Introduction/main features of high temperature electrolysis with SOEC

(**S**olid **O**xide **E**lectrolysis **C**ells)

Dr. Dimitrios Giannopoulos

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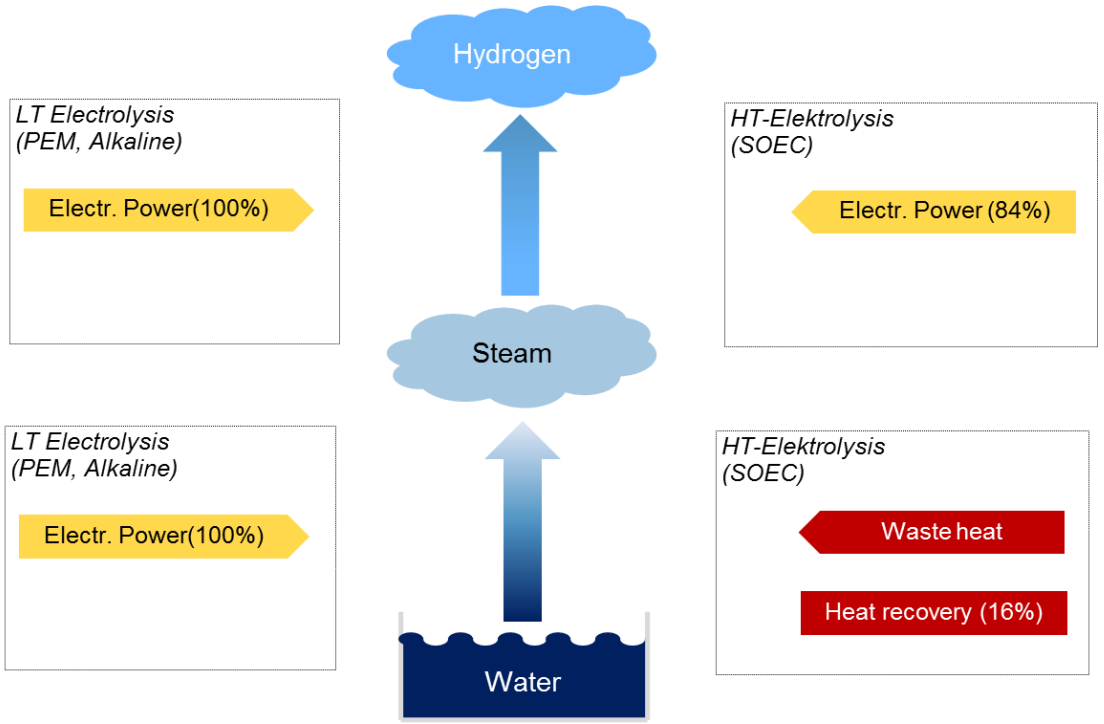
SOEC Key features

- SOEC operates at high temperatures (850°C) and therefore can utilise steam instead of water
- Utilising steam is a high benefit from efficiency point of view → no need to overcome evaporation enthalpy of water
    - Wherever excess heat for steam generation is available



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SOEC Key features

- SOC can be operated in both ways → rSOC
  - Electrolyser: SOEC – converting electrical energy to gas
  - Fuel Cell: SOFC – converting gas to electrical energy

- Additional to steam, CO_2 can be used → co-electrolysis
  - In the future this can be a key issue for production of syngas and methane
  - Reaction that takes place at HTE cell:

$$x \cdot H_2O + y \cdot CO_2 \xrightarrow[Co-electrolysis]{} x \cdot H_2 + y \cdot CO + \left(\frac{x+y}{2}\right) \cdot O_2$$

