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Roadmap for an EU Smart Sector Integration Strategy

The European Green Deal is the flagship initiative from the European Commission that will lay the path to Europe's climate neutrality. As part of that package, a well-crafted Smart Sector Integration Strategy that links all of the elements of our energy system could provide substantial contributions in bridging the gap to Europe's climate objectives.

In the recent decades the upscale of renewable electricity production has been quite significant. The development of renewable electricity has contributed towards reduction of CO2-emissions in the EU economy, foremost in the power sector but also increasingly in the transport and heating sector. However, there are sectors and applications where direct electrification might not be feasible nor possible with the technologies currently at hand (e.g. aviation, heavy-duty vehicles, certain energy-intensive industries). In view of Europe's energy transition, the discussions on the role of renewable and low carbon gases and fuels in an integrated energy mix are extremely important. Getting closer to an increasing renewable electricity system, will lead to a higher demand for flexibility and all types of storage that low carbon energy carriers could provide.

There are some key elements that will need to be considered in order to achieve a successful sector integration, while keeping in mind the key aspects for the Union's energy system: competitiveness for businesses, sustainability, security of supply, and affordability for consumers.

This paper is structured around the questions suggested by the COM:

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?

The future integrated system should send sufficient market signals for investment into low-carbon energy and flexibility solutions while managing carbon leakage challenges and keeping the prices at a competitive level for European business and consumers. Financial instruments will need to send the right signals leading to investment in innovation, infrastructure and solutions that help achieve the energy transition cost-effectively. Such market signals must be based on a stable and predictable regulatory framework.

Energy networks have evolved greatly in the past few decades. Nonetheless, the original objectives attributed to these networks are changing, considering the integration needs of the climate neutral pathways. We will need to carefully consider how molecules and electrons will provide an efficient partnership, and what potential changes will need to take place (tariffs, capacity allocation, etc.).

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Electrification is one of the building blocks of Europe's decarbonisation pathway. For certain sectors of the economy, direct electrification represents a cost-effective and energy-efficient way to decarbonise. Gas-to-Power already offers dispatchable capacity to the electricity system. Transforming renewable and low-carbon electricity into renewable and low carbon gases and fuels (as well as power-to-x), presents an untapped potential for those sectors where electrification is not feasible or is not cost-effective.

The energy system will require a number of adaptations of the underlying regulatory framework. Substantial reductions in the cost of renewable electricity has provided a opportunities to cost-efficiently integrate energy sectors, and develop renewable gaseous and liquid fuels suitable to decarbonise hard-to-abate sectors. This will require a re-thinking of current energy infrastructure. In this context gas infrastructure is not only a service provider for the electricity grid but also an important part of a rapid decarbonisation process. Coupling the gas grid with the electricity grid leads to higher efficiency of the entire energy system, more so where surplus renewable electricity is generated, and flexibility services can play a role. Further, sector integration links other economic sectors such as heating & cooling, transport, industry, building, etc. through their energy systems. This initiative represents one of the most relevant elements of the decarbonisation process and would all be dependent on the ability to implement the most cost-effective and energy efficient solutions. It will be important to take into consideration all the technologies and options available at hand in short, medium and longer term, which can provide the flexibility needed. Sector integration can increase the overall energy efficiency and raise the use of various forms of renewable and low carbon energy and adds flexibility to the energy system – a very valuable asset when electricity production fluctuates.

Successful sector-integration requires different innovations related to processes, energy carriers, infrastructure, etc. To allow for different cost-efficient solutions in different sectors, the principle of technology neutrality should be applied:

- Direct electrification of some buildings (e.g. heat pumps), passenger cars and light-duty transport or some sectors of industry (e.g. production of heat)

- Indirect electrification with renewable and low-carbon electricity used to produce low-carbon fuels (hydrogen, synthetic gas, e-fuels) and the development of other renewable and low carbon gases (biomethane, methane reforming in combination with CCS) or CCU (synthetic gas, e-fuels) which can be used for heavy-duty transport, aviation or clusters of energy-intensive industries such as steel, chemicals or cement

- District heating and cooling with renewable and low carbon energy sources provides one of the best examples of sector integration, already deployed in the market and could be further extended through different Member States.

