FACTSHEET ENERGY FROM WATER

TNO innovation for life

TECHNOLOGY DESCRIPTION

Name technology	Hydropower
Date of factsheet	10-11-2020
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Description	In this factsheet, hydropower at weirs in large rivers and hydropower at weirs in streams are viewed together. The hydroelectric power stations in rivers and streams operate on the same principle, the main difference being the size of the power stations. A river hydroelectric power station consists of three elements: a lock complex to allow ships to pass through, the hydroelectric power station and an (adjustable) weir that pushes up the water, but allows the excess water that cannot pass through the power plant to go through (Witteveen+Bos & CE Delft, 2019).

TRL LEVEL

	2020	2030	2050
TRL	8	9	9

Explanation: Advanced technology with which there already is a lot of experience. First commercial applications (TRL 8) of fish-safe turbines that are also suitable for low head locations (Witteveen+Bos & CE Delft, 2019).

Source: http://www.microhydropower.net/nl/linne.php

CURRENT INSTALLED CAPACITY AND ANNUAL ELECTRICITY PRODUCTION IN THE NETHERLANDS

Installed capacity	35 MW
Annual electricity production	100 GWh (0,37 PJ)
Explanation	This concerns larger installations: 25 MW in the Maas (79 GWh/year) and 10 MW (24 GWh/year) (Witteveen+Bos & CE Delft, 2019). There are also smaller installations in weirs in streams and watercourses (order of 10-100 kW each) (Witteveen+Bos & CE Delft, 2019).

POSSIBLE LOCATIONS IN THE NETHERLANDS

Locations	Seven weirs in the Maas, three weirs in the Nederrijn and a large number of weirs near streams and waterways, especially in Limburg, Brabant, Gelderland, Overijssel and Drenthe (Witteveen+Bos & CE Delft, 2019).
Explanation	In the second half of this decade, a start will be made on replacement of the weirs on the Maas, creating opportunities for expanding the installations and possible combinations with aquathermal (Deltares, 2020).

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)											
	Unit	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*
Energy potential (economic)		1	0.5				1				
	PJ/year	*Witteveen+Bo*	*Ecofys 2017*	*Source*	*Source*	*Source*	*Witteveen+Bo*	*Source*	*Source*	*Source*	*Source*
Mitigation potential											
	Unit	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*

Explanation: Economic energy potential of 1 PJ/year from Wittenveen+Bos & CE Delft (2019) is based on 0.9 PJ/year for large rivers and 0.1 PJ/year for smaller streams and waterways. The energy potential of individual weirs in streams is small, the potential lies in the large numbers (Witteveen+Bos & CE Delft, 2019). It is assumed that this is also the maximum extractable potential for 2050. This includes the 0.37 PJ/year already generated by existing hydropower plants.
Ecofys (2017) estimates market potential (economic potential to be expected) at 0.45-0.5 PJ/year, depending on policy.

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		8000	6000	4000	8333	12500										
	€/kW	*PBL (2020a)*	*PBL (2020b)*	*Witteveen-*	*Witteveen-*	*Witteveen-*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*
Fixed Opex		100	125													
	€/kW/year	*PBL (2020a)*	*PBL (2020b)*	*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																
	Unit	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*
LCOE		0.161	0.131	0.08	0.21											
	€/kWh	*PBL (2020a)*	*PBL (2020b)*	*Witteveen-*	*Witteveen-*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*	*Source*

Explanation:

The SDE ++ 2020 assumes 5,700 full load hours per year in the category Hydropower ≥ 50 cm for new power stations (PBL, 2020a). In the draft advice for the SDE ++ 2021, the investment costs have been reduced and the operational costs increased (PBL, 2020b). The SDE ++ assumes an economic lifetime of 15 years. Witteveen+Bos & CE Delft (2019) calculate with a lifespan of 40 years and an interest rate of 3%, which means that the LCOE is lower. They also calculate various cases. For large installations in rivers, lower full load hours are assumed (2,500-3,500), but these can be combined with other activities to decrease investment costs (€ 4,000/kW) and LCOE (€ 0.08-0.11/kWh). For smaller installations, the Dommelstroom power station is used as a reference (8,333 €/kW) and 50% higher investment costs are assumed for less favorable locations. The high limit value of the LCOE determined by Witteveen+Bos & CE Delft (2019) is based on a small power plant in an unfavorable location with 50% higher investment costs and 40% fewer charging hours.