  - Water gas shift (WGS) reaction takes place even at OCV condition

$$H_2 + CO_2 \leftrightarrow H_2O + CO$$

→ main reaction at cell is likely to be steam electrolysis

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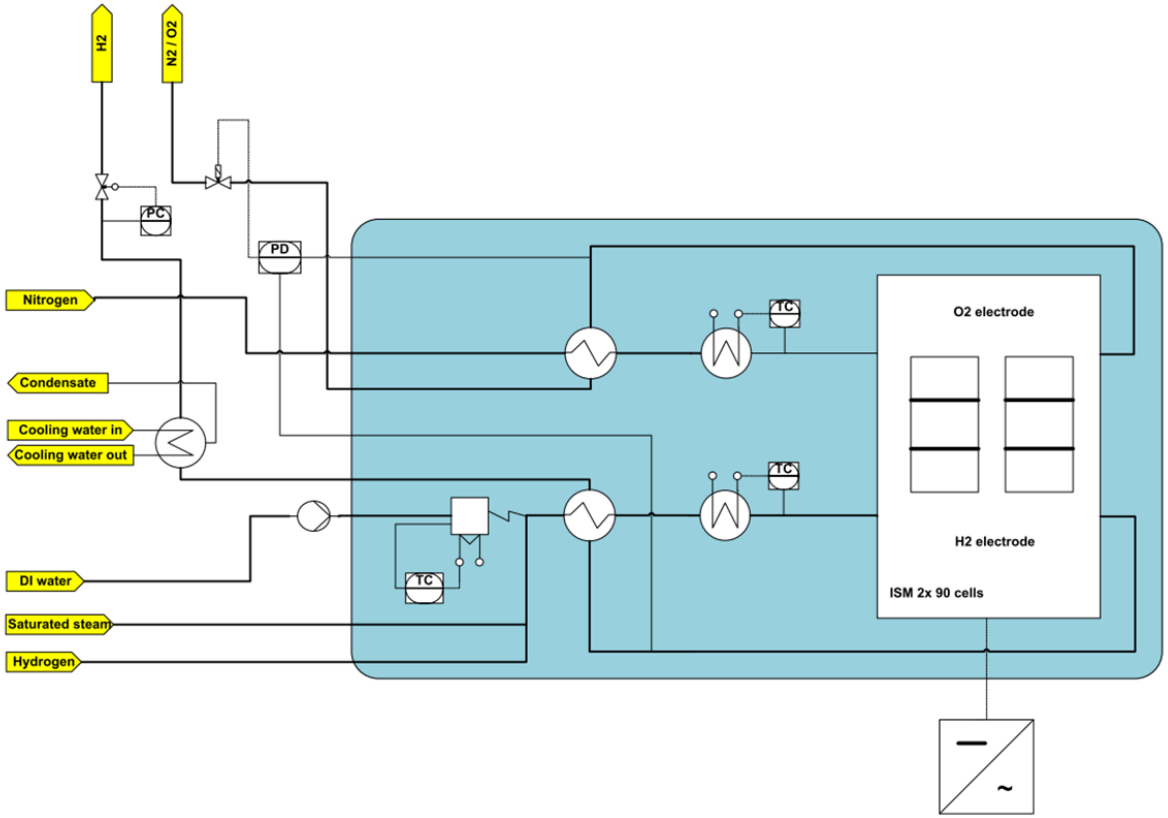
SOEC Key features

- Pressurized operation for higher overall efficieny
  - Product gas is often needed under pressure → save energy for compression while operating at elevated pressures



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Fuel cell operation – detailed view

