resilience oriented operational planning using stochastic approaches including multi-contingencies occurrence 4. DER solutions to handle network constraints in planning. HV, MV and LV network reinforcements and LV, MV grid expansion planning considering the flexibility offered by controlling RES, demand, energy storage, power electronics, etc. (includes the use of data coming from the field (smart meters, monitoring systems at all levels, fault detection). 5. Probabilistic planning including DER stochasticity. RES, demand response, storage, self-consumption, and their uncertainty including for heating and cooling and the demand for mobility. 6. Distribution System planning and asset management to cater for the integration of massive integration of EVs with fast, very fast, and inductive recharge technologies. (short-, medium- and long-term scenarios for the implementation of the adequate charging infrastructures, incl. battery swapping infrastructures. 7. Planning of LV and MV DC industrial and residential grids. Added value of DC grids in integrating DER, incl. lower costs of BoS (Balance of System). Taking care for safety, especially in homes.

Joint activities:
• A4-IA0-1:
  o JI -1: A joint COST or Coordination & Support activity within the H2020 program;
  o JI -2: A joint light house (or research infrastructure) project for an HPCC dedicated to the energy domain;
  o JI - 3: Government to Government information exchange;
  o JI -4: Workshops on GIS interfaces
  o JI - 5: Transnational calls
  o Further collaboration ideas (bilateral actions…)
• A4-IA1.1-2
  o JI-1: Align national, transnational and international RD&I programmes
  o JI-2: Share results and best practices
  o JI-3: Further collaboration ideas
• A4-IA1.2-1
  o JI-1: Align national R&I programs to include the above activities
  o JI-2: Share results and best practices
  o JI-3: National, transnational and European calls for RD&I projects on the above given topics
• A4-IA1.2-2
  o JI-1 National, Transnational and European Calls for RD&I projects on the above given topics.
• A4-IA1.3-2
  o JI-1: Align national, transnational and international RD&I programmes
  o JI-2: Share results and best practices

◦ JI-3: National, Transnational and European calls for RD&I projects on the above given topics. • A4-IA1.3-5 ◦ JA-1: Integration of Storage and vRES ◦ JA- 2: integration of different Storage technologies • A4-IA1.4-2 ◦ JI-1: Align national, transnational and international RD&I programmes ◦ JI-2: Share results and best practices ◦ JI-3: National, Transnational and European calls for RD&I projects on the above given topics.
Impact of the RD&I Activities: • ***Short-term impact:*** ◦ Learning from validation of advanced planning techniques adapted to the energy system transition. ◦ Faster, easier appraisal of the potential of exploiting local flexibility or deploying new local storage facilities and/or as an alternative to build new lines. ◦ Scaled-up experimentation results in real planning procedures of innovative techniques that have proven efficient and robust in pilot projects. • ***Long-term impact:*** ◦ Validated tools and platforms enabling effective sector coupling as tested in large demonstration projects. ◦ Maximal efficiency of costs for upgrading grids while fully guaranteeing security, reliability, market-compatibility and resilience of grid planning and operation. ◦ Consolidated methodology to evaluate the impacts on OPEX and CAPEX connected to the integration of flexibility from storage and other energy sectors.
TRL: 3-5 / 6-8

Expected deliverables: tbd	**Timeline:** tbd

5.13 Asset management and maintenance (maintenance operation, failure detection, asset lifecycles, lifespan and costs, ageing)

Implementation Plan - Activity Fiche 13 – Flagship 1
Innovation Target: • Increase observability and controllability ◦ A4-T1.1.-2: Develop and implement solutions and tools to manage the load profile by demand response and control, in order to optimise use of the grid and defer grid investments.
Title: Asset management and maintenance (maintenance operation, failure detection, asset lifecycles, lifespan and costs, ageing)
References to ETIP SNET Implementation Plan 2021-2024: RA 4 - Topic 4.3 Reference to the IWG4 Implementation Plan 2018 Innovation fiches: A4-IA1.1-2;
Challenge: The power system will be progressively operating under increasing constraints: managing and balancing the system under the extreme variability linked with the integration of renewables will imply higher frequencies of equipment load cycling, temporary overloads, working conditions closer to the design limits. Moreover climate changes impose increasing mechanical, electrical, thermal, environmental stresses to all system components. Asset management approaches must evolve to ensure the level of reliability of the system. Asset management is one of the most important chapters in the operation of the energy system. Identifying critical components deserve a specific attention in view of the overall system availability,

balancing the necessity to minimise the OPEX and fulfilling the requirements of continuity and quality of supply is an important step towards a reliability or a risk-based operation. Selecting the most adequate monitoring and diagnostic quantities to be used in conjunction with well proven degradation and end-of-life mathematical models is the rationale on which to build the asset management policy: this must be complemented by sensors, monitoring systems, ICT, data, information and knowledge management tools (data analytics and big data). Critical assets must be managed based on risk and optimization, to reduce OPEX, while increasing network flexibility and ensuring adequate power quality. Finally, lifetime extension of existing power system components, based on improved monitoring and measurement of their health state and residual lifetime is key to optimise CAPEX.
There is a strong need to develop and validate tools which address the lifecycle management of energy system components. They must span from the study of performance degradation laws to components and systems diagnostics and monitoring. Maintenance approach and residual life evaluation must be addressed at the light of the threats deriving from the radical changes in operation cycles and environmental constraints.

Scope:
This ACTIVITY FICHE addresses the advanced management of assets in the energy system along their entire lifecycle, from the commissioning to the end-of life covering the identification of the degradation phenomena and the indicators of the failure development, the sensors and methods for diagnostic and monitoring, the setting up of maintenance policies and end-of-life decision making at the light of the progressive advancement of data acquisition and management techniques.
The research activities included in this topic aim at cost-efficient and highly effective probabilistic risk-based approaches for increasing system reliability through enhanced equipment maintenance and lifetime extension of existing power components based on improved monitoring, measurements and models to determine their health and remaining lifetime. The topic will consider diffused asset monitoring enabled by distributed sensors (IoT technology) for a real-time view of the status of the grid, the identification of grid component anomalies through inspections with minimal human intervention, evidencing use cases for drones, robotics, AR applied to maintenance.
Deployment of IoT sensors, communication, data management & analysis and feedback to control systems encompasses a huge number of devices and systems, so high TRL R&I actions are definitely needed.
With the onset of observability solutions and IoT utilization, systems and components can be constantly monitored through intelligent systems capable of offering improved operational regimes and advanced sensing capabilities that can offer accurate usage of installed infrastructure. Together with the prespecified capabilities of installed equipment and systems by the manufacturers, maintenance decisions can be more accurate and in time to safeguard flawless operation of the system. This can be of real value to operators and R&I in this direction can offer a family of solutions that can improve operation and maintenance practices. Acquisition, elaboration and interpretation of the huge amount of data available from system monitoring and inspection will also be considered leveraging data analytics based on AI, and machine learning.

Description of RD&I or Programming Activities:

1. Development of ageing and failure models for condition (risk) in planning LV/MV based maintenance, considering maintenance cycling profiles (including extreme events), different time scales (from operation to planning) both for power system components (lines, substations, transformers, switches, breakers), ICT infrastructures (sensors, communication infrastructures) and smart meters.
2. Development of models for State of Health (SoH) estimates of transmission system components conditions, e.g. SoH related to components' wear, oil level in transformer oil pits, SF6 level in switchgear and probabilities of failure. Investigation of parameters which impact the lifespan of HV transmission system components.
3. Model-based detection of component failures with sensors, conditions monitoring; robotics for hostile environments in HV systems; live maintenance (drones). Improved maintenance of HV-system

components related to environmental (e.g., tree growth rate, wind) and operational (e.g., hazard rate) effects on assets' lifetime (Holistic approaches). 4. Remote LV/MV maintenance operations by digital communications and monitoring equipment 5. HV and MV-asset management considering resiliency against rare, severe-impact events due to natural catastrophes, terrorism, cyber-attacks using standardisation for diagnostic methodologies (for validating measuring chain, for safety of [live] operation). 6. Training of maintenance operators for their adaptation to digital environments (i.e. human-machine interfaces) and new robotic solutions. Optimise maintenance-related costs (accuracy, redundancy, etc.) of the ICT infrastructure for collecting and processing data (both for on-line monitoring of components and data storage) 7. Optimized lifespan of storage systems and the failure modes, including stochastic cycling profiles, CAPEX, OPEX, efficiency. 8. Smart sensors and online monitoring and diagnostic systems for the optimal maintenance of hydropower and pumped-storage units. 9. Improved lifetime of thermal generation with fast cycling ability and fuel flexibility.

Joint activities:
• A4-IA1.1-2
  ○ JI-1: Align national, transnational and international RD&I programmes
  ○ JI-2: Share results and best practices
  ○ JI-3: Further collaboration ideas

Impact of the RD&I Activities:
• ***Short-term impact:***
  ○ Safer grid operation and reduction of accidents in maintenance, through the use of validated systems for diffused asset monitoring by distributed sensors (IoT technology) for a real–time view of the status of the grid.
  ○ Extended lifetime of existing power system components based on improved monitoring and measurement of their health state and residual lifetime.
  ○ Optimized costs up to 50% for asset maintenance activities while increasing the life-time of existing assets (up to 60%).
  ○ Reduced OPEX, through the use of common asset models for interpretation of the huge amount of data available from system monitoring and inspection.
  ○ Cost efficient solutions and policy guidelines to use drones for large campaigns (data acquisition of power lines with drones are fully competitive in terms of performance and costs).
• ***Long-term impact:***
  ○ Full application of probabilistic asset management methodologies based on risk evaluation.
  ○ Validated automatic detection software to assess electrical lines and grid components anomalies also supported by on-board dedicated Software with no human intervention.
  ○ Maximized efficiency of system management costs, guaranteed levels of reliability and resilience, and adequate planning of the network modernisation investments.
  ○ Validated robotic procedures and solutions to replace live line working activities .

