FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

ECo

Efficient Co-Electrolyser for Efficient Renewable Energy Storage

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Programme Review Days 2019

Brussels, 19-20 November 2019

PROJECT OVERIVEW

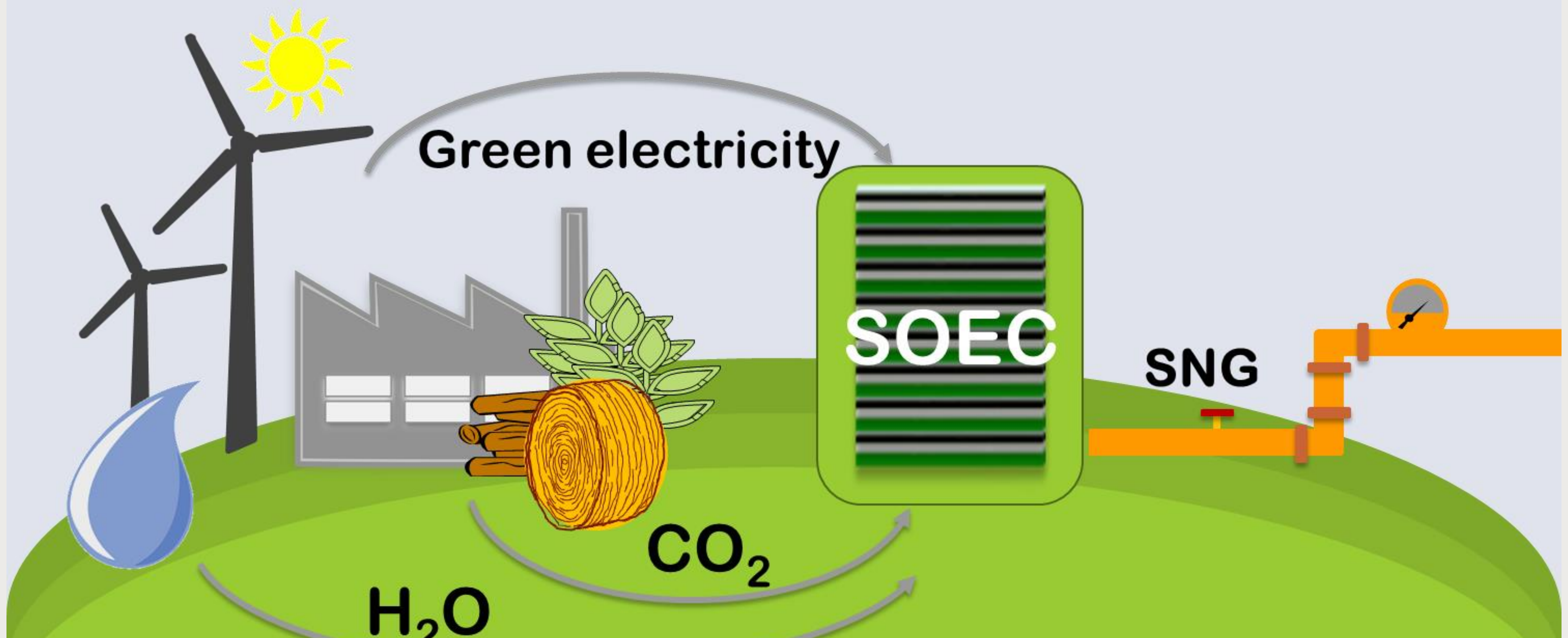
- **Call year:** 2015
- **Call topic:** H2020-JTI-FCH-2015-1, Development of co-electrolysis using CO_2 and water
- **Project dates:** 01 May 2016 – 30 April 2019
- **% stage of implementation 01/11/2019:** 100 %
- **Total project budget:** 3,239,138.75 €
- **FCH JU max. contribution:** 2,500,513.75 €
- **Other financial contribution:** 738,625 €
- **Partners:** Technical University of Denmark, Commissariat à l'Energie Atomique et aux énergies alternatives, European Institute for Energy Research, École polytechnique fédérale de Lausanne, Catalonia Institute for Energy Research, Htceramix/SolidPower, LABORELEC/ENGIE, Enagás, VDZ gGmbH

PROJECT SUMMARY

ECo: Efficient Co-Electrolyser for Efficient Renewable Energy Storage

- **Challenge: Increasing shares of fluctuating electricity production from renewable sources to achieve the EU ambition of reducing greenhouse gas emissions by 80-95% by 2050. Storage needed.**
- **Overall objective: Develop and validate a highly efficient co-electrolysis process for conversion of excess renewable electricity into distributable and storable hydrocarbons via simultaneous electrolysis of steam and CO_2 through SOEC (Solid Oxide Electrolysis Cells)**

- **Improve SOEC** for operation at ~100 ^{o}C lower temperatures than State-of-the-Art (SoA)
- Achieve **durability** under realistic co-electrolysis conditions with degradation rates below 1%/1000 h at stack level
- **Validation** at system level
- Design a **SOE plant** and integrate into CO_2 emitting plants for **techno-economic & life cycle analysis**



A. Hagen, ECo Project - Efficient long-term storage of renewable energy as synthetic natural gas, Winter 2018 European Energy Innovation, open access

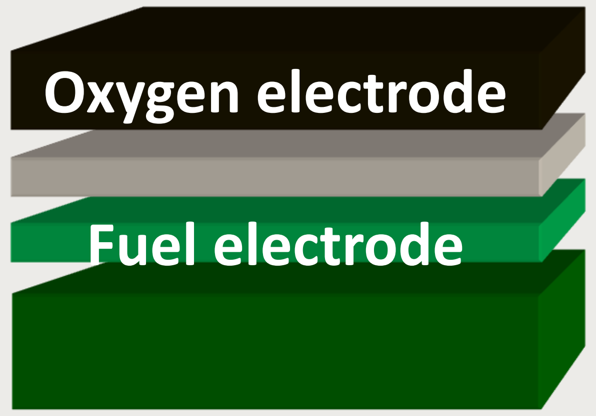
PROJECT PROGRESS/ACTIONS – Improve SOEC vs. SoA

Achievement to-date

Area Specific resistance at 750 ^{o}C (ASR)
0.4 Ohm cm^2

25% 50% 75%

✓ 0.2 Ohm cm^2



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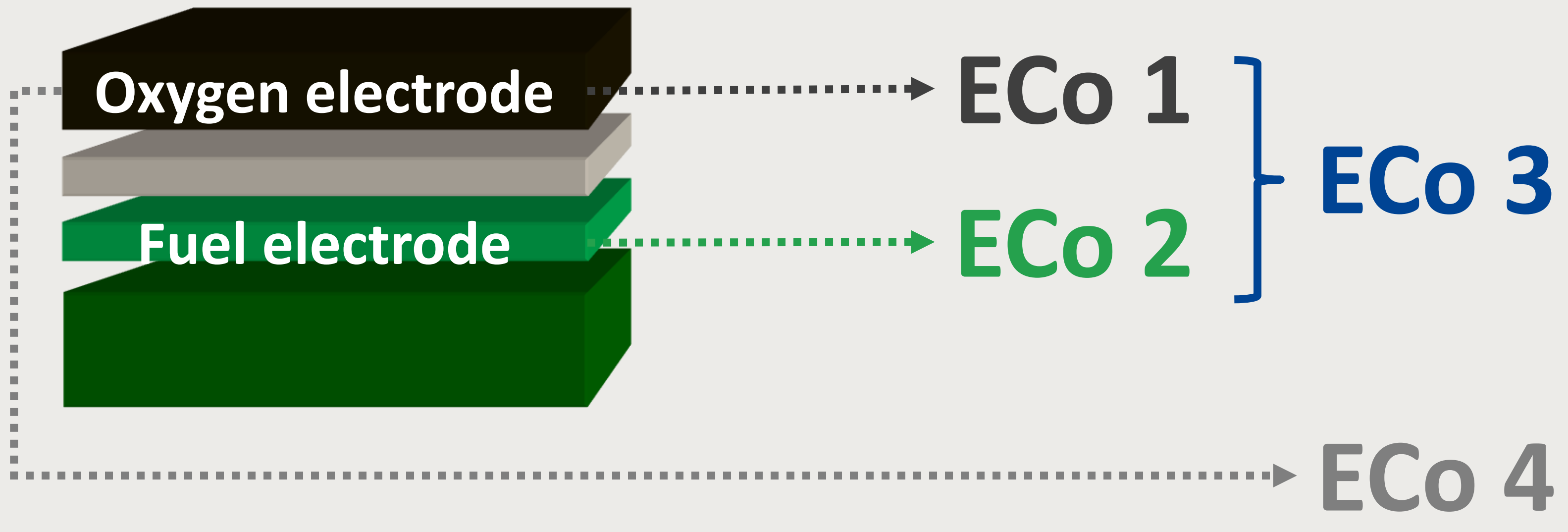

- Improvement of fuel (Ni/YSZ) and oxygen (LSCF/CGO) electrodes based on test results, 3D reconstruction of the micro structure and modelling
- Combination of the improved electrodes into one cell
- Development of improved button cells based on LSCF infiltrated into CGO mesoporous scaffold
- Half cells & electrodes from four partners involved

✓ **The decrease of the area specific resistance (ASR) of SOEC allows for decreasing the operating temperature by 50-100 °C, which decreases thermally activated degradation processes thereby leading to longer lifetimes.**