A fuel cell…

…is a power generator

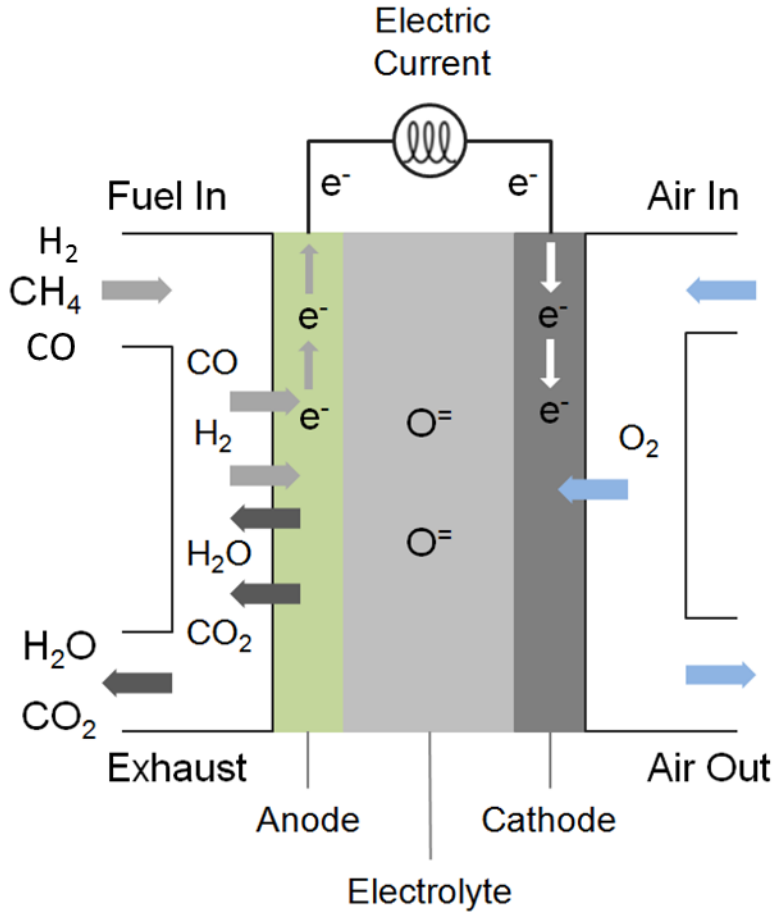
…converts chemical energy to electrical energy.

…is a galvanic element. („a gas battery“)

…operates continuously (unlike batteries).

…is clean and silent.

… has a very high efficiency!



A fuel cell is a device that converts the chemical energy from a fuel (i.e. methane/SNG) into electricity and heat through a chemical reaction with an oxidizing agent (i.e. oxygen) in a continuous process. Unlike conventional fuel cells, sunfire fuel cells run on hydrocarbons (i.e. natural gas, methanol).

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sunfire SOC stack technology

ESC (Electrolyte Supported Cell)

Metal sheet cassette of Mk200 stack

- Electrolyte supported cell
  - Active cell area: 128 cm²
  - Electrolyte: 3YSZ or 5YbSZ
  - Hydrogen electrode: Ni-GDC
  - Oxygenelectrode: LSCF
- Sheet metal interconnects
  - CroFer 22 APU ®
- Sealing
  - Special developed glas seals
- Stack: 30 cells/stack