TRL: 3-5 / 6-8

Expected deliverables: tbd	**Timeline:** tbd

5.14 System Stability analysis

Implementation Plan - Activity Fiche 14 – Flagship 1
Innovation Target: • Flexibility of all types of generation

o A4-T1.1.-3: Develop and implement solutions to increase flexibility of all types of generation
Title: System Stability analysis
References to ETIP SNET Implementation Plan 2021-2024: RA 4 - Topic 4.4 Reference to the IWG4 Implementation Plan 2018 Innovation fiches: A4-IA1.3-1;

Challenge:

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

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

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

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

Scope:

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

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

In addition to the ETIP SNET implementation plan, reference is made here to the potential of dispatchable renewable energy sources such as CSP, biomass and hydro, to decouple generation variability from load, providing synchronous power and inertia to the grid.

Description of RD&I or Programming Activities:

1. Grid stability support by DER (distributed generation, storage and flexible demand) and by microgrids and nanogrids connected at the distribution networks to the stability and control of the bulk transmission network.
2. Control concepts for providing synthetic inertia from power electronic converters and additional damping of oscillations, for instance by conventional rotating machine concepts like the VFT (Variable Frequency Transformer)
3. Stability and control of AC, DC and Hybrid Microgrids in islanded mode of operation.
4. Models and tools for converter driven stability including fast interaction (dynamic interactions of the control systems of power electronic-based systems, e.g. DGs, HVDC, and FACTS with fast-response components of the power system, such as the transmission network, or other power electronic-based devices) and slow interaction (dynamic interactions with slow-response components, such as the

electromechanical dynamics of synchronous generators phenomena. 5. Models and techniques (incl. artificial analysis) for rotor-angle, voltage and frequency stability of large-scale transmission systems with high penetration of Variable RES. 6. Development and validation of equivalent models of aggregated network and system components consisting of multiple technologies and potential energy carriers in different environments for energy system stability. 7. Methods and tools to analyse large-scale inter-area oscillations. Dynamic stability in grids with multiple control systems.

Joint activities:
• A4-IA1.3-1:
  ○ JI-1: Align national, transnational and international RD&I programmes
  ○ JI-2: Share results and best practices
  ○ JI-3: National, Transnational and European calls for RD&I projects on the above given topics.

Impact of the RD&I Activities:
• Short-term impact:
  ○ Focused, location and situation dependent identification of the most relevant parameters and technologies to ensure the stability of power systems in front of large perturbations linked with vRES
• Long-term impact:
  ○ Stable and reliable power systems with 100% and more vRES, using adequate technologies (like synthetic inertia) and design criteria (like advanced sector coupling).

TRL: 3-5 / 6-8

Expected deliverables: tbd	**Timeline:** tbd

5.15 Demand flexibility (household and industry related)

Implementation Plan - Activity Fiche 15 – Flagship 1
Innovation Target: • Manage the load profile by demand response and control   ○ A4-T1.1.-2: Develop and implement solutions and tools to manage the load profile by demand response and control, in order to optimise use of the grid and defer grid investments.
Title: Demand flexibility (household and industry related)
References to ETIP SNET Implementation Plan 2021-2024: RA 5 - Topic 5.1 Reference to the IWG4 Implementation Plan 2018 Innovation fiches: A4-IA1.2-1; A4-IA1.2-3; A4-IA1.3-1;
Challenge: The progressive decarbonisation of the energy system relies on the deep integration of variable renewable energy sources. A paradigm shift is needed in the management of the energy system in front of all uncertainties, to guarantee the stability and efficiency of the system at all time and geographical scales. All sources of flexibility must be employed along the entire value chain. The present demand-related technologies, market models and integrated energy system policies do not provide sufficient features and incentives to the customer/prosumer, to engage in DSM and DR programs and market initiatives. There is also a lack of knowledge about customers behaviour and motivation to involve them in the energy markets. Power systems need to be increasingly flexible to accommodate rising shares of distributed, non-controllable renewable generation. Demand side flexibility in this context refers to enabling final customers/prosumers to become active in the market but also to enable system operators to make best

use of flexibility in order to ensure low-carbon, secure, reliable, resilient, accessible, cost-efficient, and market-based system operation at affordable costs. There is a need to assess, in a reliable way, the full potential of flexibility to be addressed in different context and to simulate the effects of different technical and economic measures.

Scope:
This ACTIVITY FICHE will include, as a basis for further works, comprehensive studies of consumers on social behaviours and motivation patterns to adapt their consumption profile, aimed to assess customer and prosumer awareness of importance of demand response and design of stimulation packages.
Societal studies will be conducted to characterise and segment the different types of users (from households to the industry) and to identify the levers (behavioural, societal, economical, technical) to foster their participation into the flexibility arena. Suitable market mechanisms will be developed and analysed for the exploitation of services based on demand side flexibility, able to support both system adequacy and system security in an integrated and coordinated way. They will include suitable price signals and/or incentives for leveraging the wide-spread electrification of the economy, such as DSR and V2G.
Market models will be developed and validated, to drive more cost-effective demand-related investments in a coordinated approach including also other energy sectors and vectors, with market mechanisms to facilitate and integrate very large shares of variable RES generation in a cost effective way as sector coupling, while ensuring the flexibility that is needed to maintain system adequacy and security. Suitable and validated methodologies will be developed, for evaluating the full potential of optimal utilisation of available flexibilities including technical, economic and regulatory aspects, and consider the efficient planning and operation of the power grid using the full potential of demand side flexibility. The design of new architectures for the flexibility markets will integrate local and European-wide markets in an efficient way and enabling multilateral flexibility where several operators (TSOs and DSOs) may be present at the same time.

Description of RD&I or Programming Activities:
1. Optimal utilization of DSR (Demand Side Response) by TSOs and DSOs and their coordination, respecting demand requirements, and required data.
2. Direct load control in close collaboration with telecom operators
3. Incorporation of Active Demand in DSO planning and operation, to serve the needs of the connected end user and aggregators and to defer grid investments. Prediction of the amount of shifted energy or modified consumption in Distribution Networks considering data availability and information exchange models.
4. Models for demand flexibility provided by integrated energy-intensive industries (e.g. steel production) and bulk energy storage (P2G, CAES, LAES, etc.).

Joint activities:
- A4-IA1.2-1
    - JI-1: Align national R&I programs to include the above activities
    - JI-2: Share results and best practices
    - JI-3: National, transnational and European calls for RD&I projects on the above given topics
- A4-IA1.2-3
    - JI-1: National, Transnational and European Calls for RD&I projects on the above given topics.
- A4-IA1.3-1:
    - JI-1: Align national, transnational and international RD&I programmes
    - JI-2: Share results and best practices
    - JI-3: National, Transnational and European calls for RD&I projects on the above given topics.

Impact of the RD&I Activities:
• ***Short-term impact:***
  ○ Accelerated availability of market based sustainable flexibility services for the grid.
  ○ Increased market participation of a wide range of flexibility products, both short and long term, through remuneration in multiple balancing / flexible markets.
  ○ Improved market conditions of flexibility products at both supply and demand sides to ensure balancing and ancillary service provision in the markets.
  ○ Transparent knowledge (catalogue) of flexibility products.
  ○ Standardised ICT requirements to collect, deliver and utilize data, including data from different energy sector, to enable efficient flexibility markets.
 	
• ***Long-term impact:***
  ○ Increased flexibility investments for business in electricity sector to other energy vectors and their networks and businesses.
  ○ PtX solutions enabling DER entities – connected to distribution grids – to become more and more active, allowing new service portfolio for the whole energy system beyond electricity.
  ○ Fully standardized flexibility products and services.
  ○ Welfare-maximised, fully unlocked peer-to-peer transactions for energy and flexibilities.
  ○ Fully integrated (in the electricity market) storage and multi-service (stacking concept).
  ○ Fully deployed market architecture for EU-wide sector coupling.
  ○ Developed and validated multi-energy markets considering flexibility resources.

TRL: 3-5 // 6-8

Expected deliverables: tbd	**Timeline:** tbd

5.16 Generation flexibility (flexible thermal, RES (Hydro, PV and wind generators))

Implementation Plan - Activity Fiche 16 – Flagship 1

Innovation Target:
• Increase observability and controllability
  ○ A4-T1.1.-1: Develop and implement solutions to increase observability and controllability in the energy system
• Manage the load profile by demand response and control
  ○ A4-T1.1.-2: Develop and implement solutions and tools to manage the load profile by demand response and control, in order to optimise use of the grid and defer grid investments.
• Flexibility of all types of generation
  ○ A4-T1.1.-3: Develop and implement solutions to increase flexibility of all types of generation
  ○ A4-T1.1.-3.1: Develop and implement solutions to enable Renewable Energy Sources to provide grid services.
  ○ A4-T1.1.-3.2: Develop and implement solutions to improve the flexibility capabilities for new as well as retrofitted thermal power plants

Title: Generation flexibility (flexible thermal, RES (Hydro, PV and wind generators))
References to ETIP SNET Implementation Plan 2021-2024: RA 5 - Topic 5.2 Reference to the IWG4 Implementation Plan 2018 Innovation fiches: A4-IA1.1-1; A4-IA1.2-3; A4-IA1.3-1; A4-IA1.3-2; A4-A1.3.-3; A4-IA1.3-4; A4-IA1.3-5;

Challenge:

The progressive decarbonisation of the energy system relies on the deep integration of variable renewable energy sources. Thermal power generation will be more and more based on CO2-neutral fuels, while –at the same time-guaranteeing a higher level of flexibility. This means faster up/down ramping, increased resilience and lower maintenance costs. Hydropower generation, already a major source of flexibility for the electricity system, will improve its capacity of supporting network balancing needs. Wind turbine and PV MPPT (Maximum Power Point Tracking) controls must consider flexibility and reserve sharing.

