HIGH VOLTAGE OFFSHORE SUBSTATION IN BORSSELE WIND FARM, AUGUST 2020, WIND FARM OPERATOR BLAUWWIND. PICTURE SOURCE: RVO

THE NETHERLANDS

In 2020, the total installed wind power capacity was 6.6 GW, which is considerably more than the 4.5 GW in 2019. This is mainly due to the increase in offshore wind power from 1 GW to 2.5 GW in line with the planned rollout of the Borssele wind farms.

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At the end of 2024, about 4.5 GW wind power should be installed in the Dutch part of the North Sea according to the first road map. Until 2030, another 6 GW is currently under development according to the second road map bringing total offshore capacity to 11 GW in the Dutch part of the North Sea.

The commissioning of the onshore wind farms is going slowly, but steadily towards the 6 GW goal of 2020. In

TABLE 1. KEY NATIONAL STATISTICS 2020: THE NETHERLANDS

Total (net) installed wind power capacity*	6.6 GW
Total offshore capacity	2.5 GW
New wind power capacity installed	2.1 GW
Decommissioned capacity (in 2020)	0.07 GW
Total electrical energy output from wind	13. 896 TWh
Wind-generated electricity as percent of national electricity demand	13.1%
Average national capacity factor**	24%
Target	17 GW in 2030 (11 GW offshore and 6 onshore)
National wind energy R&D budget	21 million EUR

*Installed wind power capacity: Use nameplate power ratings of the installed wind turbines

**Average National Capacity Calculation: In the course of 2020 2.1 GW new capacity was installed, which is 47% more wind power compared to 2019. This resulted into a somewhat lower capacity factor in 2020. However, it is expected that this will be 31% in 2021 because most new wind turbines are offshore where the capacity factor is 40% or higher .

2020, a total of 4.1 GW was installed. The growth rate in 2020 has increased compared to last year, 537 MW new onshore wind power was installed. The growth, however, remains hampered because of the spatial and permit issues and opposition by local residents. More than 6 GW onshore wind power seems unlikely in the Netherlands.

All R,D&D projects supported by a subsidy grant concerned offshore wind energy, covering quieter installation of monopiles through various techniques, improvements of wind turbine blades, new connection techniques for wind turbine masts, and mitigation of leading-edge erosion and improved installation of wind turbines.

Market development

Targets and policy

- According to the Dutch climate agreement there must be a reduction of 49% in CO2 emissions in 2030 compared to the 1990 level. All sectors electricity, industry, mobility, built environment, and agriculture have to contribute to achieving this goal. The renewable electricity production must increase from 17 TWh in 2017 to 84 TWh in 2030 of which 49 TWh has to be generated by offshore wind and 35 TWh by renewables onshore. 18 TWh of the onshore electricity will be generated by 6 GW wind energy capacity and the rest by other renewables like solar PV. For offshore the 49 TWh can be entirely generated by the planned 11 GW in 2030 in the Dutch part of the North Sea. No other power sources are foreseen at sea until 2030

- According to the Dutch climate agreement, the electricity system must be completely CO2-free by 2050. Therefore, all fossil electricity sources must be replaced by renewable sources. The growth of this renewable electricity must be aligned with the increasing demand due to electrification of society and industry. The big effort is how to integrate this growing amount of renewable energy into the system. Offshore wind and maybe offshore solar energy with an expected 60 GW installed capacity in 2050 will play a very important role in the generation of CO2-free electricity. These offshore facilities will be very large and centralized, whereas the renewable electricity production onshore is more decentralized produced by citizens, farmers, and small companies using wind, solar, and other options. The gigantic increase of renewable electricity requires coordination, storage, and a flexible grid.

- In 2020, the renewable energy subsidy (HER) has been transformed into the renewable energy transition subsidy (HER+). The HER+ now also stimulates innovations in techniques which result in lower CO2 emissions rather than just renewable energy techniques. This wider scope enables many more techniques to submit an innovation proposal. The reason for widening the scope is to accelerate the decrease of the CO2 emissions. Innovations in wind energy can still apply. The budget was 50

million EUR in 2020 and will be also 50 EUR million in 2021.

