Netherlands Enterprise Agency

Dutch Offshore Wind Market Report 2023

April 2023

Imprint

Written by:

Guidehouse

Authors:
Timothée Macquart
Duygu Kucukbahar
Bob Prinsen

Design:
Phuong Ha

Photo credits:
Mischa Keijser
TenneT

Editorial:
Gail Rajgor, Editorial Rescue

Commissioned by:

Netherlands Enterprise Agency

Ministry of Economic Affairs and Climate Policy

Contact:
Netherlands Enterprise Agency (RVO)
Graadt van Roggenweg 200, 3531 AH
Utrecht, The Netherlands
P.O. box 8242 | 3503 RE | Utrecht |
The Netherlands
woz@rvo.nl
rvo.nl/windenergie-op-zee

Dutch Offshore Wind Market Report 2023

Table of Contents

Foreword

Landmark moment in Dutch offshore wind

2023 is the year the Netherlands successfully delivers on its first Offshore Wind Energy Roadmap, achieving our target for 4.5 GW of operational capacity by the end of the year on time and well within the subsidy budget. This is a significant milestone that the Netherlands, and the European wind industry in general, can be proud of.

With the Offshore Wind Energy Roadmap 2023, our aim was to achieve our targets cost-effectively by providing long-term visibility of project pipelines. Minimising risks for industry, reducing offshore wind costs and ensuring maximum benefit to society as a whole have been at the heart of our energy strategy.

To achieve our collective goals, the government adopted a proactive and supportive role, supported by a strong market framework. State agencies took responsibility for offshore wind farm site selection and surveys, project requirements, tenders, environmental impact assessments, site decisions and more. In addition, TenneT developed the offshore grid. This enabled project developers to focus successfully on optimisation of wind farm designs and construction methods.

Cooperation and commitment

It has been a concerted, joint effort with industry, knowledge institutes and other stakeholders to get to where we are today. We have done more than simply increase installed offshore wind capacity. Together we have built a strong domestic industry and seen offshore wind costs fall significantly. Indeed, with Hollandse Kust (zuid) Sites I and II, we saw the world's first subsidy-free offshore wind farm awarded in 2018, with all subsequent Dutch projects also being subsidy-free.

Our focus on qualitative criteria also increased. The industry stepped up with market-leading innovations to boost efficiency, minimise ecological impact and improve system integration of the electricity generated.

Making the international value chain more sustainable is also important. A significant first step towards this took place on 6 March 2023: a broad coalition of parties, including the Dutch government and wind power companies, signed the new International RBC (IRBC) Agreement for Renewable Energy. The aim of the IBRC Agreement, which has a five-year implementation phase, is to jointly tackle and prevent risks in the field of human rights violations and environmental damage related to renewable energy techniques

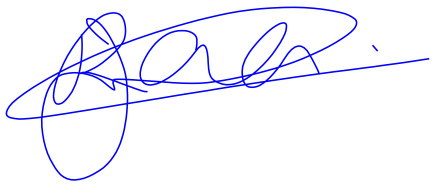
Bolder ambitions

Thanks to our work for Roadmap 2023, we learned to do things better. Our present aim is to achieve roughly 21 GW of offshore wind by 2030/31, as confirmed in the North Sea Programme 2022-2027 and outlined in the latest Additional Offshore Wind Energy Roadmap 2030/31.

Furthermore, we will soon develop new offshore wind targets for 2035, 2040 and 2050 in the National Energy System Plan. The North Sea Consultation (Noordzeeoverleg) is critical to this, as we continue to work jointly on implementation of the North Sea Agreement and overcome new challenges for the energy, nature and food transitions. Together, I am sure, we will succeed, just as we did for Roadmap 2023.

On behalf of the Government, my thanks and congratulations to all the parties who have contributed to the success of the Dutch Wind Energy Roadmap 2023.

We look forward to making even greater progress together as we look to 2050 and beyond.



Rob Jetten
Minister for Climate and Energy Policy

Facts and Figures of Offshore Wind Energy Roadmap 2023

At a glance

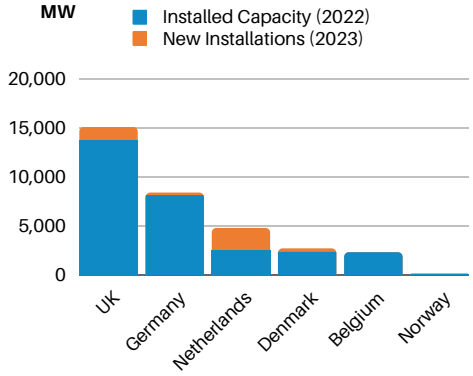
Under the Offshore Wind Energy Roadmap 2023, successful tenders in three designated offshore wind zones have been completed. These are: Borssele (Sites I & II, III & IV, and V) between 2016 and 2018, Hollandse Kust (zuid) in 2018 and 2019 and Hollandse Kust (noord) V in 2020.

Key figures *(by end of 2023)*

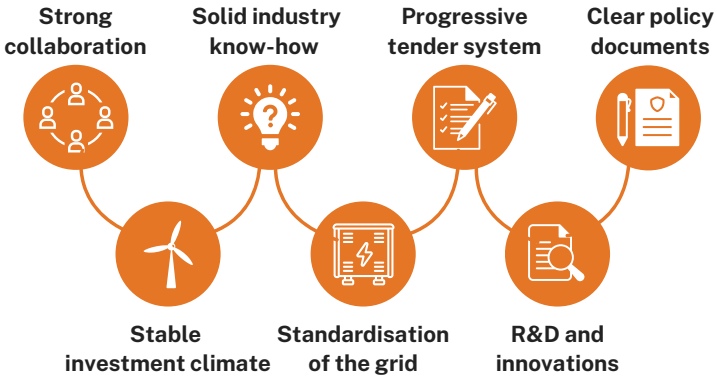
4.7 GW
offshore wind capacity

15.8 %
expected share of offshore wind generation in total electricity consumption

3,500 MW
offshore connection, in standardised concept of 700 MW per connection by TenneT



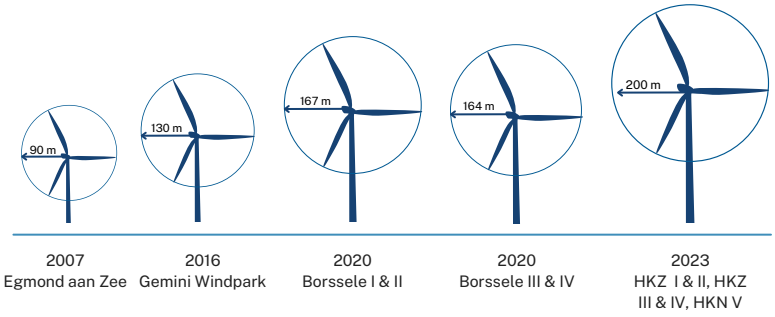
KEY DRIVERS



ACHIEVEMENTS

1. Pre-bid costs and risks for offshore wind developers significantly reduced thanks to implementation of a one-stop shop approach.
2. Cost saving of around €7 billion for Borssele, and the world's first zero-subsidy offshore wind farm – Hollandse Kust (zuid) Sites I & II.
3. Nature Inclusive Design – ecology-friendly measures integrated as a basic condition for offshore wind development.
4. The capacity of individual Dutch offshore wind farms increased seven fold, up from 110 MW for Egmond aan Zee in 2007 to 760 MW for Hollandse Kust (noord).
5. Connection costs for offshore wind farms have been reduced and development time for projects is down to just 3-4 years (from 7-10 years previously).

TURBINE DEVELOPMENT



1. Introduction and Background

Since its first offshore wind farm (Egmond aan Zee) in 2007, the Netherlands has developed roadmaps for the rollout of offshore wind farms to 2023 and 2030, reached approximately 4.7 GW of total installed capacity, and created a strong market framework for offshore wind. These developments put the Netherlands in a leading position in offshore wind alongside countries such as the United Kingdom, which currently has the highest installed offshore wind capacity in the North Sea (approximately 13.5 GW), and Denmark, the first country in the world to build and operate an offshore wind farm in 1991 (Vindeby wind farm, which was decommissioned in 2017).

Drivers for the successful rollout of offshore wind in the Netherlands include: excellent physical conditions (i.e. good wind resource, shallow waters, and sandy seabed); strong support from the Government, which has put offshore wind energy at the heart of its strategy to achieve its climate and renewable energy targets; and a one-stop shop approach for offshore wind farm tenders.

One of the major policies that has helped accelerate the rollout of offshore wind in the Netherlands has been the Energy Agreement (*Energieakkoord*), signed by the Government in 2013. The Government was already supporting offshore wind through subsidy schemes, but the Energy Agreement went a step further. It set binding targets for the uptake of renewable energy and the number of installed wind turbines in the Netherlands. The targets were for 14% of all energy to be generated from renewable energy resources by 2020, rising to 16% by 2023, with a goal for an additional 1,000 wind turbines to be installed.

Photo credits: Mischa Keijser, Netherlands Enterprise Agency

In the decade following the Energy Agreement, the Netherlands signed various international climate policy agreements and promote the reduction of greenhouse gas emissions in the Netherlands and/or the development of offshore wind. Examples include the Paris Agreement, signed in 2016, which sets a global framework to limit global warming to well below 2°C, and the EU Fit-for-55 policy package[1] which stipulates that Member States of the European Union (EU) should reduce their greenhouse gas emission by at least 55% by 2030 compared to 1990 levels. More recently in 2022, the RePowerEU[2] package set targets for 90 GW and 300 GW of offshore wind in the European Union in 2030 and 2050 respectively. In 2022, the Netherlands also signed the Esbjerg[3] and Dublin[4] declarations. Under the Esbjerg declaration, the Netherlands, Belgium, Denmark and Germany, committed to reaching a combined target for installed offshore wind capacity of at least 65 GW by 2030 and 150 GW by 2050. Under the Dublin declaration, the members of the North Seas Energy Cooperation (the Netherlands, Belgium, Denmark, Germany, Ireland, France, Norway and Luxembourg) agreed to reach a combined target of at least 260 GW of offshore wind by 2050.

To provide long-term visibility of project pipelines in its bid to achieve its targets, the Dutch Government has prepared a series of offshore wind energy roadmaps. The first, Roadmap 2023, set a target for 4.5 GW installed capacity by 2023. Next, Roadmap 2030 aimed for 11.5 installed capacity GW by 2030. This was updated with the Additional Roadmap 2030+ which increased the target to 21 GW by 2031.

