Scenario study for the Dutch part of the North Sea

following the European Marine Strategy Framework Directive

Client: RWS

Rotterdam, 31 May 2023

Scenario study for the Dutch part of the North Sea

following the European Marine Strategy Framework Directive

Client: RWS

Manfred Wienhoven
Jochen Maes
Tim van Doorn
Hannah Schutte
Kenan Salkovic

Rotterdam, 31 May 2023

Table of contents

Preface

This report presents the results of a scenario analysis for the economic use of the Dutch part of the North Sea and the direct and indirect effects of this use on the state of the marine environment.

The European Marine Strategy Framework Directive (MSFD[1]), published in 2008, aims to protect the good condition of the marine environment in European seas and oceans, and to restore them where necessary. The MSFD requires each European Member State to determine a marine strategy for its own sea area.

One of the mandatory parts of the so-called initial assessment is to perform an economic and social analysis of the use of the North Sea's Dutch part. A scenario analysis has been carried out by Ecorys for this purpose for the Dutch Ministry of Infrastructure and Water Management (I&W). The aim of this study is to give a description of insights with regard to possible future developments and trends of various economic activities and sectors that are active on and around the North Sea, including the expected environmental pressure that is related to those in a qualitative way.

The North Sea is a hub of intense economic activities, including offshore wind energy generation, fishing, aquaculture, and the installation of cables and pipelines on the seabed. These activities have been categorised into three thematic areas: 'static water use,' 'dynamic water use,' and 'seabed use.' More information about these can be found in Chapter 2.

In this study, these economic activities will be examined by conducting an inventory of their current status and recent developments. Armed with this knowledge of the present situation, possible developments leading up to 2035 and 2050 will then be explored. For the analysis, scenarios for the year 2050 will be utilised. It is worth noting that the Dutch PBL (or Netherlands Environmental Assessment Agency, Planbureau voor de Leefomgeving) is currently working on a new edition of the WLO scenario studies, scheduled for publication in 2024. These scenarios will play a significant role in policy assessment and the formulation of various policies in the Netherlands. Since the previous WLO scenarios were developed before the Paris Agreement and significant developments have taken place since then, there is need for an updated version. Although the scenarios were not available at the time of this research, the analysis has been aligned with the work of PBL through differentiation in intensity of the climate transition as a major differentiating factor. More details on this can be found in Chapter 3.

In Chapter 4, the scenarios will be translated into environmental pressures, using the standard sets of descriptors provided by the MSFD. Through a qualitative approach, insights into likely developments and their potential impacts will be provided.

The Ecorys team consisted of Jochen Maes (project manager), Manfred Wienhoven (expert and project director), and analysts Tim van Doorn and Kenan Salkovic. The results were supervised by Rob van der Veeren and Xander Keijser (RWS WVL). Moreover, representatives of the relevant economic activities were invited to two stakeholder meetings. They also launched a survey to collect feedback for the data collection part and to gain insights on the expectations of these experts for short- and long-term developments. The draft report was also provided to these

[1] European Commission (2008). Marine Strategy Framework Directive.

stakeholders, to verify and comment on. The responsibility for approach, results, and content of this report rests with Ecorys.

Summary

The scenario analysis of the economic use of the Dutch part of the North Sea provides insights for both the short-term (2035) and long-term (2050). The report categorises the economic activities into three thematic areas: 'static water use,' 'dynamic water use,' and 'seabed use,' including activities such as offshore wind energy, fishing, aquaculture, and the installation of cables and pipelines.

The report presents an overview of the current status and recent developments in these economic activities. It utilises quantitative data, primarily sourced from Statistics Netherlands (CBS) data (2023), to depict the performance of the economic activities.

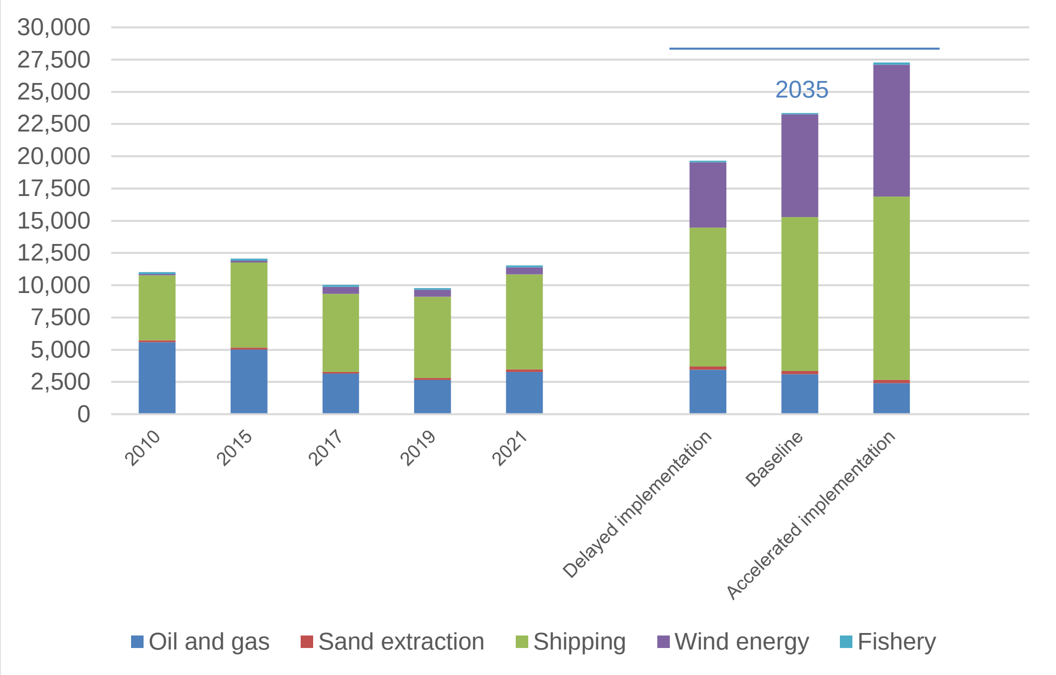
Key economic indicators considered in the study include production value, intermediate consumption, gross added value (GVA), and employment.

The findings reveal that the **Dutch part of the North Sea** generates an **annual economic production** of approximately **11 bn. EUR (2021)**. The majority of the economic value is, according to CBS, attributed to maritime shipping and oil and gas extraction, while offshore wind energy production is a growing segment for the added value. The current geopolitical situation and high inflation creates many uncertainties for the sea shipping sector.

As far as this can be predicted now, the Dutch and European economies appear to be stagnating in 2023. Transhipment volumes are expected to fall slightly before recovering. The direction of the energy transition is important for the future cargo volumes of the Dutch ports. The trends follow the current Ecorys policy outlook, and impact thereof **up to 2035**, by which offshore wind energy is identified as a key resource needed to meet the European and Dutch climate policy objectives. Based on short-term forecasts, the overall economy and added value of activities on the North Sea are expected to increase sharply by 2035: primarily driven by the substantial growth in offshore wind energy activities, and secondly by the maritime sector.

Currently, hydrogen-based energy is seen to be produced locally at first and sourced internationally subsequently. Although, no expert is able to confirm the outlook yet. Currently, maritime experts foresee that the mass of deep-sea transported goods is expected to increase significantly by 2030, and onwards. This development is mainly attributed to a growing capacity per ship, increasing demand by consumers and industry and new markets as Hydrogen-based energy, on top of current containerised flows and fossil imports. The number of ships themselves is hardly expected to increase, though. In total, an annual production maritime-related value of 7 bn. EUR can be expected in 2023, making it a significant contributor to the Dutch North Sea’s economic value. This share is expected to increase by 2035 to 11-14 bn. EUR (in current prices). Till now only 2021 data and 2023 Q1 port throughput is available. The 2035 economic value of offshore wind energy on the North Sea area will lead to an increase in added value, to 5-10 bn; EUR by 2035, and jobs as well. Shipping will result in a relatively higher contribution to the labour market than offshore wind, which mostly generates employment during the construction phase. The results have been visualised in the next figure. The total value is expected to increase strongly to 20-27 bn. EUR, a strong increase of at least 9 bn. EUR.

Figure S1: Growth in economic production by 2035 visualised (in mln. EUR)



Source: CBS (2023) and Ecorys outlook

Looking towards the **long-term trends up to 2050**, scenarios are employed to explore different qualitative developments. **Three scenarios** consider alternative timelines for achieving sustainable policy objectives and highlight underlying barriers and accelerators. The interlinkages between different economic functions are examined within each scenario. Future scenarios for energy systems (supply and demand) and the North Sea Energy Outlook (Noordzee Energie Outlook[2]) indicate that around 38 to 72 GW of offshore wind capacity will be needed by 2050. Also after 2035, this activity will be a main contributor to the potential growth of the total value of the Dutch part of the North Sea. The realisation of this type of capacity could in turn lead to a sharp decrease in the demand and therefore extraction of gas (and oil, to a minor extent). Following the trends in economic growth and global trade, the shipping sector will maintain a structural share of the added value of the Dutch North Sea's economy

In chapter 3, insights from the scenarios are compared to the autonomous trends up to 2035, also extended towards 2050. This **scenario analysis provides a range of economic parameters** (added value, employment, etc.) for the economic sectors and activities on and around the Dutch part of the North Sea. While the trends are clear, the **transition paths (actual implementation) remain uncertain**. The baseline scenario anticipates further development in terms of volume and added value, with offshore wind energy production being a key factor, as it represents a substantial increase in added value. Delayed installation of the projected capacity of offshore wind energy could extend oil and gas extraction. The number of ship movements will increase even more if the Dutch economy becomes more dependent on hydrogen-based energy instead of oil and gas. These are examples of how economic activities are linked throughout the scenarios.

To conclude, in Chapter 4, a **link** will be made **between the socio-economic forecasts and the environmental impacts of the economic activities** therein. The framework of descriptors will be used for this, and to describe the environmental pressures using an analysis of trends and

[2] More details can be retrieved via: https://www.rijksoverheid.nl/documenten/kamerstukken/2020/09/01/rapport-noordzee-energie-outlook

developments. All outlooks are translated into a qualitative increase or decrease in environmental pressure. In general, the team sees a decoupling of the direct links between increasing economic production, added values and jobs, and environmental pressure. The technological innovations in a variety of sectors may lead to breakthroughs. For example, alternative fuels or electrification in shipping will lead to less pollution in the form of noise, fumes, and litter. More offshore wind capacity will however lead to temporary disturbance of the seabed, and long-term effects like vibrations. This could however result in a drop of environmental pressure of activities like oil and gas extraction. Some other effects will likely sustain and lead to similar pressure (like sand extraction, littering, and defence). The ecological impact of other activities remains relatively uncertain, such as aquaculture and CCS. A drop in fisheries, with current technology, will likely lead to a sharp decrease in disturbance of the seabed.

In general, a positive outlook is concluded on environmental pressure in total. But pressures will shift in form and location, owing to the changing use of the North Sea. Technological innovations are not taken into account in the analysis above, but can impact the achievement or nonachievement of GES. This means that a certain sector or activity can grow or increase, but the ecological impact can decline. For example, innovations in methods of fishing, such as beam trawling, or the development and use of alternative forms of fuel.

Abbreviations

CBS	Statistics Netherlands (Centraal Bureau voor de Statistiek)
CCS	Carbon Capture and Storage
DCS	Dutch Continental Shelf (DCS)
FTE	Fulltime-equivalent unit
GVA	Gross Added Value
H	Hydrogen energy
I&W	Dutch Ministry of Infrastructure and Water Management
LNG	Liquefied Natural Gas
MSFD	Marine Strategy Framework Directive
PBL	Netherlands Environmental Assessment Agency (Planbureau voor de Leefomgeving)
RWS	Rijkswaterstaat
WLO	Welfare, Prosperity and the Human Environment study (Welvaart, Leefmilieu en Omgeving)
GES	Good Environmental Status

1 Introduction

1.1 Objective of this study

The Marine Strategy Framework Directive (MSFD[3]) is European legislation, which aims to protect the marine environment since 2008. It requires the application of an ecosystem-based approach to the management of human activities, enabling a sustainable use of marine goods and services.

In order to implement the Directive each Member State is required to:
- describe what they consider a clean, healthy, productive sea (a Good Environmental Status)
- monitor and assess the quality of their seas against Good Environmental Status, and
- ensure they take appropriate action by 2020 to maintain or achieve Good Environmental Status.

Part I was prepared in 2012 and updated in 2018. The next update is due to be submitted in 2024.

Developments in the state of the marine environment and thus the question of whether the MSFD's environmental goals will be achieved largely depend on socio-economic developments. For example, the expansion of offshore wind farms and the growth of seaports seem economically desirable but will affect the intense use of space on the North Sea area, as well as influence its good environmental state (GES) in the long run. An economic analysis is therefore a mandatory part of the MSFD report to the European Commission in 2024.

The Dutch part of the North Sea (Dutch Continental Shelf, DCS) is a very complex and open marine ecosystem where many organisms reside. It is an important link in the international system of migration routes of birds and the home of several species of fish, as well as seals and porpoises. At the same time, the area is home to various forms of economic activity, as it is one of the most intensively used seas in the world: the large seaports attract international shipping, there are more than 100 platforms for oil and gas extraction, wind farms occupy a growing area, sand extraction takes place, and on the seabed, there is a dense network of many pipelines and cables. All these require space and have an impact on the environmental state of the water, seabed, and air.

As stated before, performing an economic analysis is one of the necessary parts of the implementation of the MSFD. An important part of this is a description of the current economic situation and the expected future developments in the socio-economic driving forces that exert pressure on the water system. Socio-economic driving forces include economic activities, demographic changes, technological developments, and political-administrative processes. Based on developments in socio-economic driving forces, an image can be formed about the possible future development of the associated pressures on the marine environment.

At the same time, the future is uncertain and complex. Global events such as the COVID pandemic and the war in Ukraine were unexpected and have a significant economic impact. In addition, the whole world has to deal with the consequences of climate change, including global warming and a rising sea level. In order to deal with this uncertain and complex future effectively, one must get a view of possible future scenarios and get an indication of potential consequences. In short, the objective of this study is twofold:

---

[3] More details can be retrieved via: https://ec.europa.eu/environment/marine/eu-coast-and-marine-policy/marine-strategy-framework-directive/index_en.htm

1. **Giving an up-to-date picture of the expected developments and trends of the various economic sectors and economic activities that take place on and around the Dutch part of the North Sea;**
2. **Translate these trends into expected changes in pressures on the marine environment.**

1.2 Approach and methodology

In this section the research team will introduce the approach used for this study, and the scope of the data collection. The research activities included the use of public data sources, a stakeholder approach, one-on-one interviews, and quantitative analysis.

Scope

Geographically, all activities that take place on the Dutch part of the North Sea are considered to be inside the scope for this study. More specifically, this covers the entire surface of the Dutch part of the North Sea outside of the so-called "twelve miles zone" and excludes the 'Waddenzee', the 'Oosterschelde', and 'Westerschelde', but includes some economic activities in the coastal zone. This cut-off is quite sensitive, as several activities take place in the 'twelve miles zone" or in seaports but derive their added value from the presence of the North Sea[4]. The shipping industry is a perfect example of this. The economic significance of the Dutch part of the North Sea is determined in extensive studies by CBS.[5] [6] This report is accomplished in consultation with CBS and makes use of their (most recent) economic scoping and findings.

Economic activities

The list of economic activities described in this study can be found in table 1. In general, economic activities are considered to fall in one of three different categories: 'on the water statically', 'on the water dynamically', or 'on the seabed'. These clusters are created because of the common position in the marine ecosystem of these economic activities, which makes them comparable to a certain degree. Interlinkages between these clusters are considered as well, e.g. an increase in offshore wind farms decreases the space available for fishing and shipping.

Table 1: Economic activities regarded in this study

Cluster	Economic activity
On the seabed	Oil and gas extraction
	Cables and pipelines
	Storage of CO_2
	Hydrogen energy (H)
On the water (static)	Solar energy
	Offshore wind energy
	Aquaculture
On the water (dynamic)	Sea shipping
	Fisheries
	Marine aggregates
Miscellaneous	Defence, recreation, archaeology

4 The scope of the MSFD partly overlaps with that of the Water Framework Directive (WFD). This is the zone up to 12 nautical miles from the base coastline (the so-called 'coastal waters'). According to Article 2 of the MSFD, the directive is applicable only to elements of interest for the protection of the marine environment here and those do not fall under the WFD. In offshore waters from 12 nautical miles, only the MSFD applies.

5 CBS (2020), Economic description of the Dutch North Sea and coast 2010, 2015 and 2017

6 Draft CBS (2023), Economic description of the Dutch North Sea and coast 2015, 2017, 2019 and 2021

Forecasts, a baseline scenario up to 2035

The underlying mechanism of this scenario study lies in the expected development of the following indicators:

- Production value in mln. euros;
- Intermediate consumption in mln. euros;
- Gross added value (GVA) in mln. euros;
- Employment (in FTE).

An economic indicator, closely related to production volumes, is selected for each of the economic activities. Through desk research and by use of expert judgement, trends are sketched on the development thereof; up to 2035. Data sources the team's forecasts were based on include, for example, CBS studies, the Maritime monitor[7], and reports of and on specific economic activities (e.g. reports form branch organisations and their representation).

The trends are translated into economic forecasts, painting a quantitative picture for performance of the economic activities based on economic indicators up to 2035. The starting point for the scenario analysis is CBS (2023). With regards to the value of the economic functions, the following two notions are important:

- Data is not available for all economic activities. Therefore, some activities will not be expressed in economic terms but will be described in a qualitative way only.
- Changes in price level or changes in the ratio between production and intermediate consumption are not within scope. Economic activities that can be expressed in monetary values will be presented in price level anno 2021 (publication of the latest CBS data). The ratio of production value, intermediate consumption, and gross added value will be assumed to be similar as in 2021.

This data collection and forecasting is part of a process to define the impacts of the various activities on the aquatic environment. In particular, production volume has a direct relation with the pressure of an economic activity on the environment. An increase in production can have a negative impact on environmental conditions through, for instance, the use of a larger area for production, more pollution, etc. Added value can be used to measure the economic impact of possible measures. Measures can have a negative impact on a sector; for instance, a limitation of production or higher investments. This will have repercussions on the added value of a sector.

Stakeholder approach

The outlooks as presented in this study are also based on experts' judgement. Sector specialists have been invited to share their views on the future of their sector during a workshop.[8] Apart from validation, these sessions were used to enrich the available data sources and gain additional overarching insights.

A survey was used beforehand to give participants the possibility to validate or disqualify the trends identified by Ecorys, and to share relevant literature. In addition, one-on-one interviews were conducted to make sure all economic trends were tested. All this collected information allowed Ecorys to make a first estimate of the course of economic development up to and including 2035. The draft report was shared with the stakeholders and their feedback has been incorporated in this report.

[7] Ministry of Infrastructure and Water management (2022), Arbeidsmarkt- en Haven Monitor

[8] A list of stakeholders can be found in Annex 1.

Forecasts, a scenario study up to 2050

The long-term trends towards 2050 will be estimated in chapter 3. Since the long-term future is uncertain, scenarios will be used to explore it. The scenarios are based on qualitative storytelling and mainly differ by the timing of achieving sustainable policy objectives.

The storylines map out the underlying barriers and accelerators that shape them too. Due to the interconnections between various (economic) functions, they may take different forms or follow different dynamics and timelines. Throughout the analysis, the interlinkages between these scenarios will be demonstrated.

The findings of these scenarios will be applied with the autonomous trends projected in Chapter 3. These trends are then extended to 2050, resulting in a scenario analysis in addition to the baseline. This analysis establishes a range of possible economic parameters for different economic activities in and around the Dutch part of the North Sea up to 2035 quantitatively, and up to 2050 qualitatively.

The three scenarios are as follows:

Delayed implementation

A variation on the baseline scenario in which sustainable policies are implemented later due to obstructing factors, barriers, and practical implications, such as a lacking business model for aquaculture and limited building capacity for offshore wind parks.

Baseline scenario

Current policy-based assumptions translated into short- and long-term developments. In the data collection step, trends are identified up until 2021. With these trends, and insights gained via a literature review, a desk-research based 2035 forecast - and 2050 outlook - is drawn.

Accelerated implementation

A variation on the baseline scenario in which sustainable policies are implemented at a faster pace, following more public and governmental support, innovation, and investments by companies in the green economy.

Consistency with PBL scenarios

In a previous version of a scenario study of the Dutch part of the North Sea[9], the former WLO (Welfare, Prosperity and the Human Environment study (Welvaart, Leefmilieu en Omgeving)) scenarios of PBL (Netherlands Environmental Assessment Agency (Planbureau voor de Leefomgeving)) were used as an inspiration for this applied approach. For this scenario study, the decision was made not to make use of the existing WLO scenarios, as they are outdated. But to create specific scenarios taking into account of the expected assumptions of the soon to be published new WLO.

First, it will be explained why the currently available WLO scenarios are no longer relevant for a long-term scenario study.

9 Ecorys (2013) Baseline Scenario Marine Strategy Framework Directive.

PBL is currently working on a new edition of the long-lasting series of WLO scenario studies. The newest version will be published in 2024 and will play an important role in the *ex-ante* assessment and calculation of policies in the Netherlands. More than ever, the climate transition plays an important role in the scenarios. Since the previous edition in 2015, there have been various new developments that create a need for a new WLO. In a paper by van Eck and Hilbers (2022[10]), and an informative session with PBL representatives (April, 2023), these new insights were sketched:

- The previous WLO-assessment predates the Paris Agreement. Currently, the European Union and the Netherlands have implemented more comprehensive and ambitious domestic and foreign climate policies compared to 2015. It is worth noting that the previous WLO assessment focused on using CO_2 prices as part of a two-degree policy, without considering other aspects such as sector structures and trends in transport and mobility.
- The economic outlook in the 2015 WLO is based on a CPB study from 2004 (Huizinga & Smid 2004); the economy has changed since then. The Climate Policies, mentioned in the first bullet, also contributed to this.
- Current population trends lie outside the bandwidth of the past WLO. That requires an update and will lead indirectly to economic and environmental impacts.
- The Covid-19 pandemic raised new questions about the future of the Dutch economy, urbanisation, and mobility. This also applies to the war in Ukraine and the question about the economic developments in Europe.

Second, we explain why we judge the former (2015) WLO approach to be outdated. In past WLO scenario studies, PBL made use of four scenarios over two axes, these being economic and demographic growth on the one hand, and sustainable policy on the other. Given the fact that the existing WLO scenarios are old and the new WLO scenarios will be available in 2024, it was decided to create a specific approach for this study. Our assumptions have been discussed in the previously mentioned meeting with PBL representatives (April, 2023). **We aimed to align with the work that PBL is doing at this moment, but could not wait to finalise this report till the formal publication moment**. The team sees a much higher dependency on the economic functions of the Dutch North Sea for the implementation of sustainable policy than economic or demographic growth than in the 2015 WLO, and therefore developed the approach of increased political support for sustainable development of the economy. More information on the approach is outlined in Chapter 3.

Qualitative translation of the environmental impact

The last step of this research is a qualitative translation of the 'environmental pressures' that can arise as a result of trends and developments for the different economic activities on the North Sea. Based on the three scenarios, outlined in Chapter 3, a variation for the environmental impact in the period 2023-2050 for the scenarios is assessed. The environmental indicators assessed, are based on existing frameworks and deliverables from the Ministry of I&W, OSPAR, PBL, Deltares, Wageningen Marine Research, and Wageningen Economic Research.

The indicators are depicted below in Table 2. They encompass a link between the economic activities at the North Sea, the environmental pressure factors and the indicators thereof.

---

[10] Van Eck and Hilbers (2022), WLO 2024: Hoe combineren we de klimaattransitie in de mobiliteit met een bruikbare bandbreedte? retrieved via: https://www.pbl.nl/sites/default/files/downloads/pbl-2022-wlo-2024-hoe-combineren-we-de-klimaattransitie-in-de-mobiliteit-met-een-bruikbare-bandbreedte-4993.pdf

Table 2: Possible environmental impact of economic activities

Economic activity	Environmental pressure factors	Indicators thereof
Oil and gas extraction	Pollutants	Number of platforms M³ of contamination
	Physical disturbance of seabed	Number of discharges and incidents
	Sound	Number of seismic surveys
Marine aggregates	Physical disturbance of seabed	M³ sand extraction
Shipping	Sound	Type of engines Number of vessel movements
	Introduction or spread of species (ballast water and fouling on ships' hulls)	Number of (sailing/ship) movements
	Pollutants	Type of fuel
Fisheries	Spread of non-native species	Number of far-distance vessel movements Ballast water exchanges
	Nutrients (aquaculture)	Nutrient use
	Damage biodiversity	Extent and location of shellfish transport
	Physical disturbance seabed	Number of vessels trawling
Aquaculture	Nutrient depletion	Scale of aquaculture
	Eutrophication	Scale of aquaculture and model (intensive or extensive approach)
Offshore wind energy	Sound	Number of wind turbines
	Biodiversity (birds, underwater nature, benthic life)	Location wind turbines
	Physical disturbance seabed	Number of new monopiles/windmills
Solar energy	Algae growth due to reduced light, physical disturbance seabed	Number of m² installed, see m² covered
Hydrogen energy	Noise, leaks	Number of platforms, generated volumes at sea
Cables and pipelines	Physical disturbance of the seabed at intersection with other cables and pipelines (rock dumping)	Number of cable and pipe crossings, usage of pipelines
Defence & recreation	Sound, pollution in the water, on the seabed	Type of engines, ammunition used, gun shots from defence drills
	Introduction or spread of species (ballast water and hull fouling)	Number of (sailing/ship) movements
	Pollutants	Type of fuel, Munition from defence drills
Overarching	Marine litter	Fishing vessels Maritime transport Oil and gas platform decommissioning Recreational sector

The Marine Strategy, like the Dutch strategy 'Mariene Strategie (deel 1)[11]', elaborated in 2018, encompasses all elements of the so-called DPSIR[12] cycle of activities (driver), pressure, state change (status), impacts, and responses. This publication, and details therein, were used as a conceptual framework for Chapter 4. As such this study aligns with aforementioned approaches.

