North Sea Energy
offshore
system
integration

2.3

North Sea Energy 2020-2022

Quick-scan policy analysis offshore system integration options North Sea countries

North Sea Energy 2020-2022

Unlock the low-carbon energy potential North Sea with optimal value for society and nature

The North Sea Energy program and its consortium partners aim to identify and assess opportunities for synergies between energy sectors offshore. The program aims to integrate all dominant low-carbon energy developments at the North Sea, including: offshore wind deployment, offshore hydrogen infrastructure, carbon capture, transport and storage, energy hubs, energy interconnections, energy storage and more.

Strategic sector coupling and integration of these low-carbon energy developments provides options to reduce CO2 emissions, enable & accelerate the energy transition and reduce costs. The consortium is a public private partnership consisting of a large number of (international) partners and offers new perspectives regarding the technical, environmental, ecological, safety, societal, legal, regulatory and economic feasibility for these options.

In this fourth phase of the program a particular focus has been placed on the identification of North Sea Energy Hubs where system integration projects could be materialized and advanced. This includes system integration technologies strategically connecting infrastructures and services of electricity, hydrogen, natural gas and CO2. A fit-for-purpose strategy plan per hub and short-term development plan has been developed to fast-track system integration projects, such as: offshore hydrogen production, platform electrification, CO2 transport and storage and energy storage.

The multi-disciplinary work lines and themes are further geared towards analyses on the barriers and drivers from the perspective of society, regulatory framework, standards, safety, integrity and reliability and ecology & environment. Synergies for the operation and maintenance for offshore assets in wind and oil and gas sector are identified. And a new online Atlas has been released to showcase the spatial challenges and opportunities on the North Sea. Finally, a system perspective is presented with an assessment of energy system and market dynamics of introducing offshore system integration and offshore hubs in the North Sea region. Insights from all work lines have been integrated in a Roadmap and Action Agenda for offshore system integration at the North Sea.

The last two years of research has yielded a series of 12 reports on system integration on the North Sea. These reports give new insights and perspectives from different knowledge disciplines. It highlights the dynamics, opportunities and barriers we are going to face in the future. We aim that these perspectives and insights help the offshore sectors and governments in speeding-up the transition.

We wish to thank the consortium partners, executive partners and the sounding board. Without the active involvement from all partners that provided technical or financial support, knowledge, critical feedback and positive energy this result would not have been possible.

North Sea Energy offshore system integration

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Disclaimer

This report represents a quick-scan of policies in North Sea countries. It represents the status as of summer 2021. Since then many policy updates have been processed, partially as a consequence of the Russian invasion of Ukraine and the following energy crisis. Information in this report may thus be outdated. For a more updated overview of relevant policies, ambitions and regulations we refer to more recent reports 'Legal Challenges for Offshore System Integration in Energy Hubs' and 'North Sea Energy Roadmap 2050. Both reports are available on the North Sea Energy website https://north-sea-energy.eu/nl/results-2022/

1 Introduction

European Commission's provisional agreement based on the European Green Deal is setting into law the objective of a climate neutral EU by 2050, and a collective, net, greenhouse gas emissions reduction target of at least 55% by 2030 compared to 1990[1]. Offshore renewable energy is the cornerstone of the European Energy System to reach such ambitious targets by 2050. The EU offshore renewable strategy presents a general enabling framework, addressing barriers and challenges common to all offshore technologies and sea basins but also sets out specific policy solutions adapted to the different state of development of technologies and regional contexts. To ensure that the EU targets are met, by EU regulation, each Member State has released the 2021-2030 National energy and Climate Plans (NECP) setting out how to reach its national targets, including the binding national target for reducing greenhouse gas emissions that are not covered by the EU Emissions Trading System (ETS)[2].

The aim of the North Sea Energy program[3] is to deliver, by the end of 2022, a roadmap for offshore system integration in the North Sea towards 2050 in which the multidisciplinary results from all phases of the program are integrated to support reaching climate neutrality by 2050. It will include practical timelines to develop system integration projects and assess whether the transition to the new energy system is creating barriers to aligning investment agendas with infrastructure developments, and how to resolve them.

This report is a guideline document to align and compare the vision and policies of the North Sea countries' (Belgium, Denmark, Germany, Netherlands, Norway and United-Kingdom). The following offshore technologies that will play a key role in the future North Sea energy system are outlined:

- Offshore wind production: European vision unveils 450 GW of offshore wind by 20504, making it a crucial pillar in the energy mix together with onshore wind. Out of this 212 GW will be generated from The North Sea.
- Hydrogen production: In order to launch the scale up of hydrogen production, distribution and use, the European Hydrogen Strategy sets a strategic approach to install at least 6 GW by 2024 and 40 GW of renewables linked electrolysis capacity in the EU by 2030, adapt infrastructure needs and boost demand in end-use sectors.5.
- Offshore Carbon Capture and Storage (CCS): Ultimately CCS and CCU (carbon capture and utilisation) are mutually supportive solutions, since both require access to capture facilities and to gas infrastructure and transportation services. They should both be seen as technology options to cost-effectively meet the EU's climate targets for 2030 and 2050. Europe is well placed to benefit from CCS and CCU due to its extensive pipeline infrastructure which can be used to transport CO2 and other renewable and decarbonised gases6.
- Platform electrification: Research is being done into the connection and electrification of offshore oil and gas platforms. This will allow part of the electricity generated offshore to be used by these oil and gas platforms, without the need for transportation to land. A large gas and for transport to land7.

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[1] nl_final_necp_main_en.pdf (europa.eu)

[2] necp_factsheet_nl_final.pdf (europa.eu)

[3] North Sea Energy (north-sea-energy.eu)

[4] WindEurope-Our-Energy-Our-Future.pdf

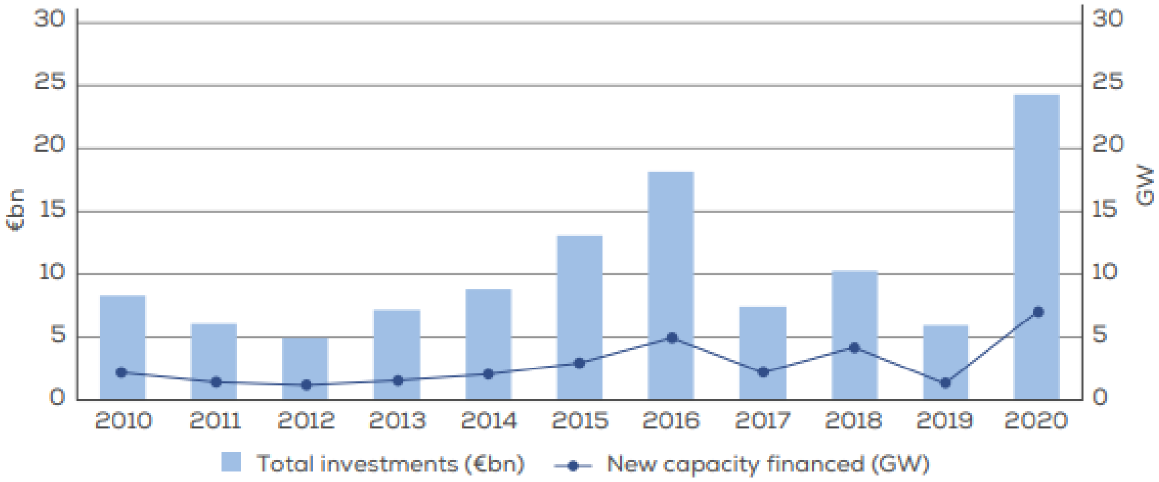
[5] General 1 — European Clean Hydrogen Alliance (ech2a.eu)