- Circular economy with waste gases from industry, CCU for feedstock and fuels, and excess heat

- Connecting transmission and distribution grids, cross border interconnections allowing for reverse flows on pipelines for gas and heat networks.

- Low carbon high-efficiency combined heat and power generation.
- Promote energy efficiency in all sectors of the European economy and throughout the energy system.
- The active participation of consumers (including industrial consumers) in energy markets by actively managing their consumption (demand response)

All of these solutions will require a well-functioning and connected energy system, that will allow for cost-effective initiatives.

What policy actions and legislative measures could the Commission take to foster an integration of the energy system? What are the main barriers to energy system integration that would require to be addressed in your view?

A coordinated cross-sectoral approach is needed notably to ensure and safeguard the necessary flexibility in storage and back-up capacities to facilitate low carbon and renewable energy. At the same time, overregulation – in its broadest sense –as well as conflicting or overlapping policy instruments must be avoided by all means.

A truly integrated energy system enabling a climate neutral future is one where each energy vector is used where it provides maximum CO_2 emission reduction in the most cost-effective and energy-efficient way where possible. The regulatory framework and market rules should aim at enabling such an integrated system. In the current context of economic crisis, the capacity of such a strategy to trigger low carbon investments and to underpin jobs creation in Europe will be critical.

Even though there is already an existing exchange of information between power and gas TSOs on ENTSO level, increased cooperation between ENTSO-E and ENTSO-G in order to ensure accurate levels of security of supply and other types of planning, including long term scenarios underpinning the Ten-Year Network Development Plan (TYNDP), should be considered. Intensified communication at both EU and national level could help in this regard.

Usual network infrastructure planning relies on TSOs at national level, as well as ENTSOs at European level, which is normally done for electricity and gas separately. Continuing a reliable joint TYNDP for gas and electricity with realistic assumptions (e.g. electricity peak demand with increasing electrification, grid projections in line with NECPs, and on flexibility sources in the electricity system with high levels of electrification) is required. A transparent and cost-reflective tariff system for the use of all (new and existing) gas infrastructure is necessary to provide household and industrial customers with a robust basis for decision-making. Optimal cost-allocation, affordability and security of supply should be leading principles in infrastructural planning.

EU energy policy should start taking a more holistic approach, considering a technology's contributions/benefits across multiple sectors. Cogeneration plants are good examples of efficient energy integration, but today fall between two sectors (*electricity & heating/cooling*). Applying the EU's electricity and heat market rules often leads to results that are distorted for cogeneration plants. Sometimes this is reflected in EU policy (*e.g. the EU ETS contains special provisions for cogeneration plants, which ensures that they're on a level playing field vis-à-vis heat-only production*) but it is often overlooked.

Digitalisation should be used to improve the smart integration of renewables by managing supply and demand according to the specific climate conditions. Smart electricity and smart thermal grids at both local and European level enable flexibility and a cost-effective use of renewable and low-carbon energy across different sectors, applications, time and space.

The European Commission should leverage R&D investments and deploy technologies that are promising for the achievement of a EU's smart sector integration. In this context, several frameworks and tools exist (e.g. Horizon Europe's partnerships and missions, IPCEIs, Connecting Europe Facility, etc.) and synergies shall therefore be implemented among these. Beyond funding mechanisms, the regulatory framework must support innovation: EU's regulatory sandboxes will be key to test and deploy highly innovative technologies in a controlled environment.

Energy efficiency is likely to become even more important as we move towards climate neutrality, trying to make the most of the limited resources. Nonetheless, there will be occasions where efficiency might not be able to take priority, for example when processes are progressively reducing their CO2 intensiveness, they might consequently diminish results on energy efficiency. New disruptive and innovative technologies can be energy intensive (hydrogen production, CCS, etc.).

When possible, we suggest to make use of the existing Article 14 (5) if the Energy Efficiency Directive, requiring Member States to ensure that an assessment is carried out for new substantially refurbished industrial installations regarding the possibility to operate as a high-efficiency cogeneration installations, or connecting them to a district heating/cooling network. This provision presents an untapped potential for some Member States.