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

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

Scope:

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

Suitable tools will be developed to optimize the different flexibility resources, assessing their availability, the retrofitting technologies, the operating (and external) costs, both under a planning point of view and in a more short-term operational horizon. Improved combustion systems for CO2-neutral fuels (including renewable “green” hydrogen/ natural gas mixtures) will be demonstrated, with particular attention to efficiency and reliability, as well as faster thermal generation ramping down and up and start-up/shut down. Energy storage systems such as batteries, hydro reservoirs, hot water tanks, cooling systems storage, storage for CO2-neutral or free gases, integrated with power generation plants, will be demonstrated via pilot experiences. New technologies and operational methodologies will be developed and demonstrated to increase hydropower and pumped hydro-storage plants flexibility.

In addition to the ETIP SNET implementation plan, reference is made here to the integration of dispatchable renewable energies (CSP, Biomass and hydro) with intermittent renewable energies(PV, WIND) at plant level (hybrid plants) or at system level (by controlling the penetration rates of both non- and dispatchable sources).

Description of RD&I or Programming Activities:

1. Contribution of WTs (Wind Turbines) and PVs to system flexibility. Development of efficient controls for wind turbines and PV MPPT (Maximum Power Point Tracking) to consider flexibility and reserve sharing.
2. Increase operational flexibility of hydropower and pumped storage plants, while reducing the negative effects on highly reduced lifetime and security risks from sudden outage.
3. Increase the flexibility of thermal generation, i.e. their speed of ramping up and down, start-up/shut down capabilities and minimum loads. Increase efficiency and lower GHG and CO2-emissions without compromising ability for waste heat recovery (ORC).
4. Increase fuel flexibility of thermal power plants for using (mixing and switching) different sources of CO2-neutral fuels (hydrogen, biomass and biofuels).
5. Develop and test solutions for integrated flexible small and medium scale thermal generation of electricity, heating and cooling, storage, develop impact studies and demonstration (including

environmental, user and societal and economic impacts).
6. Development of highly efficient, integrated cogeneration units of varying size with decoupled use of heat & power, powered by hydrogen, biomass and biofuels.
7. Develop European hydro energy system model based on hydro power data set. Develop European wide reservoir and river inflow data set based on up to date climate simulations.

Joint activities:

- A4-IA1.1-1:
    - JI-1: Align national, transnational and international RD&I programmes
    - JI-2: Share results and best practices
    - JI-3: Further collaboration ideas
- A4-IA1.2-3
    - JI-1: National, Transnational and European Calls for RD&I projects on the above given topics.
- A4-IA1.3-1
    - JI-1: Align national, transnational and international RD&I programmes
    - JI-2: Share results and best practices
    - JI-3: National, Transnational and European calls for RD&I projects on the above given topics.
- A4-IA1.3-2
    - JI-1: Align national, transnational and international RD&I programmes
    - JI-2: Share results and best practices
    - JI-3: National, Transnational and European calls for RD&I projects on the above given topics.
- A4-A1.3.-3
    - JI-1: Align national, transnational and international RD&I programmes
    - JI-2: Share results and best practices
    - JI-3: National, Transnational and European calls for RD&I projects on the above given topics.
- A4-IA1.3-4
    - JI-1: Align national, transnational and international RD&I programmes
    - JI-2: Share results and best practices
    - JI-3: National, Transnational and European calls for RD&I projects on the above given topics.
- A4-IA1.3-5
    - JA-1: Integration of Storage and vRES
    - JA- 2: integration of different Storage technologies

Impact of the RD&I Activities:

- ***Short-term impact:***
    - Ensured knowledge that power generation –including for existing generation capacities – is ready to optimally use the gases generated under novel Power-to-Gas concepts, where alternative fuels are provided.
    - Optimized operation of power generation through storage, for instance by bridging between stop and restart of a generator or by providing the needed time to achieve optimal ramp-up/-down, allowing fast load changes to be met.
    - Optimized coupling of the gas, heat and electricity networks and adaptation to the flexibility challenge connected to the increased penetration of variable renewables in the system
- ***Long-term impact:***
    - Leveraged flexibility on the generation side to enhance the integration of variable renewables in the electricity system, but also for heating and cooling and carbon-neutral gas systems.
    - Support the effective penetration of the novel Power-to-Gas concepts, where alternative "green" fuels are provided.

TRL: 3-5 / 6-8

Expected deliverables: tbd	**Timeline:** tbd

5.17 Storage flexibility & Energy Conversion flexibility (PtG&H, PtG, GtP, PtL, LtP; PtW; WtP)

Implementation Plan - Activity Fiche 17 – Flagship 1

Innovation Target:
• Increase observability and controllability
  ○ A4-T1.1.-1: Develop and implement solutions to increase observability and controllability in the energy system
• Manage the load profile by demand response and control
  ○ A4-T1.1.-2: Develop and implement solutions and tools to manage the load profile by demand response and control, in order to optimise use of the grid and defer grid investments.
• Flexibility of all types of generation
  ○ A4-T1.1.-3: Develop and implement solutions to increase flexibility of all types of generation
  ○ A4-T1.1.-3.2: Develop and implement solutions to improve the flexibility capabilities for new as well as retrofitted thermal power plants
• Reduce the cost of all energy storage solutions
  ○ A4-T1.4.-1: Reduce the cost of all energy storage solutions contributing to the minimisation of the overall system costs

Title: Storage flexibility & Energy Conversion flexibility (PtG&H, PtG, GtP, PtL, LtP; PtW; WtP)
References to ETIP SNET Implementation Plan 2021-2024: RA 5 - Topic 5.3 Reference to the IWG4 Implementation Plan 2018 Innovation fiches: A4-IA1.1-1; A4-IA1.2-2; A4-IA1.2-3; A4-IA1.3-1; A4-IA1.3-2; A4-IA1.3-4 ; A4-IA1.3-5; A4-IA1.4-2;
Challenge: The progressive decarbonisation of the energy system relies on the deep integration of variable renewable energy sources. Storage such as batteries appear as the more accessible technological option to guarantee to RES generation the needed flexibility; on the other side, PtX technologies are emerging as a promising option, allowing as well the desired integration with other "energy-related" networks, i.e. the gas and the heating/cooling ones. Storage systems and Energy conversion technologies are key factors in ensuring a high degree of flexibility to the energy system as a whole, as well as guaranteeing the deep de-carbonization requested. Storage still lacks a proper valorisation in many scenarios and context, thus limiting the unlocking of its full potential. PtX technologies need extensive R&I activities, followed by the suitable demonstration at different scales. Storage systems including batteries will be developed to ensure flexibility and balancing services at all the network levels, at the same time contributing both to the optimal operation of power generation (conventional, fed by CO2-neutral fuels, and Renewable) and to the DSM (Demand Side Management) at the level of final customers. PtX technologies (the most promising appears to be the Power-to-gas one) will increase their role and penetration into the energy system. Potential and limits of these technologies need to be carefully assessed, via simulation and demonstration activities; regulatory issues must also be investigated. There is a strong need to assess the costs/ benefits ratio of PtX technologies and to understand their effective integration in real scenarios, taking into account realistic synergies with gas, heating/cooling and water networks. **Scope:** This ACTIVITY FICHE addresses the contribution to flexibility of energy storage integration, together with the advanced conversion technologies, aimed to transform electricity into gas, liquids and water and vice versa. Massive and effective storage penetration requires, on one side, a new regulatory framework and market design (including storage services remuneration), and the availability of comprehensive tools to assess cost/benefit balance and to evaluate the economics of each initiative (including bankability). Suitable tools

and models, to determine optimal size, location and utilisation of storage and PtX technologies and plants, is a pre-condition to ensure their effective deployment.
Demonstration activities will be undertaken on LONG-TERM energy storage systems (from advanced pumping hydro to other alternative solutions as PtX), solutions for district heating and cooling as sector integration for flexible operation at different energy levels and carriers, solutions for industry and industrial clusters for integrated flexible generation, consumption and storage.

In addition to the ETIP SNET implementation plan, reference is made to the potential of dispatchable renewables (such as CSP, biomass, hydro).

Description of RD&I or Programming Activities:

1. Studies for storage flexibilities in operation of electrical grids (including Microgrids). Storage sizing and siting (also hybrid technologies) depending on applications and their characteristics (CAPEX, OPEX, cycling, lifetime, efficiency, interconnection with other energy carriers, environmental and social aspects (LCA)).
2. Integration of energy storage systems with conventional power generators, such as cogeneration, hydropower, thermal plants to increase their flexibility and improve operation (incl. effectiveness and load hours of combined heat and power).
3. Flexibility potential from aggregated heating (and cooling) storage at household / building / industrial level to provide system services (balancing). Power-to-heat technologies, like heat pumps, and heat boilers.
4. Large-scale power-to-gas applications: Dynamics of coupled, integrated energy systems when producing large quantities of methane (power-to-gas) to be injected into the gas system (pipelines and underground storages).
5. Stand-alone (islands) buildings, living quarters and small and medium sized businesses and industries, supplied by renewable generation, sector-coupling and storage components (P2hydrogen, P2G, P2H, P2fuels (involving carbon capture), P2chemicals and vice versa; flex control of P2H conversions.

Joint activities:

- A4-IA1.1-1:
    - JI-1: Align national, transnational and international RD&I programmes
    - JI-2: Share results and best practices
    - JI-3: Further collaboration ideas
- A4-IA1.2-2
    - JI-1 National, Transnational and European Calls for RD&I projects on the above given topics.
- A4-IA1.2-3
    - JI-1: National, Transnational and European Calls for RD&I projects on the above given topics.
- A4-IA1.3-1:
    - JI-1: Align national, transnational and international RD&I programmes
    - JI-2: Share results and best practices
    - JI-3: National, Transnational and European calls for RD&I projects on the above given topics.
- 4-IA1.3-2
    - JI-1: Align national, transnational and international RD&I programmes
    - JI-2: Share results and best practices
    - JI-3: National, Transnational and European calls for RD&I projects on the above given topics.
- A4-IA1.3-4
    - JI-1: Align national, transnational and international RD&I programmes
    - JI-2: Share results and best practices
    - JI-3: National, Transnational and European calls for RD&I projects on the above given topics.
- A4-IA1.3-5
    - JA-1: Integration of Storage and vRES
    - JA- 2: integration of different Storage technologies

• A4-IA1.4-2
  ○ JI-1: Align national, transnational and international RD&I programmes
  ○ JI-2: Share results and best practices
  ○ JI-3: National, Transnational and European calls for RD&I projects on the above given topics.	

