TECHNOLOGY FACTSHEET

COMPRESSED HYDROGEN STORAGE

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Sector	Hydrogen
ETS / Non-ETS	Non-ETS
Type of Technology	Storage
Description	Stationary storage of compressed gaseous hydrogen at 200 bar in steel or aluminum vessels (or commonly refered to as Type-I tanks). Applications are at industrial sites or at H2 filling stations for mobility services. The storage installation consists of a compressor, a rack of storage vessels and an expander, which can be a simple valve. A typical unit consists of a rack of vessels able to store 500 kg or, equivalently, 16.7 MWh of hydrogen. The capacity of the compressor is typically 50-60 kg/h, or 1.67-2 MW_H2. For storage up to 200 bar specific cooling is not required. The storage units may either be placed on the H2 pipeline or in the distribution network. Inlet pressures to the compressor may vary between 1 -70 bar. The volumetric density of hydrogen compressed at 200 bar and 273°C is 15.6 kg/m3 or 520 kWh/m3 (Lower Heating Value). Investment cost of compressed hydrogen storage consists of major two parts, the costs of the vessels which scale with the amount of hydrogen (kg or MWh) that can be stored, and the cost of the compressor which scale with the maximum flow of hydrogen (kg/h or MW_H2) into the compressor. Here we use MW as the unit of capacity for the installation.
TRL level 2020	TRL 9
	Widely used technology, suppliers e.g. NEL Hydrogen.

TECHNICAL DIMENSIONS

	Functional Unit		Value and Range								
Capacity	MW		2.00								
			1.67			-			2.00		
			Current			2030			2050		
Potential			-			-			-		
			Min	–	Max	Min	–	Max	Min	–	Max
Market share		%	-			-			-		
			Min	–	Max	Min	–	Max	Min	–	Max

Capacity utlization factor	1.00
Full-load running hours per year	8,256.00
Unit of Activity	PJ/year
Technical lifetime (years)	25.00
Progress ratio	
Hourly profile	No
Explanation	All energy data refer to the H2 Lower Heating Value of 120 MJ/kg or 0.033 MWh/kg. The capacity corresponds to H2 flows of 50-60 kg/h.

COSTS

Year of Euro	2015

	Euro per Functional Unit	Current			2030			2050		
Investment costs	mln. € / MW	0.48			0.38			0.18		
		0.38	–	0.48	0.38	–	0.38	0.18	–	0.29
Other costs per year	mln. € / MW	-			-			-		
		Min	–	Max	Min	–	Max	Min	–	Max
Fixed operational costs per year (excl. fuel costs)	mln. € / MW	0.01			0.01			0.00		
		0.01	–	0.01	0.01	–	0.01	0.00	–	0.00
Variable costs per year	mln. € /	-			-			-		
		Min	–	Max	Min	–	Max	Min	–	Max

Costs explanation	The costs were derived for a typical installation with a 500 kg H2 storage capacity and 50-60 kg/h compressor capacity. For installations with a different ratio of storage and compressor capacity, corrections must be made. Costs of the tank are 470-600 €/kg H2 for 2020 (FCHJU, 2017; Danish Energy Agency, 2018). Costs of the compressor depend on the H2 flow required and on the pressure range. The higher cost values refer to ambient inlet pressure, the lower to 30 bar inlet presure. Fixed operational costs are 2% per year of the CAPEX. The Danish Energy Agency foresees significant cost reductions (order 50%) both for the vessels and the compressors. For the vessels this is due to a reduction of the amount of steel used and steel cost development. In the case of the compressor, technology modificaton and industry growth are the drivers for cost reduction.

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		
			-1.00	–	-1.00	-1.00	–	-1.00	-1.00	–	-1.00
	Hydrogen	PJ	1.00			1.00			1.00		
			1.00	–	1.00	1.00	–	1.00	1.00	–	1.00
	Electricity	PJ	0.07			0.06			0.06		
			0.07	–	0.12	0.06	–	0.06	0.06	–	0.10
		PJ	-			-			-		
			Min	–	Max	Min	–	Max	Min	–	Max

Energy in- and Outputs explanation	The electricity input is mostly compression energy. This depends strongly on the inlet pressure. Lower values apply to 30 bar inlet pressure, higher values to ambient. For 2020 the lower value assumes a compression energy 2 kWhe/kg H2, the higher value 4 kWhe/kg H2. Auxiliary equipment use is equivalent to 1% of the H2 output. Storage losses are negligible, the permeation of the tanks is 2.84×10-27 mol/s/m/MPa1/2.

MATERIAL FLOWS (OPTIONAL)

	Material	Unit	Current			2030			2050		
Material flows			-			-			-		
			Min	–	Max	Min	–	Max	Min	–	Max
			-			-			-		
			Min	–	Max	Min	–	Max	Min	–	Max
Material flows explanation											

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										

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	
1	FCH JU (2017) - Study on early business cases for H2 in energy storage and more broadly power to H2 applications. Final report www.fch.europa.eu/sites/default/files/P2H_Full_Study_FCHJU.pdf.
2	Danish Energy Agency and Energinet (2018) - Technology Data -Energy Storage.http://www.ens.dk/teknologikatalog.
3	NREL (2014) - Hydrogen Station Compression, Storage, and Dispensing. Technical Status and Costs. Technical Report NREL/BK-6A10-58564.
4	NREL (1998) - Amos WA. Costs of storing and transporting hydrogen (1998) NREL/TP-570-25106.
5	https://nelhydrogen.com/product/hydrogen-supply-storage-ss001/