[11] More details can be retrieved via: https://www.noordzeeloket.nl/beleid/mariene-strategie-krm/deel-1-milieutoestand/

[12] This cycle is based on the reasoning that human activities exert pressure on the marine environment, leading to changes in the environmental state with potential negative consequences that can be prevented or mitigated through measures. The measures result in adjustments to activities, completing the cycle. The five functions of the DPSIR cycle correspond to different articles of the Marine Strategy.

Pressures, specifically, can be considered ‘at source’ (close to the activity generating the pressure), with relevance for environmental targets and measures, and ‘at sea’ (level in the marine environment), with relevance for GES determinations and assessments.

- **At source**: some pressures, such as nutrients, contaminants, and litter, originate on land and enter the marine environment as diffuse sources (including via the atmosphere) or from point sources. Pressures generated by sea-based activities remain closely associated with those activities (e.g. dredging or bottom trawling), while others dissipate away from the activity (e.g. contamination from oil extraction, noise from shipping).
- **At sea:** i.e. the level of the pressure in the marine environment. This is relevant for determining GES (for the pressure-based descriptors) and for assessment of environmental status in relation to GES.

As a way to link the economic sectors analysed (and described in Chapters 2 and 3) and the pressures (sketched above) a matching table was constructed in alignment with the Dutch strategy ‘Mariene Strategie (deel 1) of 2018, by Ecorys. This analysis is clarified in the last chapter specifically, and summarised below. For example, if an environmental pressure is expected from developments in one sector, and is monitored via one or more descriptor(s), an ‘X’ is provided. For example, marine aggregates. The sand extraction at the Dutch part of the North Sea is leading, in a direct and indirect way via physical disturbance of the seabed, to impacts on D1 (biodiversity), D6 (sea-floor integrity) and D7 (hydrographical conditions).

Table 3: Matching table main relationships environmental pressure (factors) and economic activities

Economic activity	Environmental pressure factors	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11
Oil and gas extraction	Pollutants								X	X	X	
	Physical disturbance of seabed						X	X				
	Sound											X
Marine aggregates	Physical disturbance of seabed	X			X		X	X				
Shipping	Sound											X
	Introduction or spread of species	X	X		X							
	Pollutants								X	X	X	
Fisheries	Spread of non-native species	X	X		X							
	Damage biodiversity	X		X	X						X	
	Physical disturbance seabed			X			X	X				
Aquaculture	Eutrophication					X						
Offshore wind energy	Sound											X
	Biodiversity (birds, underwater nature, benthic life)	X			X							
	Physical disturbance seabed						X	X				
Solar energy	Algae growth due to reduced light	X			X							
Hydrogen energy	Sound											X
	Pollutants								X	X	X	
Cables and pipelines	Physical disturbance of seabed at intersection (rock dumping)	X			X		X	X				
Defence & recreation	Sound											X
	Introduction or spread of species	X	X		X							
	Pollutants								X	X	X	

Note: Descriptors are based on Dutch strategy ‘Mariene Strategie (deel 1) ’, elaborated in 2018, encompasses all elements of the so-called DPSIR, and explained in Chapter 4

2 Economic development before 2022 and up to 2035

One of the mandatory parts of the initial assessment is to perform an economic and social analysis of the current use of the Dutch part of the North Sea. The aim of chapter 2 is to give a description of insights with regards to recent and current developments, as well as expected trends for each economic activity.

In this chapter, as well as the study as a whole, the following economic activities are included, for which data, trends, and observations for the period 2010 till 2021 will be presented:

- Oil and gas extraction;
- Marine aggregates;
- Sea shipping;
- Offshore wind energy;
- Fisheries;
- Aquaculture;
- Capture and storage of $CO_{2;}$
- Solar energy;
- Hydrogen (H);
- Cables and pipelines;
- Defence;
- Recreation.

This chapter provides a retrospective look as well as an outlook towards 2035. The outlook is based on identified trends in the data, as well as insights gained from a literature study, stakeholder sessions, and one-on-one interviews.

The trends are translated into economic forecasts, painting a quantitative picture for performance of the economic activities based on economic indicators up to 2035. The starting point for the scenario analysis is CBS (2023). The long-term trends towards 2050 will be estimated too. The findings of these scenarios will be compared with the autonomous trends projected up to the year 2035, which are based on current data trends. Since the long-term future is uncertain, scenarios will be used to explore it. Scenarios map out the underlying barriers and accelerators that shape and have an impact on environmental impacts expressed in pressure factures, discussed in the concluding Chapter 4.

Outlook

Looking forward, Ecorys estimates the specific development of these economic activities, in value, added value and FTEs. This analysis is based on the expected stabel volumes of oil extraction and the declining extraction of gas, owing to the Dutch governmental policy to decrease production in the long run. In the short run however, current uncertainties regarding the European import capacity for natural gas, in LNG (Liquefied Natural Gas)-form, increase pressure on policy makers to expand the current production volumes and decrease the Dutch gas production only at a later moment in time.

The strong oil and gas demand of the European economy is also strongly linked to the Netherlands. In an indirect way, Dutch ports are responsible for facilitating the main energy import of European Member States. The ports are using the benefits of the North Sea via the usage function ‘shipping’, which will be described in more detail in section 2.3. With Amsterdam serving as the world's largest petrol port, and the Port of Rotterdam playing a large role in crude oil, the shipping of energy (in various forms) to Dutch ports is routine business. With more than 100 mln. tonnes annually, the Netherlands is the biggest crude oil importer in the EU (Port of Rotterdam annual report, 2023).

LNG imports increased five-fold in the last 5 years. Rotterdam is a key hub for LNG throughput, with 10.8 mln. tonnes in 2022, an increase of almost 50% compared to five years ago. The capacity of the terminal is 12 bn. m³ annually (import and re-export together) (Port of Rotterdam annual report, 2023). This shows that local extraction of gas and oil in the North Sea was replaced by imports. LNG imports, following the war in Ukraine, increased heavily in Groningen Seaports[13] (8 bn. m³ is the maximum capacity annually). All Dutch ports are major coal importers.

The war in Ukraine has made it clear that the Netherlands and Europe as a whole are (overly) dependent on gas imports. The Dutch State Secretary for Extractive Industries, Hans Vijlbrief, has therefore taken measures to promote the security of gas supply by slowing down the decline in gas extraction in the North Sea.[14] The Ministry of Economic Affairs and Climate Policy was asked to speed up its permit procedures for current and new fields as much as possible, without relaxing the conditions. An increase in gas extraction in the short term is part of the current government policy, together with energy conservation and the accelerated development of the generation of sustainable energy.

Looking forward, towards 2035, the following assumptions can be made for each of the commodities based on current trends in the data and policy intentions in the short to long term:

- **Oil extraction.** Given that only a limited amount of oil is extracted from the North Sea, it is to be expected that the decreasing trend regarding oil extraction, that has already set in, will continue in the long run. This means extraction of oil in the Dutch North Sea will slowly disappear towards 2035. This is a long-term development, noticeable since 2015. In the short term however, according to NOGEPA/ElementNL[15], the extraction of oil will be temporarily increased in the Dutch part of the North Sea as new permits for oil extraction are being requested.
- **Gas extraction**: As per a recent announcement by the Dutch government, in light of the disrupted gas supply from Russia, the government is issuing a strong recommendation for the sector to augment gas extraction from the Dutch North Sea in the short term and in the coming years. It is projected that gas extraction will experience a slight increase leading up to 2030, followed by a subsequent decrease. This course of action aligns with current policy and market trends but faces challenges due to rising gas prices. Furthermore, the heightened emphasis on reinforcing Europe's energy self-sufficiency has the potential to trigger policy modifications in the long run, encompassing both gas extraction and the construction of wind energy facilities.

The solid lines in Figures 1 and 2 show the progression of both activities, up to and including 2022. The dashed lines represent the Ecorys forecast up to 2035, based on trends in the data and current policy intentions.

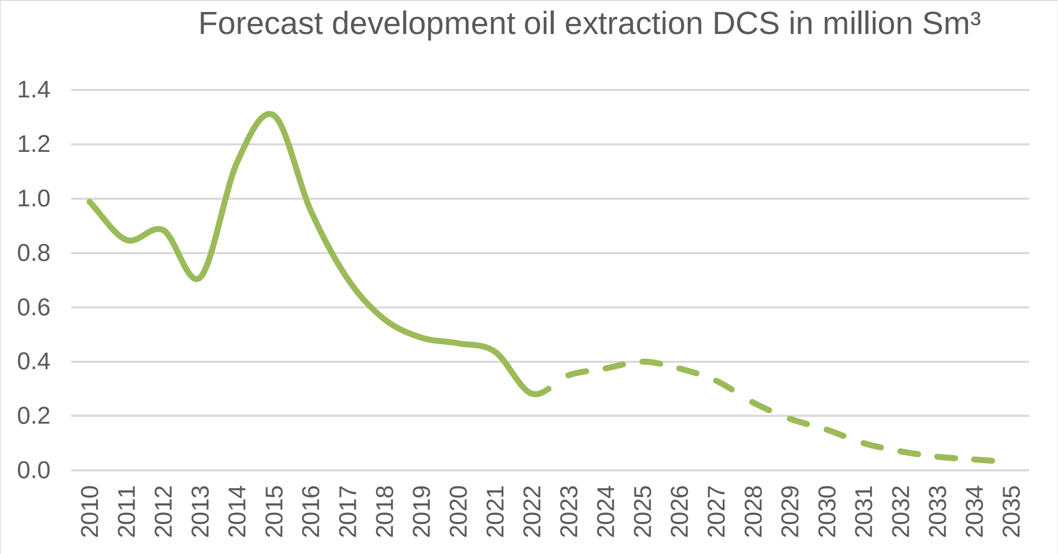
---

13 LNG terminal fully operational, 7 November 2022, https://www.groningen-seaports.com/en/nieuws/lng-terminal-fully-operational/

14 Versnelling gaswinning op de Noordzee, 15 July 2022, https://www.rijksoverheid.nl/actueel/nieuws/2022/07/15/versnelling-gaswinning-op-de-noordzee

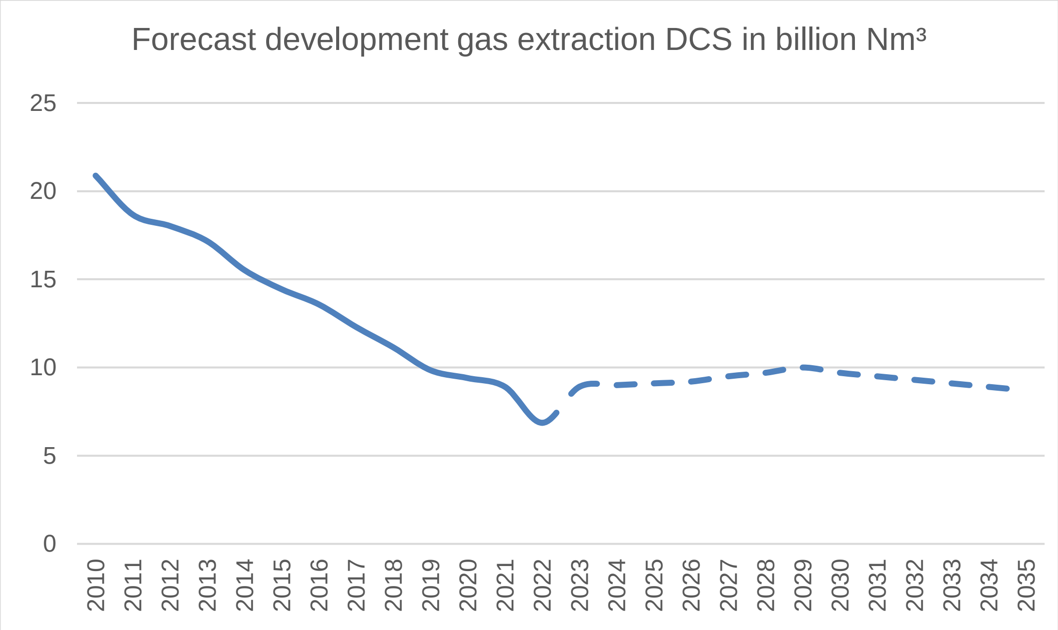
15 In the Netherlands, there are 12 companies with licences to explore for or produce natural gas. These oil and gas companies study the potential of gas reserves in our subsoil and under the seabed of the North Sea and are also responsible for bringing the natural gas to the surface after drilling. These companies are represented by Element NL. Element NL is the new name of the former sector organisation NOGEPA.

Figure 1: Data 2010-2022 and expectations 2035 for economic activity oil extraction



Source: Ministerie EZK Jaarverslagen delfstoffen en aardwarmte, Datacenter NLOG

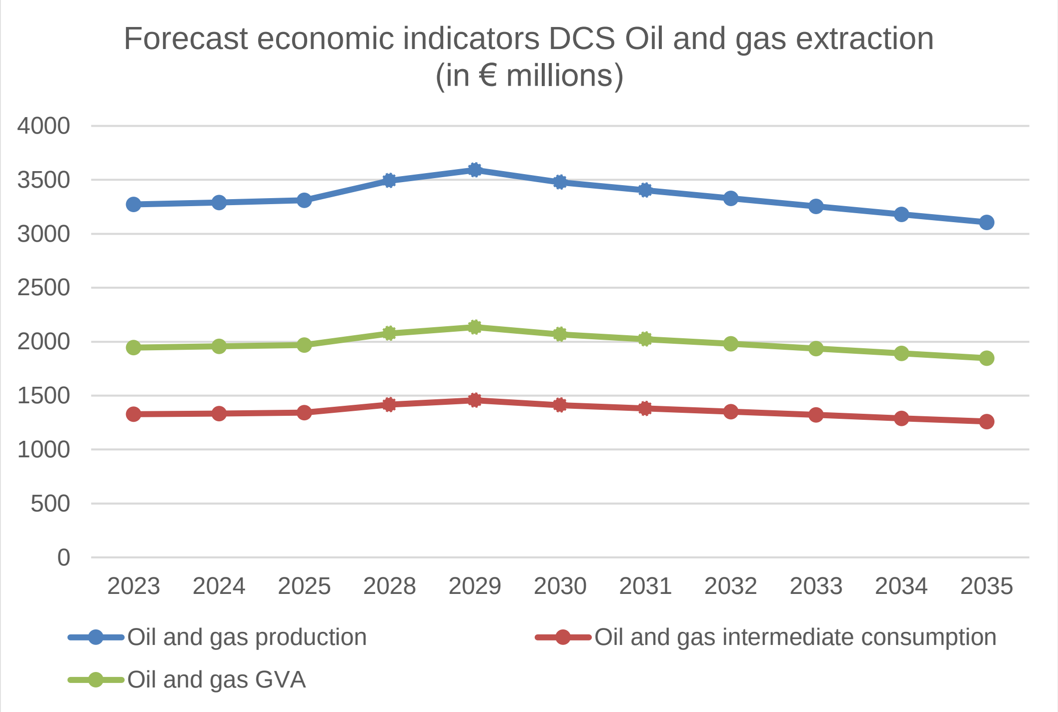
Figure 2: Data 2010-2022 and expectations 2035 for the economic activity gas extraction



Source: Ministerie EZK Jaarverslagen delfstoffen en aardwarmte, Datacenter NLOG

When applying these forecasts to the economic value of the oil and gas extraction in present values for the sector as derived from CBS, the economic forecast is as depicted in Figure 3.

Figure 3: Forecast economic values 2023-2035 for economic activity oil and gas extraction



Source: Analysis by Ecorys

Aggregated, this forecast for volumes and economic values shows that the development of these two activities, in economic terms, will likely lead to a net change of -5% by 2035 (in mill EUR current price level). **This is in current (2021) prices**. However, oil and gas prices are fluctuating considerably, as has been seen especially in the first months after the war in Ukraine. These levelled out by 2023, although future developments in prices are highly uncertain and could influence the values considerably between 2022 and 2035.

Table 4: Forecast 2035 economic value gas and oil extraction at the Dutch North Sea area

	2035
Production (in mln)	€3,107
Intermediary consumption (in mln.)	€1,260
Added value (in mln.)	€1,847
Employment (in 1000 FTE)	2

2.1 Oil and gas extraction

Retrospective

Based on the research conducted by CBS, the economic value of gas and oil extraction from the Dutch part of the North Sea area is shown in Table 3.

A downward trend is identified through a decrease in (economic) production values. Production decreased strongly from ca. 6 billion EUR to a little over 3 billion EUR in 2021. The number of jobs associated with this economic activity similarly declined over time, from roughly 4,000 FTE (fulltime-equivalent) in 2015 to 2,000 FTE in 2021.

Table 5: Economic value Gas and oil extraction Dutch North Sea area

	2010	2015	2017	2019	2021
Production (in mln.)	€5,597	€5,013	€3,144	€2,649	€3,272
Intermediary consumption (in mln.)	€911	€1,608	€1,072	€972	€1,327
Added value (in mln.)	€4,686	€3,405	€2,071	€1,676	€1,945
Employment (in 1000 FTE)	3	4	3	3	2

Source: CBS (2020). Economic description of the Dutch North Sea and coast: 2010, 2015 and 2017 for 2010 values*,*

& Draft version of CBS (2023). Economic description of the Dutch North Sea and coast: 2015, 2017, 2019 and 2021

The total of 161 gas and oil platforms encompassed some 126 km² as of 2015, or only 0.2% of the North Sea's total surface area, according to PBL's report 'The future of the North Sea' (2018), including a safety zone of 500 m. It is not clear whether the safety zones are included in this percentage. The connected pipelines represent in total 4,500 km, or 8% of the footprint (PBL, 2018 and HCSS, 2021).

2.2 Marine aggregates

Retrospective

To protect the Dutch coast from rising sea levels, the coastline is strengthened and widened with marine aggregates. Aggregates are also extracted to create new land and are a base for a small part as construction material as well (foundations for example[16]). On the North Sea, organisations with a permit can extract sand, shells, and gravel from the ongoing Amsterdam Ordnance Datum (NAP) -20 metres isobath. The extraction of gravel is rare, while the extraction of sand is very common and an activity of national importance. Shells may be extracted in waters deeper than below 5 metres NAP.

Only a specific area in the North Sea has been reserved for the extraction of marine aggregates. Based on the research by CBS, the economic value of the extraction of marine aggregates in the Dutch part of the North Sea area is shown in Table 5. In recent years, an upward trend can be seen following an increase in (economic) production values. The production value increased from 146 mln. EUR annually in 2015 to 213 mln. EUR by 2021, with a slight dip in this progression in 2017.

Currently, marine aggregates are used to maintain the coast (about 12 mln. m³ per year) and as filling material on shore (about 13 mln. m³ per year).[17] Incidental large-scale projects determine a substantial part of the variance in trends. Large amounts of sand are used for specific projects. For coastal maintenance, as was done for the Sand Motor in Delfland (21.5 mln. m³ in 2011/2012) and the Hondsbossche and Pettemer sea defences (35 mln. m³ in 2014). A much larger quantity of marine aggregates was extracted for the construction of Maasvlakte 2 (approx. 213 mln. m³ in 2009-2013). Incidental extraction of North Sea sand has a large influence on the total volumes and values. The number of FTEs is limited compared to the total North Sea economy however, with about 250 on average.

[16] In the past, it was presumed that sea sand was not suitable for use in the construction sector. However, numerous studies have disproven these assumptions. Nevertheless, river sand remains a better option. It is utilised in various construction applications, including housing the production of concrete, mortar, and other building materials.

[17] Programma Noordzee 2022-2027, 2022

Table 6: Economic value of marine aggregates in the Dutch North sea

	2010	2015	2017	2019	2021
Production (in mln.)	€146	€145	€123	€149	€213
Intermediary consumption (in mln.)	€82	€93	€76	€91	€131
Added value (in mln.)	€64	€52	€47	€58	€82
Employment (in 1000 FTE)	<1	0.3	0.2	0.2	0.3

Source: CBS (2020). Economic description of the Dutch North Sea and coast: 2010, 2015 and 2017 for 2010 values*,*

& Draft version of CBS (2023). Economic description of the Dutch North Sea and coast: 2015, 2017, 2019 and 2021

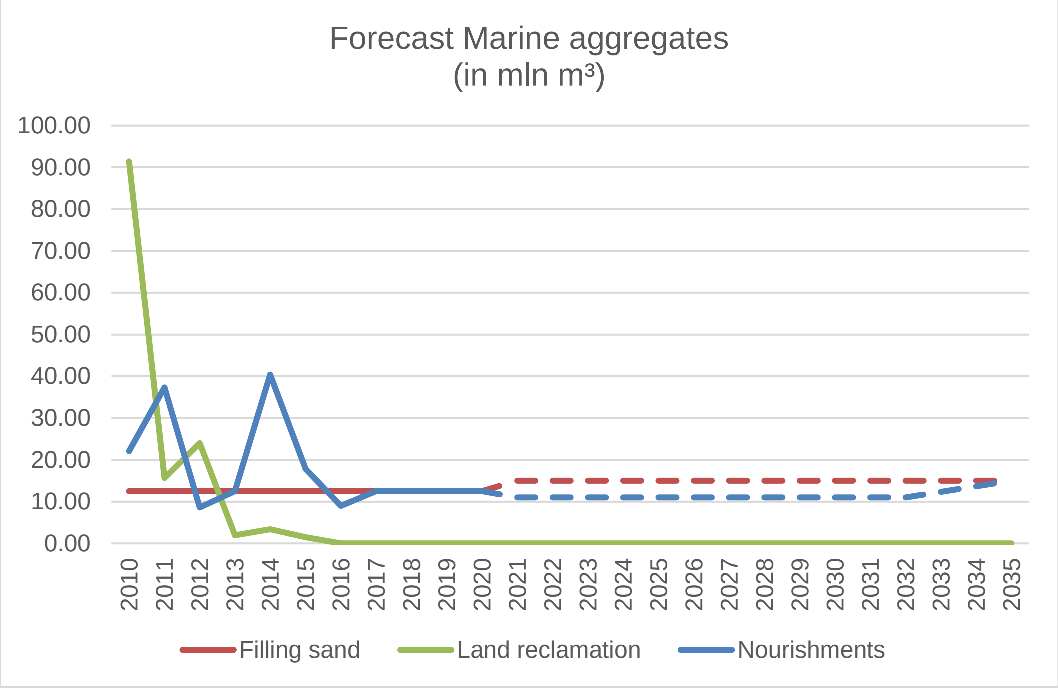
Outlook

Looking ahead, the development of these economic values will be estimated based on the expected development of the extraction of marine aggregates in the North Sea. To ensure proper management, a marine aggregate extraction strategy has been prepared based on a balanced consideration of all relevant interests. Rijkswaterstaat Zee & Delta is responsible for the strategic management of the sand reserve by managing the planning (both in time and space) in the extraction areas and by granting permits. Extraction volumes until 2035 are subdivided into three categories, as they are the most common types of marine aggregates extracted: filling sand, nourishment sand, and sand for land reclamation. This distinction was made because, on the one hand, the aggregates will be used for different purposes, and on the other hand, it might concern a different type of aggregate (e.g. granular size).

The solid lines in Figure 4 show the actual development, up to and including 2021. The dashed line represents the team's current estimate for the future. The following assumptions were applied:

- **Filling sand**: Based on the North Sea Programme, the extraction of filling sand in the North Sea is estimated to remain constant up to and including 2032 (15 mln. m^3 per year). This is in line with the goal of building 1 mln. homes before 2030. Beyond 2032, the amount of filling sand expected to be extracted is constant because of the expected need of the building sector in the long run.
- **Land reclamation**: The peaks for land reclamation in the past can be attributed to the construction of the second *Maasvlakte*. Towards 2035, there are no concrete plans for large-scale land reclamation.
- **Nourishments**: Based on the North Sea Programme, sand extraction in the North Sea is assumed to be constant up to and including 2032 for nourishments (11 mln. m^3 per year). After 2032, sand extraction for nourishment is expected to increase slowly towards 35 mln. m^3 per year in 2050 as stated in the North Sea Programme.

Figure 4: Data 2010-2022 and expectations 2035 for economic activity marine aggregates



Source: H2H advies (2017). Rapportage monitoring bouwstoffen 2017, Programma Noordzee & Ecorys data extraction.