Impact of the RD&I Activities:
• ***Short-term impact:***
  ○ Estimated impact and developed scenarios of distributed and concentrated (and virtual) storage
  ○ Best practices for the optimal use of different storage systems, such as a large storage plants, or aggregation of distributed storage devices (industrial and residential storage), or hybrid storage systems able to provide a staking of multiple services and/or advanced specific services (e.g. Virtual Inertia for fast frequency response).
  ○ Stable regulation framework for storage integration and valorisations Integration of new storage technologies for operating the grid.
  ○ Optimised balancing procedures for the integration of energy storage and flexibility from sub-systems (such as DSO or Citizen Energy Communities) in a system of systems approach (3.2).
  ○ Optimised impacts on OPEX and CAPEX for the integration of flexibility from distributed storage.
 	
• ***Long-term impact:***
  ○ Increased level of flexibility in transmission and distribution grid management to allow increased integration of RES while maintaining the security of supply at the pan-European level and reducing the need of grid reinforcement
  ○ Optimised balancing procedures for the integration of energy storage and flexibility from sub-systems (such as DSO or Citizen Energy Communities) in a system of systems approach.	

TRL: 3-5	
Expected deliverables: tbd	**Timeline:** tbd

5.18 Network flexibility (FACTS, FACDS, smart transformers and HVDC)

Implementation Plan - Activity Fiche 18 – Flagship 1

Innovation Target:
• Increase observability and controllability
  ○ A4-T1.1.-1: Develop and implement solutions to increase observability and controllability in the energy system
• Manage the load profile by demand response and control
  ○ A4-T1.1.-2: Develop and implement solutions and tools to manage the load profile by demand response and control, in order to optimise use of the grid and defer grid investments.

Title: Network flexibility (FACTS, FACDS, smart transformers and HVDC)
References to ETIP SNET Implementation Plan 2021-2024: RA 5 - Topic 5.4 Reference to the IWG4 Implementation Plan 2018 Innovation fiches: A4-IA1.1-2; A4-IA1.2-3;

Challenge:
The progressive decarbonisation of the energy system relies on the deep integration of variable renewable energy sources, requiring the use of all sources of flexibility. A key issue is the increased electricity network observability and controllability, to improve the optimal management of power flows and voltages. Power Electronics has strong potential to increase cost-effective system flexibility at all network levels.
Development and deployment of innovative technologies and tools, to increase network observability and controllability, communication and monitoring, as well as increased interaction and information exchange, are enablers to provide local, regional and system wide flexibility solutions.
Transmission and Distribution networks, HVDC systems and on-shore and off-shore RES generation plants need the development and standardization of new components and devices, based on power electronics, to ensure full interoperability, optimal flow control, improved grid controllability, thus helping greater flexibility and stability of operation. Extensive demonstration of ready-to-use network flexibility devices is necessary.

Scope:
This ACTIVITY FICHE addresses the flexibility improvements gained in the T&D networks thanks to the use of advanced Power Electronics.
Standardization activities will cover HVDC converter stations, Dynamic Line Rating solutions, and ready-to-use Power Electronics devices and components.
Extensive demonstration activities will be conducted, focussing on Smart inverters and Smart transformers, providing grid support functions, on full scale interoperability of HVDC Converter stations and on innovative solutions for HVDC multi-terminal networks.

Description of RD&I or Programming Activities:
1. Increasing flexibility in transmission and distribution networks by flexible, power electronics grid technologies, such as FACTS, PSTs and HVDC links, smart transformers (power electronics OLTCs), open soft points, FACDS, and fault current limiters.
2. Flexibilities provided by distribution network reconfiguration.
3. Standardised HVDC multi-terminal networks to coordinate power flows among different regions and to connect off- and onshore wind power plants.
4. Dynamic Line Rating (DLR) solutions in capacity calculations of transmission and distribution grids.

Joint activities:
- A4-IA1.1-2
  - JI-1: Align national, transnational and international RD&I programmes
  - JI-2: Share results and best practices
  - JI-3: Further collaboration ideas
- A4-IA1.2-3
  - JI-1: National, Transnational and European Calls for RD&I projects on the above given topics.

Impact of the RD&I Activities:
- ***Short-term impact***:
  - Better system controllability which can benefit from utilization of large-scale new power generation technologies.
- ***Long-term impact:***
  - Leveraged flexibility on the generation side to integrate variable RES in the electricity system and for heating and cooling and carbon-neutral gas systems.

TRL: 3-5

Expected deliverables: tbd	**Timeline:** tbd

5.19 *Transport flexibility (VtG/EV; railway, trams, trolleybus)*

Implementation Plan - Activity Fiche 19 – Flagship 1
Innovation Target: • Manage the load profile by demand response and control   o A4-T1.1.-2: Develop and implement solutions and tools to manage the load profile by demand response and control, in order to optimise use of the grid and defer grid investments.
Title: Transport flexibility (VtG/EV; railway, trams, trolleybus)
References to ETIP SNET Implementation Plan 2021-2024: RA 5 - Topic 5.5 Reference to the IWG4 Implementation Plan 2018 Innovation fiches: A4-IA1.2-2; A4-IA1.2-3;
Challenge: The progressive decarbonisation of the energy system relies on the deep integration of variable renewable energy sources. All sources of flexibility must be employed along the entire value chain, to guarantee the stability and efficiency of the system at all time and geographical scales. The transport sector, with the growing penetration of electricity, could offer a valuable potential of flexibility to the grid. There is a lack of charging infrastructures and storage systems, both in urban and extra-urban areas. They should be planned and developed, keeping into account the mobility needs, the impact on network adequacy (especially at the level of Distribution) and the flexibility and balancing potential offered. Suitable market models are missing. They must be developed and tested, where effective price signals could orientate customers in the offer/demand of recharging services (V2G), keeping into due account the peculiarities of mobility services. Electrified public transport (both urban and long-distance) could as well offer flexibility and balancing potential, provided careful planning and operation methodologies to be adopted. There is a strong need of reliability analysis, quantification and optimization of the impact (opportunities and constraints) of EV interaction with the grid (Smart Charging and V2G) on urban and transmission grids. Services offered to the distribution and/or transmission network (flexibility and balancing) by electricity penetration in transport sector – both V2G and urban/long-distance public transport – need to be quantified and demonstrated. **Scope:** This ACTIVITY FICHE addresses the grid flexibility and balancing opportunities offered by electric transport, taking into account both V2G (Vehicle to Grid) and electricity transport networks. V2G has high potential to support the grid. The flexibility potential of electric transport in the future depends on how rapidly the amount of electric vehicles and machinery increases and this depends heavily on the policy measures. In any case, electrification of the transport sector is expected to proceed rapidly and IEA estimates total electricity consumption for EVs to be at the range of 640 - 1100 TWh in 2030 of which 100-200 TWh in Europe depending on the scenario (IEA Global EV Outlook 2019). A significant portion of the total EV fleet can be utilized to provide flexibility and balancing to the system and, therefore, the potential is high. Typically, V2G will give the substantial benefit of load shifting, useful for balancing out spikes (both upwards and downwards) in supply and/or demand. Scenarios will be tested and simulations will be performed, to assess the impact of transport system electrification on distribution grids. Recharging and storage facilities management systems and algorithms are to be developed and tested, enabling integration of V2G into urban distribution grid. Future mixed electric and carbon-neutral fuels vehicles strategies will be investigated, to ensure smooth transition to a fully decarbonised mobility.

Description of RD&I or Programming Activities:

1. Centralized and distributed algorithms for efficient management of EV charging, supporting business-to-customers and business-to-business relationships and ensuring easy and secure payments for customers (incl. roaming services).
2. Energy management in transport electricity network (railway, metro, tramway, trolleybus etc) to provide ancillary services to DSOs via storage facilities in the substation of the PCC (Point of Common Coupling).
3. Flexibility services offered by transport electrification, especially Electric Vehicles with Grid to Vehicle G2V and Vehicle to Grid VtG capabilities on distribution grid operation, especially for load flattening, system balancing and voltage support.

Joint activities:

- A4-IA1.2-2
  - JI-1 National, Transnational and European Calls for RD&I projects on the above given topics.
- A4-IA1.2-3
  - JI-1: National, Transnational and European Calls for RD&I projects on the above given topics.

Impact of the RD&I Activities:

- ***Short-term impact:***
  - Growing integration into (especially distribution) network of EV smart charging stations and systems

- ***Long-term impact:***
  - Integrated management of electricity transport network to offer services to the T&D network including V2G.

TRL: 3-5

Expected deliverables: tbd	**Timeline:** tbd

5.20 Supervisory Control and State Estimation

Implementation Plan - Activity Fiche 20 – Flagship 1

Innovation Target:

- Crosscutting activities
- Increase observability and controllability
  - A4-T1.1.-1: Develop and implement solutions to increase observability and controllability in the energy system
- Increase flexibility of all types of generation
  - A4-T1.1.-3: Develop and implement solutions to increase flexibility of all types of generation

Title: Supervisory Control and State Estimation

References to ETIP SNET Implementation Plan 2021-2024: RA 6 - Topic 6.1

Reference to the IWG4 Implementation Plan 2018 Innovation fiches: A4-IA0-3; A4-IA1.1-1; A4-IA1.1-2; A4-IA1.3-1;

Challenge:

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

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

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

Scope:

This ACTIVITY FICHE will consider the entire process of observability and supervision of the electricity system in presence of high variabilities from generation (renewables), network (contingencies) and load and of all flexibility tools adopted (such as storage (batteries, heating and cooling storage, storage for carbon-neutral gases), and VtG).