- From 2017 to 2019, CO2 emissions were stable and 1% above 1990 levels. In 2020, CO2 emissions were lower due to reduced economic activity caused by the corona pandemic. That means that many measures will be required to further reduce CO2 emissions . One of these measures and the most important instrument is the SDE++ feed-in support which has been available since 2008. Since autumn 2020, apart from the renewable energy techniques, in the SDE++ a wide scope of techniques reducing the CO2 emissions can also be subsidized. In autumn 2021, a new subsidy round will be available with a budget of 5 billion EUR. All the above-mentioned techniques may qualify for innovation subsidies if they can lower the costs of the reduction of CO2 emissions.

Progress and operational details

- In 2020, the Borssele wind farms 1&2 and 3&4 were commissioned, in total 1.5 GW. This is the first step towards 4.5 GW offshore wind in 2023 in the Dutch part of the North Sea, which seems an achievable goal as all permits now have been issued.

- The Borssele 1&2 wind farm was developed and built by the Ørsted. It consists of 94 Siemens Gamesa wind turbines (each 8 MW) connected to one offshore substation. The total capacity is 752 MW, generating enough electricity for 1 million households. The neighbouring wind farm Borssele 3&4 is developed and build by Blauwwind, a consortium consisting of Eneco, Shell, Van Oord and DGE. This wind farm has 77 MHI Vestas wind turbines (each 9.5 MW) generating 3 TWh per year. Both wind farms receive subsidy on the electricity generated, however much less than expected due to a competitive tender system with a clear cost structure.

- Vattenfall which has been awarded the permits for Hollandse Kust Zuid (HKZ) wind farms will commission about 1.5 GW in 2023. These are the first offshore wind farms without subsidy. HKZ will consist of 140 Siemens Gamesa wind turbines (each 11 MW).

- In 2020, the permit for the Hollandse Kust Noord (HKN) offshore wind farm (700 - 750 MW) was awarded to Crosswind, a consortium consisting of Shell, Eneco, Siemens Gamesa, and Van Oord. In the tender for HKN, innovations were required. The next innovations will be developed and tested at HKN: intelligent wind turbine control, steering the wake, floating solar, energy storage. HKN must be operational in 2024.

- The 700 MW offshore substations in the Dutch part of the North Sea are standardized, developed, and built by the Dutch TSO TenneT. Wind farm operators can connect free of charge.

- Onshore, several large wind farms and many smaller ones were realized in the Netherlands, together 517 MW installed power. These were often the result of very long procedures, hampered by objections. These larger farms are: Zeewolde 100 MW, N33 149 MW and Drentse Monden Oostermoer 170 MW. Construction of the 383 MW Fryslân wind farm, in a lake, started in 2020 and should be commissioned in 2021. At the end of 2020, 4.1 GW wind power will have been installed of the 6 GW originally foreseen in 2020. Most projects for the 2020 goal are either under construction or already have their permits. Various agreements have been made to speed up the process to achieve the goal in 2023.

Matters affecting growth and work to remove barriers

- The Dutch onshore wind capacity target in 2020 is 6,000 MW. It is a complex process to achieve this target because many stakeholders are involved: provinces, municipalities, residents, wind farm developers, landowners—each with their own and often conflicting interests. Other issues are industry and housing, military radar, height limits near airports, and turbine lightning. A core team consisting of the national government, the provinces, municipalities, and companies from the wind sector monitors the progress and the solution of the bottlenecks. Due to these issues and the corona pandemic, the 2020 6,000 MW goal will be met later, probably in 2023 or 2024. More than 6 GW onshore wind power seems unlikely in the Netherlands.

R,D&D activities

National R,D&D priorities and budget

- The new MOOI subsidy was put out to tender in 2020 for the first time. MOOI stands for Mission-Oriented Research, Design, and Innovation. Project proposals had to provide integral solutions, multi-disciplinary cooperation, and active sharing of knowledge. Wind energy projects must contribute to a combination of cost reduction and optimization, integration in energy system (including storage and conversion), and spatial integration (ecology and multi-use). For offshore wind, the budget was 10 million EUR and for renewable onshore 11 million EUR. In 2021, there will be a new tender which projects can apply for, focusing on innovations for the integration of large amounts of renewable electricity generated by wind and solar PV. The budget is 13.8 million EUR.

