Commissariat à l'énergie atomique et aux énergies alternatives
Atomic Energy and Alternative Energies Commission

Answer to the European Consultation

An EU Strategy for Smart Sector Integration

May 2020

What would be the main features of a truly integrated energy system to enable a climate neutral future? Where do you see benefits or synergies? Where do you see the biggest energy efficiency and cost-efficiency potential through system integration?

Interconnection of networks

A truly integrated energy system needs a high-level of interconnection between energy networks (electricity, gas including hydrogen, heat…), as well as between countries, in order to increase the flexibility and reduce the need for storage. Indeed storage results in energy loss and it requires expensive infrastructures for energy conversion, storage and re-conversion.

There is no technological silver bullet to reach carbon neutrality

There is no magic solution – nor set of magic solutions – that enables a deep level of decarbonisation consistent with the objective set by the Commission to reach carbon neutrality in 2050, without significant efforts from the whole society, to save energy and make its use evolve, sometimes deeply. To become carbon neutral, the energy system will have to evolve not only on the supply side but also on the demand one, the frontiers becoming more and more blurred (prosumers…). It is a huge shift from today's situation, where the balance in energy networks is mainly guaranteed from the supply side. To better use the flexibility offered by the consumption side, networks and energy operators will have to develop predictive models to better anticipate energy (especially electric) peaks of demand. This will enable the implementation of effective regulations and economic incentives to influence energy demand, for instance real-time prices representative of the imbalance between demand and supply, which means prices connected to the energy market. To that end, digitalization of energy networks will be necessary. It demands also a higher responsiveness of the consumers (to price or other incentives).

Efforts to improve energy efficiency, whether passively through building insulation (for instance) or actively by replacing equipment (boilers…) or modernizing industrial processes, will also be key to reduce fossil energy demand.

The need for energy storage

A large-scale development of intermittent energy sources such as wind and solar power throughout Europe will require a significant amount of energy storage. R&D and deployment of technologies enabling the conversion of electricity in fuel molecules (gas and liquid E-fuels), known as "Power to X" – including *Power to Liquid* "P2L", *Power to Gas* "P2G" and *Power & Biomass to X "PB2X"*, need to be supported. Converting electricity into those storable and transportable fuels is not only necessary to increase the interconnection between power, heat and fuels networks but also to take advantage of existing infrastructures and reduce the cost of storage and distribution (electricity cannot be stored as such). Moreover, it provides a local capability to produce fossil-free fuels including hydrocarbons for very common usages for mobility, residential and industry. Finally, when electricity spot prices are negative because a large part of Europe is massively producing solar, wind or other low-carbon electricity (including nuclear), and production exceeds the demand, those technologies offer a way of keeping generating power as long as the grid or electrochemical storage with batteries are not strong enough to absorb this extra amount of electricity.

Power storage should not be thought of only as a dedicated function, with gigantic infrastructures specifically dedicated to this end. It has to take advantage of storage capacities developed for other purposes, such as mobility. Vehicle-to-grid (V2G) – or the ability for electric cars to give back some of the energy contained in their batteries to the grid during peak demand hours – would help stabilize the grid, reducing the need for flexible (and often fossil-based) power capacities. Development of V2G technologies will require large-scale deployment of bidirectional plugs.

Other electrochemical storage systems, such as using the second life of batteries, could provide services to the grid.

The EU will need low-carbon dispatchable power capacities on the long run

When dealing with energy matters, it is essential to always keep an eye on figures and orders of magnitude, for instance between an irreducible demand and the supply. The European Union will always need a diversified mix of energy sources, to reflect the different needs of the population (power supply, mobility, applications that will be difficult to electrify, etc.) and the territories. In any case, the EU will keep needing on the long run dispatchable power supply such as hydropower and nuclear. Member states have to be careful not to rely too much on each other to solve their potential flexibility issues. Grid operators are warning against such a trend they already notice and that could threaten power grids and supply[1][2]. To depend on other states for flexibility needs also raises environmental and sovereignty issues, especially if those states are not EU ones: environmental because nothing guarantees that neighbouring states won't provide the required flexibility with coal or gas, sovereignty because such a dependence gives a huge power to the neighbouring country without whom the energy supply is compromised. Therefore, the EU level is certainly the proper level to tackle the complementarities between Member States' energy profiles.