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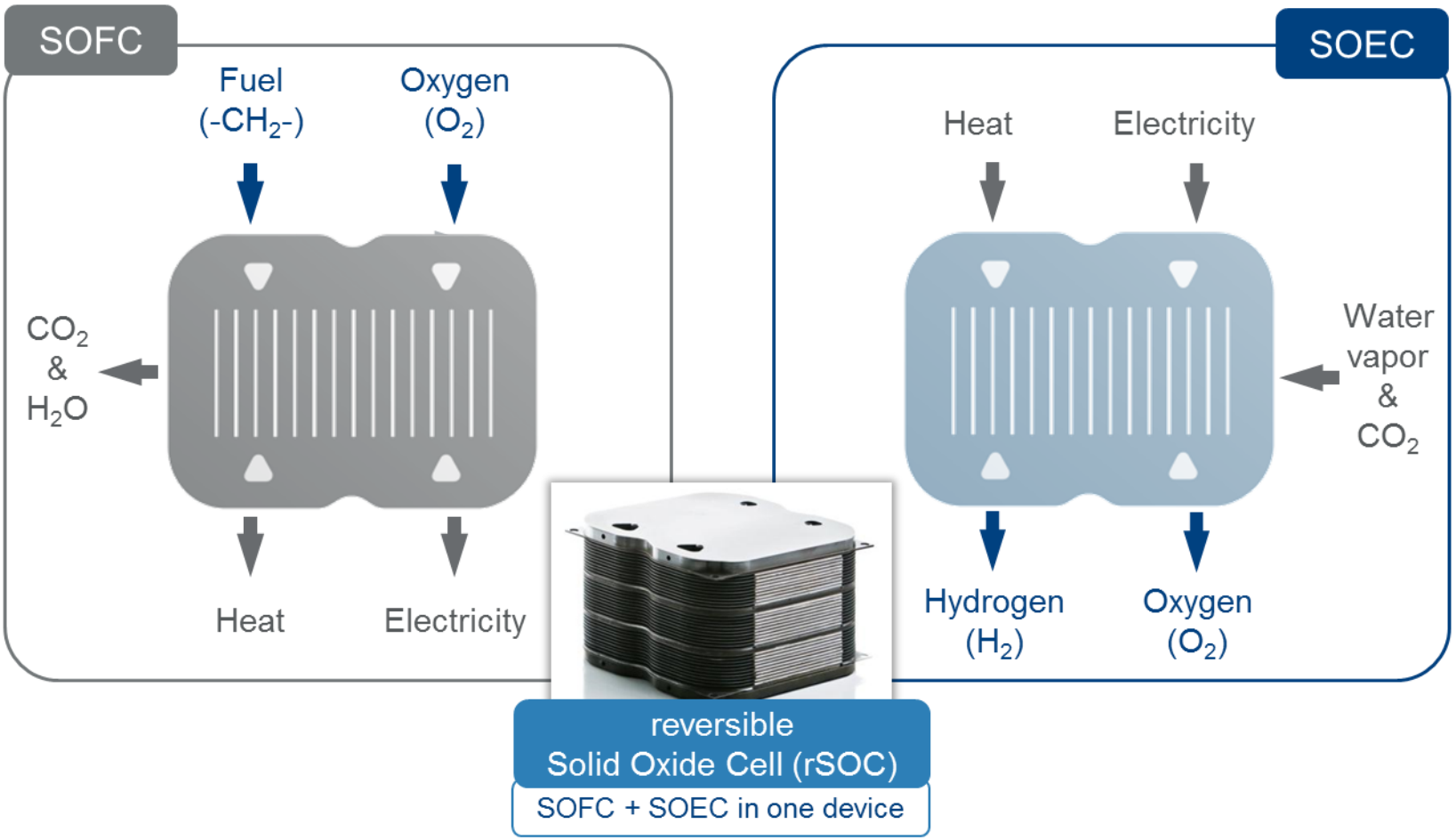
A Solid Oxide Electrolyser Cell converts…

…chemical energy into electricity and heat

…electricity into hydrogen



reversible
Solid Oxide Cell (rSOC)