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

Market forces are key to raising capital for investment into a more sustainable energy system and to ensure that European companies remain strong competitors in international markets. A stronger internal energy market allows energy to flow freely across member states.

Whereas the discussions on the role of renewable and low-carbon gases and electricity, and how to better integrate them into the overall energy system need to take place, there are some other elements that need to be considered first. Discussions on remaining issues in the gas market in order to achieve a full integration of the markets should be considered in parallel to regulatory changes aiming at sector integration.

The future European market the design should be optimized in a way that it is able to respond to the upcoming challenges of the energy system and to adapt to the energy mix of the future. Numerous technologies are currently being discussed but not all of them have been deployed or are cost-efficient yet. Further efforts and support will be needed to integrate these new technologies into the energy network. Electrification has the potential to play a crucial role in decarbonising the European economy. However, the consumption of renewable electricity remains challenging for certain large industrial consumers in particular[1]. This constitutes a significant barrier for industrial consumers attempting to decarbonise their processes via electrification.

Furthermore, ACER's recent evaluation on the gas markets[2] revealed an overall successful model, where some markets still faced competition, institutional and structural issues. The North-Western region shows the highest price convergence, Central and Eastern Europe (CEE) showed improvements, whereas Mediterranean hubs showed lower price convergence.

Lack of convergence identified in some areas could be caused by low interconnection capacity, transportation tariffs and weaker competitive pressure and hub functioning. On places where the entry-exit zones are relatively small and the transits crosses several borders, gas flows are being charged exit and entry fees each time, leading to a pancaking effect for users.

Short-term flexibility will be an important aspect for a successful sector coupling strategy and in order to enable the gas market to respond to fluctuating energy supply on the electricity side.

Way forward

- The completion of the internal European gas market is crucial to strengthen the competitiveness of the European Union and to increase security of supply. For this, existing regulatory, operational and commercial barriers need to be removed. A proper implementation of the third Energy Package and its related Network Codes and Guidelines across all EU Member States as well as Member States of the Energy Community are important. For the electricity markets, proper implementation of the Clean Energy Package and network codes e.g. completion of European flow-based market coupling is crucial.

- In order to achieve better price convergence and a level playing field for all users, the Member States might need to review their interconnection targets in view of the future role for decarbonised energy carriers[3]. If Europe's objectives are to have an interconnected, flexible system, we will need to increase our efforts to connect missing links and remove existing market barriers with a rigorous forward-looking cost-benefit analysis taking into account future projections. We will need to avoid a fragmented market, taking advantage of Europe's purchasing power as a whole.

[1] European Commission "Competitiveness of corporate sourcing of renewable energy"
[2] ACER & CEER "The Bridge Beyond 2025 – Conclusions Paper "
[3] CEPS: The future of gas in Europe 2019

- The strategy for smart sector integration should optimize the current design in place and respond to the challenges of the future (flexible electricity system and capacity, sector coupling, integration of renewable and low carbon gases in the infrastructure and market system). In this regard, any review of the gas market design should consider the needs for an efficient integration of renewable and low-carbon energy carriers in the future (capacities and infrastructure planning). The integration of renewable and low carbon gases should be done in a way that does not harm market liquidity that has been established over the last decades, and in a way that it does not lead to a fragmentation of the European gas market.

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

The role of natural gas as an energy carrier supporting the energy transition has been recognised by decision-makers[4] and proven as a step on the road to decarbonisation. Most projections for the next decade foresee a demand for natural gas and a certain increase of imports due to the decrease in European domestic production.

Particular consideration should be paid to the role that existing and future gas infrastructure plays in the overall European security of supply and resilience. They introduce an element of flexibility as well as back-up of renewable electricity. The long lifespans[5] of the infrastructure are met with strict climate targets in the next decades, which puts them at risk of becoming stranded assets. On one hand, they will need to take account of the demand for natural gas in the transition phase, as it represents an important step towards decarbonisation of the energy system. On the other hand, these assets will need to be fit for to transport renewable and low-carbon gases in the future.