[6] The potential for CCS and CCU in Europe (europa.eu)

[7] Programme 2030 - TenneT

- Hydrocarbons: Traditionally fossil fuels have been used as the main resource to obtain energy but its use has several negative impacts, such as global warming and air pollution.8 Europe is well placed to benefit from its extensive oil and gas pipeline infrastructure.

Europe remains the global leader in offshore wind, with 80 % of total capacity and significant new investments planned by several Member States, located in the North and Baltic Sea. According to figures from the European Investment Bank, 10 million households in the EU-27 and UK are now served by offshore wind energy: Belgium (6.4%), Denmark (7%), Germany (34%), the Netherlands (6.4%) and the UK (44 % share of capacity, see Figure 1 below. Offshore wind could theoretically meet over 80 % of Europe's electricity needs if all reasonably priced locations, including other European Sea basins were exploited (at an average cost of €65/MWh), while up to 25 % of Europe's energy needs could be met just by exploiting the most favorable offshore locations (at an average cost of €54/MWh).



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total investments (€bn)	8.4	6.1	5	7.2	8.8	13.1	18.2	7.5	10.3	6	24.2
New capacity financed (GW)	2.2	1.5	1.3	1.6	2.1	3	5	2.3	4.2	1.4	7.1

Figure 1 New offshore wind investments and capacity financed 2010-2020

In 2020 the European Commission released its Hydrogen Strategy which aims to decarbonise hydrogen production and expand its use in sectors where it can replace fossil fuels[9]. The strategy focuses on hydrogen produced from renewable energy sources, otherwise known as "green hydrogen". For the governmental targets on hydrogen installed capacity for 2030, see Figure 2.

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[8] Fossil fuel energy consumption in European countries - ScienceDirect

[9] Questions and answers: a Hydrogen Strategy for a climate neutral Europe", European Commission (https://ec.europa.eu/commission/presscorner/detail/en/QANDA_20_1257), pg. 1.

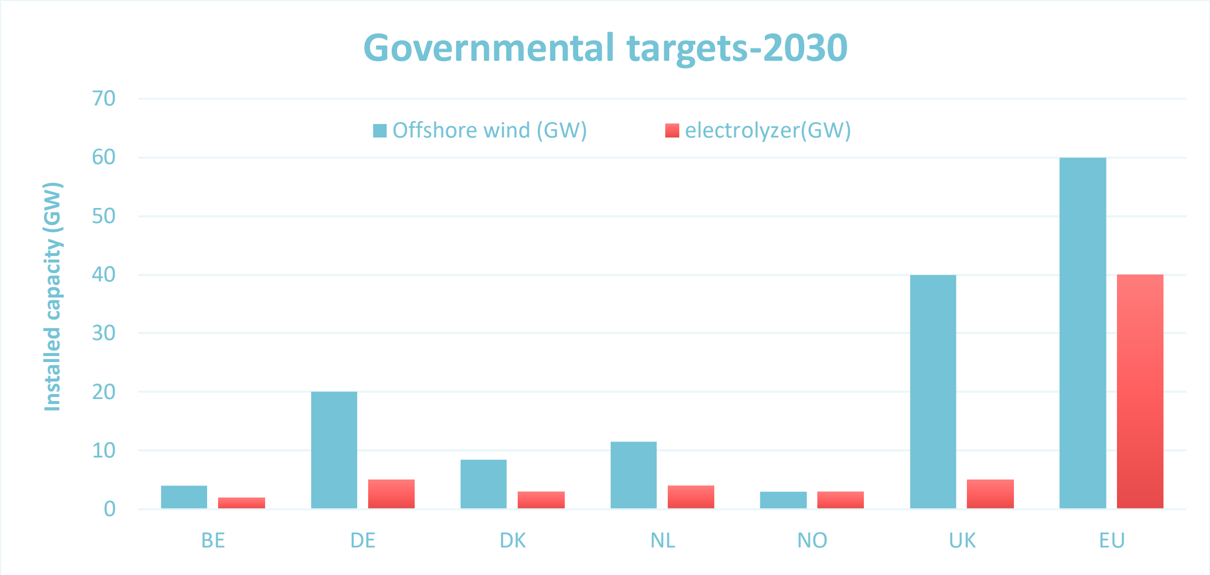

Figure 2 Government targets on offshore wind and hydrogen installed capacity for 2030 (Note: UK targets 5 GW low carbon hydrogen and Netherlands targets between 3-4 GW

The European Green Deal Investment Plan is the investment pillar of the Green Deal. This, together with the new instruments under the EU Recovery Package could mobilise at least €1 trillion in sustainable investments over the next decade to fund the green transition. These cover funds in the EU Budget, Just Transition Mechanism, InvestEU instrument (including contribution from the European Investment Bank) and co-financing from Member States under different programmes and instruments. The innovation fund and EU green investment plan has started, and CCS will be an integral part of this funding opportunities.

Improved EU funding instruments are being designed to support CCS projects. For instance, the Innovation Fund[10] will be one of the largest funding instruments in the world for demonstration of innovative low-carbon technologies. Compared to its predecessor, the NER300, it is much more flexible: it improves the risk-sharing for projects, as its grants cover up to 60% of the additional capital and operational costs of innovation; the cash flow of the project is ensured through predefined milestones; it has simplified processes and allows synergies with other EU funding programmes. This positive trend should continue and all relevant EU funding instruments for both private investors and Member States should offer the opportunity to fund CCS projects and its value chain to develop a European decarbonised industry. CO_2 can be stored underground in saline aquifer or depleted oil & gas fields. Europe is well place to benefit from CO_2 storage sites available in the North Sea.

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[10] https://ec.europa.eu/commission/presscorner/detail/en/IP_20_1250

2 Strategic visions of North Sea countries

The main aspects include targets and investments/financing activities, long-term outlook, and infrastructure and grid connections. By 2030 all countries have binding targets, currently under EU regulation and the NECP. Beyond 2030, by 2050, the figures included are aims and goals but not binding yet, until the EU Climate Law is in place with national targets. Current and future offshore deployment for each technology is lined out in Table 1.

