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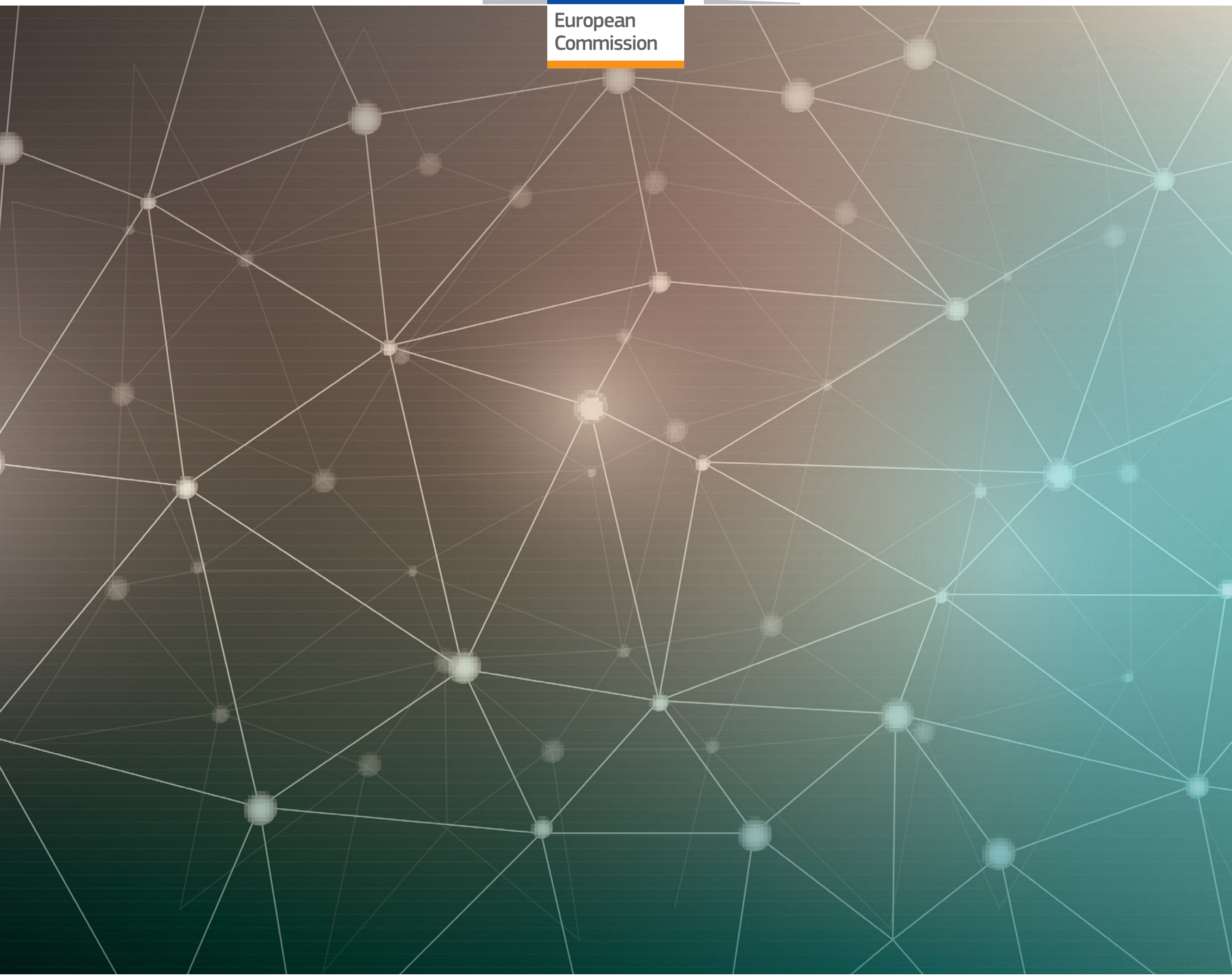

Contribution of the Electricity Sector to Smart Sector Integration

Fourth report of the European Commission expert group on electricity interconnection targets

Energy

FOURTH REPORT OF THE EUROPEAN COMMISSION EXPERT GROUP ON ELECTRICITY INTERCONNECTION TARGETS

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Contents

EXECUTIVE SUMMARY

In this report on the "Contribution of the Electricity Sector to Smart Sector Integration", the Expert Group considers avenues to make an optimal use of the opportunities offered by sector integration. The report focuses on the contribution of the electricity system to a climate-neutral European energy system through smart sector integration.

This report highlights four complementary dimensions for an effective contribution of smart sector integration to climate neutrality in Europe by 2050: 1) increased electrification, 2) generation of sufficient amounts of renewable electricity, 3) availability of flexibility tools, and 4) transforming some sectors that cannot efficiently reach carbon neutrality through direct electrification.

Smart sector integration requires careful considerations for electricity grids, thermal grids and storage, gas/liquid fuel grids and storage, given that in long-term projections, climate neutrality and smart sector integration rely essentially on infrastructures that still need to be planned or deployed, and also on technologies that still need to be scaled up. Therefore, the report investigates five main risks likely to have an impact on electricity infrastructure: 1) technology maturity risks, 2) capability to generate and host massive investments in electrification, renewable energy, and infrastructure, 3) improved market design and regulations to ensure an efficient use of the infrastructure and mitigate investors' risks on both end consumer and energy industry sides, 4) specific obstacles for the deployment of renewables, in particular in terms of space and infrastructure planning, and 5) uncertainties regarding the imports of carbon-neutral energy.

To address these risks, the Expert Group emphasizes that the operation and development of the entire energy system should guide efficient decisions regarding energy consumption, production and energy related investments. It stresses two guiding criteria. First, the need to continuously assess the SSI risks and their interactions with other elements and decisions. Second, the need to ensure the appropriate functioning of markets to coordinate all the decisions regarding energy consumption, production and energy-related investments to that purpose. In particular, the energy market design should be consistent with three principles:

- Fully internalising the cost of carbon emissions and of other significant environmental costs in energy prices.
- Ensuring a level playing field between energy carriers to incentivise the right choice of carrier in any given situation.

- Markets should reflect the varying supply and demand, incentivising thereby flexibility of consumption and generation.

In addition, the report provides fourteen specific recommendations to mitigate and tackle the risks and uncertainties associated to electricity and SSI.

1. INTRODUCTION

The European Commission set up the Expert Group on electricity interconnections targets in 2016. The group has issued three reports, on the EU electricity interconnection targets, on electricity interconnections with neighbouring countries and on public engagement and acceptance in the planning and implementation of European electricity interconnectors.

For the present report, the Expert Group has decided to look beyond the specific aspect of electricity interconnections. Already in its first report (November 2017), it identified the following trend: “further integration of the electricity, gas, heat and transport sectors, including through power to hydrogen and synthetic gas, and hybrid technologies for transport and heating. As electricity is only one part of the energy system, the emerging smart energy systems approach emphasises the need to look across sectors to identify synergies and cost-effective energy storage options as well as energy efficiency and energy savings options.” The Expert Group thus recommended a “holistic view on energy infrastructure development” and in particular stepping up the EU’s “efforts to develop a consistent and interlinked electricity gas market and network model.”