Uncertainty lies within climate change and adaptation policies. It is expected that the demand for sand for coastal maintenance will grow to approximately 25-35 mln. m³ per year after 2050, with the demand for sea sand onshore also increasing.[18] Therefore, it is important to have a strategic stock of sufficient size and to ensure efficient extraction and use of space. This will be considered in the scenario analysis leading to 2050 forecasts. Sand stocks are declining worldwide, while more and more sand from the North Sea will be needed to protect the Dutch coastline against a rising sea level.[19]

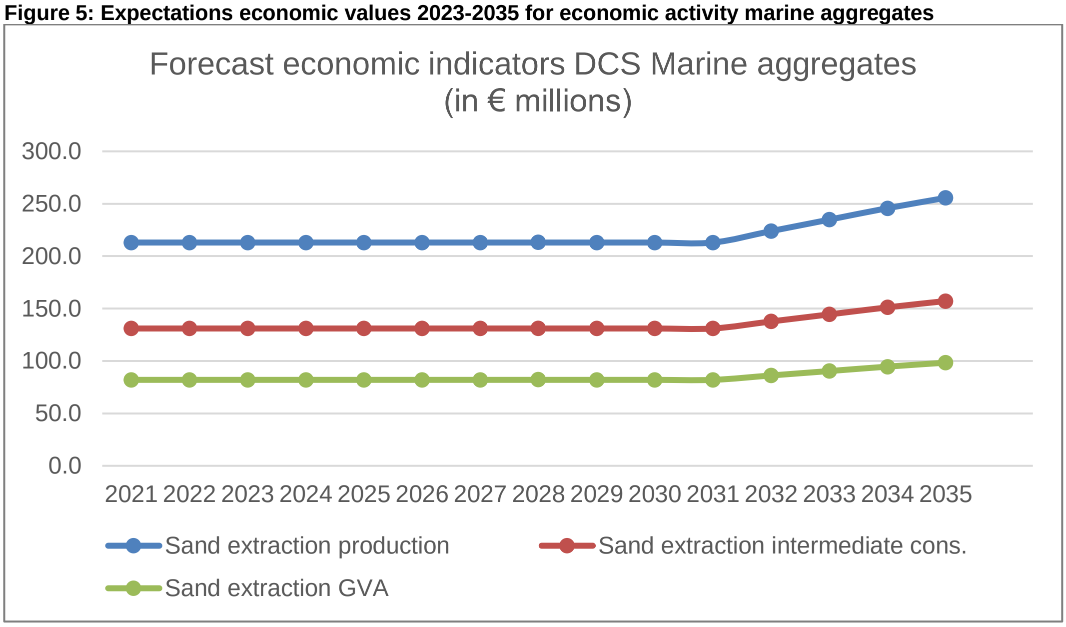
Sand extraction might have an environmental impact on the marine ecosystem. Existing research points out that there is no evidence for long-term negative effects of the extraction of marine aggregates.[20] However, these findings are not conclusively accepted, as the Dutch Association for Scientific Research (NWO) is exploring the environmental impact of sand extraction more thoroughly.

[18] Programma Noordzee 2022-2027, 2022

[19] Nioz, Four years research into the effects of sand extraction in the North Sea, https://www.nioz.nl/en/news/four-years-research-into-the-effects-of-sand-extraction-in-the-north-sea

[20] Arcadis & WUR (2017). Zandwinning in de Noordzee 2018-2027

Figure 5: Expectations economic values 2023-2035 for economic activity marine aggregates



Source: Analysis by Ecorys

In aggregate, this brings the next baseline in development of economic values, with an expected net increase of 20%. This is leading to a total economic production of 256 mln. EUR on annual basis.

Table 7: Forecast 2035 economic value Marine aggregates Dutch North Sea area

	2035
Production (in mln.)	€256
Intermediary consumption (in mln.)	€156
Added value (in mln.)	€98
Employment (in 1000 FTE)	0.4

2.3 Sea shipping

Retrospective

The North Sea plays a crucial economic role in linking North-Western Europe to global maritime trade routes.[21] Maritime transport handles over 80% of global merchandise trade, thereby underpinning global supply chains and economic interdependency. Within the EU-28, the ratio of international trade in goods and services relative to GDP rose from 14.9% in 2008 to 17.6% by 2018, thereby confirming that trade in goods and services was growing at a faster pace than the overall EU economy. [22]

Situated in North-Western Europe, close to where production and consumption in the EU is concentrated, the Netherlands consequently hosts numerous large deep-sea ports. The largest European seaport in Rotterdam is situated at the coast. As the largest Dutch port, all kinds of cargo are processed there, with the port covering 10,000.5 hectares – including 89 kilometres of quay walls. It accommodated 467.4 mln. tonnes of import and export cargo in 2022, almost equal to 2021 (Port of Rotterdam, annual report 2022). Container traffic is dominant with 14.5 mln. TEU, a sharp

21 HCCS, Value of the North Sea, https://hcss.nl/wp-content/uploads/2021/10/Value-of-the-North-Sea-HR.pdf

22 World trade in goods and services – an overview – Statistics Explained (europa.eu). In comparison, the average value of exports and imports for goods and services for Singapore represented 163.1 % of its GDP in 2018, for China 19.1 % and for the US 13.7 %; https://ec.europa.eu/eurostat/statistics-explained/index.php?title=World_trade_in_goods_and_services_-_an_overview#World_exports_of_goods_and_services

decrease of 6.5% from 2021. In 2022, the port shifted sharply from consumer goods (in containers), crude oil and cars, to import of energy (coal and gas). Approximately 15,000 vessels visit the port on an annual basis. Following the global trend of ever-increasing loading capacity per ship, the port is decoupling strong growth in tonnages and is flattening the number of ship calls.

The second-largest Dutch sea port, the Port of Amsterdam, lies at the junction of the North Sea Canal and the Amsterdam Rhine Canal. It consists of 35 specialised berths handling breakbulk, liquid cargo, project cargo, Roll-On-Roll-Off cargo, general cargo, and forestry products. It is divided into three port areas, including the subsidiary facilities of Zaanstad, IJmuiden, and Beverwijk. The port is responsible for some 5,000 ship calls on an annual basis. Amsterdam is the fourth biggest port in Western Europe.

Terneuzen and Vlissingen, located at the river Scheldt and close to the North Sea, are the third largest port. Terneuzen consists of an outer Braakman Harbour and the inner port of Axel Plain, Sluiskil, and Sas van Gent. It handles different kinds of cargo such as chemicals, oil products, ores, coal, fertilisers, paper, timber, gravel, sand, and agricultural products. The total throughput is around 40 mln. tonnes of cargo annually. With the port of Ghent included, merged in 2018 to North Sea Port, the total is 72 mln. tonnes currently.

The fourth port area, Port of Groningen Seaports (GSP), manages the two seaports Delfzijl and Eemshaven along with adjacent industrial areas. Groningen Seaports processed more than 7 mln. tonnes of cargo in 2022. About half of this consisted of minerals, such as salt, limestone and sand, and a quarter of oil products and chemicals. More than 8,000 ships, more or less evenly divided between seagoing and inland vessels, called at the ports. Currently, the port is growing at a fast pace in LNG import and has been a platform for building offshore wind installations in the Dutch and German parts of the North Sea.

The economic value of sea shipping in the Dutch part of the North Sea area, based on research conducted by CBS, is shown in Table 8. An upward trend is identified due to an increase in (economic) production. In 2021, the economic activity has a production value of around 7.3 bn. EUR on an annual basis, an added value of 2.4 bn. EUR and is responsible for some 9,000 FTEs.

Table 8: Economic value of sea shipping volumes in the Dutch North sea

	2010	2015	2017	2019	2021
Production (in mln.)	€5,035	€6,601	€6,059	€6,310	€7,352
Intermediary consumption (in mln.)	€3,754	€4,694	€4,327	€4,758	€4,954
Added value (in mln.)	€1,281	€1,907	€1,687	€1,552	€2,398
Employment (in 1000 FTE)	9	9.5	9.2	8.7	9.2

Source: CBS (2020). Economic description of the Dutch North Sea and coast: 2010, 2015 and 2017

& Draft version of CBS (2023). Economic description of the Dutch North Sea and coast: 2015, 2017, 2019 and 2021

The majority of the added value is generated at land, at terminals and inland logistics activities

Outlook

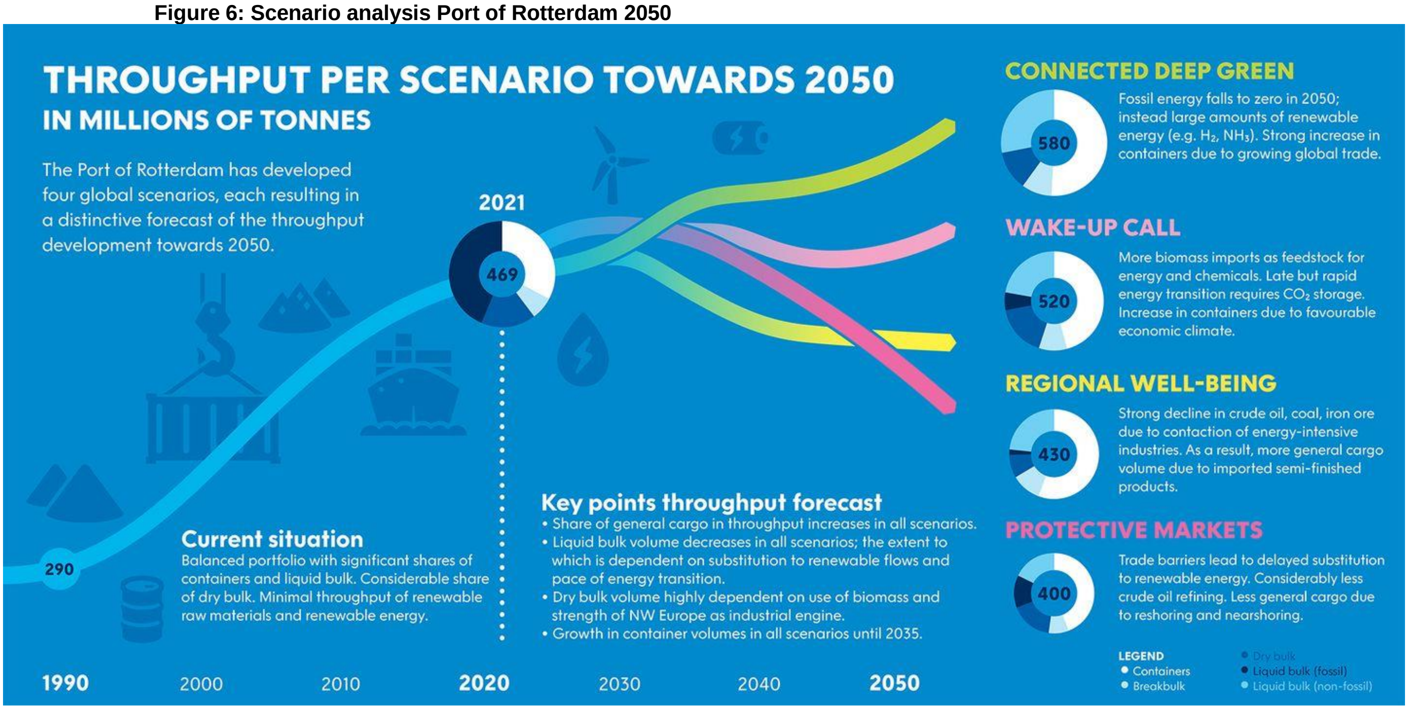
The current geopolitical situation and high inflation creates many uncertainties for the sea shipping sector.[23] As far as this can be predicted now, the economies of the Netherlands and Europe appears to be stagnating in 2023. Transhipment volumes are expected to fall slightly. The direction of the energy transition is important for the future cargo volumes of the ports.

[23] Port of Rotterdam 2022, Annual report

The Port of Rotterdam Authority has developed four diverse global scenarios in detail in 2022. Central to these analyses was the issue of how changes in geopolitics, economics, society, and technology would impact the port-industrial complex and the size and composition of the port's throughput. The four scenarios towards 2050 and their corresponding concise storylines are:

- **Connected Deep Green**: effective global cooperation with acceleration on digital transparency in logistics chains and global commitment to targets to combat climate change, resulting in global carbon neutrality by 2050, broad prosperity and high economic growth and a maximum temperature rise of 1.5 degrees Celsius this century.
- **Regional Well-Being**: from a shared commitment to transition, in the absence of sufficient global trust, a tilt towards a regional focus on clean and healthy environments, privacy, and well-being emerges within clusters of countries by early 2030. This results in a deteriorating business environment for basic industry in North-Western Europe and moderate economic growth.
- **Protective Markets**: a world with distrust between power blocks, global geopolitical tensions, and suboptimal integration in logistics chains. There are competing economic interests in a fragmented world with focus on self-sufficiency, financial prosperity, resilience, and defence. No global carbon neutrality before 2100 and low economic growth.
- **Wake-Up Call**: increasing concerns about the economic impact of external shocks such as food and energy availability or extreme weather mark a turning point. There is growing awareness that strategic cooperation and rigorous measures are needed to reduce carbon emissions. This results in strategically strong EU policies, moderate economic growth, and a late but rapid transition to renewable energy.

Figure 6: Scenario analysis Port of Rotterdam 2050

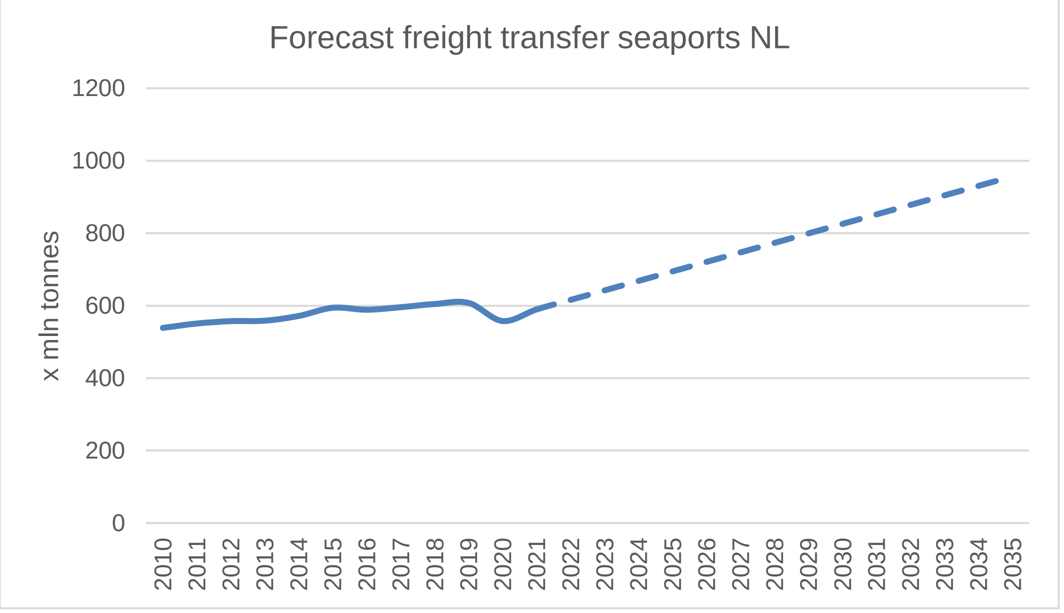


Source: Port of Rotterdam

Looking ahead, the economic value of sea shipping is expected to develop similarly to the advancement of the throughput of goods transported through all Dutch seaports. The solid line shows the realised development of both indicators, up to and including 2022 (Figure 7). The dashed line represents the team's estimate for the future volumes, based on current literature. The team adheres to the following assumptions:

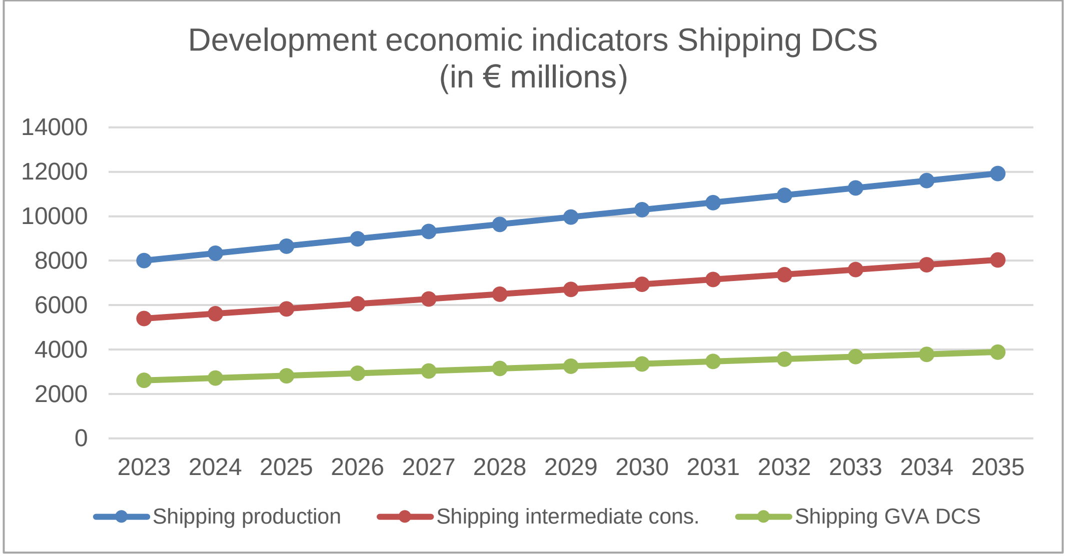
- **Goods transhipment seaports** NL: the mass of deep-sea transported goods is expected to increase by 30-40% in 2030. [24] This development is mainly attributed to a growing capacity per ship. The number of ships themselves is hardly expected to increase. Being the largest EU port, cargo throughput in the Port of Rotterdam area generally defines the total throughput of Dutch Ports. Though the growing trend in last decades could be an optimistic forecast, as for example 'Connected Deep Green' (depicted in the 2050 scenario analysis of the Port Authority) suggests the likelihood of decreasing volumes.

Figure 7: Data 2010-2022 and expectations 2035 for economic activity sea shipping



Source: CBS (2023), and North Sea Programme 2022-2027

Figure 8: Expectations economic values 2023-2035 for economic activity sea shipping



Source: Analysis by Ecorys

This outlook can be translated into a forecast of economic activity, as visible in the Figure above. Aggregated, this brings the baseline trend for the economic value to a 55% net-increase in 2035.

[24] Nioz, Four years research into the effects of sand extraction in the North Sea, https://www.nioz.nl/en/news/four-years-research-into-the-effects-of-sand-extraction-in-the-north-sea

Table 9: Forecast 2035 economic value sea shipping Dutch North Sea area

	2035
Production (in mln.)	€11,927
Intermediary consumption (in mln.)	€8,036
Added value (in mln.)	€3,890
Employment (in 1000 FTE)	14.9

2.4 Offshore wind energy

Retrospective

The Netherlands holds a position in the sub-top of the EU27 with 17% of energy produced by wind energy production (in 2022).[25] Only Spain, Sweden and France have realised a higher production. The Netherlands is ranked fourth in the EU where offshore wind energy is concerned (ca. 3 GW installed capacity in 2022), after Germany, Denmark, and Belgium.

The economic value of offshore wind energy on the Dutch part of the North Sea area is shown in Table 9. An upward trend can be identified due to an increase in (economic) production, which stagnated by 2021. Since 2010, production volumes have increased significantly though. The total production, in economic value, increased from 90 to over 350 mln. EUR on an annual basis, leading to an increase in added value and jobs.

Table 10: Economic value of offshore wind on the Dutch North sea

	2010	2015	2017	2019	2021
Production (in mln.)	€90	€158	€547	€541	€552
Intermediary consumption (in mln.)	€55	€70	€207	€203	€485
Added value (in mln.)	€35	€88	€341	€339	€67
Employment (in 1000 FTE)	<1	0.06	0.14	0.13	0.32

Source: CBS (2020). Economic description of the Dutch North Sea and coast: 2010, 2015 and 2017 for 2010 values,

& Draft version of CBS (2023). Economic description of the Dutch North Sea and coast: 2015, 2017, 2019 and 2021

Outlook

On 19 November 2020, the European Commission published a dedicated EU strategy on offshore renewable energy (COM(2020)741) which proposes concrete ways forward to support the long-term sustainable development of this sector[26]. The strategy sets targets for an installed capacity of at least 60 GW of offshore wind energy and 1 GW of ocean energy by 2030, and 300 GW and 40 GW, respectively, by 2050. The installed offshore wind capacity in the EU was 14.6 GW in 2021 and is set to increase by at least 25 times by 2030, using the vast potential of the five combined EU sea basins (North Sea, Baltic Sea, Atlantic Ocean, East and West Mediterranean, and the Black Sea[27]). Often, these basins are used as a framework, in which investments and interlinkages are developed[28].

[25] Our World in Data, https://ourworldindata.org/energy

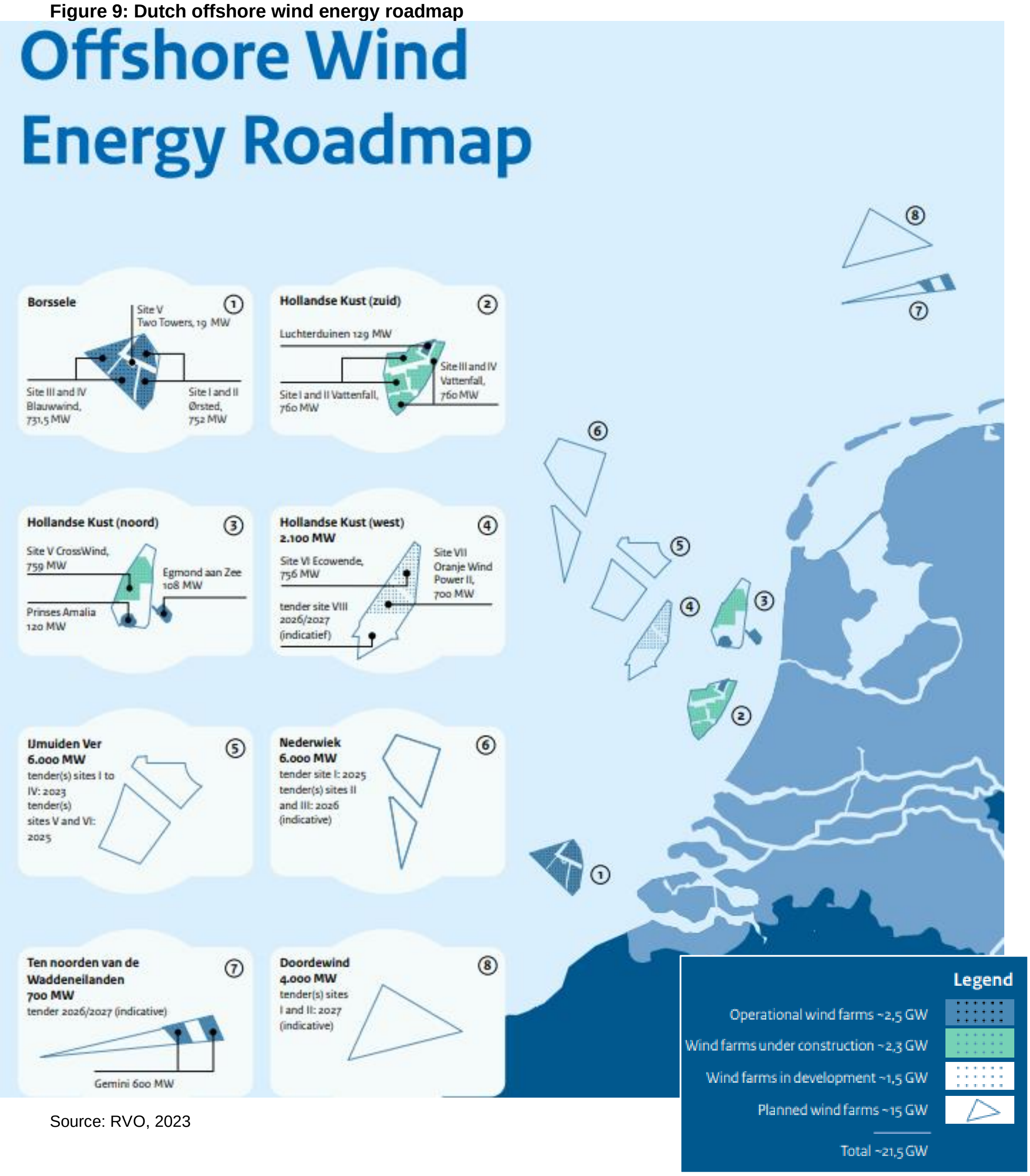
[26] EU strategy on offshore renewable energy , https://energy.ec.europa.eu/topics/renewable-energy/offshore-renewable-energy_en

[27] The six EU sea basins, https://maritime-spatial-planning.ec.europa.eu/msp-practice/seabasins

[28] Four regional sea conventions cover EU marine waters: the Convention for the Protection of the Marine Environment of the Baltic Sea (Helsinki Convention - HELCOM), the Convention for the Protection of the Marine Environment of the North-east Atlantic (Oslo-Paris Convention - OSPAR), the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention – UNEP-MAP) and the Convention for the Protection of the Black Sea against Pollution (Bucharest Convention, to which the EU is still trying to accede). However, OSPAR does not cover the entire European Macaronesia subregion, only the Azores archipelago. (For more info please refer to: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0259)

Currently, the EU is a global leader in the manufacturing of key wind turbine components, as well as in the foundations and cables industry: almost half of the active companies in the wind sector (onshore and offshore) are headquartered in the EU. To explore offshore sites further out to sea with stronger and more consistent winds, several European developers are working on floating offshore wind turbines. Multiple pilot projects are already up and running, with deployment expected to accelerate towards the end of this decade.