SOFC + SOEC in one device

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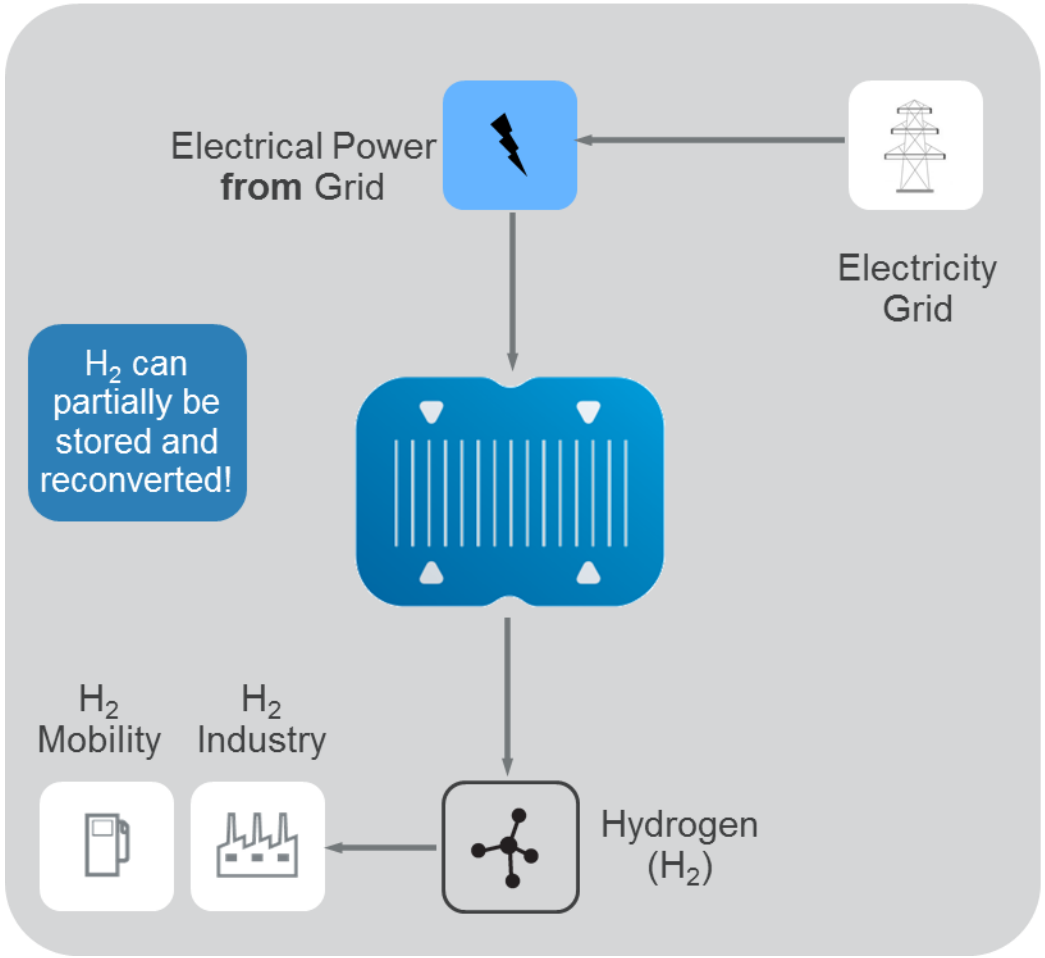
Electrolysis Mode (Charging)



ADVANTAGES:

+ High-temperature technology enables high electrolysis efficiencies of ca. 90% (55% round trip)
+ Hydrogen can be sold to many different applications (e.g. industry and mobility)
+ No limitations in storage capacity permit maximization of operation hours

