FACTSHEET ENERGY FROM WATER

TNO innovation for life

TECHNOLOGY DESCRIPTION	
Name technology	Dynamic Tidal Power
Date of factsheet	11-12-2020
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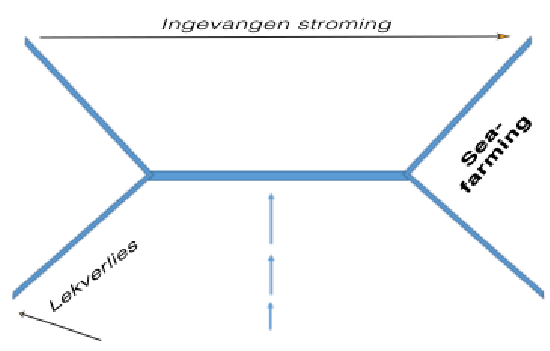
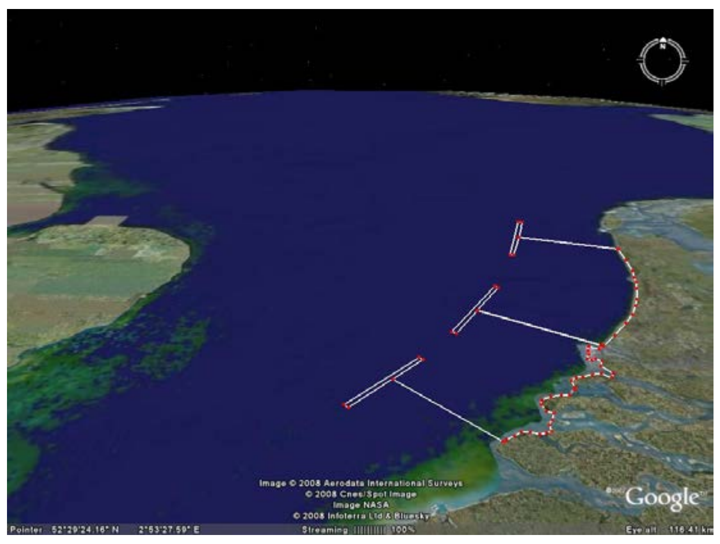
Description	Dynamic Tidal Power (DTP) is a technique which generates energy from the interaction between a tidal wave running along the coast and a dam that is tens of kilometers long at a right angle to the tidal wave. Two new tidal waves are created along the entire length of the dam, which are exactly in opposite phase to each other. So whenever a new crest appears on the left along the dam, there is a new valley on the right, and 6 hours later the other way around. As a result, along the total dam length, the head changes in size and direction over time. By creating openings (approx. 10% is considered optimum) for turbines in the dam, electricity can be generated (Hulsbergen, 2008, May, 2012). There are several variations of DTP, of which the two most important are: (1) a dam of 30 to 50 km from the coast with a perpendicular dam (T-profile) of several tens of kilometers at the end. (2) a dam of 30 to 50 km not connected to the coast with a so-called whale tail at both ends (Walraven, 2020). The yield of a DTP system increases with the length of the dam by a power of 2.5 (Hulsbergen, 2008). A 50 km dam therefore provides considerably more energy per kilometer at a lower cost than a 30 km dam. Mei (2020) applies an analytical model in which almost the same drop over a straight dam of 20, 30, 40 and 50 km is found as according to the approach of Kolkman and Hulsbergen (2005, 2008).

TRL LEVEL

	2020	2030	2050
TRL	3	5	9

Explanation: The principle of DTP, which, as described above, is based on a different principle than other forms of tidal energy, has a theoretical foundation (Mei, 2020; Hulsbergen, 2005). The principle of the creation of a height difference over a barrier has also been measured in, a.o., peninsulas (Hulsbergen, 2012). You could therefore say that proof-of-principle has been delivered (TRL 3). DTP as a concept has not yet been applied in practice, but the components that make up a DTP installation have already been proven on a large scale. The dam can be constructed using existing techniques with which Dutch coastal water contractors and Rijkswaterstaat have unique experience (Witteveen+Bos & CE Delft, 2019). The intended turbines have a large diameter (approx. 9 m) and must have good permeability to fish and other marine animals. Fish-safe turbines from Pentair Nijhuis have been tested on a scale of 0.5 m (van Berkel, 2015).





HUIDIG GEÏNSTALLEERD VERMOGEN EN JAARLIJKSE ELEKTRICITEITSPRODUCTIE

Geïnstalleerd vermogen	-
Jaarlijkse elektriciteitsproductie	-
Toelichting	DTP wordt nog niet toegepast.

