**TECHNOLOGY FACTSHEET**

TNO

# SOLID-OXIDE ELECTROLYSIS

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|---|---|
| Date of factsheet | 16-11-2020 |
| Author | Binod Koirala |
| Sector | Hydrogen |
| | Production |
| ETS / Non-ETS | Non-ETS |
| Type of Technology | Electrolysis |
| Description | High-temperature solid-oxide electolyser (SOEC) is a technology for electrolysis of steam into hydrogen or co-electrolysis of steam and CO2 into syngas [1-6]. In this factsheet, the focus is on hydrogen production. Solid-oxide electrolyzers are most commonly used high-temperature electrolyzers [5] but it is also the least developed electrolysis technology [2]. Solid-oxide electrolysers operate between 650-1000 °C and already offers impressively higher efficiency level (93%, higher heating value (HHV)) than other electrolyzers [3]. The electrical efficiencies could be increased up to 97 % (HHV) by integrating derived heat and thermal coupling to exothermal processes such as chemical methanation [3]. Broadly, there are two categories of SOEC: electrolyte supported (operating temperature > 800 °C) and anode supported (operating temperature 600 -850°C). As it mainly requires ceramics and few rare materials for the catalyst layer, It has a substantial cost reduction potential in the future [6]. Yet, the need for external high-temperature heat source (preferably from renewables such as concentrated solar power (CSP) or geothermal or industrial waste heat) at vincinity also provides challenges to its economic viability [6]. However, It can, in principle, also be operated without external high-temperature heat sources by using heat recovery, high-efficiency insulation, and compensating heat losses from electrical heating. Despite high capacity and efficiency, the electrolyser currently has reached life-time of 25000 operation hours and technology improvements such as stabilising components materials, developing new materials and lowering the operation temperature (500 -700 C) are being done to improve it further [2]. Current capacities of operational SOEC system are in the range lower than 1 MW, however, a 2.6 MW SOEC system is currently being developed in Rotterdam within the framework of H2020 MULTIPLHY [7]. |
| TRL level 2020 | TRL 6 |
| | There are varying reports on current TRL level of SOEC technology. Adelung et al (2018) reports TRL 7 as the SOEC prototype has been demonstrated in a relevant operational environment [1] whereas Store&go(2019) reports that it has been demonstrated in an industrial environment with TRL 6 [3]. Hychain 3 reports TRL 5-6 for SOEC [5]. Solid-Oxide eletrolysis still needs large scale research and demonstration to reach the commercial stage. It is expected that the TRL 9 will be reached in 2030 [1]. |

**TECHNICAL DIMENSIONS**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Capacity | Functional Unit | | Value and Range | | | | | | | | |
| | MWe | | 5.00 | | | | | | | | |
| | | | 1.00 | | | - | | | 100.00 | | |
| Potential | | | Current | | | 2030 | | | 2050 | | |
| | | | - | | | - | | | - | | |
| | | | Min | – | Max | Min | – | Max | Min | – | Max |
| Market share | Global | % | - | | | 0.10 | | | 0.20 | | |
| | | | Min | – | Max | 0.10 | – | 0.10 | 0.20 | – | 0.20 |
| Capacity utlization factor | 1.00 | | | | | | | | | | |
| Full-load running hours per year | 8,000.00 | | | | | | | | | | |
| Unit of Activity | | | | | | | | | | | |
| Technical lifetime (years) | 20.00 | | | | | | | | | | |
| Progress ratio | - | | | | | | | | | | |
| Hourly profile | Yes | | | | | | | | | | |
| Explanation | Current functional capacities of SOEC system are below 1 MW. A 2.6 MW Sunfire SOEC demonstrator is being developed in Rotterdam within H2020 MULTIPLHY project . Based on available theoretical studies, 5 MW is used as reference functional capacity in this factsheet, with the range of 1-100 MW for the year 2020, 2030 and 2050. However, it is unlikely that 100 MW SOEC systems will be available in 2020 [3]. The expected lifetime is 20 years [8]. | | | | | | | | | | |

