TECHNOLOGY FACTSHEET

WIND OFFSHORE

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Author	Luuk Beurskens
Sector	Electricity generation
	Renewable
ETS / Non-ETS	ETS
Type of Technology	Renewable
Description	Offshore wind power is a mature technology, deployed mainly in Europe and Asia. To produce more power against lower costs, wind turbine rotors have grown significantly over the past decades. The larger the diameter of a wind turbine rotor, the larger the swept area, which increases quadratically with the length of a blade. This makes upscaling both technically and economically attractive. The issue of landscape integration for onshore wind is an important barrier, which is much less relevant for offshore wind power. On the other hand, for offshore wind the impact on the marine environment is a point of attention. Offshore wind power benefits from economies of scale by increasing wind turbine capacity. Another offshore advantage is that maritime wind speeds on average are higher than continental wind speeds. Offshore wind turbines are combined in large wind parks, and three main approaches exist for locating the offshore wind turbines: attached to the seabed through a monopile, through a tripod or similar construction, or floating. For the typical Dutch North Sea circumstances, monopiles are commonly used. In offshore wind turbines, just like onshore, the turbine blades are driving a hub attached to an electric generator, located in the nacelle. The electricity is led to a power substation, from where the undersea cable is connected to the onshore electricity grid. The connection is often very long, from a few kilometers to several tens of kilometers, or above 100. Besides water depth and distance to shore, operation and maintenance costs are relatively high for offshore wind power, making maintenance concepts and strategies an important aspect of offshore wind power operation. The yield of wind turbines depends on the average annual wind conditions.
TRL level 2020	TRL 9
	According to the Global Wind Energy Council (GWEC, 2021), 707 GW onshore wind and 35 GW offshore wind are cumulatively installed at the end of 2020 worldwide. For Europe, GWEC estimates 194 GW onshore wind and 25 GW offshore wind (both 2020). For the Netherlands, Statistics Netherlands (CBS, 2021) estimates the offshore wind capacity by the end of 2020 to be 2460 MW (electricity generated in 2020: 4985 GWh, normalised). Dutch capacity for onshore wind in 2020 was 4159 MW (normalised electricity generated in 2020: 8960 GWh).

TECHNICAL DIMENSIONS

	Functional Unit		Value and Range								
Capacity	MW		10 MW (2020)								
			-			-			-		
Potential	NL	GWe	Current			2030			2050		
			2.46			11.5			108 GW		
			2.46	–	2.46	11.50	–	11.50	-	–	-
Market share		%	-			-			-		
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
Capacity utlization factor	1.00										
Full-load running hours per year	4735 hrs/year according to TNO (2021)										
Unit of Activity	PJ/year										
Technical lifetime (years)	For 2020: 20 years. For 2030 and 2050: 30 years										
Progress ratio											
Hourly profile	Yes										
Explanation	For 2020, the offshore wind realisation according to CBS is given. For 2030, the Climate agreement specifies that 49 TWh should be generated from offshore wind annually, translating into 11,5 GW (Klimaatakkoord 2019). The report Noordzee Energie Outlook (DNV, 2020) sketches two pathways to 2050: one in which renewable electricity import will still be needed (32 GW offshore wind in 2050, 170 TWh) and one in which the Netherlands could be self-sufficient in renewable electricity by 2050. The latter scenario assumes 72 GW (325 TWh) offshore wind by 2050. The potential for offshore wind on the Dutch continental plateau is even larger: 108 GW when economical optimisation is applied (6 MW/km2), and 180 GW based on technical optimisation (10 MW/km2), accepting higher losses and higher costs (DNV, 2020). For the potential the economical optimum is selected: 108 GW. Assumed turbine capacities are 10 MW in 2020 and 20 MW for the period after 2030. From 2030 onwards, lifetime for offshore wind power is estimated 30 years, increasing from 20 years in 2020 (Bulder 2021).										

