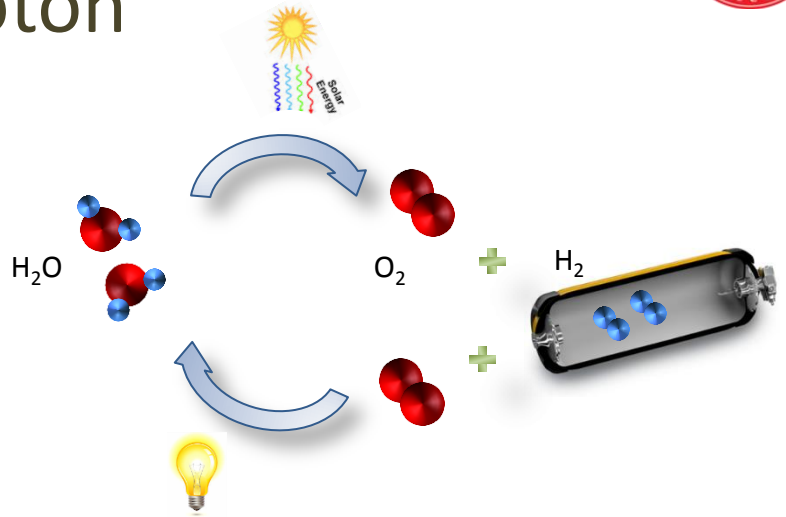
UiO : Department of Chemistry
University of Oslo

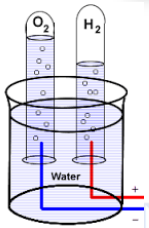
# Steam to hydrogen using proton ceramic electrolysers

