FACTSHEET ENERGY FROM WATER

TNO innovation for life

TECHNOLOGY DESCRIPTION	
Name technology	Tidal barrage
Date factsheet	11-12-2020
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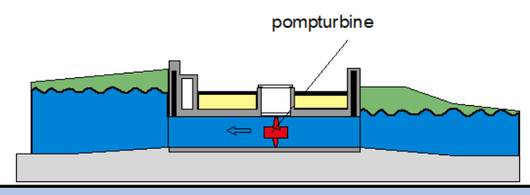
Description	Tidal barrage systems work on the principle that ebb and flow at sea cause a water level difference across a dam or flood defence structure. This potential energy can be harvested with turbines (Witteveen+Bos & CE Delft, 2019). In addition to bi-directional low-head turbines, free-flow turbines can also be used. There are a number of locations where bi-directional low-head turbines are in the picture for possible projects, partly due to a possible dual role as pump and turbine. That is why tidal barrage at dams has been included in a separate fact sheet, despite the overlap with the tidal stream category.

TRL LEVEL

	2020	2030	2050
TRL	7	9	9
Explanation	Advanced technology (TRL 9) that has been used in France for 50 years. Fish-safe turbines that are suitable for the smaller tidal range in the Netherlands are still in a demonstration phase (TRL 7) (Witteveen+Bos & CE Delft, 2019).		



Example of a tidal power plant with a bi-directional pump/turbine at the Brouwersdam. Source: Van Berkel and Van Bruggen (2019).

CURRENT INSTALLED CAPACITY AND ANNUAL ELECTRICITY PRODUCTION IN THE NETHERLANDS	
Installed capacity	0 MW
Author	0 GWh
Explanation	As of yet, no tidal barrage power plant has been installed in the Netherlands.

POSSIBLE LOCATIONS IN THE NETHERLANDS	
Locations	All possible locations are in Zeeland: the Brouwersdam, the Grevelingermeer and near the Waterdunen.
Explanation	The greatest potential is at the Brouwersdam (25-60 MW). The potential at the Grevelingermeer and the Waterdunen is more modest (1-2 MW).

POTENTIAL IN THE NETHERLANDS

		2030					2050				
	Unit	Main Source	Source 2	Source 3	Source 4	Source 5	Main Source	Source 2	Source 3	Source 4	Source 5
Energy potential (technical)	PJ/year	0.3 *Witteveen+B*	*Source*	*Source*	*Source*	*Source*	0.68 *RES Zeeland*	*Source*	*Source*	*Source*	*Source*
Energy potential (economic)	PJ/year	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*
Mitigation potential	*Unit*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*
Explanation	Potential in 2030 is based on 25 MW at the Brouwersdam, 2 MW at the Grevelingendam and 2 MW at the Waterdunen and 2400 full load hours (Witteveen+Bos & CE Delft, 2019). In the RES of Zeeland (draft version 2.0) the technical potential at the Brouwersdam and the Grevelingenmeer is estimated at 27.5 MW in 2030 and 65 MW in 2050. In 2030 these are demonstration projects and in 2050 commercial projects, which explains the increase the potential in 2050. Based on 2750 full load hours, this amounts to 0.29 PJ/year in 2030 and 0.68 PJ/year in 2050. (RES Zeeland draft version 28 June, 2019).										