**COSTS**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Year of Euro | 2015 | | | | | | | | |
| Investment costs | Euro per Functional Unit | Current | | | 2030 | | | 2050 | |
| | mln. € / MWe | 1.96 | | | 1.06 | | | 0.53 | |
| | | 1.96 | – | 4.37 | 0.48 | – | 4.25 | 0.28 | – | 2.04 |
| Other costs per year | mln. € / MWe | - | | | - | | | - | |
| | | Min | – | Max | Min | – | Max | Min | – | Max |
| Fixed operational costs per year (excl. fuel costs) | mln. € / MWe | 0.13 | | | 0.05 | | | - | |
| | | 0.11 | – | 0.13 | 0.05 | – | 0.05 | Min | – | Max |
| Variable costs per year | mln. € / | - | | | - | | | - | |
| | | Min | – | Max | Min | – | Max | Min | – | Max |
| Costs explanation | Due to low TRL level, there are significant differences on the cost development of SOEC. Cost development of electrolysis systems related to scaling effects and technological learning [3]. The study estimated the global electrolysers capacity of 6400 -14200 GW in 2050 [3]. Further investigations into cost structures and experience rates are still necessary to allow reasonable estimations of future investment costs [3]. | | | | | | | | |

**ENERGY IN- AND OUTPUTS**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Energy carriers (per unit of main output) | Energy carrier | Unit | Current | | | 2030 | | | 2050 | | |
| | *Main output:* Electricity | PJ | 1.07 | | | 1.03 | | | 1.03 | | |
| | | | 1.05 | – | 1.10 | 1.02 | – | 1.05 | 1.02 | – | 1.05 |
| | Hydrogen | PJ | -1.00 | | | -1.00 | | | -1.00 | | |
| | | | -1.00 | – | -1.00 | -1.00 | – | -1.00 | -1.00 | – | -1.00 |
| | | PJ | - | | | - | | | - | | |
| | | | Min | – | Max | Min | – | Max | Min | – | Max |
| | | PJ | - | | | - | | | - | | |
| | | | Min | – | Max | Min | – | Max | Min | – | Max |
| Energy in- and Outputs explanation | SOEC already offers impressively higher efficiency level (93%, higher heating value) than other electrolyzers [3]. The electrical efficiencies could be increased upto 97 % by integrating derived heat and thermal coupling to exothermal processes such as chemical methanation [3]. As the temperature increases, lower electrical input is required increasing the electrical efficiency. To be specific, the electrical input required at 800°C is 25 % lower than at 100°C [5]. | | | | | | | | | | |

**MATERIAL FLOWS (OPTIONAL)**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Material flows | Material | Unit | Current | | | 2030 | | | 2050 | | |
| | | | - | | | - | | | - | | |
| | | | 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)**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Emissions | Substance | 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 |
| Emissions explanation | | | | | | | | | | | |

| OTHER | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Unit** | **Current** | | | **2030** | | | **2050** | | |
| Stack size | MWe | 0.50 | | | 1.00 | | | 3.00 | | |
| | | 0.50 | – | 0.50 | 1.00 | – | 1.00 | 3.00 | – | 3.00 |
| Current density | A/cm2 | 0.80 | | | 1.10 | | | 2.00 | | |
| | | 0.30 | – | 2.00 | 1.10 | – | 1.10 | 2.00 | – | 2.00 |
| Cold start duration | minutes | <60 | | | - | | | - | | |
| | | - | – | - | *Min* | – | *Max* | *Min* | – | *Max* |
| Technical lifetime | Hours | 20,000.00 | | | - | | | 100,000.00 | | |
| | | 20,000.00 | – | 50,924.00 | *Min* | – | *Max* | 100,000.00 | – | 100,000.00 |
| Explanation | The operating temperature varies between 650 - 1000 C. Regarding technical life time, Schmidt et.al reports lower and upper bound, an average is reported here [2]. The technical lifetime reported are for controlled conditions, the actual technical lifetime of SOEC in practical conditions is still unknown. | | | | | | | | | |

**REFERENCES AND SOURCES**


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