PROJECT PROGRESS/ACTIONS – Improve SOEC vs. SoA

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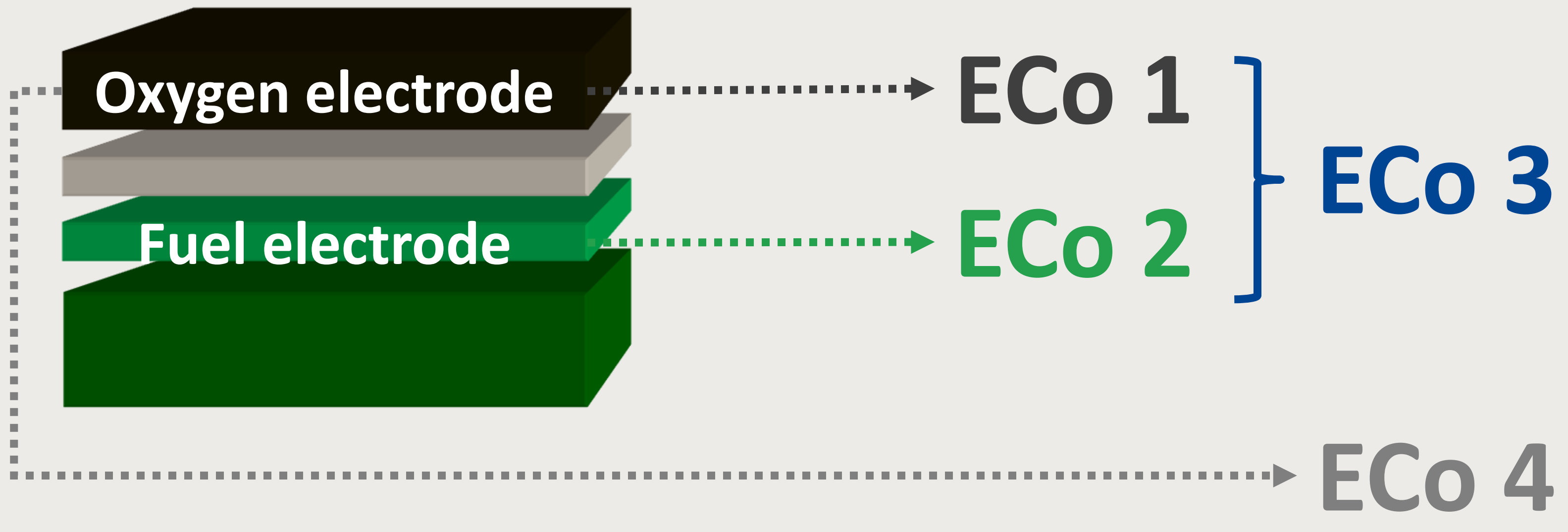