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

Description of RD&I or Programming Activities:

1. Steady State and Dynamic State Estimation of transmission systems using intelligent monitoring devices, like PMUs, intelligent sensors and data processing. (Distributed observability of the transmission system).
2. Increased Observability and State Estimation of distribution systems (MV and LV) using smart meter consumer data. Advanced forecasting and data flow between DSOs and TSOs.
3. Real-time observability of RES (algorithms and tools) and improved forecasts for operational planning purposes.

Joint activities:

- A4-IA0-3:
    - JI-1 Transnational Calls
    - Further collaboration (Promotion of forum for discussion taking into account all relevant stakeholders: Network operators, market operators, retailers and aggregators, generators, equipment manufacturers, ICT solution providers, regulatory bodies, R&D institutes, end-user associations, organisation promoting standard.)
- A4-IA1.1-1:
    - JI-1: Align national, transnational and international RD&I programmes
    - JI-2: Share results and best practices
    - JI-3: Further collaboration ideas
- A4-IA1.1-2
    - JI-1: Align national, transnational and international RD&I programmes

- JI-2: Share results and best practices
    - JI-3: Further collaboration ideas
- A4-IA1.3-1
    - JI-1: Align national, transnational and international RD&I programmes
    - JI-2: Share results and best practices
    - JI-3: National, Transnational and European calls for RD&I projects on the above given topics.

Impact of the RD&I Activities:

- ***Short-term impact:***
    - Increased hosting capacity for variable RES.
    - Use the entire span of possible working conditions for the energy system, thus increasing its availability and security.

- ***Long-term impact:***
    - System hosting capacity for 100% and more variable renewables.
    - Full observation of the distribution grids though the right combination of sensors, monitoring equipment and algorithms, software, at total minimal cost

TRL: 3-5 / 6-8

Expected deliverables: tbd	**Timeline:** tbd

5.21 Short-term control (Primary, Voltage, Frequency)

Implementation Plan - Activity Fiche 21 – Flagship 1

Innovation Target:

- Increase observability and controllability
    - A4-T1.1.-1: Develop and implement solutions to increase observability and controllability in the energy system
- Flexibility of all types of generation
    - A4-T1.1.-3: Develop and implement solutions to increase flexibility of all types of generation

Title: Short-term control (Primary, Voltage, Frequency)

References to ETIP SNET Implementation Plan 2021-2024: RA 6 - Topic 6.2
Reference to the IWG4 Implementation Plan 2018 Innovation fiches: A4-IA1.1-1; A4-IA1.3-1;

Challenge:
The integration of extensive shares of variable renewable energy sources connected to the network via inverters and the use of power electronics (FACTS, smart transformers etc.) throughout the power system requires a rapid evolution of methods and tools adopted to guarantee system stability.
The stability of the present electricity system leverages on the existence of the physical mass of rotating generating machines enabling, through their inertia, the damping of oscillations in front of rapid perturbations, thus allowing the intervention of the primary control systems. The extensive use of power electronics devices, used especially in the connection of variable renewables sources will create issues for the system stability of the power system because of the decrease in physical inertia. Moreover, the adoption of power electronics will substantially change the system protection philosophies.
Systems are needed to control and protect the Pan-European power system in an effective way, by being ready at any time for handling the normal operation as well as different types of contingency system states through preventive and corrective actions based on a system-wide, highly coordinated, fully interoperable grid observability, state estimation, new containment measures and protection criteria, under all scenarios (for example weather, failure, or attack).

Scope:

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

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

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

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

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

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

In addition to the ETIP SNET implementation plan, reference is made to the potential of dispatchable renewables (such as CSP, biomass, hydro).

Description of RD&I or Programming Activities:

1. Optimal Load Frequency Control considering requirements for telecommunication infrastructures, latencies and reliabilities.
2. Contribution of RES to primary voltage and frequency control of power grids with emphasis on weak grids (including islands). Provision of primary reserves by kinetic energy of WT rotors, synthetic inertia by PE interfaced DER, PE based reactive power control.
3. Primary voltage and frequency control of distribution grids (interconnected or islanded) with very low or no inertia by Power Electronics interfaced DER, local storage and load, and VPPs.

Joint activities:

- A4-IA1.1-1:
    - JI-1: Align national, transnational and international RD&I programmes
    - JI-2: Share results and best practices

◦ JI-3: Further collaboration ideas • A4-IA1.3-1 ◦ JI-1: Align national, transnational and international RD&I programmes ◦ JI-2: Share results and best practices ◦ JI-3: National, Transnational and European calls for RD&I projects on the above given topics.
Impact of the RD&I Activities: • ***Short-term impact:*** ◦ Smarter and safer grid operation. ◦ Improved, more reliable network state knowledge. ◦ Real-time estimation of intrinsic power system parameters. ◦ Boosted coordination between TSO and DSOs and cross border actors to increase amount of ancillary services and flexibility resources across the interconnected borders and market zones. ◦ Comprehensive methodologies to support the selection of optimal power flow control technologies considering system security criteria and efficiency of grid investments. ◦ Evaluation of the effectiveness of state of the art on Dynamic Line Rating solutions with analysis of the synergies with forecasting models and tools. • ***Long-term impact:*** ◦ Increased level of flexibility in transmission and distribution grid management to allow full integration of RES (beyond 100% of demand) while maintaining the security of supply at the pan-European level. ◦ Optimised real-time transmission and distribution grids architecture and operational efficiency.
TRL: 3-5 / 6-8

Expected deliverables: tbd	**Timeline:** tbd

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

Implementation Plan - Activity Fiche 22 – Flagship 1
Innovation Target: • Crosscutting activities • Increase observability and controllability ◦ A4-T1.1.-1: Develop and implement solutions to increase observability and controllability in the energy system • Flexibility of all types of generation ◦ A4-T1.1.-3: Develop and implement solutions to increase flexibility of all types of generation
Title: Medium and long-term control (Forecasting (Load, RES), secondary & tertiary control: LFC, operational planning: scheduling/optimisation of active reactive power, voltage control)
References to ETIP SNET Implementation Plan 2021-2024: RA 6 - Topic 6.3 Reference to the IWG4 Implementation Plan 2018 Innovation fiches: A4-IA0-3; A4-IA1.1-1; A4-IA1.1-2; A4-IA1.3-1;
Challenge: In addition to being stable and reliable, the electricity system must be efficient and able to ensure the adequate level of power quality. Measures to reduce internal inefficiencies such as the excessive reactive power flows and the energy imbalances, especially in presence of uncertainties need to be designed and applied. The evolution of the power system in a resources-constrained context must be ensured minimizing

stranded assets and prioritizing investments. This can be achieved by identifying and implementing medium and long-term control strategies and tools (reactive power control) and enhancing the performances of forecasting the exogenous parameters influencing the behaviour of the system.
Solutions are needed to optimise the production of renewable energy sources by means of generation forecasting/ nowcasting and forecasting and profiling of load and consumer behaviour, as influenced by the variable market conditions and mechanisms. Medium and long-term control strategies and tools are needed to support system operations, effective and sufficient security margins assessment, load sharing between substations, and control systems in secondary substations.

Scope:
This ACTIVITY FICHE addresses the solutions for operational planning of the energy systems, with special reference to resources scheduling (through adequate generation and load forecasting) and optimisation of active/reactive power and voltage control.
The research and demonstration activities will start from the development of forecasting and monitoring tools for primary energy sources, system behaviour and load dynamics and profiles of real-time tools for improved security analysis and decision making, using probabilistic algorithms, enhanced forecasting of RES integrated in the short-term operational planning optimisation. Validated tools for the dynamic power unit commitment, reserve allocation and optimal power flow for the highest integration of vRES will also be developed.

Description of RD&I or Programming Activities:

1. Advanced RES forecasting considering weather forecasts, local ad-hoc models, historical data and on-line measurements.
2. Hydropower forecasting based on weather, precipitation models and live sensors.
3. Solving location-based grid constraints with the use of short-term forecasting of generation and load and exploiting customer behaviour and flexible loads, including EV charging.
4. Optimal scheduling of generation units (unit commitment, economic dispatch), reserve allocation and optimal power flow in highly uncertain conditions.
5. Optimal distribution network configuration including increased monitoring capabilities at distribution level, automatic LV and MV System Topology identification and day-ahead forecasting.
6. Massive use of control technologies in secondary substations and the resulting coordination needs for system operators.

Joint activities:

- A4-IA0-3:
    - JI-1 Transnational Calls
    - Further collaboration (Promotion of forum for discussion taking into account all relevant stakeholders: Network operators, market operators, retailers and aggregators, generators, equipment manufacturers, ICT solution providers, regulatory bodies, R&D institutes, end-user associations, organisation promoting standard.)
- A4-IA1.1-1:
    - JI-1: Align national, transnational and international RD&I programmes
    - JI-2: Share results and best practices
    - JI-3: Further collaboration ideas
- A4-IA1.1-2
    - JI-1: Align national, transnational and international RD&I programmes
    - JI-2: Share results and best practices
    - JI-3: Further collaboration ideas
- A4-IA1.3-1
    - JI-1: Align national, transnational and international RD&I programmes
    - JI-2: Share results and best practices
    - JI-3: National, Transnational and European calls for RD&I projects on the above given topics.

Impact of the RD&I Activities:
• ***Short-term impact:***
  ○ More accurate forecasting of generation, system behaviour and load.
  ○ Risk analysis capability of forecasting errors and remedial actions.
  ○ Identification of grids constraints and mitigation of effects of congestions.
 	