Table 1 Summary of the estimated cumulative capacity per offshore technology for each of the North Sea countries for the years 2020, 2030 and 2050. BE=Belgium, DE= Germany, DK= Denmark, NL= Netherlands, NO=Norway, UK= United Kingdom

Country	BE			DE			DK			NL			NO			UK		
Year Technology	2020	2030	2050	2020	2030	2050	2020	2030	2050	2020	2030	2050	2020	2030	2050	2020	2030	2050
Offshore wind (GW)	2.3	4	6	7.8	20	36	1.3	8.5	35	4.9	11.5 – 18.6	60 - 75	12	4.5	30	10.4	40	80
Hydrogen*[11] (GW)		2			5	10		2-3		<0.5	3-4						5	
CCS (MtCO$_2$/year)										1.7	10.2						10	
Platform electrification (GW)													1					
Hydrocarbons**																		

* Data available from governmental strategy and vision documents does not show the split between offshore and onshore installed capacity. Moreover, in some countries like the UK targets for installed capacity do not distinguish between electrolyser and other technologies (e.g. synthetic methane reforming -SMR).
** projection for oil and gas production.

2.1 Belgium

Similar Europe as a whole, Belgium is largely dependent on imports of primary energy sources (oil, natural gas, coal, nuclear fuel) to meet domestic demand. Belgium does not have a clear policy on the diversification of its energy supply when it comes to oil, natural gas or coal. Belgium already has an efficient and well-developed natural gas network, with well-established internal infrastructure complemented by interconnections with all its neighbouring countries, Belgium's gas transmission system operator, Fluxys, has a major stake in key projects in central and western Europe. This provides added flexibility and enhances both security of supply and the attractiveness of Belgium's natural gas market. The interconnection rate makes an enormous contribution to energy security, provided that this security can be guaranteed for Belgian consumers. This aspect will need to be developed in future and will be included in measures relating to market function

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[11] Electrolysis or SMR/ATR capacities

2.1.1 Offshore wind production

2.1.1.1 Targets and financing activities

Belgium is a country with a political-administrative structure shared between the Federal government and three regions: Wallonia, Flanders and the Brussels-Capital Region 12. To date, the country has eight operational wind farms in the Belgian section of the North Sea with a total installed capacity of nearly 2.3 GW. Belgian offshore wind farms generated 6.7 TWh of electricity in 2020, which represented 8.4% of total electricity consumption in Belgium, or the electricity consumption of around 1.9 million families[13.]

The Belgian government invested 2.728 million EUR in offshore and land-based wind in 2017. Several key technologies that Belgium wants to invest in for the future have been put forward via the Steering Group of the SET-Plan. With some research projects, like GREDOR or SmartWater in the Walloon Region, Belgium is developing services that will ease the future integration of a larger share of wind energy by modernizing the electric grid and offering capacity for clearly tailored storage[14].

2.1.1.2 Long term outlook

According to the draft NECP, the contribution of offshore wind to Belgium's renewable energy mix will grow to 4 GW by 2030. The expansion will allow the country to install wind turbines with enough capacity to replace some nuclear power capacity, supporting Belgium's strategy for growing renewables and phasing out nuclear power by 2025[15].

2.1.1.3 Infrastructure and grid connection

Offshore wind energy is an indispensable aspect in the Belgian Climate Plan[16]: without the large wind turbines off the North Sea coast (wind turbines are mainly installed offshore, in the Flemish and in the Walloon Regions), it will be impossible for Belgium to reach its European targets. Existing and future offshore wind parks are expected to provide no less than 50% of all renewable energy production by 2020. A study conducted by the independent bureau Futureproofed (commissioned by C-Power) has shown that the CO_2 emission produced during the construction and exploitation of a wind park is 'won back' within the first year. Over its expected operational lifespan of 20 years, a wind turbine park emits 115 times less CO_2 than the current Belgian electricity mix and 175 times less than the most modern gas power station. Recent studies have also shown that wind parks at sea not only offer shelter to various species of fish and other maritime fauna and flora, but also make a positive contribution to the marine environment in general[17].

As regards the interconnection capacity, Belgian and Danish transmission system operators, Elia and Energinet, have signed a political agreement to assess the possibility of connecting the countries' grids via the energy island in the North Sea (February 2021). It concluded between the Danish Minister for Climate, Energy and Utilities and the Belgian Federal Minister of Energy and the energy island in the North Sea is now central to assessing three possible electricity interconnections to Germany, the Netherlands, and Belgium. The energy island in the North Sea will be an artificial island consisting of one or more types of caissons 80 kilometres off the Danish coast. The island needs to be established by 2033 or sooner, if possible. By this point, it must be ready to deliver 3 GW of offshore wind power. The island's capacity will be increased to 10 GW in the 2030s.

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[12] The three regions are Wallonia, Flanders and the Brussels-Capital Region. This distributed decision-making structure is blamed as the primary reason for the lack of a well-developed strategic vision on energy and climate for the country

[13] Belgian Offshore Wind Farms Generate 6.7 TWh in 2020 | Offshore Wind

[14] IEA, 2020

[15] Belgium plans new offshore wind zone in line with 4-GW goal | Global Wind Energy Council (gwec.net)

[16] be_final_necp_parta_en.pdf (europa.eu)

[17] https://www.belgianoffshoreplatform.be/en/services/sustainable-enterprise/

2.1.2 Hydrogen production

2.1.2.1 Targets and financing activities (investments)

The annual costs to produce green hydrogen (including the cost of dedicated renewable electricity sources), to develop the transport infrastructure (or adapt the existing one) and end-user applications would in the considered scenarios reach respectively 270 and 1200 million EUR. These activities will generate value added in the domestic economy, amongst others by creating jobs in manufacturing, construction and operation of hydrogen technologies and will contribute to greenhouse gas emission reductions. This is particularly important in hard-to-decarbonize industries[18].

2.1.2.2 Long term outlook

Wallonia has mentioned in the NECP that 1% of its passenger cars should be hydrogen driven by 2030, and that hydrogen could become an alternative fuel to decarbonise heavy logistic vehicles. To enable this shift to hydrogen, 10 hydrogen refuelling stations would be required by 2025 and 20 by 2030.

To cover the estimated hydrogen demand from new uses and from substitution of fossil-based hydrogen, 1.5 to 8.6 GW of dedicated renewable electricity capacity would have to be installed to produce green hydrogen via electrolysis. While “surplus” electricity might be available in times of high renewable electricity production, the main share will have to be covered by dedicated sources. Part of the 2030 hydrogen demand would still be covered by fossil-based hydrogen produced via steam-methane reforming of fossil fuels[19].

According to the European EUCO3232.5 scenario 6, the Belgian GHG emissions should be reduced by 33 Mt CO_2 in 2030, compared to 2015. In the scenarios considered, the deployment of hydrogen could contribute 0.4 – 1.8 Mt CO2 to this goal, which is equivalent to 1% - 6% of the required emission reduction.