R&D is key to develop technologies and plan for their integration

To promote energy system integration, R&D is necessary and not only to develop new technologies but also to plan for their integration and guarantee that the energy supply will keep being able to answer to the demand. Research programmes dedicated to multi-scale (space[3] and time from the second to the year) and multi-physics modelling of demand, supply, public policies and physico-economics need to be implemented or improved. Such models need to take into account the depletion of fossil fuels and the needs and supply prospects for all non-energy critical raw materials necessary for the energy transition.

Eventually, a carbon-neutral Europe is not a Europe that will not use carbon anymore. Carbon is one of the elements most widely used in chemistry and the EU will still need liquid and gaseous fuels. Therefore, it has to develop other ways to synthesize organic molecules than from fossil hydrocarbons. It can be done through the bioproduction of high added value molecules and the storage of energy in biomass, using the most abundant photosynthetic organisms with the prospect of using them to

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[1] Tennet, "European cooperation vital for security of supply after 2025", 17/01/2020

[2] Elia, Press Release, 28/06/2019 – "*Elia prévoit un manque de capacité en hausse lors de la sortie du nucléaire en Belgique : son nouveau rapport souligne l'urgence de la situation et la nécessité de prévoir un filet de sécurité structurel pour garantir la sécurité d'approvisionnement.*"

[3] In particular for materials and components

sustainably produce biofuels. There is still a lot of research to carry out to close as much as possible the carbon cycle, and rely on non-fossil carbon for all uses.

What are the main barriers to energy system integration that would require to be addressed in your view?

Digitalization

Energy system integration requires digitalization. Hence, interoperability (systems and data), data privacy and cybersecurity are three main barriers to address. Digitalization should not lead to a more efficient but weakened energy system.

Imbalance between energy demand and supply – potential of each energy source

The potential of each energy source has to be assessed and compared to energy demand. This evaluation has to include fossil fuels because they are still by far the main sources of energy in Europe and a potential shortage of supply has to be foreseen, even if the final target is to stop using them. It also has to include nuclear and renewable energy sources (wind, hydropower, solar, biogas, etc.) with a geographic and time consideration to evaluate if they are able to provide what is expected from them (and if not, how to improve their potential or review our expectations). The evaluation of the potential of each energy source has to be carried out with a systemic approach and include energy resources (how much biogas can be made without growing dedicated cultures, for instance), non-energy resources (metals, minerals…), land-use, cost projections for an equivalent level of service, etc. The social and political dimensions have to be integrated in this assessment to get not only the theoretical potentials, but also the "reasonably accessible" ones.

Since reaching carbon neutrality implies to get rid of 80% of the primary energy we use today (fossil fuels), we will need much more energy from other low-carbon sources (renewables, nuclear…). It is therefore necessary to continue supporting the deployment of power and non-fossil gaseous and liquid fuels production capacities.

We cannot decide *a priori* that some energy sources have the potential to replace fossil fuels because we need/would like them to do so. We have to ensure that the potential (including deployment speed) for each of them matches the demand (and if not try to improve it or reduce the demand).

To this end, Member states and the European institutions have to be careful about the competition between uses. Each sector cannot intend to use all of a resource. The extent of a resource has to be shared and the sum of each sector's projections has to match it. For instance, the whole production of biogas cannot be mobilized for heating purposes and at the same time for the industry and maybe tomorrow for mobility. Resources allocation is therefore an important issue for the future pathways, which needs to be addressed.

We should not switch from a dependence on fossil fuels imports to a dependence on metal imports

Member states have to be careful not to switch from a dependence on fossil fuels imports to a dependence on metal (and other major inputs) imports with the development of resource-intensive renewable energy sources and storage capacities. To reduce the need for metal imports, eco-design and urban mining (recycling) have to be supported with strong policies as well as the improvement of/research on new catalysts.