*Einar Vøllestad*



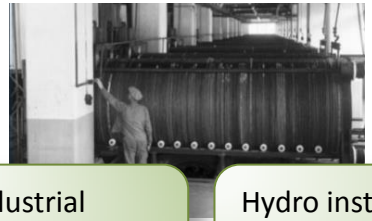

Electra

# Hydrogen technology developments over the last centuries




Electrolysis discovered

1800



Industrial electrolysis developed

1888

Hydro installs world's largest electrolysis plant

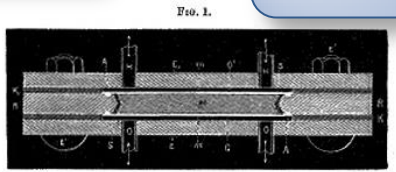
1940

PEM electrolysis discovered

1960s

1840-90

Fuel cells invented

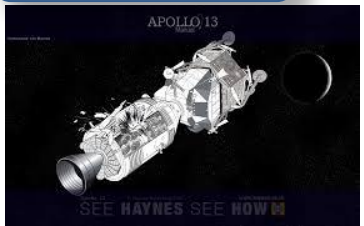



1930s

First functional fuel cells

1960s

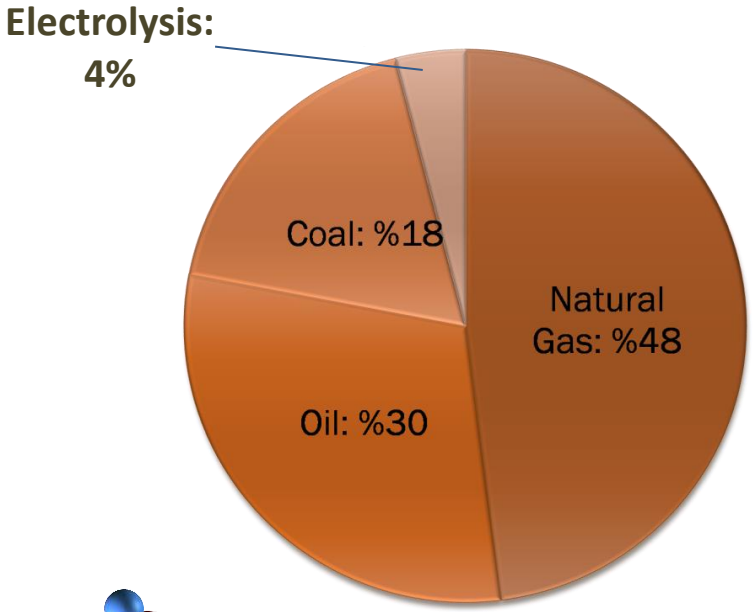
NASA starts using fuel cells in space

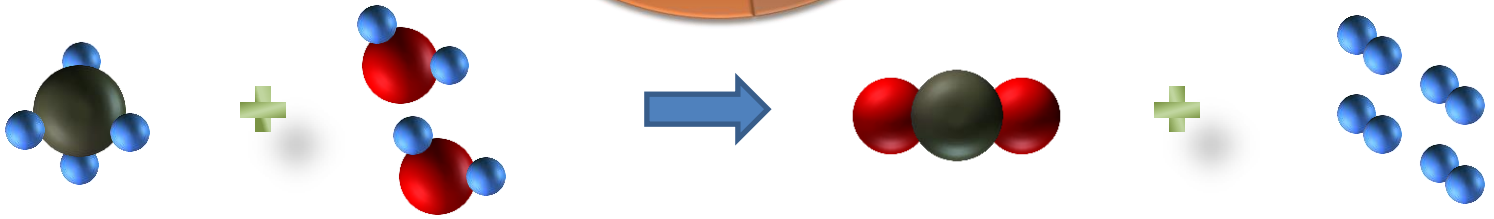



2000's

Hydrogen cars reach the market

# Today’s hydrogen production is dominated by fossil fuel reforming

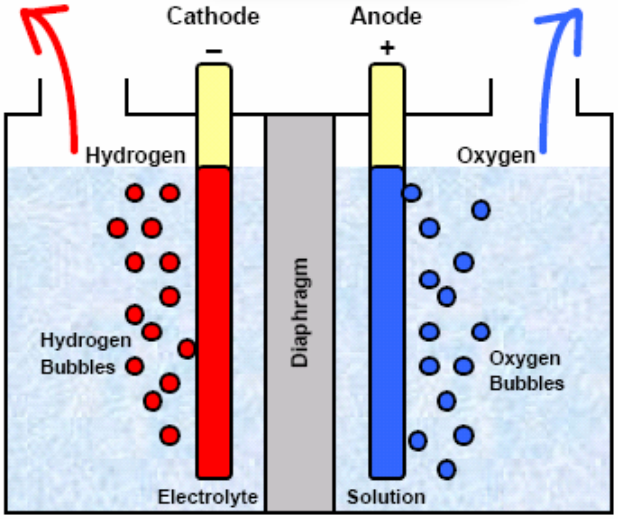


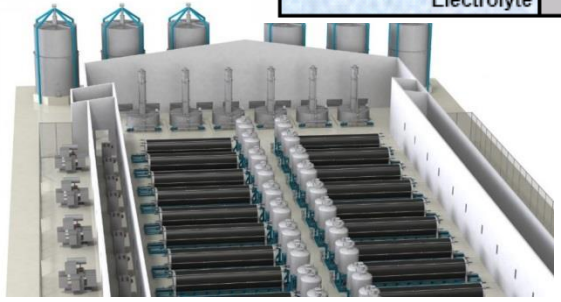



$CH_4$ $H_2O$ $CO_2$ $H_2$

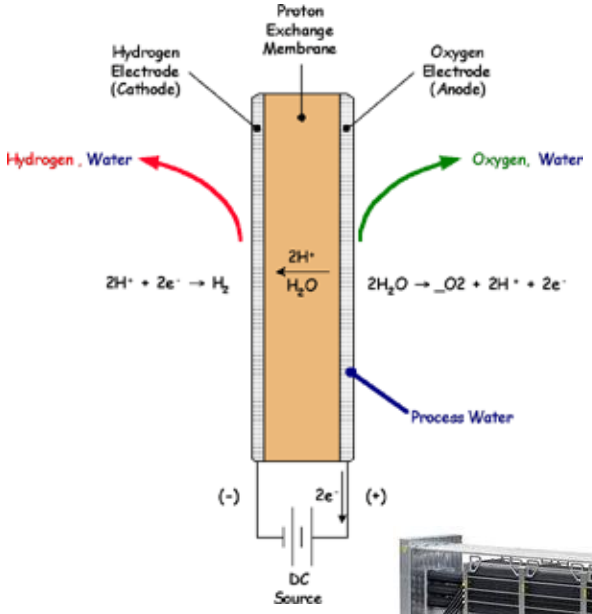
# Electricity costs comprise >80 % of total cost of hydrogen with current technologies