POSSIBLE LOCATIONS IN THE NETHERLANDS

Locations	The location depends on the selected type of dam. The coast-connected dam will be built on the North Sea coast. The energy output of the dam depends on the maximum tidal flow velocity, which increases from approx. 0.8 m/s in the north to approx. 1.2 m/s in the south of the Dutch North Sea coast. Building two or three DTP dams makes it possible to continuously produce electricity. (Witteveen+Bos & CE Delft, 2019). The non-coast-connected dam can be built further from shore in the North Sea, for example in an area where wind farms are planned (Walraven, 2020).
Explanation	*Toelichting*

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
		0					220	112	100		
Energy potential (technical)	PJ/year	*Own estima*	*Bron*	*Bron*	*Bron*	*Bron*	*Witteveen+E*	*Hulsberge*	*Walraven,*	*Bron*	*Bron*
Energy potential (economic)	Unit	*Bron*	*Bron*	*Bron*	*Bron*	*Bron*	*Bron*	*Bron*	*Bron*	*Bron*	*Bron*
Mitigation potential	Unit	*Bron*	*Bron*	*Bron*	*Bron*	*Bron*	*Bron*	*Bron*	*Bron*	*Bron*	*Bron*

Explanation: Preparatory research, project development and construction will take such a long time that energy production with DTP will not be possible until a few years after 2030. The main source for the technical potential is based on the realization of two 50 km coast-connected dams with a T-piece of 50 km and 15 GW each (Witteveen+Bos & CE Delft, 2019). Source 2 is based on a single 50 km T-dam on the coast (Hulsbergen, 2014) and source 3 on a 50 km non-coast-connected dam with whale tails (Walraven, 2020) In Walraven (2020) there are two tables showing that the energy yield of a dam not connected to the coast is approximately 90% of a dam connected to the coast.

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
							2581	1690	2406			2581	1366	2406		
Capex	€/kW	*Source*	*Source*	*Source*	*Source*	*Source*	*Runia, 2014*	*Walraven,*	*Walraven,*	*Source*	*Source*	*Runia, 2014*	*Walraven,*	*Walraven,*	*Source*	*Source*
							26	26	26			26	19	33		
Fixed Opex	€/kW/yea	*Source*	*Source*	*Source*	*Source*	*Source*	*Runia, 2014*	*Runia, 201*	*Source*	*Source*	*Source*	*Runia, 2014*	*Walraven,*	*Walraven,*	*Source*	*Source*
Variable Opex	*Unit*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*
Grid connection	*Unit*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*
							0.07	0.032	0.055			0.07	0.032	0.055		
LCOE	€/kWh	*Source*	*Source*	*Source*	*Source*	*Source*	*Runia, 2014*	*Walraven,*	*Walraven,*	*Source*	*Source*	*Runia, 2014*	*Walraven,*	*Walraven,*	*Source*	*Source*

Explanation: A detailed design of a DTP system for the North Sea has not yet been created, cost estimates referred to in literature are based on various assumptions that will be tested and refined in the follow-up process. The estimates apply to the construction of a DTP system that will be operational after 2030 at the earliest. The same costs have been assumed for 2030 and 2050.

Runia et al (2014) base the costs for a 50 km T-dam on the following assumptions: Turbine dam excl.turb: M€ 140 / km, Closed T-dam: M€ 100 / km, Turbine generators: T50: € 1.1/W, electrical infrastructure: M€100 / GW and a number of smaller items (Hulsbergen and Steijn, 2020). 4% Interest has been taken into account. Together with operational costs, this leads to an LCOE of 0.07 €/kWh (Runia, 2014). Walraven (2020) assumes lower construction costs (turbine dam including turbine: M€ 400 / km, Closed T-dam: M€ 40 / km, no further specification) and an interest rate of 4.5%, which leads to a considerably lower LCOE: 0.032 €/kWh. The costs per kW depend on the chosen location, source 2 assumes a location where the tidal flow velocity is 1.2 m/s. At a more northerly location (source 3) the flow speed is 0.8 m/s. In both cases it concerns the costs of the DTP installation itself, excluding any batteries.

ENERGY PROFILE

Energy profile	A single dam follows the tide and delivers approximately 2000 full load hours per year (Witteveen+Bos & CE Delft, 2019). A baseload can be created by installing a double dam at a distance of approximately 150 km away or by combining it with a storage system.
Explanation	In principle, a single DTP installation follows the tide, whereby the tidal current at high and low tide is briefly zero. The electricity production of a single DTP dam thus follows a fluctuating, but very predictable profile. Two ways are mentioned to turn DTP into constant electricity production. (1) By placing two or three dams at a distance from each other in such a way that they are out of phase with the coastal tidal wave, a virtually flat production profile can be created (Witteveen+Bos & CE Delft, 2019). (2) By linking the DTP installation with a storage system (e.g. Li-ion batteries) where the peak production is stored, to be released when the production of the DTP system is at the minimum. (Walraven, 2020)