Figure 9: Dutch offshore wind energy roadmap



Source: RVO, 2023

The Dutch government has set ambitious targets for offshore wind energy generation for the longer term. The goal was to have 11.5 GW of offshore wind capacity by 2030. In 2022, the Dutch government raised this initial target for offshore wind capacity from 11.5 to 21 GW by 2030/2031. Achieving this target means that offshore wind farms then will supply 16% of the Dutch energy need. This would also equate to approximately 75% of the current Dutch electricity consumption[29].

[29] RVO, https://english.rvo.nl/information/offshore-wind-energy/offshore-wind-energy-plans-2030-2050#:~:text=In%202022%2C%20the%20Government%20raised,of%20our%20current%20electricity%20consumption.

The electricity consumption is, however, expected to increase. Therefore, an even larger amount of offshore wind energy needs to be developed after 2030 in order to meet the Dutch consumption needs.

Future scenarios for energy systems (supply and demand) and the North Sea Energy Outlook (Noordzee Energie Outlook) indicate between 38 and 72 GW of offshore wind capacity will be needed by 2050. To achieve this target, the Dutch government has planned several tenders for new offshore wind farms in the Dutch part of the North Sea. Figure 9, depicted below, shows where wind farms can be developed. Recently, the Dutch Government also joined the **Esbjerg declaration** on expanding offshore renewable energy[30]. It is also a structural partner in the 'The North Seas Energy Cooperation', developing an offshore grid, linking the nine countries in the North Seas region, to promote renewable energy and boost economic growth[31].

To support this development of offshore wind energy, the Dutch government has already put a range of policies and measures in place, including funding (currently many projects can be realised without any support) and (tax) incentives for renewable energy producers, as well as regulations to streamline the planning and construction of offshore wind farms.

In 2020, the Dutch government announced plans to schedule two tenders for the construction of new offshore wind farms, each with a capacity of at least 700 MW. These new wind farms are expected to be operational by 2027. Additionally, the government plans to launch a third tender for a 2 GW offshore wind farm in 2023.

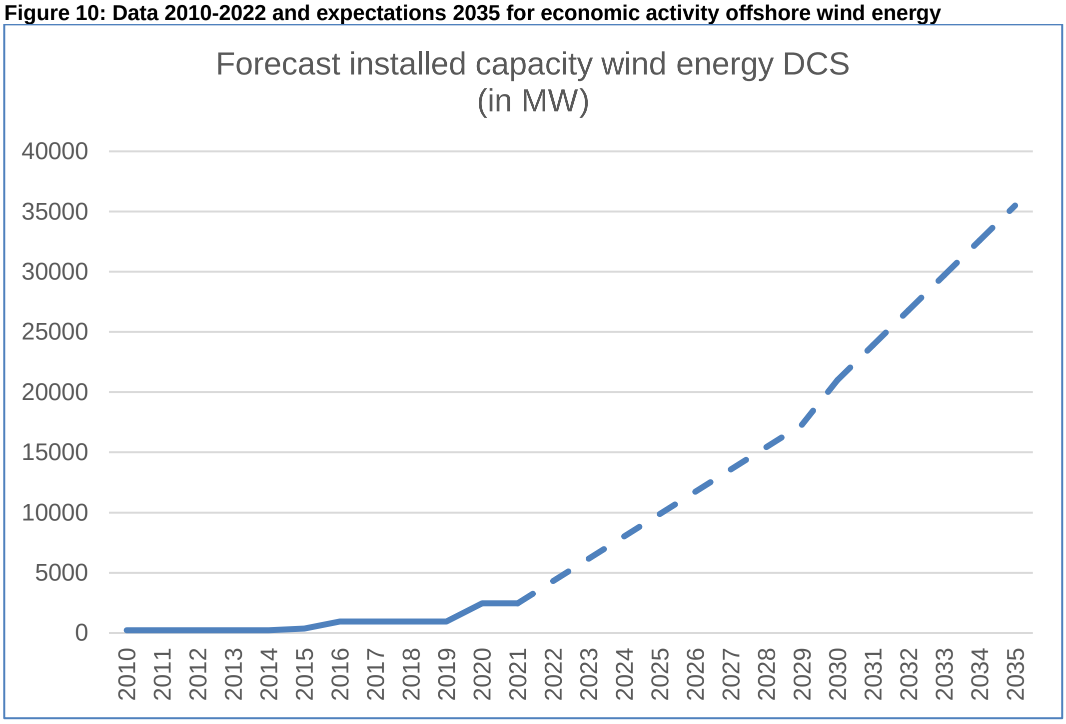
Looking ahead, the development of the economic parameters is based on the expected development of the installed capacity of wind turbines in the Dutch North Sea area. The solid line in Figure 10 shows the realised development of installed capacity, up to and including 2022. The dashed broken line represents the estimate for the future, using the following assumption:

- Installed offshore wind energy capacity: as described in 'Offshore wind energy plans 2030-2050', the Dutch cabinet has set the target of 21 GW of installed offshore wind energy capacity in the North Sea around 2030, 40 GW around 2040 and 70 GW around 2050.

30 EU countries have agreed on new, ambitious long-term goals for the deployment of offshore renewable energy up to 2050 in each of the EU's five sea basins, with intermediate objectives to be achieved by 2030 and 2040. The combined figures give an overall ambition of installing approximately 111 GW of offshore renewable generation capacity by the end of this decade - nearly twice as much as the objective of at least 60 GW set out in the EU Offshore Renewable Energy Strategy in November 2020. This then rises to around 317 GW by mid-century, reaching the very goal of the Strategy. (More details can be found here)

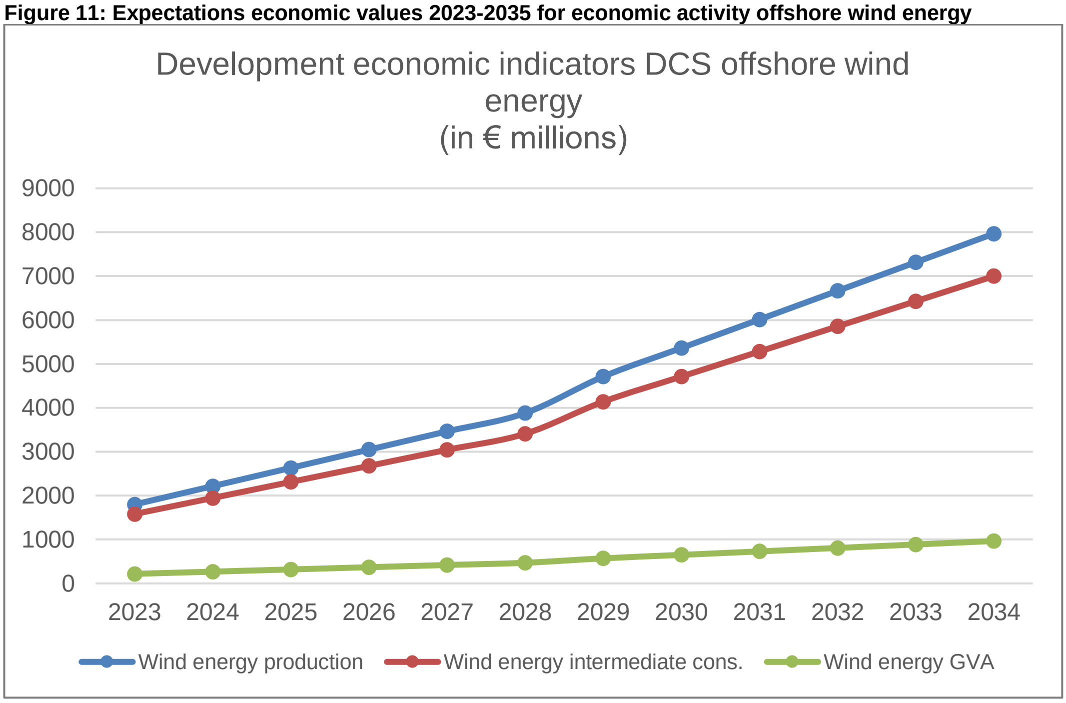
31 https://energy.ec.europa.eu/topics/infrastructure/high-level-groups/north-seas-energy-cooperation_en

Figure 10: Data 2010-2022 and expectations 2035 for economic activity offshore wind energy



Source: CBS (2023) for realisations

Figure 11: Expectations economic values 2023-2035 for economic activity offshore wind energy



Source: Analysis by Ecorys I The added value (for the total of the sector) is increasing with production values. With the realised efficiency gains, advantage by scale, the sector is expected to realise in time diminishing added value per production volume

Overall, following policy initiatives, the future of Dutch offshore wind generation on the Dutch part of the North Sea seems prosperous. The EU and Dutch government are committed to ambitious targets and policies to support the development of this source of renewable energy. Aggregated, the economic value of offshore wind energy is expected to rise by a net increase of 480% in 2035 (see table 10).

Table 11: Forecast 2035 economic value offshore wind energy Dutch North Sea area

	2035
Production (in mln.)	€7,966
Intermediary consumption (in mln.)	€6,999
Added value (in mln.)	€967
Employment (in 1000 FTE)	4.6

2.5 Fisheries

Retrospective

Based on data provided by Statistics Netherlands (2023), the economic value of fisheries in the Dutch part of the North Sea area is shown in table 11. The data depicts the production of Dutch vessels at the Dutch part of the North Sea only.

No trendline can be identified for the period 2010-2021. Currently however, the sector is experiencing a difficult time[32]. Over the first 8 months of l2022, Dutch cutter fishing suffered an estimated loss of 20 to 30 mln. EUR, with all applied fishing methods being loss-making on average. The year 2021 (a full year) shows a provisional result of -3 mln. EUR. In the years 2018, 2019 and 2020 the results were respectively +48, +9 and +5 mln. EUR. Cutters are expected to have earned significantly less or to make high losses. Even though prices were higher, operational costs were too. The deployment of ships has been 25-30% lower compared to 2021. Many ships have been idle for a longer period of time. Cutter owners (flatfish vessels) are considering making use of the restructuring scheme (to compensate for the negative effects of Brexit, high diesel oil prices, and decreasing fishing volumes)[33]. With the 'Noordzeeakkoord', ca. 200 mln. EUR in total is earmarked. It stimulates innovation in the Dutch fishery sector and companies that cannot or will not make this step can voluntarily end their activities with a compensation by the Government. Cutters are targeted specifically by the agreement. The conditions for remediation are that the cutter is scrapped or converted. All fishing licenses will be withdrawn and the fisherman in question may not engage in fishing activities for five years. At the end of 2022, it became clear that many vessels will be scrapped. One out of three, some 80 cutter vessels, have registered their interest in ending the activity.

High diesel prices would be one of the reasons, while the decreasing fishing volumes is, indirectly, another. During the Brexit negotiations on the conditions under which the United Kingdom could leave the European Union at the end of 2020, it was agreed that the UK would be allocated a larger share of the Total Allowable Catch (TAC) of a large number of shared fish stocks than was the case at the time of the UK's EU membership. As a result, the Dutch share of the TACs will gradually decrease during the adjustment period that lasts until 30 June 2026 (Wageningen University, 2022).

Table 12: Economic value of fishery sector on the Dutch North Sea

	2010	2015	2017	2019	2021
Production (in mln.)	€142	€153	€151	€135	€142
Intermediary consumption (in mln.)	€64	€64	€56	€54	€57
Added value (in mln.)	€78	€89	€95	€81	€85
Employment (in 1000 FTE)	1	0.8	0.7	0.7	0.7

[32] Kottervisserij is dit jaar fors verliesgevend na een moeilijk 2021, Wageningen University and Research, https://agrimatie.nl/NieuwsDetail.aspx?subpubID=2526&itemid=7848

[33] Analysing the restructuring of the Dutch fishing fleet under the BAR scheme, update 2022, https://edepot.wur.nl/573868

Source: CBS (2020). Economic description of the Dutch North Sea and coast: 2010, 2015 and 2017 for 2010 values*,*

& Draft version of CBS (2023). Economic description of the Dutch North Sea and coast: 2015, 2017, 2019 and 2021

Dutch consumer expenditures on fish and seafood were equal to 2 bn. EUR in 2021. Consumer expenditure is expected to continue to rise. Apart from that, the Dutch fishing industry which focuses on sole and plaice is under heavy competition from importing competitors who supply alternative types of fish (e.g. Pangasius). The Netherlands is a net-exporter of fish and seafood. Between 2008 and 2018, Dutch exports increased by 48%, while imports increased 34%.

In 2021, the Netherlands was the world's tenth largest importer of seafood, with imports of ca. 5 bn. EUR or 2.8% of global seafood imports for 2021. In recent years the Dutch seafood sector has been a strong market. Top seafood imports in the Netherlands in 2021 consisted mainly of frozen fish and had little relationship with fishing vessels in the North Sea[34].

In 2018, the Dutch fishing fleet consisted of 833 powered vessels, in total, which means an increase of 1% since 2008. Small-scale vessels, those below 12 metres in length, accounted for 41.2% of the total number of vessels. These are most likely active on the Dutch coastal and inshore waters. Larger vessels are predominantly active on the North Sea while the large pelagic trawlers operate in both EU and international waters. The total gross tonnage of the Dutch fleet in 2018 was 120,509 tonnes, which corresponds to a reduction of 23% since 2008. Small-scale vessels accounted for 0.7% of the total gross tonnage (OECD, 2021).

Outlook

The moderate catches and supply of fish from the North Sea led to concerns throughout the chain and uncertainty about the future. The Dutch government have reserved 155 mil EUR for a remediation fund for cutters[35], towards which 78 cutter owners replied positively[36]. If the remediation of a large group of cutters actually continues, then the question is whether the trading and processing companies that depend on North Sea fish can still remain profitable. The fish auction at Den Helder has already closed in 2022.

The supply of fish supplied by Dutch ships is decreasing, which means that trading and processing companies are importing more and more fish and are becoming dependent on it. The demand for fish products is much greater and more diverse than the supply of North Sea fish (Wageningen University, 2022).

Besides the economic challenges currently faced by the fishing industry, there is an ongoing debate over the allocation of the limited space at the North Sea, and the place of fishing vessels therein. The continued expansion of offshore wind farms in particular leaves less fishing ground, and nature organisations and government policies are claiming more areas closed for fishing in favour of nature conservation. Furthermore, beam trawling is under social and political debate and sustainability initiatives in the sector are progressing slowly or have come to a standstill, after electric pulse fishing was restricted in 2021[37]. That said, innovations are still developed and tested; for example, alternative fuels for decreasing noise and pollution. In addition, the use of static gears

---

34 Sector Trend Analysis – Fish and seafood trends in the Netherlands, https://agriculture.canada.ca/en/international-trade/market-intelligence/reports/sector-trend-analysis-fish-and-seafood-trends-netherlands-0

35 Rijksoverheid 2022

36 Visserij.nl, 2022

37 Pulse fishing was originally banned by the EU more than 20 years ago, in 1998, but the Dutch government argued that research and innovation to improve pulse beam trawls should be allowed, and a derogation was introduced in 2006. Dutch fishermen argued the pulse technique is environmentally friendly because it allows trawlers to use far less diesel than traditional beam trawlers, and it does not damage the seabed. (https://www.seafoodsource.com/news/environment-sustainability/dutch-pulse-fishing-ban-upheld-by-the-european-union)

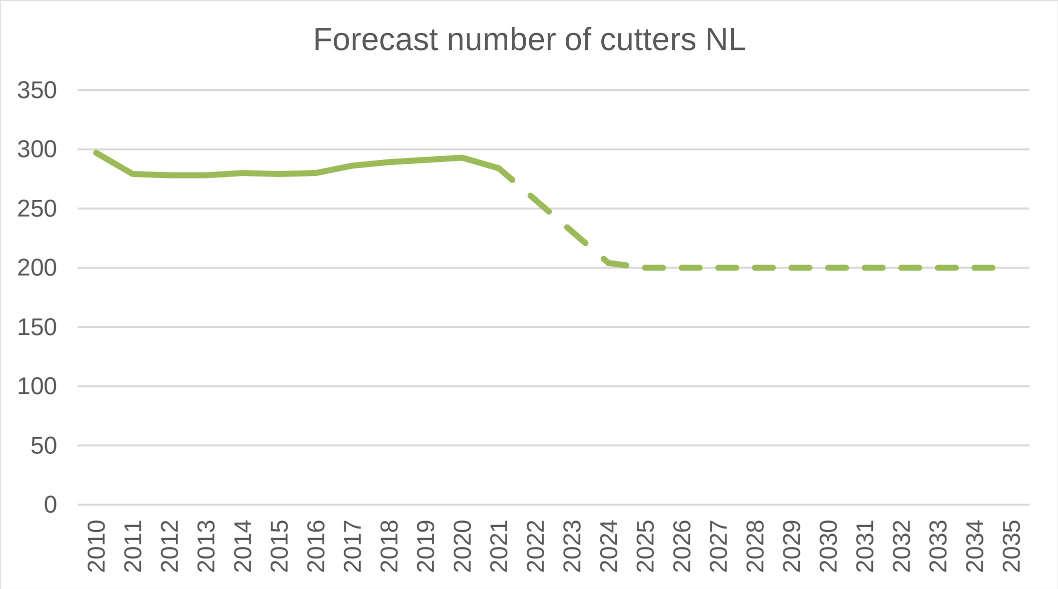
in the windfarm areas is also explored, although this cannot be seen as an alternative for the declining fishing opportunities in the offshore areas.

Looking ahead, the number of fishing boats, the average catch per vessel and, as a result, the total mass of fish landed will be used to forecast the economic development of fishing on the Dutch part of the North Sea, as depicted in Figure 11 and 12: The solid lines show the realised trends until 2021, the dashed lines represent estimates for up to 2035.

The following assumptions have been used:

- **Development of the fishing fleet**: figure 11 shows the development of the fishing fleet for cutter fishing, which is the dominant form of fishing on the Dutch part of the North Sea. The fleet for cutter fishing has increased slightly in recent years. A decrease in cutters is expected in the coming years, due to rising diesel prices, the ban on pulse fishing, lack of space due to the construction of wind farms and decreasing catches. An indication of this is visible in the fact that 78 cutters of the sole and plaice fleet signed up for a purchase scheme at the end of 2022. After the decrease, a new and lower steady state of cutters is assumed.
- **Average landings of fish per ship**: the average landings per ship have declined in recent years for cutter skippers. This trend is expected to continue, until a lower steady state has been reached (Figure 12). [38]
- **Development of the supply of fish**: this is a multiplication of the expected number of vessels per type of fleet and the average supply per vessel.

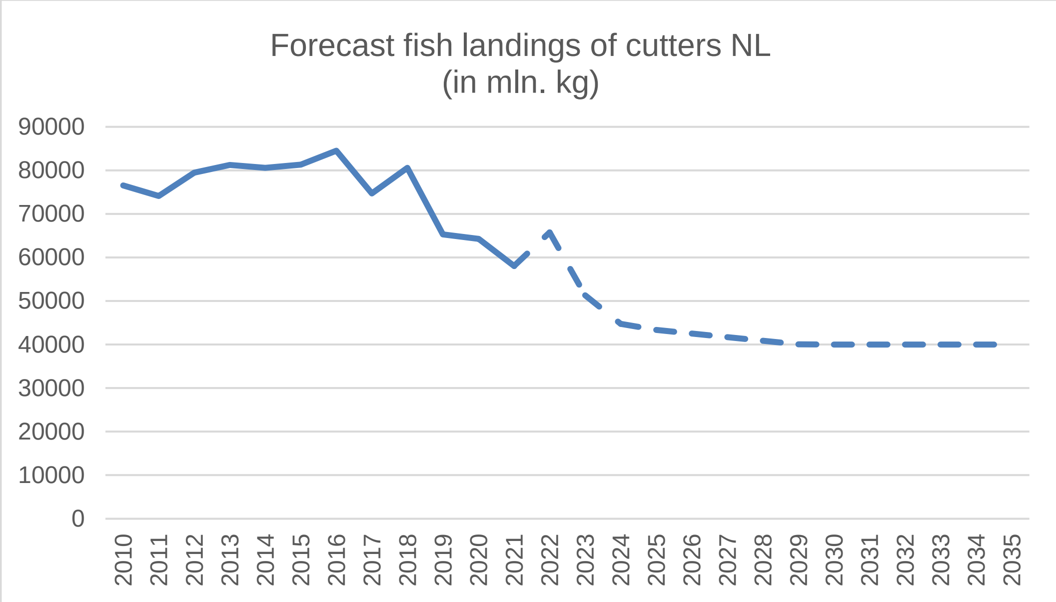
Figure 11: Expectations commercial fishery fleet (cotters) 2010-2021 and 2035



Source: Visserij in Cijfers WUR (2023) for realisations

[38] These assumptions are also based on an interview with a fishing economist of the Wageningen University of Research

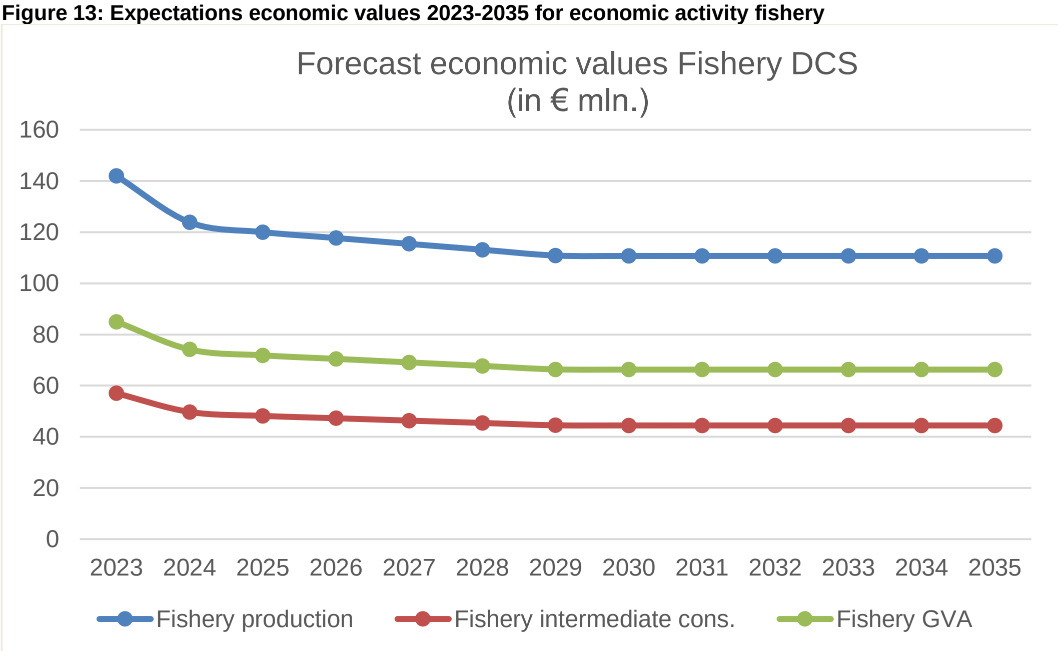
Figure 12: Expectation for volumes for economic activity fishery



Source: Visserij in Cijfers WUR (2023) for realisations

Figure 13 shows the economic forecast for fisheries at the Dutch part of the North Sea, based on the forecast for the number of cutters and the average landings per cutter. In aggregate, this forecast foresees a net decrease of 22% in economic value in 2035.

Figure 13: Expectations economic values 2023-2035 for economic activity fishery



Source: Analysis by Ecorys

Table 13: Forecast 2035 economic value Fishery Dutch North Sea area

	2035
Production (in mln.)	€111
Intermediary consumption (in mln.)	€44
Added value (in mln.)	€66
Employment (in 1000 FTE)	0.5

2.6 Aquaculture

The North Sea is a location which could be suitable for building sea-based aquaculture; the Netherlands is developing offshore operations via research pilots. North Sea Farm 1 is one of these pilots, which will be co-financed by Amazon and will be developed in between Dutch offshore wind parks.[39]

In recent years, there has been a growing interest in expanding aquaculture tests in the North Sea, driven by factors such as increasing demand for seafood, declining wild fish stocks, and the need for more sustainable food production. Additionally, aquaculture could pose a viable form of multi-use of the available space between offshore wind parks, which are no longer available as fishing grounds, as fishing between offshore wind parks is still in an experimental phase. Since 2013, commercial seaweed has been grown on a small scale in the Netherlands.

