SFERA III - Doctoral Colloquium

European Union's Horizon2020 Research and Innovation programme under grant agreement n°823802

Application scenario of thermochemical thermal energy storage in solar powered high temperature electrolysis process

Agenda

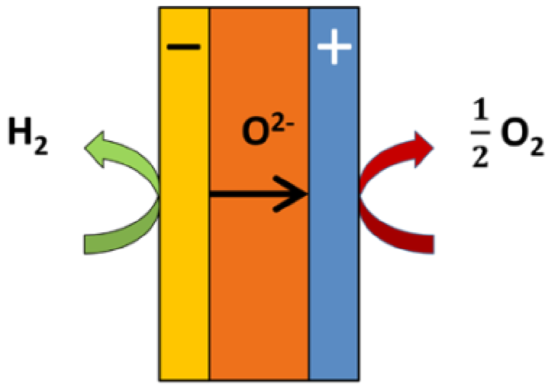
- High temperature electrolysis (HTE) operation conditions
- Direct coupled process
- TES – Integration
- Steady State process analysis

HTE Operation conditions

- Thermoneutral Operation (SOEC)
- Steam Parameter (Cathode)
  - T = 820°C
- Sweep Gas Parameter (Anode)
  - T = 840-850°C
  - $\dot{m}_{SG} = 4 \cdot \dot{m}_{H_2O}$

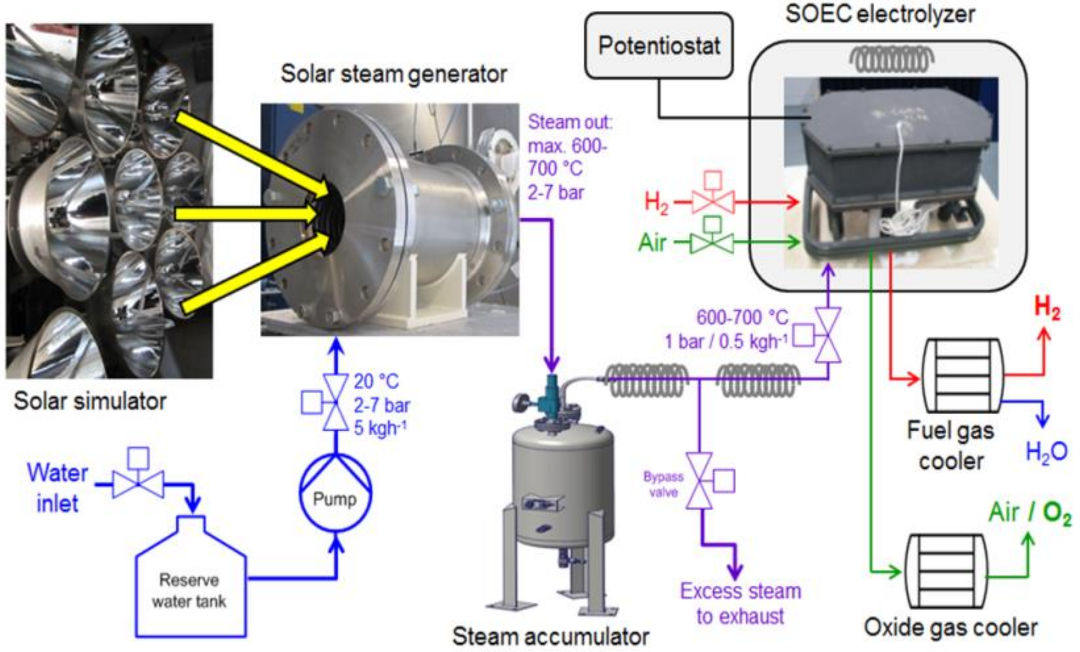
High Temperature Electrolysis
700 – 1000°C