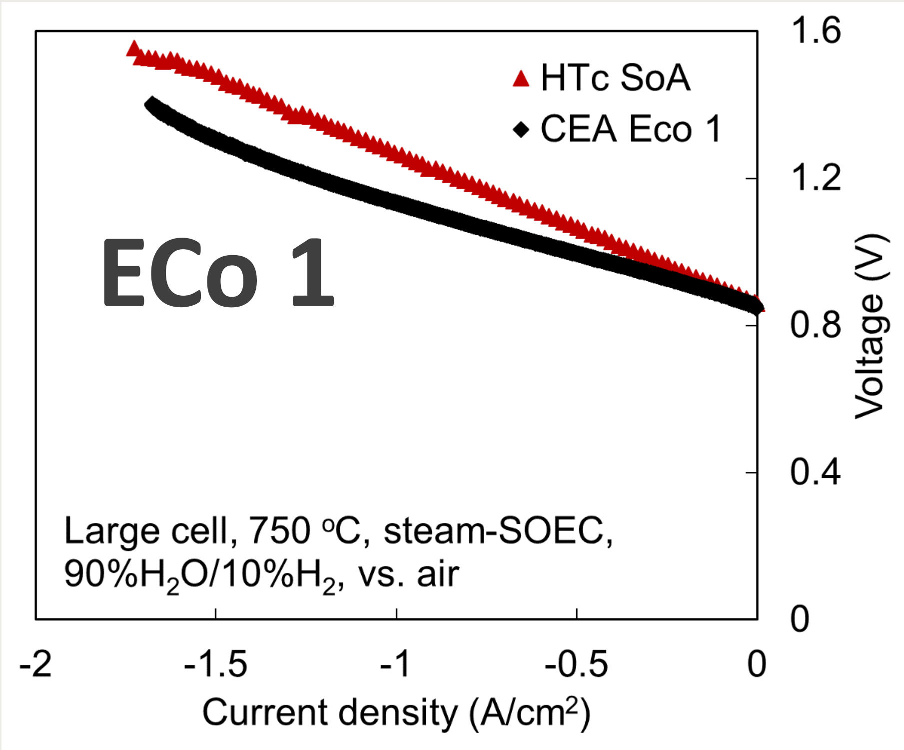

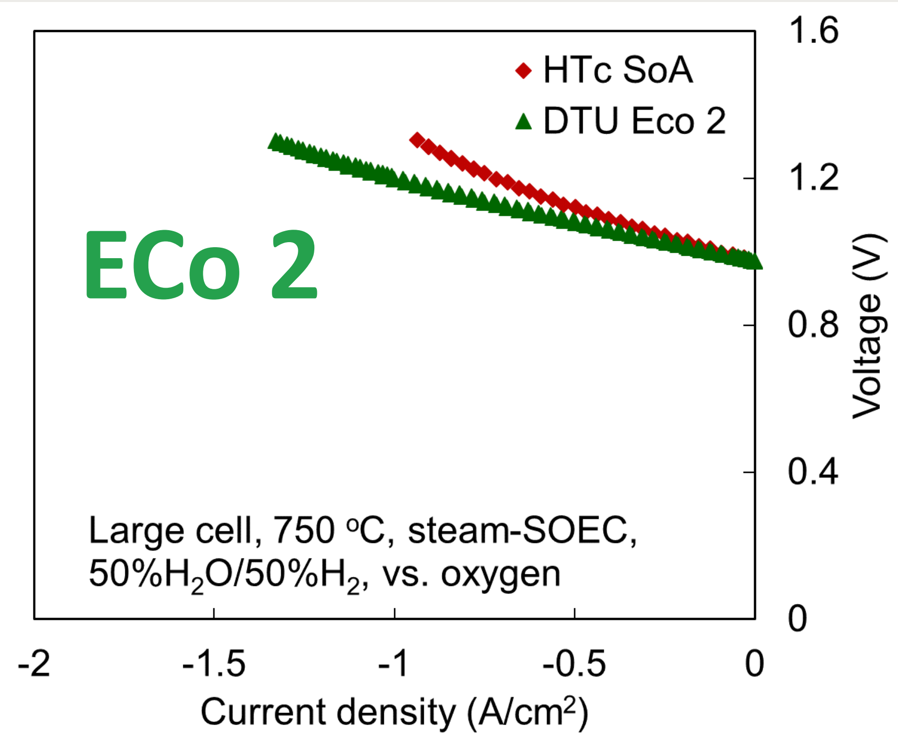

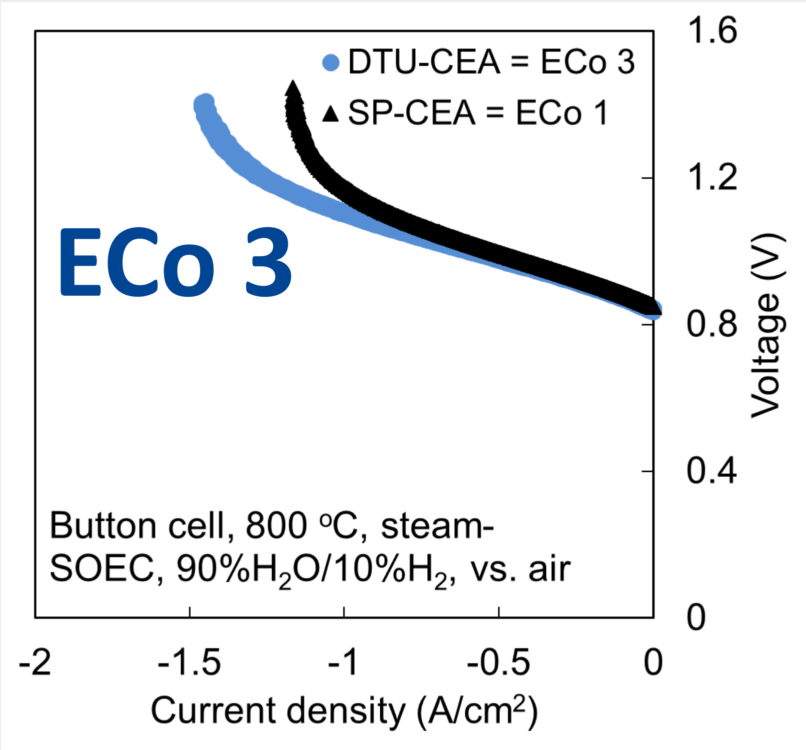

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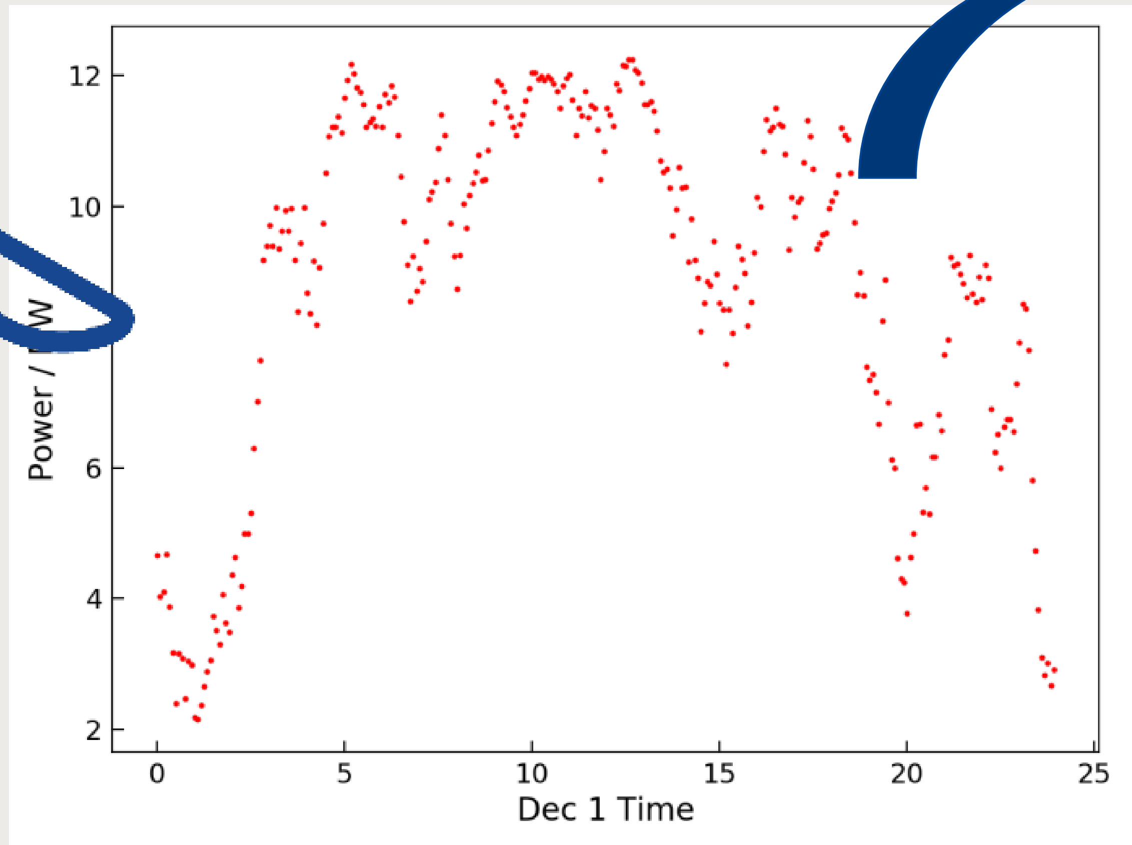
PROJECT PROGRESS/ACTIONS – Durability

Achievement to-date

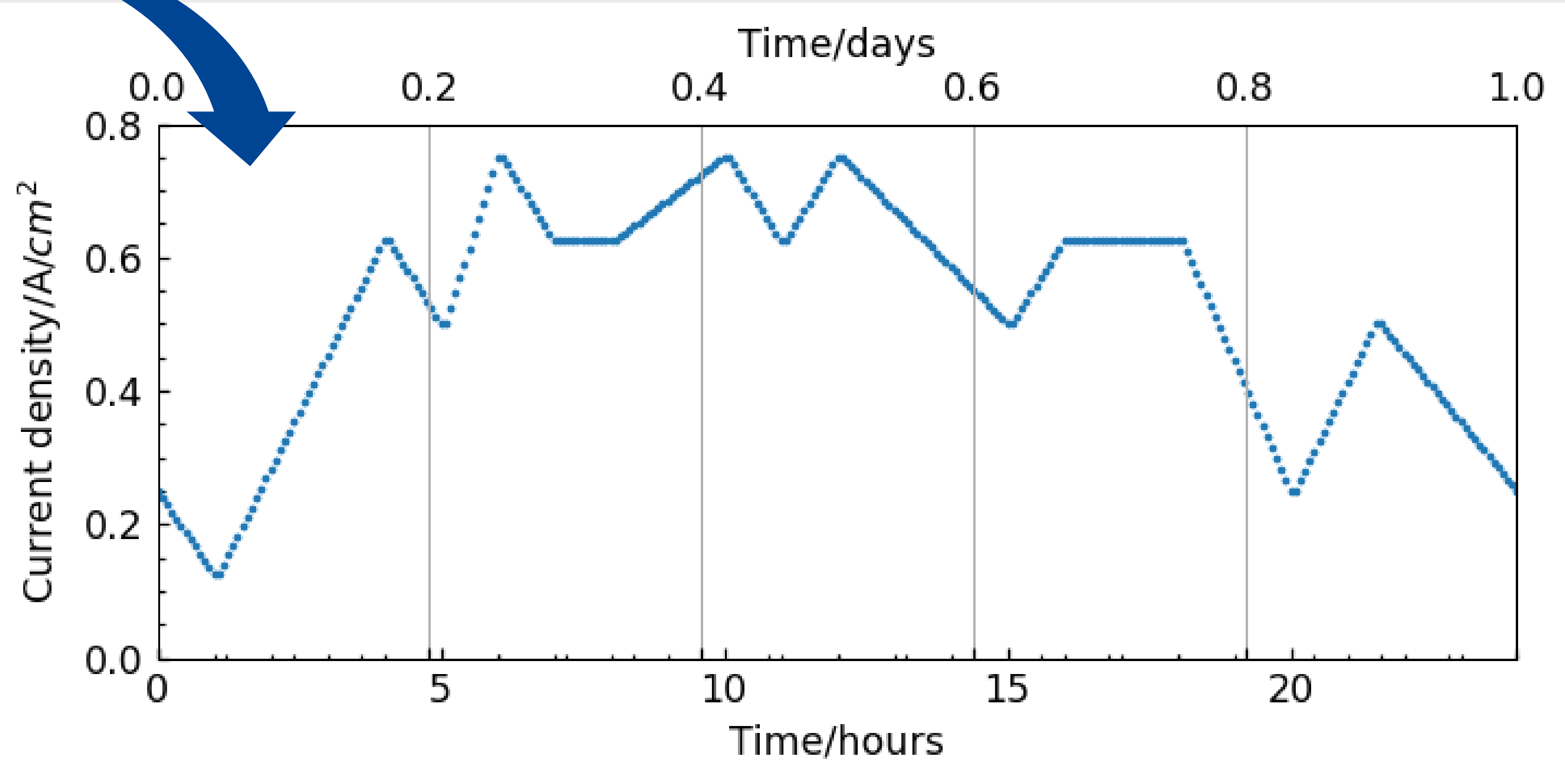
Degradation rate >1%/1000 h at constant operation

25% 50% 75%

✓ <1%/1000 h, dynamic operation



Measured wind date (DK)



Profile for testing

✓ **0 - <1%/1000 h degradation in co-SOEC mode on cell and stack level under conditions relevant for coupling with fluctuating electricity input from renewable sources**

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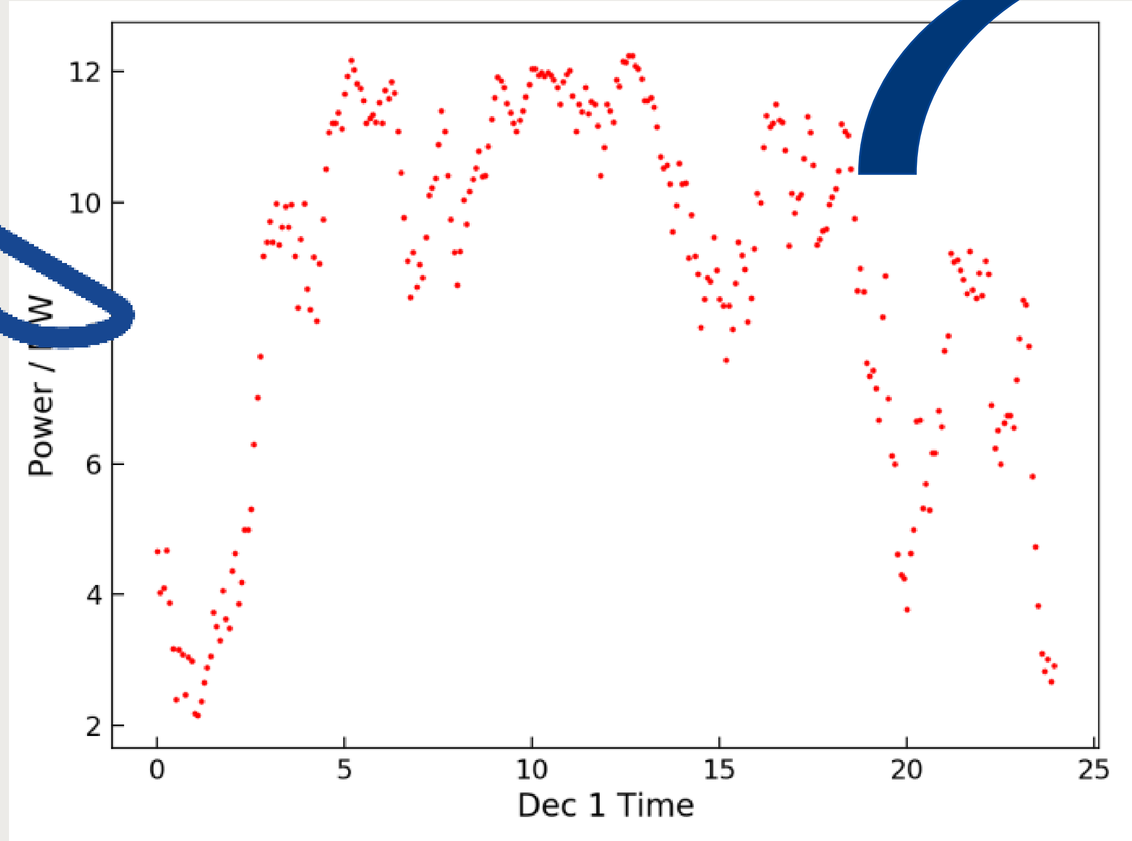