According to the OECD, in 2018, Netherlands produced 0.5 mln. tonnes of seafood (including fish, molluscs, and crustaceans), with a value of some 600 mln. EUR. 17% of this value came from aquaculture and 83% from fisheries. The majority of this aquaculture is currently based on the Waddenzee and in the province of Zeeland, so not in the Dutch part of the North Sea. Globally, aquaculture is an activity in developing nations in sub-Saharan Africa and Asia. Due to its very small share in global production, the Dutch aquaculture sector cannot make a significant contribution yet to the increasing global demand for seafood. The products grown in the Netherlands (mussels and crustaceans) are mainly grown for surrounding countries[40].

The aquaculture sector (at sea) is an economic activity that is in the experimental phase. The Dutch government has set targets for the development of offshore aquaculture, with the aim of establishing 5-10 large-scale offshore aquaculture operations by 2030. These will primarily focus on the production of high-value species such as seaweed, mussels, and oysters, which are well suited to the North Sea environment. Three projects have been awarded funding, one is SEASeeds that will conduct research into protein production in sea, large-scale seaweed production effects on marine ecology and new business models[41]. Another project is From Sea to Society, of NIOZ[42]. Together, they have been awarded 2.6 mln. EUR (Knowledge and Innovation Covenant (KIC) 2020-2023). Public and private partners will provide co-funding. It is yet to be seen what the production volumes could be considering barriers such as the deficiency of nutrients at sea. The third project is CircAqua, which will be coordinated by Wageningen University.

Until now, offshore aquaculture has been rather small-scale, often started in pilot form. This in addition to the established sectors of mussels (ca. 60 mln. EUR turnover on an annual basis) and oysters (ca. 6 mln. EUR), together a job market of some 225 FTE. Most of those activities do not take place at the North Sea however, but inland. Compared to e.g. the fishing industry, the market is not large (it is at least 10 times smaller). According to the Dutch National Strategic Aquaculture Plan, Dutch production is to remain a niche market, and the potential to allow production volumes to increase structurally is low. There is still a number of primarily technical challenges in the production of algae and seaweed before offshore production can possibly be developed on a commercial scale. In addition, for many forms of aquaculture the cost of production is still too high to create a viable business case.

---

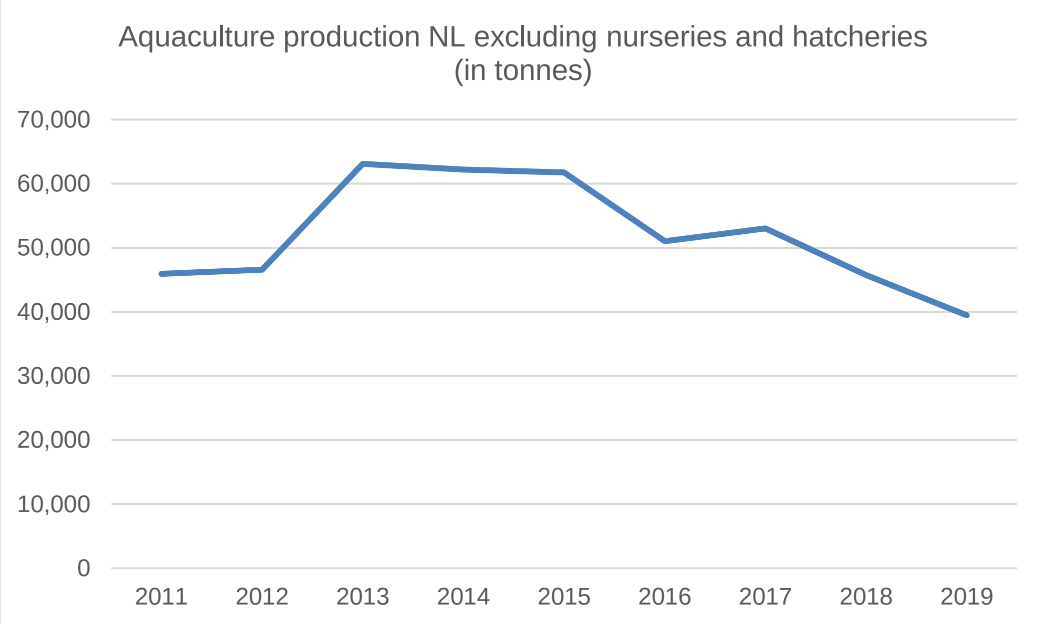
39 Amazon (2023), https://www.aboutamazon.eu/news/sustainability/introducing-the-worlds-first-commercial-scale-seaweed-farm-located-between-offshore-wind-turbines

40 Nationaal Strategisch Plan Aquacultuur, 2014-2020, https://edepot.wur.nl/346754

41 Netherlands hopes research project will jumpstart large-scale seaweed production offshore, https://thefishsite.com/articles/netherlands-hopes-research-project-will-jumpstart-large-scale-seaweed-production-offshore

42 'From Sea to Society' project awarded, https://www.nioz.nl/en/news/from-sea-to-society-project-awarded

Figure 14: Expectations volumes for economic activity aquaculture



Source: Eurostat (2022)

For the time being, there are no sectoral reports that convert the volumes (in tonnage) into added value figures or number of jobs in a stable manner; these will be made possible as the sector develops further. In economic data available for aquaculture (at the statistical office), no distinction is made between aquaculture at sea, and aquaculture on the seabed or land. On the basis of the scarcely available data, it is not possible to make statements about the direct and indirect production value, added value, and employment per scenario and per reference year for aquaculture at sea. On the one hand, this is because the growth factors are not quantified; on the other hand, because the basic data on aquaculture in the North Sea is missing (except for a pilot project with seaweed, there is no commercial aquaculture).

Economic estimates have been made with regard to a theoretical situation in which the potential yields of mussel cultivation in (Dutch) offshore wind farms have been calculated. Consultant agency Decisio indicatively estimated the added value in 2018, partly on the basis of previous research by Wageningen University & Research. They[43] refer to two studies that can provide insight into the potential yield of mussel cultivation in wind farms. The first is Kamermans *et al*. (2016), where via a business case it was calculated that about 25% of the area of a wind farm can be used for mussel cultivation, then harvesting some 20 tonnes of mussels per hectare per year. The other study presents the results of a trial in Germany (Buck *et al.* 2010), with an annual harvest of approximately 10 tonnes of mussels per hectare per year and on which a profit can be made, assuming a price of 1,000 euros per tonne. Based on the above principles of the first study, the calculation of the production value is 270 mln. euros by 2030. With a profit margin of 23%, it gives this an annual added value of 60 mln. Euros. Based on the second study, the calculation for the production value would be 135 mln. Euros, with an added value on an annual basis of 65 mln. Euros. What is not taken into account in the above calculation is that, if production will increase sharply, the selling price per tonne will probably decrease (see also van Oostenbrugge et al 2017). Also, no account has been taken of higher costs for the cultivation of mussels further from the coast[44]. After the pilot phase it remains to be seen whether the estimated added values, and

[43] Decisio, 2018. Integrale kosten-batenstudie vervolgroutekaart windenergie op zee, https://www.rijksoverheid.nl/documenten/rapporten/2018/04/03/eindrapport-kosten-batenstudie-vervolgroutekaart-windenergie-op-zee

[44] De economische effecten van twee toekomstscenario’s voor de Noordzee, Wageningen, 2019

production volumes, are feasible. Another reason why exact estimates in economic indicators is not feasible at this moment.

2.7 CCS

Carbon capture and storage (CCS) is an important technological way to reduce CO_2 emissions and will play an essential role for countries to achieve their Paris Agreement climate commitments. According to investor and stakeholder Neptune Energy[45], CCS could be an enabler of lower-cost, low-carbon hydrogen production, and can tackle emissions in sectors where other technological options are limited, such as the production of steel or cement. On the other hand, CCS also could possibly take an incentive away to alter industrial processes as CO_2 can be captured.

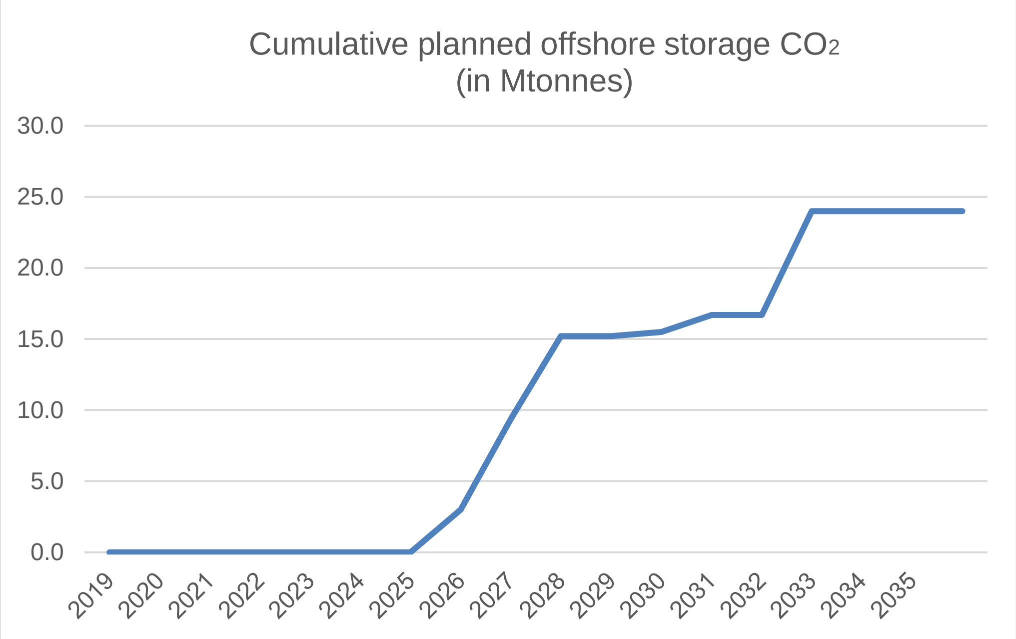
Nevertheless, CCS serves to minimise carbon offshoring (moving carbon-intense production to other regions) and retains employment opportunities for Europe. There is currently no CO_2 storage in the Dutch part of the North Sea. However, a series of initiatives have been set up, with the corresponding expectation of CO_2 storage in the period 2025-2035. The following initiatives are the most concrete[46]:

- Porthos;
- Aramis;
- Zeeland Refinery;
- Dow Benelux;
- Yara;
- Everest Initiative Tata Steel;
- OCI, Geleen;
- L-10 & Noordkaap Neptune Energy

Currently for example, oil and gas company Neptune Energy has teamed up with several firms – ExxonMobil, Rosewood, and EBN – to pool resources for the development of a CCS project in the Dutch part of the North Sea. Their L10 carbon capture and storage project has the potential to store 4-5 mln. tonnes of CO_2 annually (120-150 mln. tonnes at maximum for this project). The figure below shows the expected cumulative storage of these projects, which will lead to a possible total of 24 mln. tonnes per year in 2035. The effective roll-out is still highly uncertain, however.

45 Decarbonising Dutch sector, https://www.neptuneenergy.com/esg/l10-area-ccs-development
46 Royal Haskoning DHV (2021) Nationale CO2-opslagbehoefte tot 2035.

Figure 15: Current expectations volumes for economic activity CCS



Source: Analysis by Ecorys

For the time being, there are no volumes (in tonnes), and the projects are too uncertain to convert these into added value figures (or number of jobs). These may become clear as the sector develops further. There is a clear interlinkage with the gas extraction industry, as the gas fields that are emptied by companies working in this sector can be used for CCS. Also, the pipes can be reused when decommissioned for gas extraction. Gas extraction jobs, as volumes are expected to decline eventually, are at risk. CCS could give the extractions platforms and pipelines new economic value, after reinvestments. As such, jobs could be shifted from gas extraction to CCS. However, this would require an almost immediate shift from the current gas extraction to CCS, since otherwise platforms will have to be dismantled and removed because they cannot be left idle; regular checks and maintenance cost money also when platforms are not in use, and according to existing legislation, platforms that are not used should be removed.

2.8 Solar energy

Solar energy is an economic activity that is not yet used on the Dutch part of the North Sea but could be a promising location for solar panels in the future. At this point in time only pilots have been started within the 12-mile coastal radius. Floating solar panels have the potential to be a viable renewable energy source in the Dutch part of the North Sea. Offshore solar is theoretically very complementary to offshore wind.[47] In addition, floating solar panels have several advantages over traditional land-based solar panels, such as increased yield due to the cooling effect.[48] However, there are also some challenges associated with floating solar panels, such as the cost of installation and maintenance, durability of the floating PV-installations and the potential impact on marine ecosystems.[49] Nevertheless, research and development efforts are ongoing to address these challenges and improve the efficiency and effectiveness of floating solar panels.

47 https://www.sciencedirect.com/science/article/pii/S0038092X20313219 (Pooling the cable, Golroodbari et al., 2020)

48 Golroodbari, S. Z.; van Sark, W. Simulation of Performance Differences between Offshore and Land-Based Photovoltaic Systems. *Progress in Photovoltaics: Research and Applications* 2020, *28* (9), 873–886. https://doi.org/10.1002/PIP.3276

49 Pouran et al. (2022) https://www.sciencedirect.com/science/article/pii/S2589004222015255

Offshore wind farms can be supplemented by “floating solar parks”. Under a new plan to boost renewable energy in Europe and reduce reliance on Russian gas, Dutch/Norwegian start-up ‘SolarDuck’ partnered with German energy firm RWE for a project which will realise a pilot with floating solar panels within an offshore wind farm. This installation will be placed in the near future, off the coast of Ostend in Belgium. The solar park will use photovoltaic panels linked together, floating several metres above the water to ride waves “like a carpet”. The pilot will have a capacity of 0.5 MW by next year, with hopes that further commercialisation of the technology will continue from 2023 onwards. Arrays of solar panels will utilise the same undersea cables that carry electricity generated by offshore wind turbines ashore, meaning complex infrastructure will not be required.[50]

The following initiatives for offshore solar pilots (past, ongoing, and future at the time of finalising the report) on the North Sea were supplied by Oceans of Energy:

- CSEALAND;
- North Sea 1 (NS1) Zon op Zee Project;
- North Sea 2 (NS2) Project;
- EU-Scores H2020;
- OFS consortium Merganser;
- Solar@Sea II project;
- SENSE-Hub project.

2.9 Hydrogen

Hydrogen-based energy production is currently not yet present in the Dutch part of the North Sea but has the potential to be a significant economic activity in the future. Through electrolysis at sea, one can convert electricity into hydrogen and transport the gas using existing gas pipelines and platforms.

Hydrogen-based energy production is expected to be a viable form of energy storage in the future. No consensus is found on the future of hydrogen at sea. Two scenarios can be expected.

- Either generating hydrogen-based energy will mainly take place in the port areas, on land in general and only at a secondary stage at sea. The hydrogen-based energy can also be produced elsewhere and shipped to the Netherlands via maritime transport.
- Or, via the re-use of existing pipelines, a significant saving in capital expenses for long-distance cables will lead to a strong increase of conversion of wind-energy at sea into Hydrogen. At a later stage, maritime transport of Hydrogen produced at sea will then be an option.

Still, large-scale investments will be needed to facilitate the re-use of assets, e.g. in connections and compression stations. The re-use of pipelines (converting them from gas pipelines to H2 pipelines) could become an alternative to realising large scale investments in more cable carrying capacity, for getting the offshore produced energy at land. Transporting hydrogen molecules over longer distances might be cheaper, and more efficient, than extending the cable networks on the seabed.

This economic activity will have direct and indirect effects on the North Sea, as the activity might be making use of cables (to wind farms), pipelines, and ships. The size of the market, and the use of assets, is not clear yet.

The first ever trial offshore hydrogen plant is being built in the North Sea in the near future. On the Dutch North Sea, more than 10 kilometres from The Hague, the planned pilot plant PosHYdon will produce for the first-time green hydrogen from sustainable electricity generated by wind and solar. A second investment is planned north of the Waddenzee. An offshore wind park, with a size of 500 MW electrolysis capacity is foreseen for 2031[51]. These pilots are a first step towards offshore hydrogen production from wind power at sea.

The biggest competitor for production at sea is the production of hydrogen in the port area as well as imports from elsewhere. The expectations for hydrogen at sea are still a debate in the industry and between academics. On one hand, production at sea could become necessary if offshore wind is generated further from land, at larger quantities. Then it could facilitate bringing the energy at land in a levelled manner, in contrast to peak usage of electricity cables only when energy is generated at maximum installed capacity. Local bunkering of hydrogen-fuelled vessels could then become reality. On the other hand, before this will be a viable option, many aligned investments are needed which are only seen as possible in the long run (after 2030). It could also turn out that hydrogen-based energy production at sea will be too expensive compared to imports.

2.10 Cables and pipelines

Cables and pipelines, together, encompass 7% of the Dutch part of the North Sea, including the ca. 750 m. safety zone around them [52]. On the bottom of the North Sea lies a network of roughly 4,000 km of cables for data traffic, telecommunication and electricity combined. Volumes of cables and pipes at the seabed do not fluctuate, but link to the network capacity. The total network (data and electricity cables) expands with new large-scale projects that require long-term plans and investments. Therefore, a stepwise expansion of the networks is expected.

Cables beneath the surface facilitate data/telephone communication and energy transport

- Communication cables transport gigabytes of information to and from data hubs worldwide. This is a long-lasting network, which is expanded still. The majority of cables are for telecommunication, and account for 20 active lines across 2,000 km[53]. The cables have to lie at a certain depth below the seabed and are not allowed to cross certain areas that have been reserved for other activities.
- The need for new electricity cables is directly related to the development of offshore wind capacity. The electricity cables of offshore wind farms are the fastest expanding sub-sector. While telecom cables usually rest upon the seafloor, power cables are buried below the seabed for protection against accidental damage; for example, by ship’s anchors, fishing nets, or dropped objects. Specific protection against deliberate damage (or tapping, in the case of communication cables) is minimal.

Pipelines transport oil and gas, and likely H2 and CO_2 in the future as well.

- Oil and gas flows through pipelines from production platforms to onshore users.
- The same pipes may well be repurposed for large scale hydrogen or CO_2 transport in the decades to come.

---

51 Windpark boven Groningen beoogd als ’s werelds grootste waterstof op zee productie in 2031, https://www.rijksoverheid.nl/actueel/nieuws/2023/03/20/windpark-boven-groningen-beoogd-als-s-werelds-grootste-waterstof-op-zee-productie-in-2031

52 On either side of a pipeline or cable on the seabed is a safety zone. Within that area, no activities may take place on the seabed, HCCS, Value of the North Sea, https://hcss.nl/wp-content/uploads/2021/10/Value-of-the-North-Sea-HR.pdf

53 Noordzeeloket, https://www.noordzeeloket.nl/en/policy/noordzee-natura-2000/betrokkenen/kabels-leidingen/

The need for more pipelines is directly related to the development of CCS, oil, and gas extraction, and to the production of hydrogen. Also, the total network needed depends strongly on potential re-use of existing capacity of platforms at sea.

Outlook

To connect new wind farms, increased investments in high voltage cabling is underway, both nationally and internationally.

TenneT, appointed in 2016 as lead administrator for the Dutch offshore electricity network, is in the process of executing 15 cabling projects. The Netherlands has also seen a recent proliferation of international high voltage cables, which are intended to increase the flexibility of the national grid. In total, TenneT will be responsible for the cables supplying 40 GW of the planned 65 GW offshore wind energy carrying capacity by 2030. The systems will make use of seabed-based cables, and converting platforms where wind-generated AC power is converted to DC power.

- The first realisation is planned by 2028 (IJmuiden Ver Beta), gradually realising the total network by 2031 (with connecting Nederwiek 3)[54].
- At the end of March 2023, TenneT selected three partnerships consisting of Hitachi/Petroac, GE/SMOP and GE/McDermott to realise eight Dutch and three German 2 GW grid connection systems up to and including 2031, to bring larger amounts of green electricity from the North Sea wind farms on land. This includes a long-term contract of 2 GW HVDC (High Voltage Direct Current) cables, leading to a considerable network at the North Sea.
  - One example is the 2019 COBRA cable connecting the Netherlands to Denmark, with cables laid to both the UK (BritNed) and Norway (NorNed) in the decade before.
  - Another is the LionLink[55], a 250 km long cable planned to connect the energy grids of the UK and the Netherlands by 2030.

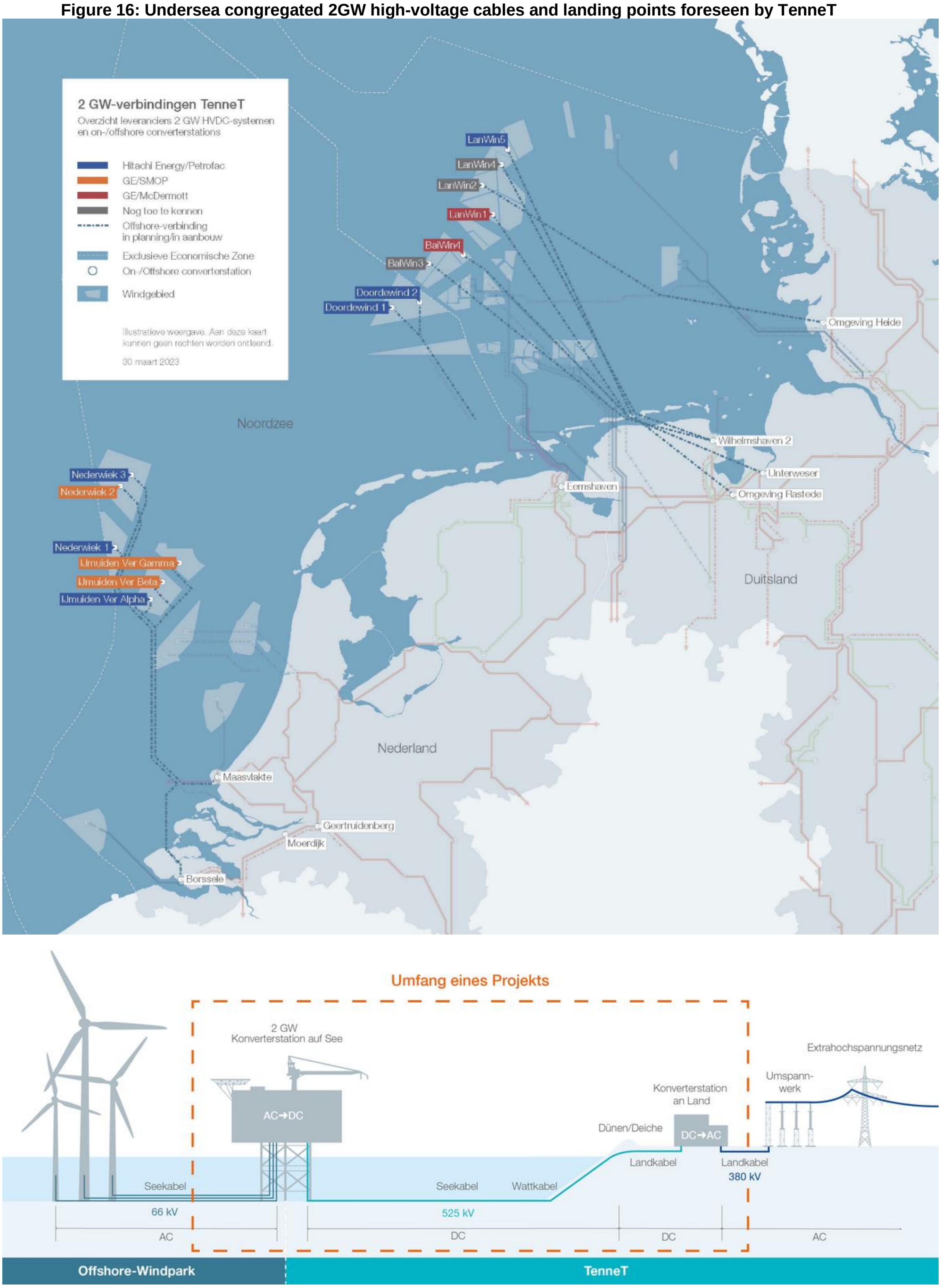
As illustrated in the figure below, the use of cables at sea for offshore wind energy is one option. These could perhaps be replaced by pipelines if the offshore wind industry realises hydrogen production at sea. This is a replacement of transport of electricity by cables, which will only be executed if this proves to be a more efficient way than long energy cables at the seabed.

---

[54] More information can be retrieved via: https://www.tennet.eu/nl/het-2gw-program

[55] Nederland en het VK breiden energie-samenwerking uit met nieuwe elektriciteitsverbinding, https://www.rijksoverheid.nl/actueel/nieuws/2023/04/24/nederland-en-het-vk-breiden-energie-samenwerking-uit-met-nieuwe-elektriciteitsverbinding

Figure 16: Undersea congregated 2GW high-voltage cables and landing points foreseen by TenneT



Source: TenneT, 2023 (source: https://www.tennet.eu/nl/nieuws/transmissiecapaciteit-ter-grootte-van-22-elektriciteitscentrales-de-noordzee-tennet-gunt)

Currently, communication cables provide the needed capacity, but new ones will be added in the coming decades. The space taken up by pipelines and cables will increase yet further as the overall capacity for telephony and data transport increases. The trend is unclear.

