Smart Ways for In-situ Totally Integrated and Continuous Multisource Generation of Hydrogen

D8.7: Annual Data Reporting

WP , T 8.2

Date of document

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Technical References

Project Acronym	SWITCH
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Project Coordinator	Luigi Crema - FBK crema@fbk.eu
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[1] PU = Public

PP = Restricted to other programme participants (including the Commission Services).

RE = Restricted to a group specified by the consortium (including the Commission Services).

CO = Confidential, only for members of the consortium (including the Commission Services).

Versions

Revision Version	Date	Changes	Changes made by Partner
0.1	8 July 2021	First release	Diego Giuliani (FBK)
0.2	29 July 2021	Second release	Diego Giuliani (FBK), Chiara Pellegrini (FBK)
0.3	30 July 2021	Third release (including feedback from all partners)	Diego Giuliani (FBK), Chiara Pellegrini (FBK)
1.0	02 August 2021	Final release after quality check	Diego Giuliani (FBK), Chiara Pellegrini (FBK)

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1 Introduction

The SWITCH project aims to develop an in-situ, fully integrated and continuous multisource hydrogen production system, based on solid oxide cell technology. The core of the system is a reversible Solid Oxide Cell (SOC) operating in two modes: Electrolysis Mode (SOE) and Fuel Cell Mode (SOFC). In electrolysis mode, the SWITCH system will use renewable electricity, water and heat to produce green hydrogen, with no emissions. In fuel cell mode, the SWITCH system will use natural gas or bio-methane to produce grey or green hydrogen, electricity and heat when renewable power is not available.

Figure 1: The SWITCH system is designed for integration at hydrogen refuelling stations (HRS).

This deliverable reports the data uploaded in the TRUST (Technology Reporting Using Structured Templates[2]) platform by the SWITCH partners in the first year of the project. The data concern the descriptive and operational parameters of the Electrolyser (SOE mode) and the Fuel Cell System (SOFC mode).

[2] https://trust.fch.europa.eu

2 SWITCH - Electrolyser

2.1 Descriptive parameters

Nr.	Title/Display Name	Value	Data Provider Comment
1	Country	Netherlands	
2	Town	Amsterdam	
3	Postcode	1031HW	
4	Deployment date	01/06/2022	
5	Technology	SOEC - Solid oxide electrolysis cell	
6	Electricity origin	Solar|Wind|Grid	
7	Electrolyser manufacturer	SOLIDpower	
8	Stack manufacturer	SOLIDpower	
9	KPI - Electrolyser Footprint	51.2 m2/MW	Footprint referred to the SOE unit, BoP not included.
10	Electrolyser price	300000 EUR	indicative price for a SOE module only.
11	System minimum power	15%	
12	Stack nominal capacity	18.75 kW	Power of each stack included in the 75 kW SOE module.
13	Number of stacks	4	4 stacks arranged in one 75 kW SOE module.
14	Electrolyser Volume	1.74 m^3	Volume of a single 75 kW SOE module not including the BoP.
15	Input voltage	79 V	Input voltage DC for each stack of each SOE module.
16	Maximum overload capacity	10%	Indicative value.
17	Nominal hydrogen weight capacity	50 kg/day	
18	Nominal power	75 kW	One SOE module of 75 kW each.
19	Operating pressure	1.05 bar	Absolute pressure.
20	Operating temperature	750 °C	Range of temperature between 700°C and 790°C.
21	Power converter	AC/DC	

22	Power usage of auxiliary equipment at nominal capacity		No data available.
23	Power usage of auxiliary equipment - in standby		No data available.
24	Rated stack electrical efficiency (HHV, DC current)	109%	Since it is a HT electrolyser, the electrical efficiency referred to the H2 HHV is more than 100%.
25	Rated stack durability	40000 h	Based on durability data of stacks in SOFC mode.
26	Rated system lifetime		Not defined yet.
27	Rated system electrical efficiency (HHV, AC current)	78%	Taking into account an estimated AC/DC conversion efficiency of 95% and the electrical power for steam generation.
28	Hydrogen purity	99.999%	
29	KPI- Estimated CAPEX of electrolyser @ 100MW annual production scale	1500 EUR/(kg/d)	Including BoP, LSM stack module.
30	KPI- CAPEX electrolyser	412000 EUR	5500 €/kW SoE including the BoP and LSM stack module.
31	KPI- OPEX @ 10 years	360 EUR/(kg/d)/yr	Actual value referred to the electrolyser only (without the BoP), including one stack set replacement and general maintenance on the LSM module.
32	KPI - Catalyst at the cathode	LSCF	
33	KPI - Catalyst at the anode	Ni-YSZ	
34	KPI - Reversible capacity of the Electolyser (Specific System)	33%	The SOE module can produce 25 kW of electrical power in SOFC mode.

