TECHNOLOGY FACTSHEET

SMALL SCALE ALKALINE-ELECTROLYSIS H2 INSTALLATION

Date of factsheet	30-10-2018
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Sector	Transport
ETS / Non-ETS	Non-ETS
Type of Technology	Electrolysis

Description

Alkaline-electrolysis (AEL) is a known and developed technology used for production of hydrogen from water and is currently the main route used to produce electrolytic hydrogen. It is considered more developed than competing electrolysis technology Proton Exchange Membrane (PEM) (Weeda, 2018).

Electrodes in AEL are made of nickel or of porous metal structures (NOW 2018). Hydrogen ions move towards the cathode and hydroxide ions move towards the anode. A diaphragm is used to separate the two electrode compartments. Gas receivers are then used to collect the formed hydrogen and oxygen gases. To ensure good conductivity the used electrolyte should consist of high-mobility ions. Potassium hydroxide (KOH) is normally preferred over sodium hydroxide (NaOH) because of higher conductivity (Santos, Sequeira, & Figueiredo, 2013).

Cathodic reaction:
2 H2O + 2e- => H2 + 2 OH-

Charge carrier:
OH-

Anodic reaction:
2OH- => 0.5 O2 + H2O + 2e-

AEL operates at a temperature of around 60-70 degrees C (Weeda, 2018) and can produce hydrogen at a pressure of 30 bar (De Vita, et al., 2018), although installations that operate at atmospheric pressure also exist (ECN, 2018).. This is expected to increase to 40 bar by 2030 and 70 bar by 2050 (NOW, 2018).

Alkaline Electrolysis Cells have a limited ability to respond to load changes, which is essential when flexibility is required by the power system.
The current start-up time is around 50 minutes (NOW, 2018).

The electrolysis takes place in cells, which can be stacked (called a 'stack'). An installation can consist of multiple stacks.

TRL level 2020	TRL 9
	Alkaline electrolysers are commercially available (De Vita, et al., 2018).

TECHNICAL DIMENSIONS

Capacity	**Functional Unit**		**Value and Range**								
	MWH2;out;LHV		3								
			0			-			3		
Potential	NL	MW	**Current**			**2030**			**2050**		
			-			-			-		
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
Market share		%	-			-			-		
			-	–	-	*Min*	–	*Max*	*Min*	–	*Max*
Capacity utlization factor	0.97										
Full-load running hours per year	8,497.00										
Unit of Activity	PJ/year	0.03									
Technical lifetime (years)	20-40										
Progress ratio	0.82										
Hourly profile	No										

Explanation

According to (ECN, 2018) a typical small scale electrolyser installation, as offered by suppliers, is 5 MW, although smaller installations of around 300-500 kW are also found in literature (Hydrogenics, Colruyt, Sustesco, & WaterstofNet, 2016).

Typical stacks sizes reported by (ECN, 2018) for small scale installations are 0.5 to 2.25 MW.

The reported area requirements for an AEL installation of around 5 MW (ECN, 2018) vary from 500 m2 to 750 m2.

There appears to be no dedicated AEL installations in the Netherlands at the moment (2018), although chlo-alkali electrolysers are used by Akzo Nobel (salt and chemicals) and Sabic (in Bergen op Zoom).

An AEL installation can run 97% of the time (8497 hours per year) and is to be used to its fullest capacity (no hourly profile) according to (Hydrogenics, Colruyt, Sustesco, & WaterstofNet, 2016). This profile would change when connected to an intermittent source of electricity (for example, an offshore wind park).

The total installation has a technical lifetime (including maintenance) of 20-40 years (ECN, 2018) .

The cells and stacks have a lifetime of 9 to 15 years according to (Fraunhofer, 2014). The lifetime of the stacks is expected to increase according to (NOW, 2018) from the current 60,000 hours to 80,000 hours by 2030 and 110,000 by 2050.

Until 2030, the main evolutions expected for the alkaline technology are an increased size of the cell stack (from 1000 cm² to 2500 cm²) and an increased output pressure (from 10 to 60 bars) (Hydrogenics, Colruyt, Sustesco, & WaterstofNet, 2016).

AEL electrolysis is still developing and its investment cost are expected to decrease over time. (Detz, Reek, & van der Zwaan, 2018) estimates a learning rate of 18%.

COSTS

Year of Euro	2015								
Investment costs	**Euro per Functional Unit**	**Current**			**2030**			**2050**	
	mln. € / MWH2;out;LHV	1.82			1.38			1.26	
		0.9	–	3.3	0.4	–	2.0	0.4	–	1.3
Other costs per year	mln. € / MWH2;out;LHV	-			-			-		
		Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
Fixed operational costs per year (excl. fuel costs)	mln. € / MWH2;out;LHV	0.13			0.11			0.09		
		0.0	–	0.1	0.0	–	0.1	0.0	–	0.1
Variable costs per year	mln. € / MWH2;out;LHV	-			-			-		
		Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*

