Clean Hydrogen Partnership

prometeo
GREEN HYDROGEN FROM SUNSHINE

Hydrogen PROduction by MEans of solar heat and power in high TEmperature Solid Oxide Electrolysers

Modelling and Performance Analysis of a SOE System Integrating PV, Concentrating Solar and Thermal Energy Storage

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EHEC 2022
EUROPEAN HYDROGEN ENERGY CONFERENCE

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AeH2
ASOCIACIÓN ESPAÑOLA DEL HIDRÓGENO

Outline

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2. Process Flow Diagrams
3. Methodology: component modelling
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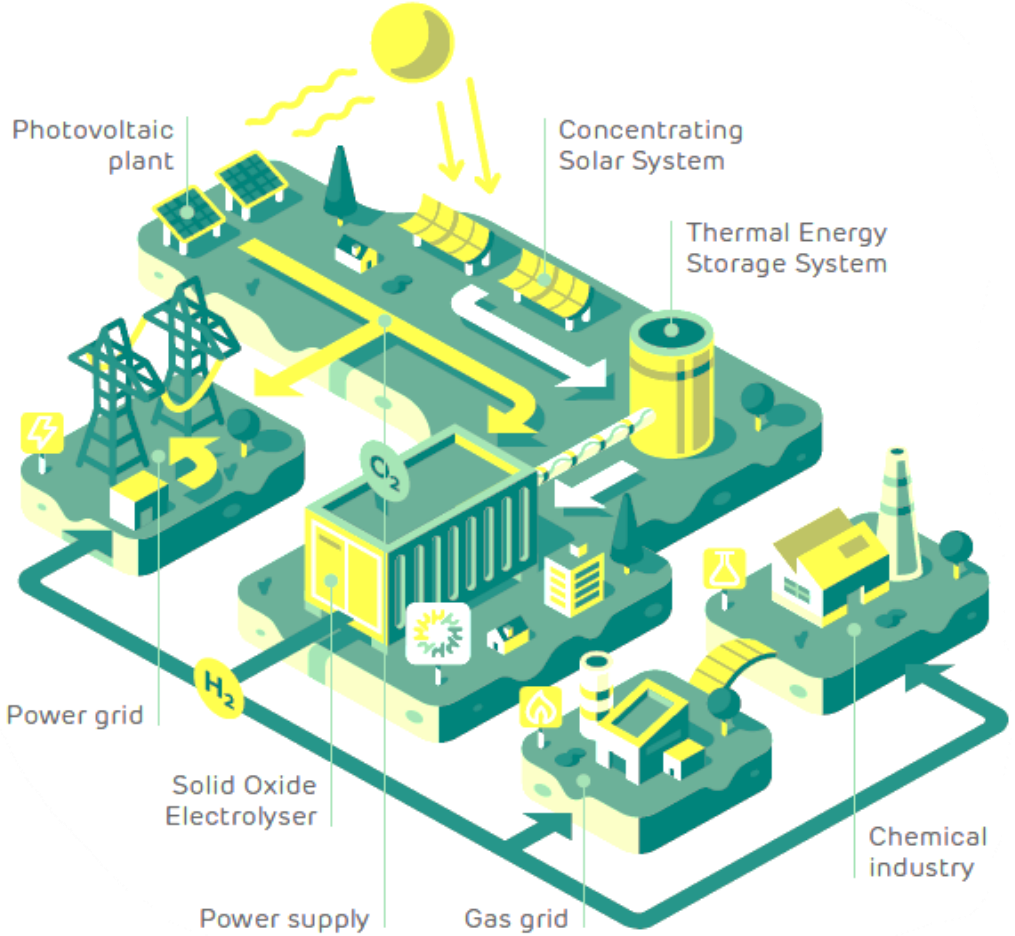
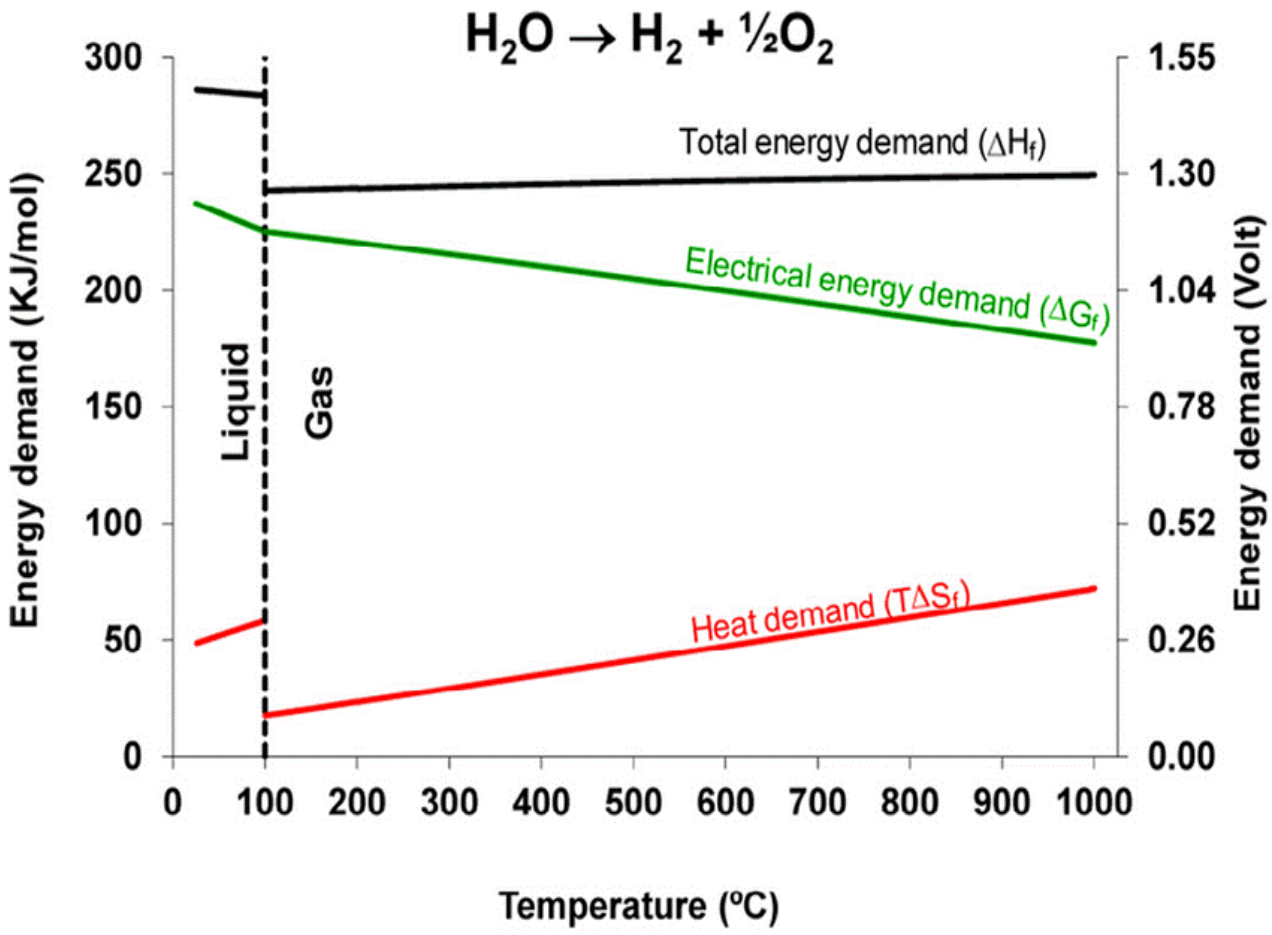
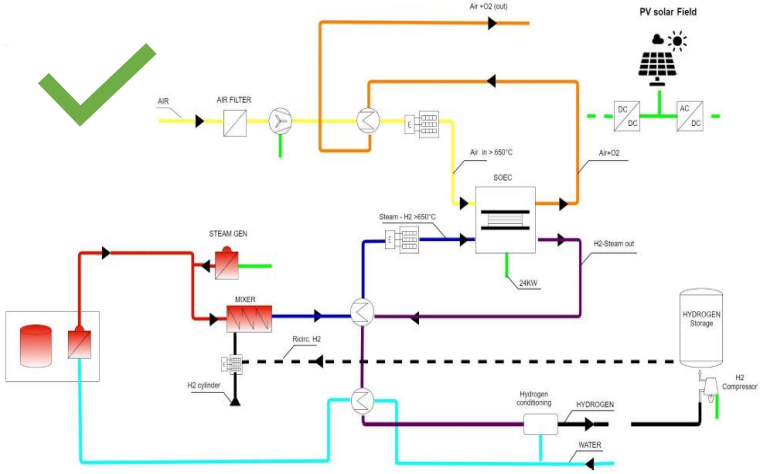
   II. Solar Field and TES
4. PFD selection and Design Point simulation results
5. Exploitation study: 1-Year simulation results
6. Conclusions and outlook