[1] https://www.consilium.europa.eu/en/press/press-releases/2022/11/08/fit-for-55-eu-strengthens-emission-reduction-targets-for-member-states/
[2] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/repowereu-affordable-secure-and-sustainable-energy-europe_en
[3] https://open.overheid.nl/documenten/ronl-1e299d084fbc5bfc2968d934ca2f4a97b3931d9f/pdf
[4] https://energy.ec.europa.eu/topics/infrastructure/high-level-groups/north-seas-energy-cooperation_en
Photo credits: TenneT (see https://www.tennet.eu/nl/projecten/offshore-projecten-nederland)

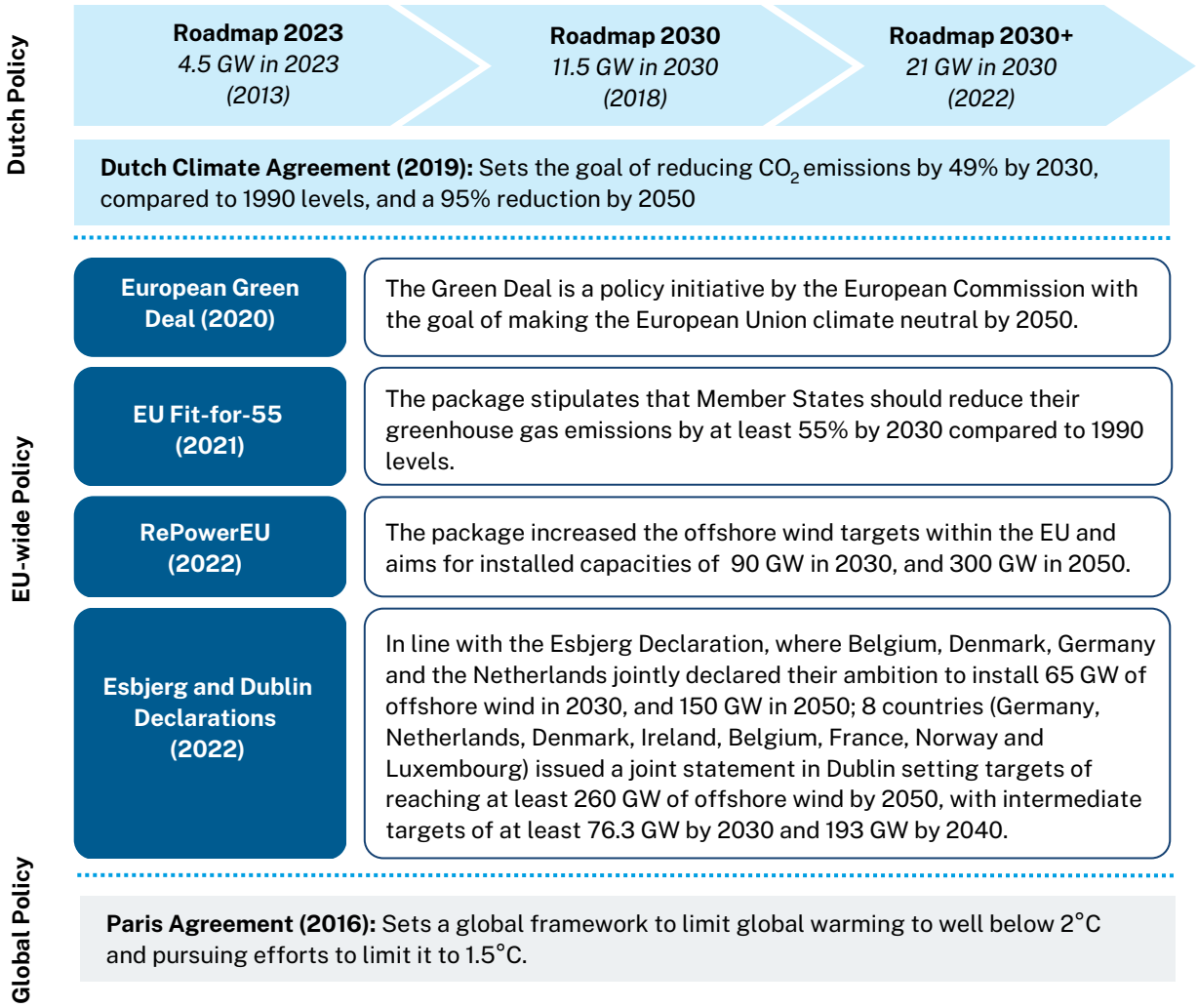


Figure 1. Policy frameworks promoting offshore wind and climate policies

This document provides an overview of the current status of offshore wind in the Netherlands and the achievements under Roadmap 2023. First, the position of the Netherlands with other North Sea countries is examined and the achievements under Roadmap 2023 are discussed. The *Offshore Wind Tenders and Future Rollout* section then looks at Roadmap 2030+ and the proposed rollout from 2030 to 2050. The *Electricity Market and Power Production* section provides quantitative figures on the performance of offshore wind in the Netherlands and the price evolution in the wholesale electricity market. Finally, *Offshore Wind Innovations in the Netherlands* discusses the innovations applied in the Dutch offshore wind sector and looks at the research and innovation ecosystem in the Netherlands.

2. Successful Conclusion of Roadmap 2023

2.1. Current status of the Dutch offshore wind energy market

Today, the Netherlands is a front-runner in providing cost-efficient offshore wind power. With approximately 4.7 GW installed by the end of 2023, it is in the top three for capacity installed in the North Sea.

Whilst it was one of the early movers in offshore wind with the Egmond aan Zee wind farm in 2007, offshore wind development truly accelerated in 2016 when 1.5 GW of capacity was tendered for the Borssele wind farm sites. Other tenders would soon follow in 2017, 2019, 2020 and 2022 to increase installed wind capacity from 1 GW in 2016 to 4.7 GW in 2023.

The acceleration in offshore wind is linked to two key policy developments in the Netherlands. The first is the Energy Agreement, discussed in the introduction to this document. The second is the more proactive, centrally-led approach to offshore wind development adopted by the Dutch Government.

Until 2016, developers were responsible for site selection and investigation and permitting. The grid connection process and subsidy allocation rounds were organised separately from the permitting process, leading to long development times and significant development risk. Since Borssele Sites I & II, this process was simplified drastically for the offshore wind developers, through the one-stop shop approach. Within this process, roles and responsibilities are divided between RVO, Rijkswaterstaat (RWS) and TenneT. RVO is responsible for the preparatory site studies and the wind farm tenders. RWS conducts environment impact assessments (EIAs) and drafts the site decisions and TenneT is responsible for the grid connections between offshore wind farms and the onshore network. Tender winners receive permits to build and operate projects and access to the offshore and onshore grid network. This new approach has enabled the Netherlands to significantly increase its installed offshore wind capacity.

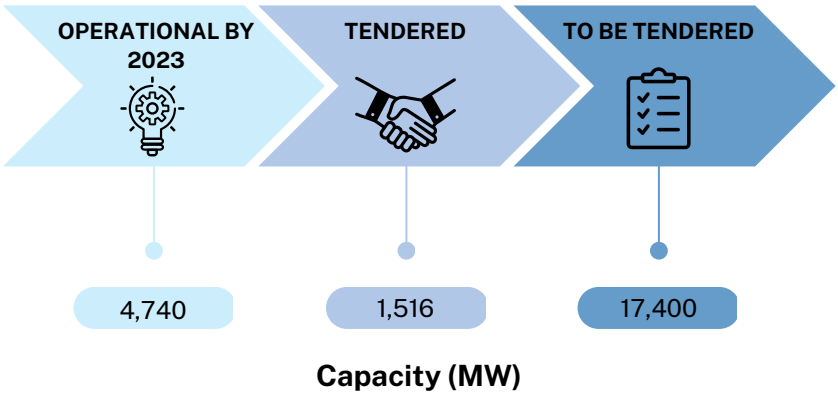


Figure 2. Offshore wind capacity in the Netherlands (2023)

Looking towards 2030, the Netherlands plans to increase its installed offshore wind capacity significantly, boosting it almost tenfold compared to 2022 levels. The planned growth in the Netherlands stands out from the likes of Denmark and Belgium, which currently have similar installed capacities (Figure 3).

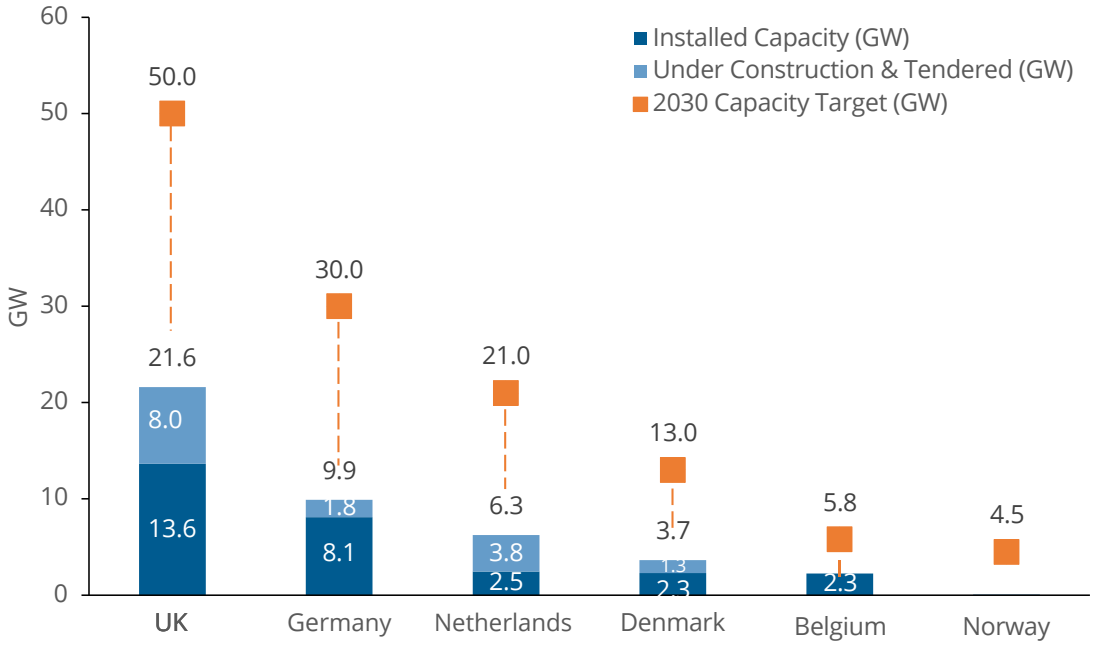


Figure 3. Installed, under construction & tendered and target capacities in the North Sea (GW) 2030 (2022) *(Source: RVO)*

Photo credits: TenneT (see https://www.tennet.eu/nl/projecten/offshore-projecten-nederland)

2.2. Achievements Roadmap 2023

Achievement #1. Successful deployment of the one-stop shop approach

The Dutch Government has successfully implemented a one-stop shop approach for offshore wind development. Thanks to this approach, pre-bid costs and associated risks have reduced and coordination between government entities has improved. Timeframes for developing wind farms has also reduced significantly.

