FACTSHEET ENERGY FROM WATER

TNO innovation for life

TECHNOLOGY DESCRIPTION

Name technology	Salinity Gradient Power
Date of factsheet	2-11-2020
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Description	Energy from the difference in salinity of two water bodies (also known as Salinity Gradient Power) can be extracted by placing membranes between a fresh and a salt water stream. There are two promising techniques for generating electricity from fresh-saltwater differences: Reverse ElectroDialysis (RED) and Pressure Retarded Osmosis (PRO) (Witteveen+Bos & CE Delft, 2019). In reverse electrodialysis (RED), two types of ion-selective membranes allow positive and negative sodium and chloride ions to pass through, creating a small current. By placing several membranes in series, a voltage difference is created, which is converted into electricity (Witteveen+Bos & CE Delft, 2019). Reverse electrodialysis is the opposite of the process used to desalinate salt water using membranes (electrodialysis or ED). With Pressure Retarded Osmosis the membrane allows water to pass through, but not dissolved salt. Because water naturally wants to flow from the fresh to the salt side, a pressure difference arises with which electricity can be generated via a turbine (Witteveen+Bos & CE Delft, 2019). The development of techniques that extract energy from fresh-salt water is highly dependent on the development of membranes. Learning effects of the development of comparable membranes for other applications, such as desalination of salt water or storage of electricity in fresh and salt water (see AquaBattery, 2020), are therefore also relevant.

TRL LEVEL

	2020	2030	2050
TRL	7	9	9
Explanation	Witteveen+Bos and CE Delft (2019) estimate the status of both RED and PRO at TRL 7 in 2019. There are a number of companies (REDstack in the Netherlands with a RED test installation and Saltpower in Denmark with a PRO test installation of a few kW) with plans for further development and upscaling, therefore it is expected that the technology will have reached TRL 9 by 2030.		

CURRENT INSTALLED CAPACITY AND ANNUAL ELECTRICITY PRODUCTION IN THE NETHERLANDS

Installed capacity	50 kW (2019)
Annual electricity production	Specify here
Explanation	The Dutch impact-scale-up REDstack has been running a prototype with a maximum capacity of 50 kW on the Afsluitdijk (Witteveen+Bos & CE Delft, 2019).

POSSIBLE LOCATIONS IN THE NETHERLANDS

Locations	Places of fresh water discharge into the ocean, such as rivers (including river arms of the Rhine (South Holland, Zeeland and the IJssel)), discharge sluices or pumping stations that discharge surface water or purified waste water. The Schelde, Eem and Volkerak also have potential. (Witteveen+Bos & CE Delft, 2019; REDstack, 2020)
Explanation	With a low supply of water in the summer, there is a discharge of 1,250 m3/s of fresh water into the ocean. Most fresh water flow into the ocean takes place a the Nieuwe Waterweg (Hoek van Holland or Tweede Maasvlakte): 1,000 m3/s (Witteveen+Bos & CE Delft, 2019).

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						21	22			
		Source	*Source*	*Source*	*Source*	*Source*	*Witteveen+Bos*	*Ecofys 2017*	*Source*	*Source*	*Source*
Energy potential (economic)	PJ/year	0									
		Ecofys 2017	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*
Mitigation potential	Unit										
		Source	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*

Explanation

To determine the technical potential, Witteveen+Bos & CE Delft (2019) assume that a maximum of half of the discharge at the Nieuwe Waterweg (500 m3/s) can be extracted, with regard to adaptability - a.o. the necessary construction in part of the waterway and shipping. The other 250 m3/s is considered fully exploitable. It is assumed that a total of 750 m3/s, and 1 MW per m3 flow rate should be technically feasible.

In order to utilise the full technical potential at the Nieuwe Waterweg, it is expected that the Maas estuary will have to be (partially) closed off, which will make integration difficult, unless the Maas estuary will be closed in the future due to water safety considerations. Smaller installations at the Nieuwe Waterweg that utilize part of the flow and potential may be easier to fit in. Witteveen+Bos & CE Delft (2019) do not expect a large-scale contribution from blue energy before 2030. The industry does expect a substantial contribution in 2030 (150 MW or approximately 4.3 PJ/year; 60 MW in Zeeland, 25 MW in Ijmuiden, 50 MW at the Afsluitdijk and 15 MW at the Europoort) (REDstack, 2020).

Up to 2030, the market potential (economic potential that is expected to be realized) is estimated by Ecofys (2017) at (rounded) 0 PJ/year. The market potential for 2035 is estimated at 1-8 PJ/year.

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	37000					8000					4000				
		PBL (2020)	*Source*	*Source*	*Source*	*Source*	*Berekening op l*	*Source*	*Source*	*Source*	*Source*	*Berekening o*	*Source*	*Source*	*Source*	*Source*
Fixed Opex	€/kW/year	213					240					120				
		PBL (2020)	*Source*	*Source*	*Source*	*Source*	*Berekening op l*	*Source*	*Source*	*Source*	*Source*	*Berekening o*	*Source*	*Source*	*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*
LCOE	€/kWh	0.41	0.41	1.00			0.1	0.15				0.05				
		PBL (2020)	*Witteveen+E*	*Witteveen+*	*Source*	*Source*	*Witteveen+Bos*	*REDstack 20*	*Source*	*Source*	*Source*	*Witteveen+B*	*Source*	*Source*	*Source*	*Source*

Explanation

In the SDE ++ 2020 costs for Salinity Gradient Power are estimated to be higher than € 0.200 / kWh (PBL, 2020). An exact LCOE is not mentioned, but it has been calculated by Witteveen+Bos & CE Delft (2019) as € 0.41 / kWh based on the investment and operational costs from the SDE ++.