2.1.2.3 Infrastructure and grid connection

Under Belgium’s administrative structure regions have stronger say on fuel and infrastructure development. As such, with NECP, Flanders has stated “the ambition to become a European leader in hydrogen technologies.” Moreover, the region of Wallonia stated within the NECP that 1% of its passenger cars should be hydrogen driven by 2030, and that hydrogen could become an alternative fuel to decarbonize heavy logistic vehicles. Overall, current deployments indicate that Belgium could become one of the leading countries in Europe for the deployment of renewable or low-carbon hydrogen.

2.1.3 Carbon Capture and Storage (CCS)

NECP[20] states Belgium's strategy on CCS in the context of fostering green and circular economy. As such, there is no clearly stated CCS target or allocated budget at the Federal level. Belgium has limited readiness for wide-scale deployment of CCS. Belgium has no suitable sites for CO_2 storage on its territory but could have access to the storage potential in the Netherlands. The three regions stated their intention to develop CCS. The region of Flanders aims to develop CCS to decarbonize the petrochemical cluster within the region. Moreover, the deployment of CCS is considered as enabler of the region's ambitious hydrogen strategy. Flemish region intends to deploy CCS to decarbonize waste incineration facilities in 2050 and use it as a raw material in a circular economy.

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[18] https://www.fch.europa.eu/sites/default/files/file_attach/Brochure%20FCH%20Belgium%20%28ID%209473032%29.pdf

[19] https://www.fch.europa.eu/sites/default/files/file_attach/Brochure%20FCH%20Belgium%20%28ID%209473032%29.pdf

[20] be_final_necp_parta_en.pdf (europa.eu)

2.1.4 Platform electrification

2.1.4.1 Targets and financing activities (investments)

Belgium does not have oil and gas platforms to adopt electrification, so no targets and financing activities have been specified.

2.1.4.2 Long term outlook

Belgium does not have oil and gas platforms to adopt electrification, so no long-term outlook has been specified.

2.1.4.3 Infrastructure and grid connection

Belgium does not have oil and gas platforms to adopt electrification, so no infrastructure and grid connection has been specified.

2.1.5 Hydrocarbons

2.1.5.1 Targets and financing activities (investments)

Like many EU Member States, Belgium is strongly dependent on imports for its natural gas as well as its oil consumption. Switching from imported fossil fuel to nationally produced hydrogen for industrial processes and heating applications and facilitating the use of hydrogen in the transport sector will contribute to reducing the energy import dependence. As Belgium imports all its oil and gas consumption, its reduced usage of fossils fuels will have implications on the countries within the North Sea that exports oil and gas to Belgium including the Netherlands, Norway, UK, and Germany.

2.1.5.2 Long term outlook

Almost half of Belgium's gas imports come from the Netherlands with most delivered through a dedicated network connected to the Groningen gas field, which will stop production in mid-2022[21]. By 2025, new fossil fuel-based infrastructure will be avoided wherever possible in new workplace-home developments still to be connected to utilities. By 2030 procurement of new public utility equipment based on fossil fuels should be avoided wherever possible[22].

2.1.5.3 **Infrastructure and grid connection**

Belgium is working to address energy security issues and has one of the most interconnected electricity grids in Europe.

2.2 Denmark

Denmark is committed to ceasing all oil and gas extraction activities in the North Sea by 2050 and accelerate the production of renewable energy and other low carbon technologies

2.2.1 Offshore wind production

2.2.1.1 Targets and financing activities (investments)

The focus for Denmark is on the North Sea. Their review and strategy for offshore wind in the North Sea is known and in progress. By end 2020, the total Danish capacity of offshore wind farms is 1,271 MW. Ongoing offshore wind farm projects are further expected to add more than 1,000 MW in 2021.

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[21] Belgium - Countries & Regions - IEA

[22] ec_courtesy_translation_be_necp.pdf (europa.eu)

2.2.1.2 Long term outlook

The Sector strategy for energy and industry provides for the establishment of two energy Islands of 5 GW capacity by 2030. In total, Denmark plans to build 7.2 GW of offshore wind capacity between 2027 and 2030[23].

The tendering process for the North Sea energy hub is planned to start in 2022, with the announcement of the winner of the tender at the beginning of 2023. The hub is the largest construction project in the history of Denmark. The total cost of constructing the island, building a capacity of 10 GW wind farms and deploying the necessary infrastructure will be around €28bn[24].

2.2.1.3 Infrastructure and grid connection

One island will be established in the Danish section of the North Sea with 3GW offshore wind capacity with a potential expansion to 10 GW (same island as the one described in the Belgian vision for offshore wind). Besides, Denmark also plans to build another island in Baltic Sea with a plan to connect 2GW offshore wind power. With the development of energy islands, the government envisioned to increase the amount of renewable energy significantly and produce green electricity-based fuels.

The NSEC serves as a platform to jointly work on concepts for potential joint wind offshore projects and for coordinated electricity infrastructure including transmission infrastructure. Denmark works together with the other North Seas Energy Cooperation countries on the possibilities for concrete cooperation projects. Besides joint offshore wind projects that would be connected to and supported by several Member States, this includes the work on possible 'hybrid' solutions that would use cross-border solutions for connecting offshore wind farms to the grid and seek synergies with interconnection capacity between countries, and on the corresponding market arrangements.

2.2.2 Hydrogen production

2.2.2.1 Targets and financing activities (investments)

Denmark has not yet developed a hydrogen strategy, but the according to the National Energy and Climate Plan (NECP), the country foresees Power-to-X (PtX) to be a key technology that can contribute to fully decarbonizing the economy. A key part of the PtX plan is the development of green hydrogen. As such, development of PtX is tied to the expansion of offshore wind and development of offshore islands with the transport as a target demand sector.

2.2.2.2 Long term outlook

With this vision, the country aims to reduce 0.5–3.5 million tonnes of CO_2 by 2030 and 1.5-7.5 million tonnes of CO_2 in the longer term. This translates installing 2-3 GW installed electrolysis capacity [25].

2.2.2.3 Infrastructure and grid connection

Denmark's NECP does not include specific objectives or targets for the production or use of hydrogen, so no infrastructure and grid connections have been specified.

2.2.3 CCS

2.2.3.1 Targets and financing activities (investments)

The Danish strategy and vision on CCS are laid out within the government's Energy and Industry Sector and Green Research Strategies. Overall, the CCS strategy is intricately linked to developing and maturing PtX technologies. With the Green Research Strategy, the government will initiate a mission-based

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[23] https://ec.europa.eu/energy/sites/ener/files/documents/dk_final_necp_main_en.pdf

[24] Denmark to build 'first energy island' in North Sea - BBC News

[25] I_maal_med_den_gronne_omstilling_2030_klimapartnerskab_energi_forsyningssektor.pdf (danskenergi.dk)

research and development effort for CC(U)S and PtX. For CCS, the objective is for scientists, companies, and authorities to join forces to developing cost-effective solutions. Thus, there is no clearly stated CCS deployment target.