As an illustration, one new project is concrete, called 'BT North Sea'. It is a proposed undersea cable system that will comprise two individually distinct branches, North and South. The North branch (Iceni) will travel from Eastern England (Winterton-on-Sea) to the Netherlands (Callantsoog). The Southern branch (Mercator) will travel from South-Eastern England (Broadstairs – Joss Bay) to Belgium (Oostende). The objective of this project is to install a subsea fibre-optic system providing connectivity across the North Sea between England and Belgium and England and the Netherlands. The new system will increase telecommunication reliability and diversity between the regions and increase data transmission capacity and speeds, helping to satisfy the growing demand for transmission capacity in Europe, the UK, and the wider globe. According to Arcadis (2020), the cable is buried to a minimum depth of 1 m and a target depth of 2 m.

Figure 17: Planned undersea cables of BT North Sea

Source: Arcadis, 2020, https://www.brugge.be/mercator-telecomproject-niet-technische-samenvatting

Burying cables disturbs the seabed, but after burial the seabed and nature can recover. Studies indicated that cables pose minimal impacts on life in these environments. In sampling sediment cores around cables and in areas removed from cables, there were few statistically significant differences in organism diversity. The main difference was that the cables provided an attachment point for anemones that typically could not grow in soft sediment areas[56].

2.11 Defence

The Dutch armed forces (navy, air force) are present in the North Sea for surveillance and security tasks in an allied context. In addition, there are exercises for education and training purposes in a few designated areas. This involves exercises in firing from ships and aircraft, the coordination between ships, planes, and helicopters, and specific exercises such as laying and clearing sea mines. There are also some shooting ranges along the coast, aiming towards the sea.

All together less than 7% of the surface of the Dutch part of the North Sea is in use for military training and exercises. None of these areas are exclusively in use by the armed forces. To prevent dangerous situations though, some of the training areas can temporarily closed off when shooting is

56 Carter, L.; Burnett, D.; Drew, S.; Marle, G.; Hagadorn, L.; Bartlett-McNeil D.; Irvine N. (December 2009). "Submarine cables and the oceans: connecting the world

taking place. That is also why permits for the extraction of marine aggregates, the building of platforms or the laying of pipelines in these areas are coordinated with the military authorities.

Figure 18 shows where the relevant training areas are located.

Besides activities in these locations, the navy has the task of guaranteeing the safety of the Dutch part of the North Sea by detecting and destroying sea mines and explosives from the WWII period. In the period after WWII, batches of surplus ammunition were dumped at several locations in the North Sea. These areas are not managed by the Ministry of Defence. The economic activity ‘defence’ does not provide any direct economic value in the form of value added, FTE, or production. Nevertheless, indirectly the detecting and destroying of explosives at sea does make these waters safer and more accessible.

Whether the presence of the armed forces and the use of training areas will change (considerably) in the coming years depends on several developments. New weapon systems, like subsea drones, may introduce new training activities. Also, the need for protection of critical infrastructure may lead to new tasks. At the same time, it is not expected that the amount of designated training areas will increase.

Figure 18: DCS areas reserved for military exercise

Source: Noordzeeloket (2023)

Potential environmental impact from military activities comes in the form of sound, vibrations, and debris of shooting exercises, detonation of sea mines and ammunition remnants, and eventually from planes and helicopters. [57] Low frequency sonar causes problems for marine mammals when used at short distances. That is why the navy has implemented new sonar systems and new procedures to reduce this pressure on the marine ecosystem.

2.12 Recreation

The long and wide beaches, the surrounding dunes and the variation in seaside towns lure domestic and foreign tourists to the North Sea coast. Bathers, surfers, kite surfers, hang gliders, fishermen, sailors, and power boaters, they all like spending their free time on and around the water. Recreational use of the North Sea Coastal Zone requires a large amount of space, though often only in the first mile of the beach, and to a lesser extent at sea. The recreative use of the DCS takes several forms, pleasure boating being the most dominant one. Recreative ships, both sailing as well as motorised vessels, make use of the Dutch part of the North Sea.

[57] Programma Noordzee 2022-2027, 2022

Coastal tourism includes the full range of tourism that takes place in coastal zones and coastal waters, including the supporting infrastructure. When ocean-based tourism like yacht cruising is considered, one can speak of maritime tourism. Another definition for coastal and maritime tourism, earlier published by Ecorys, is as the following:

- "Maritime tourism covers tourism that is largely water-based rather than land-based (…) but includes the operation of landside facilities, manufacturing of equipment, and services necessary for this segment of tourism.
- Coastal tourism covers beach-based recreation and tourism (…), and non-beach related land-based tourism in the coastal area (…), as well as the supplies and manufacturing industries associated to these activities." (Ecorys, 2013[58]).

The exact number of recreational vessels is unknown. Studies approximate the fleet in the Netherlands at 400,000. Almost 75% of the vessels are owned by people over the age of 50. In 2050, these people will all be over 80 and will most likely have stopped sailing. These vessels, about 150,000, could be sold or scrapped in the next years[59]. Because few new boats are being delivered, the supply of recently used boats is also falling. There is no data on the recreational vessels sold in the Netherlands. A large part uses the inland waterways, such as rivers, canals, and other bodies of water.

Almost all passenger ships, sea cruises, river cruises, boating, round- and charter trips are highly dependent on international tourism. Sea cruises and river cruises are almost wholly owned by foreign investors and organisers, especially Americans and Swiss-based shipping companies. The growth figures have been strong in recent years. Due to the pandemic, all passenger shipping had come to a sudden standstill. In vessel movements, this economic activity represents only a minor share of vessel movements at the North Sea (1,000-2,000 movements per year as a rough estimate). The cruise industry is recovering after the COVID-pandemic froze the market and seems to pick up former growth trends.

The majority of vessels are staying on inland waters and rivers, or close to the coastline. A new segment of larger vessels is developing, in which an elite buys large vessel and navigates longer distances at rivers and at sea. A significant part of recreational ship movements involves sailing vessels or yachts, and a trend is noticeable in which these turn out to be more internationally orientated.

The number of recreational vessels making use of the DCS appears to decrease, while the size of these vessels increases (small vessels decrease in number, larger sea-worthy yachts increase strongly but are still an exception). The environmental impact from this economic activity is limited. This is mostly because of the limited number of movements in total and the small ship sizes, compared to, for example, fishing vessels and cargo transport. The vibration coming from recreational ship movements is less prevalent, and water pollution is limited given the increase of movements is partly driven by the sailboat segment.

2.13 Summary table

The findings reveal that the Dutch part of the North Sea generates an annual economic production of approximately 11 bn. EUR (2021). The majority of the economic value is, according to CBS, attributed to maritime shipping and oil and gas extraction, while offshore wind energy production is a growing segment for the added value. The current geopolitical situation and high inflation creates

[58] Ecorys. (2013). Study in support of policy measures for coastal and maritime tourism at EU level. Rotterdam/Brussel.
[59] Waterrecreaties Advies BV (2016) Prognose ontwikkeling recreatievaart in 2030, 2040 en 2050 s

many uncertainties for the sea shipping sector. As far as this can be predicted now, the economies of the Netherlands and Europe are expected to be stagnating in 2023. Transhipment volumes are expected to fall slightly.

By forecasting the development for the individual economic activities, it is also possible to provide a forecast on the entire economy of the Dutch part of the North Sea. Table 13 combines the 2035 baseline scenario forecasts in one table and compares them to the economic parameters for previous years. Based on short-term forecasts, the overall economy and added value of activities on the North Sea are expected to increase sharply by 2035: primarily driven by the substantial growth in offshore wind energy activities, and secondly by the maritime sector.

Based on the results of the analysis of trends per segment, an increase in the overall DCS economy is expected: in production, added value, and employment. This increase comes mainly from the substantial increase in the activities surrounding offshore wind energy. Shipping is an economic activity that is also expected to increase in value, but to a smaller extent. 'Oil and gas extraction' and 'fisheries' are expected to decrease in economic value, whereas 'marine aggregates' is likely to show a limited growth. Sea shipping remains the largest economic activity in the Dutch part of the North Sea. Where in the period 2010-2021 oil and gas extraction were the second-largest source of economic value, renewable energy in the form of offshore wind energy is expected to take over this position in 2035.

Table 14: Summary table baseline scenario forecast 2035 economic activities Dutch part of North Sea

	2010	2015	2017	2019	2021	f2035[60]
Production (in mln.)						
Oil and gas extraction	€5,597	€5,013	€3,144	€2,649	€3,272	**€3,107**
Marine aggregates	€146	€145	€123	€149	€213	**€256**
Sea shipping	€5,035	€6,601	€6,059	€6,310	€7,352	**€11,927**
Offshore wind energy	€90	€158	€547	€541	€552	**€7,966**
Fishery	€142	€153	€151	€135	€142	**€111**
Total	*€11,010*	*€12,070*	*€10,024*	*€9,784*	*€11,531*	***€23,366***
Intermediary consumption (in mln.)						
Oil and gas extraction	€911	€1,608	€1,072	€972	€1,327	**€1,260**
Marine aggregates	€82	€93	€76	€91	€131	**€157**
Sea shipping	€3,754	€4,694	€4,327	€4,758	€4,954	**€8,036**
Offshore wind energy	€55	€70	€207	€203	€485	**€6,999**
Fishery	€64	€64	€56	€54	€57	**€44**
Total	*€4,866*	*€6,529*	*€5,738*	*€6,078*	*€6,954*	***€16,497***
Added value (in mln.)						
Oil and gas extraction	€4,686	€3,405	€2,071	€1,676	€1,945	**€1,847**
Marine aggregates	€64	€52	€47	€58	€82	**€98**
Sea shipping	€1,281	€1,907	€1,687	€1,552	€2,398	**€3,890**
Offshore wind energy	€35	€88	€341	€339	€67	**€967**
Fishery	€78	€89	€95	€81	€85	**€66**
Total	*€6,144*	*€5,541*	*€4,241*	*€3,706*	*€4,577*	***€6,869***
Employment (in 1000 FTE)						
Oil and gas extraction	3	4	3	3	2	**2**
Marine aggregates	.	0.3	0.2	0.2	0.3	**0.4**
Sea shipping	9.0	9.5	9.2	8.7	9.2	**14.9**
Offshore wind energy	.	0.06	0.14	0.13	0.32	**4.62**
Fishery	1.0	0.8	0.7	0.7	0.7	**0.5**
Total	*13.0*	*14.7*	*13.2*	*12.7*	*12.5*	***22.3***
Sectors without available CBS data[61]						
Aquaculture CCS Solar energy Hydrogen Cables and pipelines Defence Recreation	/	/	/	/	/	/
DCS Total						
Production (in mln.)	€11,010	€12,070	€10,024	€9,784	€11,531	**€23,366**
Intermediary consumption (in mln.)	€4,866	€6,529	€5,738	€6,078	€6,954	**€16,497**
Added value (in mln.)	€6,144	€5,541	€4,241	€3,706	€4,577	**€6,869**
Employment (in 1000 FTE)	13.0	14.7	13.2	12.7	12.5	**22.3**

60 The economic values for 2035 are forecasts, meaning that the preciseness of these numbers should be interpreted with caution in comparison to the realized economic values for the years 2010-2021.

61 Only economic activities which are quantified by CBS have been summed up in this table.

3 Outlook up to 2050

In this chapter, the research team looks further in time through scenarios. For each of three scenarios developed, a differentiation via uncertainties is applied which leads to a unique future storyline. In this way, it is possible to map the effects of a change in underlying trends and developments compared to the forecast based on existing plans (which were portrayed in chapter 2 with an outlook towards 2035). The scenarios will be described qualitatively, and will give an outlook for the activities on the Dutch part of the North Sea up to 2050, as such expanding the horizon further. At the end of this chapter, the assumptions made are translated back to a quantified scenario analysis up to 2035. This will provide insight in the economic development in each scenario up to 2035 for the economy of the Dutch part of the North Sea, and the activities specifically.

Scenarios typically map uncertainties for the underlying driving forces behind economic activities, projects, policies etc., taking interlinkages between economic activities into account. After discussions with stakeholders, collecting data and policy intentions, the research team comes to the conclusion that the uncertainties about trends and developments per economic activity are related to the time horizon on which realisations and innovations in the area of sustainability and climate change policy take place. This main uncertainty leads to either 'accelerated implementation' or 'delayed implementation' of sustainable policy in general, as a differentiation around the trend 'autonomous policy development' (the forecast for 2035 as described in chapter 2).

The core of the three scenarios is as follows:

Delayed implementation A variation on the baseline scenario in which sustainable policies are implemented later due to obstructing factors, barriers, and practical implications, such as a lacking business model for aquaculture and limited building capacity for offshore wind parks.
Baseline scenario Current policy-based assumptions translated into short- and long-term developments. In the data collection step, trends are identified up until 2021. With these trends, and insights gained via a literature review, a desk-research based 2035 forecast -and 2050 outlook- is drawn.
Accelerated implementation A variation on the baseline scenario in which sustainable policies are implemented at a faster pace, following more public and governmental support, innovation, and investments by companies in the green economy.

The uncertainty regarding realisation can be found in the underlying drivers and barriers, and the economic constellation.

- A faster realisation of policies (for example expanding offshore wind capacity) than planned can occur, if legislation, financing and labour markets allow it: leading to the scenario '**Accelerated implementation'**.
- In the scenario '**Delayed implementation'**, the growth path of the baseline scenario is obstructed by implementation problems. This could be true if the investment capacity, labour shortages or technical challenges hinder the implementation of the climate change policies.

Then, the Netherlands and Europe probably should rely longer on fossil fuels and known economic approaches.

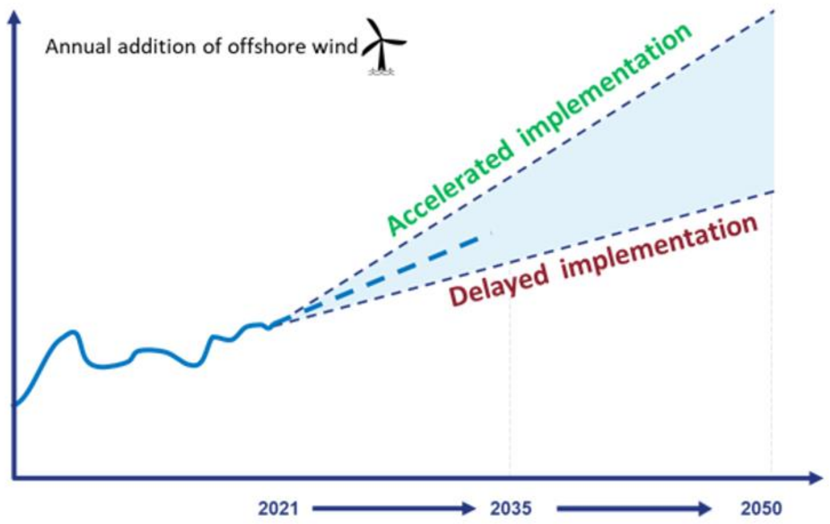
An example of the technique applied to the capacity expansion of offshore wind energy

The Dutch government has set ambitious targets for offshore wind energy capacity. The original objective was to realize 11.5 GW of offshore wind capacity by 2030. In 2022, the Government raised the target for the capacity of offshore wind energy from 11 to 21 gigawatts (GW) by 2030. To achieve these ambitious targets, the Dutch government has facilitated several tenders for new offshore wind farms in the Dutch part of the North Sea. This was the baseline, used underlying the analysis in chapter 3. And will be the baseline, up to 2050, in this chapter. So, the 2050 trendline is a continuation of the 2023-2035 trendline sketched in chapter 2. The scenarios 'accelerated implementation' and 'delayed implementation' are applied to the economic activity offshore wind energy via:

- In the event of **accelerated implementation** for offshore wind energy, the planned 2035 capacity of GW is realised sooner than the Dutch government has anticipated now. This means that the various climate agreement targets are more likely to be met in time – or earlier (agreed in the Paris climate agreement and European Green Deal, and Dutch Klimaatakkoord). Consequently, the need for gas and oil extraction falls too, and the catches of fisheries will fall even more, because the available fishing grounds diminish due to fast expansion of offshore wind. The need for CCS falls as well, as the energy sector makes a sharp turn.
- In the event of **delayed implementation** for offshore wind energy, the planned 2035 capacity of GW is realised later than the Dutch government has anticipated now. This means that the climate agreement targets are less likely to be met in time. Consequently, the need for gas and oil extraction is extended, and the catches of fisheries decreases to a smaller extent, because the available fishing grounds diminish at a slower pace than in the former scenario. The need for CCS increases due to lacking production of sustainable energy, and are the fallback for decreasing the CO_2 emitted in the atmosphere.

To illustrate, Figure 19 depicts how the progress in both scenarios would look like graphically, compared to the baseline scenario which is the 2023-2035 trend, in terms of capacity.

Figure 19: Drafting scenarios for 2050, example offshore wind capacity at the North Sea



3.1 Differentiation via three scenarios

This section contains the qualitatively described economic scenarios for the economic activities of the Dutch part of the North Sea up to 2050. The three scenarios are constructed in a highly comparable matter, in which drivers and barriers fuelling the dynamics are defined. It is important to note that in our view, one scenario is not more likely to happen than the other. Assumptions have been derived from the expected developments as seen in chapter 2 and are not necessarily deemed to be realistic or unrealistic. External factors, like the state of the economy, international climate policy targets and time paths, Dutch policy intentions and the development of economic activities at sea specifically and in general, will lead to time paths as outlined in the scenario analysis.

First, the 2050 expectations are presented, with a story line on the potential future development for every economic sector for the three scenarios. This is described in the next three tables. Then, we make use of these scenario's to further quantify the impact of these three scenarios. We compare the results on the 2023- 2035-2050 volumes (the baseline scenario), in section 3.3.

Baseline scenario

2050 forecast	Baseline scenario
General description of this scenario	*The chance that each scenario is realised cannot be determined. The scenarios are a way to study the uncertainties, and should therefore be regarded as a theoretical framework with realistic assumptions.* The planned policies and expected plans as described in chapter 2 for 2035 are realised, and extended further towards 2050. The 15 years after the 2023 targets for 2035 are met, The Netherlands continues onto this path; with a few technological advancements compared to 2023-2035. After 2035, fossil fuels constitute only **a minimal part** of the energy consumption of the Dutch economy. By **2050**, no more fossil fuels are extracted from the Dutch part of the North Sea at all. Renewable forms of energy have replaced the use of oil and gas **almost entirely**, in the form of wind energy, solar energy and hydrogen-based energy; as well as Dutch nuclear energy. The small amount of oil and gas that is still used in the Netherlands by specific industries will be imported, and CCS technologies will be used to make **this industry carbon-neutral**. Hydrogen is one of the dominant carriers of energy used in the Netherlands in general, in addition to the general electrification. Only a **small part** of the hydrogen conversion takes place on own platforms on the Dutch part of the North Sea, via converting wind energy into hydrogen there. The platforms that were previously used for the extraction of oil and gas, this way, get an **alternative use** for new companies who specialise in the production of hydrogen-based energy. Additionally, a **considerable number** of carriers for hydrogen-based energy import the product via shipping. And hydrogen is converted at land, likely in port areas. The expected capacity of 70 GW of offshore wind energy has been realised with no doubt by **2050**. Technological innovation has made it possible to inflate

	solar panels and aquaculture between **a fraction** of the offshore wind parks, which adds to the production of sustainable energy and food production. Although this form of food production is **limited** in comparison to the fishery sector, which is still present after a turnaround to newer vessels. Even though the climate goals of the Paris agreement and the Dutch 'Klimaatakkoord' have been met, the rising sea level still poses a threat for the Netherlands. The extraction of **marine aggregates** is therefore **essential** to protect the Netherlands against floods by building coastal protection. Also, the continuously growing need for houses results in a persisting need for marine aggregates, to shape foundations. Sea shipping, in various forms, is still an abundant source of income for the Netherlands. For example, goods transport, decommissioning of former platforms, building offshore wind capacity, importing Hydrogen-based energy. The need to transport chemical substances (such as ammonia) for hydrogen-based energy transportation has **increased** the demand for international shipping of liquids strongly. However, technological innovation has made it possible for freight carriers to be **less polluting and more silent** over time, and certainly by 2050. Ships are in general larger, and so the impact of the sector per transported quantity is decreasing. By 2050, there are almost **no more cutters** active on the Dutch part of the North Sea. The dominant form of fish catching takes place on the oceans in the form of pelagic fishing. Only a limited number of cutters remain due to **diminishing catches** and diminishing fishing grounds due to offshore wind parks. But the vessels that are there represent a strong turnaround of the sector. The cutters that are still active are **less polluting and more silent** than the cutters in 2023; **new technologies** are available and economically viable.
Drivers	Continuation of current policies leads to further investments in sustainable energy, decreasing fossil energy use, stimulating hydrogen-based energy transport.
Barriers	Technological, and financial barriers could lead to difficulties in realising the needed investments; like breakthroughs in new ship engines or the labour and capital market. Uncertain policy developments at the EU and Member State level could slow down investments in sub-sectors, or limit the level playing field between sectors or between Member States. It could be that the Netherlands can rely on other EU Member States for realising its climate policy objectives too. Also, it could be possible that the Netherlands is leading, and that its offshore wind industry also assists other Member States. This conflicting barrier, and at the same time opportunity, affects the predictability of the usage of the Dutch part of the North Sea in the baseline.
State of play per economic activity	**Oil and gas extraction** By 2050, oil and gas extraction are no longer an economic activity on the Dutch part of the North Sea. Platforms are reused for hydrogen conversion at sea, via pilots. The majority of them is decommissioned and removed.

	Marine aggregates More marine aggregates than ever are being extracted from the Dutch part of the North Sea, to construct and heighten dikes for increased coastal protection, and facilitate the demand for sand in the building sector too. **Sea shipping** The yearly transported volume through sea shipping keeps on increasing globally, as in recent decades, partially due to the growing need for imports of hydrogen-based energy. Rotterdam keeps its position as global port, serving the EU market. Globally, there is still an increase of trades like containerised imports, RoRo (Roll on and roll off cargo, like cars and trucks), agriculture, steel products and chemicals. **Offshore wind energy** 70 MW of installed capacity has been realised on the Dutch part of the North Sea as planned. The 2035 targets are met, and the investment levels are continued in the decades afterwards. **Fisheries** The number of cutters active on the Dutch part of the North Sea continues to decline, due to diminishing catches and a difficult business case, e.g. due to high fuel prices and low prices for the fish sold. Additionally, the space needed for offshore wind energy decreases the available fishing grounds for cutters. The limited fishery companies in the Netherlands left, have found a profitable business model owing to the shrinking vessel fleet, and go trough a strong turnaround (new vessels, new technology, larger capacity). **Aquaculture** A fraction of the surface of offshore wind parks is being used for aquaculture. Volumes are mostly small, and the business case rests uncertain. Large scale developments are not seen at the North Sea, as a result of the economic drivers and barriers. In addition, the case for aquaculture at sea is also influenced by the limited availability of nutrients at sea and competition of aquaculture elsewhere, at land or at other parts of the globe. **Capture and storage of CO_2** The industry in the Netherlands that still produces CO_2 uses CCS to make sure they are carbon neutral. This leads to new economic activities at sea, storing Dutch and EU CO_2 emissions in empty gas fields. **Solar energy** A **fraction** of the surface of offshore **wind parks** is being **used for solar energy**. This is more pilot-size oriented at first. The business case of solar at sea is difficult, compared to solar at land and therefore, the baseline is depicting minor and gradual increase. This is an indirect of the offshore wind market, and therefore volumes might be higher than in the baseline. Still, the majority of solar energy is produced at land. **Hydrogen (H) energy** Sea-based hydrogen-converted electric energy, created on the platforms that were previously used for oil and gas, contributes to be a small share in the Dutch energy consumption. Some platforms are left behind, others are

	decommissioned by Dutch companies. The majority of this hydrogen-based energy is imported from elsewhere, replacing crude oil imports in Rotterdam via new tradelines. **Cables and pipelines** The existing pipelines are used for CCS and the transport of hydrogen-based energy from platforms on the Dutch part of the North Sea. The TenneT plans for cables connecting 60 GW of offshore wind to the coast are realised at the pace of the expansion of offshore wind capacity (2035-2050). This provides the needed interlinkages between EU Member States. **Other economic activities** The existing volumes of the other economic activities, like defence, recreation and cables and pipelines does not differ in the scenario analysis. The total of these functions is only described in a qualitative way, and weighs to a minor extent on the added value of the total economy of the Dutch part of the North Sea.