The manufacturer REDstack expects a cost price of 0.10-0.15 € / kWh based on a business case made by EY (2018), with 0.10 € / kWh for power plants larger than 50 MW. Given REDstack's target of installing 150 MW by 2030, it is possible that this limit will be reached by 2030. Another estimate for the future cost of Salinity Gradient Power lies at 0.19 €/ kWh for a 1 MW power station (Witteveen+Bos & CE Delft, 2019).

Witteveen+Bos & CE Delft (2019) estimate reductions to 0.10 € / kWh in 2030 and to 0.05 € / kWh in 2050 are possible. The investment costs and fixed O&M costs are calculated on the basis of the assumption that fixed O&M costs are 3% of the investment costs (Ecofys, 2007), an interest rate of 5.6% (PBL, 2020) and a functional lifetime of 30 years.

ENERGY PROFILE

Energy profile	Salinity Gradient Power is a baseload energy source. Installations can easily be switched on and off. Buffering (postponing production) is possible (REDstack, 2020).
Explanation	There are seasonal variations in flow, which can have an effect on electricity production. Current concepts are dimensioned for minimum available flow, taking into account seasonal variations, shipping and other uses of river currents. In principle, this means that production can be carried out continuously throughout the year and at maximum design capacity, and the power plant can deliver as a base load. It is possible to install larger systems and to produce more or less depending on the flow rate, so that the plant will no longer operate as a base load.

EXPORT POTENTIAL

Export potential	Worldwide potential has been estimated at 1 TW (Ecofys et al., 2016) and also at 647 GW (IRENA, 2014). In principle, the RED and PRO technologies can both be applied to exploit the potential. REDstack is a global leader in the development of reverse electrodialysis and is therefore well positioned to supply this market (REDstack, 2020). The PRO technology is not being developed in the Netherlands, but international parties are working on it. Part of the international market can therefore possibly be used by PRO installations.
Explanation	There is a large potential for Salinity Gradient Power worldwide. Utilization of the knowledge of RED (membrane and stack knowledge) in desalination of brackish water and seawater into drinking water (with ED technology) also leads to considerable export potential, both in new installations and in the replacement market (REDstack, 2020).

POSSIBLE NON-ENERGETIC SIDE EFFECTS

Ecological effects	With large inlet volumes, inlet systems must be carefully designed to prevent the impingement and entrainment of fish and other organisms (Deltares, 2020). Recently the effect of a commercial REDstack installation at the Afsluitdijk on organisms has been investigated using field measurements (Deltares et al., 2020). In particular, the effects of sucking organisms into the inlets of the installations, of the pre-filtration of the water flows, of the energy recovery process and of the rinsing techniques were examined (REDstack does not use chemicals). In addition, model-based research was carried out into the effect of draining brackish water from the power plant in the Waddenzee. Conclusion was that the main effect of a Salinity Gradient Power plant on the environment will be landuse for the intake and pre-treatment of the water. If well designed, it is expected that other environmental effects and direct mortality effects on zooplankton and other organisms can be limited by mitigating measures. (Deltares et al., 2020). Noise and fish safety are not expected to be a problem because inlets and outlets can be closed off (REDstack, 2020).

Multiple use	In places where fresh water can no longer be drained off by a naturally ocurring slope, Salinity Gradient Power plants can also fulfill the function of drainage.
Social and landscape effects	Limited societal resistance is expected because power stations will be installed in places where they can be easily fitted (Witteveen+Bos & CE Delft, 2019). Installation at water level is possible, with a favorable effect on the efficiency of the process (REDstack, 2020). Use of space depends on the energy density of the membranes. For a 1 MW power station, an area of 1,500 square meters must be taken into account (Witteveen+Bos & CE Delft, 2019). According to REDstack, an installation takes up a comparable space as a coal-fired power station of the same size (REDstack, 2020). In addition to space utilization for the membrane stacks, space utilization for water intake and pre-filtration can be significant (Deltares et al., 2020)
Material use/circularity	RED membranes are designed to have a lifespan of 5-7 years, stacks 15-20 years, and a high degree of reuse is possible (REDstack, 2020).

SOURCES	
1	Witteveen+Bos & CE Delft (2019) - Perspectieven energie uit water: Nationaal potentieel voor 2030 en 2050 (in Dutch).
2	AquaBattery (2020) - https://aquabattery.nl/. Accessed 22 June 2020.
3	Ecofys (2017) - Overige hernieuwbare energie in Nederland. Een potentieel studie (in Dutch).
4	PBL (2020) - Eindadvies basisbedragen SDE++ 2020 (in Dutch).
5	EY (2018) - Blue energy investment memorandum (confidential).
6	Ecofys (2007) - Energie uit zout en zoet water met osmose (in Dutch).
5	REDstack (2020) - Interview 27 May 2020 and written response to draft factsheet (in Dutch).
6	RES Zeeland (2019) - Conceptversie 28 juni 2019 (in Dutch).
7	Ecofys, Netherlands Water Partnership, Blueconomy (2014) - Marktkansen en bijdrage aan verduurzaming van innovatieve technologie voor energie met water (in Dutch)
8	IRENA (2014) - Salinity gradient energy: Technology brief.
9	Deltares, Wageningen Marine Research, NIOZ, ZiltWater en REDstack (2020) - Onderzoek omgevingseffecten blue energy (in Dutch).
10	Deltares (2020) - Interview and written response to draft factsheets.