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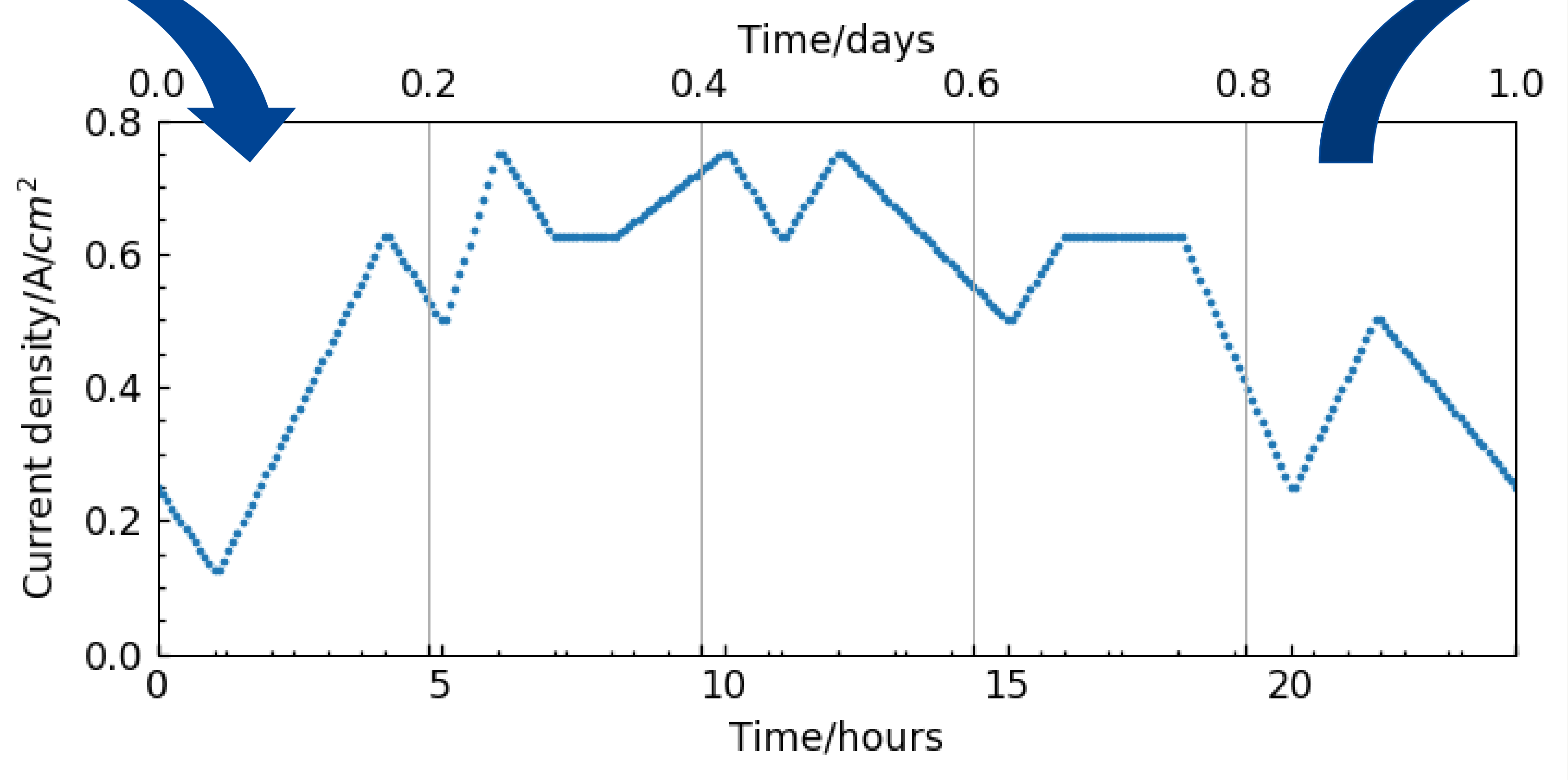
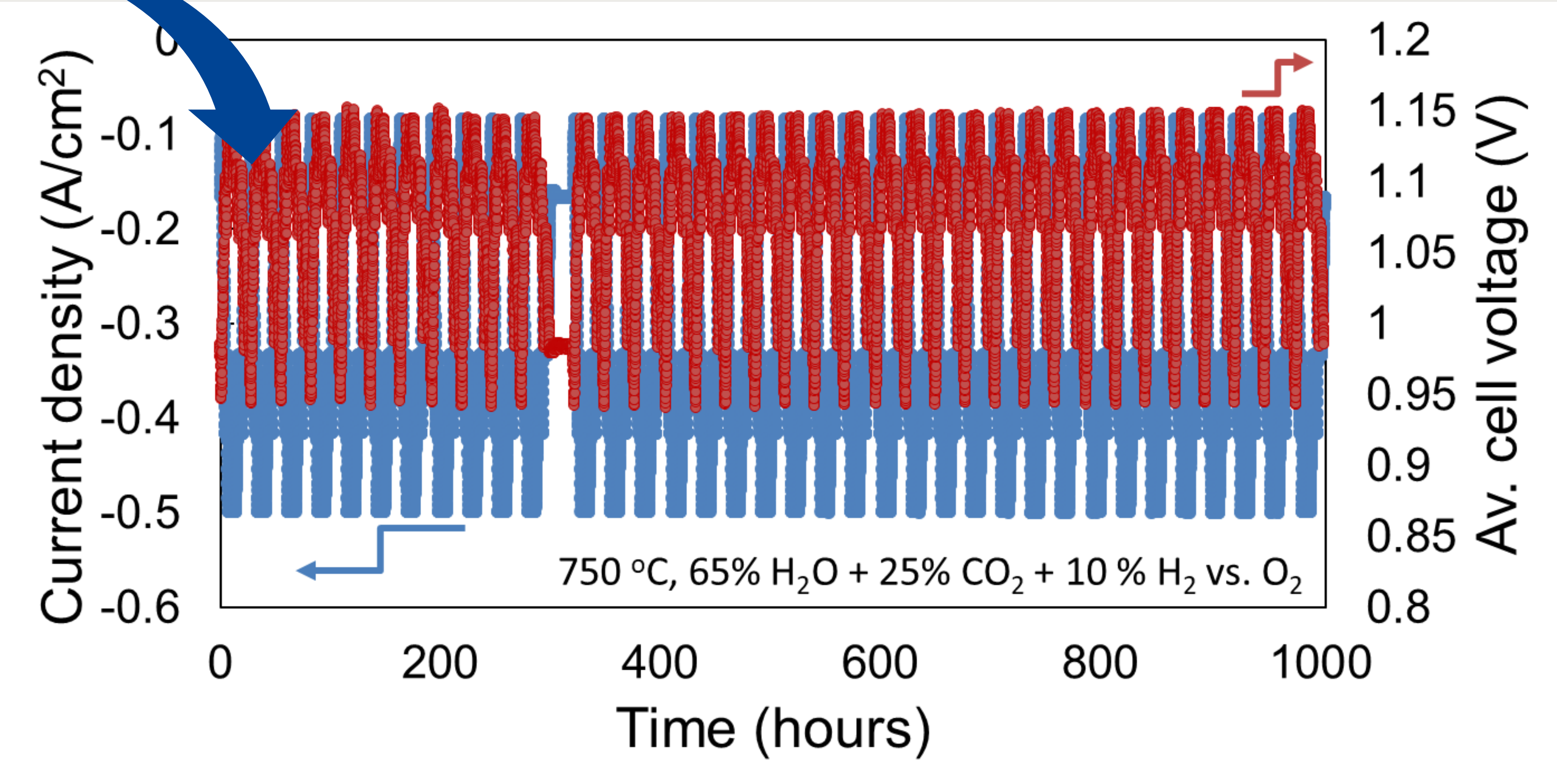


Profile for testing



6-Cell stack (ECo 2), co-SOEC at 750 °C

✓ **0 - <1%/1000 h degradation in co-SOEC mode on cell and stack level under conditions relevant for coupling with fluctuating electricity input from renewable sources**

PROJECT PROGRESS/ACTIONS – Co-SOE plant design & integr.