As the potential of electrifying uses in several sectors, there will be a need of reinforcing the electricity grid– interconnections, transportation and distribution grids, including smarter networks - is therefore the next step. Frequent occurrence of congestion may serve as a good reference to places where further investments are needed.

Through smart electricity grids, sectors of the economy will be increasingly connected and synergies will be developed. For instance, vehicle-to-grid technology and industrial demand side response can create value for users and contribute to the flexibility needs of a power system with high shares of intermittent renewables.

Data and digitalisation will be key drivers in the development of a cost-efficient integration of the energy systems across member states and a necessity for a stronger internal market

[4] https://www.climatechangenews.com/2019/10/04/next-eu-energy-chief-backs-gas-part-climate-transition/

[5] Large pipelines and LNG projects have a normal lifespan of five decades (with adequate maintenance), gas-powered generators are designed to last up to 20 years, and gas storage can potentially be functional for up to 40-50 years.

and energy infrastructure. It is therefore increasingly important to support advancements towards more voluntary data sharing, particularly as a means of stimulating or catalysing innovation. Supporting the Commission's intention to create common European Data Spaces should enable systems and services to be developed so that the best solutions can be found for the energy sector. Establishing the necessary framework requires focus on developing interoperability standards for information exchange and an overarching governance framework that ensures cybersecurity, privacy and IP protection through clear guidelines. Focus on interoperability is essential as this makes it easier to share data.

Specifically, in terms of integration of the energy system, data-interoperability is key. Necessary communications must be ensured through different systems and services being cross-compatible. More concretely, synergies could be achieved through the development of interfaces between electricity and gas systems, energy forms, and across borders, where this provides value.

Way forward

- Any future European strategy should consider the role of the NECPs as a tool for implementation, where natural gas still plays a considerable role in their decarbonisation strategies. With consideration to security of supply levels, new investments in gas transport capacities or interconnections should be carefully assessed taking into account the most efficient solutions from an overall system viewpoint, long term consumption forecasts, and climate targets. It is important that new investments in gas infrastructure are built ready to transport low carbon or renewable gases in the future to avoid the risk of future stranded assets. In addition, most existing gas infrastructure and assets will require upgrading to remain fit for purpose and climate resilient.

- A European assessment on the best possible uses of the existing energy infrastructure combining all energy carries and sectors should be executed, considering to the future energy demand. Inconsistent national strategies will have negative impacts on the liquidity of the market, and therefore it should provide sufficient security to the markets knowing that long-distance transport of energy will be required in a decarbonised energy system.

  Some studies already prove the possibility for large savings based on the use of gas-based end-user appliances such as in the heating sector (€11.7 - 13.3 billion per year), industrial processes (€4.1 - 4.6 billion per year) and in transport sector (€3.5 - 5.5 billion per year)[6] . Further savings could be reached by using existing gas networks and avoiding new investments in electricity transmissions (€2.5 - 3.2 billion per year) and distribution (€7.6 - 9.2 billion per year) networks. We therefore support the repurposing of existing networks to avoid stranded assets and to ensure cost-efficiency.

[6] https://www.frontier-economics.com/media/3120/value-of-gas-infrastructure-report.pdf

How could electricity drive increased decarbonisation 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?

Today electricity represents 22% of the total energy consumption in the EU. Going forward, it will drive the decarbonisation of certain sectors through direct electrification, wherever this is deemed economical/cost-efficient vis-a-vis alternative decarbonisation methods.

The most promising sectors for direct electrification are heating (e.g. heat pumps), light transport and lower temperature industrial processes. In the case of industry, there are existing technologies today to electrify heat processes up to 400°C with direct use of electricity. It will also be necessary to decarbonize the production of heat beyond 400°C and other industrial process (e.g. steel, chemicals).

The electrification of numerous sectors does not come without some challenges. It remains uncertain whether there will be enough physical space in Europe to build all the renewable units needed as well as the deployment speed to reach climate neutrality. Europe has considerable untapped potential for cross-border PPAs for low-carbon electricity. Imported electricity might see future increase. Our interconnector capacities will need to prove sufficient in order to import sufficient volumes of renewable electricity and transfer it between Member States. When signing a PPA with a producer you need to reserve interconnector capacity, which is usually done for short periods of times (up to a year), whereas PPAs are done usually on longer periods (10+ years). The lack of guarantee risks the upscale of this practice.