Alkaline electrolyser

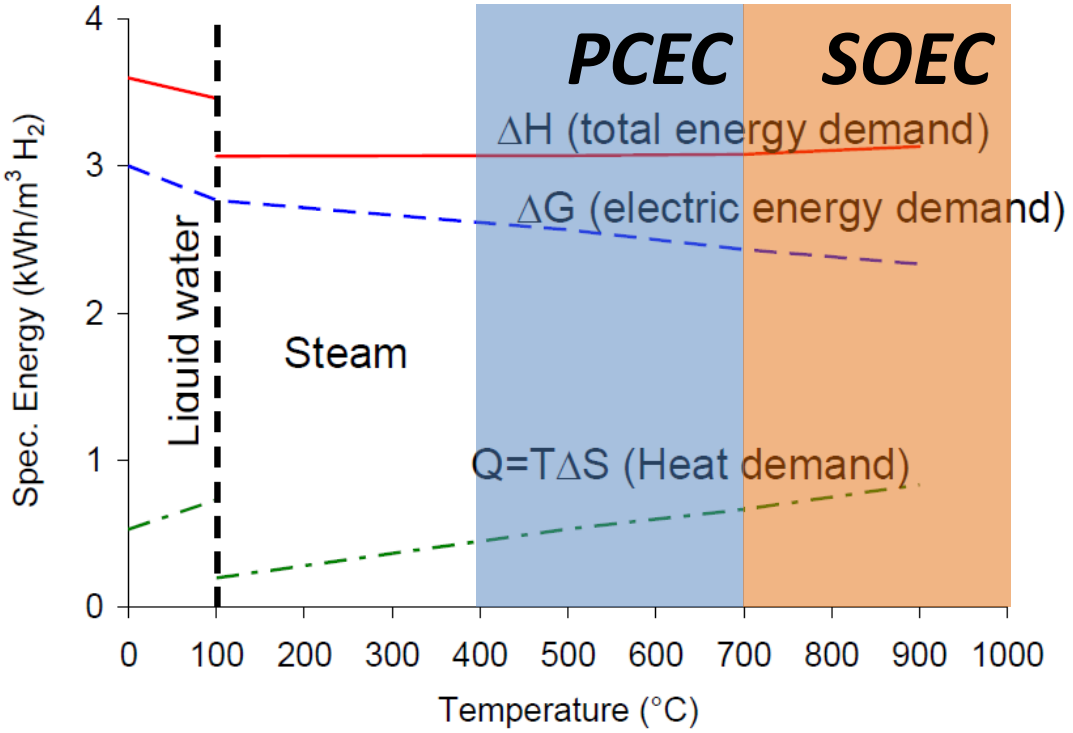


PEM electrolyser

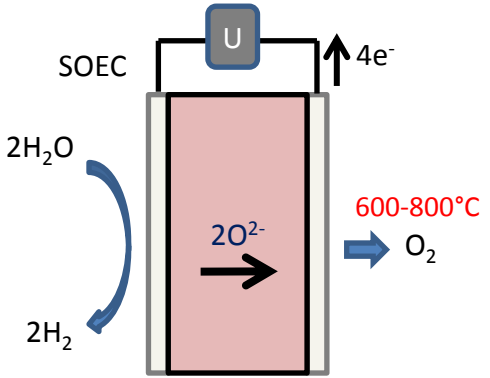



# Increasing operating temperature allows reduction of electricity consumption by utilization of thermal energy

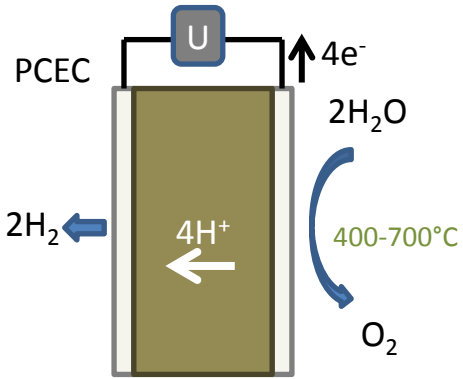


# Comparison of SOEs and PCEs

- Solid Oxide Electrolysers (SOEs)
  - Well proven technology
    - Scalable production
    - High current densities at thermo-neutral voltage
  - Long term stability challenges
    - Delamination of $O_2$-electrode
    - Oxidation of $H_2$-electrode at OCV
  - High temperatures