Cathode | Anode

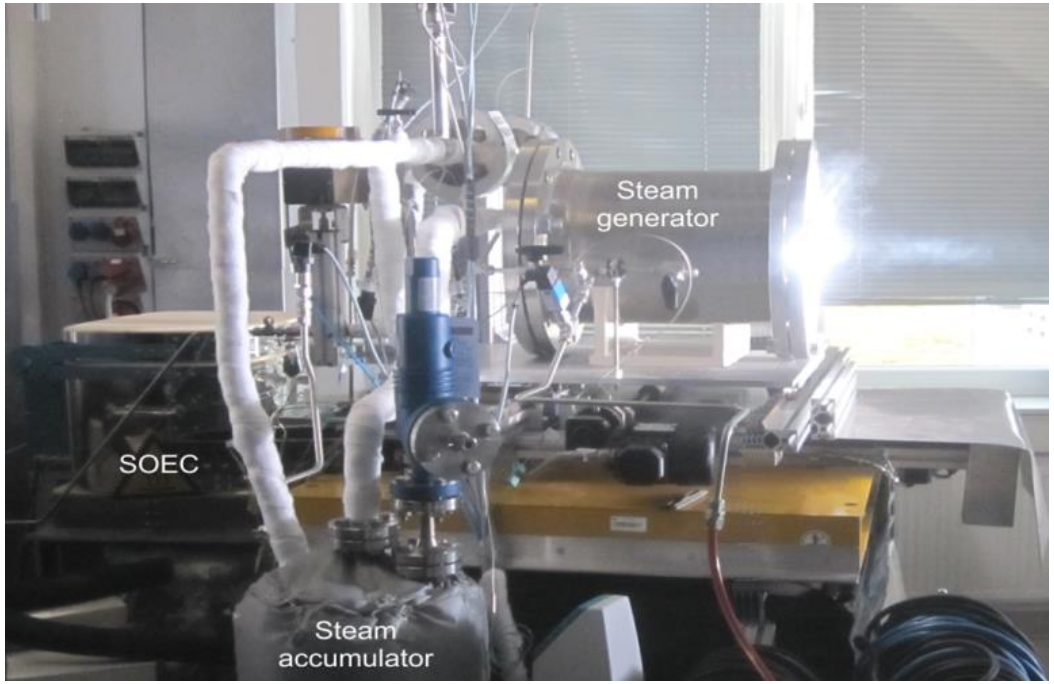


Anode	O^{2-}	→	$2e^- + ½\ O_2$
Cathode	$H_2O + 2e^-$	→	$H_2 + O^{2-}$
	H_2O	→	$H_2 + ½\ O_2$

Direct coupled Process



Experimental setup of solar heat integrated SOE system



SOE electrolyzer and solar steam generator in operation

Schiller et al. (2019)

TES - Systems

- Sensible

$$Q_{sens} = m\, c_p\, \Delta T$$

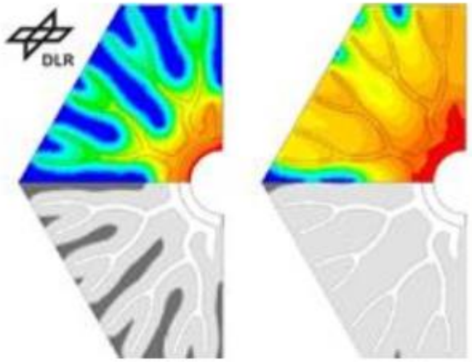
- Latent Phase Change

$$Q_{latent} = \int_{T_1}^{T_m} m\, c_{ps}\, dT + m\, \Delta T + \int_{T_m}^{T_2} m\, c_{pl}\, dT$$