National research initiatives and results

- The Dutch government has supported several research and development initiatives in the field of O&M, offshore foundations, wind turbines, and installations. A few projects will be highlighted here.

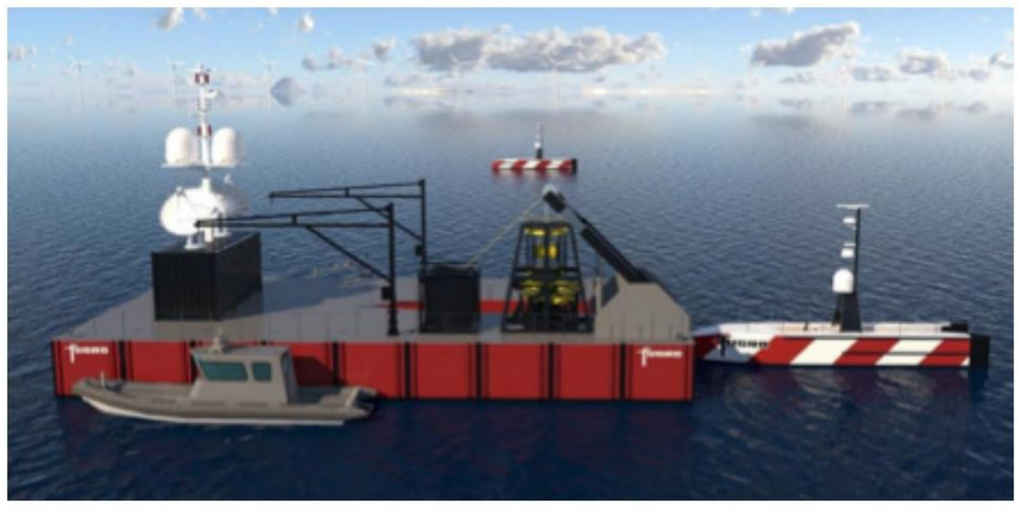
- **Tetrahedron crane:** With wind turbines getting bigger and bigger, new challenges for the wind installation industry have emerged. One of them is to lift higher. The Tetrahedron crane can lift an additional 50 metres compared to traditional cranes on the same vessel while lifting performance is preserved. Existing crane vessels can be upgraded with the Tetrahedron crane. The consortium consists of Tetrahedron, Van Oord, DNV-GL, and TU Delft.

(IMAGE FROM TETRAHEDRON B.V.)

- **HyPE-ST,** Hydraulic Pile Extraction Scale Tests: In the future, many offshore wind farms have to be dismantled and the seabed has to be restored to the condition prior to the construction of the wind farms. Instead of cutting off the monopiles below the seabed, this technique uses water pressure inside the monopiles to remove the entire monopiles. Successful lab tests at small scale were performed and now lager scale tests will be performed over the next years. The consortium consists of RWE, Deltares, TNO, DOT, IHC, DCR, and Sif.

- **SIMOX,** Sustainable Installation of XXL Monopiles: Monopiles will be the dominant foundation for wind turbines in the Dutch part of the North Sea, also for the 15 MW turbines and beyond. The classical hammering generates much under water noise and fatigue loads in the monopile. The underwater noise reduces the available installation time and requires expensive mitigation measures. In the SIMOX project, several new installation techniques are therefore developed, tested, and compared. These techniques are: vibratory driving with a purely vertical excitation (Vibro), a combination of vertical vibratory excitation with a high-frequency torsional shaking (GDP), aiding vibratory techniques by fluidizing the internal soil column in the pile (JET), hammering with a water column (Blue Piling). Also, pile extraction techniques will be investigated making use of vibrations or pressure (DECOM). The consortium consists of TU Delft, Deltares, TNO, Van Oord, DOT, Boskalis, Seaway7, Sif, IHI IQIP, Cape Holland, GBM Works, Shell, RWE, and Siemens Gamesa.