• ***Long-term impact:***
  ○ Self-setting energy system integrating large shares of vRES, leveraging the advanced forecasting capabilities of exogenous and endogenous parameters and the controllability of the system.	

TRL: 3-5 / 6-8	
Expected deliverables: tbd	**Timeline:** tbd

5.23 Preventive control/restoration (Contingencies, Topology incl. Switching optimisation, Protection, Resilience)

Implementation Plan - Activity Fiche 23 – Flagship 1

Innovation Target:
• Increase observability and controllability
  ○ A4-T1.1.-1: Develop and implement solutions to increase observability and controllability in the energy system
• Flexibility of all types of generation
  ○ A4-T1.1.-3: Develop and implement solutions to increase flexibility of all types of generation

Title: Preventive control/restoration (Contingencies, Topology incl. Switching optimisation, Protection, Resilience)
References to ETIP SNET Implementation Plan 2021-2024: RA 6 - Topic 6.4 Reference to the IWG4 Implementation Plan 2018 Innovation fiches: A4-IA1.1-1; A4-IA1.3-1;
Challenge: Extreme events linked with climate change are increasing in frequency and intensity. Cyber-threats and intentional attacks may be increasingly dangerous for systems relying on extensive digitalisation. The power system is exposed to different types of threats both natural or intentional and needs to increase its level of resilience. Evaluating and increasing the resilience of the power system starts from the analysis of normal and abnormal operational conditions, identifying threats from external natural and intentional origin, assessing the system responsiveness to contingencies, minimising the risk, determining the right balance between “hardening” the power system infrastructures and smartening the network operation, identifying preventive and curative actions such as, for example, automatic fault clearing procedures and developing system restoration tools. Solutions are needed to increase the system resilience: for example the ability to anticipate and prepare for critical situations, to absorb impacts of hazards, prevent deterioration in service to the point of failure, to respond to and recover rapidly from disruptions, and to make adaptations that strive to provide continued electrical supply under a new condition. **Scope:** This ACTIVITY FICHE addresses the power system resilience, starting from the evaluation and forecasting of natural and human-related threats, assessing the system and components vulnerabilities, identifying and modelling the contingencies (single and multiple), evaluating the effects of mitigation of the threats through hardware (increasing robustness) or intelligence (smart management) solutions and identifying

measures for the rapid restoration of power system performances (even reduced) to progressively restore the adequate level of supply quality.

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

- Threats: natural threats, such as natural disasters (earthquakes, tsunami, volcano eruptions etc.), extreme weather events like wind, heavy rains, snowfalls, heat waves, thunderstorms, and their consequences like draughts, floods, terrain drifts will be studied historically, to assess their return time and project their frequencies along climate changes scenarios and will be predicted (when applicable) using advanced forecasting methods. Cyberattacks and intentional threats (terrorism) will also be considered based on technology evolution and geopolitical analysis.
- Vulnerability: the power system vulnerability, intended as composed by the fragility of network components and the system vulnerability in front of different types and combinations of contingencies will be evaluated, based on equipment tests (such as fault-ride tests) and system simulation adopting stochastic reliability approaches, thus replacing the current reliability principles.
- Resilience: assessment and validation of self-healing techniques for defence and restoration, probabilistic approaches, and enhanced reliability criteria; general methodological frameworks ("resilience doctrine") to be adopted by network operators to assess and to increase the power system resilience considering all the management phases (planning, operational planning and operation) and possible failures of both physical and digital infrastructures.
- Restoration: identification of pan European and regional system restoration algorithms, procedures and tools taking into consideration the possible contribution of DER/RES and storage systems (such as batteries, hot water tanks, cooling systems storage, storage for CO2-neutral or free gases), to system restoration and immediate power reserves (such as black start capability).

Description of RD&I or Programming Activities:

1. Protection of distribution networks with low fault currents due to high penetration of PE interfaced DER.
2. DC grid protection, protection relays and breakers, multi-vendor solution with the consideration of interoperability, standardisation.
3. Distribution network operational measures, like topology optimisation and DER operational planning for increasing network resilience against natural disasters, terrorism and cyber-attacks.
4. Bottom up restoration by DER support and storage including intentional islanding techniques via Microgrids and Web-of Cells approaches. Synchronisation of DER and storage reconnection.
5. Self-healing techniques at distribution level by automatic fault clearing procedures in automatic power system restoration.
6. Efficient Load Shedding techniques and tools considering reactive power and voltage control.
7. Security support by various multi-energy carriers in the distribution electricity network (e.g. electric pumps in the district heating and cooling networks, or in the drinking and wastewater networks, as well as electric compressors and control equipment in the gas network).
8. Pan-EU or multi-regional system restoration based on coordination of tie lines and/or black start units, whilst considering system condition, system constraints, available resources and regulatory rules. Minimise negative impacts of switching actions from one Transmission System to the neighbouring ones.

Joint activities:

- A4-IA1.1-1:
  - JI-1: Align national, transnational and international RD&I programmes
  - JI-2: Share results and best practices
  - JI-3: Further collaboration ideas
- A4-IA1.3-1
  - JI-1: Align national, transnational and international RD&I programmes
  - JI-2: Share results and best practices
  - JI-3: National, Transnational and European calls for RD&I projects on the above given topics.

Impact of the RD&I Activities:
• ***Short-term impact:***
  ○ Increased RES penetration without undermining main system stability.
  ○ Increased resilience – ability of society in emergency and partial failure situations to continue their activities with critical loads, and immunity so that the supply to energy communities is not disturbed in case of the main grid failures.
  ○ Improved cyber incident management capabilities within energy organisations, quicker time to recovery.
  ○ A consolidated methodology for resilience assessment and for identification of the optimal combination of measures to increase power system reliability and resilience, accounting also for failure modes of ICT, as validated in several pilots and demonstration projects across the whole Europe.
  ○ Criteria indicators to help network operators take decisions for preventive and curative actions and to assess efficiency and cost-effectiveness of the different solutions.
 	
• ***Long-term impact:***
  ○ Reduced effects of major catastrophic events (such as wide-spread blackouts) on society
  ○ Increased local availability of critical operational activities during wide-spread blackouts by resilient Microgrids (as temporary electrical islands)
  ○ Full support by citizen and local communities
  ○ Available protection and control to enhance the component resilience and for precise fault location in both AC and HVDC systems.

TRL: 3-5 7 6-8

Expected deliverables: tbd	**Timeline:** tbd

5.24 Control Center technologies (EMS, platforms, Operator training, Coordination among Control Centers)

Implementation Plan - Activity Fiche 24 – Flagship 1
Innovation Target: • Increase observability and controllability   ○ A4-T1.1.-1: Develop and implement solutions to increase observability and controllability in the energy system
Title: Control Center technologies (EMS, platforms, Operator training, Coordination among Control Centers)
References to ETIP SNET Implementation Plan 2021-2024: RA 6 - Topic 6.5 Reference to the IWG4 Implementation Plan 2018 Innovation fiches: A4-IA1.1-1; A4-IA1.1-2;
Challenge: The management of the integrated energy system under progressively new constrained conditions requires the development of control center technologies, the associated new skills and the training of operators to cope with the new responsibilities. Decisions on more complex systems will be taken more rapidly to guarantee the continuity, safety and quality of service. Innovative training systems are to be made available leveraging the available technologies such as AI and AR to be massively introduced into control rooms and operators training centres. Automated monitoring and control of networks at all voltage levels (HV, MV and LV), using digital and advanced operators control centres environments are needed to foster decision making, thus enhancing time and quality of reaction; these environments must be complemented and enhanced for the training of

operators so as to adapt to Network Energy Management platforms using real-time system implementation (digital twin) to simulate human grid operator roles and intervention.

Scope:
This ACTIVITY FICHE addresses the necessary network operators control room features as well as the operator training tools at all level of the integrated system development, management and operation to ensure adequate level of decision making and the uniform level of skills and approaches.
The research and demonstration activities will start from the analysis and development of the functions to be implemented for a combined central and decentralized control of energy systems based on advanced smart power systems architectures. The tools developed will be used also for training network operators based on close-to-real world concepts (like digital twins), able to react to all types of perturbations and system variabilities and events; tools for training of grid maintenance operators, assisted by AI and AR (Augmented Reality) during their interventions, thus facilitating the operators' full adaptation to the new digital environment will also be considered.

Description of RD&I or Programming Activities:

1. Wide Area Monitoring and Control Architecture for Transmission Systems: High-performance and high-speed communication infrastructure combined with sensing technologies, automation and control methods, also for critical situations.
2. Energy Management platforms for TSOs (with the associated monitoring and control systems) able to interact with local markets and with embedded functionalities such as self-healing capabilities for fault management.
3. Energy Management Platforms for DSOs allowing active participation of customers in energy market and in the grid operation optimization, interoperability with other actors (retailers, aggregators, TSOs) for grid status and data and smart metering data processing. Advanced functionalities for forecasting, protection and optimization in preventive and corrective way.
4. Control center architectures for distributed network control (Web-of-Cells and Microgrids) considering new sensors, such as fault detectors, voltage and current sensors in generation, storage, buildings, EVs, industry and MV levels with limited bandwidths.
5. Anti-islanding protection, control of intentional islanding. Technical, economic and regulatory dimensions of interaction with local DER for islanding.
6. Advanced Training simulators for DSOs and TSOs (using Digital Twins) in order to adapt to new Network Energy Management platforms (including multi-energy carrier systems).
7. Advanced MMI (Man-Machine-Interface) for Energy Management System control rooms at all voltage levels, provision of suitable indicators for resilience / vulnerability and other criteria to help network operators to make decisions for preventive and corrective actions.