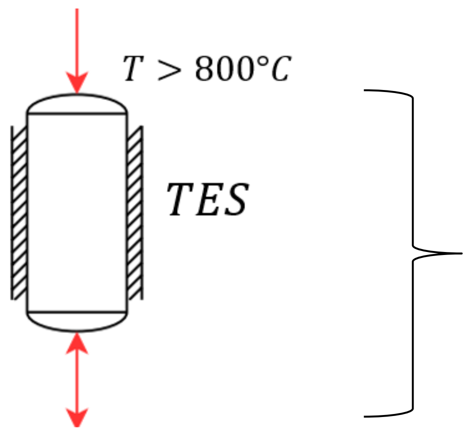
- Thermochemical Reaction

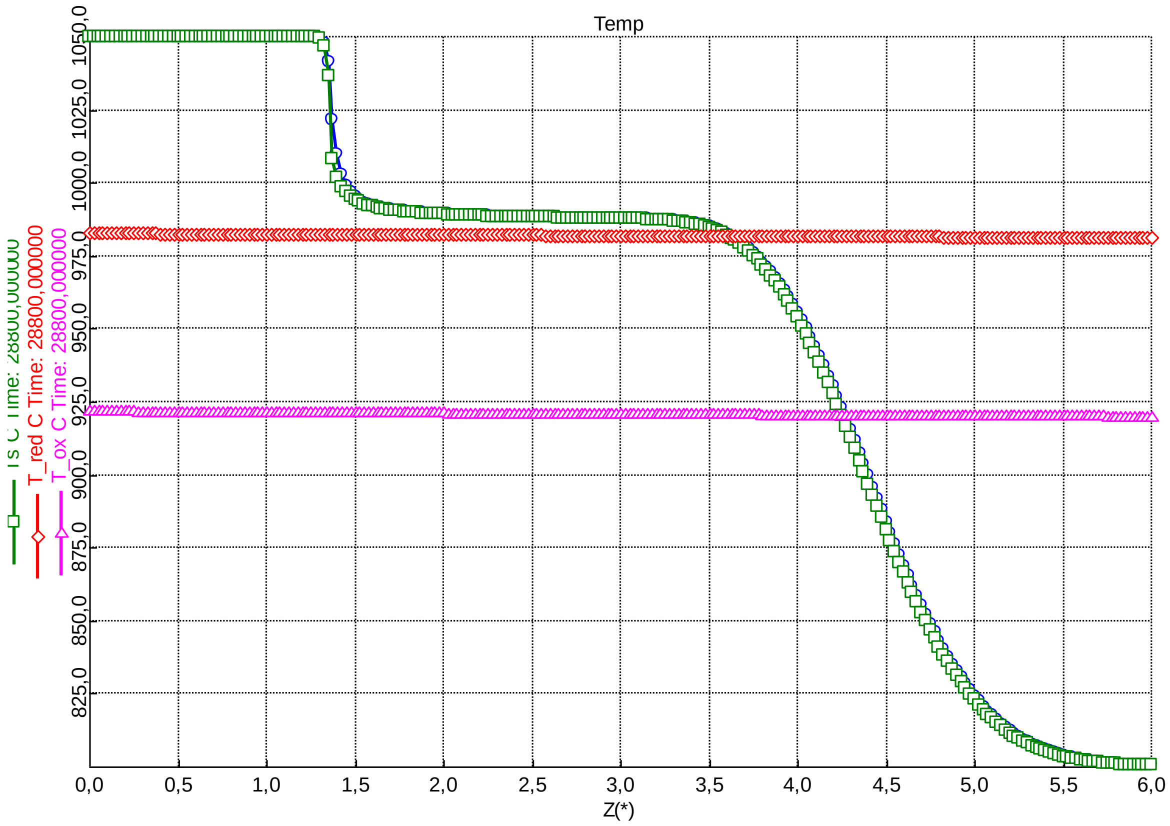
$$A + B \leftrightarrow C + \Delta H$$
$$Q_{TC} = Q_{sens} + \Delta H$$