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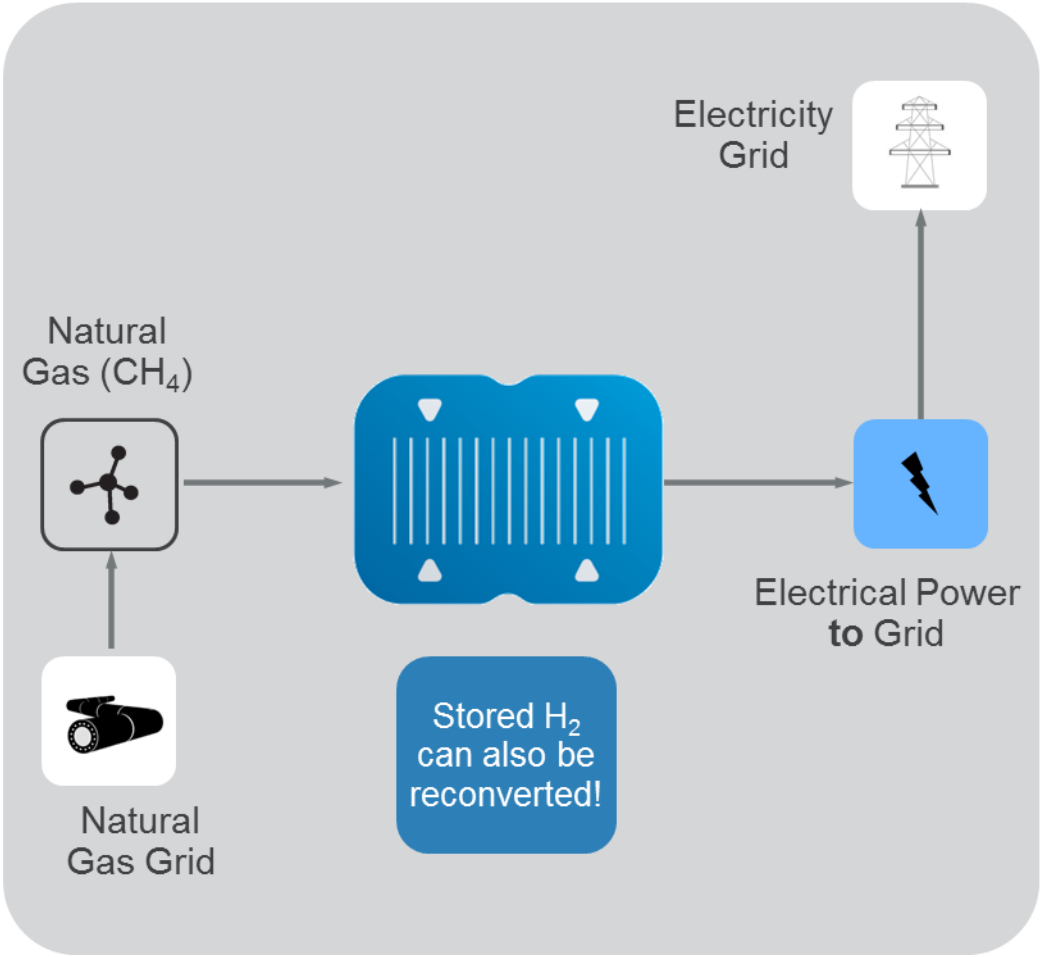
Fuel Cell Mode (Discharging)



ADVANTAGES:

+ High-temperature technology enables high fuel cell efficiency of ca. 60% (55% round trip)
+ Fuel cell can use cheap natural or bio gas to produce backup power
+ No limitations in storage capacity permit maximization of operation hours

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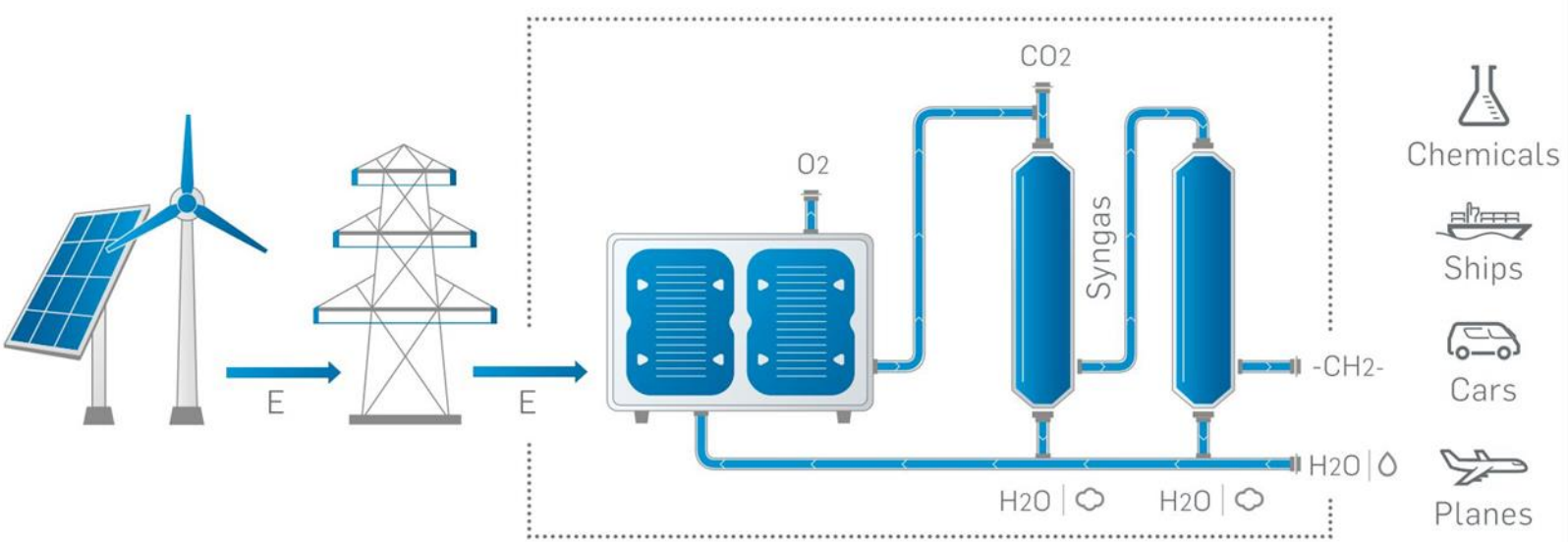
Power-to-Fuel with SOEC

