Task 32: Solid Oxide Cells (SOC)

Solid oxide cells (SOCs) enable flexible storage of renewable electricity and provide the best available efficiency for decentralized production of sustainable heat and power in applications scaling from one kW up to several MW. Due to the flexible operation in different modes and the usability of carbon containing gasses or fuels, SOCs provide solutions to numerous energy challenges under many different local, geographic, and political conditions. They help to integrate a high degree of energy production from renewable sources such as wind and solar into energy systems, to reduce CO_2 emissions, and to reduce the carbon footprint of energy production towards carbon neutral concepts. The key advantages of the SOC technology have been established as:

- High conversion efficiency
- Flexibility regarding fuel
- Low-cost materials and
- Possibility to produce/utilize heat.
- Insignificant NO_x, SO_x and particulate emissions, reduced CO_2 emissions
- Silent and vibration-free operation

Fuel cell mode (SOFC): High operating temperatures make SOFCs well suited for combined heat and power production (CHP). Fuel processor design is simplified compared to low temperature fuel cell types thanks to the possibility of direct oxidation of carbon monoxide and the use of hydrocarbon fuels via internal reforming reactions. SOFCs can be utilized for various applications with different power scales e.g. auxiliary power units for cars and trucks, residential combined heat and power production (CHP), distributed CHP or stationary power production. In particular, the most promising areas where pioneering companies and product development are looking at are:

- Mobile, military and strategic (< 1 kW)
- Auxiliary Power Units (APU) and back-up power (1 - 250 kW)
- Residential combined heat and power (1 - 5 kW)
- Stationary medium-large scale (20 kW - 10 MW)

Whereas fuel efficiency is proven, long lifetime of fuel cell systems under real-life operation is a challenge for the durability of both fuel cell stacks and system components. Significant improvements in this respect have been achieved in the last years: robust designs and more stable materials have been developed in laboratories worldwide, but these need to be engineered and assembled into end-use products with sometimes-aggressive utilization profiles. This poses a challenge both to the fuel cell stacks as well as the other components of SOFC systems. An operating lifetime of at least 40 000 hours in the case of small-scale systems and even more for large-scale systems is required, which calls for better overall designs, given by real operational feedback. At the same time, investment costs related to the deployment of SOFC systems has to be decreased as much as possible in order to enable breakthrough on the commercial energy markets and thereby generate this operational experience.

When compared to established technologies for energy production, e.g. engines or gas turbines, widespread commercialization of the SOFC technology is hindered by a relatively **high cost** of the SOFC-specific system components and limited availability of products, again due to the absence of developed markets and production.

Electrolysis mode (SOEC): Electrolysis based on solid oxide cells has been implemented in numerous, real-life mimicking laboratory set-ups and field demonstration. The potential for large-scale, flexible and long-term storage of renewable electricity by converting water to hydrogen through SOC electrolysis is acknowledged, especially in cases where waste heat is available to operate the system. Furthermore, co-electrolysis with captured CO_2 enables utilizing SOCs for delivering feedstock for liquid fuel production. In particular, the most promising areas where pioneering companies and product development are looking at are:

- Renewable energy storage: Long term and seasonal storage
- Hydrogen production for transportation and industrial use
- Carbon monoxide production (CO) for industrial use
- Syngas production (CO + H_2) for industrial use

Cost reduction, **long lifetime** and **availability** are the high-level objectives for the SOC technology in general, and for the AFC IA – Task 32 in particular. As an example, some critical KPIs for Solid Oxide Fuel Cell installations (100-250kWe) in successful commercialization are following:

- Capex < 1500 €/kWe
- Maintenance costs < 2,5 € Ct/kWh
- Lifetime > 15 years (operating hours > 8500/year)
- Thermo-cycling > 300
- Efficiency > 90% (Electrical efficiency > 60% & Thermal efficiency > 30%)

The means Task 32 intends to employ to reach these overall objectives are:

- The continuation and intensification of the open information exchange to focus and accelerate the development of SOC towards commercialization.
- The organization of a series of annual workshops where representatives from the participating countries present the status of SOC research, development and demonstration in their respective countries, in addition to discussing a selected topic.
- Where possible, these workshops will be linked to other relevant conferences, in order to maximize scientific impact and minimize travelling costs. The workshops lead to open discussions relating to common problems and will be organized to have realizable and achievable aims.

Active partners of Task 32 are Denmark, Finland, France, Germany, Italy, Japan, Korea, Sweden, Switzerland, United States and Netherlands.

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