Accelerated implementation

2050 forecast	Accelerated implementation
Description	*The chance that each scenario is realised cannot be determined. The scenarios are a way to study the uncertainties, and should therefore be regarded as a theoretical framework with realistic assumptions.* The planned policies and objectives as described in chapter 2 - for 2035 - are generally realised, with the distinction that policy implementation, constructions, and the green turnaround of the economy happens at a faster pace. **Fossil fuels** are **no longer** part of the energy consumption of the Dutch economy. Ten years earlier than expected in the baseline, no more fossil fuels are extracted from the Dutch part of the North Sea. Renewable forms of energy have replaced the use of oil and gas gradually and early before 2050 **entirely;** in the form of wind energy, solar, hydrogen-based, as well as Dutch nuclear energy. There is **no more need** for imports of oil and gas (for domestic use). CCS was necessary in the period 2022-2040, but by 2050 is only used to facilitate the CO_2 emission ambitions of **other countries**, providing a new type of business model for the Dutch economy. Hydrogen is one of the dominant carriers of energy used in the Netherlands, in addition to the electrification of the economy. **A substantial part** of this production takes place on platforms on the Dutch part of the North Sea using off shore wind energy. The platforms that were previously used for the extraction of oil and gas, are currently **completely** in use by companies who specialize in converting wind energy into hydrogen. Still, **a considerable number** of carriers of hydrogen-based energy are imported via shipping, and some is produced at land (for example in port areas). The expected capacity of 70 GW of offshore wind energy has already been realised in **2040**, ten years earlier than expected, and researchers are looking for additional places to build offshore wind parks. Technological innovation has made it possible to make use of solar panels and aquaculture on a **substantial** scale between offshore wind parks, which adds **significantly** to the sustainable energy and food production of the Netherlands. It is by then proven that the aquaculture sector is viable economically and that the sector can expand in an ecological way; not needing the large-scale addition of nutrients for example. By then, this form of food production is **comparable in scale** to the fishery sector on the Dutch part of the North Sea at that point in time. Even though the climate goals of the Paris agreement and the Dutch 'Klimaatakkoord' have been met, the rising sea level still poses a threat for the Netherlands. The extraction of marine aggregates is essential to protect the Netherlands against floods by building coastal protection. Also, the continuously growing need for houses results in a persisting need for marine aggregates. **The amount of aggregate extraction is equal to the baseline scenario.** Sea shipping is still an abundant source of income for the Netherlands. However, technological innovation has made it possible for freight carriers to be

	less polluting and more silent in 2050 than in 2021. Additionally, the large need for hydrogen-based energy has increased the demand for international shipping **even more than in the baseline scenario**, and is of a big economic value for the Netherlands. The Dutch fishery sector experienced a period of **downfall due to diminishing catches and high diesel prices**. However, technological innovation causes **electrically (or Hydrogen) powered vessels** to be able to continue to fish in the Dutch part of the North Sea **without any pollution** (in the form of sound, vibrations or chemicals). The dominant form of fishing still takes place on the oceans in the form of pelagic fishing. Still, the vessels fleet is way smaller than in 2023.
Drivers	• Technological innovation continues, so offshore wind is realised with larger turbines. Therefore, hydrogen at sea becomes a viable sector. While CCS at sea is a stable service for the Netherlands' own economy, and for other EU Member States. • An acceleration in realising climate policies, following EU leadership and Member State's plans • The business case for aquaculture and solar at sea becomes feasible, increasing volumes compared to the baseline expectations as additional usage function.
Barriers	• Technology advances at a rapid pace. Business models must be present for the economy and investors to follow. • Uncertainties of the interlinkages between greening the economy, offshore wind, hydrogen (production and import) and CCS need to be resolved at a rapid pace.
Consequence per economic activity	**Oil and gas extraction** **Oil and gas extraction is no longer an economic activity** on the Dutch part of the North Sea, as of **2040**. Which is 10 years earlier than under the baseline assumptions. All platforms still present re reused for hydrogen conversion at sea, via pilots at first. It is possible that a few of them are being decommissioned and removed. **Marine aggregates** The **volumes are stable**, **as in the baseline**, and are needed to increase and heighten the dikes for coastal protection and facilitate the demand of the building sector. **Sea shipping** The annually transported **volume** through sea shipping **keeps on increasing**, and significantly due to the need for imported hydrogen-based energy. Rotterdam keeps its position as global port, servicing the EU market. Globally there is still a **stabilisation of traditional trades** like containerised imports, RoRo, food and chemicals. Relative to the baseline scenario, shipping volume **increase due to hydrogen-imports**. **Offshore wind energy** 70 GW of installed capacity has been realized on the Dutch part of the North Sea and feasibility **studies seek for additional expansion of capacity**. This

capacity has been reached 10 years before originally planned. TenneT develops capacity of cables at a rapid pace, and might switch expansion of capacity from cables to Hydrogen-conversion of offshore wind energy at sea.

Fisheries

The **number of cutters active** on the Dutch part of the North Sea **continues to decline**, due to diminishing catches and a difficult business case. However, the number of cutters still active revives, after electrically powered cutters become available and have an economic value. But the space needed for offshore wind energy **decreases** the fishing grounds for cutters further. Both trends need to be weighed against each other, but have a **net positive effect** on fisheries compared to the baseline scenario.

Aquaculture

A significant portion of the surface of offshore wind parks is being used for aquaculture. This increases the production volumes and values significantly. Large scale developments are not seen at the North Sea, as a result of the economic drivers and barriers. The case for aquaculture at sea is also influenced by the limited availability of nutrients at sea and competition of aquaculture elsewhere, at land or at other parts of the globe.

Capture and storage of CO_2

After the strong turnaround of the Dutch economy (strong electrification), the Netherlands still makes use of **CCS**, but **to a small extent than in the baseline**, mainly for the storage of CO_2 emissions from other countries (CCS as ‘service’ to others).

Solar energy

A **significant portion of the surface of offshore wind parks is being used for solar energy**. By then, the total offshore wind capacity increased strongly, therefore, this increases production of solar significantly too. This is an indirect of the offshore wind market, and therefore volumes might be higher than in the baseline. Still, the majority of solar energy is produced at land.

Hydrogen (H) energy

Hydrogen energy created on the platforms that were previously used for oil and gas contributes significantly to the Dutch hydrogen energy consumption. Many platforms are decommissioned by Dutch companies.

Cables and pipelines

The existing pipelines are mostly used for the transport of hydrogen-based energy from platforms on the Dutch part of the North Sea, and to a smaller extent for CCS.

Other economic activities

The existing volumes of the other economic activities, like defence, recreation and cables and pipelines does not differ in the scenario analysis. The total of these functions is only described in a qualitative way, and weighs to a minor extent on the added value of the total economy of the Dutch part of the North Sea.

Delayed implementation

2050 forecast	Delayed implementation
Description	*The chance that each scenario is realised cannot be determined. The scenarios are a way to study the uncertainties, and should therefore be regarded as a theoretical framework with realistic assumptions*. The planned policies and expected plans as described in chapter 2 for 2035 are still in place, however realization of these developments happens at a slower pace, after 2035 and before 2050. Fossil fuels still constitute a **small part** of the energy consumption of the Dutch economy. By 2050, no more oil is extracted from the Dutch part of the North Sea. The extraction of gas is expected to be phased out completely by **2060, ten years later than in the baseline scenario**. Renewable forms of energy have largely replaced the use of oil and gas, in the form of wind energy, solar energy and hydrogen-based energy. Coal plants are still stand by for energy production, nuclear is planned but realisation by then is uncertain. **Dutch households and a specific part of the Dutch industry still makes use of fossil fuels**. CCS is used on a rather **large scale** to compensate CO_2 emissions. Hydrogen based energy is one of the sources of energy used in the Netherlands. **All** hydrogen-based energy production in the Netherlands takes place on the **mainland**. Pilots at sea are not economically viable. The rest of the demand for hydrogen-based energy is met through **import**. **Some of the existing platforms** are still used for the extraction of gas, others are used for CCS. The expected capacity of 70 GW of offshore wind energy has not been realized yet in 2050. Instead **35 GW** has been realized. The multi-use of wind parks turned out to be **infeasible**, so there was **no business case** for solar energy and aquaculture on the Dutch part of the North Sea. The climate goals of the Paris agreement and the Dutch ‘Klimaatakkoord’ have been met late, after the planned milestones, hence rising sea level still poses a threat for the Netherlands. The extraction of marine aggregates is essential to protect the Netherlands against floods by building coastal protection. Also, the continuously growing need for houses results in a persisting need for marine aggregates. **This development is equal to the baseline scenario.** In all scenario’s, the Netherlands is depending on other countries meeting their climate change policy objectives. And therefore, investments in adaptation is a standard policy approach. Sea shipping is still an abundant source of income for the Netherlands. Technological innovation has made it possible for some freight carriers to be **less polluting and more silent** in 2050 than in 2021. Hydrogen-based energy is imported to a **minor extent** by shipping, **less than in the baseline scenario**. This levels out with the continuous import of fossil fuels by shipping.

<table>
<tr><td></td><td>By 2050, the number of cutters active on the Dutch part of the North Sea has decreased slightly due to diminishing catches and a difficult business case. This decrease is limited however, because diesel is still relatively payable and the fishing grounds remain sizeable due to lacking realization of offshore wind parks. The dominant form of Dutch fisheries still takes place on the oceans in the form of pelagic fishing. The demand for fish in the Netherlands is primarily met through import.</td></tr>
<tr><td>Drivers</td><td>Sustainable policy is the objective, but timely implementation of those policies turns out to be impossible due lack of support by EU residents, the industry and banking.
The economy and investments in renewable energy do not match the energy demand.
Fossil fuels are still necessary to meet the energy demand.</td></tr>
<tr><td>Barriers</td><td>Lacking technological innovation;
Uncertainties of the interlinkages between greening the economy, offshore wind, hydrogen (production and import) and CCS are not solved, leading to a delay.
Lacking business case for solar panels on sea and aquaculture;
Shortages in qualified personnel and materials needed for realizing offshore wind parks.</td></tr>
<tr><td>Consequence per economic activity</td><td>Oil and gas extraction
Oil extraction is no longer an economic activity on the Dutch part of the North Sea. The extraction of gas still takes place to a limited extend, but is decreased strongly compared to 2023.

Marine aggregates
More marine aggregates than ever are being extracted from the Dutch part of the North Sea, to increase and enforce the coastal protections, dikes, and facilitate the building sector. The annual volumes are larger than in the baseline as climate change effects continue to have more impact.

Sea shipping
The annual transported volume through sea shipping keeps on increasing, for a relatively small part due to the import of hydrogen-based energy. In addition, oil and gas are still imported facilitating the EU's energy needs.

Offshore wind energy
35 GW of installed capacity has been realised by 2050 on the Dutch part of the North Sea, which is significantly less than the 70 GW that was expected (and realised under the baseline scenario) due to implementation challenges (technical, labour market, and capital needs). The Netherlands does not meet planned ambitions.

Fisheries
The number of cutters active on the Dutch part of the North Sea continues to decline, due to diminishing catches. Some cutters are still powered by fossil fuels. On the other hand, the lacking realisation of offshore wind parks causes</td></tr>
</table>

	more fishing grounds to be available for cutters. Therefore, still some fishing takes place. Only a small share of the vessel fleet is concerted to hydrogen or electric propulsion. **Aquaculture** **Aquaculture at sea is not competitive**, compared to aquaculture on the riverbeds and at land (in Europe and elsewhere). In addition, aquaculture at sea is not profitable because of the high costs involved and the limited size of the market. Pilots failed. **Capture and storage of CO_2** A significant part of Dutch households and industry in the Netherlands still produce CO_2, making **CCS on a large scale** necessary to be carbon neutral; The Netherlands mainly focuses on own emissions and can only facilitate the CCS needs of other Member States. **Solar energy** **Solar energy is not competitive at sea**, compared to solar energy on land. Pilots failed. **Hydrogen (H) energy** **Hydrogen** based energy is only created **on the mainland and imported**, not at sea. **Offshore wind is transported to land via cables**. **Cables and pipelines** The existing **pipelines are only used for CCS and the transport of extracted gas**. There is no hydrogen-based energy production at sea, and therefore no need for transport of hydrogen onshore. **Other economic activities** The existing volumes of the other economic activities, like defence, recreation and cables and pipelines does not differ in the scenario analysis. The total of these functions is only described in a qualitative way, and weighs to a minor extent on the added value of the total economy of the Dutch part of the North Sea.

3.2 Scenario analysis translated into impacts, up to 2035

The assumptions for each of the scenarios allow to differentiate around the baseline projections until 2035 as presented in chapter 2. Table 15 provides an overview of the difference in assumptions between each of the scenarios for the economic activities where quantification of forecasts is possible. In **bold** difference between the scenarios are highlighted.

Table 15: Assumptions scenario analysis up to 2035

	Delayed implementation	Baseline scenario	Accelerated implementation
Oil and gas extraction	• The extraction of oil slowly phases out and disappears completely in **2050**;	• The extraction of oil phases out and disappears completely by **2035**;	• The extraction of oil swiftly phases out and disappears completely by **2030**;

	Delayed implementation	Baseline scenario	Accelerated implementation
	• The extraction of gas increases up until 2030 for geopolitical reasons and phases out gradually until **2060**.	• The extraction of gas increases up until 2030 for geopolitical reasons and phases out gradually until **2050**.	• The extraction of gas remains the same up until 2030 for geopolitical reasons and phases gradually until **2040**.
Marine aggregates		• The extraction of filling sand remains constant at 15 mln. m³ per year; • No sand is extracted for land reclamation; • Extraction for nourishments is constant until 2032 at 11 mln. m³ and increases up to 35 mln. m³ in 2050.	
Shipping	• Transport (tonnes) increases by **30%** up to 2030, following current trends and investments, a trend which continuous afterwards.	• Transport (tonnes) increases by **40%** up to 2030, a trend which continuous afterwards. Current markets are gradually exchanged for hydrogen imports.	• Transport (tonnes) increases by **50%** up to 2030, owing to more hydrogen imports, a trend which continuous afterwards.
Offshore wind energy	• The installed capacity of offshore wind energy grows up **to 10 GW in 2030, 20GW in 2040 and 35 GW in 2050.**	• The installed capacity of offshore wind energy grows up **to 21 GW in 2030, 40GW in 2040 and 70 GW in 2050**.[62]	• The installed capacity of offshore wind energy grows up **to 21 GW in 2030 and 70 GW in 2040.**
Fishery	• The number of cutters falls due to diminishing catches. This effect is tempered compared to the baseline scenario because diesel remains payable and the fishing grounds remain sizeable due to lacking realization of offshore wind parks; • The average amount of catch per ship decreases over time. The market goes through a gradual turnaround in terms of propulsion and innovations.	• The number of cutters falls by a third due to high diesel prices and decreasing catches; • The average amount of catch per ship decreases over time. The market goes through a gradual turnaround in terms of propulsion and innovations.	• The number of cutters falls by a third due to high diesel prices and decreasing catches, but resurges due to electric fishing ships; • The average amount of catch per ship decreases over time. The market goes through a significant turnaround in terms of propulsion and innovations.
Other economic activities	• The existing volumes of the other economic activities, like defence, recreation and cables and pipelines does not differ in the scenario analysis. The total of these functions is only described in a qualitative way, and weighs to a minor extent on the added value of the total economy of the Dutch part of the North Sea.		

Source: Ecorys outlook

[62] RVO (2023) *Plannen windenergie op zee 2030-2050.*

These assumptions, differentiating the outlook up to 2050, led to the relative bandwidth of economic values presented in Table 16, compared to the realized values of 2021 as calculated by CBS. The values haven been estimated by Ecorys, similarly to the way calculations were made for chapter 2, only here they are visualized relatively instead of nominal to increase comparability of the trends. Compared to the current economic value of the functions, similar trends occur in each of the three scenarios. For example, offshore wind energy and shipping will be the most dominant economic activities in the Dutch part of the North Sea in 2035 under these conditions. Both have a strong growth potential. Others, like oil- and gas extraction will eventually decrease, but the time path is uncertain. And this path is interlinked with alternative sources of energy being developed (e.g., offshore wind and hydrogen imports could lead to a stronger decrease of fossils).

Table 16: Scenario analysis up to 2035 in relative terms

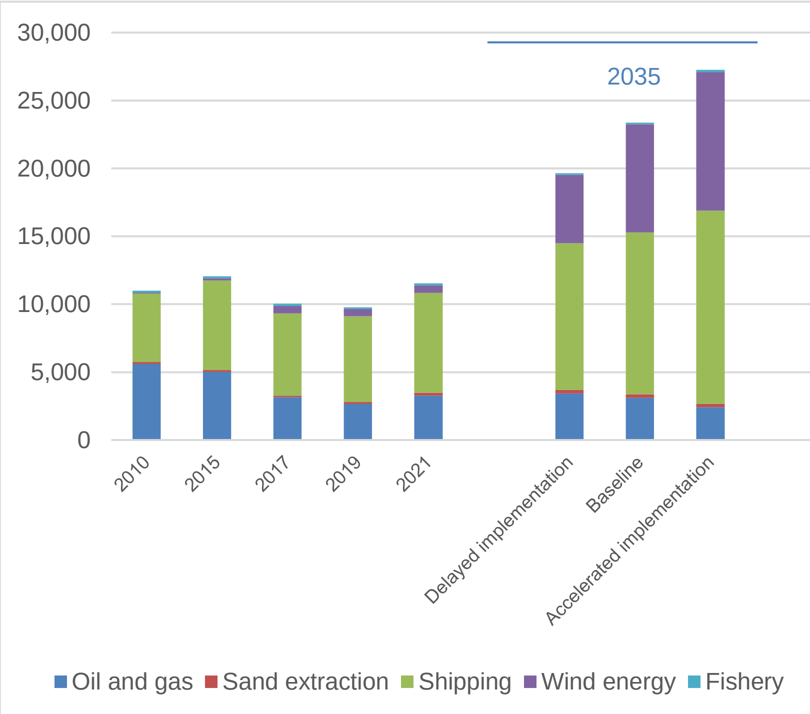
	Realised 2021	Delayed implementation	Baseline scenario	Accelerated implementation
Growth per economic activity				
Oil and gas extraction	100	105	95	74
Marine aggregates	100	120	120	120
Shipping	100	147	162	193
Offshore wind energy	100	915	1443	1850
Fishery	100	84	78	123
Growth all economic activities combined				
Production	100	170	203	236
Intermediary consumption	100	191	237	284
Added value	100	139	150	164
Employment	100	156	178	211

Source: Ecorys outlook

To summarise: the entire economy of the Dutch part of the North Sea grows substantially in all three scenarios. The bottom row of Table 16 show that most economic parameters almost double in size up until 2035, where the accelerated implementation scenario causes the most economic growth and the delayed implementation scenario the least economic growth.

The results of Table 15 have been visualized in Figure 20. The driving factor is the sharp increase in offshore wind capacity, and the shipping sector is expected to continue to grow, in a modest or strong trend depending on the volume of hydrogen-based energy imports.

Figure 20: Growth in economic production by 2035 visualised (in mln. EUR)



Source: CBS (2023) and Ecorys outlook

4 Environmental impacts up to 2050

4.1 Introduction

To help Member States interpret what Good Ecological Status (GES) means in practice, the Marine Strategy Framework Directive sets out, in its Annex I and II, eleven qualitative descriptors, which describe what the environment will look like when GES has been achieved. Indicators have been drawn up for the actual assessment, that are generally recognized as workable and reliable. These are summarised in Table 17 below, Annex III of the Directive provides indicative lists of characteristics, pressures and impacts which are relevant to marine waters, and a basis for the ‘initial assessment’. They are taken into account when determining GES and setting targets and are used to further clarify the trends and outlooks in our scenario approach.

Table 17: Descriptors marine environment

D1 Biodiversity	Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions.
D2 Non-indigenous species (NIS)	Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems.
D3 Commercial fish and shellfish (stock)	Populations of all commercially exploited fish and shellfish are within safe biological limits, exhibiting a population age and size distribution that is indicative of a healthy stock
D4 Food webs	All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity.
D5 Eutrophication	Human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters.
D6 Sea-floor integrity	Sea-floor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected.
D7 Hydrographical conditions	Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems.
D8 Contaminants	Concentrations of contaminants are at levels not giving rise to pollution effects
D9 Contaminants in seafood	Contaminants in fish and other seafood for human consumption do not exceed levels established by Community legislation or other relevant standards.
D10 (Marine) litter	Properties and quantities of marine litter do not cause harm to the coastal and marine environment.
D11 Energy, including underwater noise	Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.

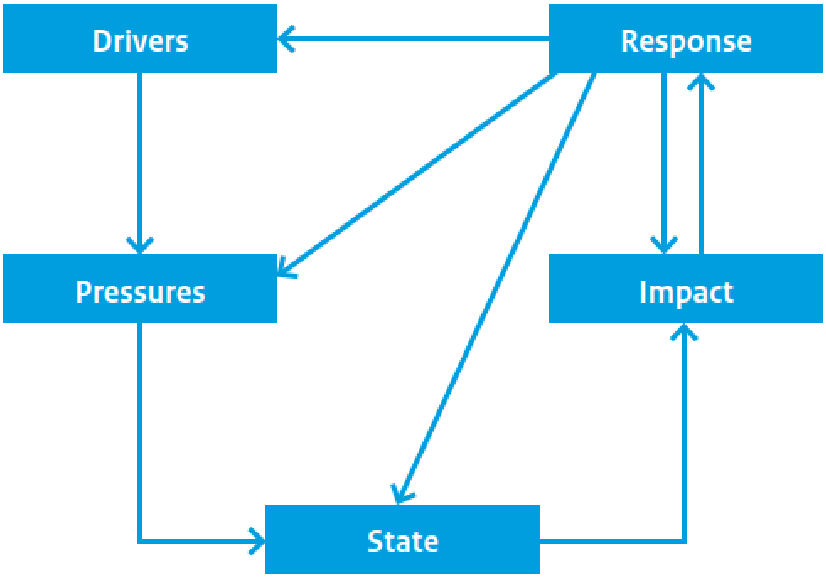
Source: EC, SWD(2020) 62 final, https://commission.europa.eu/system/files/2020-06/swd202062final.pdf

In this chapter, a link is made between the socio-economic forecasts for 2035 and 2050, and the environmental impacts of the economic activities in the forecasts. We make use of the framework of descriptors, and describe the environmental pressures using an analysis of trends and developments.

4.2 The likely environmental impacts for each of the scenario's

The Marine Strategy, like the Dutch strategy 'Mariene Strategie (deel 1, 2018)[63]', encompasses all elements of the so-called DPSIR cycle (see Figure below) of activities (driver), pressures, state change (status), impacts, and responses. This cycle is based on the reasoning that human activities exert pressure on the marine environment, leading to changes in the environmental state with potential negative consequences that can be prevented or mitigated through certain measures. The measures result in adjustments of activities, completing the cycle. The five elements of the DPSIR cycle correspond to different articles of the Marine Strategy. In this chapter, we describe the pressures arising from the drivers (the scenario's) as described in the previous chapters.

Figure 21: Drivers, Pressure, State, Impact and Response-model



In the MSFD, conceptual terms like pressure, impact and state (status) are used with specific meanings. Pressures, specifically, can be considered 'at source' (close to the activity generating the pressure), with relevance for environmental targets and measures, and 'at sea' (level in the marine environment), with relevance for GES determinations and assessments.

- At source: some pressures, such as nutrients, contaminants and litter, originate on land and enter the marine environment as diffuse sources (including via the atmosphere) or from point sources. Pressures generated by sea-based activities remain closely associated to those activities (e.g. dredging or bottom trawling), while others dissipate away from the activity (e.g. contamination from oil extraction, noise from shipping)
- At sea – i.e. the level of the pressure in the marine environment. This is relevant for determining GES (for the pressure-based descriptors) and for assessment of environmental status in relation to GES.

As a way to link the economic sectors analysed (and described in previous chapters) and the descriptors, Table 18 was constructed and aligned with the Dutch strategy 'Mariene Strategie (deel 1) of 2018, by Ecorys.

If an environmental pressure is expected from developments in one sector, and is monitored via one or more descriptor(s), an 'X' is provided. For example, marine aggregates. The sand extraction at the Dutch part of the North Sea is leading, in a direct and indirect way via physical disturbance of

[63] https://www.noordzeeloket.nl/beleid/mariene-strategie-krm/deel-1-milieutoestand/

the seabed, to impacts on D1 (biodiversity), D6 (sea-floor integrity) and D7 (hydrographical conditions). As such, a relationship is seen between the economic activities, their environmental pressure factors, and the descriptors.

Table 18: Matching table main relationships environmental pressure (factors) and economic activities

Economic activity	Environmental pressure factors	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11
Oil and gas extraction	Pollutants								X	X	X	
	Physical disturbance of seabed						X	X				
	Sound											X
Marine aggregates	Physical disturbance of seabed	X			X		X	X				
Shipping	Sound											X
	Introduction or spread of species	X	X		X							
	Pollutants								X	X	X	
Fisheries	Spread of non-native species	X	X		X							
	Damage biodiversity	X		X	X						X	
	Physical disturbance seabed			X			X	X				
Aquaculture	Eutrophication					X						
Offshore wind energy	Sound											X
	Biodiversity (birds, underwater nature, benthic life)	X			X							
	Physical disturbance seabed						X	X				
Solar energy	Algae growth due to reduced light	X			X							
Hydrogen energy	Sound											X
	Pollutants								X	X	X	
Cables and pipelines	Physical disturbance of seabed at intersection (rock dumping)	X			X		X	X				
Defence & recreation	Sound											X
	Introduction or spread of species	X	X		X							
	Pollutants								X	X	X	

The next sections aim to link the economic activities at sea and their respective environmental impact, with the descriptors. We make use of the formal descriptors, as a framework, and present the change in environmental pressures via a qualitative analysis of developments. 'Pressures' may be deviations from natural conditions (e.g., nutrients, certain contaminants, underwater noise). This exercise is in no way a specific mapping of the level of environmental pressure on the Dutch part of the North Sea, but shows the differences between the three scenarios in term of environmental impact. Ecorys sketches the underlying effect (the direction) of the pressure, following the scenarios for each of the activities.