Achievement to-date

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✓ Co-SOE Plant design & analysis

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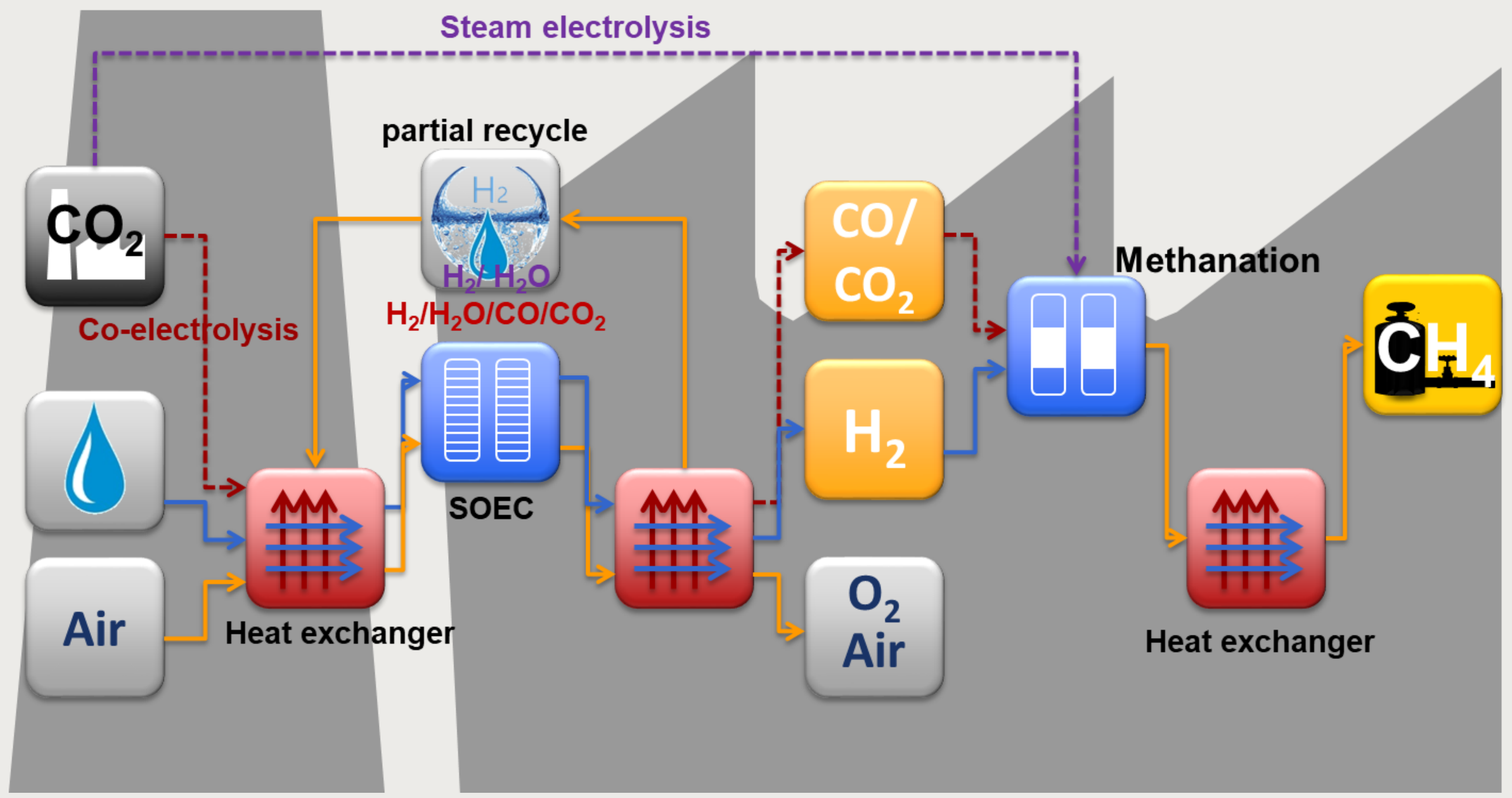
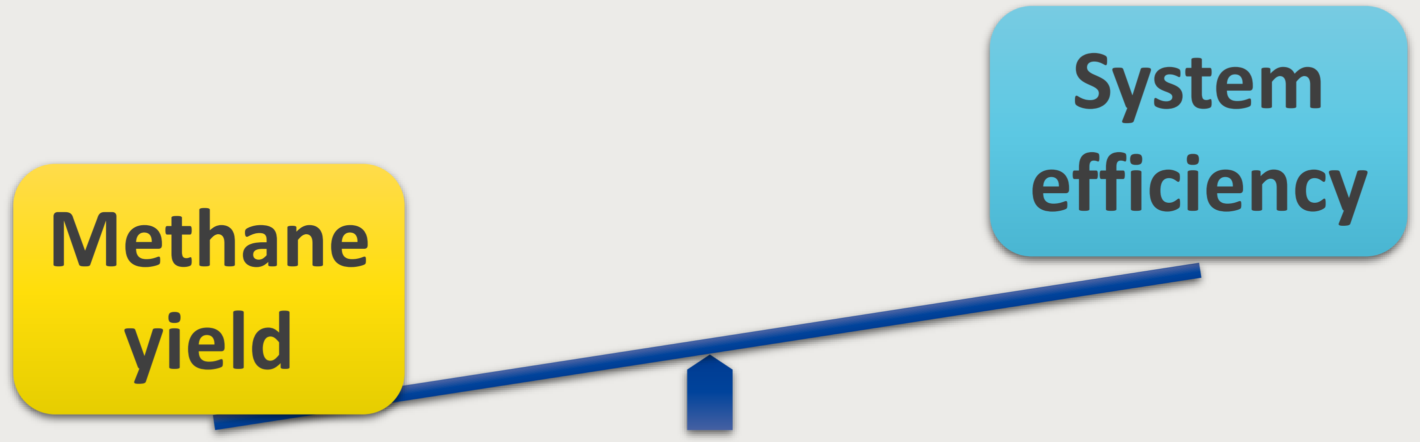
Plant model designed
- SOE and methanation (internal & external)
- steam or co-electrolysis
- considering thermodynamic & electrochemical parameters
- heat integration





✓ **Trade off between high methane yield (up to ~30 vol% at stack outlet) & system efficiency (~90%)**

✓ **Co-electrolysis offers better system-level heat integration achieving higher system efficiency**

PROJECT PROGRESS/ACTIONS – Co-SOE plant design & integr.

Achievement to-date

25% 50% 75%

✓ Co-SOE Plant design & analysis

Integration study with CO_2 emitting plants:

- Cement plant
- Biomass gasification
- Biogas plant

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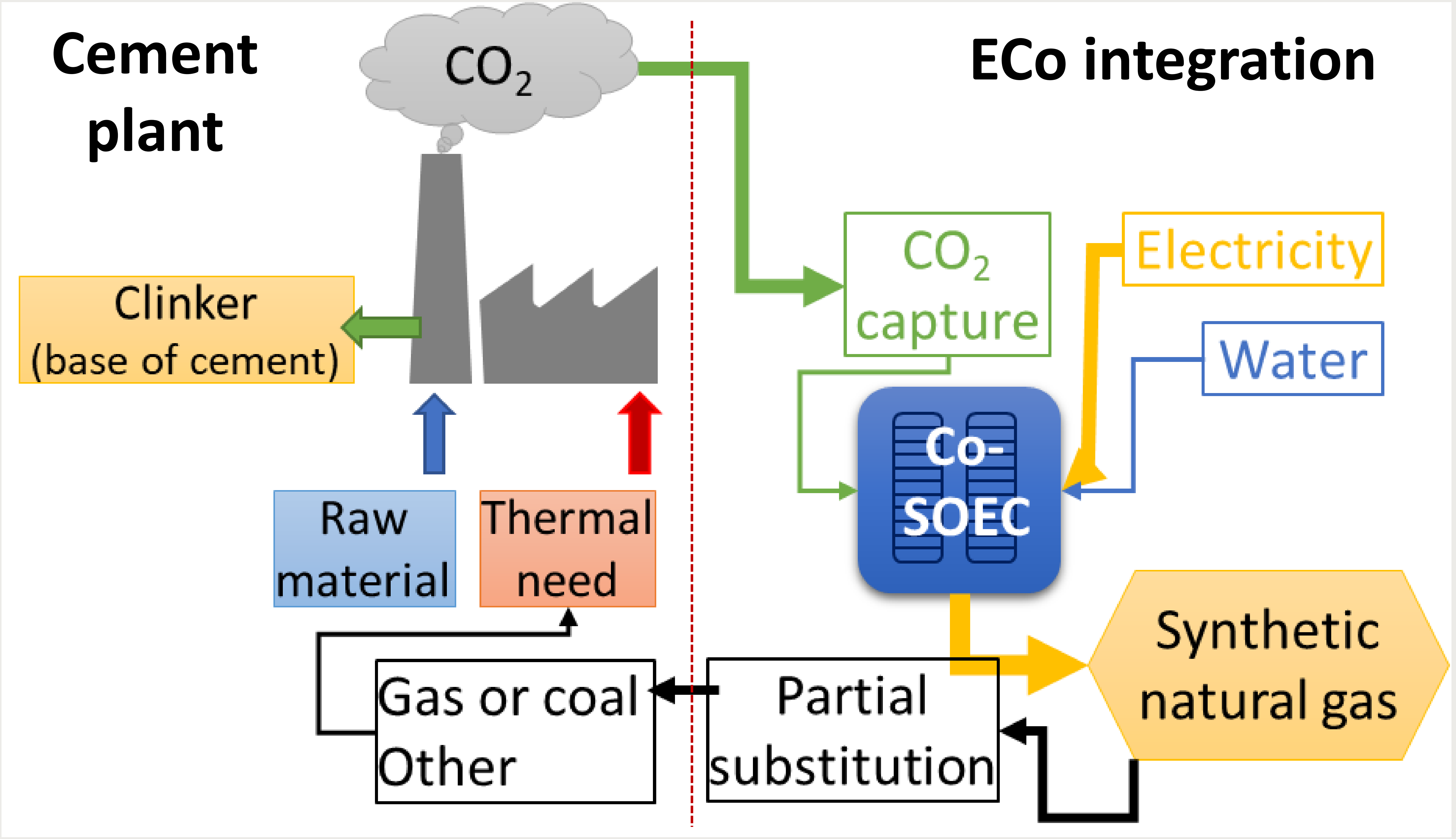