The adoption in December 2019 of the *European Green Deal* by the European Commission, with the introduction of the climate neutrality target by 2050, has created a very different context for the development of the EU’s energy policy. This ambitious target requires the mobilisation of the whole energy system towards full climate neutrality: gradual progress in the electricity sector is no longer sufficient and the contribution made by renewable sources must create benefits for the system as a whole. Considering energy carriers in isolation has become insufficient, just as demand sectors cannot remain locked in fossil-based energy vectors, and the energy infrastructure must contribute to the integration of these different sectors. The efforts to increase the renewable energy electricity penetration must be integrated with other sectors to increase the pace toward the climate neutrality of the European energy system as a whole. Energy storage outside the electricity sector as well as waste heat and green gases also need to be considered part of the solutions, see Mathiesen, B. V. et al (2015). For these reasons, the Expert Group has decided to consider the potential contribution of the electricity sector through smart sector integration (SSI) to the new objectives established by the European Green Deal.

Climate neutral scenarios

The target of "No net emissions of greenhouse gases by 2050" has been proposed by the European Commission in the framework of the European Green Deal, a "new growth strategy that aims to transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy". This strategy derives from the EU's ratification of the Paris Agreement, which aims to limit global warming to well below 2°C, whilst pursuing efforts to limit it to 1.5°C. The cumulative greenhouse gas emissions must be limited to a value still to be defined, currently estimated at between 60-65 GtCO2eq, according to the European Commission. The current binding EU target for 2030 includes a 40% decrease in annual greenhouse gas emissions, a 32.5% energy efficiency improvement and a 32% increase in renewable energy. These targets refer to the energy system as a whole, not to specific sectors such as transport, industry, buildings or agriculture. The future energy system design, as well as the supply and demand for heat, liquid fuels, electricity or gas must be aligned to this. Moreover, as future energy systems will be connected across sectors, targets will also need to be more interconnected.

In 2018 the European Commission issued "A Clean Planet for all - A European strategic long-term vision" (the so-called EU Long-Term Strategy), where, for the first time, it put forward key scenarios to achieve the Paris Agreement's 1,5°C target. The publication contains eight scenarios in which the long-term climate obligations would be met. In September 2020 the European Commission published the "Climate Target Plan" proposing to increase the greenhouse gas emission reduction target to 55% by 2030, along with a set of updated scenarios.

Many other stakeholders and organisations have also issued scenarios for the future European energy system, including in particular the scenarios for the Ten-Year Network Development Plan (TYNDP) 2020 by the two European networks of transmissions system operators, ENTSO-E and ENTSOG. Nevertheless, two remarks on all scenarios are in order. First, they do not deliver enough detailed information required for planning infrastructure in an integrated energy system for 2050 yet: among other things, they do not include proper assessment of district heating infrastructure. Second, all scenarios indicate larger shares of electrification, while there are differences in the balance between energy efficiency and renewable energy electricity, the level of other resources that should be used and the energy system design. The level of electrification differs but increases in all scenarios. Therefore, for the purpose of this report, further electrification and further efforts on energy efficiency are considered as a starting point.

What is smart sector integration?

The concept of smart sector integration (SSI) that will be used in this report encapsulates the challenge of making an optimal use of the opportunities offered by sector integration to create pathways for the climate neutrality of the energy system in the most cost-efficient and sustainable manner through, particularly, promoting energy efficiency and the efficient use of infrastructures by supporting the most efficient allocation of energy vectors to demand areas.

Through sector integration, the different energy carriers in the energy system (electricity, gas, liquids, heat) are progressively linked with each other, but also with the end-use sectors (buildings, mobility, industry, agriculture). This creates the opportunity for synergies across sectors by optimizing the energy system as a whole, instead of addressing each sector independently; in particular, it allows for the achievement of climate neutrality of additional end-use sectors. A good example of sector integration is the electrification of road transport, which is more energy efficient, links a demand sector to a different energy carrier and opens up the opportunity for electricity from renewable sources to feed more energy demand. Electrification of road transport can contribute to the cost-efficiency of the energy system and increase demand flexibility through the management of the charging and the usage of the vehicle fleet. Another example is the connection of district heating with large-scale heat pumps, combined heat and power, as well as excess heat from electrolysers. As the energy efficiency of buildings improves, large-scale heat pumps become more performant, reducing overall costs.

Embedded in SSI is sector coupling, which refers to linking the supply side of electrons and molecules as well as their related transmission and distribution networks, also in order to enable the optimisation and climate neutrality of the energy system. Admittedly, both gas-fired power plants and combined heat and power generation have long brought a sector coupling element to the energy system. Part of these generation plants may gradually switch to renewable or climate neutral gas, whereas non climate-neutral power plants will run less in a renewable energy system. In addition to large-scale heat pumps and the deployment of district heating, a new technological pathway that could reinforce sector coupling are power-to-gas installations (electrolysers), which convert energy in the form of electricity to energy in the form of gas or liquid and can provide waste heat for district heating. The production of these fuels through sector coupling can enable the climate neutrality of other sectors, such as aviation, heavy transport or industrial demand requiring high-temperature processes, where direct electrification is not possible. This would also represent a form of sector integration through indirect electrification and inject a potentially significant demand flexibility to the electricity system.

SSI implies an optimisation of involved processes and sectors, as well as an overarching coherence and complementarity of the policy, legislative and regulatory frameworks. Sector integration can only be considered smart if it addresses multiple policy objectives consistently, including climate neutrality, but also energy efficiency, security of supply, sustainability and inclusion. There is also no one-size-fits-all approach to SSI, since the starting point of each Member State is different. These multidimensional interactions will ultimately determine the feasibility and success of the sector integration process.

The purpose of this report is to explore how the electricity sector and SSI may support progress towards a climate-neutral EU energy system. The composition and purpose of the Expert Group are the reasons behind the emphasis on the electricity sector. The report is limited to technologies closely related to SSI; other relevant climate-neutral technologies are not analysed. Two initial observations are in order. First, while the Group acknowledges that different technologies have different environmental impacts, the report does not assess each of them individually, instead, it assumes that all efforts are made to prevent and reduce negative impacts. Second, the COVID19 crisis is likely to alter some scenarios and assumptions underpinning this report, but its impacts are not considered.

The report is organised as follows: Section 2 investigates four main paths for the electricity sector to contribute to climate neutrality through SSI, while section 3 explores the related risks and difficulties. Section 4 presents the Expert Group's recommendations.

2. HOW CAN THE ELECTRICITY SECTOR CONTRIBUTE TO CLIMATE NEUTRALITY THROUGH SSI?

The general consensus is that sector integration is an essential piece for the climate neutrality of the EU energy system. Although the energy system designs put forward by the different scenarios diverge substantially, electrification and sector integration are common elements to all of them, as means to reach climate neutrality. The potential contribution of SSI to the climate-neutrality process should therefore be carefully assessed to identify both the major risks linked to the deployment of different technologies, as well as the most promising opportunities to reach climate neutrality.

The main paths through which SSI can support climate neutrality are the following:

1. Electrification of additional sectors
2. Sufficient amounts of renewable electricity and availability of infrastructure
3. Availability of strong and diverse flexibility services
4. Climate neutrality of demand sectors that cannot be easily electrified
5. Creation of a circular economy
6. Energy efficiency
7. Use of heat as carrier of climate-neutral energy
8. Diversification of supply and improved reliability of energy systems.