1. PROMETEO project, motivation and system description

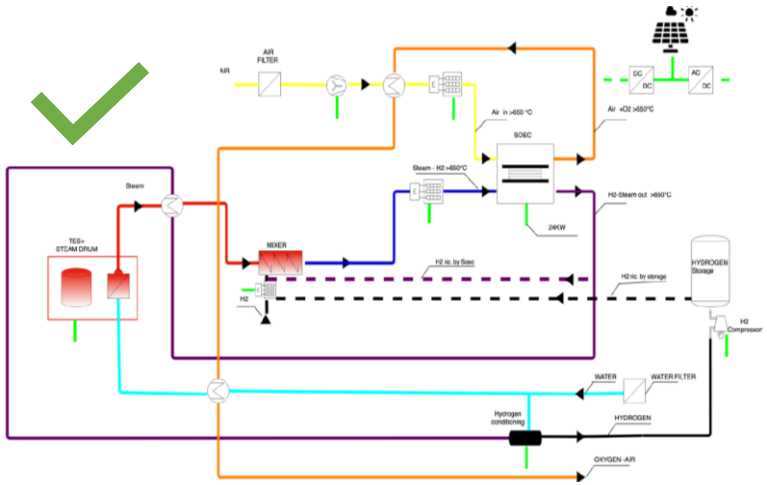




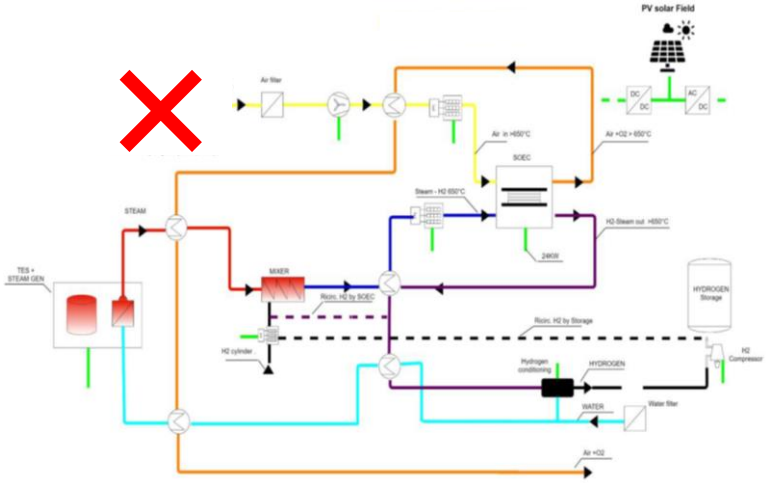
2. Process Flow Diagrams (PFDs)