Costs explanation	(De Vita, et al., 2018) estimates a 1,650 EUR/kW_outputH2 (1,177 EUR/kWinput), that will drop sharply to 380 EUR/kW_outputH2 (271 EUR/kWinput) in 2030 and will ultimately go down to 300 EUR/kW_outputH2 (214 EUR/kW/input) (Hydrogenics, Colruyt, Sustesco, & WaterstofNet, 2016) assumes 2,000 EUR/kW_input_elec, which goes down to 1,200 EUR/kW_input_elec by 2030 and 660 EUR/kW_input_elec by 2050 (note that the size of the installation also increases to 1,500 MW). According to (De Vita, et al., 2018) the fixed OPEX cost are 41 EUR/kWoutput/yr, this is expected to go down to 17 EUR/kWoutput/yr in 2030, and to 15 EUR/kWoutput/yr in 2050. Assuming a conversion efficiency of 71.35% of electricity to hydrogen (HHV), the current OPEX cost are 29 EUR/kWinput/yr and goes down to 12 EUR/kWinput/yr in 2030 and 11 EUR/kWinput/yr in 2050. The CAPEX of (Hydrogenics, Colruyt, Sustesco, & WaterstofNet, 2016) (2,000 EUR/kW_input_elec, is for a hydrogen refuelling station for cars, 500 kW in size, with a compressor for 900 bar. Also described is a limited storage for the output of half a day of electrolyser full load operation, being approximately 100 kg. The civil works cost are 100.000 €, and connection cost to the public power grid is 50.000 € (limited, low voltage connection). According to (Hydrogenics, Colruyt, Sustesco, & WaterstofNet, 2016) the OPEX for a small scale AEL installation is currently 80 EUR/kW/year, and is expected to go down to 64 EUR/kW/year in 2030 and 56 EUR/kW/year in 2050. (NOW, 2018) (does not differentiate in CAPEX for large scale and small scale installations) assumes a current CAPEX of 620 – 1,220 EUR/kWel, which is expected to go down to 410 – 970 EUR/kWel by 2030, and 250 – 750 EUR/kWel by 2050. A major component of AEL equipment is the cell stack (about 30% of the total equipment cost) (Hydrogenics, Colruyt, Sustesco, & WaterstofNet, 2016), which need to be replaced once during the the total installation's lifetime. Used factors to convert the CAPEX and OPEX found in the literature to the values above: Energy content hydrogen HHV of 12.7 MJ/m3 (source: Bossel, Ulf & Eliasson, Baldur (2003) Energy and The Hydrogen Economy) Energy content hydrogen LHV of 10.8 MJ/m3 (source: RVO (2018) The Netherlands list of fuels) Density H2 at STP 0.0899 kg/m3 (source: https://encyclopedia.airliquide.com/)

ENERGY IN- AND OUTPUTS

	Energy carrier	Unit	Current			2030			2050		
Energy carriers (per unit of main output)	*Main output:* hydrogen	PJ	-1.00			-1.00			-1.00		
			-1	–	-1	-1	–	-1	-1	–	-1
	electricity	PJ	1.55			1.50			1.47		
			1	–	2	2	–	2	1	–	1
		PJ	-			-			-		
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
		PJ	-			-			-		
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*

Energy in- and Outputs explanation	The energy efficiency of the AEL system is defined by the amount of kg H2 can be produced per electricity input (kWh). According to (Weeda, 2018) and (De Vita, et al., 2018) this is currently 55 kWh/kg_H2 (or 60.7%, assuming an energy content for H2 of 10.8 MJ/m3 and an energy density of 0.0899 kg/m3 LHV, or 72% based on HHV). The energy efficiency may exceed 85% (HHV based) in the long term (De Vita, et al., 2018). According to (NOW, 2018) the current energy consumption for a 10 MW AEL installation is currently (2018) around 4.6 kWh/m3_H2, by 2030 it will be 4.5 kWh/m3_H2 and by 2050 it will be 4.4 kWh/m3_H2. Assuming a density of 0.0899 kg/m3 this translates to a current energy consumption of 52.3 kWh/kg_H2. This is expected to lower to 50.1 kWh/kg_H2 by 2030 , and to 48.9 kWh/kg_H2 by 2050.

MATERIAL FLOWS (OPTIONAL)

	Material	Unit	Current			2030			2050		
Material flows		kg H2	-1.00			-1.00			-1.00		
			-1.0	–	-1.0	-1.0	–	-1.0	-1.0	–	-1.0
		kg water	14.50			14.50			14.50		
			14.5	–	14.5	14.5	–	14.5	14.5	–	14.5

Material flows explanation	According to (Hydrogenics, Colruyt, Sustesco, & WaterstofNet, 2016), around 1.3 liter/Nm3_H2 is required (14.5 kg_water/kg_H2)

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	

REFERENCES AND SOURCES

Weeda (2018). Routekaart Waterstof TKI Nieuw Gas

NOW (2018). Industrialisierung der Wasserelektrolyse in Deutschland

De Vita et al. (2018). Sectoral integration- long term perspective

Hydrogenics et al. (2016). Power to Gas

DNVGL (2017). rapport verkenning waterstofinfrastructuur

E4tech et al. (2014). Development of water electrolysis in the European Union

Detz, R.J., Reek, J.N., & van der Zwaan, B.C. (2018). The future of solar fuels

Pesonen, O. & Alakunnas, T. (2017). Energy storage.

Berenschot (2017). Electrification in the Dutch process industry

ECN. (2018). Internal industrial electrolyser data.

Santos, D., Sequeira, C., & Figueiredo, J. (2013). Hydrogen production by alkaline water electrolysis.