2.2 Operational parameters

Nr.	Title/Display Name	Value	Data Provider Comment
1	Days of operation	7.5 day	
2	Start date for reporting	01/01/2020	
3	End date for reporting	31/12/2020	
4	Days of operation - cumulative	7.5 day	
5	Cost of the hydrogen produced		Not available. Only laboratory test of the SOE unit only have been carried out.

6	Voltage degradation rate in %/kh		Not available yet. Tests under potentiostatic operation.
7	Price/cost of electricity	20 EURc/kWh	Average cost in the country where the laboratory tests have been carried out.
8	KPI - Availability	100%	Only short laboratory tests has been carried out. During this tests the electrolyser was fully available.
9	Duration of planned maintenance		Not available.
10	KPI-Efficiency degradation per 1000 h for LT electrolysers		Not applicable for this SOE unit (HT electrolyser).
11	KPI-Estimated Efficiency degradation per 1000 h @ 10 year lifespan for LT electolysers		Not applicable for this SOE unit (HT electrolyser).
12	Energy consumption for H2 compression		No data available.
13	KPI- Electricity consumption @ nominal capacity		Not available yet.
14	Electricity consumed	10500 kWh	Energy consumed during lab testing.
15	Fraction of renewable energy input		Unknown.
16	Hours of operation	175 h	
17	Hours of operation - cumulative	175 h	
18	Maximum overload capacity	10%	Indicative value.
19	Maximum % power for 98% efficiency		No data available.
20	Number of safety incidents	0	No safety accident.
21	Minimum part-load operation	80%	Laboratory tests has been carried out at about 80% of full load with some test at full load.
22	Stack electrical efficiency (HHV, DC current)	113%	In SOE stacks of HT electrolyser the efficiency referred to HHV can be higher than 100% as far as the power to the steam generator has not taken into account.
23	System electrical efficiency (HHV, AC current)	108%	In SOE stacks of HT electrolyser the efficiency referred to HHV can be higher than 100% as far as the power to the steam generator has not taken into account.
24	KPI- OPEX		Not enough data available yet.
25	Thermal Energy Consumption @ nominal capacity	11.5 kWh/kg	This energy consumption is related to the steam generation only.

26	Transient response time		No data available.
27	Quantity of hydrogen produced	0.28 t	Indicative quantity of hydrogen produced during the laboratory tests.
28	KPI - Hot idle ramp time	45 s	
29	KPI - Cold start ramp time	86000 s	About 24 hours are required to heat up the SOE stack module from room temperature to the operating temperature (750°C).
30	KPI - Production loss rate for HT Electolyser		No data available.
31	KPI - Current Density	0.74 A/cm^2	
32	KPI-Cathode catalyst loading per W		No catalyst loading at the cathode since the unit is an SOE HT electrolyser.
33	KPI - Anode catalyst loading per W		No catalyst loading at the anode since the unit is an SOE HT electrolyser.
34	KPI - Reversible efficiency of the Electrolyser (Specific System)	62%	
35	KPI - Production loss rate for HT Electolyser @ 10 year lifespan		No data available.