2.2.3.2 Long term outlook

The Danish Council on Climate Change, which advises the government, has identified the potential for offshore CO_2 storage to provide a domestic carbon sink for onshore industrial emissions from 2025 and there is broad popular support for CCS in Denmark. Project Greensand, which involves Ineos, operator of the Nini West oil field, Wintershall and Maersk Drilling, has received certification of the field as suitable for storage of 0.45 mt CO_2 per annum[26] and it may be among the first projects to proceed if a commercial model, involving some public funding, can be agreed.

The financial incentive is currently not big enough to achieve the full reduction potentials of the technologies without subsidy. The sector strategy for energy and industry therefore allocates a market-based funding pool corresponding to €108 million a year, phased in from 2024, for reducing CO2 emissions through capture and storage or capture and use. The funding pool will run for 20 years and is expected to result in annual CO2 reductions of 0.9 million tonnes by 2030[27].

The potential for carbon capture in 2030-2040 is difficult to determine precisely and depends on factors such as the development in the sectors for which the technology can be relevant. The potential for using the technology as a tool to achieve Denmark's climate targets is assessed to be able to provide reductions of 4-9 million tonnes of CO_2 by 2030 (in addition to the expected reduction from the CCS pool in the sector strategy for energy and industry) in the industrial, energy and waste sectors and by carbon capture from biogas plants. The assessment is based on the expected developments in the individual sectors and will be determined more accurately during the continued efforts in the coming CC(U)S strategy work.

2.2.3.3 Infrastructure and grid connection

CC(U)S is an efficient societal tool for achieving Denmark's climate objectives, but the companies that may be able to use the technology lack a personal finance incentive to do so. We have not yet gained experience with CCS in Denmark, but the technology is being used in other countries, such as Norway. The potential for carbon capture from large Danish point sources is extensive but depends on the specific development of the individual sources. It is assessed that the Danish subsoil can potentially accommodate up to 500 times the current total annual Danish CO_2 emissions.

2.2.4 Platform electrification

2.2.4.1 Targets and financing activities (investments)

The territorial binding emissions reduction targets of The Climate Act has put pressure on the oil and gas sector to find ways to reduce emissions in existing operations such as platform electrification and to use its infrastructure at the end of the production phase for carbon removal, principally CO_2 storage, or hydrogen production.

In 2020, Total (the largest operator of oil and gas in Danish part of the North Sea) recently announced that they are joining the O/G Decarb innovation project to explore the possibility of using a combined

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[26] Subsea CO2 storage plan offshore Denmark clears first regulatory hurdle', World Oil, 25 November 2020.

[27] https://unfccc.int/sites/default/files/resource/ClimateProgramme2020-Denmarks-LTS-under-the%20ParisAgreement_December2020_.pdf

wind and wave technology on a floating foundation to electrify platform[28]. The project is seen as means to reduce emissions, increase the lifetime of production and a steppingstone for future hydrogen production.

2.2.4.2 Long term outlook

Electrification of platforms, either from shore or from offshore wind, is economically hampered by the maturity and small scale of most remaining resources[29].

2.2.4.3 Infrastructure and grid connection

2.2.5 Hydrocarbons

Denmark has produced oil and gas from the Danish part of the North Sea since 1972. The country is the biggest oil producer in the European Union. In 2020, the Danish government announced that they will end new oil and exploration in the North Sea, as part of the country's plan to become climate neutral by 2050. With this announcement, the government also stated that the country will phase out fossil fuel extraction by 2050.

2.3 Germany

2.3.1 Offshore wind production

2.3.1.1 Targets and financing activities (investments)

The vast majority of Germany's offshore turbines are located in the North Sea, with about 1,230 spinning off Germany's western coast, compared to just over 230 in the Baltic Sea in the East. As of early 2020, the higher target for offshore wind had not been put into law. According to research institute Fraunhofer IWES, Germany could potentially install up to 54 GW of offshore and generate nearly 260 TWh of electricity at sea.

2.3.1.2 Long-term outlook

The German federal government has set specific objectives to meet this target: in 2020, offshore wind farms had a capacity of 6.5 gigawatts (GW) are to be connected to the grid. At the end of 2020, 1,501 offshore wind turbines (OWT) with a capacity of 7,770 MW were in operation. In a European comparison, this puts Germany in second place behind the United Kingdom. There are no new offshore wind energy projects (OWP) under construction, thus no capacity additions are expected for the upcoming year 2021. From 2022, the OWP awarded in the 2017/2018 tender rounds are to be commissioned. These OWP will successively increase the cumulative capacity to 10.8 GW by 2025. By 2030, a total of 20 GW should be available[30]. Recently, the German government has adopted an amendment that raises offshore wind power target to 40 GW by 2040.

2.3.1.3 Infrastructure and grid connection

The clustering of power generation capacity in northwestern Germany creates challenges for providing sufficient grid capacity to transmit large volumes of electricity produced centrally in a small area. Lacking grid connection from the sea to the mainland in the past already led to a situation mocked by critics of

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[28] O/G Decarb innovation project, 2020. New innovation project will reduce CO2 emissions from offshore oil and gas production - Centre for Oil and Gas - DTU

[29] Denmarks-phase-out-of-upstream-oil-gas.pdf (oxfordenergy.org)

[30] Energy from the sea and land, www. tennet.eu 2020_From_Sea_to_Land_Webversion.pdf (tennet.eu) https://www.wind-energie.de/fileadmin/redaktion/dokumente/dokumente-englisch/statistics/Status_of_Offshore_Wind_Energy_Development_-_Year_2020.pdf

the technology in which turbines had to be powered with diesel generators to prevent corrosion and other damage. Regular operation of the turbines was not possible since these produce much more electricity than what is needed to power them up while the surplus could not be disposed of. However, this sort of problem largely appears to be a thing of the past. In the offshore wind power industry's 2019 status report, industry association BWO said there were merely 16 out of nearly 1,500 turbines that still lacked a grid connection. The existing grid in 2018 had a transmission capacity of 6.8 GW and another 1.4 GW were slated for completion by the end of 2020. Transmitting power from production sites at sea to the mainland is only one part of the problem. Another and perhaps even bigger challenge is to cover the much longer distance from windy northern Germany to industrial centers in the south, which the Federal Network Agency (BNetzA) has outlined in its offshore grid-development plan.

The major transmission line projects, SuedLink and SuedOstLink, are scheduled for completion by 2025 [See the CLEW dossier on Germany's power grid for background]. However, constant opposition from both local residents and lawmakers to the large-scale infrastructure projects that run hundreds of kilometers through the country has put this timeline in danger[31].