- **RoboDock:** With the increased availability of operational wind farms in the North Sea and the safety concerns and scarcity of qualified staff, robotics-based inspection, maintenance, and other services of the offshore wind assets will contribute to reducing the downtime of installed wind turbines and overall O&M costs. However, as offshore wind farms are placed at increasing distances from the coast, deployment of the robotic systems is getting more problematic without facilities nearby that can support such systems. The current robotic systems lack autonomy, and they are deployed and serviced from separate systems. This project introduces therefor the RoboDock platform which is a safe docking point for robotic systems for O&M, surveillance, and inspection tasks. At the platform, drones and unmanned vessels (surface and subsea) can recharge, upload data, communicate, and be deployed in the wind farm. The RoboDock is situated in or near the wind farm which allows rapid and frequent deployment. The consortium consists of Fugro, Shipyard De Hoop, RC Dock, NIOZ, and Ørsted.



(IMAGE FROM RC DOCK, FUGRO)

- **WindSense:** As wind turbine blades become longer, the blade roots tend to become larger. The objective of this project is to develop more slender blades

from the root on. This project thus focuses on the integration of optical sensory fibres running from the blade root to the point with the widest chord. These fibres provide insight in the actual loads. As a consequence, the minimum required dimensions of the blade can be determined more accurately. The consortium consists of We4Ce engineering and TNO.

- Winds of the North Sea in 2050: In 2050, up to 60 GW of wind power is foreseen in the Dutch North Sea. It is vital to better understand the interactions between a large-scale roll-out of wind energy and the atmosphere. Global blockage, farm-to-farm interactions, deep array effects, and limits to yields because vertical exchange of momentum can no longer compensate for wake effects. This project therefore aims to provide a wind atlas which incorporates existing and future wind farms. Various models are used to develop the atlas. The consortium consists of Whiffle, KNMI, and TU Delft.

Test facilities and demonstration projects

- **Wind turbine rotor test rig.** At LM Wind Power's WMC Technology Center in the Netherlands, the largest wind turbine rotor test rig has been constructed. The rotor test rig will allow for verification of the strength and the dynamic behaviour of wind turbine rotors under the enormous mechanical loads caused by the large blades. Knowledge gained in the project will be used to improve existing design tools which, after verification through digital twin concepts, will contribute to the design of larger rotors.

- **TIADE:** Turbine Improvements for Additional Energy. In the Wieringermeer test site a 3.8 MW GE wind turbine is being equipped with easy exchangeable and heavily instrumented outer blade parts. Various profiles, blade tips, vortex generators and blade add-ons will be tested without the need to manufacture a completely new blade. The measured results will be compared with various models.

Collaborative research

- The Netherlands participates in 12 of the 21 active tasks. Four of them are new tasks: Wind farm flow control (44), Recycling wind turbine blades (45), Blade erosion (46), and Aerodynamics (47), the successor of task 29.

Impact of wind energy

Economic benefits and industry development

- The Dutch industry is strong in the field of offshore wind farm installation, the operation and maintenance of the wind farms, and the development of foundation technology. Industrial development in the Netherlands therefore mainly takes place in these fields and the Dutch industry exploits these developments. Typical examples of recent developments include the Tetrahedron crane for lifting higher using the same jack-up vessel, silent installation of monopiles using vibrator tools, docking station as base for autonomous inspections, and maintenance and complete extraction of monopiles by applying internal pressure.

- The Netherlands is also seeing great developments in other related fields, including: various developments on and for wind turbine blades, new connection techniques for masts and blades, and research into wind and wind farm climate. The companies and research institutes involved provide services to wind turbine OEMs and wind farm operators.

Next term

The Dutch climate goals for the reduction of greenhouse gasses are 49% in 2030 and 95% in 2050 compared to 1990 levels. For that reason, the Dutch government, nationally and locally, will stimulate and support the development of the generation of renewable energy in various ways. Especially wind, offshore but also onshore and solar PV will be the backbone of a renewable energy system.

However, the transition is not only about generating sufficient renewable energy or renewable electricity. It is also a huge economic and societal transition. Amongst others, the electrification of industry and households, spatial integration of wind and solar, reduction of energy consumption, transitions in agriculture, and insulation of houses are important and complex issues. For all these issues, policies are in place or have to be developed.