Need for a better modelling of energy supply, demand and risks

It is difficult to address future energy systems with current tools and public statistics. To better describe them and the characteristic processes of the transition leading to a carbon-neutral and integrated energy system, we would need to add three dimensions.

1. Identification of the potential of each energy source (as detailed above);
2. Evaluation of use, functions and services values with a flexible granularity (ex. existing or foreseeable flow diagrams based on physics, value...);
3. Fine identification of the potential of each energy vector according to its physico-chemical characteristics.

Another barrier to energy system integration is the lack of risk and opportunity analyses for different actors, who need to be accompanied and trained. For instance, if in an industrial A needs the waste heat from an industrial B, what happens if industrial B goes bankrupt, decides overnight not to provide its waste heat to industrial A anymore, or fails to confer with industrial A to plan for the shutdown of his plant for maintenance? Communication, guarantees and education of both industrials is needed to provide them with a reassuring framework to carry on with their activities in the best conditions. In general, a new regulatory system should be set up to enable the development of innovative collaborative arrangements.

Need for national and inter-governmental policies and long-term planning

When dealing with energy matters, lifetime of infrastructures has to be taken into account (60+ for a nuclear power plant, 20+ for a wind turbine, 100+ for a dam…). Because of these long lifetimes, long-term planning of energy systems is necessary, and it implies a strong role for states and EU institutions. Moreover, an energy technology currently under development that would have a TRL level of 3-4 could be on the market in 10-12 years. R&D efforts have therefore to be sustained on the long run, which also means support to fundamental research and low TRL activities from which technological innovations may result.

Tomorrow's energy converters will have to be made with tomorrow's energy sources and it is another aspect that has to be taken into account for long-term planning. For instance, if today solar panels or batteries can be made thanks to cheap, flexible and abundant fossil fuels (often coal in the industry), tomorrow they will have to be made with more expensive, often not flexible and less abundant sources of energy. Therefore, the choices we make today will condition the future energy landscape and its long-term evolution.

Energy integration to reach carbon neutrality needs strong industrial actors to accompany these transitions. Start-ups are useful but not enough. Large industrial integrators are required and the European Commission has a role to play in order to help them emerge and develop. This is in phase with the reindustrialisation policies that are currently being promoted by EU governments, in the aftermath of the COVID-19 pandemic.

The long-term state and EU planning required for an integration of the energy sector will have to materialize through strong policies to promote, deter or prohibit some practices. Such policies can have powerful effects and they are necessary to change the game. For instance, the penetration of electric vehicles in car sales in Norway is around 50% thanks to strong incentives, when it's only 3% in France. Waiting is not an option for the transition to happen. If Member States are committed to decarbonize their economies, strong public policies must support this target.

Risk of a "band-gap" to implement an integrated energy system

A deep evolution of energy infrastructures requires huge investments. Even if a system can be competitive once in place, the size of the initial investment can prevent its deployment. This covers for instance the initial investment in grids strengthening and interconnection, large-scale installation of bidirectional plugs for electric vehicles, R&D, building capital-intensive energy converters (nuclear power and heat plants, dams, wind turbines…), etc. States will have a major enabling role to support the industry and the society to cross this bridge. The market alone won't finance the implementation of a low-carbon integrated energy system by itself.

How could electricity drive increased decarbonization in other sectors? In which other sectors do you see a key role for electricity use? What role should electrification play in the integrated energy system?

Mobility

Electricity has a role to play in mobility decarbonization through the deployment of electric vehicles (PHEV, BEV and FCEV) to replace thermal ones. It is also a way to help stabilize power grids by dispatching the load of electric vehicles at times of low power demand (smart mono-directional loading) or, better, by contributing to the power supply at times when demand peaks. For electric vehicles to be able to deliver energy to the network, and not only take it, Europe needs a large-scale deployment of bidirectional plugs, along with incentives to the consumer to participate to grid stabilization services.

Industry

In the industry, low-carbon electricity will have a growing role to play, either directly in replacement of fossil fuels, or through hydrogen produced by electrolysis. Sometimes, this will require deep and costly evolutions of some industries. Member states and the EU have to provide companies with the good incentives in order to help them cross the bridge.

