IEA Technology Collaboration Programme
Advanced Fuel Cells

# POSITION PAPER ON SOLID OXIDE CELLS (SOCs)

**ANNEX 32 OF THE**
**ADVANCED FUEL CELL TECHNOLOGY COLLABORATION PROGRAMME**
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ANNEX 32

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**MAIN MESSAGE:** 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. SOC technology integrates solid oxide fuel cells (SOFC) and solid oxide electrolysers (SOE) which are based on identical ceramic technology.

**STATUS-QUO OF TECHNOLOGY:** The key advantages of the SOC technology have been established as: (i) high conversion efficiency, (ii) flexibility regarding fuel, (iii) low-cost materials and (iv) possibility to produce/utilize heat, (v) real technical ability of reversible operation.

SOFC have been utilized on an industrial and residential scale for years. In residential applications they produce combined heat and power (0.5-2 kWe) and large-scale systems (>1MWe) are used e.g. in biogas applications, with significant process heat produced as surplus. For example, in Europe SolidPower and in the US Bloom Energy and in the Japan Kyocera, Miura and Osaka gas are supplying SOFC systems commercially.

SOE have been implemented in numerous, real-life mimicking laboratory set-ups and in field demonstration, e.g. in steel plants. 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 Europe, Sunfire provides SOE systems on a pre-commercial basis, and the European development projects GrInHy and BALANCE are good examples of this technology in action.

Some critical current KPIs for SOFC installations of 100-250kWe are following:

- Capex > 4000 €/kWe
- Maintenance costs > 2,5 € Ct/kwh
- Lifetime > 10 years (operating hours > 8500/year)
- Thermo-cycling > 100
- Efficiency > 85% (Electrical efficiency > 55 % & Thermal efficiency > 30%)

**WHAT DOES THE FUTURE LOOK LIKE?** SOC technology is becoming a significant solution for a variety of applications. SOFC offer fuel flexibility, e.g. at biogas plants, and/or where the added efficiency is worth the extra investment, i.e. where fuel is expensive. SOE technology has the potential to be a major pathway for affordable, green hydrogen and thus becoming a cornerstone of the future hydrogen economies.

**HOW TO GET THERE?** For SOFC technology, effort should be put into reducing system cost through mass production of components and systems. The SOE technology is still at a pre-commercial stage and efforts need to be targeted to large-scale demonstrations that are integrated with renewable power sources and where waste heat is utilized.

Some critical KPIs for SOFC installations (100 to 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%)

To achieve cost targets by 2040 a minimum manufacturing volume of 250MW/year is required per manufacturer.

**DISCLAIMER:** Position paper made by the Technology Collaboration Programme on Advanced Fuel Cells (AFC TCP) and coordinated by the core group (Jari Kiviaho, Antti Pohjoranta, Anke Hagen, Olivier Bucheli, Robert Steinberger-Wilckens and Stephen McPhail). The presented paper intends to give an overview of the status and perspectives, was prepared using available sources. AFC TCP does not claim that the data provided is complete. AFC TCP functions within a framework created by the International Energy Agency (IEA). The position paper does not necessarily represent the views or policies of the IEA Secretariat or of its individual member countries.

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