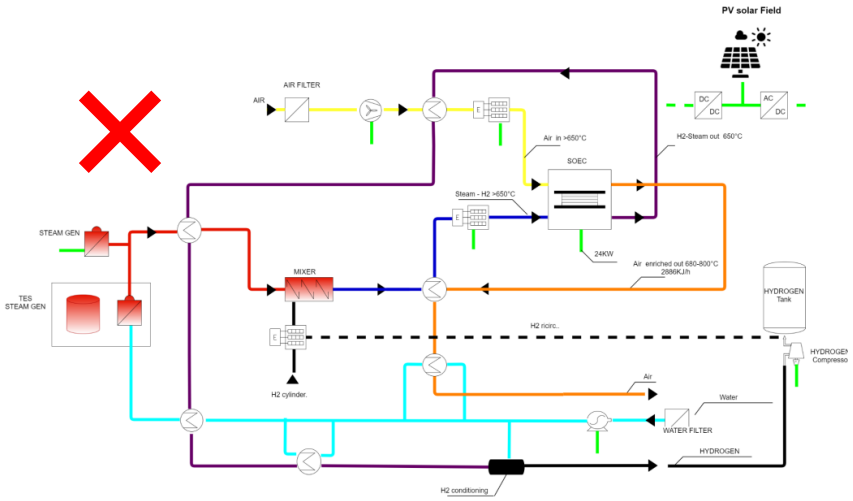
Anode-Anode Cathode-Cathode



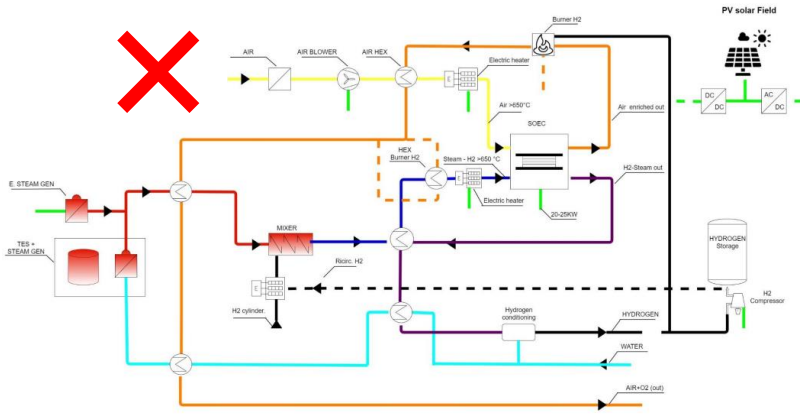
Anode Supported



Improved Anode Supported



Cross-Flow



H2 Burner

FONDAZIONE BRUNO KESSLER

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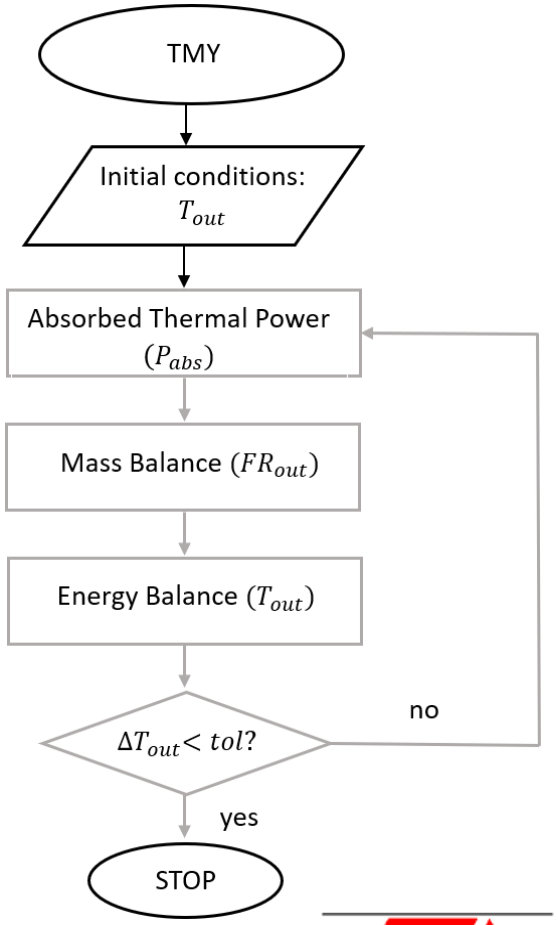
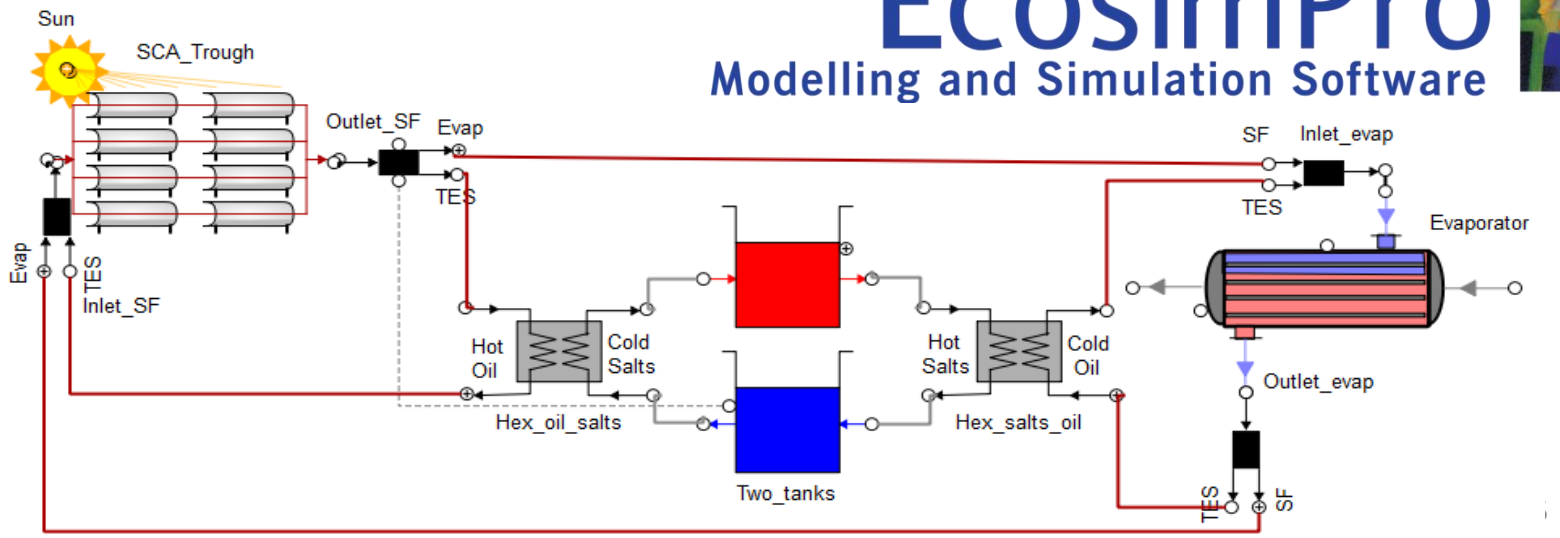
3. Component Modelling : Solar Field, TES and Evaporator