These paths tend to complement and support each other towards the goal of climate neutrality, provided that the technological, economic, political and societal conditions enable the decisions of consumers and investors. SSI implies the optimization of diverse opportunities: it leverages the complementarity of actions and measures by matching the needs of different actors and by targeting cost-efficient climate neutrality in the different energy sectors. However, due to the experience and background of the Expert Group, only the first four paths are discussed in this report.

2.1. Electrification of additional sectors

The main path for the electricity sector to support climate neutrality through SSI is an increase in the share of total energy consumption covered by electricity generated with renewable resources. Electrification of end-user demand, where this is practicably and economically feasible, is the most important path through which SSI contributes to climate neutrality. Indeed, direct electrification offers opportunities to avoid conversion losses and reach a very high energy-system efficiency at a low cost, due to the intrinsic efficiency of electricity and the technological maturity of areas such as wind and solar as well as heat pumps and e-vehicles. Moreover, the opportunities for electrification are reinforced by the declining costs of electricity generation from wind and solar, the high efficiency or electric engines and the strongly decreasing cost of batteries. Several scenarios coincide in pointing out that electrification is the main path.

For instance, Eurelectric (2018) indicates that electricity will play a leading role in transport where up to 63% of total final energy consumption will be electric in the most ambitious scenario. District heating and cooling are expected to keep playing critical roles in some regions, while 45% to 63% of energy consumption in buildings could be electric in 2050, driven by the adoption of electric heat pumps. A series of industrial processes can technically be directly electrified with up to 50% direct electrification in 2050.

Since additional electrification leads to a reduction in overall primary energy needs, it is by default a good option. However, some sectors are difficult to electrify, for example heavy industry, high-temperature processes, long-haul transport, shipping and aviation. For these sectors, alternative climate-neutral energy carriers must be available. In addition, it should be acknowledged that higher electricity demand will require more renewable capacity and significant infrastructure deployment and that the system costs should be kept under control. For example, a conversion from gas boilers to electric heating with heat pumps can be very expensive if it requires the expansion of the electricity distribution grid. Several studies point to a large potential for district heating in Europe, since it can provide cheaper infrastructure, lower upstream costs and a more robust energy system.

2.2. More renewable electricity in Europe and neighbouring countries

The electrification of final demand is, as already mentioned, a central feature of SSI. In an increasingly electrified energy system, renewable energy generation gradually becomes the main source. SSI is expected to support electrification in sectors that are not electrified today, but also to contribute to providing the required flexibility in order to deal with variable generation from renewable sources. However, for SSI to contribute dynamically to the goal of climate neutrality, sufficient (and efficient) renewable energy generation must be made available, in order to satisfy the increasing electricity demand. Already available opportunities in the EU must be strengthened, diversified and enhanced, including in particular the integration of renewable electricity across the EU countries and between the EU and third countries.

Better integration of renewable electricity across the EU was the focus of the Expert Group's first report, and it will not be discussed again here. Nevertheless, two of its recommendations should be underlined. First, interconnection targets must have a triple dimension, measuring: a) the degree of market integration, b) the capacity of interconnectors and related internal grid reinforcement for importing electricity, and c) the capacity of interconnectors and related internal grid reinforcement for exporting renewable electricity. Second, priority should be given to the more efficient functioning of the European electricity market.

The Expert Group highlights the contribution of SSI to climate neutrality through the timely, efficient and sustainable integration of renewable energy from four specific sea basins with very high RES potential. It is essential to plan infrastructure development so that additional renewable energy resources (wind power and PV) can address new and existing electricity demand centres. This will be particularly important in developing the renewable energy potential from the following four regions (in alphabetical order): the Atlantic Ocean, the Baltic Sea, the Mediterranean and the North Sea. These regions provide a dense geographical concentration of renewable energy, while the countries in these regions comprise an interesting mix of EU Member States, EEA and EFTA countries, as well as third countries. These features and particularities offer new opportunities and present new challenges.

- The Atlantic Ocean (including the Irish Sea and the English Channel) has an offshore wind potential of about 85 GW in 2050 as estimated by WindEurope (2019). As of 2019, less than 1 GW per year is installed in this region. However, given cooperation over the past 10 years between the United Kingdom and the Republic of Ireland in Northern Seas Offshore fora related to the North Sea basin, there is a strong overlap between developments in this sea basin and in the North Sea and adjacent basins as discussed below.
- The Baltic Sea region is already developing fast in terms of infrastructure for offshore wind parks and electricity interconnections. It has eight interconnectors linking the Nordic, Continental Europe and Baltic States. The High-Level Group on Baltic energy market interconnection plan (BEMIP HLG) has proved truly successful in driving the integration of regional electricity and gas systems forward. Moreover, the ensuing synchronisation of the Baltic States with the Continental Europe network will enhance the

processes of market integration in the wider region. This region has already today over 2.2 GW of offshore wind capacity installed and operating (Denmark: 872 MW, Finland: 68 MW, Germany: 1.074 MW and Sweden: 192 MW). WindEurope (2019) estimated that installed offshore wind capacity in the Baltic Sea could reach 9.5 GW by 2030 and 85-93 GW by 2050. New generation and infrastructure projects, in both the electricity and gas sectors, are emerging quickly in the region.

- The potential for affordable and cost-competitive renewable energy production in the Mediterranean Sea region is huge, particularly in terms of solar and wind energy. Southern EU Member States and North African countries are among those with the highest Direct Normal Irradiance (DNI) in the world, more than 2300-2500 W/m2 around the Mediterranean Sea. Although widely accepted estimations of solar potential in the Mediterranean are lacking, the figures suggest between 50 and 60 GW by 2030. For example, the National Energy and Climate Plans (NECP) of Italy and Spain alone indicate that the installed photovoltaic capacity will reach 52 GW and 39 GW respectively. Although it depends on the development of floating offshore wind technology, which is not mature yet, the region's offshore wind potential is very significant: WindEurope (2019) estimates it at about 70 GW for 2050. This offshore wind potential is concentrated in Portugal, Spain, France, Italy, Greece, Tunisia and Libya. In addition, the European Commission's initiative "Clean Energy for EU Islands", launched in 2017, creates opportunities for islands in the Mediterranean Sea to become innovation leaders in the clean energy transition, for Europe and beyond. The political cooperation between the European Union and the Mediterranean third countries takes place in the framework of the Union for the Mediterranean supported by MedTSO, where cooperation in energy and climate-related sectors is a major component.
- The installed offshore wind capacity in the North Sea, today about 20 GW, is expected to increase to 212 GW by 2050 (WindEurope, 2019). This would require up to 1000 more offshore substations, cable routes and onshore substation connections. Taking into account the related increase in on- and offshore cross-border interconnections, required to best manage variable renewable generation, which the Expert Group has previously recommended to be linked to capacity of renewable electricity sources, it follows that the total grid infrastructure requirements would be even larger. Today several subsea interconnectors are either in operation or under construction and will be complemented by planned

interconnections between the region's four synchronous areas – including the UK and Ireland. The capture of massive North Sea wind energy resources also opens up many opportunities for the energy chain: production, storage, transformation (power-to-gas, power-to-X), transportation and final use (industrial/commercial/domestic). Some energy island projects are already envisaged combining it all. The North Sea region also offers the potential for demonstration of cross-sector integration considering the significant oil and gas energy footprint and the advances being made in Carbon Capture Utilisation and Storage (CCUS) with geological storage in this region.