Hydrogen produced by electrolysis with low-carbon electricity will not only be an energy vector but also a basis to synthetize many molecules used in the chemistry sector. To make organic molecules requires carbon, therefore a coupling of hydrogen and carbon capture and utilization (CCU), all powered by low-carbon electricity, makes sense in view of the carbon neutrality objective.

Because of this need to turn low-carbon, industry is expected to grow its power consumption by a factor of 4-9 until 2035[4].

Electricity is not the answer to every energy need: thermal energy sources and non-fossil hydrocarbons are also necessary

Today, electricity represents only 20-25% of the final energy consumption in Europe. If this share is expected to grow in the coming decades, electricity is not suited to every energy use. Power production and storage (in batteries, H2, etc.) will not be enough – by far – to reach carbon neutrality. Deep changes in the energy demand (to reduce and dispatch it) will be necessary, as well as other low-carbon energy sources, such as thermal ones: heat pumps, solar thermal, geothermal, non-fossil fuels, nuclear heat (for heating networks or the industry), etc. will have a significant role to play. In the transport and

[4] A. de Pee, D. Pinner, O. Roelofsen, K. Somers, E. Speelman and M. Witteveen, Decarbonization of industrial sectors: the next frontier, a McKinsey & Company report, June 2018

chemistry segments, carbon based products will remain key energy and carbon vectors to produce chemicals and fuels with a high energy density.

What role should renewable gases play in the integrated energy system?

Definition

First, it is important to redefine renewable gases in non-fossil gases. These can be produced through several processes such as methanisation/methanation of biomass, H2 production and conversion in methane with low-carbon (renewable or nuclear) electricity, or directly from solar energy.

These gases are sometimes qualified as "decarbonized" in the questions formulated by the Commission (in a sense that they emit low amounts of GHG on their life cycle). It is important to keep in mind that some (actually, all gases not being hydrogen) may contain carbon (e.g. methane…). They are not "decarbonized" from a chemistry point of view. That's why in the following paragraphs and answers we will keep referring to "non-fossil gases".

A role constrained by limited resources and limited low-carbon non-fossil alternatives

The role non-fossil gases can play in an integrated energy system is linked to their deployment potential. For instance, biomass is not an unlimited resource and this limitation has to be taken into account. A hierarchy has to be made for the resources, for instance for biomass that can be used in many ways: direct combustion, production of biogas, liquid fuels or molecules for the chemical industry, etc.

Since the potential of non-fossil gases is limited – and today several times more expensive than fossil gas – a hierarchy has also to be made between their different applications. We might for instance find it more pertinent to use non-fossil gases in priority where electrification is not possible or particularly difficult, rather than making a competition between non-fossil gases and low-carbon power.

The carbon neutrality and sustainability of non-fossil gases has to be guaranteed

The development of non-fossil fuels and molecules (e.g. methane, methonal and hydrocarbons) has to be considered through a systemic approach of the carbon cycle. It is important to know from where the carbon comes and if and how it is captured once burnt, to ensure the carbon neutrality and sustainability of the development of these synthetic fuels, including gases.

A life-cycle impact assessment of non-fossil gases, including methane leaks, has to be carried out thoroughly for all gas technologies, to ensure that they bring a real climate benefit compatible with the carbon neutrality objective.

Storage

Today, states already have gas storage capacities that enable them to import gas in summer to use it in winter. Non-fossil gases can use these storage capacities and help bringing seasonal flexibility to integrated energy systems. The gas network itself can also be used as a storage capacity.

What measures should be taken to promote decarbonised gases?

The deployment of non-fossil gases depends on measures taken by states and the European Union to promote them. There can be regulation (for instance a minimum amount of non-fossil gas in the gas network) and fiscal measures: incentives to develop methanisation, P2G, PB2G, etc. and penalties for the use of fossil gas (carbon price, for instance) to reduce the price gap between fossil and non-fossil gas.