The reconfiguration of responsibilities under the one-stop shop. For governance under the one-stop shop approach, roles were designated for the Ministry of Economic Affairs and Climate Policy (Min EZK), the Ministry of Infrastructure and Water Management (Min I&W), RVO, Rijkswaterstaat and TenneT. Their roles are listed in the Figure 4.

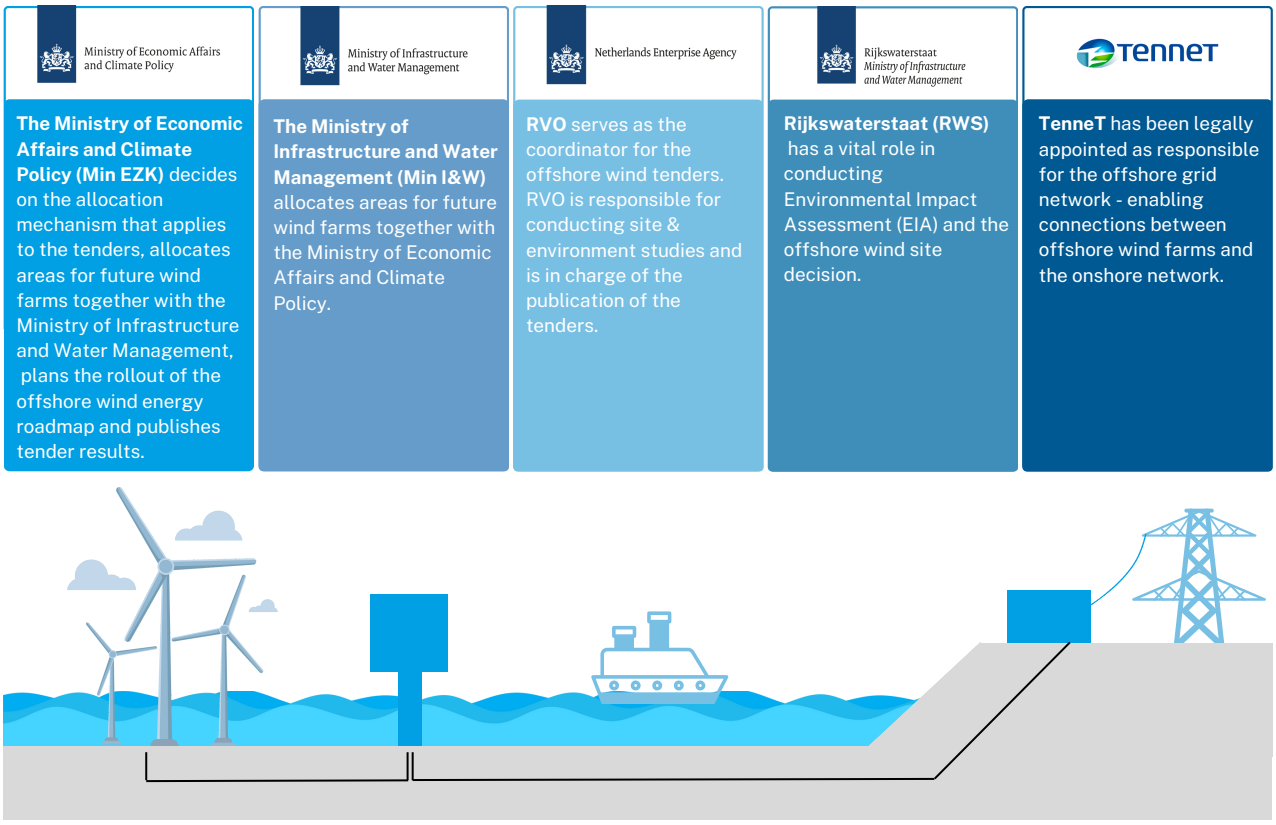


Figure 4. Responsibilities of government agencies and TenneT
(Source: Wind & Water Works)

Achievement #2. Cost reductions and zero-subsidy bids

The Netherlands Court of Audit *(De Algemene Rekenkamer)* estimates that the sum of the wind farm and offshore grid costs have reduced by 71% by 2018 compared to the reference price calculated in 2013 (15 cents/kWh) by Energy Research Center of the Netherlands – which are shown in Figure 5. The figure shows the cost per wind farm from Egmond aan Zee (tendered in 2003) until Hollandse Kust (zuid) I & II (HKZ I & II tendered in 2018) and clearly illustrates there was a significant cost reduction from Borssele I & II onwards.

The cost savings for the Borssele I & II and Borssele III & IV wind farms are estimated at around €2.3 billion and €4.7 billion respectively. Following the decreasing tender prices of the Borssele I & II and Borssele III & IV tenders in 2016, the Netherlands saw its first subsidy-free bid awarded to Vattenfall in 2018 for HKZ I & II.

The zero-subsidy bid for HKZ I & II was followed up in 2019 with the second subsidy-free concession awarded to Vattenfall for HKZ III & IV. These zero-subsidy bids were evaluated based on their qualitative merits regarding identification and mitigation of revenue, construction, and operational risks. Both wind farms are fully operational in 2023.

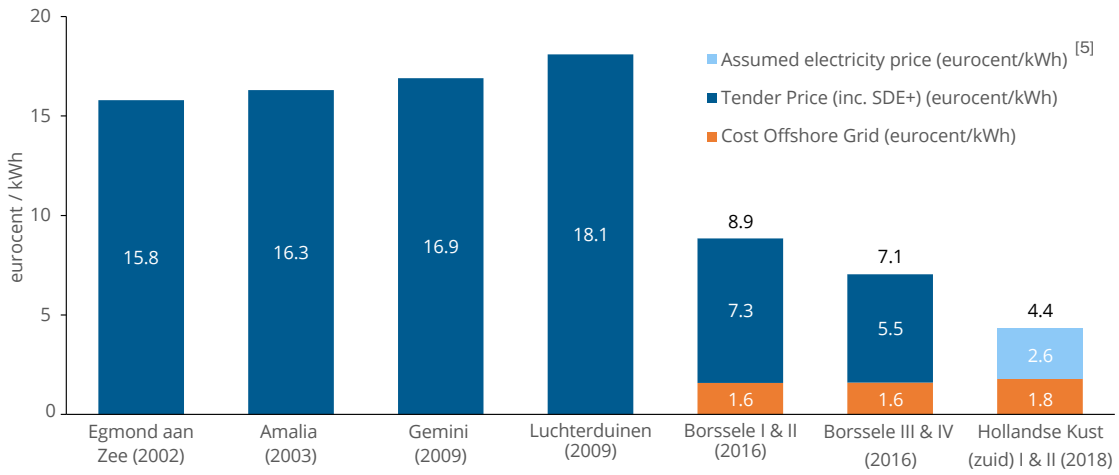


Figure 5. Cost of offshore wind farms from Egmond aan Zee until Hollandse Kust (zuid) I & II *(Source: Algemene Rekenkamer)* [6]

There are several elements that make zero-subsidy tenders feasible in the Netherlands:

- *The certainty provided by the one-stop shop principle of awarding concession, permit, and grid connection.*
- *Cost reduction realised throughout the supply chain.*
- *The Netherlands' established power purchase agreement market.*
- *The good site conditions (shallow water depth, strong wind resources, and sandy seabed).*
- *The size of sites and their limited distance to shore.*
- *The grid connection costs being attributed to TenneT.*

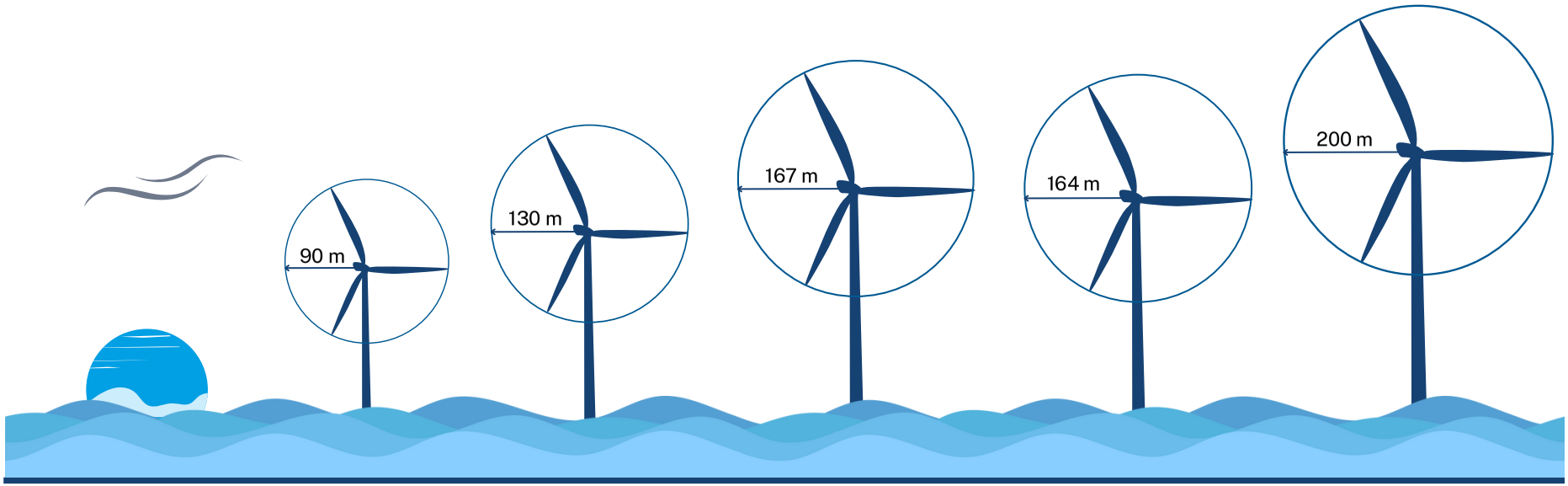
[5] The Court of Audit assumed that the electricity price of the Borssele V innovation site would apply to HKZ as the wind farms were tendered shortly after each other.
[6] Estimated cost is in current prices. The tender price is the sum of the electricity price and the subsidy (SDE+).