- Proton Ceramic Electrolysers (PCEs)
  - Less mature technology
    - Fabrication and processing challenges
  - Produces dry, pressurized $H_2$ directly
  - Potentially intermediate temperatures
    - Slower degradation
    - Slow $H_2O$-electrode kinetics



# Processing of single tube proton ceramic electrolysers

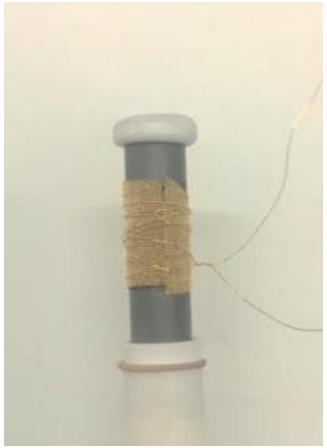
Single segment, reduced at 1000°C for 24h in 5% $H_2$

Capped and sealed using custom-made glass ceramic

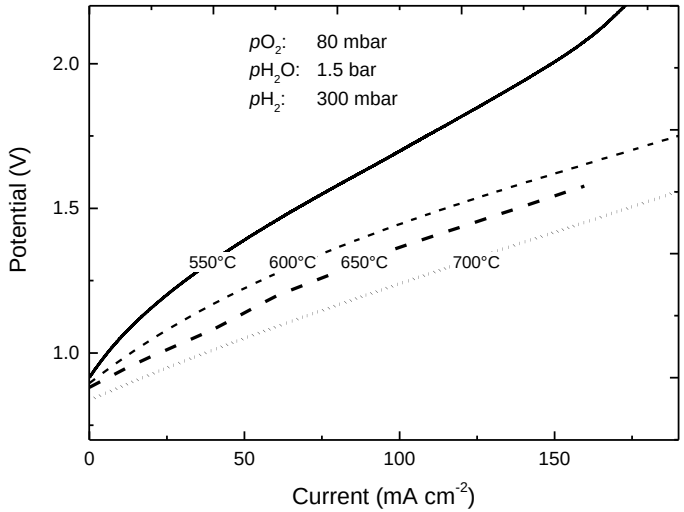
Steam electrode (BGLC785) drip-coated and brush-painted

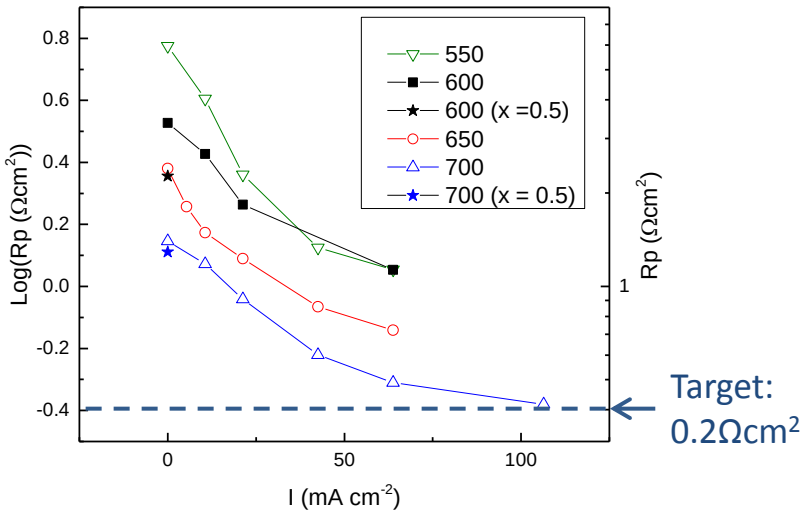
Fired in dual atmosphere with applied bias:
- 2% $O_2$ outside, 5% $H_2$ inside
- $E_{cell}$ = 1.4 V during firing (above 500°C)

Electrolysis tests with gold current collector.