3 SWITCH – Fuel Cell System

3.1 Descriptive parameters

Nr.	Title/Display Name	Value	Data Provider Comment
1	Country	Netherlands	
2	Town or region	Amsterdam	
3	Postcode	1031HW	
4	End user	Shell Technology Centre, Amsterdam	
5	Deployment date	01/06/2022	
6	Manufacturer	SolidPower/HyGear	
7	Model	LSM	Extensive model unit not assigned yet.
8	Stack manufacturer	SolidPower	
9	Technology	SOFC - Solid oxide fuel cell	
10	Stationary application	Off-grid power	System will produce both electrical power and hydrogen simultaneously.
11	Fuel	Natural gas | Biogas	
12	Does the fuel cell system include a fuel reformer?	yes	
13	Number of stacks	4	The stacks are integrated in a large system module (LSM) in bundles of 4 stacks. Each module is rated 25 kW.
14	Electrical power of stacks	6.25 kW	Power of a single stack in the LSM module.
15	Rated system electrical capacity	25 kW	Total power of the LSM module.
16	Rated system thermal capacity		No data available. Most of the produced heat is recycled into the process for steam generation.
17	KPI - Rated system electrical efficiency (LHV)	54%	It is expected the rated electrical efficiency of the SP commercial system Bluegen, which is 54% net AC.
18	KPI - Rated system thermal efficiency (LHV)		No data available.
19	Description	SOFC unit for power and H2 generation using	

		Natural gas/Biogas that can work also as HT electrolyser	
20	KPI - Lifetime of the fuel cell system	10 y	The system expected lifetime is 10 years, including one stack replacement. The system is considered at the end of life when the voltage drop of the replaced stack is more than 10%.
21	KPI - Stack durability	40000 h	There are on-going durability tests at SP. With the measured relative voltage drop of 0.26% / 1000 h, the expected life of the tack is 40'000 hours, when the total voltage drop is about 10%.
22	KPI - Reliability	40000 h	MTBF referred to a single stack.
23	Start-up time	72000 s	Time required for heat up the system from room temperature to hot stand-by, when the stacks are ready to be polarised.
24	Transient response time	1200 s	
25	Part load operation electrical efficiency - 30%	46 s	Referred to commercial FC complete system from SolidPower (Please note that the value is in [%] and not in [s]).
26	Part load operation electrical efficiency - 50%	53%	Referred to commercial FC complete system from SolidPower.
27	KPI - Hydrogen tolerance	100% (volume)	The FC system can operate with partially reformate natural gas, Syngas, Biogas, LNG and Hydrogen.
28	CO emissions at rated conditions		No data available yet.
29	NOx emissions at rated conditions		No data available yet.
30	SOx emissions at rated conditions		No data available yet.
31	Sound power level at rated condition		No data available yet.
32	KPI - CAPEX	10000 EUR/kWe	Actual cost of one stack modules (LSM) at current production level. It has not been considered the BoP and all the ancillary equipment.
33	Est. system CAPEX (per kW) @ mass production	500 EUR	Estimated cost for one stack modules (LSM) at mass production level. It has not been considered the BoP and all the ancillary equipment.
34	System installation costs		Data are not available yet.
35	Estimated Cost of spare parts	6250 EUR/kWe	Net cost of a stack replacement per kWe not including labour cost.
36	KPI - Land use / footprint	0.051 m^2/kW	Excluding BoP and ancillary equipment.

3.2 Operational parameters

Nr.	Title/Display Name	Value	Data Provider Comment
1	Start date for reporting	01/01/2020	
2	End date for reporting	31/12/2020	
3	Hours of operation	0 h	The FC system has not operated in 2020.
4	Days of operation	0 day	The FC system has not operated in 2020.
5	Hours of operation - cumulative	0 h	The FC system has not operated for electricity production since the project start.
6	Energy input from fuel	0 kWh	The FC system has not operated in 2020.
7	Electricity produced	0 kWh	The FC system has not operated in 2020.
8	Useful heat output	0 kWh	The FC system has not operated in 2020.
9	KPI - Availability		No data available.
10	Efficiency degradation rate		No available data yet. The FC system has not operated in 2020.
11	Power degradation rate		No available data yet. The FC system has not operated in 2020.
12	Number of safety incidents	0	The FC system has not operated in 2020.
13	Fuel		No fuel has been feed yet into the FC system since the system has not operated yet. Nevertheless, Natural gas and Biogas are expected to be used as feeding fuel in the frame of this project.
14	Fuel price		No fuel price paid in 2020 since the FC system has not operated in 2020
15	KPI - Operational and maintenance costs (OPEX)		No operational and maintenance costs took place in 2020 since the system has not operated in 2020.
16	KPI - Number of stack replacements	0	No stack has been replaced in 2020. The system has not operated.