Renewable electricity | Electrolysis (SOEC) | Conversion | Fischer-Tropsch | Fuel infrastructure



ADVANTAGES:

+ Process efficiency (Power → Fuel) ≈ 70 %
+ Production cost (liquids) ≈ 1.00 €/liter
+ GHG-mitigation > 85 %
+ Fits with existing infrastructure

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rSOC System overview (example)

530 kW_{AC}

131.6 kW_{AC}

58 kW_{AC}

500 kW_{DC}

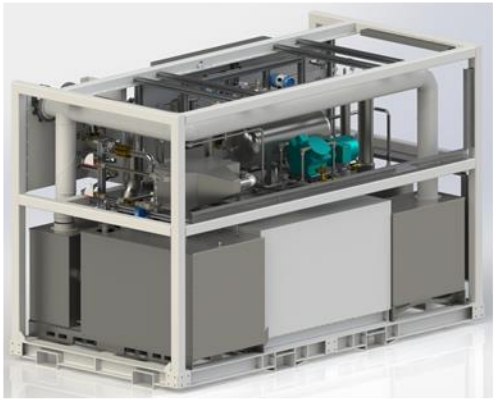
140 kW_{DC}

EFFICIENCIES

SOEC: 85 $\%_{LHV}$ with steam

76 $\%_{LHV}$ with water (l)

SOFC: 55 $\%_{LHV}$



H_2: 164.7 Nm^3/h
(14.7 kg/h; 500 kW_{LHV})

CH_4: 24 Nm^3/h
(17.56 kg/h; 240 kW_{LHV})

Steam @ 150 °C,
3 bar(g), 165 kg/h, (125 kW)

Heat: 70 kW

rSOC module
500 $kW_{DC,SOEC}$

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Pressurized HT-Electrolysis in HELMETH

- Pneumatic pressure control valves
- Pressure vessel in container
- Fluid supply panel
- H_2 / H_2O condenser
- Container ventilation inlet

- Operation pressure fixed to max. 16 bar (approved by TÜV due to pressure equipment directive)