In summary, the opportunities for large-scale, efficient renewable energy generation in these four sea regions are huge, offering options both for direct integration into the EU electricity network and for transformation into other energy carriers. The effective contribution of these regions to climate neutrality requires integrated approaches that, in turn, demand long-term planning, huge capital investments and political support. Financial and technological risks, unavoidably attached to investments of this scale, are compounded by political and regulatory risks, which themselves are amplified by the mix of EU and third countries existing in each of these regions. This has implications for the design of market arrangements, which should be flexible to accommodate these regional opportunities and to encourage the participation of EEA, EFTA and third countries in this shared challenge of climate neutrality. Finally, it is essential for the exploitation of resources in these regions to ensure the availability of sufficient transport capacity, the planning of which should go hand-in-hand with generation planning to reduce delays and the risk of stranded assets.

2.3. Increasing the flexibility of the electricity system

Flexibility is an important feature, a valuable service which requires appropriate tools for the energy system, particularly electricity systems, increasingly characterized by variability in both supply and demand. A power system employing large amounts of wind and solar energy requires proper tools and components to increase system flexibility, so that it can cope effectively and efficiently with variability, while minimizing system costs and avoiding generation overcapacity. An adequate geographical planning of local renewable energy sources may also facilitate flexibility management and reduce costs.

Increasing demand-side flexibility is an important step to achieve a climate-neutral energy system. Demand-side management is in general a cost-efficient way to avoid curtailment and consume electricity when it is most economical. Its effective exploitation can reduce the need for back-up capacity, including imports of fossil fuels. Demand-side management, complemented by an optimal use of distributed resources, can also reduce the need for additional transmission and distribution capacity. The most promising options for demand-side management are in sectors and technologies such as electric vehicles, large-scale heat pumps, industry and new electrolysis plants. The following examples illustrate how electrification must be combined with demand-side management, in order to actually increase its contribution to overall efficiency, reduced fossil-based generation needs for flexibility purposes and lower conversion losses:

- Electric vehicles are able to charge batteries at night and will increasingly be able to delay charging up to a week, mainly consuming electricity when renewable generation is high and prices are low.
- Large heating systems, including district heating, may use electricity when the load is low and electricity prices are low or medium, while using other energy carriers such as waste heat from industry, bioenergy or climate neutral gases at peak hours when electricity prices are higher.
- Local heating systems may also invest in heat storage, which is relatively cheap and may become cheaper in the future, to increase flexibility and reduce dependence on other energy carriers. Heat pumps may also be flexible, in particular when combined with heat storage, or with a gas boiler as hybrid heat pumps or large storage batteries.

In addition to the abovementioned demand flexibility options, supply-side flexibility tools are also needed in order to compensate for the variability of renewable electricity supply that cannot be compensated with demand measures. Available options will change over time but already today, in some European regions, especially in its geographical periphery, there is a need for solutions and tools that can promptly offer technologically mature, cost-efficient flexibility, while at the same time reduce harmful air and climate emissions to a minimum. Hydro storage, both pumped (PHS) and with water reservoir, has long been an available option to increase supply-side flexibility. However, the potential storage capacity of water reservoirs in the EU is limited, while PHS has a much larger potential. Relevant studies estimate that the existing PHS capacity has the potential to more than double in the next decade (JRC, 2013). For EU Member States and for EEA and EFTA countries with rich hydro resources, pumped storage is a prime opportunity. However, consideration must also be given to how the potential for supply-side flexibility can be increased by more interconnection between power systems.

Other flexibility options such as natural gas power plants are available, but their impact on emissions advise limiting their use to those hours with insufficient renewable energy production, unless they run on biogas, syngas or green hydrogen or are equipped with carbon capture, utilisation and storage (CCUS) systems. An alternative could be gas-fired power devices, be it small decentralised or in larger units fuelled by green hydrogen or other power-to-X fuels. In some regions, batteries in buildings are promoted. So far, batteries are expensive, but costs are declining rapidly and batteries in buildings may in future contribute substantially to flexibility. Batteries may also be beneficial at the distribution grid level to ensure grid stability, prolong the lifetime of transformer stations and facilitate electrification while limiting grid investments. Electric vehicle charging guided by well-designed electricity markets and grid tariffs can also increase demand flexibility.

Given the right incentives from market prices and good regulations, many flexibility options may be developed with the involvement of renewable power generation facilities, demand-side actors or grid operators.

SSI offers opportunities for increasing system flexibility both by incorporating sectors with complementary and flexible loads and by transforming variable renewable power supply into storable energy through power-to-gas or power-to-liquids. However, the capacity to provide such flexibility is constrained by technological uncertainties and cost inefficiencies. Electrolysers in future energy systems need to be dispatchable and use renewable electricity to reduce infrastructure needs. Moreover, incentives to the flexible use of electricity transmission and distribution grids are important in order to avoid costly infrastructure expansion due to the deployment of electrolysers. Efficient market prices may, together with good planning processes, lead to a localisation of electrolysers that is beneficial to the grid and to the use of the waste heat they generate.

Given the increasing share of intermittent renewable generation, the flexibility of the power system needs to be promoted further by an appropriate functioning of the short-term energy markets to dispatch efficiently the flexibility sources both on the demand (interruptible load, demand-side management) and the supply sides (hydro reservoirs, pumped hydro storages, batteries). Gas-fired power plants using renewable or climate-neutral gases are expected to remain expensive options in the years leading to 2030 because of higher fuel costs. However, they will be key to providing firm capacity and contributing to a flexible and secured energy system in the long term. In addition, interconnections between power systems also contribute to flexibility.

Notice that options to provide flexibility strongly depend on the system context. Regions with easy access to complementary regions by means of transmission networks are in a very different situation than islanded regions, be it islands or peninsulas, which have to use local resources to provide flexibility. Moreover, EU Member States with limited interconnections to the European grid and increasing shares of renewable generation have rapidly rising needs for electricity flexibility. The development and realisation of the large European PHS potential (70-75 GW until 2030, according to the JRC(2013) study "Assessment of the European potential for pumped hydropower energy storage"), which has been relatively slow so far, should be put at the forefront of actions to ensure the flexibility required for SSI.

2.4. Transforming some sectors that cannot efficiently reach climate neutrality through direct electrification

Electrification is not expected to cover all energy demand. European mainstream scenarios estimate a future electrification rate between 50% and 70%. Climate neutrality requires increasing electrification and renewable electricity generation, as well as solutions for sectors that cannot be directly electrified. It is of paramount importance to bring clarity as to in which particular sectors, and under what circumstances, can the use of renewable gases or liquid fuels be viable and cost efficient, so as to adopt relevant preparatory measures and actions for them. With the current level of knowledge, it appears that some high-temperature industrial processes, feedstock for chemical industries and liquid fuels for air and maritime transport may require such solutions.