The International Energy Agency evaluated methane leaks from the oil & gas industry at 2.4 billion tons of CO2 equivalent in 2017[5], which is 5% of the total global anthropic GHG emissions. It is far from being a marginal issue. However, very often only combustion is taken into account when greenhouse gases emitted by gas are considered. Lifecycle analyses, that include methane leaks, are necessary to have an unbiased view of gas impact on climate.

Life cycle analyses have to be carried out for all fossil and non-fossil gases. In addition, a traceability system of gases has to be put in place, to help valorise the use of non-fossil gases and guarantee the sustainability of those alternatives.

Finally, for electro-gases, all sources of low-carbon power have to be taken into account. To reach carbon neutrality, electricity demand is due to grow strongly and even now it is far from being low-carbon on the European scale. Therefore, we cannot offer not to consider all low-carbon sources of power, especially the ones that are dispatchable, and that includes nuclear.

What role should hydrogen play and how its development and deployment could be supported by the EU?

Context

Today, 95% of hydrogen is produced from fossil hydrocarbons (mainly through Steam Methane Reforming or Coal Gasification), reactions that emit CO2[6]. If electrolysis is used only for marginal and specific applications – namely when high-purity H2 is required or as by-product from chlor-alkali electrolysis – it is because it is several times more expensive. Physically, the high-cost for hydrogen produced from water through electrolysis can be explained with the cost of the electrolyser and the energy loss inherent to the change of energy vector. According to a study made by RTE, the French power grid operator, the most competitive way to produce H2 would be a baseload production to maximize the load factor of the electrolysers (such an option is not compatible with an intermittent power generation…). This way, the cost of electrolysers would be allocated on a larger production base. For a CO2 price of €30 per ton (which was the price on the ETS market last summer) RTE evaluates H2 price produced through baseload electrolysis at €3.0 per kg against €1.8 per kg when produced through Steam Methane Reforming[7]…

In an integrated energy system, hydrogen can provide four main kinds of services

- Temporal flexibility: with the deployment of intermittent renewable energy sources, H2 could help stabilize the system by enabling energy storage on the long run (seasonal flexibility) and short term (services to the grid).
- Geographic flexibility: H2 is an energy vector that can be produced where energy is available and transferred to an area where it is not. Studies in Germany are carried out to try to find H2

[5] *Tracking Fuel Supply*, AIE, November 2019.
[6] IFPEN, https://www.ifpenergiesnouvelles.fr/enjeux-et-prospective/decryptages/energies-renouvelables/tout-savoir-lhydrogene
[7] RTE, *La transition vers un hydrogène bas-carbone*, 01/2020, https://www.concerte.fr/system/files/concertation/Rapport%20Hydrogene%20VF.pdf

alternatives to power lines between the north (where power is produced) and the south of the country (where power is used).

- Decarbonisation of sectors difficult or impossible to electrify: heavy and long-distance freight & mobility, industry (steel, methanol-ammoniac chemistry, refining…)
- Sector coupling: electricity, mobility, industry, gas network…

EU can support hydrogen deployment

The support expected from the European Union for hydrogen deployment is not only a financial one. Some regulatory barriers also need to be lifted if hydrogen is to have a large-scale future. Some have been explored by F. Dolci et al.[8] For instance:

- in France every H2 production or storage system from a certain size is considered as an ICPE (Environment Protection Classified Installation), a classification that leads to constraints and costs;
- a clear and shared European regulation would be needed on the maximum level of H2 in gas networks.

Some financial support would also be necessary to help the sector emerge:

- to help industries currently using hydrogen to shift to a low-carbon H2 supply (produced by electrolysis), in turn this will help to lower the costs of electrolyzers;
- to clarify the possibility and modalities of a payment for H2 flexibility;
- a feed-in-tariff for H2 injection in gas networks;
- collaborations with industrials to deploy H2 infrastructures;
- tax exemptions for H2 used as a fuel (as least as a first step to help the development of the sector);
- EU should support its cutting-edge fundamental research on H2 bioproduction to anticipate a worldwide leadership on the next step of bioproduction of hydrogen such as photoproduction of hydrogen from water with photosynthetic organisms or artificial bio-inspired complexes with photocatalytic properties.