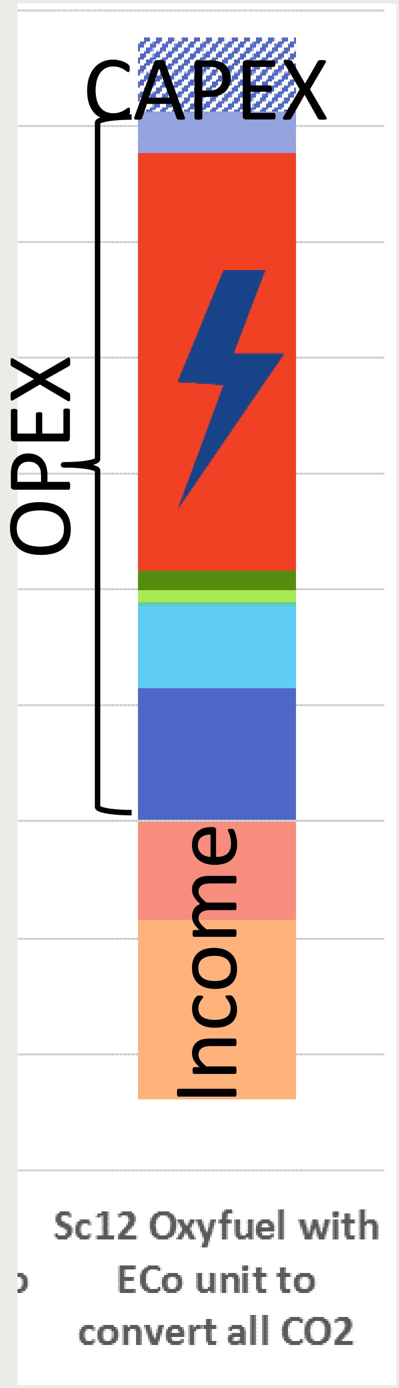

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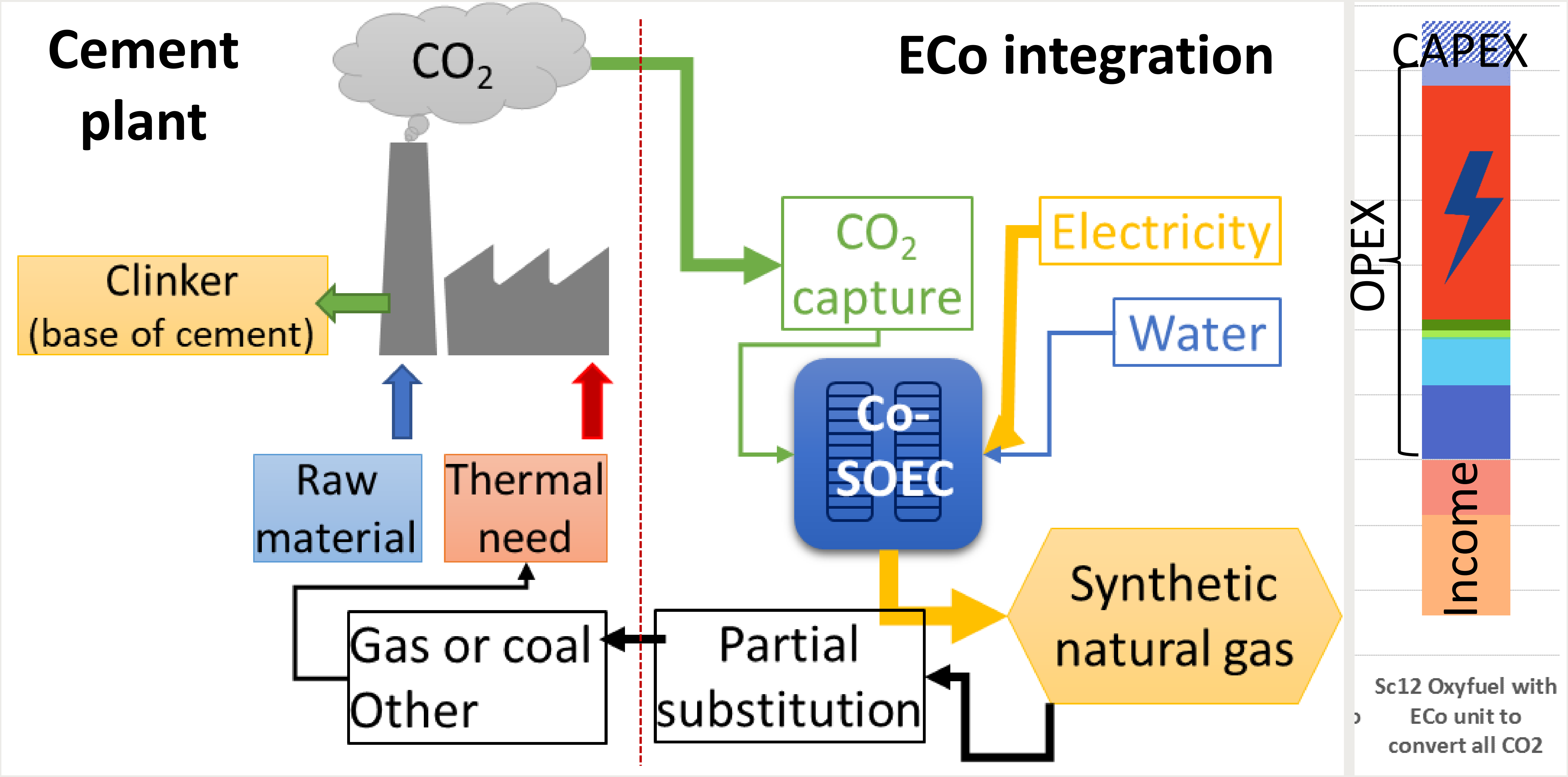
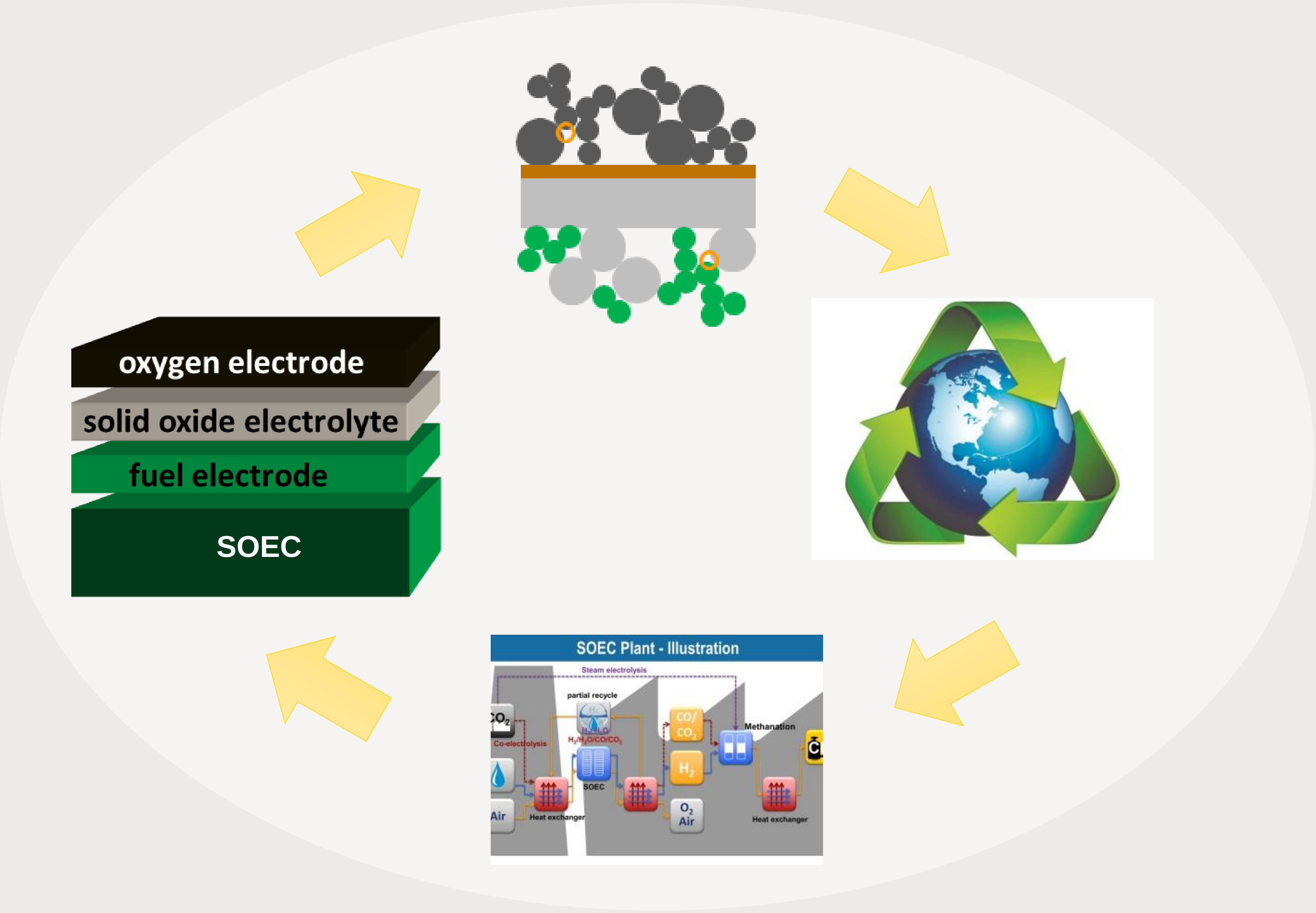
In all cases, access to cheap and CO_2-lean electricity is the key to market potential

The share of renewables in the electricity input determines the reduction of global warming potential



Risks and Challenges



Risks and Challenges

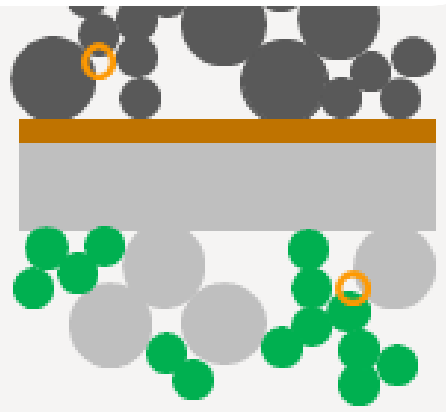
Co-SOEC (durability) tests are technically enormously challenging, particularly under relevant conditions