EXPORT POTENTIAL	
Export potential	DTP can be applied in shallow seas in which a tidal wave runs along the coast, which occurs in various parts of the world. It is important for the market potential that there is also sufficient demand. In addition to the North Sea, the Irish Sea and the Yellow Sea between China and Korea also meet these conditions. For the application of DTP in the Yellow Sea, research has been carried out and designs have been made by the Power group in collaboration with Chinese parties (Hulsbergen et al, 2012). DTP is an interesting product for Dutch companies that are active in hydraulic engineering. Antea group (part of Oranjewoud) and Arcadis are or have been involved in DTP. DTP would also be an extremely interesting export product for turbine manufacturers such as Pentair Nijhuis: there are approximately 2000 turbines in a 50 km DTP dam. Each DTP project will be unique, with unique challenges and political situations. Each project will require many preliminary studies, in which Dutch companies and knowledge institutes may also be involved, especially in the case of a successful implementation of a DTP project in the Netherlands.
Explanation	*Toelichting*
POSSIBLE NON-ENERGETIC SIDE EFFECTS	
Ecological effects	The ecological effects of DTP can potentially be very large and require extensive research. The use of fish-friendly turbines (with a mortality of <0.5%) can probably keep the death rate of fish low (Witteveen+Bos & CE Delft, 2019). Little is known about the secondary effects on marine mammals (such as migration routes). One or more 50 km coastal dams can bring about a major change in the anti-clockwise current in the North Sea, which, among other things, is used by fish larvae. Nutrient flows can also be strongly influenced. Furthermore, erosion and sedimentation patterns can change, as a result of which habitat suitability for various soil types will change over large parts of the coast (Asjes, 2020). Large parts of the Dutch coast (roughly north of Egmond and south of Hoek van Holland) are Natura 2000 areas. Research is needed - including model calculations - to map out the effects. In the past, similar research has been done on the effects of an airport at sea. Students at Wageningen University (Berlee et al., N.d.) also mention possible positive effects, in particular that a dam can function as a fish nursery ('artificial reef effect'). There is a debate among marine biologists whether such structures do not disturb the natural state of the North Sea, a sandy seabed, too much (Asjes, 2020)
Coastal protection or multiple use	DTP dams can contribute to coastal protection (Hulsbergen, 2012): the dams can have a damping effect on the astronomical tide, wave and storm set-up, which can reduce the maximum storm set-up on the coast. The dams could also provide higher water levels from a certain direction during storms, which may necessitate coastal reinforcement (Hulsbergen and Steijn, 2020). A limited increase in sand replenishment may also be necessary. The exact effects on coastal protection depend on the location and construction of the DTP dams and require further research. There are several options for multiple use of DTP dams. Sea-farming, especially at the T-pieces and whale tails, is another possibility for use (Walraven, 2020). A DTP dam can possibly be combined with an airport at sea or as a landing point for electricity cables from offshore wind farms (Witteveen+Bos & CE Delft, 2019).
Social and landscape effects	The construction of one or more DTP dams on the coast can obstruct access to ports or necessitate detours, which can hinder fishing, commercial shipping and recreational boating activities. It can also affect coastal tourism.
Material use/circularity	A DTP dam consists of large submersible concrete caisssons of approximately 100 m long, 35 m wide and 25 m high, with openings for turbines. A 50 km dam therefore contains about 500 caissons and a T-piece or whale tail will also consist of hundreds of caissons. In addition, a DTP system is comprised of approximately 2000 turbines that contain, among other things, steel and copper.

SOURCES	
1	Hulsbergen et al. (2008), 2nd International Conference on Ocean Energy (ICOE 2008), 15th – 17th October 2008, Brest, France.
2	Mei (2012), Applied Ocean Research 36 (2012) 22–25. 23.
3	Walraven (2020), Website Stichting DTP Netherlands, Dynamic Tidal Power, Aan de kust en in open zee (in Dutch), www.dtp-netherlands.eu, October 2020.
4	Witteveen+Bos & CE Delft (2019), Perspectieven elektriciteit uit water. Nationaal potentieel voor 2030 en 2050 (in Dutch), 22 October 2019.
5	Van Berkel (2015), Pilot Tidal Turbines C49Testing for Performance , pro-tide.eu, 28 augustus 2015.
6	Berlee et al., (N.d.), Dynamic Tidal Power in the North Sea, An exploration of ecological effects and socio-economic opportunities, Project studenten WUR voor Stichting DTP.
7	Runia et al. (2014), Responding to questions from Economic Affairs on Dynamic Tidal Power (DTP), 3 March 2014.
8	Asjes (2020), Interview with Jakob Asjes from Wageningen Marine Research in the framework of this project, 10 June 2020.
9	Hulsbergen en Steijn, 2020, Interview with Kees Hulsbergen and Rob Steijn in the framework of this project, 3 June 2020.
10	Mei (2020) - Tidal diffraction by a small island or cape and tidal power from a coastal barrier, Journal of Fluid Mechanics, vol.897, A13 1-24.
11	Hulsbergen, de Boer, Steijn en van Banning (2012) - Dynamic Tidal Power for Korea, 1st Asian Wave and Tidal Conference Series.