Way forward:

- When it comes to electric renewables such as wind, solar, hydro, the existing barriers to investments and development must be addressed. They include undeveloped supply chains, the need for more grid infrastructure to bring cheap renewable power to demand centers, the lack of public acceptance, lengthy permitting procedures and administrative barriers, financing, or high costs for some less mature technologies.

  The uptake of renewable Power Purchase Agreements (PPAs) by industrial consumers should be supported and facilitated in order to facilitate energy intensive industries in their decarbonising process. Signing a long-term PPA with an industrial consumer gives the renewable producer a crucial long-term stability as support schemes are slowly phased out.

- Ensure that suitable, cost-competitive products are offered for the long-term allocation of interconnector capacities (i.e. for a period of multiple years), which will enable the signing of cross-border low-carbon power-purchasing agreements (PPAs).

- Measures on electric mobility should allow for a steeper adoption of local low carbon mobility by promoting the investments and operation of the charging infrastructure.

The market has not been significantly developed in most EU countries yet and existing local policies still prevent an easy operation of the charging infrastructure and the use of new technology for the new grid operation activities (e.g. Vehicle-to-Grid V2G)

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

The presence of both electrons and molecules will be necessary in order to meet the long-term energy demand of industry and other sectors. Renewable and low carbon gases should be used in sectors or processes in an economically efficient manner, including: heat-intensive industrial processes, residential heating, heavy transport, shipping and aviation.

Renewable and low carbon gases should serve as a steppingstone to the introduction of renewable gases to achieve emission reductions in the short and medium term, given that buildout of renewable energy generation and production of renewable gases have a longer-term perspective. The decarbonisation of gases will heavily rely on the continuous investments in renewable and low carbon sources in the power sector, which will also need to be addressed as part of the energy system integration.

The roll-out of low-carbon and renewable gases will require sufficient regulatory predictability for the next decades, and therefore an evaluation of all these potential elements should be considered in advance. Prior to any change of gas specifications at grid entry points, the consequences at any grid exit point shall be carefully assessed. In case of changes on gas quality at an exit point, compared to the current standard, the technical and financial consequences for the final industrial consumers connected to the network shall be evaluated. This assessment shall be performed in relation with stakeholders.

What measures should be taken to promote decarbonised gases?

Classification of gases**:** the potential expansion of new gas technologies raises numerous questions around the technical standards on gas quality, the production methods or the level of emissions. The variety of feedstock and conversion pathways that play into gas production, open a wide range of possibilities.

In order to avoid a patchwork of national classifications, a harmonised view at EU level across MS will facilitate the roll out of low-carbon and renewable gases. A clear classification will be key in order to work with a dynamic legislation based on consistent principles rather than detailed rules for all the upcoming new technologies.

A European-wide standardised classification for renewable and low-carbon gases that takes into consideration their net CO2 emission levels based on a whole life-cycle assessment, should be the basis for any future classification and consistent with the taxonomy initiatives. It will be important that legislation remains flexible enough to ensure that new technologies are not excluded from the definitions, and that positive externalities are also accounted for.

The flexibility in the gas quality is a sensitive and important question. It might be necessary to create an EU framework on gas quality standards, which would cover all types of gaseous or gas-based energy carriers (LNG, biogas, H2, biomethane). All future EU provisions need to ensure that the standards across the Member States enable and support functioning support cross-border trade for renewable and low–carbon gas.

Guarantees of Origin (GO)*:* Under RED II, Member States are required to ensure the possibility of issuing GOs for renewable electricity, gas, and hydrogen, whereas this is optional for non-renewables sources such as decarbonised natural gas. Currently, different national schemes coexist in Denmark, the Netherlands, Austria, Belgium or Sweden. The fragmentation of national and even regional schemes is currently hindering the transferability of the gases across the MS (i.e. Switzerland faces difficulties when importing what is considered as "biogas" in Germany-hydrogen produced from wind energy-, since it is considered natural gas in Switzerland).