COSTS

		2020					2030					2050				
	Unit	Main Source	Source 2	Source 3	Source 4	Source 5	Main Source	Source 2	Source 3	Source 4	Source 5	Main Source	Source 2	Source 3	Source 4	Source 5
Capex	€/kW	3380 *Calculation b*	2683 *Calculation*	5610 *Calculation*	5878 *Calculation*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*
Fixed Opex	€/kW/year	84.5 *Calculation b*	100 *Witteveen+*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*
Variable Opex	Unit	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*
Grid connection	€/kW/year	11 *Van Berkel e*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*
LCOE	€/kWh	0.1194 *Van Berkel e*	0.09 *Witteveen+*	0.14 *Witteveen+*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*
Explanation	Van Berkel and Van Bruggen (2019) have calculated a business case for a variant of the Brouwersdam tidal power plant of 20 MW, with 47-50 GWh electricity production (2350-2500 full load hours). Investment costs of € 67.7 million consist of the following components: civil engineering modifications (€ 3.5 million), turbines (€ 53.9 million) with a 10% uncertainty margin (€ 5.4 million) and connection costs (€ 4.8 million). For operational costs, only maintenance is included here (2.5% of investment per year). For annual grid connection costs, Van Berkel and Van Bruggen (2019) use a statement from RVO for offshore wind (11 €/kW/year). Witteveen+Bos & CE Delft (2019) compare several designs of the Brouwersdam, the most recent from 2018 is a 24.9 MW power plant that produces 60 GWh/year at 2400 full load hours. The other two variants are more expensive, but produce more electricity (41 MW/116 GWh/year and 24.6 MW/85 GWh/year). For free-flow turbines at the Brouwersdam, the LCOE is estimated at € 0.19/kWh (Witteveen+Bos & CE Delft, 2019). Due to the limited number of potential locations in the Netherlands, projects for learning effects depend on international developments. There is little information about this, so no assumptions have been made about learning effects and cost reductions for tidal barrage turbines towards 2030 and 2050. For cost reductions for free-flow turbines, see the fact sheet for tidal stream energy.															

ENERGY PROFILE	
Energy profile	Tidal energy is a predictable energy source, with 2400-3460 full load hours annually (Witteveen+Bos & CE Delft, 2019). Short-term (~ 1 hour) storage or postponement of production is possible at the Brouwersdam due to pump function (Jacob van Berkel, 2020).
Explanation	For the Brouwersdam, the application of a pump turbine is being considered, with which the water level can also be managed.

EXPORT POTENTIAL	
Export potential	Deltares (2019) identified 461 locations worldwide as potential locations for a power plant similar to the design of the Brouwersdam tidal power plant. Van Berkel and Van Bruggen (2019) estimate the energy potential of these 461 locations at 760 GW. With an 11% market share over 50 years (4,180 Brouwersdam-sized systems (20 MW)), Van Berkel and Van Bruggen estimate the export potential at € 171 million per year.
Explanation	Export potential is estimated by Van Berkel and Van Bruggen (2019) on the basis of 2% for engineering (20% of investment) and 1% for local guidance (80% of investment).

POSSIBLE NON-ENERGETIC SIDE EFFECTS	
Ecological effects	Fish-safe low-head turbines are under development. Scale turbines from Pentair Fairbanks Nijhuis were tested in the European project Pro-tide (Pro-Tide, 2015). Test results agreed well with model predictions (0-6% fish mortality, but with reasonable margins of uncertainty) (Pro-Tide, 2015). As per the calculations, fish mortality at the Brouwersdam will be <0.1% (Jacob van Berkel, 2020). Full scale tests have yet to be performed.
Multiple use	Turbines can be used that can also function as a pump. In such a case, the power plant can also be used for drainage (Witteveen+Bos & CE Delft, 2019). At the Brouwersdam, a power plant with a pump function is being considered (Van Berkel and Van Bruggen, 2019). In the case of the Brouwersdam project, energy production is a secondary use: the project is first of all a project to reduce (limited) tide on the Grevelingenmeer in order to improve the water quality (Deltares, 2020).
Social and landscape effects	The power plant will be integrated into an existing flood defense system, resulting in little or no additional impact on the landscape.
Material use/circularity	The turbines can usually be integrated into existing or in planned structures, so that the additional material use remains limited to the turbines. The turbines can last a long time.

BRONNEN

1	Witteveen+Bos & CE Delft (2019). Perspectieven energie uit water: Nationaal potentieel voor 2030 en 2050 (in Dutch).
2	Van Berkel en Van Bruggen (2019). Business case Variant 2 Getijdencentrale Brouwersdam (in Dutch).
3	RES Zeeland draft version 28 June 2019.
4	Jacob van Berkel (2020). Interview 27 May 2020.
5	Pro-Tide (2015). Evaluation of fish injury and mortality associated with scale models of the Pentair Fairbanks Nijhuis modified bulb turbine and the Water2Energy cross flow turbine.
6	Deltares (2020) Interview and written response to draft Factsheets.