# Electrolysis tests reveal that the electrodes still need further development and improved processing to reach target performance



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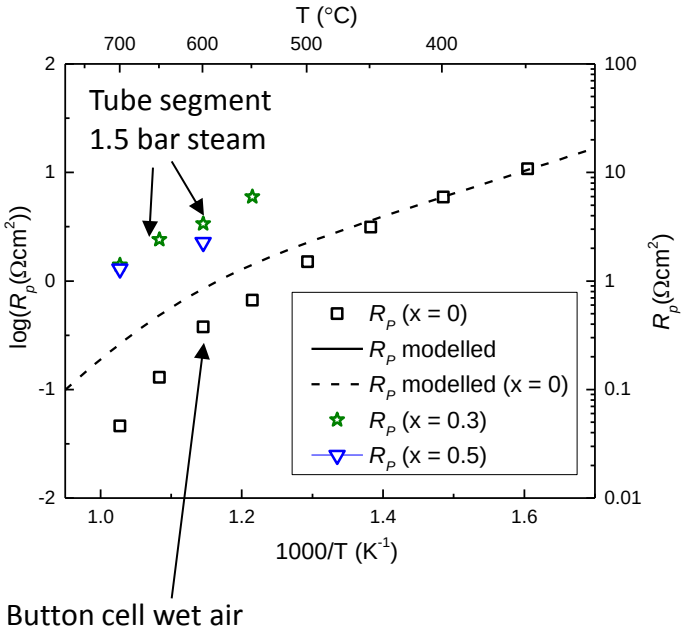
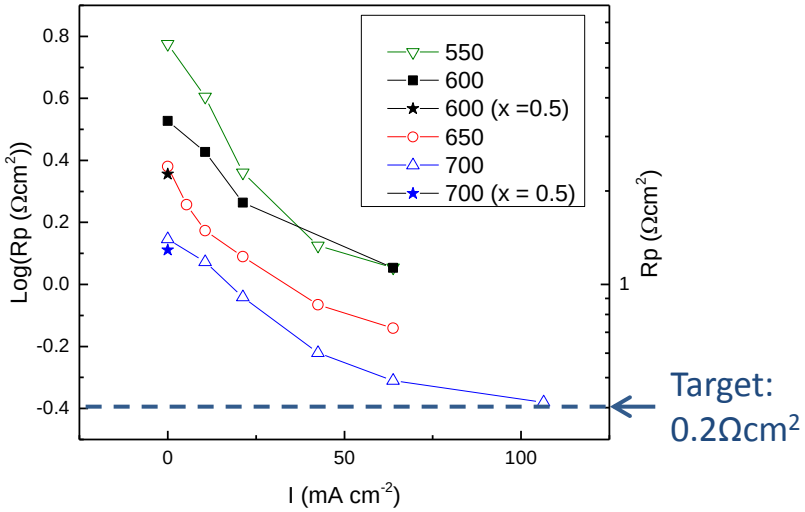
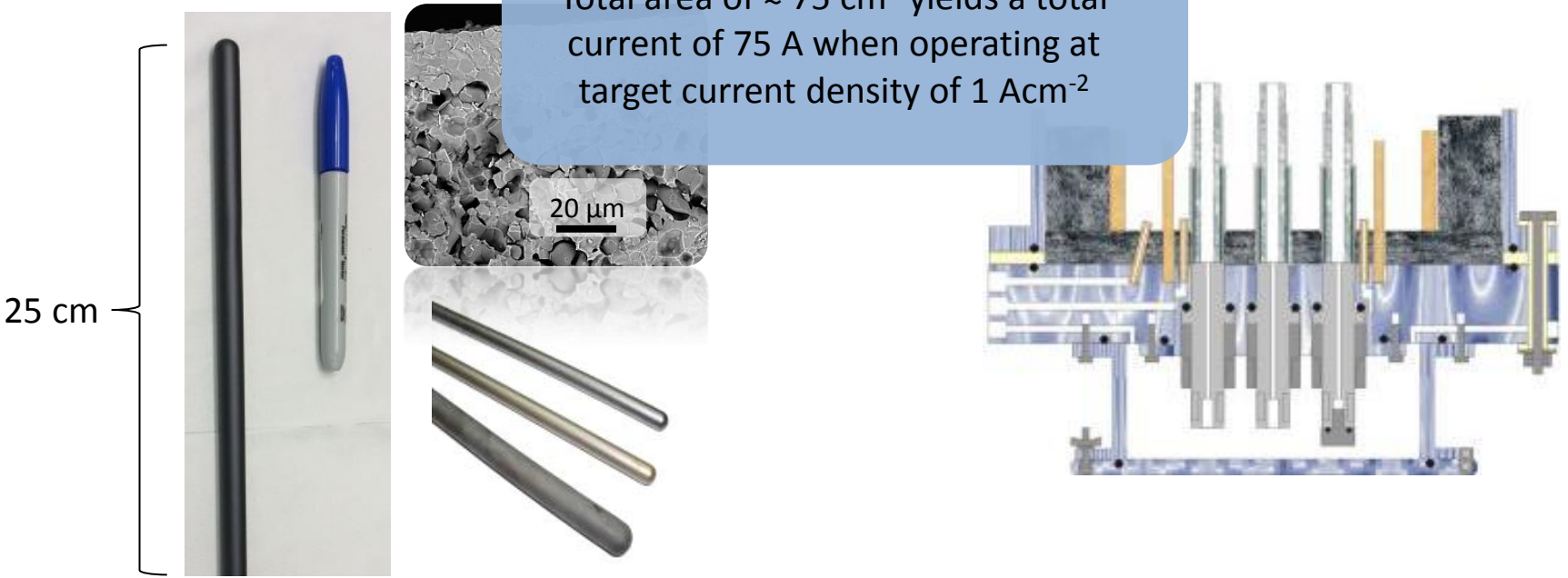