Currently synthetic hydrogen is mostly produced from fossil fuels, whereas only a small part of methane is produced in a renewable way from biomass. However, power-to-gas technologies can use renewable electricity to produce synthetic hydrogen through electrolysis. This hydrogen can either be used directly or be converted into synthetic methane through methanation using carbon dioxide. If the latter is captured from biomass/biogas or directly from the air, it can further reduce the carbon footprint of the full cycle. The advantage of methanation is that methane can be used directly in any of today's standard gas infrastructures and applications; at the same time, each conversion step leads to additional energy losses, increasing the production cost of the final carrier. CCUS can contribute to hydrogen development when sourced directly from a fossil fuel, in particular natural gas. It can enable hard-to-electrify industries to contribute to a climate-neutral economy. However, the usefulness and extent of CCUS will be determined by the availability of suitable storage facilities, by the technology costs and, last but not least, by the degree of public acceptance. Some EU countries show resistance to CCUS, due to lack of experience with geological risks especially in seismically active regions.

Electrolysers producing hydrogen from water using renewable sources are likely to play the most significant role in the long term. IRENA (2018) highlights the potential of hydrogen to channel large amounts of renewable energy to sectors for which electrification is otherwise difficult, such as industry and transport, as well as in niche applications, such as in remote locations. Hydrogen from renewable power can directly displace hydrogen produced from fossil fuels, as well as replace fossil fuels and feedstocks in several processes. Moreover, the addition of hydrogen storage facilities is necessary to decouple the variable operation of electrolysers from the continuous hydrogen demand. Nevertheless, attention should be given to ensuring that the use of renewable electricity for hydrogen production does not increase emissions in the overall energy system.

Finding the best locations for electrolysers will represent a challenge for infrastructure planning processes. Locations close to excess renewable generation, water, and affordable transportation to hydrogen demand clusters, in particular via repurposed natural gas infrastructure, would contribute to maximizing their benefits. In other cases where sufficient electricity transmission lines to demand centers are available, proximity to demand sites may prove more beneficial.

3. MAIN RISKS FOR THE CONTRIBUTION OF SSI TO CLIMATE NEUTRALITY

The review of different scenarios and the analysis of the opportunities offered through the main SSI paths provide a perspective for the contribution of SSI to the goal of climate neutrality of the EU energy sector. However, it is essential to underline the risks and difficulties surrounding the realisation of those projections and processes. The Expert Group recognises that there is a large variety of risks hampering the attainment of the climate neutrality goal by 2050; this report focuses on the specific category of risks affecting the potential contribution of SSI.

3.1. Technology maturity questions

SSI involves a wide range of technologies and services and many of them are at an early stage of development and deployment. For example, applications for power-to-gas and power-to-x production are still characterised by low technology readiness levels and/or relatively high costs in comparison to prospective assumptions in scenarios. The same can be said about other technologies, such as floating offshore wind technologies. In other words, the potential unavailability of technologies that are assumed to be available in the different scenarios would prevent the realisation of the corresponding investments and results. Although such technologies should be included in long-term projections, sensitivity analysis must inform regulatory and investment decisions to properly consider the related uncertainties and evaluate and manage the risks associated.

The following list provides examples of divergences in the range of existing scenarios that point to substantial uncertainties on cost and availability of the following technologies:

- Climate-neutral natural gas imports: the TYNDP 2020 Global Ambition scenario (one of the three scenarios developed by ENTSO-E and ENTSOG in the framework of the EU-wide Ten-Year Network Development Plan) forecasts 1800 TWh/year of climate-neutral natural gas imported from outside Europe in 2050 against no imports of climate-neutral natural gas on 2020.
- Hydrogen and methane produced from electricity on a large scale: the Eurelectric 90% scenario forecasts 200 GW in 2050 against 650 GW in the 1.5TECH scenario in the EU Long-Term Strategy, and less than 1 GW in 2020.
- Demand response solutions: the Eurelectric 90% scenario forecasts 150 GW in 2050 against 30 GW in 2020.

- Battery storage: the Eurelectric 90% scenario forecasts 150 GW in 2050 (60 GW in TYNDP 2020 Global Ambition scenario) against less than 1 GW deployed in 2020.
- Domestic biomethane production: the TYNDP 2020 Global Ambition scenario forecasts 750 TWh/year in 2050 against 450 TWh in the baseline scenario in the EU Long-Term Strategy. Lack of clear consensus on the use of methane may pose risks of investing more into natural gas infrastructure.
- There are large divergences between the level of energy efficiency in both buildings and industry, even from the baseline scenario in the EU Long-Term Strategy for 2050 compared to other scenarios.
- Use of hydrogen in heavy-duty vehicles transport. The uncertainty in the level of electrification in the transport sector leads to difficulties in energy infrastructure planning decisions.
- Direct electrification on high temperature industrial processes is also uncertain, both in terms of technical feasibility and of economic viability.

Power-to-gas pilot projects show that these technologies enable closer integration between power and end-use sectors. However, they are not yet economically viable, due to several factors, the most relevant being: high technology costs, high life-cycle energy losses, slow progress in scaling-up pilot projects, relatively low carbon prices, and lack of consensus on whether and how market models need to adapt. According to Mathis W. (2020), if hydrogen costs reach $1 per kilogram, a price of at least $50 per ton of carbon dioxide would enable the switch from fossil fuels to clean hydrogen in steel-making by 2050 and at least $60 per ton to enable the switch to hydrogen for heat in cement production. To switch to hydrogen in chemicals production, including ammonia, a price of at least $78 is required, while it would take at least $145 for the switch to happen in the ship transport sector.

If technological uncertainties are not properly taken into account in investment decisions, this may lead to the construction of infrastructure that may become stranded. This may in turn prevent the construction of other infrastructure that would have provided a better contribution to the goal of climate neutrality. SSI solutions demand consistent changes over multiple networks (e.g. electricity, gas, heat, transport, and other) that must be timely planned and implemented to reach the projections of some long-term scenarios. Delays in the deployment of one or the other infrastructure may lead to significant economic losses.

3.2. Huge investment for electrification, renewable generation and infrastructure

According to the EU Long-Term Strategy, climate-neutral scenarios require annual investments for the period 2030-2050 between 500 and 575 billion 2013 euros (excluding transportation). Such investment would represent around 2.8% of the EU´s GDP, while today around 2% of the EU's GDP is invested annually in the energy system and related infrastructure. In most climate-neutrality scenarios, the investment needs are concentrated on power grids (17%-23%), renewable generation (10%-20%) and the residential sector (43%-50%). These figures give an idea of the efforts required by consumers and investors and the associated financial risks during the coming 20-year period.

The Expert Group envisions relevant obstacles for investments supporting SSI and climate neutrality. The EU is spending about 20% of its overall budget for 2014-2020 in climate change-related action. The European Council agreed in July 2020 to increase this climate mainstreaming to 30% for the future EU budget for 2021-2027. Although EU spending remains a catalyst to leverage private and public investment, the currently planned increase is insufficient compared to the required additional investments. Although the obstacles can affect all kinds of investment, there are specific issues and difficulties associated to: 1) electrification of additional sectors and 2) Deployment of infrastructure and renewable generation.

1) <u>Electrification of additional sectors.</u>

The huge investment needs, together with the energy prices and tax structure in place today are challenges for most sectors and in particular for the electrification of additional sectors. For example, according the EU's Long-Term Strategy, the transformation of buildings would require around 200 billion euros per year. In most EU countries, currently the return on investments transforming fossil-based heating systems to electricity is still negative. This may largely be the result of too low carbon prices and distorting taxation on energy carriers. Moreover, even in those cases in which the transformation options generate positive present value, full investment recovery takes many years, thus requiring long-term financing schemes as well as sustainable and innovative regulatory frameworks reflecting this situation. Therefore incentives and risk-management tools may be too weak for private investments and communities to undertake such transformations. To mitigate the lack of incentives for electrification, individual sector analysis are required, since challenges and hurdles differ. The European Commission launched in October 2020 a "Renovation wave" initiative in the buildings sector, with a set of measures to promote the transformation of buildings and increase renovation rates.