Joint activities:

- A4-IA1.1-1:
  - JI-1: Align national, transnational and international RD&I programmes
  - JI-2: Share results and best practices
  - JI-3: Further collaboration ideas
- A4-IA1.1-2
  - JI-1: Align national, transnational and international RD&I programmes
  - JI-2: Share results and best practices
  - JI-3: Further collaboration ideas

Impact of the RD&I Activities: • ***Short-term impact:*** o Increased observability and controllability of the power systems, with a higher degree of transformation of data into information and knowledge to the advantage of network operators, thus increasing their decision making capabilities and improving their time and quality of reaction to disturbances and threats • ***Long-term impact:*** o A self-healing power system supervised by system operators fully trained using AI, AR, digital twins to continuously optimize the network operation during normal service as well as in front of all types and levels of threats.	
TRL: 3-5 / 6-8	
Expected deliverables: tbd	**Timeline:** tbd

6 Flagship Initiative 2 - "Integrated Local and Regional Energy Systems" – revision not yet endorsed by Member Countries

6.1 Digitalization for interoperability including testing

Implementation Plan - Activity Fiche 1 – Flagship 2
PRELIMINARY NOT YET ENDORSED BY MEMBER COUNTRIES

Innovation Target:
• Crosscutting activities.
• Observability and controllability
    o A4-T1.1.-1: Develop and implement solutions to increase observability and controllability in the energy system.
• Flexibility of the generation
    o A4-T1.1.-3: Develop and implement solutions to increase flexibility of all types of generation

Title: Digitalization for interoperability including testing
References to ETIP SNET Implementation Plan 2021-2024: RA 3 - Topic 3.1 Reference to the IWG4 Implementation Plan 2018 Innovation fiches: A4-IA0-1; A4-IA0-5; A4-IA1.1-1; A4-IA1.1-2; A4-IA1.3-1
Challenge: Interoperability is an essential aspect for the realization of various applications and services in smart energy systems where different approaches, solutions, components and devices from multiple vendors need to exchange information in real-time and work together on various applications. There are several ways and principles to realize interoperability between two interconnected systems by applying interoperability-by-design, by the provision of reference architectures as well as by following well-defined rules, guidelines and standards. However, in order to ensure interoperability in smart energy systems usually it is not sufficient to follow the aforementioned principles. Instead, corresponding interoperability tests need to be realized. Also, certificates need to be issued which provide evidence that the interoperability has been tested and can be ensured. However, testing of smart energy system interoperability is a huge challenge due to the high number of potential use cases, the steadily increasing number of digital devices and complex services – based on different hardware, software, and communication protocols. There exists already a couple of interoperability testing approaches, usually more advanced on the component level (e.g., IED 61850 includes guidelines for such tests); on the system level they are currently more on the research and development stage. The existing standardization and interoperability of digital technologies are not yet sufficient for the upcoming challenges in the smart energy system. Harmonized interoperability testing principles, concepts, guidelines and procedures as well as corresponding test and certification facilities for smart energy systems does not exist in Europe so far which would be essential in order to support the roll-out of digital interoperable solutions on a wide scale. **Scope:** This ACTIVITY FICHE will support interoperability and its testing in order to overcome the current shortcomings in the smart energy system mentioned before. Already existing interoperability standards will be collected in a first step as well as most important use cases in the energy systems will be analyzed as well as their interoperability aspects including the testing approaches and potential test cases. Based on the relevant standards, use cases and test cases, interoperability profiles will be defined. These interoperability profiles will specify the requirements for software, hardware, and communication interfaces and services as part of the digital energy system and ensure a proper level of interoperability and functionality – 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, aiming to be applied for European testing facilities to become interoperability certification centers for smart energy system devices, services, and applications.

Qualified centers ensure proper equipment and follow the defined testing and certification procedures.

Description of RD&I or Programming Activities:

1. Collection of existing standards, use cases, testing approaches, and test cases in the smart energy domain.
2. Definition of interoperability profiles – requirements for software, hardware, and communication interfaces, services, and applications to ensure a proper level of interoperability and functionality
3. Harmonization and development of interoperability testing approaches
4. Design of digital twins for interoperability testing
5. Definition of interoperability certification procedures for European testing facilities

Joint activities:

- A4-IA0-1:
    - JI-1: A joint COST or Coordination & Support activity within the H2020 program
    - JI-2: A joint light house (or research infrastructure) project for an HPCC (High Performance Computing Cluster) dedicated to the energy domain
    - JI-3: Government to Government information exchange
    - JI-4: Workshops on GIS interfaces
    - JI-5: Transnational calls
    - Further collaboration ideas (bilateral actions…)
- A4-IA0-3
    - JI-1: Transnational Calls
- A4-IA0-5:
    - JI-1: Setup a joint transnational structure for a European organisation 'IES Europe'
    - JI-2: 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 centers
- A4-IA1.1-1:
    - JI-1: Align national, transnational and international RD&I programmes
    - JI-2: Share results and best practices
    - JI-3: Further collaboration ideas
- A4-IA1.1-2
    - JI-1: Align national, transnational and international RD&I programmes
    - JI-2: Share results and best practices
    - JI-3: Further collaboration ideas
- A4-IA1.3-1:
    - JI-1: Align national, transnational and international RD&I programmes
    - JI-2: Share results and best practices
    - JI-3: National, Transnational and European calls for RD&I projects on the above given topics.

Impact of the RD&I Activities:

- ***Short-term impact:***
    - Higher degree 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 creating new testing facilities and certification centers

- ***Long-term impact:***
    - System-wide implementation of standardized and interoperable energy services and business models.
    - Fostered participation of new players (SMEs) in the energy markets by easy use of standards and interoperability.
    - Integrated Pan-European network of testing facilities and certification centers

TRL: 4-7

Expected deliverables: tbd	**Timeline:** tbd

6.2 Digital services for integrated regional energy systems

INNOVATION FICHE TO BE FINALISED

6.3 Contributing to the European wide collaboration frameworks through interaction with National, Regional and local stakeholders

Implementation Plan - Activity Fiche 3 – Flagship 2
PRELIMINARY NOT YET ENDORSED BY MEMBER COUNTRIES
Innovation Target: • Provide innovation frameworks to develop attractive services, creating value for the participants in the energy system and allowing for participation in the development of local and regional value chains
Title: Contributing to the European wide collaboration frameworks through interaction with National, Regional and local stakeholders
References to ETIP SNET Implementation Plan 2021-2024: Reference to the IWG4 Implementation Plan 2018 Innovation fiches: new fiche Reference to other European initiatives: ETIP RHC, ETIP PV, ETIP DeepGeothermal; CETP etc.
Challenge: Based on a common vision of the decarbonized energy system in 2050[2], the different SET Plan initiatives dedicated to the integrated energy system have developed and continuously update their R&D&I roadmaps, agendas, implementation, and financing plans[3] . This work is based on the continuous interaction among the stakeholders (European Commission, member states representatives, network operators, solution and technologies providers, services providers, associations etc.) and represents a very solid and expert-based ground of development and perspective. The approach normally adopted starts from the long term vision of the integrated energy system, identifies the use cases that will progressively be needed during the system evolution and sets the development pathways (R&D&I) for new technologies and solutions at the light of the state of the art and the ongoing activities, experience and progress, derived from surveys, monitoring sessions, expert analysis of gaps and needs. Research journeys and priorities are identified to ensure consistence with the vision scenarios, and consensus is sought to align plans at European, national and regional level, so as to ensure results achievements while maximizing efficiency and reducing overlaps and duplication of efforts. However, there is clear evidence that, despite the efforts made, the above initiatives, although addressing the major workstreams, are unable to capture the extensive value of programs and projects planned and carried out in regional and local initiatives as well as those where the prime mover is the private sector. Among the local initiatives to be considered, the financing schemes promoted in Regional innovation clusters (more than 50 of potential interest have been identified in the European Cluster Collaboration Platform) gather stakeholders interested in the development of the energy system and in the application of innovative solutions. Moreover, the light beam points towards the direct actors of the energy system, while a great deal of information and knowledge is often developed in other contiguous fields such as agriculture and forestry, local transport initiatives, local communities of users etc. Missing these sources of information and failing to address their points of view, expectations and priorities make lose part of the value of the approach undertaken and misses important connections, involvement and impact. The challenge addressed in this innovation fiche is to involve the direct or indirect stakeholders of the energy system at local level (public and private) in a dialogue to identify needs, opportunities, best practices and lessons learned that can contribute to the development of the integrated energy system. **Scope:** This initiative addresses the challenge of expanding the audience of stakeholders, to include as far as possible the local actors, project managers, communities and interested parties (public and private), to enhance the level of dialogue about the experience, needs and priorities for innovation in the field of integrated energy systems, to ease the

[2] ETIP SNET Vision 2050: https://www.etip-snet.eu/etip-snet-vision-2050/

[3] See for example: ETIP SNET roadmap 2020-2030 https://www.etip-snet.eu/etip_publ/etip-snet-ri-roadmap-2020-2030/ ; ETIP SNET Implementation plan 2021-2024 https://www.etip-snet.eu/wp-content/uploads/2020/05/Implementation-Plan-2021-2024_WEB_Single-Page.pdf ; IWG4 Implementation plan https://setis.ec.europa.eu/system/files/2021-04/set_plan_esystem_implementation_plan.pdf

transition toward net zero emissions to 2050.
The final scope is to boost the activities of the National Stakeholders Coordination Group (NSCG) established to support the ETIP SNET and the SET Plan IWG4 through the launch of a series of discussion links with the numerous parties and projects delivering outstanding experience and results at local and regional levels to continuously update them about the European and global developments, capturing and enhancing their voice, experience and priorities to a higher level of decision making, to increase the efficiency of the development process, fostering and speeding up the adoption of the most promising solutions and identifying the right pathways in the R&D roadmapping exercise.