In the following paragraphs, the future state and the current state are compared. For example, '(strongly) decreasing environmental pressure'-, indicates strongly decreasing environmental impact compared to 2021, meaning an improvement of the environmental state. Causal relationships are complex, since many pressures arise from land-based activities in an indirect way, and from activities in other Member State's economies on the North Sea basin. Therefore, the descriptions below should be seen as indicative for the developments on the Dutch part of the North Sea area. This analysis does also not take into account whether the activities surpass the acceptable pressure levels, now or in the future.

4.2.1 D1 Biodiversity and D4 food webs

Biological diversity, or biodiversity, describes the variety of life on earth, and this diversity operates at various scales, from genes, species to entire ecosystems. With Descriptor 1, the MSFD aims to ensure that biodiversity is "maintained", that is, kept in line with the natural state appropriate to the area in question and also corresponding to the large-scale ongoing climatic change. The conditions of the seawater, such as temperature and salinity, in which marine organisms live, play a major role in structuring the biodiversity.

Biodiversity is essential to the stability of food webs, since it increases complex interactions between organisms and increases their ability to handle disturbances. Since biodiversity is directly linked to D4 (food webs), effects on D4 are not described separately.

Biodiversity is influenced by a wide range of external environmental pressures. Some pressures are very direct, whereas others are far less obvious and therefore more difficult to interpret. For example, fisheries and shipping directly influence populations of fish and marine mammals, and sediment extraction causes localised habitat destruction. However, biodiversity is also affected by the ongoing rise in sea water temperatures and ocean acidification.

Physical damage to the marine environment, in particular to the seafloor, can create disturbances in the structure and composition of seabed habitats and in the species composition of the communities associated with these habitats. Invasive species can directly outcompete local populations and in some cases cause large-scale changes in food-web structures. Marine litter poses a threat to biodiversity because animals can ingest objects, such that they accumulate in the stomach and intestines. Finally, energy, such as heat or noise, can change the occurrence and behaviour of a wide range of organisms.

Table 19: Environmental impact comparison over three scenarios, D1 Biodiversity

	Baseline scenario	Delayed implementation	Accelerated implementation
Sea shipping	The baseline scenario foresees generally the same number of passages as occur present day, albeit with an increase in cargo load, with an increase due to demand for hydrogen based energy. Nevertheless, new ship technologies (low-sulphur fuel, low emission), will further decrease local depositions of tailpipe emissions.	Compared to the baseline scenario, technological innovations will lack behind and therefore worsen the environmental state comparatively. Also the amount of ship movements is similar to the present day.	Compared to the baseline scenario, technological innovations will occur sooner and therefore improve the environmental state comparatively. Additionally, due to an increase in demand for hydrogen based energy the number of ship movements increases more than in the baseline scenario.
Marine aggregates	The extraction of marine aggregates is a main contributor to disturbing the seabed and in the long run to disturbing the biodiversity. Since the amount of marine aggregates extracted in the future is comparable to the present day (only a small increase), so is the environmental pressure.	No differentiation in scenarios.	No differentiation in scenarios.

	Baseline scenario	Delayed implementation	Accelerated implementation
Fisheries	Fisheries on the Dutch part of the North Sea are expected to decrease, also decreasing the environmental pressure. Additionally, technological innovation will make cutters less disturbing for endogenous species.	Compared to the baseline scenario, more cutters are still active on the Dutch part of the North Sea and therefore have a larger impact on the biodiversity. Lacking technological innovation will cause the cutters to be more disturbing also.	Compared to the baseline scenario, more (completely electric) cutters are still active on the Dutch part of the North Sea.
Offshore wind energy	Birds can collide with wind turbine blades, resulting in death among bird populations. Since the installed capacity of offshore wind energy grows at an ambitious pace in this scenario, bird populations will be negatively affected due to an expected increase in wind turbine collisions.	Compared to the baseline scenario, biodiversity/bird populations will be impacted to a smaller extent, since offshore wind energy capacity will grow at a slower pace.	Compared to the baseline scenario, biodiversity/bird populations will be impacted to a larger extent, due to the realisation of larger offshore wind energy capacity.
Overall trend in environmental pressure compared to the present day	**Equal to increasing environmental pressure**	**Increasing environmental pressure**	**Increasing environmental pressure**

4.2.2 D2 Non-indigenous species

Non-indigenous species are species introduced outside their natural past or present range (either on purpose or by accident), which might survive international travel. Subsequently they reproduce and possibly overtake existing populations. These species are introduced in situations where exchange of people or goods take place between countries and continents, for example by shipping. Along the whole coast of Europe many species of seaweed, seagrass, molluscs, fish and birds were introduced last century. In certain cases, non-indigenous species can become "invasive" species and have enormous and long-lasting impacts on the region, although some non-indigenous species do not harm the regional ecology.

The number of introductions of non-indigenous species has increased globally and at the European level over the past century. One can expect this to stabilise, with current trade volumes stabilising, or to increase when trade volumes increase, owing to increasing hydrogen-based energy imports. The main driving factor is and will be global shipping. Rotterdam, being the largest EU port, will continue to attract ships from across the globe. Depending on the developments in the hydrogen-based energy import, shipping will continue to grow at a moderate or rapid pace.

Table 20: Environmental impact comparison over three scenarios, D2 Non indigenous species

	Baseline scenario	Delayed implementation	Accelerated implementation
Sea shipping	The baseline scenario foresees generally the same number of passages as occur today, albeit with an increase in cargo load, due	The number of ship movements is lower compared to the baseline scenario and similar today.	Due to an increase in demand for hydrogen-based energy the number of ship movements

	Baseline scenario	Delayed implementation	Accelerated implementation
	to demand for hydrogen-based energy. Depending on the network and direction of the global trade lanes, ship sizes, port infrastructure developments in Europe and legislation, about the same number of non-indigenous species can be expected to follow trade lanes.		increases, also compared to the baseline scenario.
Trend in environmental pressure	**Equal to increasing environmental pressure**	**Equal environmental pressure**	**Increasing environmental pressure**

4.2.3 D3 Commercial fish stock

Commercially exploited fish and shellfish are living marine resources targeted for economic profit. The main contributor to this environmental pressure is the fishery sector. Heavy fishing pressures, such as overexploitation or overfishing, can have negative environmental impacts. The current situation is that most fish stocks have been overexploited as a result of excess fishing capacity (63% of the total, according to EEA, 2010). Good Environmental Status is achieved if commercially exploited fish stocks are in a healthy state and that exploitation is sustainable. The Common Fisheries Policy (CFP) of the EU, has also been providing funding and technical support for initiatives that can make the industry more sustainable.

Two fishing rules[64] are particularly important:

- Restriction of the size of the fleet that sets to sea and the amount of time it can spend fishing;
- Restriction of the quantity of fish that can be taken from the sea before fishers need to stop fishing (total allowable catches).

Table 21: Environmental impact comparison over three scenarios, D3 Commercial fish stock

	Baseline scenario	Delayed implementation	Accelerated implementation
Fisheries	The number of cutters falls further, by a third due to high diesel prices and decreasing catches. The average amount of catch per ship decreases over time, following fishery policies.	In this scenario, the number of cutters falls only slightly, after the sharp decrease currently witnessed, and diesel remains payable. The average amount of catch per ship still decreases over time, limiting the environmental impact compared to the present day.	The number of cutters falls by a third due to high diesel prices and decreasing catches, but resurges due to alternatively-fuelled fishing ships become available. The environmental pressure regarding commercial fish stock is therefore relatively higher than in the baseline scenario. The average amount of catch per ship still decreases over time.
Trend in environmental pressure	**Decreasing environmental pressure**	**Decreasing environmental pressure**	**Decreasing environmental pressure**

64 More info on the CFP can be retrieved via: https://ec.europa.eu/fisheries/index_en.htm

4.2.4 *D5 Eutrophication*

Eutrophication is a process driven by the enrichment of water by nutrients, especially compounds of nitrogen and/or phosphorus, leading to: increased growth, primary production and biomass of algae; changes in the balance of organisms; and water quality degradation. The consequences of eutrophication are undesirable if they degrade ecosystem health and biodiversity, and therefore the sustainable provision of goods and services. The MSFD requires the Members States to reduce the nitrogen and phosphorous loads to the marine environment and thereby to reduce eutrophication.

The majority of the nutrients find their way via rivers, towards the North Sea. This is an external factor, and is only in an indirect way linked to economic activities at sea. The predominant nitrogen load comes from diffuse sources on land, especially agricultural areas. Human-introduced phosphate comes from domestic and industrial sewage and waste water, managed by the Urban Waste-Water Treatment Directive (1991). Given the intentions of the Dutch and Belgian governments do decrease nitrogen emissions from land based sources, this likely has an indirect positive contribution to the reduction of eutrophication at sea too.

The (likely) disturbing trend at sea is the scale of aquaculture farms at sea. Since current policies forbid that nutrients are added in these farms, the environmental pressure due to eutrophication are not expected to significantly increase in all scenario's.

Table 22: Environmental impact comparison over three scenarios, D5 Eutrophication

	Baseline scenario	Delayed implementation	Accelerated implementation
Aquaculture	Due to policies being in place that forbid the addition of nutrients in aquaculture, an equal or decreasing environmental pressure is expected.	No differentiation in scenarios.	No differentiation in scenarios.
Trend in environmental pressure	**Equal to declining environmental pressure**	**Equal to declining environmental pressure**	**Equal to declining environmental pressure**

4.2.5 *D6 Sea floor integrity*

The sea-floor integrity reflects the characteristics (physical, chemical and biological) of the sea bed. These characteristics delineate the structure and functioning of marine ecosystems, especially for species and communities living on the sea floor (benthic ecosystems). In the ocean, the sea-floor is a key compartment for marine life, since it is a high biomass productivity area, especially in shallow waters. One can link the building of new installations, but also the decommissioning of oil and gas rigs, to this descriptor. Secondly, in the zoning concerned, the extraction of sediment, gas and oil, has an impact on the sea bottom. Thirdly, cables and pipelines can be regarded to be an influential factor too.

Table 23: Environmental impact comparison over three scenarios, D6 Sea floor integrity

	Baseline scenario	Delayed implementation	Accelerated implementation
Offshore wind energy	The installed capacity of offshore wind energy grows at an ambitious pace, and will in the short and long run disturb the soil when realising monopiles.	Compared to the baseline scenario, the integrity of the sea floor is impacted to a smaller extent.	Compared to the baseline scenario, the integrity of the sea floor is impacted to a larger extent.

	Baseline scenario	Delayed implementation	Accelerated implementation
Marine aggregates	The extraction of marine aggregates is a main contributor to disturbing the seabed in the respective locations where extraction takes place. Since the amount of marine aggregates extracted is comparable to the present day (only a small increase), so is the environmental pressure.	No differentiation in scenarios.	No differentiation in scenarios.
Oil and gas extraction	The extraction of oil and gas phases out and disappears completely in respectively in 2035 and 2050. Depending on the reuse of the infrastructure for converting electricity to hydrogen, at sea, this might change the soil integrity.	The extraction of oil slowly phases out and disappears completely in 2050; depending on the reuse of the infrastructure for converting electricity to hydrogen, at sea, this might change the soil integrity. When not reusing the platforms, the soil is damaged when decommissioning the infrastructure.	The extraction of oil phases out fast and disappears completely in the short run. Depending on the reuse of the infrastructure for converting electricity to hydrogen, at sea, this might change the soil integrity.
Cables and pipelines	More offshore wind capacity, when transported by cables, will lead to a change of the soil integrity (following construction of more cable capacity). It is expected that TenneT will add significant amount of cable kilometres, on the short term, preparing for the extensive growth in offshore wind capacity.	Compared to the baseline scenario, the integrity of the sea floor is impacted to a smaller extent as less offshore wind capacity is realized.	Compared to the baseline scenario, the integrity of the sea floor is impacted to a smaller extent as more offshore wind capacity is realized.
Fisheries	Fisheries will decline on the Dutch part of the North Sea due to diminishing catches, high fuel prices and low prices for fish. Space needed for offshore wind energy in turn decreases the space available for fishing. Furthermore, sustainability initiatives, such as a ban on beam trawling, are expected to increase. Physical disturbance of seabed is therefore expected to decline, stimulating sea floor integrity.	In this scenario, the number of cutters only slightly declines. The physical disturbance of the seabed is therefore expected to stay equal or decline.	Due to alternatively-fuelled fishing ships becoming available, the amount of cutters will resurge. The environmental pressure regarding disturbance of the seabed is therefore relatively higher than in the baseline scenario.
Trend in environmental pressure	**Equal to increasing environmental pressure**	**Equal to increasing environmental pressure**	**Strongly increasing environmental pressure**

4.2.6 D7 Hydrographic properties

Hydrographical conditions are characterized by the physical parameters of seawater: temperature, salinity, depth, currents, waves, turbulence, turbidity (related to the load of suspended particulate matter). They play a crucial role in the dynamics of marine ecosystems and can be altered by human activities, especially in coastal areas.

Table 24: Environmental impact comparison over three scenarios, D7 Hydrographic properties

	Baseline scenario	Delayed implementation	Accelerated implementation
Offshore wind energy	The installed capacity of offshore wind grows at an ambitious pace, and will disturb the hydrographic state of the Dutch part of the North Sea.	The installed capacity of offshore wind energy grows at a slower pace than in the baseline scenario, so the hydrographic impact is smaller, yet present.	The installed capacity of offshore wind energy grows at a faster pace than in the baseline scenario, so the hydrographic impact is greater.
Marine aggregates	The extraction of marine aggregates is a main contributor to disturbing the seabed in the respective locations where extraction takes place. Since the amount of marine aggregates extracted is comparable to the present day (only a small increase), so is the environmental pressure.	No differentiation in scenarios.	No differentiation in scenarios.
Oil and gas extraction	Depending on the reuse of the infrastructure for converting electricity to hydrogen, at sea, this might change hydrographic properties, such as turbulence.	When reusing platforms, the turbulence is not changing considerably.	Converting electricity to hydrogen, at sea, might change the soil integrity less, pipelines in favour of cables, will lead to less changes in currents and waves.
Trend in environmental pressure	**(Strongly) increasing environmental pressure**	**Increasing environmental pressure**	**(Strongly) increasing environmental pressure**

4.2.7 D8 Pollutants & D9 Pollutants in fish & D10 (Marine) litter

Contaminants are defined in the European legislation as: “substances (i.e. chemical elements and compounds) or groups of substances that are toxic, persistent and liable to bio-accumulate and other substances or groups of substances which give rise to an equivalent level of concern” (Water Framework Directive, Article 2(29)).

Examples of such substances found in the marine environment include pesticides, anti-fouling, pharmaceuticals and heavy metals, among others. Contaminants can arise from sources such as land-based industrial activity, pollution by ships, atmospheric deposition, oil, gas and mineral exploration and exploitation and riverine inputs.

Apart from these pollutants, marine litter can also cause harm to the marine and coastal environment, for example by the disposal of fishing nets or plastic bottles. A large contribution of pollution in the form of lotter at sea is found in land-based activities, and pollution from other

Member States and global seas. Nevertheless, is a relationship assumed between the amount of litter coming from ships and the amount of ship movements associated with an economic activity.

D9 Contaminants in seafood specifically

D9 refers to the compliance of contaminant levels in fish and other seafood of a defined marine region or subregion with human health threshold values. This requires georeferenced samples that are often difficult to obtain when relying on commercial fisheries or programs designed for monitoring human exposure. Contaminants in fish and other seafood for human consumption should stay in levels established by Community legislation or other relevant standards. The GES is not reached yet. As a consequence, the biodiversity has decreased, fish stocks have declined, and the resilience of marine ecosystems has dwindled in many parts of the world. In this outlook no clear relationship is seen between the individual scenarios and the environmental pressure.

Coastal areas are mainly subject to pollution originating from land, like inputs from rivers, run-off from agricultural sites, and wastewaters from industrial and municipal wastewater treatment plants, while ship traffic, dumping, off-shore activities, and atmospheric deposition are the major sources of pollution in the open sea too (Fliedner et al., 2018[65]). The direct effect of activities at the Dutch part of the North Sea cannot be extracted of the total North Sea. It requires field research to determine current trends in contamination, and the accountability of activities on the Dutch part of the North Sea specifically.

D10 (Marine) litter specifically

Marine litter is any persistent, manufactured or processed solid material that is discarded, disposed of, or abandoned in the marine and coastal environment. The provisions of MSFD D10 aim to protect the marine environment against harm caused by litter. Litter from land-based activities and resulting from poor waste management enters the marine environment via drainage or sewage systems, drains, rivers, winds, road run-offs and storm-water outflows. Land-based sources include tourism and recreational uses of the coast, general public, fly tipping, local businesses, industry, harbours and unprotected waste disposal sites. Sea-based sources of marine litter include merchant shipping, ferries and cruise liners, commercial and recreational fishing vessels, military fleets and research vessels, pleasure craft, offshore installations such as oil and gas platforms, drilling rigs and aquaculture sites (Galgani et. Al., 2013[66]).

According to research, plastic accounts for about 83% of the observed marine litter items. In some tourist areas more than 75% of the annual waste production is generated in the summer season. Marine litter does cause harm to the coastal and marine environment. Litter can be caused by activities at the North Sea, but also comes from further away, and from rivers flowing into the North Sea. Most of the marine litter comes from land-based rather than sea-based sources[67].

In this outlook no clear relationship is seen between the individual scenarios and the environmental pressure. The direct effect of activities at the Dutch part of the North Sea cannot be extracted of the total North Sea.

---

[65] Fliedner, A., Rüdel, H., Knopf, B. et al. Assessment of seafood contamination under the marine strategy framework directive: contributions of the German environmental specimen bank. Environ Sci Pollut Res 25, 26939–26956 (2018). https://doi.org/10.1007/s11356-018-2728-1

[66] F. Galgani, G. Hanke, S. Werner, and L. De Vrees (2013) Marine litter within the European Marine Strategy Framework Directive, ICES Journal of Marine Science, Volume 70, Issue 6, September 2013, Pages 1055–1064, https://doi.org/10.1093/icesjms/fst122

[67] PNUE/PAM/MEDPOLResults of the assessment of the status of marine litter in the Mediterranean, Meeting of MED POL Focal Points No. 334, 91 pp, 2009

Table 25: Comparison over three scenarios, D8 Pollutants & D9 Pollutants in fish & D10 (Marine) litter

	Baseline scenario	Delayed implementation	Accelerated implementation
Oil and gas extraction	The extraction of oil and gas resurges in short term, but slowly phases out completely in 2035 (oil) and 2050 (gas). This is the time span in which pollution could happen. Though the oil and gas spill risk is considered generally low.	Both the time horizons at which oil and gas extraction will be phased out increase, causing more pollution and risk of spillage.	Both the time horizons at which oil and gas extraction will be phased out decrease, causing less pollution and a lower risk of spillage.
Shipping	As the total amount of ship movements is expected to remain similar to today, so is the amount of litter following form shipping. Pollution is expected to fall slightly, as ships become more eco-friendly.	As the total amount of ship movements is expected to be similar to today, so is the amount of litter following form shipping. Pollution is expected to remain similar.	As the total amount of ship movements is expected to increase compared to today, so is the amount of litter following form shipping. A strong increase of the use of alternative fuels in shipping, and fishery, will decrease pollution levels.
Fisheries	Fisheries will decline on the Dutch part of the North Sea due to diminishing catches, high fuel prices and low prices for fish. Space needed for offshore wind energy in turn decreases the space available for fishing. Marine litter due to fishing is expected to stay equal or decrease.	In this scenario, the number of cutters only slightly declines. Marine litter due to fishing is therefore expected to stay equal or decrease.	Due to alternatively-fuelled fishing ships becoming available, the amount of cutters will resurge. The environmental pressure regarding marine litter is therefore relatively higher than in the baseline scenario.
Trend in environmental pressure	**Decreasing environmental pressure**	**Decreasing to equal environmental pressure**	**Decreasing environmental pressure** -

4.2.8 D11 Energy including underwater noise

The Marine Strategy Framework Directive identifies anthropogenic inputs of energy into the maritime environment, such as underwater noises and light, as pollution. Human sources are related to transport, mining and fishing and construction. They include:

- Shipping including freighters, ferries, cruise ships, recreation and fishing, all produce noise;
- The use of sonar systems;
- Underwater noise due to exploration (seismic surveys), construction (piling) and exploitation of offshore oil and gas platforms and wind parks;
- Dredging for shipping lanes, sand mining and for laying pipes and cables;

- Operation of platforms and their lights;
- Submarine cables carrying electric power emits electromagnetic fields;
- Military activities, which produce noise;

Table 26: Environmental impact comparison over three scenarios, D11 Energy incl. underwater noise

	Baseline scenario	Delayed implementation	Accelerated implementation
Oil and gas extraction	The extraction of oil and gas resurges in short term, but slowly phases out completely in 2035 (oil) and 2050 (gas), lowering the energetic pollution like noise and light compared to the present day.	Both the time horizons at which oil and gas extraction will be phased out increase, causing more energetic pollution like noise and light, compared to the baseline scenario.	Both the time horizons at which oil and gas extraction will be phased out decrease, causing less energetic pollution like noise and light, compared to the baseline scenario.
Defence	Defence activities are not directly linked to any of the scenarios.	Defence activities are not directly linked to any of the scenarios.	Defence activities are not directly linked to any of the scenarios.
Shipping	As global shipping volumes continue to increase, the amount of energetic pollution increases as well. Technological advancements make fright carriers more silent and less polluting, mitigating this effect. at moderate pace. The larger ships used, decoupled growth trends of GDP, trade, tonnages and movements.	Compared to the baseline scenario, a delay in technological advancements decreases the mitigating effect on the environmental pressure.	Compared to the baseline scenario, faster technological advancements increases the mitigating effect on the environmental pressure regarding energetic pollution. Nevertheless, the amount of ship movements increases even more in this scenario compared to the baseline. A strong increase of alternative fuels in shipping, and fishery, could decrease noise pollution levels. Shipping volumes continue to increase. The larger ships used, decoupled growth trends of GDP, trade, tonnages and movements. Import of hydrogen-based energy could increase passages strongly.
Trend in environmental pressure	**Decreasing to equal environmental pressure**	**Equal environmental pressure**	**Decreasing environmental pressure**

4.3 Innovation

The analysis above shows that, depending on the scenario and sector, it will be either difficult or easy to achieve GES. Given the uncertainty of developments, the impact on the different sectors and descriptors is hard to predict. Technological innovations are not taken into account in the analysis above, but can impact the achievement or nonachievement of GES. This means that a certain sector or activity can grow or increase, but the ecological impact can decline. For example, innovations in methods of fishing, such as beam trawling, or the development and use of alternative forms of fuel.

Annex I – Stakeholders consulted

Organisation
Groningen Seaports Port Authority
Ministerie van Infrastructuur en Waterstaat
Rijkswaterstaat Zee & Delta
Koninklijke Vereniging van Nederlandse Reders
Ecorys experts
LNV
DGLM
NWEA
Port of Amsterdam
Watersportverbond
Neptune Energy (gas, CCS, hydrogen H2opZee/PosHYdon)
Dienst der Hydrografie
Element NL (previously NOGEPA)

About Ecorys

Ecorys is a leading international research and consultancy company, addressing society's key challenges. With world-class research-based consultancy, we help public and private clients make and implement informed decisions leading to positive impact on society. We support our clients with sound analysis and inspiring ideas, practical solutions, and delivery of projects for complex market, policy, and management issues.

In 1929, businessmen from what is now Erasmus University Rotterdam founded the Netherlands Economic Institute (NEI). Its goal was to bridge the opposing worlds of economic research and business – in 2000, this much respected Institute became Ecorys.

Throughout the years, Ecorys expanded across the globe, with offices in Europe, Africa, the Middle East, and Asia. Our staff originates from many different cultural backgrounds and areas of expertise because we believe in the power that different perspectives bring to our organisation and our clients.

Ecorys excels in seven areas of expertise:
- Economic growth;
- Social policy;
- Natural resources;
- Regions & Cities;
- Transport & Infrastructure;
- Public sector reform;
- Security & Justice.

Ecorys offers a clear set of products and services:
- preparation and formulation of policies;
- programme management;
- communications;
- capacity building;
- monitoring and evaluation.

We value our independence, our integrity, and our partners. We care about the environment in which we work and live. We have an active Corporate Social Responsibility policy, which aims to create shared value that benefits society and business. We are ISO 14001 certified, supported by all our staff.

P.O. Box 4175
3006 AD Rotterdam
The Netherlands

Watermanweg 44
3067 GG Rotterdam
The Netherlands

T +31 (0)10 453 88 00
F +31 (0)10 453 07 68
E netherlands@ecorys.com
Registration no. 24316726

W www.ecorys.nl

Sound analysis, inspiring ideas