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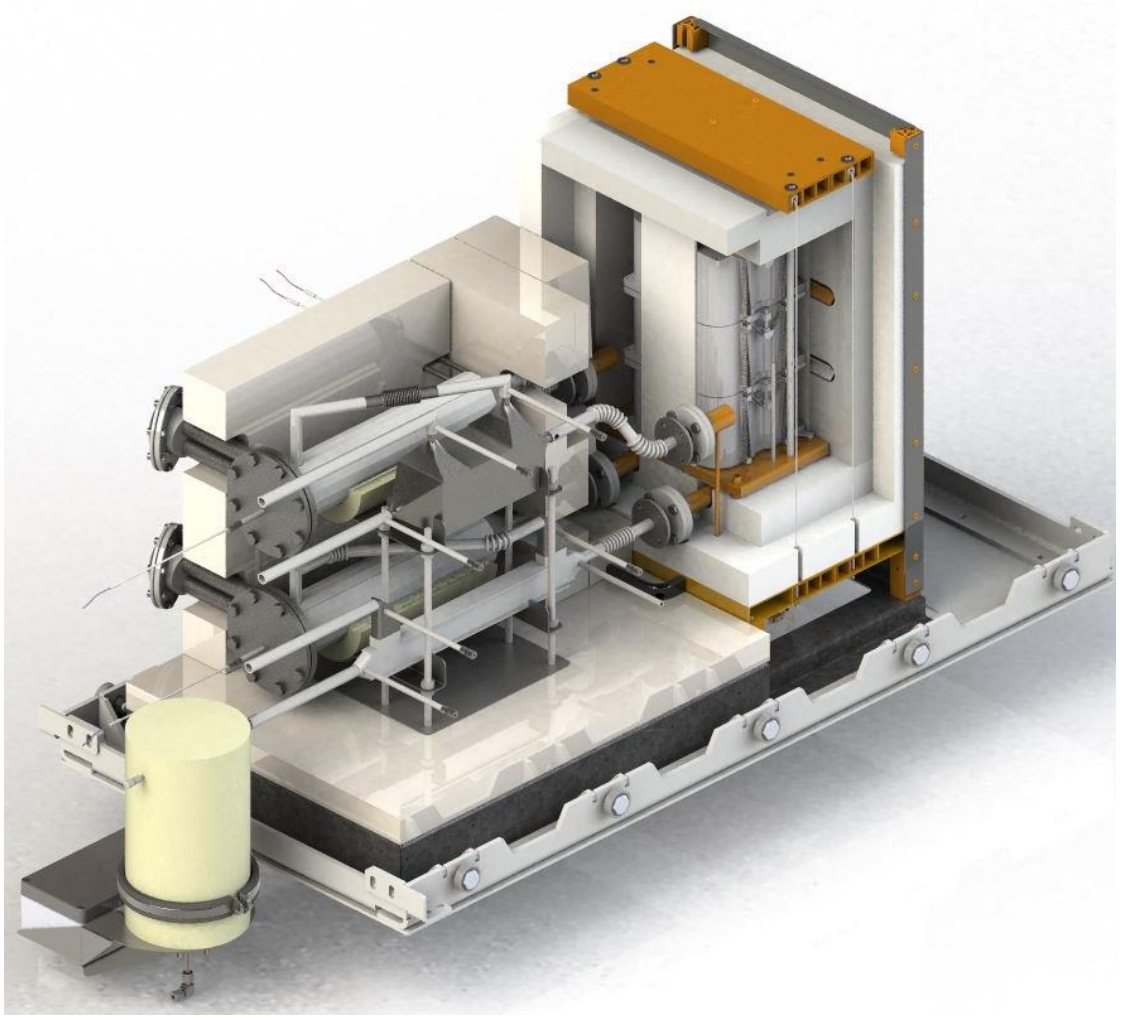
HotBOP components for SOEC

- Stack module (right side)
- Hot BoP components developed by sunfire
  - plate-type heat exchanger (HEX)
  - electrical gas heaters
  - electrical evaporator (for independent operation)
  - Additional HEX produced with new technology DMLS by Polito/IIT



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Conclusions

Within HELMETH it is demonstrated that

- SOEC technology from sunfire is capable to produce hydrogen in an efficient way by using steam
- Pressurised operation to decrease energy demand for gas compression has been demonstrated in small scale (7.5 kW; 10 bar)
- Co-electrolyis (CO_2 as additional feed gas) can be performed with this technique (aim: produce syngas without additional components)

Next steps

- Optimise components for pressurised operation
- Increase power density
- Start operation with new setup in Summer 2016
- Couple SOEC and Methanation in early 2017

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Questions ?

www.helmeth.eu

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