2.3.2 Hydrogen production

2.3.2.1 Targets and financing activities (investments)

To support the development of hydrogen within Germany, the government published its "National Hydrogen Strategy" in June 2020. Besides the German National Hydrogen Strategy, several regional strategies have been published, including those for North-Rhine Westphalia, Bavaria, Eastern and Northern Germany. To speed up the hydrogen market rollout within Germany the government is making €7 bn available for hydrogen and hydrogen-related projects or instruments. Financial support of a further €2 bn will be provided for international partnerships. The federal government believes that only RES-based hydrogen will be sustainable in the long term. Hence, only this kind of hydrogen is addressed and supported by the national strategy. It does recognise that other forms of low-carbon hydrogen will be an option in other countries, and therefore contemplates other forms of low-carbon hydrogen imports (e.g. natural gas-based blue hydrogen), at least initially[32].

2.3.2.2 Long term outlook

The government strategy gives preference to green hydrogen produced by electrolysis using electricity from renewable energy sources. As such, the strategy sets a target for a cumulative electrolysis capacity of 5 GW by 2030. A further 5 GW is planned between 2035 and 2040. Assuming 4000 full load hours for electrolysis, the targeted capacity of 5 GW generates only 14 TWh. That is way lower than the projected hydrogen generation of 90-110 TWh by 2030. By 2050 hydrogen consumption will be between 110-643 TWh as indicated by various studies (e.g. Environment, Nature Conservation and Nuclear Safety, and projects by the regional government of North-Rhine Westphalia). As a result, the strategy gives emphasis to imports. Moreover, considering the high projected demand and low RES based hydrogen capacity, the national strategy also recognizes that other types of low carbon hydrogen (e.g. natural gas based blue hydrogen) will play a role, particularly at early stages but will have to be imported from other countries[33].

2.3.2.3 Infrastructure and grid connection

Since hydrogen is often generated onsite, being produced and consumed within the same chemical park, there are hardly any mature or liquid markets for the energy carrier. However, some vertically integrated

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[31] German offshore wind power - output, business and perspectives | Clean Energy Wire

[32] BMWi (2020), Die Nationale Wasserstoffstrategie, Nationales Reformprogramm 2020 - Die Nationale Wasserstoffstrategie (bmbf.de)

[33] Contrasting-European-hydrogen-pathways-An-analysis-of-differing-approaches-in-key-markets-NG166.pdf (oxfordenergy.org)

industrial gas producers such as Air Liquide or Linde do produce, transport, and market hydrogen to larger industrial clients or the retail market. Some pipeline networks exist, which connect different hydrogen sources and sinks. In Germany, Air Liquide operates a hydrogen infrastructure network in the Rhine-Ruhr Area in North-Rhine Westphalia, connecting chemical parks and refineries from Dortmund through Marl and Düsseldorf to Leverkusen. Linde also operates a hydrogen pipeline network of more than 130 km, connecting industrial consumers in Eastern Germany.

2.3.3 CCS

2.3.3.1 Targets and financing activities (investments)

In the Climate Action Programme 2030, which was approved in autumn 2019, the government says it will set up an CCS programme, noting that most studies show the technology to be indispensable for reaching greenhouse gas neutrality by 2050. CCS offers “a comparatively low-cost reduction possibility for unavoidable emissions from industrial processes in the mid-term”, it points out. The government thus plans to intensify CCS research and development, as also stated in the economy ministry’s Industry Strategy 2030.

A large part of the European offshore is potentially available for storage. For this purpose, Germany needs to cooperate with countries such as Norway, required in the Netherlands and Great Britain. The BMWi is therefore the further development support various elements of these technologies and work in cooperation with European partners for a corresponding industrial pilot project[34].

2.3.3.2 Long term outlook

2.3.3.3 Infrastructure and grid connection

2.3.4 Platform electrification

2.3.4.1 Targets and financing activities (investments)

Electrification can be considered as a retrofit of existing platforms or in the design of new developments. No detailed information has been found on the vision of Germany on platform electrification.

2.3.4.2 Long term outlook

2.3.4.3 Infrastructure and grid connection

2.3.5 Hydrocarbons

2.3.5.1 Targets and financing activities (investments)

In its energy transition so far, Germany has maintained a high degree of oil, natural gas and electricity supply security. Planned nuclear and coal phase-outs are set to increase the country’s reliance on natural gas, making it increasingly important to continue efforts to diversify gas supply options, including through liquefied natural gas imports.

Nonetheless, to date, the electricity sector has been shouldering a sizeable share of the Energiewende’s costs and progress. Now, the government must refocus its efforts to achieve stronger emissions reductions in other sectors, notably transport and heating. In order to achieve extensive decarbonisation in these sectors by 2050, efficient technologies must be used which maximise the replacement of fossil

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[34] Industriestrategie 2030 (bmwi.de)

fuels while using as little renewable electricity as possible. Thus far, fossil fuels for transport and heat have been less expensive for consumers than electricity, because through surcharges, taxes and levies, electricity makes a greater contribution to financing the Energiewende. Key questions of developing sector coupling are being discussed in the consultation processes for the Green Paper on Energy Efficiency and Electricity 2030[35].

2.3.5.2 Long term outlook

The medium-term target is to cut greenhouse gas emissions in Germany by at least 55% by 2030, 70% by 2040 and 80-95% by 2050 compared to 1990 levels. The aim is to increase renewable energy, modernize fossil fuel power plants and develop more co-generation plants[36].

2.3.5.3 Infrastructure and grid connection

Germany wants to avoid any new investment in fossil energy infrastructure and the resulting lock-in effects[37].

2.4 Netherlands

2.4.1 Offshore wind

2.4.1.1 Targets and financing activities (investments)

In the Esbjerg declaration of June 20, 2019, energy ministers of the North Sea countries declared their ambition to accelerate the deployment of offshore wind. A successful transition to a low-carbon energy system in the Netherlands will see 61% of electricity generation coming from offshore wind. Expected capacities of 38 GW or 72 GW was factored into the Import-Dependent and Self-Sufficient Scenarios. 32020 was a record year for offshore wind financing in Europe with €26.3bn raised for the financing of new offshore wind farms, including €2.1bn in offshore transmission infrastructure. It was also a record for new capacity financed with 7.1 GW, indicating an important shift of speed and volume in the European offshore wind sector (Figure 2). Notably 2020 saw the final investment decisions taken in the Netherlands, on two offshore wind farms, the 1.5 GW Hollandse Kust Zuid (1-4) wind farm and in the UK, the first two phases of Dogger Bank wind farm Dogger Bank A and B, with a combined capacity of 2.4 GW. The capital raised for these two alone was almost €13bn which, on their own, would have been amongst the highest annual amounts on record in Europe (SETWind, 2021)[38] [39].