Achievement #3. Large wind farm tenders

For the Borssele and HKZ wind farm zones, a total of four tender rounds were held, each offering two 350-380 MW sites (or lots) for development. In practice, the winning bidders of those tender rounds secured both sites, enabling them to develop them as single projects resulting in large wind farms with a capacity of 730-760 MW. This is a significant increase compared to the first wind farms installed in the Netherlands, which ranged from 110-130 MW (i.e. Egmond aan Zee in 2007, Prinses Amaliawindpark in 2008 and Luchterduinen in 2015). The individual site capacity offered for development by the Government was subsequently increased to 700-760 MW for Hollandse Kust (noord).

To date, under its roadmaps, the Netherlands has awarded permits for seven 760 MW wind farms. Five are operational – Borssele I & II, Borssele III & IV, HKZ I & II, HKZ III & IV, and Hollandse Kust (noord), all tendered under Roadmap 2023. An overview of the parameters of these wind farms is provided in Table 1, together with a visual of the wind turbines being used in them. The tenders for the other two 760 MW wind farms (HKW VI and HKW VII, the first projects under Roadmap 2030) were completed in 2022.

> *The Borssele I & II wind farm is fully operational since 2020 and produces green electricity equivalent to the energy consumption of a million Dutch households.*
>
> *The successful collaboration with key stakeholders, including RVO, TenneT, RWS, Province of Zeeland, North Seaports and Municipality of Vlissingen, has been fundamental in realising the first large scale wind farm of the 2023 Roadmap, entirely built during the COVID-19 pandemic. From our operation & maintenance (O&M) base in Vlissingen, we successfully perform full O&M services for the Borssele I & II wind farms with a dedicated team of 70 wind technicians.*
>
> ***Marjolein Hormes, Director Borssele wind farm sites I & II***



Operational Year	2007	2016	2020	2020	2023
Wind Farm(s)	Egmond aan Zee	Gemini Windpark	Borssele I & II	Borssele III & IV	HKZ I & II, HKZ III & IV, HKN V
Number of Turbines	36	150	94	77	70 (HKZ), 69 (HKN)
Turbine Rating (MW)	3	4	8	9.5	11
Wind Farm Size (MW)	108	600	752	732	760
Turbine Supplier	Vestas	Siemens	Siemens Gamesa	Vestas	Siemens Gamesa
Turbine Type	V90-3MW	SWT- 4.0–130	SG 8 MW	V164 9.5MW	SG DD-200
Rotor Diameter	90 m	130 m	167 m	164 m	200 m

Table 1. Turbine development for offshore wind *energy in the Netherlands*

Achievement #4. Standardisation of grid connections of 700 MW

Upon appointment of TenneT as the offshore transmission system operator in 2016, TenneT started working on the expansion of the offshore grid and standardisation of grid connections in line with the targets defined by the Dutch Government. This resulted in the development of a 700 MW substation standard by TenneT. The offshore substation transforms the voltage levels from 66 kV to 220 kV and connects to the onshore grid via two 220 kV alternating current (AC) cables. TenneT will install a total of seven standard AC substations by 2026. The standardisation has contributed greatly to the reduction of costs, and the faster development time of offshore wind farms. The first five offshore wind projects, from the Roadmap 2023, have been realized by TenneT in line with the investment budget of 2 billion euros *(i.e. CAPEX, the investments to build the assets*).

In 2023, TenneT announced that it has completed the development of a 2 GW grid connection standard using direct current (DC), which it will start using from 2028 for the IJmuiden Ver Wind Farm Zone. The 2 GW standard is an enabler for connecting larger wind farms which are situated further from shore, through greater transmission capacity and avoiding reactive power losses.

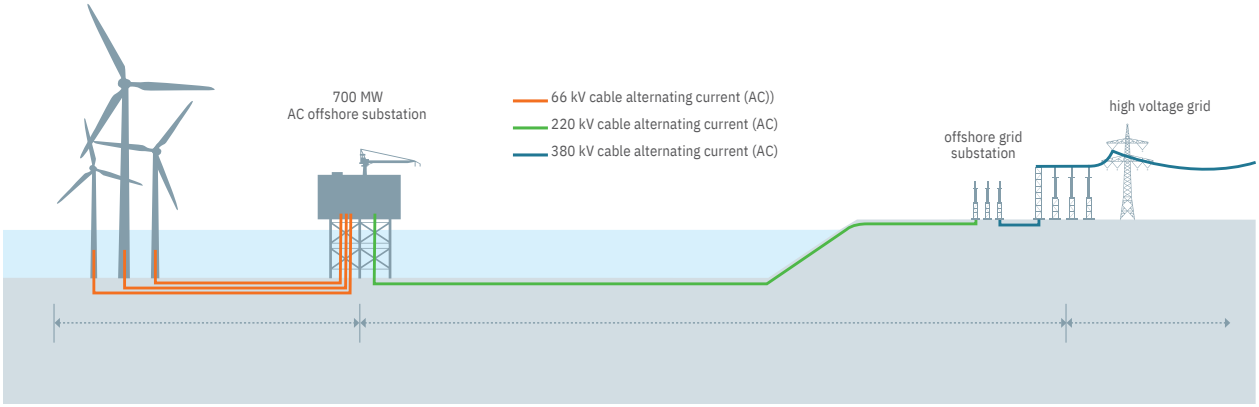


Figure 6. Offshore grid with 700 MW AC offshore substation *(Source: TenneT)*

Achievement #5. Reduced timeframe of developing wind farms

The development time of offshore wind farms was reduced in the Netherlands from 7 - 10 years to 3 - 4 years. There are several factors which contributed to this: the one-stop shop approach enables the site studies, permitting processes and the development of the grid to start before the wind farm tender.

FULLY OPERATIONAL					
Project	**# of Turbines**	**Turbine Rating (MW)**	**Turbine Type**	**Total Capacity (MW)**	**Year of commissioning**
Egmond aan Zee (OWEZ)	36	3	Vestas V90-3MW	108	2007
Prinses Amaliawindpark	60	2	Vestas V80-2MW	120	2008
Luchterduinen	43	3	Vestas V112/3000	129	2015
Gemini Windpark	150	4	Siemens SWT- 4.0–130	600	2016
Borssele I & II	94	8	Siemens Gamesa 8 MW	752	2020
Borssele III & IV	77	9.5	MHI Vestas V164 9.5MW	731.5	2020
Borssele V (Innovation lot)	2	9.5	MHI Vestas 9.5MW	19	2021
Hollandse Kust (zuid) I & II	70	11	Siemens Gamesa SG DD-200	760	2023
Hollandse Kust (zuid) III & IV	70	11	Siemens Gamesa SG DD-200	760	2023
Hollandse Kust (noord) V	69	11	Siemens Gamesa SG DD-200	760	2023
UNDER CONSTRUCTION OR TENDERED					
Project	**# of Turbines**	**Turbine Rating (MW)**	**Turbine Type**	**Total Capacity (MW)**	**Expected Year of Commissioning**
Hollandse Kust (west) VI	To be determined	To be determined	To be determined	756	2026
Hollandse Kust (west) VII				760	2026
TO BE TENDERED					
Project	**# of Turbines**	**Turbine Rating (MW)**	**Turbine Type**	**Total Capacity (MW)**	**Expected Year of Commissioning**
IJmuiden Ver III	To be determined	To be determined	To be determined	1000	2028
IJmuiden Ver IV				1000	2028
IJmuiden Ver I				1000	2029
IJmuiden Ver II				1000	2029
IJmuiden Ver V				1000	2029
IJmuiden Ver VI				1000	2029
Nederwiek I				2000	2030
Nederwiek II				2000	2030
Nederwiek III				2000	2031
Hollandse Kust (west) VIII				700	2031
Ten noorden van de Waddeneilanden				700	2031
Doordewind I				2000	2031
Doordewind II				2000	2031

Table 2. Overview of offshore wind farm projects in the Netherlands

Looking back to the past years - in which Dutch offshore wind policy was shaped and started to be rolled out by the Dutch Government - it has been an amazing journey that led offshore wind to reach subsidy free levels and a maturity that was not expected in such a short timeframe. The project Hollandse Kust South is clear proof of that! By setting up a stable competitive tender system where market parties intensively compete for projects, meanwhile keeping a very open dialog with the market and building in-depth relations with all stakeholders, the Dutch Government managed to make offshore wind the key success factor for a fossil free future, driving innovations and unique corporations going forward.

Gijs Nijsten, Head of Permit, Stakeholder Management & Communications (Hollandse Kust (zuid))

Photo credits: Mischa Keijser, Netherlands Enterprise Agency

2.3. Shareholder structure of the offshore wind farms

The shareholder structure of the offshore wind farms mostly consist of energy providers and financial investors. Energy companies typically lead the development of the project and attract other financiers as the project matures. Partnerships have been common in recent tenders, but they are not a requisite for success, as evidenced by RWE's win of Hollandse Kust (west) VII.

Within the Netherlands, Shell and Eneco are leading the ownership of operational wind farms and projects under development and have been successful as a partnership in several tenders.

Fully Operational	**Ownership**					
Egmond aan Zee (OWEZ)	100% Shell					
Prinses Amaliawindpark	100% Eneco					
Luchterduinen	50% Eneco			50% Mitsubishi		
Gemini Windpark	60% Northland Power		20% Siemens	10% Van Oord	10% HVC Groep	
Borssele I & II	50% Ørsted			50% Norges Bank Investment Management		
Borssele III & IV	25% Partners Group	20% Shell	20% Swiss Life Asset Managers	10% Eneco	15% INPEX	10% Luxcara
Borssele V (Innovation lot)	33% Green Giraffe		33% Octopus Energy		33% Investri Offshore	
Hollandse Kust (zuid) I & II	50.5% Vattenfall		25.2% Allianz		24.3% BASF	
Hollandse Kust (zuid) III & IV	50.5% Vattenfall		25.2% Allianz		24.3% BASF	
Hollandse Kust (noord) V	80% Shell			20% Eneco		
Under Development	**Ownership**					
Hollandse Kust (west) VI	50% Shell			50% Eneco		
Hollandse Kust (west) VII	100% RWE					

Table 3. Ownership of offshore wind farms (%)

3. Offshore Wind Tenders and Future Rollout

3.1 Dutch Offshore Wind Energy Roadmap 2030

The rollout of offshore wind in the Netherlands to 2030 is defined in the Additional Offshore Wind Energy Roadmap 2030+ which sets the target of 21 GW of total installed capacity by around that year. This version of the roadmap was announced on June 10, 2022 and was an addition to the previous 2030 Roadmap, which targeted 11.5 GW by 2030. The original 2030 Roadmap was amended following advice from two Dutch commissions: the Climate Change Green Deal Study Group (*Studiegroep Klimaatopgave Green Deal*) and the Extra Task Steering Committee (*Stuurgroep Extra Opgave*). They both recommended that the offshore wind target should be increased to ensure the Netherlands can meet its climate obligations following the European Green Deal. The Green Deal increased the greenhouse gas emission reduction target for each EU Member State from a 40% to 55% by 2030, relative to 1990 levels.