The initiative aims at setting a win-win relation with regional and local activities contributing to foster innovation in the field of the integrated energy systems. The general idea is therefore to establish a continuous dialogue among stakeholders active in the field with different profiles and interests to capture the best ideas and practices for the advantage of the entire knowledge community. The stakeholders involved from the local projects and communities will gain awareness, insight and knowledge about the European and international achievements and trends, facilitating their development leapfrogging steps based on best practices; they will showcase their experience and results and will have their say about future developments, priorities roadmaps and implementation plans participating in surveys, discussions and workshops. On the other hand, the teams working at European and international level will gain insight to validate the scenarios and proposals of development plans and R&D journeys by means of real field data and experience.

Description of RD&I or Programming Activities:

1. ***Establishing and expanding the network of stakeholders***: The first level of activities lays on the establishment of a relationship of trust with the stakeholders of interest. Starting from National and regional technological development clusters, the outreach will need to be progressively expanded and the network of contacts strengthened. In particular, local and regional financing and development agencies, communities of stakeholders (energy-related discussion frameworks, local development programs, Interreg project management, ERANet funded projects and their related support schemes etc.) will be contacted and constructive discussion will be established. This can be achieved starting the win-win relation by offering information and insight of what is at stake at European level and listening to needs and expectations from the various stakeholders.
2. ***Involvement in regional discussion:*** workshops will be organised and projects will be motivated to engage in the ongoing discussions, unleashing insights of their experience, analysis, tools and publicly available results. As mentioned above, local stakeholders will have their say about future developments, priorities roadmaps and implementation plans participating in surveys, discussions and workshops. This activity will start from national mirror groups of ETIP SNET, IWG4 and IEC/CENELEC and national clusters to expand step-by-step to further interested parties, thus widening the sectoral reach.
3. ***National and Regional stakeholder platform****:* The second level of activities is the organization of an event to be scheduled on a regular basis (mixed mode virtual-in presence) to overcome the silos approach often adopted in addressing the energy system, thus involving the stakeholders from contiguous sectors in topical discussion over crosscutting aspects of development of the energy system, leveraging the experience from other communities.

Joint activities:

- Align national, transnational and international RD&I programmes
- Share results and best practices
- Further collaboration (Promotion of forum for discussion taking into account all relevant stakeholders: Network operators, market operators, retailers and aggregators, generators, equipment manufacturers, ICT solution providers, regulatory bodies, R&D institutes, end-user associations, organisation promoting standard.)
- Contribute to the BRIDGE Task force on energy community

Impact of the RD&I Activities:

- ***Short-term impact:***
  - Contribute to the identification of programme and project results, best practices and solutions otherwise not captured through the established channels of ETIPs, BRIDGE;
  - Contribute to the prioritization of research and innovation needs from the related stakeholders, to be brought to the relevant programming platforms at national and European levels, thus fostering the voice and needs and therefore rationalizing, streamlining and optimizing the planning and resourcing of needed activities.
- ***Long-term impact:***
  - Acceleration of market uptake of clean energy solutions and of the high level use cases along the patways to net-zero integrated energy system.

TRL: NA	
Expected deliverables: tbd	**Timeline:** tbd

6.4 *Innovation ecosystems for integrated regional and local energy systems*

Implementation Plan - Activity Fiche 4 – Flagship 2
PRELIMINARY NOT YET ENDORSED BY MEMBER COUNTRIES

Innovation Target:
• **A4-T1.5 & A4-T2.3: Establish innovation environments for the development of smart services**
  o A4-T1.5.-1: Provide innovation frameworks to develop attractive services, creating value for the participants in the power system and allowing for participation in pan-European value chains.
  o A4-T2.3.-1: Provide co-creation frameworks to develop attractive services, creating value for the participants in the energy system and allowing for participation in the development of local and regional value chains
• **A4-T2.2: Develop innovative mix solutions that will reduce variability**
  o A4-T2.2.-1: RES integration at regional and local levels, including different energy vectors.
  o A4-T2.2.-2: Multi-dimensional local energy systems

Title: Innovation ecosystems for integrated regional and local energy systems
References to ETIP SNET Implementation Plan 2021-2024: new activity Reference to the IWG4 Implementation Plan 2018 Innovation fiches: this is a new fiche and the activity was not considered in the previous version
Challenge: Regional and local energy systems and networks are composed of locally and regionally available energy sources, built infrastructure, specific production and consumption characteristics as well as user and consumer structures from different sectors. Regional and local energy systems have an important role to play in reaching the Energy Union targets. They are part of the living environment of citizens, including, in some cases, highly ambitious clean energy goals of specific communities and regions. They provide appropriate services to consumers, customers and citizens as well as to the overall European energy system to help ensure the security of supply, maximise the primary energy efficiency and deliver a high share of renewable energy. Local and regional energy systems will have to cope with a fundamental transformation in the coming years, responding to actual drivers such as the increasing uptake of new and improved technologies for decentralised energy systems, the boosting digitalisation and associated business models as well as sustainable societal trends. In order to find optimal local and regional solutions and to engage the right stakeholders to create the necessary buy-in, creation of regional and local innovation ecosystems will be very important. Ecosystems are communities where members interact and seek balance and where they all flourish. Operating in open public-private innovation ecosystems enables co-development of new systemic solutions, reinventing businesses and, at the same time, meeting the set goals for sustainable development. The development of sustainable regional and local energy systems should be orchestrated within a large framework of players to reach the maximum impact. All relevant local and regional stakeholders must be involved in the ecosystem but also global players should be engaged. Wide engagement of different sectors and stakeholders ensures that the energy system transformation will be integrated and adopted to local and regional infrastructures and processes and is driven and accepted by the local municipalities, communities and industries. Supporting new cooperative approaches as well as common standards will not only strengthen local and regional transition dynamics, industrial development and entrepreneurship, but also enable steps towards EU-level solutions in the development of sustainable energy systems. **Scope:** This ACTIVITY FICHE 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. In

addition, the fiche addresses the role of local living labs as a catalyst in creating a joint understanding of the most favourable local solutions as well as the necessary buy-in for sustainable solutions in local energy communities and systems.

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. Support and trainings to strenthen build-up, growth, management and operations of local and regional innovation ecosystems for sustainable energy
3. Support and trainings to strengthen the management and operations of local Living Labs for energy (together with ENoLL)
4. Networking events for the innovation ecosystems and Living Labs for energy to share, connect and co-operate
5. Engagement of local Living Labs and local and regional innovation ecosystems in co-creation activities for new projects, demonstrations, challenge camps, market shaping, etc.

Joint activities:

- Co-operation activities with CETP TRI5 for Integrated Regional Energy Systems and with CETP TRI6 Integrated Industrial Energy Systems such as
    - Networking events for the innovation ecosystems and Living Labs to share and connect
    - Support and trainings to strenthen build-up, growth, management and operations of local and regional innovation ecosystems
    - Support and trainings to strengthen the management and operations of local living labs (together with ENoLL)
    - Co-creation activities for new projects, demonstrations, challenge camps, market shaping, etc.

Impact of the RD&I Activities:

- ***Short-term impact:***
    - 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 obtain more in-depth understanding of different infrastructural and socio-economic contexts within which the energy transition is taking place across Europe
    - 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
    - Boosting economic growth:
        - Larger markets for solution providers sooner

- ***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
    - Fast growth of solution export to global markets

TRL: N/A

Expected deliverables: tbd	**Timeline:** tbd

6.5 Heating and Cooling in an integrated energy system

INNOVATION FICHE TO BE FINALISED

6.6 Integrated industrial energy systems

Implementation Plan - Activity Fiche 6 – Flagship 2
PRELIMINARY NOT YET ENDORSED BY MEMBER COUNTRIES
Innovation Target: **A4-T1.2: Economic Efficiency** A4-T1.4.-1: Reduce the cost of all energy storage solutions contributing to the minimisation of the overall system costs. **A4-T2.1: Develop heating and cooling systems that are able to locally integrate energy from different sources of different temperature levels** A4-T2.1.-2: Flexibility **A4-T2.2: Develop innovative mix solutions that will reduce variability** A4-T2.2.-1: RES integration at regional and local levels, including different energy vectors. A4-T2.2.-2: Multi-dimensional local energy systems
Title: Integrated Industrial energy systems
References to ETIP SNET Implementation Plan 2021-2024: new activity Reference to the IWG4 Implementation Plan 2018 Innovation fiches: new activity
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. In order to establish carbon-neutrality in industrial (energy) systems, renewable-based electrification of industrial processes is an important innovation challenge. All forms of renewable power production, e.g., on- and offshore wind, ocean energy, hydropower and solar power, require research and development activities to improve their technological performance, to tackle different aspects of system integration and to lower the costs. Another important task is to introduce, develop and deploy advanced renewable heating and cooling solutions in the industries. The full utilization of their potential calls for essential developments in 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 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 technologies, new regulatory frameworks and new business models. As a first step, a greater sector-coupling within energy is needed (electricity, heat, cool, gas). In the long run, the entire energy-industry system needs to become more flexible and adaptable and the system 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, regional and national heat and power networks and systems.
Description of RD&I or Programming Activities: 6. Develop and demonstrate system integration and sector coupling concepts for local symbioses of industrial and municipal energy 7. Develop and demonstrate regionally integrated, renewable-based power systems including energy storage 8. Develop and demonstrate new mechanisms for extended industrial demand response

9. Develop and demonstrate cross-sectoral and cross-industrial energy symbioses 10. Assessment of 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 11. Design of new business models to enhance business-driven cross-industry and cross-sector co-operation in energy 12. Electrification of industrial processes (in co-operation with IWG6) 13. 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 CETP TRI6 for Integrated Industrial Energy Systems such as
  ◦ Thematic workshops and seminars
  ◦ Co-creation of a roadmap for market shaping
  ◦ Identification of potential demonstrations
•

Impact of the RD&I Activities:
• **Short-term impact:**
  ◦ Local symbioses of industrial & municipal energy
  ◦ Electrification of industrial processes (together with IWG6)
  ◦ Integrated energy solutions at 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 at full scale

TRL: TRL 2/4-9

Expected deliverables	**Timeline**