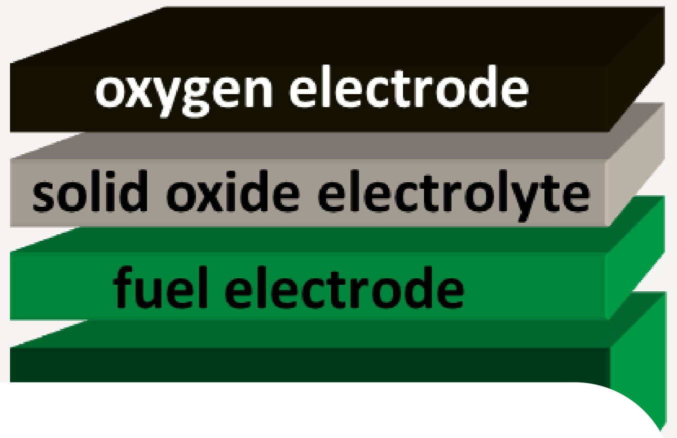
✓ ECo involved leading groups in testing of SOE (SOFC), who managed to carry out a comprehensive test matrix

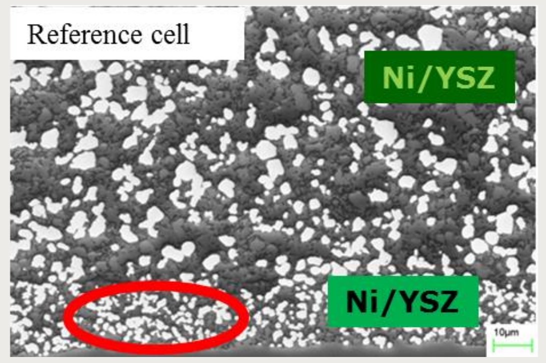
Cell version/Test type	SoA	ECo 1	ECo 2	ECo 3	ECo 4
Steam SOEC	✓	✓	✓	✓	✓
Co-SOEC	✓	✓	✓	✓	✓
Constant operation	✓	✓	✓	✓	✓
Dynamic operation	✓		✓		✓
Effect of contaminants	✓				
Atmospheric pressure	✓	✓	✓	✓	✓
High pressure	✓		✓		
Cell	✓	✓	✓	✓	✓
Stack	✓	✓	✓	✓	
System	✓		✓	✓	

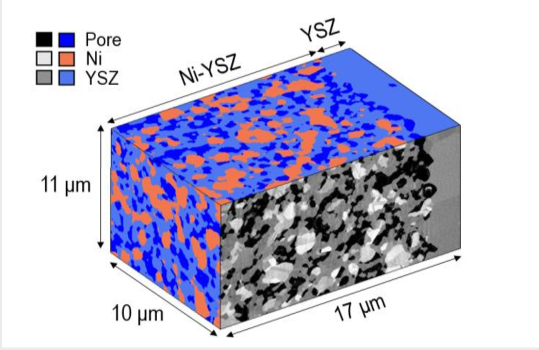
Improve SoA cells is a difficult undertaking

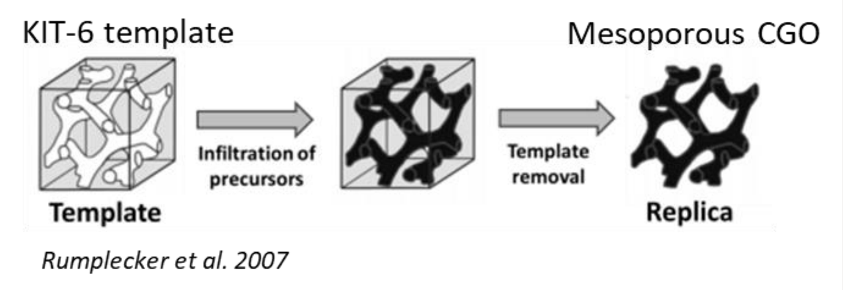
✓ ECo pursued improvement of different electrodes with different strategies – materials & structuring - to succeed.





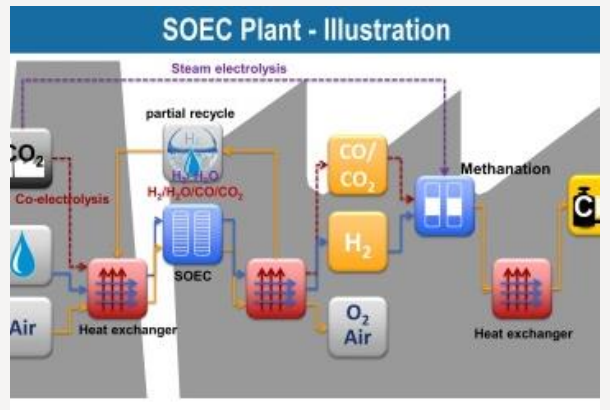






Lack of experimental data about exact composition of relevant CO_2 streams

✓ Additional analysis campaign was performed on two Post-Combustion CO_2 capture facilities

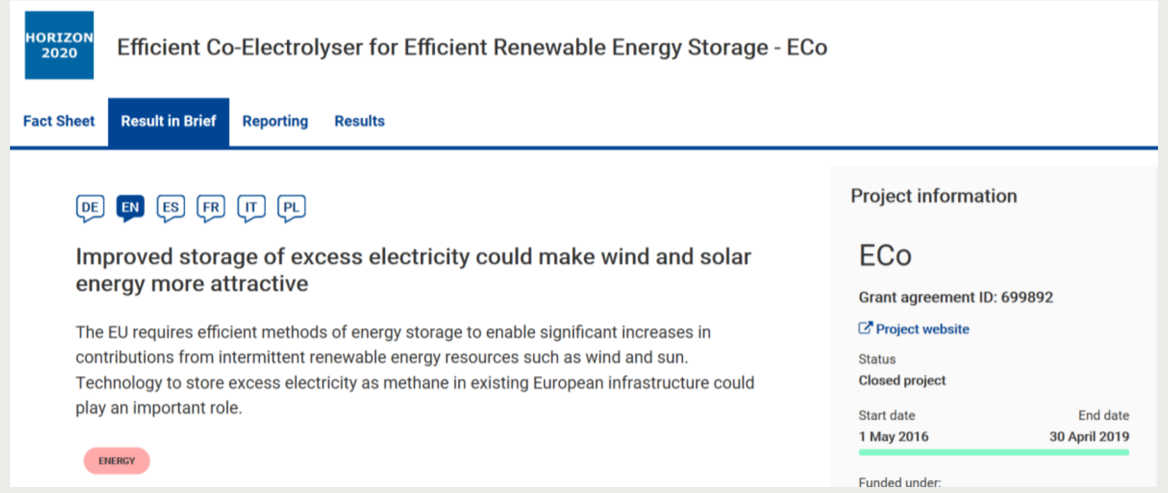


Open access publication requirement, ECo partners were among the first movers meeting serious obstacles