We therefore support the introduction of an EU-wide GO scheme mentioning GHG content of the product, it would allow buyers and consumers to know the emission levels linked to the gas they are purchasing. Energy disclosure information using the GOs present a market incentive to decarbonised products by increasing consumer awareness and willingness to demand these products. Furthermore, considering the latest trends on imported renewable or low-carbon gas into Europe, GOs could present a way to certify the quality standards from imported low carbon and renewable gases coming into the EU.

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

A European hydrogen strategy, covering all forms of hydrogen, is needed in order to allow for coordination of national efforts already at an early stage and to provide optimised holistic solutions, ensuring development and scaling of the sector. It should involve a clear strategic vision on the EU level to allow for investment and planning security, the potential need of infrastructure development of hydrogen networks, but also the potential future imports at the EU level.

In this context robust cost-benefit analysis considering the potential retrofitting of existing gas infrastructure, must be applied to ensure a cost-effective transition. When relevant, it is important to produce a large part of the hydrogen close to consumption sites to avoid expensive long-distance transport and storage. To do so, establishing and creating incentive for initial regional demand, focusing on major industrial energy and hydrogen consumers, such as chemical processing and steel, could help in this regard.

Today 90% of global hydrogen is made from natural gas without CCS, in the future renewable and low carbon hydrogen will be key. In order to allow for the scale to build such market, it is important that electrolysers can be connected to the electricity grid, as excess renewable electricity will not be sufficient to power large amounts of electrolysers. The development of an EU based electrolyser capacity production must also be supported vis-à-vis the deployment of the whole renewable capacity.

Recent reports point to the fact that Europe´s domestic market will not be sufficient to cover the hydrogen demand of the energy intensive industries and the transport sector. The German chemical industry only will require 628 TWh of electricity until 2050 to achieve climate neutrality, most of this electricity will be needed for hydrogen production. Germany's final electricity consumption is currently around 600 TWh[7]. In light of these short and mid-term challenges, gases will also play an important role, at least for the transition, in order to create a reliable basis for industry.

Europe might need to import hydrogen the way we import gas and oil. These strategic relationships should be mastered at the EU level.

Hydrogen should be considered as one of the key drivers for succeeding the Commission's objective of climate neutrality by 2050. The role of hydrogen will need to be considered, not only contributing to sector integration, but also as a key element to have a strong industrial value-chains in Europe. Furthermore, hydrogen provides for a viable storage option which is crucial to increasing flexibility of the internal energy market.

Setting up a new market, developing new hydrogen infrastructure and production plants requires funding and support for R&D. Therefore, the introduction of a strategic value chain on hydrogen under IPCEI is important to support the development of a hydrogen industry in the EU. Europe should support demonstration facilities in order to drive scalability. For this, IPCEI should look further than infrastructure and strengthen also the technology development and ramp-up.

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?

District Heating and Cooling (DHC) systems are key to capture waste heat potential, therefore support of DHC infrastructure is essential tool in this respect. Following the analyses carried out as a result of article 14 Energy Efficiency Directive, Member States should translate this information into national strategies, and concrete measures to support waste heat recovery as an integral part of decarbonisation.

The Commission should provide guidance and best practice to Member States. A better dialogue between governance levels and stakeholders is necessary to ensure the planning and realisation of waste heat recovery projects and give the possibility to the local level to showcase best practices.

An efficient way to raise significantly and effectively the role of waste heat in integrated energy systems would be to support the development of industrial clusters. Industrial clusters are industrial areas where a certain number of industrial facilities/sites are constructed close to the facility which produces heat as a by-product at a sufficient temperature and constant in time. This type of recovery of energy which would be otherwise

[7] https://www.vci.de/vci/downloads-vci/publikation/2019-10-09-studie-roadmap-chemie-2050-treibhausgasneutralitaet-kurzfassung.pdf

wasted allows avoiding significant CO_2 emissions and gives a new source of revenue for the producer.

The planned renovation wave for buildings is the opportunity to connect them to District Heating and Cooling (DHC) and therefore to decrease their carbon footprint, while increasing comfort.