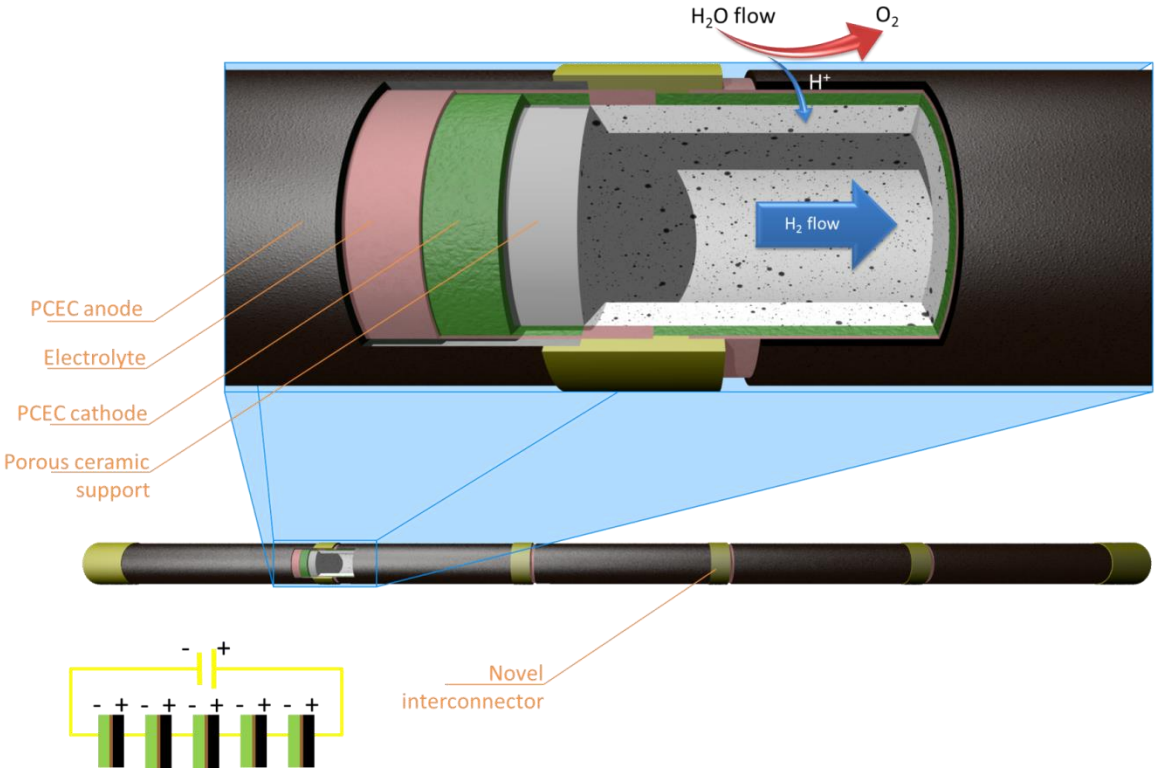



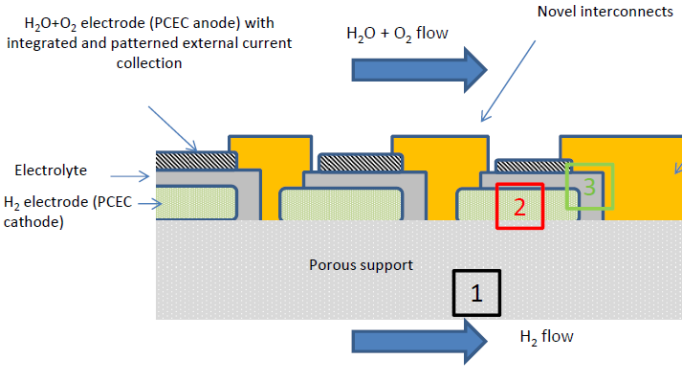
# Tubular electrolysers could improve module lifetime by individual tube monitoring and replacement

Total area of ≈ 75 $cm^2$ yields a total current of 75 A when operating at target current density of 1 $Acm^{-2}$



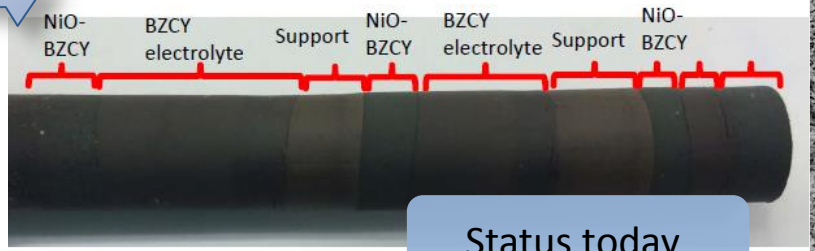
# Segment-in-series tubular cells drives up the voltage and reduces total current for each tube



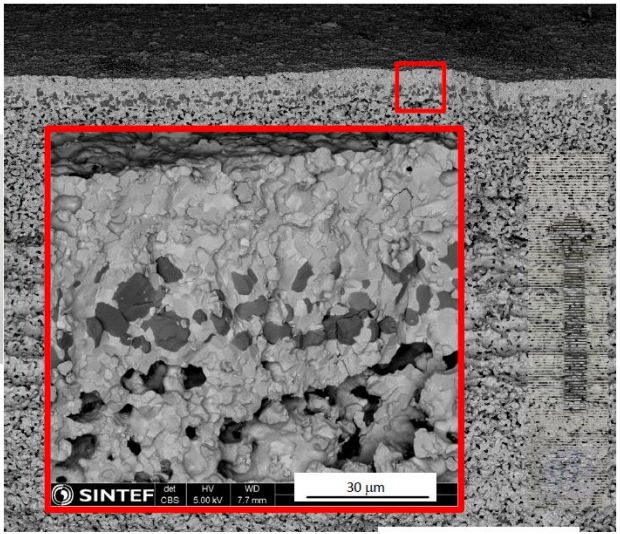



# Challenging processing routes due to differential shrinking

8 months ago




Status today



# Where do we move from here….?

- Increased and continued focus on device/cell/stack manufacturing for better performance
- Go back to more fundamental material development using what we learn during the project
- Looking more specifically into the fundamentals of PCE electrochemistry

# Acknowledgements

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