Finally, the IPCEI "Hydrogen for Climate Action" is instrumental for the deployment of a European hydrogen sector.

How could circular economy and the use of waste heat and other waste resources play a greater role in the integrated energy system? What concrete actions would you suggest to achieve this?

Circular economy could help integrate energy systems in industrial ecoparks, for instance by giving value to waste heat. Waste heat could be used for several industrial applications, for instance high-temperature electrolysis of water for H2 production. Small and modular nuclear reactors (SMRs) could make sense in such industrial ecoparks to provide them with heat and power.

Along with waste heat, several industries also emit CO2. It can be used as a resource to produce non-fossil liquid and gaseous electrofuels by reacting with hydrogen.

Member States and the EU could achieve this by helping industries assess their potential for symbiosis with other industries, by helping them to draw contractual terms to reduce the risks brought by their

[8] F. Dolci et al., Incentives and legal barriers for power-to-hydrogen pathways: An international snapshot, *International Journal of Hydrogen Energy*, Volume 44, Issue 23, May 2019, 11394-11401

interdependence, by playing the role of a trusted third-party and, in some cases by a participation to the financing of ecoparks.

It is essential that public authorities make the procedures to declassify a waste that can be valorised easier, in particular for batteries.

Research, regulation and incentives on eco-design and lifecycle analysis are also essential to improve and support recycling activities. They are necessary to develop and strengthen a secondary raw materials market.

Finally, the European Commission could create an observatory of heat and material resources (with their quantity, grade and localisation) as well as potential users to help all actors meet.

How can energy markets contribute to a more integrated energy system?

To reach carbon neutrality will require giving a higher price to CO2 along with some visibility on this price to industrials. Indeed, it is difficult to consider CO2 price when planning for long-term investments if this price is the result of an exchange system and can vary erratically. At least, in order to prevent a dropping of CO2 price (as can be seen today with the COVID-19 crisis) and give a beginning of visibility to the industry, the Commission could set up a carbon-price floor, with a planned-and-announced increase. This way, the industry would at least be able to consider this price for their economic modellings.

It is necessary to have the right fiscal incentives at the good time. It also means that markets alone won't be sufficient to enable energy sector integration: a proactive role of planning authorities is key to give the right signals and lift the barriers.

How can cost-efficient use and development of energy infrastructure and digitalisation enable an integration of the energy system?

Digitalisation enables the tracking and flexibilisation of the energy demand. On the other hand, it drives some questions linked for instance to data protection, private life and cybersecurity. By making the system more efficient, we have to be careful not to make it less resilient.

Predictive models to describe energy demand and supply need to be developed and they should lead to hourly rates, consistent with the market.

Finally, energy consumption linked to information and communication technologies is growing rapidly, and so does the CO2 emissions of the sector. Digitalization is not an end by itself but a mean to reach some benefits that have to be clearly identified and justified. Otherwise, digital sobriety should be the norm.

Are there any best practices or concrete projects for an integrated energy system you would like to highlight?

JUPITER 1000 is a power-to-gas demonstrator to study H2 and methane synthesis and injection in the gas transport network. It is a collaboration between a research organization (CEA), industries (CNR…) and power/gas network operators (GRT Gaz, Terega and RTE).

In terms of best practices, we would like to highlight the work done on Vehicle-to-grid with hourly power prices to give an incentive to the consumer to provide services to the grid.

Another promising idea would be the coupling of small and modular reactors (SMRs) to high-temperature H2 production and CCU to produce molecules for the chemical industry and gaseous and liquid fuels.

What policy actions and legislative measures could the Commission take to foster an integration of the energy system?

The Commission could valorize the feedback of projects designed to integrate energy systems by creating an observatory of experiments, to share on a large-scale the difficulties faced as well as the good practices.

As a regulator, the Commission should ensure the interoperability of energy systems. It could also promote the deployment of hourly indexed prices that will be necessary to develop the flexibility of demand.

The Commission could also design a framework to guarantee data privacy while enabling its use to improve the flexibility of systems. Without a credible protection of people's privacy, data use risks facing an opposition that could slow down the integration of the energy system.