The remaining capacity needed to meet the 21 GW by 2030 target will be offered to potential developers in line with the tender rules outlined in the Dutch Offshore Wind Energy Act (OWEA), which specifies four types of tender procedures , as illustrated in Figure 7.

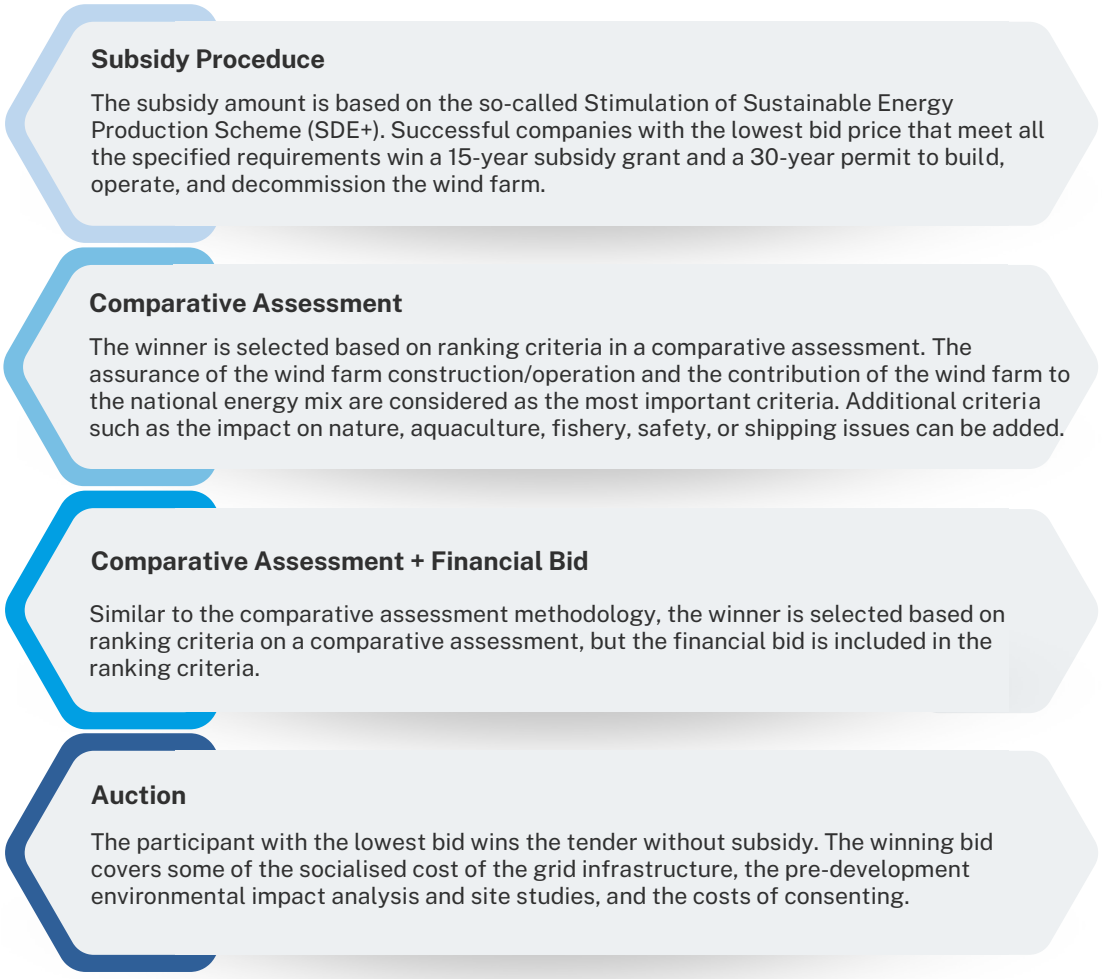


Figure 7. Tender types to be applied for offshore wind farms

Starting from the HKZ tender in 2019, the Dutch Government applied the comparative assessment + financial bid procedure. In the HKW tenders in 2022, the bids were evaluated based on 'Contribution to the integration of the wind farm into the Dutch energy system' (HKW VII) and 'Contribution to the ecology of the North Sea' (HKW VI). The two tenders for HKW VI and HKW VII were won by Eneco & Shell and RWE respectively. The procedure has also been applied for the IJmuiden Ver I to V lots tendered in 2023.

On June 10, 2022, the Ministry of Climate and Energy shared its 2030 plans through a Letter to Parliament, "Additional Roadmap for Offshore Wind Energy 2030". This letter provides details on the planned rollout of the offshore wind farms, including descriptions of the wind farm zones (WFZs), their size, and expected tender and commissioning dates. Three new WFZs were also announced: Nederwiek, Lagelander, and Doordewind. Figure 9 provides an updated overview of all Dutch WFZs to 2030/31 and indicates the current status of the wind farms.

Using the information from the Letter to Parliament, the expected annual and cumulative installed offshore wind capacity can be visualized to 2031 – see Figure 8. This shows that the total offshore wind capacity from the Roadmap 2030+ is higher than 21 GW target. This is purposefully done to be able to be flexible since some of the wind farm sites and some of the cable routes are uncertain due to ecological challenges. Please note that beyond 2023, the commissioning years are expected years as described in the Roadmap 2030+.

RVO and Rijkswaterstaat are now responsible for the next steps following the announcement of the new WFZs. These steps are the environmental impact assessments, site studies, development of the grid connections and organisation of the tenders.

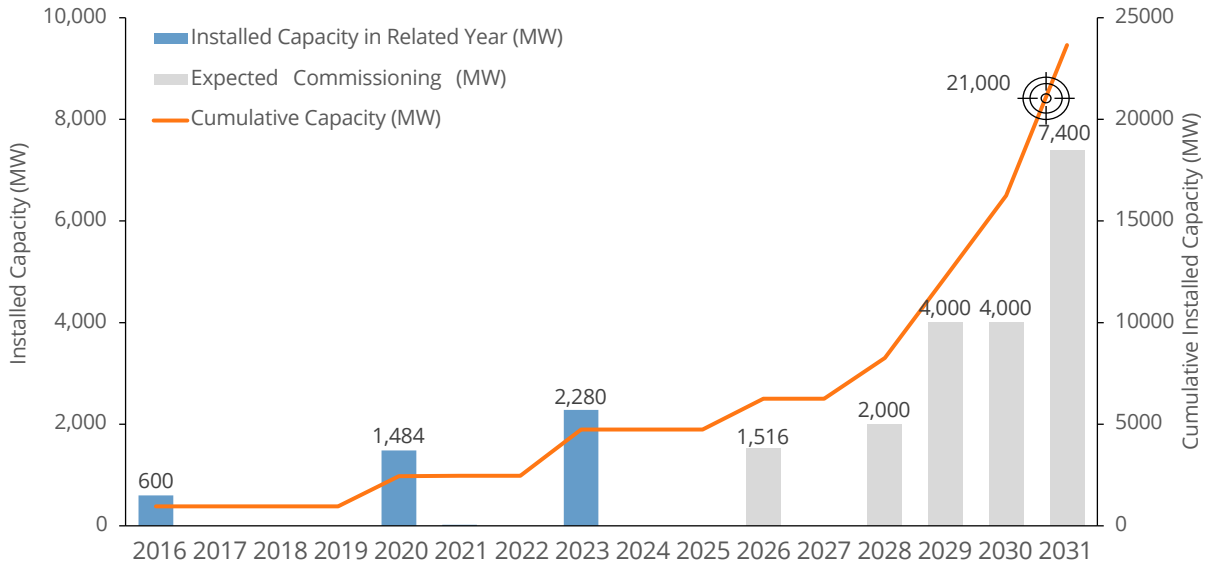


Figure 8. Cumulative and expected yearly installed capacity of offshore wind in the Netherlands from 2016 to 2031
(Source: Ministry of Economic Affairs and Climate Policy)