💰 Costly realisation

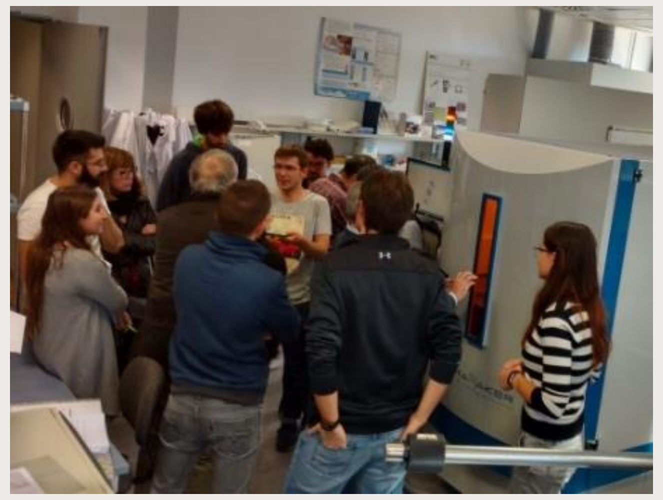
Communications Activities

Communications Activities



Cordis

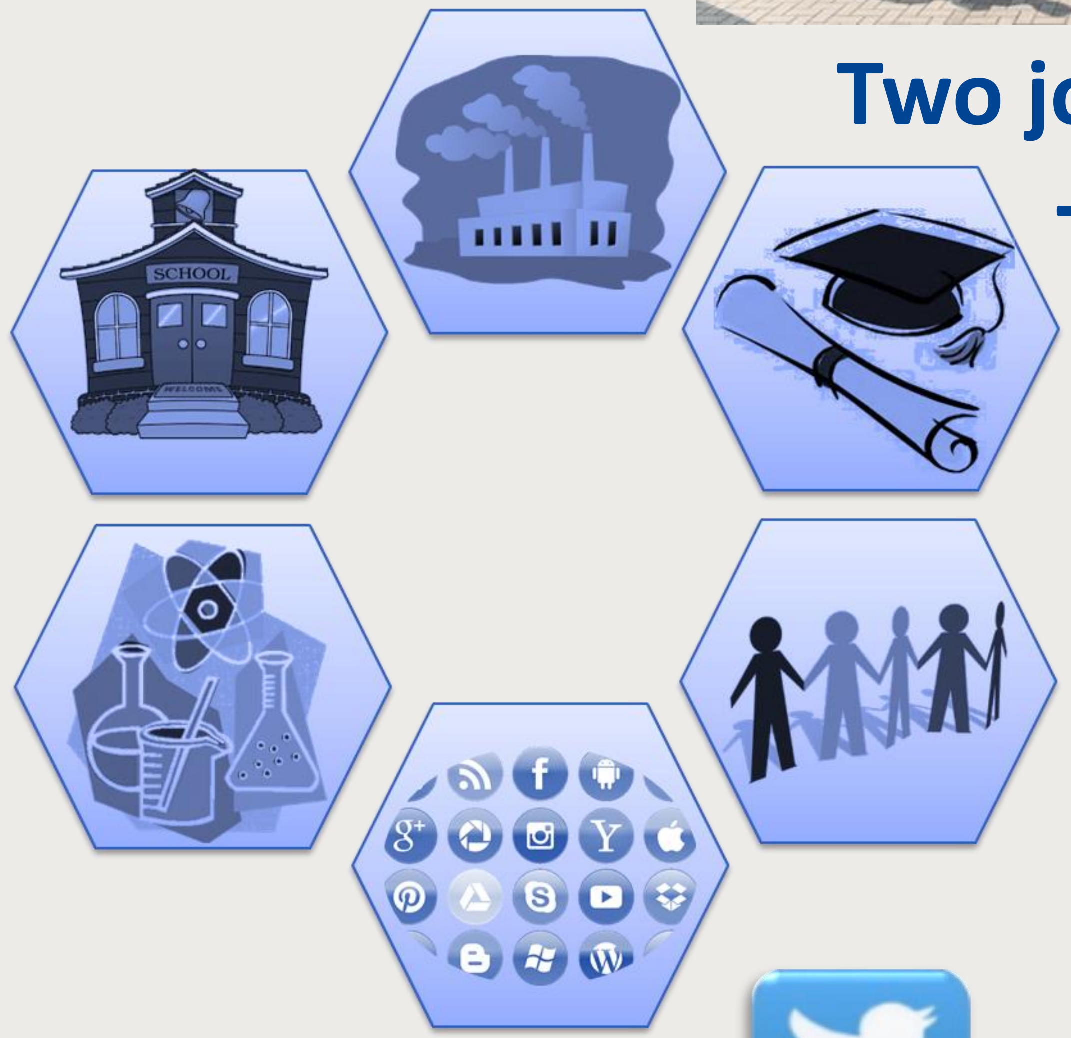
Hannover Fair



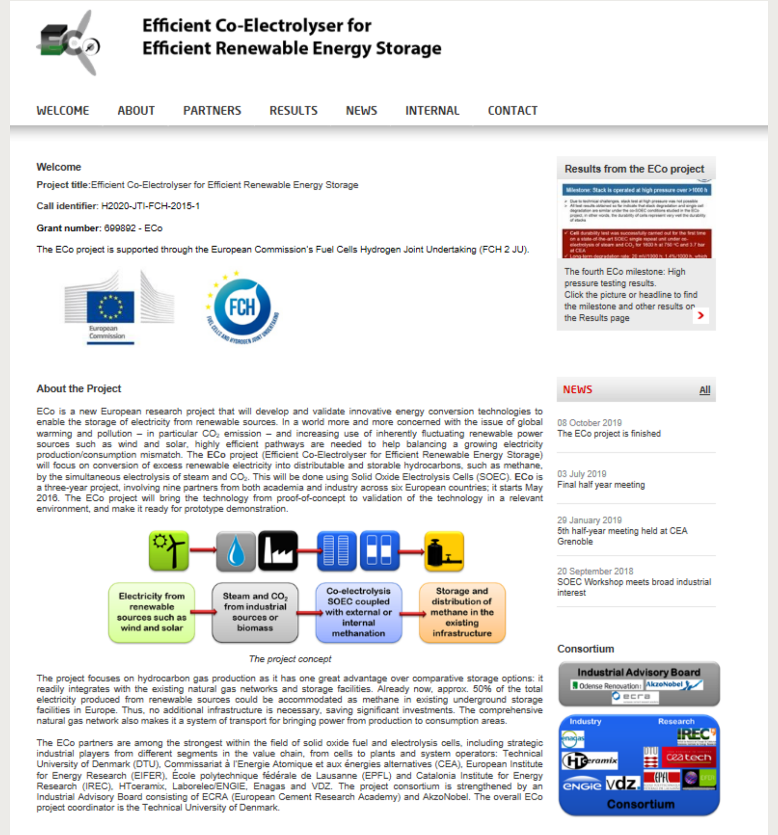
Outreach to schools (Science week, Science festival)

Two joint workshops

Two Popular articles (DK, ES)



Two PhD projects, PhD Summer School contribution



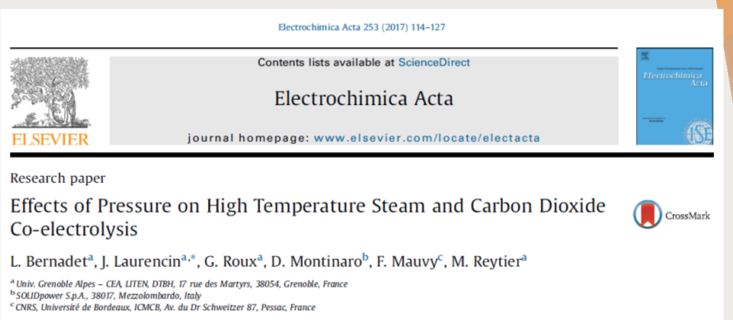
Project web page

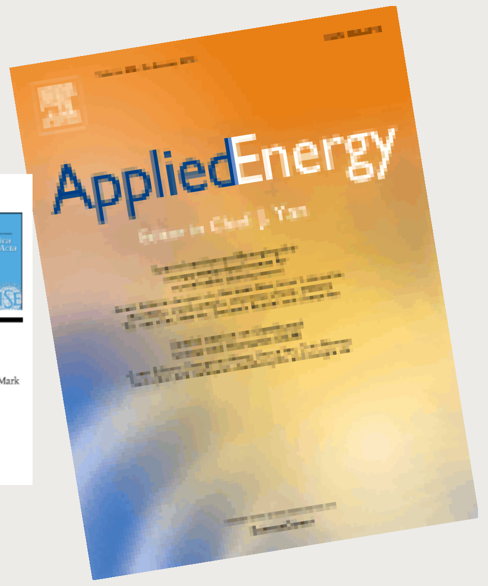
Scientific contributions

So far:

Conferences: 10 oral presentations, 9 posters

Articles: 10 peer-reviewed articles, 3 submitted

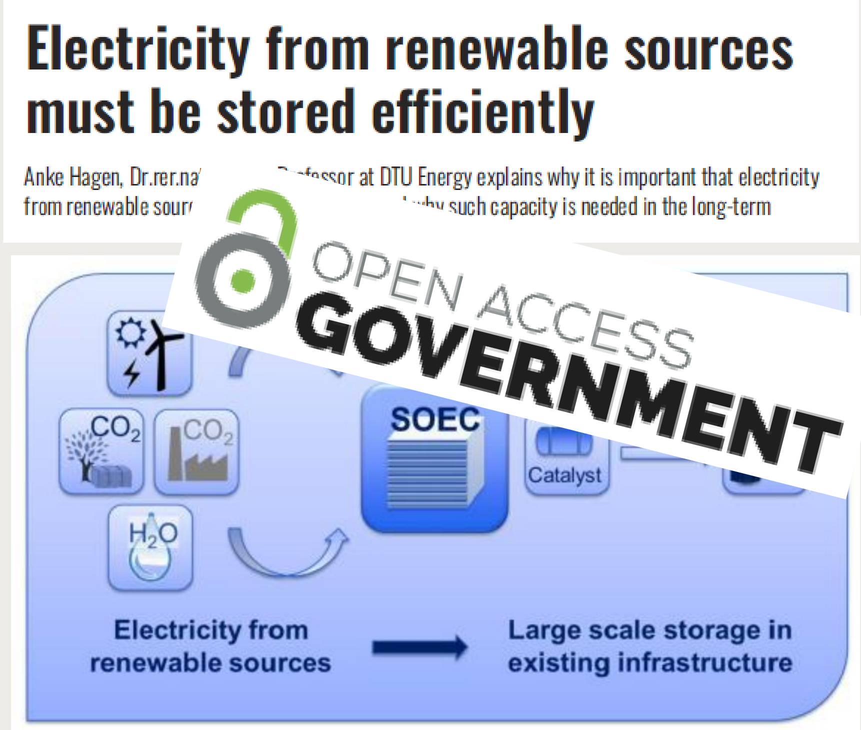




Social media

ECo SOEC

Two Information folders



Web Information

EXPLOITATION PLAN/EXPECTED IMPACT

Exploitation

- SOE technology providers: Cost reduction of SOE technology through improved performance & durability based on SoA cells
- Economic potential:
  - Cement plant with oxy combustion CO_2 capture: Supply of the needed O_2. Formed methane substitutes part of the fossil fuel input for cement production.
  - Biomass gasification plant: Boost of the methane production through using the CO_2 bi-product.
  - Biogas plant for methane production: Methane output is doubled through conversion of the inherent CO_2 in biogas into methane.

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Impact

- The improved electrolysis cells allow for 100 °C lower operating temperature with the same gas output as compared to SoA.
- Durability of cells and stacks in co-SOE operation reached a value threshold needed for commercialization (degradation rates <1% /1000 h) including realistic operation conditions such as "wind-profile" electricity and high-pressure operation.
- System validation with improved ECo cells reaching high electrolysis efficiencies of 94%.
- For the first time delivery of a co-SOE plant design including renewable electricity input and methane output, allowing for definition of optimum parameters to achieve high efficiencies, gas output, etc.

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