Although building renovation could reduce demand and trigger more electrification, there are also other relevant complementary options that balance supply and demand. Research shows that there is enough waste heat to cover all heat demand in buildings in Europe and up to 50% of the buildings in Europe could be cost-effectively supplied by district heating grids. In this framework, electricity can cover between 15% and 40% of the heat demand via heat pumps and demand-side efficiency measures. Thermal grids can have much lower costs than expanding the local electricity distribution grid and, contrary to individual heat pumps, they can ensure a flexible electricity demand by switching between electricity and other energy carriers and by using heat storage.

2) <u>Renewable and infrastructure deployment</u>.

Electrification of additional sectors will increase demand for electricity, a demand that needs to be covered by climate -neutral electricity. As a consequence, it is estimated that renewable electricity generation and related grid infrastructure require annual investments between 180 and 220 billion euros per year in most scenarios, as shown in the EU's Long-Term Strategy. The development and deployment of the required renewable generation and grid infrastructure face major risks associated with a lack of appropriate market signals for investment and flexibility tools, as well as space scarcity and public acceptance.

Europe is generally densely populated and space scarcity is already a challenge in most Member States. With increasing deployment of renewables, conflicts among competing land uses will intensify. To manage these conflicts new approaches are urgently needed, such as involving a large variety of stakeholders in energy infrastructure planning to find solutions and compromises and invest in promising emerging technologies, such as offshore generation. In particular, the participation and contribution of environmental protection civil society groups to the planning process is necessary to ensure the protection of ecosystems. Other elements, such as the development of distributed resources, can help reduce social opposition to energy infrastructure projects. The third report published by this Expert Group provided a set of recommendations on how to deal with public opposition.

3.3. Issues related to Markets and Prices

SSI is about optimizing the whole energy system by exploiting synergies between energy sectors that have traditionally operated separately. This optimization increases resource efficiency and lowers the total cost of the energy system. Markets would play a key role in achieving this optimization, since most investment and consumption decisions will be taken through markets, by using prices for individual and collective choices. Therefore, core elements in the development of SSI are:

1. Internalization of the **cost of carbon** and other environmental externalities in energy prices.
2. **A common level-playing field** for the different energy carriers and grids for electricity, heat and gas by harmonizing carbon prices between ETS and sectors outside ETS, and by removing distorting taxes and regulations.
3. Development of **efficient markets** with prices reflecting the balance between supply and demand in each region and hour. This is particularly relevant to the power market, where market conditions may change significantly hour by hour, depending on variations in demand, solar radiation, wind etc.

If these three elements are not working appropriately, the SSI energy investment and operation decisions will not be coordinated and desired results may not be reached. This is because millions of large and small investments related to energy supply and consumption are strongly influenced by current energy prices and expectations on future ones, as well as by profitability and risks associated with present and future energy markets and regulations.

Although progress has been made in eliminating price distortions, issues related to energy prices and market structures remain. This section analyses five pending developments.

1. <u>Electricity Market signals do not yet sufficiently promote investment</u>.

A set of EU electricity market failures still prevent adding renewable investment and injecting flexibility into the system. In competitive markets, capacity providers offer available electricity at a price equal to their marginal or opportunity costs. In peak periods, in which supply is lower than demand, prices are expected to reflect scarcity and be higher than marginal generation costs. However, during off-peak periods, the price of electricity on the markets is equal to the marginal cost of the most expensive capacity required to cover the load. When renewable sources can cover the entire load, the marginal cost is close to zero because their variable operating costs are extremely low. Inadequate subsidy schemes might even steer the electricity price to negative values in such situations. Since market prices tend to reflect marginal costs, the recovery of fixed costs is challenging and subject to high uncertainty, especially in systems with high shares of renewable electricity. This jeopardises any new investment and endangers the market-based revenues of high capital-intensive assets, which can in turn slow down the deployment of renewable generation assets.

2. Carbon Prices.

Optimal carbon prices and their proper internalization are key pending issues for investment and consumption decisions required for SSI to materialise. Although defining the right level of carbon prices is not a task of this group, the gradual inclusion of additional sectors in the ETS system would lead to a significant increase of current prices. Such carbon price increase would push individual decisions of consumers and investors towards low-carbon energy.

Notice that optimal carbon prices would also contribute to improve the functioning of electricity markets. Higher carbon prices will increase electricity prices the most during hours when the least efficient and most polluting power generation will be needed to cover demand. Conversely, electricity prices will generally be pushed down when solar and wind power production is very high and demand is low (cannibalization). These two price effects will increase price variations and give incentives to develop many types of flexibility, both in generation (e.g. biogas, hydrogen fuel cells) and in demand. Periods of high power prices incentivise solutions that can replace fossil power generation and periods with low prices incentivize the efficient utilization of power in hours of high solar and wind power production. In addition, both incentivise energy storage.

3. Framework for promoting climate-neutral flexibility services

Traditionally, there have been two stochastic processes in power systems, which defined the need for reserve capacities and flexibility. These were the variation of demand and the failures of components. The growth of renewable energy resources has added a third stochastic process to power systems, namely the variation of generation from variable resources. Moreover, this third process is the most dynamic among them and will become the dominant one in terms of size in the foreseeable future. As a consequence, ensuring flexibility in all time frames will become a much more central challenge in future energy systems, starting with very fast responses (seconds or minutes), continuing with variations caused by rapid changes of wind or solar irradiation over flexibility within a few hours or a day, and ending with seasonal balancing of generation and demand.

Since the early days of adding variable renewable resources to power systems and markets, several improvements have ensured a more efficient provision of flexibility. For example, shortening market-closure time down to 15 minutes today in some countries (for example, Germany) has shifted coverage of short-term flexibility needs from power plants participating in system control (with up-front reserved capacity and unused market flexibilities) to the intra-day markets. Moreover, over the last years, markets have opened to a variety of actors and this trend should further continue. An example is the acceptance of smaller generators and pools as market participants.

Nevertheless, all of the market improvements introduced so far assume sufficient dispatchable capacity as last fall-back option. With increasing shares of variable renewable energy and in the absence of investments in firm capacity to replace decommissioned or phased-out units, this cannot be taken for granted any more. Future power markets will therefore require a stronger focus on physical availability and delivery in time in the short term and the market design will have to provide the long-term visibility needed by investors and market participants. In other words, since revenues largely depend on short-term prices, visibility on future needs and tools to ensure appropriate market reactions will play an important role to secure the energy supply in the long term.

Demand-side management is a complementary no-regret option, but current practices and regulations in some EU systems constrain it. For instance, in some national power systems (e.g. Germany, Greece or Spain) the cost of back-up facilities is distributed among retailers quite independently of the retailer load variability. On the supply side, hydro storages and other assets offering primarily flexibility should be properly remunerated for the services they offer (flexibility and contribution to system adequacy) and on equal footing with the remuneration of other technologies. The market design must provide the right incentives to ensure sufficient investments, efficient operation and maintenance and trigger innovation as a means to guarantee the most efficient approach to all of these requirements in line with the climate-neutrality challenge. A well-designed framework must define all functions required to ensure balance between demand and supply.