Thermal Energy Storage



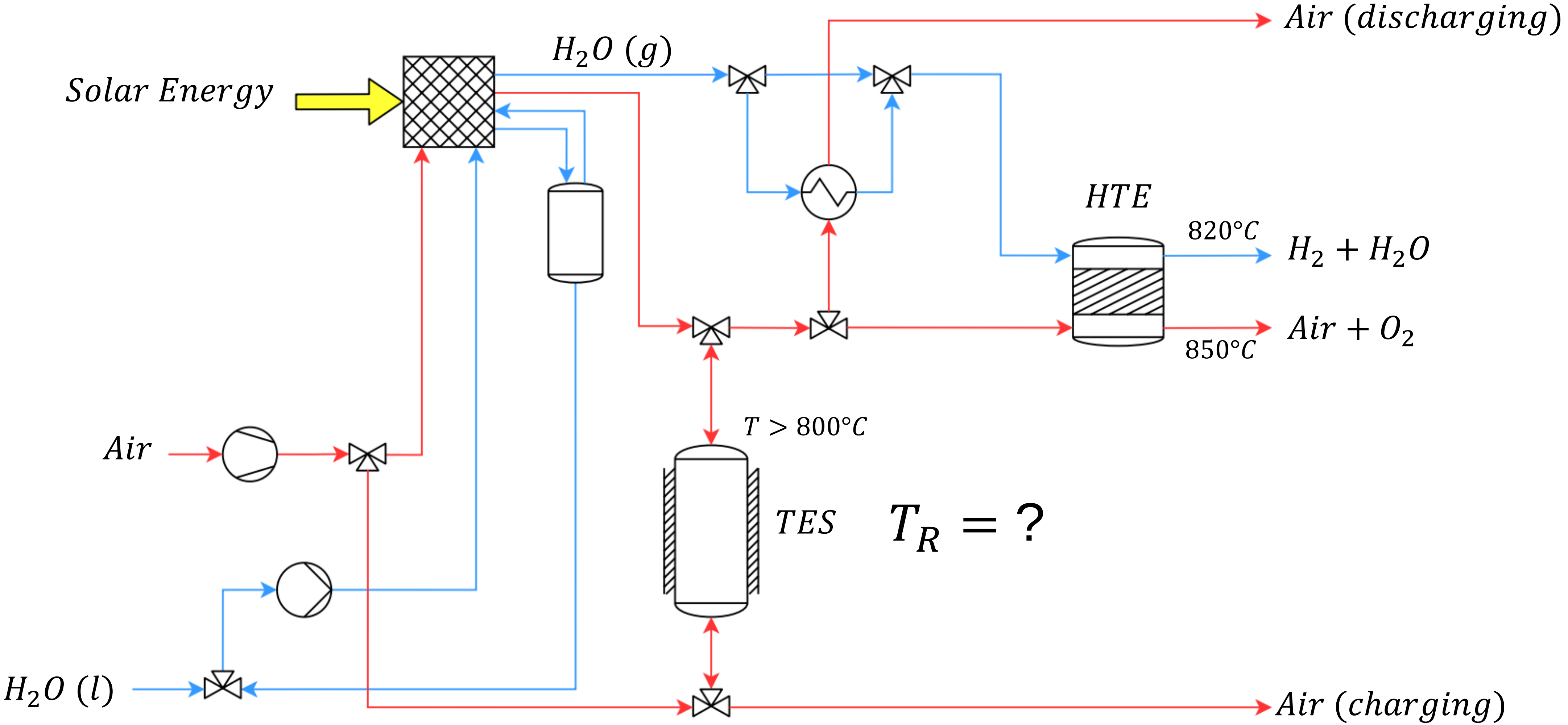


$$6\,(Mn,Fe)_2O_3 + \Delta_R H \rightleftharpoons 4\,(Mn,Fe)_3O_4 + O_2$$

↑

271 kJ/kg

TES Integration



Solar to Hydrogen Efficiency

- Solar to pressuerized Hydrogen efficiency

$$\eta_{sol,pH2} = \frac{h_{HHV} \cdot \dot{n}_{H_2}}{\dot{Q}_{sol}}$$

- Assumptions:
  - $\eta_{sol,el.} = 20\%$
  - $\eta_{PB} = 35\%$
  - $\eta_{SF} = 55\%$
  - $\eta_{SR} = 85\%$
  - $h_{HHV} = 285.84 \text{ kJ/mol}$
  - Steam conversion rate $= 90\%$

	1. Comp. Th. R.	2. Th. R. + Rankine C.
η_{sol}	27.36 %	28.93 %
$\eta_{sol,pH2}$	25.58 %	26.96 %

Conclusion

- Direct solar powered HTE can achieve high efficiencies
- Storage with thermochemical reaction are suitable
- Discharge provides oxygen lean sweepgas supporting the lifetime of the HTE

Outlook

- Determine the optimum operation conditions of the TES
- Optimize the process
- Transient process simulation (Cloud shading + day-night-shift)
- Experimental validation of the model
- Techno-economic Analysis

Thank you very much for your attention!

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