No significant cost reductions are expected for large power stations before 2030 and 2050. Due to longlasting application in the Netherlands and abroad, there is little prospect for further cost reductions for large power stations (Witteveen+Bos & CE Delft, 2019). Standardization and mass production of small turbines for weirs in smaller streams and waterways can reduce investment costs to € 4,000/kW and LCOE to € 0.05/kWh (Witteveen+Bos & CE Delft, 2019).

The SDE ++ also includes a category for the renovation of existing power plants with a head of > 50 cm. Investment costs and O&M costs are lower than for new installations (€ 1,600/kW and € 80/kW/year) and the estimated cost is therefore also lower (€ 0.097/kWh).

ENERGY PROFILE

Energy profile	Depending on discharge in rivers, streams and waterways. Limited number of full load hours: 2400-3700 for existing large plants, 5700 for new large plants. 5000 for power stations in streams (PBL, 2020a; Witteveen+Bos & CE Delft, 2019).
Explanation	At low discharge there is not enough flow and at high discharge the head across the weir is too small to run the plant at full capacity (Witteveen+Bos & CE Delft, 2019).

EXPORT POTENTIAL

Export potential	Worldwide potential for small-scale hydropower from rivers is estimated by IRENA (2014) at 150-200 GW. A large number of these small-scale hydropower plants are potential installations without a dam, comparable to the installations in the weirs in the Netherlands. For installations with low head, there may be an export market for fish-safe turbines.
Explanation	The Netherlands are at the forefront of fish-safe turbines for low-head river hydropower. This can be an export opportunity (Jacob van Berkel, 2020).

POSSIBLE NON-ENERGETIC SIDE EFFECTS

Ecological effects	Fish mortality at existing turbines is the main concern in terms of ecological impact. Currently, fish mortality is around 10-30%, while licensing requires a maximum mortality of 0.1% if the cumulative mortality in the region is greater than 10% (Jacob van Berkel, 2020; Witteveen+Bos & CE Delft, 2019; Moquette et al., 2018). However, this can be solved by applying (combinations of): 1) replacing existing turbines with more fish-safe turbines; 2) mitigating measures to limit fish mortality at existing turbines; and 3) ensuring that new turbines to be constructed cause little additional fish deaths (Witteveen+Bos & CE Delft, 2019).
Multiple use	Some fish-safe turbines can also fulfill the function of fish passage (allowing fish to migrate upstream) (Witteveen+Bos & CE Delft, 2019). Power stations in streams can also serve as flow meters and help with more adaptive water management and flexible water level control (Witteveen+Bos & CE Delft, 2019).
Social and landscape effects	Integration is not a problem because the power stations are built in places with an existing weir in the river (Witteveen+Bos & CE Delft, 2019).
Material use/circularity	*Explanation*

SOURCES

1	Witteveen+Bos & CE Delft (2019) - Perspectieven energie uit water: Nationaal potentieel voor 2030 en 2050 (in Dutch).
2	Ecofys (2017) - Overige hernieuwbare energie in Nederland. Een potentieel studie (in Dutch).
3	PBL (2020a) - Eindadvies basisbedragen SDE++ 2020 (in Dutch).
4	PBL (2020b) - Conceptadvies SDE++ 2021 Energie uit water (in Dutch).
5	IRENA (2015) - Hydropower Technology Brief.
6	Jakob van Berkel (2020) - Interview 26 mei 2020 (in Dutch).
7	Moquette, Bil en de Laak (2018) - Waterkracht ontkracht (in Dutch).