2.4.1.2 Long-term outlook

An average growth of 1.5 GW/year and 3 GW/year is required after 2030 to achieve the offshore wind energy capacity goals by 2050. This is greater than the current growth rate of 0.97 GW/year (period 2020-2030) but, comparatively speaking, markedly lower than the growth rate of offshore wind energy in Europe between 2009 and 2019. In the Dutch Climate Agreement, a capacity rollout of 1 GW/year has been agreed by 2030 and to reach 2050 the growth rate is exponential. Depending on the actual scale, by 2050, offshore wind may cover 17-26% of the Dutch Exclusive Economic Zone (EEZ) in the North Sea.

System integration will become more important to boost source reliability. To improve the societal acceptance, the ecological impact and spatial planning are crucial elements for the future development

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[35] Climate Action Plan 2050 – Principles and goals of the German government's climate policy (bmu.de)

[36] Germany 2020 – Analysis - IEA

[37] Climate Action Plan 2050 – Principles and goals of the German government's climate policy (bmu.de)

[38] WindEurope2020

[39] WindEurope2021

of offshore wind. Synergies with the declining oil & gas sector and co-operation with blue economy sectors must be larger.

2.4.1.3 Infrastructure and grid connection

Offshore wind farms compete for limited offshore space, and must be optimally planned with, around and between the other users of the North Sea. Novel techniques and knowledge should be developed to deal with the automatic control and operations[40]. New areas for offshore wind energy will be designated after careful consideration of all interests in the North Sea in the North Sea 2022-2027 programme[41].

Another important aspect for the growth of offshore wind energy after 2030 is that the electricity generated must be properly integrated into the energy system, which means that the required infrastructure such as cables and sub stations must be available in good time. An analysis of landfall options for offshore wind 2030-2040 (the 'VAWOZ' project) is set to start on 9 December 2020. This project forms the link between the North Sea 2022-2027 programme, which focuses on marine spatial planning and the National Energy Network Programme, which focuses on the spatial planning for the main energy system on land.

2.4.2 Hydrogen production

2.4.2.1 Targets and financing activities (investments)

CO2-free (green) hydrogen production is regarded as a necessary link in the move towards a sustainable energy and raw materials system. Hydrogen also has a role to play as a substitute for natural gas in the production of high temperature heat in the industrial sector and as a raw material in chemical processes. Cumulative investments in hydrogen technologies are estimated at 3.9-15.2 billion EUR until 2030, while annual expenditure would amount to 520-2000 million EUR (including end user appliances as well as power and gas grids)[42].

2.4.2.2 Long-term outlook

The following milestones have been set by the Dutch government:

- 2019-2021: At present there are eight hydrogen refuelling stations in the Netherlands. Currently, offshore electrolysis is already being actively examined but this is still in the pilot phase (for example, the PosHYdon project with 1 MW hydrogen production (PosHYdon, 2020)). Preparatory programmes are made for the roll-out of hydrogen, using a considerable number of ongoing initiatives and projects as a point of departure, to be concluded with an evaluation to inform the further specifications and objectives of the next phases. At the end of 2021, a decision will be made on the final structure of the next phase and the extent of the scaling up beyond 2030.
- 2022-2025: 20 hydrogen refuelling stations in the Netherlands are planned by end-2021 and 50 by 2025. Based on the results of the first phase, particularly if the cost reduction of electrolysis and the commitment of the relevant parties provide a sufficient basis, scaling up to 500 MW of established electrolysis capacity by 2025, in conjunction with the development of the demand for hydrogen and regional infrastructure and the connection of various clusters. In 2025, a decision will be taken on the final structure of the next phase.

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[40] https://www.topsectorenergie.nl/sites/default/files/uploads/Wind%20op%20Zee/Documenten/20190930_RAP_The-Netherlands-long-term-offshore-wind-R-D-Agenda_V05-w_0.pdf

[41] North Sea Energy Outlook establishes framework conditions for future growth of offshore wind energy | News item | Government.nl

[42] https://www.fch.europa.eu/sites/default/files/file_attach/Brochure%20FCH%20Netherlands%20%28ID%209474122%29.pdf

- 2026-2030: Hydrogen production may develop quickly using onshore technology, so it is possible it will be implemented before 2030. The electrolysis capacity in the North Sea will amount to about 100 MW by 2030. The Climate Agreement contains a target for 3-4 GW of established electrolysis capacity, connection to storage sites and expansion of infrastructure, on the condition of additional growth of renewable electricity.
- By 2050: A major potential demand for hydrogen comes from the manufacturing of synthetic hydrocarbon fuels for aviation and marine bunkers. This is estimated to lead to a hydrogen demand of 700 PJ/yr (195 TWh) or more by 2050. For industry, hydrogen is likely to have a role for providing high temperature heat, and demand in this sector is estimated at around 100 PJ/yr (28 TWh) to replace current natural gas use in that application. Industrial hydrogen demand would increase substantially to over 480 PJ/yr (135 TWh) if used to replace fossil fuels as a feedstock in base chemical production.

While the objective of the Dutch government is to focus on green hydrogen, the Dutch government sees blue hydrogen as making an optimal contribution to the development of a broader hydrogen system without impeding the growth of green hydrogen[43].

2.4.2.3 Infrastructure and grid connection

The small amount of offshore production could enable the hydrogen produced to be blended in the existing gas pipelines. The Netherlands is increasingly becoming an attractive playing field for hydrogen developers owing to its extensive natural gas pipeline infrastructure and depleted gas fields in the North Sea. Re-use of offshore wells and platforms may lead to cost savings in the opening up of storage and transport for hydrogen. Performing additional detailed studies into the suitability of wells, platforms, and pipelines is recommended. However, there would be technical constraints, it is not yet legally possible, and it would not contribute to the creation of a hydrogen system[44]. Ttechnologies for hydrogen (electrolysers and pipelines) are still at the development stage, but a target has been set for it in the Climate Agreement, and projects are expected in 2030.

2.4.3 CCS

2.4.3.1 Targets and financing activities (investments)

The Dutch CO_2 storage capacity in (former) gas fields is an estimated 2,700 to 3,200 Megatons (Mt) (excluding the Groningen gas field). Around 1,500 to 2,000 Mt of this amount are underground and around 1,200 Mt under the sea. The storage capacity of the Groningen gas field is an estimated 9,000 Mt, but this will probably only become available after 2050. It is still not definite which part of this capacity will be available for CO_2 storage. The expected total offshore cumulative storage capacity in empty gas fields in the Dutch North Sea is estimated at 1,678 Mt. It's important to note that this capacity is concentrated, i.e. 25% of the offshore fields hold about 65% of the total capacity. The potential for aquifers is far less clear-cut and is currently an estimated 700 to 1,500 Mt both onshore and offshore. Further research may lead to a different estimate of this potential.

With an estimated cumulative storage demand of 201 Mt and 434 Mt respectively, no storage constraints are anticipated. The Netherlands has excess storage capacity, which opens up the opportunity of importing CO_2 from countries with limited domestic storage options, such as Belgium and Germany.