4) Markets and opportunities for new climate-neutral products and associated services

SSI is expected to bring new products and services, some of which will not participate in existing markets. The regulation of new markets should promote an optimised, coordinated and coherent interaction between all energy sources, including a functioning and competitive hydrogen market based on a pan-European transmission infrastructure dealing with large volumes of hydrogen. Appropriate market regulation is a pre-condition for an optimal realisation of the full potential of SSI, including the potential role of power-to-gas and hydrogen to support power grid balancing in a cost-effective way.

5) Relative prices for final users

The relative prices of fuel, gas, heat and electricity often discourage electrification, power-to-gas and heating investments related to SSI. With the current relative prices, the net present value of efficient electrification investment in some EU countries is negative. The same can be said of power-to-gas, which is also hampered by low technological maturity. The current structure of energy prices faces two main issues: lack of internalisation of the negative externalities and the methodologies for the recovery of regulated fixed costs.

First, many energy prices for final users do not reflect the negative impact of fossil fuels on climate change. The ETS carbon system addresses this externality, but it is too low to reflect the societal cost of carbon emissions. Incentives for SSI are weakened by the non-inclusion of a number of economic sectors in ETS. Other relevant externalities to be internalised in prices are local and regional pollution resulting in biodiversity losses and impacts on food production and health. A partial adjustment of externalities could be achieved by the expansion of the ETS to additional sectors or the introduction of similar levels of carbon pricing on fossil fuels outside ETS.

Second, regulated fees and tariffs for using electricity networks are set to recover the total costs of the infrastructure. However, the regulatory imputation methods for setting and distributing such costs among users are quite different among Member States (there is no EU-level regulation) and often inconsistent with policies aiming at climate neutrality. For example, in some countries (e.g. Germany or Spain) the cost of ramping up renewables at a time when they still required strong financial support was stacked on top of the existing electricity prices. This created a misperception among consumers that other sources may be cheaper because their costs were not visible in the electricity bill.

3.4. Obstacles for the integration of renewable energy from specific areas

The main challenges and risks for the efficient integration of the renewable energy from the four regions identified (Atlantic Sea, Baltic Sea, Mediterranean Sea and North Sea) are related to the level of investments, the impact on the security and stability of the EU power system and the lack of harmonised regulatory frameworks across the different third countries. Next, an overview of these challenges.

First, the high levels of investments needed are the result of the consensus view that single-purpose energy developments would not be sufficient. Projects must be integrated into multi-purpose energy initiatives, such as energy hubs, that can demonstrate SSI benefits. The practical approach for this integration development is modular and incremental, evaluating technical and economic parameters on a case-by-case basis. Without a well-planned project calendar, the efficient integration of offshore renewable generation in the EU system may be delayed. This risk affects all four regions, with nuances.

The second major obstacle is the significant impact on Europe's future energy supply and system stability, as the integration of these resources will change flows and operational patterns. A level of system interoperability that provides enough flexibility to grid development is essential in order to avoid lock-in effects of purely commercially developed projects. Addressing these risks requires that technology providers should strive for compatible modular systems. It also needs consistent unbundling rules for both on- and off-shore grid infrastructure developments, since these rules are critical to ensure neutrality, non-discrimination, fair competition and security.

The third major obstacle is the availability of space required for offshore infrastructure. Seas are very busy and exploited sites with diverging and multiple interests. Moreover, the cumulated environmental impacts of human activities is already critical. It is therefore necessary to carefully plan the offshore expansion involving a large number of users and stakeholders, while finding solutions for environmental protection. The ecosystem-based approach embedded in the Maritime Spatial Planning Directive (2014/89) is a good starting point.

Finally, regulatory and political risks can act as a hurdle to investments and/or undermine the return on investment. In the absence of EU-level initiatives to address such risks, the regulatory structures of the different countries may lead to an unfair treatment of infrastructure investors and developers.

3.5. Issues associated with the importation of climate-neutral energy

Several scenarios predict that the EU and EEA countries will not manage to produce enough climate-neutral energy to cover their entire energy demand. Therefore, an integrated view on all energy sectors in the sense of SSI implies the need to continue importing energy. Such energy imports will have to be compliant with Europe's objective of climate-neutrality.

In principle, energy imports can take the form of electricity or of gaseous and liquid carriers. Electricity imports would limit sources to neighbouring countries with interconnectors to the European power system. Meanwhile, gaseous or liquid carriers can in principle be sourced from anywhere in the world. Importing primarily gaseous or liquid carriers would increase flexibility on the supply side and reduce the risk of dependencies by providing access to international markets. Moreover, importing climate-neutral energy allows an optimized use of the scarce space available for renewable generation in Europe.

The problems that may arise from energy imports are related to the global availability of climate-neutral energy. The uncertainty to establish at this point the future availability and cost of imports of climate-neutral hydrogen or biomethane is indeed reflected in the divergences between the scenarios: the TYNDP 2020 Global Ambition scenario forecasts 2500 TWh/year in 2050 against 0 TWh in the EU Long-Term Strategy baseline scenario. However, even if availability were not the issue, clear rules for assessing climate neutrality of energy imports and compliance with other EU standards would still be needed in order to mitigate the risks of directly or indirectly importing non climate-neutral energy.

4. RECOMMENDATIONS

In the context of the adoption by the European Commission of a Communication on Energy System Integration in June 2020, the Expert Group's <u>central recommendation</u> is the incorporation of a detailed vision plan on the contribution of SSI to climate neutrality by 2050, that includes attainable energy efficiency on the demand side, while considering the roles of different energy infrastructures at transmission and distribution level electricity grids, district heating, district cooling and gas networks. The implementation of this plan must then be continuously monitored, including the assessment of risks and their interactions with the overall vision plan. It stresses two guiding criteria. First, the need of continuously assess the SSI risks and their interactions with other elements and decisions. Second, the need to ensure the appropriate functioning of markets to coordinate all the decisions regarding energy consumption, production and energy-related investments to that purpose. In particular, the energy market design should be consistent with three principles:

- Fully internalising the cost of carbon emissions and of other significant environmental costs in energy prices.
- Ensuring a level playing field between energy carriers to incentivise the right choice of carrier in any given situation.
- Markets should reflect the varying supply and demand, incentivising thereby flexibility of consumption and generation.

In addition to this holistic recommendation, the Expert Group put together <u>more specific recommendations</u> to guide the design, implementation, and risk management of such a vision plan.

Related to technology maturity

I. Infrastructure planning (for electricity, heating, gases and liquid fuels) and public decisions should be based on a wide range of realistic scenarios where climate-neutrality targets are most efficiently achieved, even if the assumptions on expected cost decreases and technological developments do not materialize.

II. Decisions on both investments and public interventions should give preference to projects that have the best cost/benefit balance in most climate-neutral 2050 scenarios. The purpose would be to engage immediately projects that achieve climate neutrality with the lowest risk of regret in terms of stranded costs and reject those with high risks. High-risk options can be first supported through research and development programmes and then deployed once their risk profile improves.