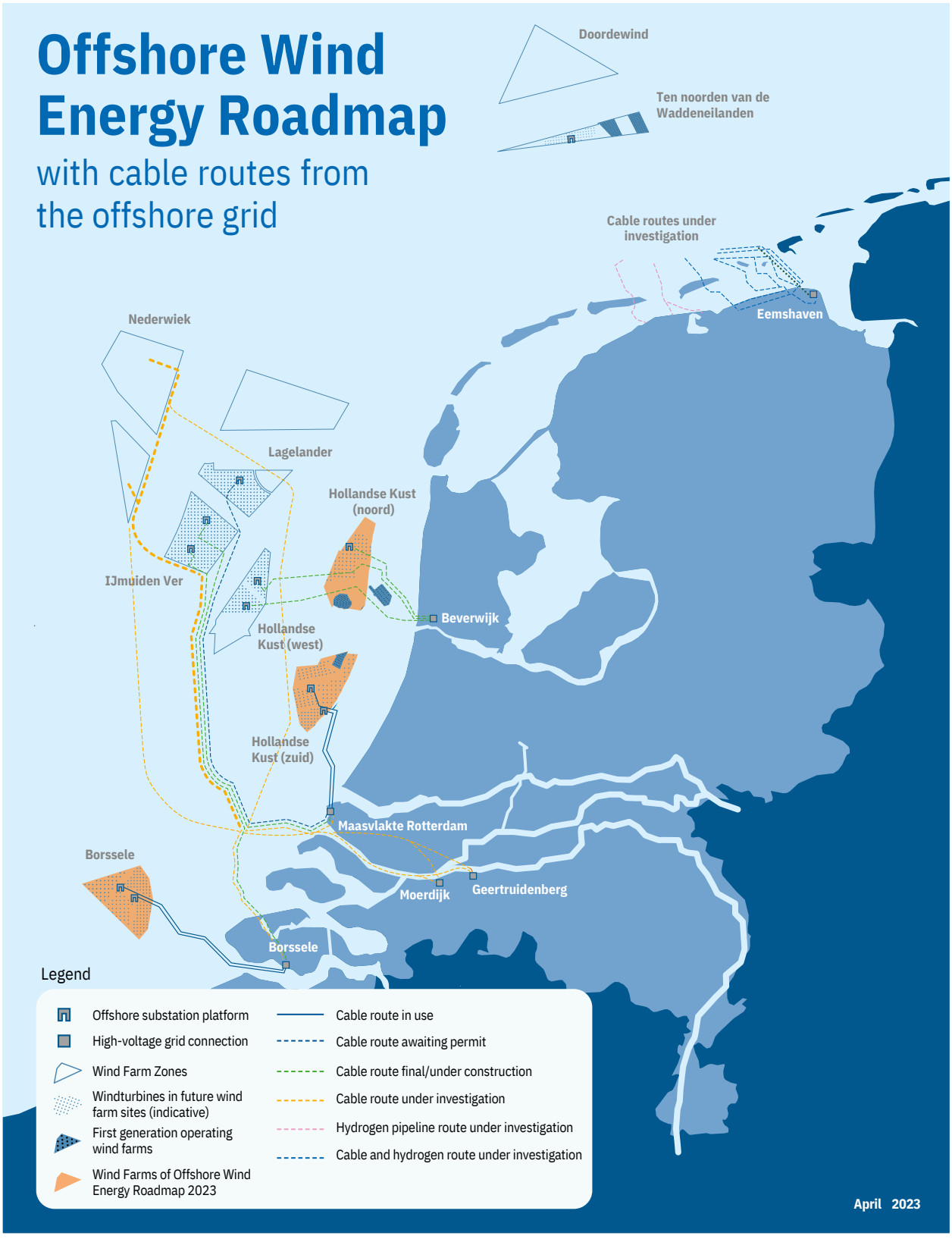


Figure 9. Dutch Offshore Wind Energy Roadmap *(Source: RVO)*

3.2. Offshore wind & North Sea developments from 2030 to 2050

A roadmap for the period of 2030 to 2050 has not yet formally been defined, but the Ministry of Economic Affairs and Climate has announced it will investigate the need for 50 GW and 70 GW for 2040 and 2050 respectively. The Minister indicated that the Netherlands will use a rolling roadmap which will be updated regularly as soon as there are new areas. The insights from the *Partial Revision of the North Sea Programme* will be used as input to supplement the roadmap. The next iteration of the programme will be in 2025.

The ministry indicated that the concept of energy hubs will be used beyond 2030. These offshore hubs will facilitate interconnection with neighbouring North Sea countries and may include offshore hydrogen production. The vision for 2050 will be defined in the North Sea Energy Infrastructure Plan. The plan will identify the energy hub areas and which infrastructure and capacity are needed.

EIPN is one of four key policy documents that give the direction of the North Sea developments for the Netherlands:

- Partial Revision of the North Sea Programme 2022-2027
- North Sea Energy Infrastructure Plan
- Offshore Wind Energy Roadmap 2030+
- Offshore Wind Energy Landing Connections Programme

These plans and programmes have varying time horizons and cover different topics, as illustrated in Figure 10.

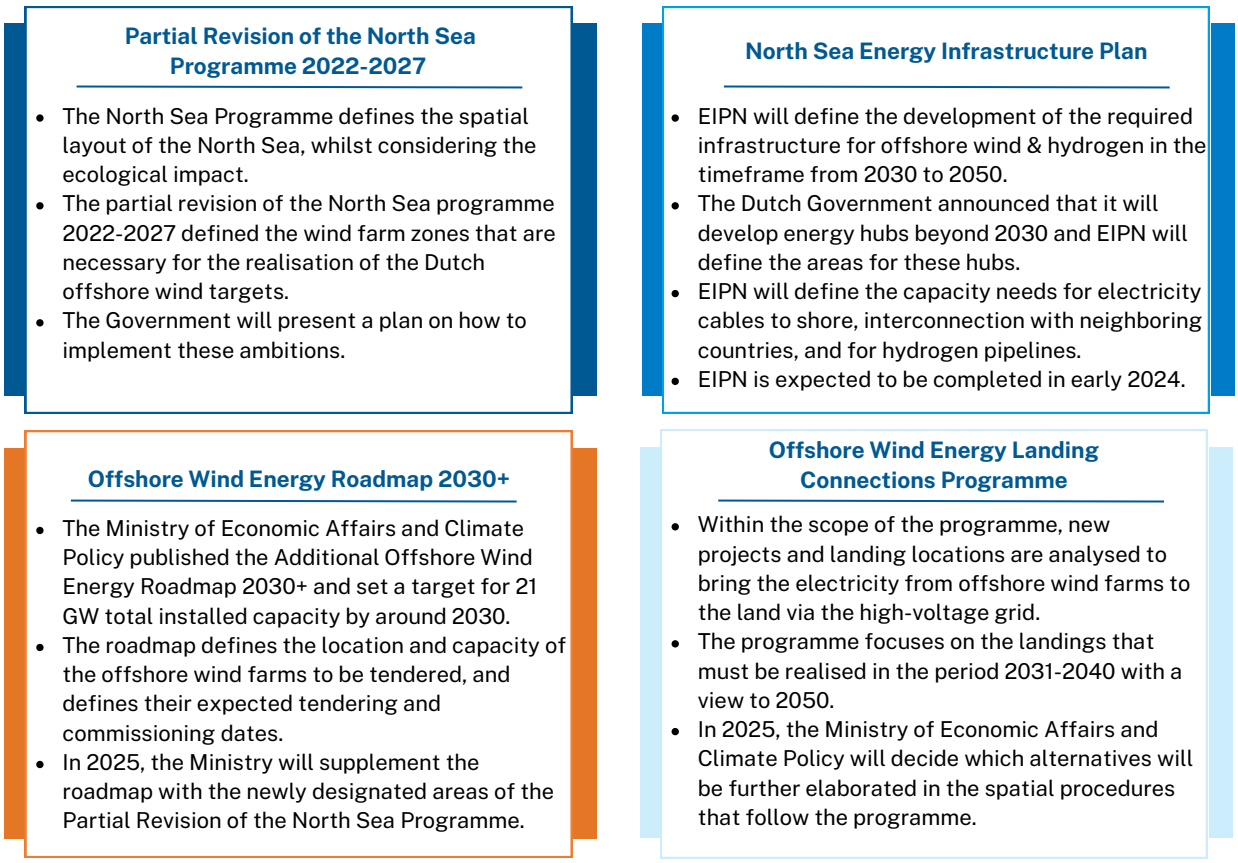


Figure 10. Future outlook for offshore wind *(Source: RVO)*

Meeting the challenges ahead

In order to meet the climate goals and the increased offshore wind energy capacity targets for 2030 and 2050, more wind areas and infrastructure for wind energy deployment are needed.

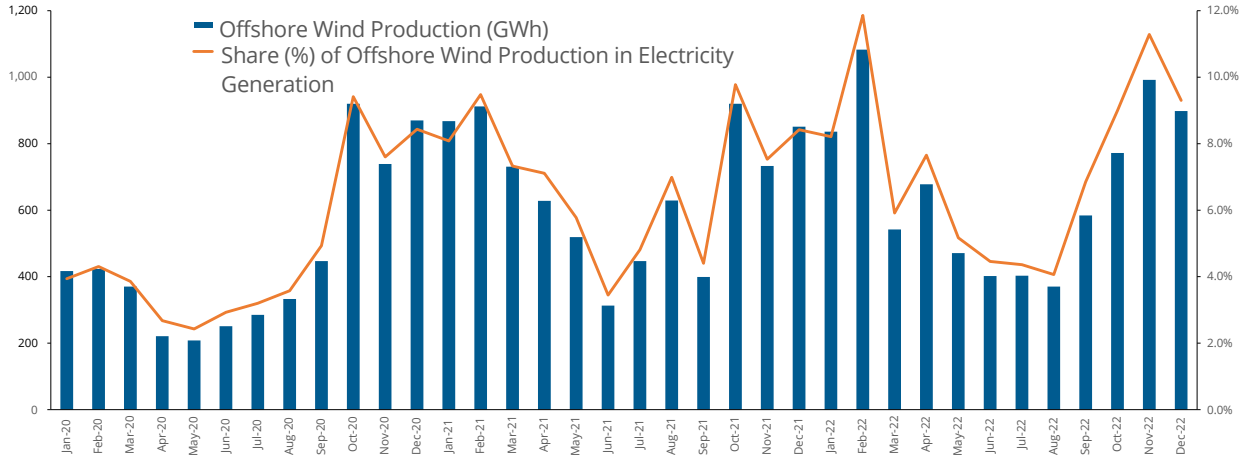
The Netherlands has strong know-how in offshore transport and installation activities, mainly coming from its role in the maritime, oil and gas industries in the past. With its seaports adjacent to the offshore wind farms in the North Sea and its expertise in project development, project management and research & development (R&D) activities, the Netherlands has a leading position in offshore wind market development. However, like other fast-growing industries, the offshore wind sector needs to keep up with the pace of developments and is facing challenges. These mainly relate to access to raw materials, unstable raw material prices, availability of the larger vessels to transport larger wind turbines and supply chain bottlenecks (i.e. cables and convertors).

In response to these challenges, the sector is applying various measures. The Dutch Government continues working closely with industry stakeholders to have clear policies and a future outlook for the offshore wind sector. The Offshore Wind Energy Roadmaps published put a vision for the offshore wind sector, which helps the industry to shape itself accordingly. Additionally, technology and ecological innovations are applied to further decrease the levelised cost of energy and mitigate ecological impacts and realise ecological benefits.

In order to mitigate supply chain bottlenecks for high-voltage direct current (HVDC) technology, TenneT has entered into framework contracts with NKT and Prysmian to secure the delivery of HVDC cables for five offshore grid connection systems in the Netherlands. Through such multi-project supply contracts, TenneT secures the production slots which are expected to be a bottleneck going forward.

4. Electricity Market and Power Production

4.1. Share of renewable electricity in the Netherlands



Together with the commissioning of new projects, share of offshore wind energy in total production increased from 4.6% in 2019 to 6.8 % in 2022.