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[43] Contrasting-European-hydrogen-pathways-An-analysis-of-differing-approaches-in-key-markets-NG166.pdf (oxfordenergy.org)=.

[44] DNV GL, 2020

About €15 million are assigned for feasibility studies and pilots to support the application of CC(U)S technologies throughout the whole CC(U)S chain (capture, transport, re-use and storage of CO_2) or in parts of the chain.

2.4.3.2 Long-term outlook

The expected level of CO_2 storage in 2030 is 10.2 Mt per year. In the Self-Sufficient Scenario, annual CO_2 storage will increase to 26.8 Mt per year by 2050. In the Import-Dependent Scenario, it will fall to 4.6 Mt per year by 2050[45].

To facilitate CO_2 capture and storage, a partially new infrastructure of pipelines will be necessary. Existing oil and gas pipelines can only be used after the relevant fields are fully depleted. At present, the Mining Act makes the closure of depleted fields (the clearing away of unused platforms) mandatory. In a CCS vision currently under development, the Government is reviewing whether policy changes are desirable in this area[46].

2.4.3.3 Infrastructure and grid connection

Re-use of offshore wells and platforms may lead to cost savings in the opening up of storage and transport of CO_2. Various obstacles are impeding the reuse of existing gas pipelines to transport CO_2 from land to an offshore platform for injection into an empty gas field.

It is indicated that the technical condition of most pipelines is unknown, making it difficult to determine the risk entailed in re-use and remaining service life. Economic interests could prompt the installation of new pipelines for integration of CO_2 storage into the (also yet to be built) onshore system. The offshore platforms to be used for CO_2 injection already exist and there are enough of them to be able to process the projected quantity of CO_2[47].

Government intervention and active policy will be required to guarantee this infrastructure remains available. Current operators are responsible for sealing and removing the wells and platforms and will do so on a market-driven basis. Once wells have been sealed and platforms removed, it is very complex and costly to make gas fields accessible again for CO_2 storage. There is a risk some existing gas extraction infrastructure that could be re-used for CO_2 storage will be removed before re-use is possible.

2.4.4 Platform electrification

2.4.4.1 Targets and financing activities (investments)

Currently, no decisions have been made as to whether and how offshore platforms will be electrified. Although their contribution to energy system integration might be small because of the limited demand of the platforms, it could prove a valuable first step towards the use or reuse of platforms for hydrogen storage, CCS, or offshore P2X, because it would mean they would also remain usable after gas extraction ends.

2.4.4.2 Long-term outlook

Offshore platform electrification might come into play before 2030. According to the European Commission, by 2050 emission-free electricity (with 84% coming from renewable sources) will meet nearly half of the EU's energy demand. To achieve this outcome, clear objectives must be set for the

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[45] NSE Outlook

[46] https://www.noordzeeloket.nl/en/functions-and-use/co2-opslag/

[47] DNV GL, 2020

electrification of industry, the transport sector, and the urban environment, and for the development of the hydrogen sector.

2.4.4.3 Infrastructure and grid connection

By connecting the platforms with the offshore electricity network, the platforms would then be suitable for re-use[48].

2.4.5 Hydrocarbons

2.4.5.1 Targets and financing activities (investments)

In recent years the investments in small fields have slowed down as a result of the advanced maturation state of many of the existing fields and the lack of prospective and economical production locations together with the low natural gas (NG) prices[49].

The development of the NG prices will continue influencing the future level of investments in the small gas fields and therefore investments in offshore infrastructure. With higher NG prices, more investments in exploration and production (E&P) offshore could be expected and current production rates could be maintained. This would in turn extend the lifespan of platforms and positively impact the time window needed to successfully implement decarbonization options. With lower NG prices, however, the E&P of NG and the options to reduce the CO2 and methane emissions could become less profitable for operators. This could result in an earlier decommission of the platforms, which would decrease the possibility to their reuse in possible synergies with other energy sectors (e.g. hydrogen production and transport, carbon dioxide storage), and reduce the benefits related to decarbonization measures. Despite the ambition to increase the use of renewable energies, EBN (2016) and the Ministry of Economic Affairs (2016) in the Netherlands foresee that NG will play an important role in the energy transition[10].

2.4.5.2 Long-term outlook

Gas extraction in the North Sea is expected to decrease substantially between 2030 and 2050. By 2030, it is anticipated that 387 PJ of natural gas will be extracted per year. There is a broad consensus that gas extraction will significantly decline, until a forecast level of 0-31 PJ per year is reached in 2050. This trend depends on market conditions, with major producers such as Russia and Norway exercising considerable control over gas prices. In this market, the Government's ability to affect the competitive position for Dutch gas through policy measures is limited.

The 2019 Climate and Energy Report forecast is being used at the starting point for the NEO (PBL, 2019). Its point of departure is an annual natural gas production rate of 11 billion m3 or 387 PJ by 2030. The demand for oil and gas in the Netherlands will therefore be significantly greater by 2030 than offshore production (PBL, 2019), so no constraints as regards marketing are envisaged.

2.4.5.3 Infrastructure and grid connection

Production of conventional energy (oil and gas) has already been integrated into the existing network. The oil and gas fields that are still operational in 2030 will be able to export their products to the existing gas grid, for which sufficient capacity is available without restriction[10].

2.4.6 Other

2.4.6.1 Targets and financing activities (investments)

In principle, floating solar PV systems, Airborne Wind Energy, and aquatic biomass compete with the space available for offshore wind. To maximise the potential, consideration could be given to joint use

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[48] Re-use-decommissioning-report-2018-English-Version.pdf (nexstep.nl)

[49] EBN, 2017

with other parties entitled to use the North Sea. For example, floating solar PV farms and aquatic biomass systems could be operated in wind farms. The turbines are more than a kilometre apart. A floating solar PV farm could then use the wind farm's electrical connection.

2.4.6.2 Long-term outlook

Based on the estimated starting point in 2030 and a growth factor founded on a historical growth factor for offshore wind, it is anticipated that, by 2050, installed capacity for floating solar PV and aquatic biomass will each reach 10 GW, to give a combined total of 20 GW, with Airborne Wind Energy making an estimated contribution of 1.4 GW. It is important to note the energy yield of 1 GW of offshore wind energy is greater than 1 GW of solar PV by a factor of 4 to 5. This must be considered in the event of a replacement. By 2040, the total contribution will be less than 10 GW, which means there is sufficient time to monitor the trends in these technologies and, for example, assess every five years whether industrial application is a possibility. Since the innovative technologies mentioned are still at an early stage of development, it is difficult to describe a future path in the run-up to 2050 for them at this point.

2.4.6.3 Infrastructure and grid connection

If these countries are met through the use of the right technology and choice of location, these technologies could contribute of similar size to offshore wind[50].

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[50] https://www.ebn.nl/wp-content/uploads/2019/02/ReducedExploratie-brochure-EBN.pdf

North Sea Energy offshore system integration

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