COSTS

	Euro per Functional Unit	Current			2030			2050		
Year of Euro	2015									
Investment costs	mln. € / MW	2.27 (1.43)			2.40 (1.62)			2.21 (1.49)		
		-	–	-	-	–	-	-	–	-
Other costs per year	mln. € / MW	-			-			-		
		Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
Fixed operational costs per year (excl. fuel costs)	mln. € / MW	0.0234			0.0234			0.0224		
		0.0210	–	0.0257	0.0184	–	0.0291	0.0171	–	0.0288
Variable costs per year	mln. € / MWh	0.000012			0.000006			0.000006		
		0.000011	–	0.000013	0.000005	–	0.000007	0.000005	–	0.000007
Costs explanation	The cost figures mentioned here refer to wind farm zone IJmuiden Ver (70 km from shore, 100 km from grid) in the North Sea with a water depth of around 40 m. For investment costs, two figures are given: the difference lies in the costs for the (DC) power export cable and the offshore power substation: the first value includes these costs, the second (in parentheses) excludes them. All figures derive from TNO (2021), completed with assumptions where relevant. Development costs are included (based on the Dutch situation). For the year 2020, a virtual but realistic wind turbine (10 MW turbine with rotor diameter of 193 m, hub at 126.5 m) is assessed; for 2030, data have been based on further upscaling (20 MW turbine with rotor diameter of 290 m, hub at 175 m). For the year 2050, a 8% cost reduction (relative to 2030) is assumed for investment cost and fixed and variable costs are based on JRC (2018) and TNO (2021). Other reports mention cost declines that are even stronger: ASSET (2018) and ETIP Wind/WindEurope (2021) and BEIS (2020), for example. The offshore wind full load hours of 4735 hrs/year are based on the 2030 value from TNO (2021) and these are assumed to remain unchanged in the period 2030 - 2050 (note that, based on this figure, the 49 TWh/year by 2030 can be met from less than the 11.5 GW that are mentioned in Dutch policy documents). Assumptions on economic lifetime (30 years from 2030 onwards) further lower the electricity generation costs. The data ranges in the cost parameters refer among others to the distance to shore and consequently to the water depth. Deeper water results in more expensive foundations. The geographical scope of this range is not further specified here.									

ENERGY IN- AND OUTPUTS

	Energy carrier	Unit	Current			2030			2050		
Energy carriers (per unit of main output)	*Main output:*	PJ	-1.00			-1.00			-1.00		
	Electricity		-1.00	–	-1.00	-1.00	–	-1.00	-1.00	–	-1.00
	Wind energy	PJ	1.00			1.00			1.00		
			1.00	–	1.00	1.00	–	1.00	1.00	–	1.00
		PJ	-			-			-		
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
		PJ	-			-			-		
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
Energy in- and Outputs explanation											

MATERIAL FLOWS (OPTIONAL)

	Material	Unit	Current			2030			2050		
Material flows			-			-			-		
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
			-			-			-		
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
Material flows explanation											

EMISSIONS (Non-fuel/energy-related emissions or emissions reductions (e.g. CCS))											
	Substance	Unit	Current			2030			2050		
Emissions			-			-			-		
			Min	–	Max	Min	–	Max	Min	–	Max
			-			-			-		
			Min	–	Max	Min	–	Max	Min	–	Max
			-			-			-		
			Min	–	Max	Min	–	Max	Min	–	Max
			-			-			-		
			Min	–	Max	Min	–	Max	Min	–	Max
Emissions explanation											

OTHER											
Parameter	Unit		Current			2030			2050		
			-			-			-		
			Min	–	Max	Min	–	Max	Min	–	Max
			-			-			-		
			Min	–	Max	Min	–	Max	Min	–	Max
			-			-			-		
			Min	–	Max	Min	–	Max	Min	–	Max
			-			-			-		
			Min	–	Max	Min	–	Max	Min	–	Max
Explanation											

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