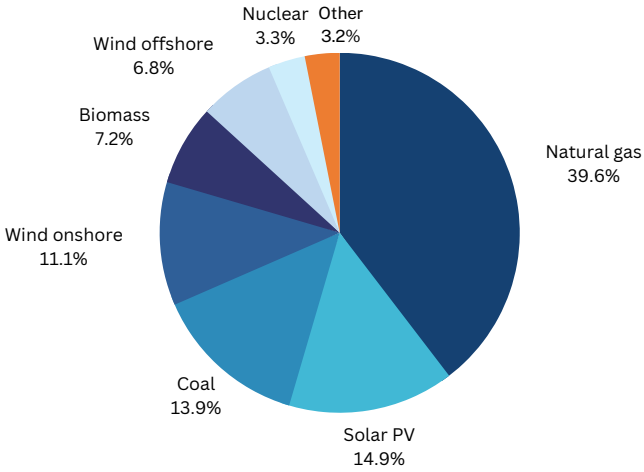


Figure 11. Offshore wind production and its' share in total electricity generation
(Source: CBS StatLine data)

Following the commissioning of an additional 1.5 GW installed capacity in 2020, with the Borssele projects coming online, electricity production from offshore wind increased from 4.6% in 2020 to 6.8% in 2022.

In 2022, offshore wind met around 7.3% of Dutch electricity consumption, up from 4.9% in 2020, with a monthly variation that closely follows the offshore wind electricity production. With the commissioning of the HKZ and HKN and their combined capacity of 2,280 MW, the share of offshore wind in the electricity consumption will double to 15.8%.[7] [8]

[7] The percentage is computed based on the electricity consumption of 2021 estimated at 117 TWh by the IEA.
[8] Whilst the electricity demand is expected to rise, a single figure was used in this report for simple comparison sake.

4.2 Indicators of electricity prices in the Netherlands

Despite the increase in the share of electricity production from renewable energy resources, including offshore wind, wholesale electricity prices in the Netherlands increased significantly in 2021 and 2022, mainly because of high natural gas prices – following the merit order concept, natural gas was setting the electricity price in the Netherlands. Nonetheless the increased production from renewables has helped to dampen price increases, as it reduced demand for natural gas. The annual average day-ahead electricity prices have been €32/MWh, €102/MWh and €241/MWh between 2020 and 2022 respectively.

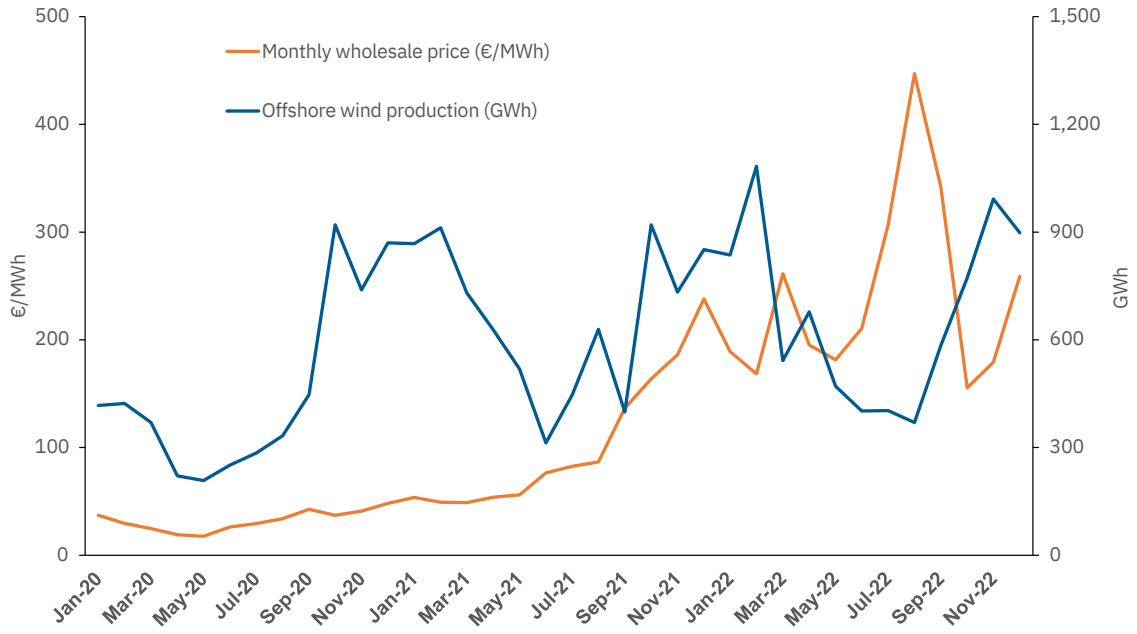


Figure 12. Development of day-ahead market prices and offshore wind production
(Source: ENTSO-E TP, CBS StatLine data)

5. Offshore Wind Innovations in the Netherlands

The Netherlands is one of the front runners within the offshore wind innovation sphere. The Dutch put themselves in this position through an early mover advantage and a strong research ecosystem, which consists of a variety of stakeholders combining academia, industry, NGOs and governmental organisations. This environment has sprouted many start-ups and innovations that are applied in the field today.

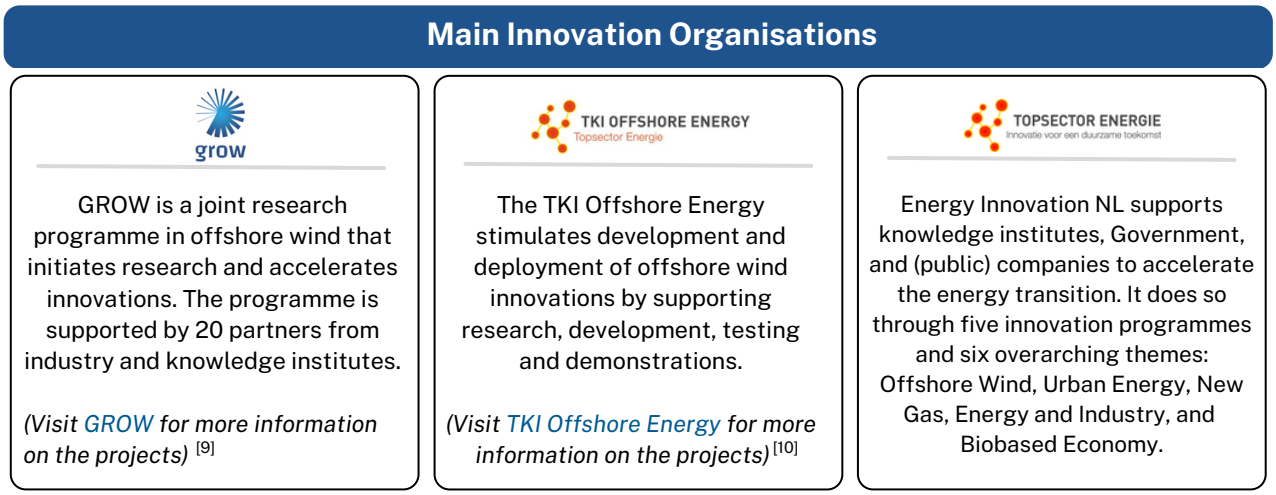


Figure 13. Main innovation organisations in Dutch offshore wind industry

The Netherlands has strong innovators in the industry, supported by knowledge institutes such as the Technical University Delft (TU Delft), Netherlands Organisation for Applied Scientific Research (TNO) and Deltares, and by organisations like GROW, TKI Offshore Energy /Topsector Energie (Energy Innovation NL) that aim to bring actors together and initiate innovations and advise policy makers.

Among these institutions, the TU Delft facilitates the development of wind energy technology and the expansion of the use of wind power all over the world through research and education, focusing on large electricity generating wind turbines on the multi megawatt scale. TNO's Energy Transition Unit complements this by supporting both the Netherlands' public authorities and the energy sector with advice, research and development and focuses on developing technologies to generate electricity from wind at lower cost and more efficiently.

Offshore wind innovations have been instrumental in the success story of the Dutch offshore wind programme as they have contributed to a significant cost reduction, increase in wind output, and the reduction of negative environmental impacts such as noise.

Parallel to policy developments in offshore wind, new programmes and schemes have been introduced for development of innovations in the offshore wind industry. The Multi-annual Mission-driven Innovation Programme (MMIP) has been shaped by the Top Sector Energy in response to the missions introduced with the Climate Agreement, defining sub-programmes and associated innovation themes to solve the supply chain bottlenecks.

[9] https://grow-offshorewind.nl/projects-overview
[10] https://www.topsectorenergie.nl/projecten-1

Among these missions, MMIP1 aims to enable the development of 21 GW (eq. 97 TWh) or more of offshore wind energy in 2030 and between 35 GW (eq. 150 TWh) and 75 GW (eq. 320 TWh) of offshore renewable electricity in 2050, at the lowest possible social cost. MMIP1 also defines which knowledge and innovation tasks must be tackled in the short term for R&D, demonstration and implementation to achieve these missions.

The Dutch Government is supportive of the offshore wind industry and has made subsidies available for innovation programmes. In addition to the funding from the European Union and private investors, funding has been made available for offshore wind innovations through the Dutch Research Council (NWO) which offers subsidies for academic research. The three prominent government funding for offshore wind innovations are:

- **Mission-Driven Research, Development and Innovation (MOOI):** Focuses on projects that help to realise the National Climate Agreement goals.
- **Renewable Energy Transition (HER+):** Supports projects that fit within the programme's goal to reduce CO_2 emissions by 2030.
- **Demonstration Energy Innovation (DEI+):** Support projects from a circular economy, energy systems and energy efficiency to carbon capture and storage.

Between 2020 and 2022 [11]

- The subsidy level available for offshore wind innovations projects are:
  - €44 million for MOOI. MOOI had a specific budget of €10 million in 2020. In 2021 and 2022 there was no specific offshore wind budget, but budget for the electricity theme (including onshore & offshore wind).
  - €150 million for HER+.
- The estimated budget allocated specifically for offshore wind R&D (via MOOI, HER+ and DEI+) is €70 million. (i.e. HER+ 2022 is still ongoing)
- The total investment amount in offshore wind innovation projects including government subsidies and private sector investments is estimated at €110 million. The private sector investment is ca. 25-50% from the total investment amount.
- The total budget (including wind projects) for the newly opened grant schemes are:
  - HER+ 2023 is €30m (application timeline between 03/04/2023 – 31/08/2023)
  - DEI+ 2023 is €65m (application timeline between 15/03/2023 – 31/08/2023)

[11] Source: RVO

Recently, NWO published a tender in the context of Dutch Research Agenda (NWA) programme for knowledge institutions and societal parties to jointly develop scientific and practice-oriented research proposals focusing on offshore wind energy. The available budget for this tender is €2.93 million.