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

CCS/U

- **Northern Lights** (Norway) is an ‘open source’ project comprising of the transport and storage scope of CCS. The project has the ambition to become a primary storage site for several carbon capture projects across Europe and a reciprocal alternative to other future storage sites. Given the number of industrial sites and companies who agreed to join this application, it clearly highlights the relevance of CCS in decarbonizing European industry. Currently the project is planned to be developed in two phases. Phase 1 consists of a capacity to transport, inject and store up to 1.5 million tons of CO2 per annum. Phase 2 would include capacity to receive, inject and store an additional 3.5 million tons of CO2 per annum, adding up to a total of 5 million tons of CO2 per annum. More info here.

- **Rotterdam CCUS project Porthos** (The Netherlands): The Rotterdam CCUS project Porthos (Gasunie, EBN, & Portof Rotterdam Authority) aims at collecting the CO2 from multiple industrial installations in the Rotterdam port area and transporting it in an open-access, public pipeline for offshore storage to a depleted gas field 25 km from the coast at a depth of around 3 km. Under the plan, around 2.5–5 Mtpa CO2 from the refineries and chemical plants in the port would be captured and stored.

  A relatively small amount of CO2 from Rotterdam industry is already being used (CCU) by greenhouse horticulture in South Holland, where it enables plants to grow faster. The Porthos infrastructure will also be suitable for transporting CO2 for use by industry, if there is demand for this in the future. In February 2019, companies were invited to participate in an ‘Expression of Interest’ to signal their potential readiness to supply volumes of CO2 into the planned public collector pipeline. As of December 2019, Porthos signed an agreement with companies ExxonMobil, Shell, Air Liquide and Air Products to work on preparations for the capture, transport and storage of CO2. The capture is to take place at the companies’ refineries and hydrogen production sites in Rotterdam. Transport to and storage beneath the North Sea is being prepared by Porthos. Sharing a common infrastructure between several industrial sites, the Porthos project aims to drive cost efficiencies relative to old CCS business models based on a single industrial emitter.

  The project was awarded CEF funding in January 2019 and has enjoyed the status of PCI since 2017. Finally, the Dutch government has put in place a financing scheme, SDE++, which is a kind of contract for differences between the current ETS price and the needed CO2 price to make the project economically viable. More info here.

- **Ravenna Hub CCS Project** (Italy): The Ravenna CCS project aims to develop a large scale project in the industrial hub of Ravenna. The district's features in terms size and the possibility to leverage existing infrastructure make an excellent case for developing a large integrated project. In the Ravenna Hub it will be possible to capture the CO2 from industrial sites, electricity generation from gas and hydrogen production and to transport it to the depleted gas fields of the Adriatic offshore. The site has a storage potential between 300 and 500 million tons of CO2. This project will have a positive impact on the socio-economic situation of the area and will also be the first large-scale CCS project in Southern Europe. More info here.

Waste heat & water

- **Kilpilahti waste heat project** (Finland): Excess waste heat from industrial area of Kilpilahti, where currently 1.1 GW of low value waste heat ends up in the sea. The project could produce up to 3-5 TWh of heat to capital region and would cost approximately 700 – 1000 M EUR. More info here.

- **Suomenoja wastewater heat pumps** (Finland) utilizes the wastewater heat from treated wastewater as well as seawater in the summer. This will increase the carbon neutral share of Espoo's district heat production to 50% in 2022. More info here.

Hydrogen

- The **NorthH2** project (The Netherlands) aims to establish a large-scale integrated green hydrogen value chain. By 2030 4 GW of electrolyser capacity, powered by additional and dedicated offshore wind, will provide 0,3 million ton/year of green hydrogen to Northwest European industrial clusters as well as to the heavy-duty mobility sector. The ambition of the project is to grow to ultimately 10+ GW by 2040, (0,8 million ton/year). The project involves the integral development of all aspects of the green hydrogen value chain: dedicated offshore wind and electrolysis capacity on a gigawatt scale (up to 2030 onshore electrolysis, after 2030 offshore electrolysis), offshore transportation of electricity respectively hydrogen, onshore hydrogen transport connecting all industrial clusters, large scale storage in salt caverns and a corresponding green hydrogen market development. More info here.

Other projects can be found here.