III. Non-regulated activities should be facilitated by markets that provide efficient signals, motivating massive investments in climate-neutrality assets and equipment. From this perspective, the Expert Group stresses that:

- Where relevant, it is necessary to adapt the European and national frameworks for State aid and energy taxation to introduce economic signals, in order to mitigate the risks that private investors cannot effectively manage.
- Special attention should be given to technologies related to:
  I. Green hydrogen, green gases and synthetic liquid fuels that are not yet profitable, but are needed for SSI between gas and electricity. In this respect, obstacles hampering progress towards competitive markets for hydrogen and other climate-neutral gases and associated services should be monitored and addressed in due course.
  II. Non-regulated district grids (heating and cooling), in order to ensure energy efficiency, use of waste heat, use of low-cost thermal energy storage and the integration of large additional, flexible electricity demand.

Related to electrification and renewable energy deployment

IV. Establishing an EU commitment, accompanied by a calendar of implementation, to undertake a revision of energy prices and taxes across all sectors and Members States to identify price distortions that prevent both the efficient operation of the current energy system and the investments needed for the system's sectorial transformation in order to reach climate neutrality. Special attention should be given to ensure both the viability of the investments needed to support the electrification of additional demand sectors and the affordability of electricity prices for low-income consumers.

V. Revising EU wholesale electricity markets to identify, taking into account, consumer preferences and decisions, which new market elements are needed to promote both renewable investment and flexibility in demand and supply, while minimizing overcapacity, ,. Addressing such issues may require appropriate long-term market signals for renewable capacity, climate-neutral dispatchable capacity, storage, specific demand flexibility mechanisms and other flexibility tools, but also the evaluation and when appropriate gradual removal of ad-hoc supporting schemes. Such signals should be implemented based on the new regulation on the internal market for electricity (EU) 2019/943, entered into force in January 2020.

VI. Completing the RES Directive 2018/2001 with more specific and targeted EU initiatives and actions in order to promote reliable and simple administrative and licensing procedures, and address the regulatory challenges associated with the development of renewable generation and electricity grid projects in progressively difficult environments. Moreover, innovative approaches must be developed to ensure local value creation where projects are being implemented.

VII. The Expert Group would like to reiterate the recommendations put forward in its report, "Public engagement and acceptance in the planning and implementation of European electricity interconnectors", (June 2019), and in particular the following:

- Develop coherent guidelines for the interpretation and application of the Environmental Impact Assessment (EIA) and Nature Directives to minimise impacts and avoid unnecessary opposition.
- Create new opportunities for stakeholder engagement that carefully consider and address opinions, concerns and needs of citizens and impacted communities.
- Seek opportunities to create and enhance local value.
- Actively pursue political coordination at local, national, regional and European level.

Related to the integration of renewable energy production from resource-rich regions

VIII. Ensuring a swift implementation of the projects included in the 4th PCI list that are essential to support the integration of renewable energy, as delays in their implementation would put the utilization of renewable energies at risk. In addition, in the ongoing revision of the TEN-E regulation, put a renewed emphasis on electricity infrastructure so as to ensure effective deployment of the projects listed in the TYNDP for the electricity transmission network whose benefits outweigh costs[1]. In this sense, the revision provides an opportunity to reinforce the role of

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[1] *ACER has a dissenting view and stresses the need for any assessment to be technologically neutral, both between different energy carriers as well as between network-based and non-network based solutions.*

smart grids for the integration of the internal energy market, for enhancing flexibility and for facilitating the secure incorporation of renewable generation. The cost-effectiveness of such solutions in comparison with other, highly complex network alternatives requiring high investments deserves to be underlined.

IX. The planning approach in geographical areas where there is a high concentration of renewable energy should ensure the consistency of national, regional and European planning. The new approach should consider the development of multi-purpose energy infrastructure. While taking into account the specific features, environmental conditions, particularities and needs of each region and Member State involved, it should be guided by the following common criteria:

- Coordination and optimization of land and resource use, while at the same time maximizing local and regional added-value and avoiding environmental damage and disruption for habitats, people and communities. This may require circular-economy structures and broad support from environment conservation bodies and relevant stakeholders.
- Common rules and standards for ensuring security and proper integration of the energy from non-EU regions into the EU system. In particular, special attention should be given to rules and standards for the operation of the electricity transmission grid.
- Adequate regulatory frameworks and structures to ensure that grid investors and developers are treated equitably, and are allowed to pursue the most efficient development options. These regulatory frameworks should also facilitate anticipatory investment, in order to deliver the most economical infrastructure in the medium to long term.
- Geographical focus on technical innovation and supply-chain development at regional level, with significant potential for export of relevant capability from the EU. Priority should be given to circular-economy principles.
- Prioritize the planning, development and investment support for “accelerator” pilot projects, at a scale that can demonstrate the benefits of sharing and efficiently integrating renewable resources into the energy systems of both the EU and third countries.

Related to flexibility in the electricity system

X. Designing and promoting the execution of a Flexibility Pilot Program, funded by the appropriate EU mechanisms, composed by a variety of pilot projects in different countries, in order to identify new technologies and Member States suited to develop efficient flexibility options that offer capacity to a wide range of regional and EU markets. The project selection criteria should include, in addition to cost, the commitments and capacity to offer short, medium and long-term flexibility to other EU markets, and the availability of infrastructures for so doing.

XI. Performing a detailed analysis, both at EU and Member State levels, to quantify flexibility needs and available means to provide such flexibility, including cost-benefit evaluations to identify net benefits for European, regional and national electricity systems. The analysis should include a large variety of options to cover flexibility needs such as further improvement of market design, storage, demand-side mechanisms, electricity interconnection with neighbouring countries, imports of gaseous or liquid fuels combined with backup power plants using them. The analysis should also identify barriers that the employment of such options is facing in today's framework and solutions to promote efficient flexibility options. If the recommended analysis is included within the framework of the European Resource Capacity Assessment required by Article 23 of Regulation (EU) 2019/43, the Expert Group want to stress the importance of its timely completion.

XII. Developing and implementing EU Guidelines for a proper, dedicated and effective operational and pricing framework for optimal flexibility options in Europe and in the Member States, ensuring that flexibility and other required system services will be offered to energy markets when needed and be fairly and fully compensated. The Electricity Balancing Guideline 2017/2195 and the Electricity Regulation 2019/943 refer to short-term markets. When fully implemented all over Europe, the corresponding signals are expected to efficiently drive the operation of the electricity system. However, the Expert Group recommends focusing on ensuring fair and reliable remuneration for these services, especially those that may be useful to manage network congestions at local level and providing reliable long-term signals (see also recommendation V.) taking into account the particularities of each Member State and regional market.

Related to climate-neutral imports

XIII. Identifying the possible sources and required infrastructures for imports of climate-neutral energy should be a priority. In the case of electricity, it implies at first an analysis of neighbouring countries with regard to their climate-neutral export potential and the complementarity of their offerings to European load and generation profiles; and secondly, the preparation of cooperation agreements and required network expansions. In case of gaseous or liquid carriers, domestic infrastructure needs must also be identified and implemented.

XIV. Establishing agreements with exporting countries on how to ensure correct measurements of the carbon footprint of the imported energy. Such agreements should include at least the following two requirements:

- First, clear settlement mechanisms for ensuring that the contribution to climate neutrality is counted appropriately by transparent multi-stakeholder processes.
- Second, embedding all agreements between countries on energy trade into an overall monitoring process to meet the objectives of the Paris agreement.

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