> *HKN One Team is in full construction offshore to deliver green electricity to Dutch society by end 2023. HKN is the first smart offshore wind farm! Our five innovations will provide a 'sneak peak' of the future offshore wind parks. CrossWind will share the innovation lessons learned to accelerate the energy transition.*
>
> ***Tjalling de Bruin, CEO and Project Director CrossWind (Hollandse Kust (noord) V)***

The Dutch offshore wind industry has produced many scalable innovations as part of the research, development & demonstration (RD&D) programmes. The new projects developed include not only technical but also ecological innovations[12] [13]. These include:

Sustainable Installation of XXL Monopiles (SIMOX): Hydraulic impact piling (hammering) is the common method used in the wind industry to install monopiles. However, this technique has disadvantages such as the generation of significant underwater noise and the difficulty of extracting piles at the end of their service life. This project will develop and implement one or more innovative technologies for the installation of XXL monopiles. SIMOX is a collaboration of more than 20 partners from industry and knowledge institutes, in interaction with government and (environmental) NGOs. This project is funded by MOOI.

Flexible Offshore Wind Hydrogen Power Plant Module (FlexH2): The project involves designing an offshore wind-onshore hydrogen production concept in order to improve the efficiency and provide greater flexibility to the power system. FlexH2 was awarded a grant as part of the MOOI- theme SIGOHE (System Solutions Integration Large-Scale Generation Renewable Electricity) in 2021. The project is developing four key components: a grid-forming [14] offshore wind turbine, a control system for the power plant for black-start and grid-forming operation, an improved AC-DC semiconductor transformers and a multi-terminal hybrid HVDC transmission system.

[12] https://grow-offshorewind.nl/projects-overview
[13] https://www.topsectorenergie.nl/projecten-1
[14] Grid-forming is an evolving technology that allows the generator to set the grid voltage and frequency and operate in an island mode, if needed.

Wrapped Composite Joints for Next Generation Offshore Wind Support Structures - Phase 1 (WrapNode-I): The project is developing composite joints for jacket foundations for offshore wind turbines, as an alternative for welding complex joints. This approach will cut costs due to a lighter structure and reduced manufacturing time. During the first phase of the project, a full-scale joint test will be carried out and a performance validation will be executed. In a second phase, a scaled jacket will be designed, assembled and tested onshore. The project is funded by HER+ subsidy.

Gentle Driving of Piles (GDP): The project develops and tests a novel pile installation method based on simultaneous application of low-frequency and high-frequency vibrators acting in several directions. It is called gentle, as it may reduce driving loads and installation noise. The objective is to make the pile installation process more efficient. In addition to delivering a solid “proof of concept” of the proposed method, models are generated to predict the effects of the GDP technique (including noise emission and soil bearing capacity). As part of the project, a first test was carried out and the technique was successfully demonstrated for application in sandy soil. This project is funded by HER+ subsidy.

Dynamic Wind Farm Flow Control: The project aims to reduce the wake effects for wind farms by closed-loop active wake steering in combination with the novel HELIX active wake mixing technology. The major improvements foreseen with the project are: increase in the annual wind farm power output of around 2 - 3% when applied to a full wind farm, decrease dependency to apparent wind speed and direction which enables a more stable output and increased wind farm power density (GWh/km^2) of utilised offshore space by a factor of two. The latter is achieved by being able to decrease the space between the wind turbines. This project is part of the Hollandse Kust (noord) wind farm innovation programme and receives no government subsidies.

Photo credits: Mischa Keijser, Netherlands Enterprise Agency

Solar@Sea II - Offshore solar power plants and wind turbines: The project installs floating solar panels at sea – more specifically between the offshore wind turbines. Within the scope of the project, a concept based on lightweight flexible floaters and flexible solar panels are tested. Floating solar panels can potentially have a higher efficiency as the sea is able to cool the solar panel to increase their efficiency. By placing the panels within offshore wind farms, the concepts aims to increase the efficient use of space and infrastructure.

AIRTuB: Automatic Turbine Blade Inspection and Repair Programme (AIRTuB) is developing an autonomous inspection, maintenance and repair tool which will reduce the time taken for O&M, cut capital expenses and improve safety. This innovation is particularly valuable as current operations are done manually.

Nature Inclusive Design at Offshore Wind Farms

Nature Inclusive Design (NID) implies that ecology-friendly measures are integrated in the offshore grid design or wind farm, as a basic condition. NID measures can be seen in various segments of the offshore wind value chain. For example:

- TenneT has reassessed the standardised 700 MW AC offshore grid concept to minimise the ecological impact of its infrastructure (e.g. high-voltage cables, land stations, platforms).
- Tenders for the grid developments require contractor to assess opportunities for nature.
- RVO has included the criteria 'Contribution to the ecology of the North Sea' within the tender for offshore wind farms.

Offshore wind developers have also embraced NID at their offshore wind farms. Some examples of this are:

- A study is being conducted at HKZ to find out how the nature inclusive design of turbine foundations can support marine life.
- At the HKN wind farm, a number of underwater noise mitigation measures - namely FaunaGuard and bubble curtain modules - are undertaken to keep the marine life out of harm.
- The Wageningen Marine Research is working at Borssele I & II on biodiversity with the purpose of creating a suitable habitat and feeding places for Atlantic cod.

6. Conclusion

The Netherlands is a front runner in the offshore wind industry having installed a total capacity of approximately 4.7 GW offshore wind farms by 2023. As part of the Roadmap 2023, successful tenders in three designated offshore wind zones have been completed: Borssele between 2016 and 2018 (Sites I & II, III & IV, and V), followed by Hollandse Kust (zuid) between 2018 and 2019 and finally Hollandse Kust (noord) V in 2020.

The successful deployment of offshore wind in this period has been linked to the following achievements:

- **Achievement #1:** The one-stop shop approach implemented by the Dutch Government reduced pre-bid costs and risk levels for offshore wind developers. It also improved coordination amongst all stakeholders.
- **Achievement #2:** The cost reduction of offshore wind farms enabled the first zero-subsidy bid tenders.
- **Achievement #3:** The tendering of large wind farms by the Dutch Government.
- **Achievement #4:** The standardisation of a 700 MW substation reduced the costs of connections and reduced the development time.
- **Achievement #5:** The reduced development time lowered costs for offshore wind developers and increased the penetration rate of offshore wind in the electricity mix.

Complimentary to the above list, the following key drivers - *also emphasised by offshore wind developers and innovation institutes in the Netherlands* - have played a significant role in the successful deployment of offshore wind:

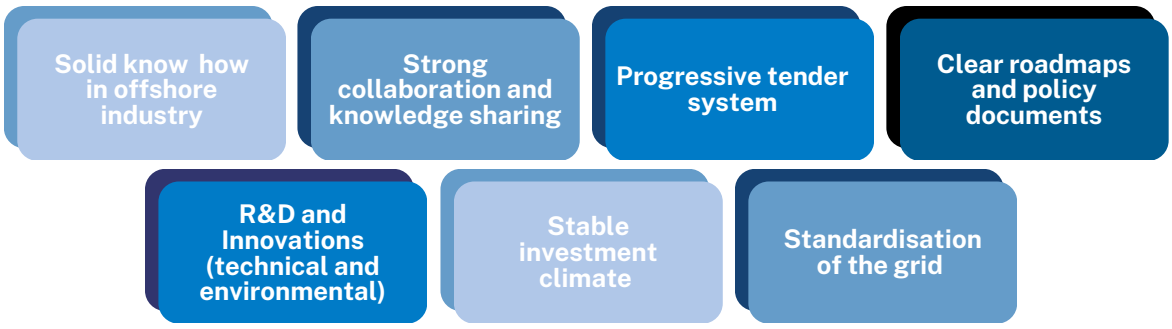


Figure 14. Key factors behind successful deployment

Looking beyond Roadmap 2023, the Dutch Government has published a roadmap to 2031 – with a target of 21 GW of installed capacity. Indicative capacity targets, which will be further detailed in the National Energy System Plan *(National Plan Energiesystem (NPE))*, have been provided as 50 GW in 2040 and 70 GW in 2050 by the Letter to Parliament (September 2022).

In addition, the Dutch Government has indicated it will develop energy hubs beyond 2030. These hubs will facilitate the interconnection and exchange of electricity with neighbouring countries such as the UK, Denmark, Belgium, Germany and Norway and over time will include the production of green hydrogen at sea, as well as pipelines to transport hydrogen to shore.

Recently in March 2023, the Government announced that a production facility of 500 MW capacity will be built to convert wind power into hydrogen in the North Sea and this facility is expected to be operational in 2031. As the first step of this project, a smaller pilot project with an electrolysis capacity of 50 MW to 100 MW will be developed to test the technology.

> *In 2023, the Dutch wind sector is proudly celebrating the completion of its ten year plan (Energy Agreement 2013) by installing 4.7 GW offshore; in addition, our ambitions are realised on time and within schedule. We now aim to achieve net zero as soon as possible and we will do so while enhancing the ecological system of the North Sea, by designing sustainable and circular products and by collaborating closely with our partners in our government.*
>
> ***Jan Vos, chair of the Netherlands Wind Energy Association (NWEA)***

List of Figures

List of Tables

The Dutch Government participates in active knowledge sharing with foreign government agencies in Europe, as well as in Asia and America. At the same time, we work with the industry, knowledge institutions, and trade organisations to create new opportunities for our supply chain in the Netherlands and across the globe. Once a year, we welcome foreign delegations and guests to the Netherlands for the Offshore Energy Exhibition and Conference (OEEC) in Amsterdam. During this three-day event, we share knowledge, network, present our innovative supply chain, and showcase new findings.

wind & water works

Organisations interested in connecting with the Dutch Government, specific businesses, or knowledge institutions within the offshore wind supply chain can find more info on the Wind & Water Works website: www.windandwaterworks.com

Disclaimer

This document was prepared by Netherlands Enterprise Agency (RVO.nl), and Guidehouse Netherlands B.V.. Input was provided by the Nederlandse Wind Energie Associatie (NWEA), Growth through Research, development & demonstration in Offshore Wind (GROW), TKI Offshore Energy and the developers of the Offshore Wind Energy Roadmap 2023. This document confers no rights. Whilst great deal of care has been taken in compiling the contents of this document, none of the above institutions or companies can be held liable for any damages resulting from any inaccuracies and/or outdated information.

April 2023

Netherlands Enterprise Agency (RVO.nl) is an agency of the Dutch Ministry of Economic Affairs and Climate Policy. Netherlands Enterprise Agency implements policy for various ministries in the areas of sustainability, agricultural, innovation and international business and cooperation. Netherlands Enterprise Agency is the contact point for business, knowledge institutions and government bodies for information and advice, funding, networks and legislation and regulations.