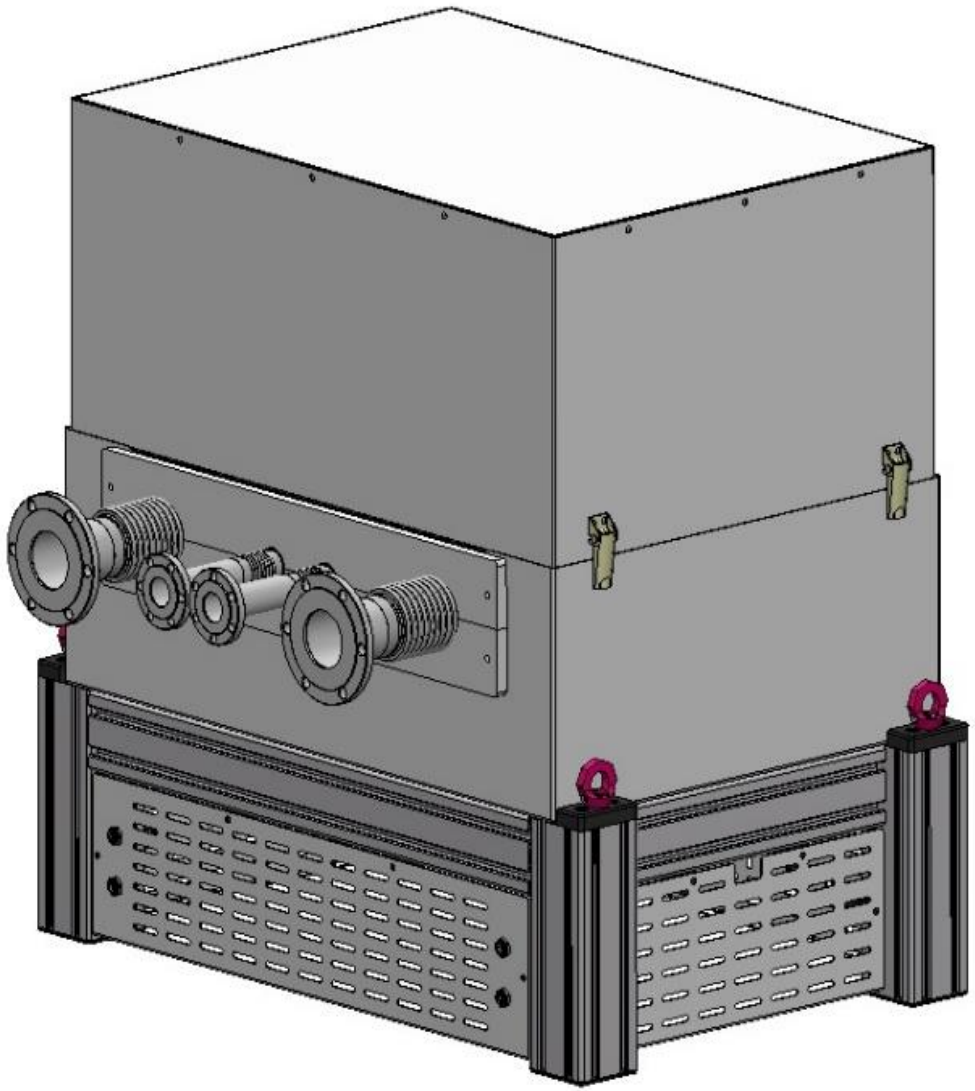
Variable	Used value
Design point	27 of April; 12:00 AM
Design point DNI	800 W/m2
Orientation	North-South
Type of collector and receiver	LS2 and Schott-PTR70
Solar field control (FRmin, stand-by)	FRmin=1kg/s, stand-by = 0kg/s
TES size	16hours (1600kg of HITEC XL)
Solar Multiple and Heat Sink	SM = 3 and 5 kW

EcosimPro
Modelling and Simulation Software

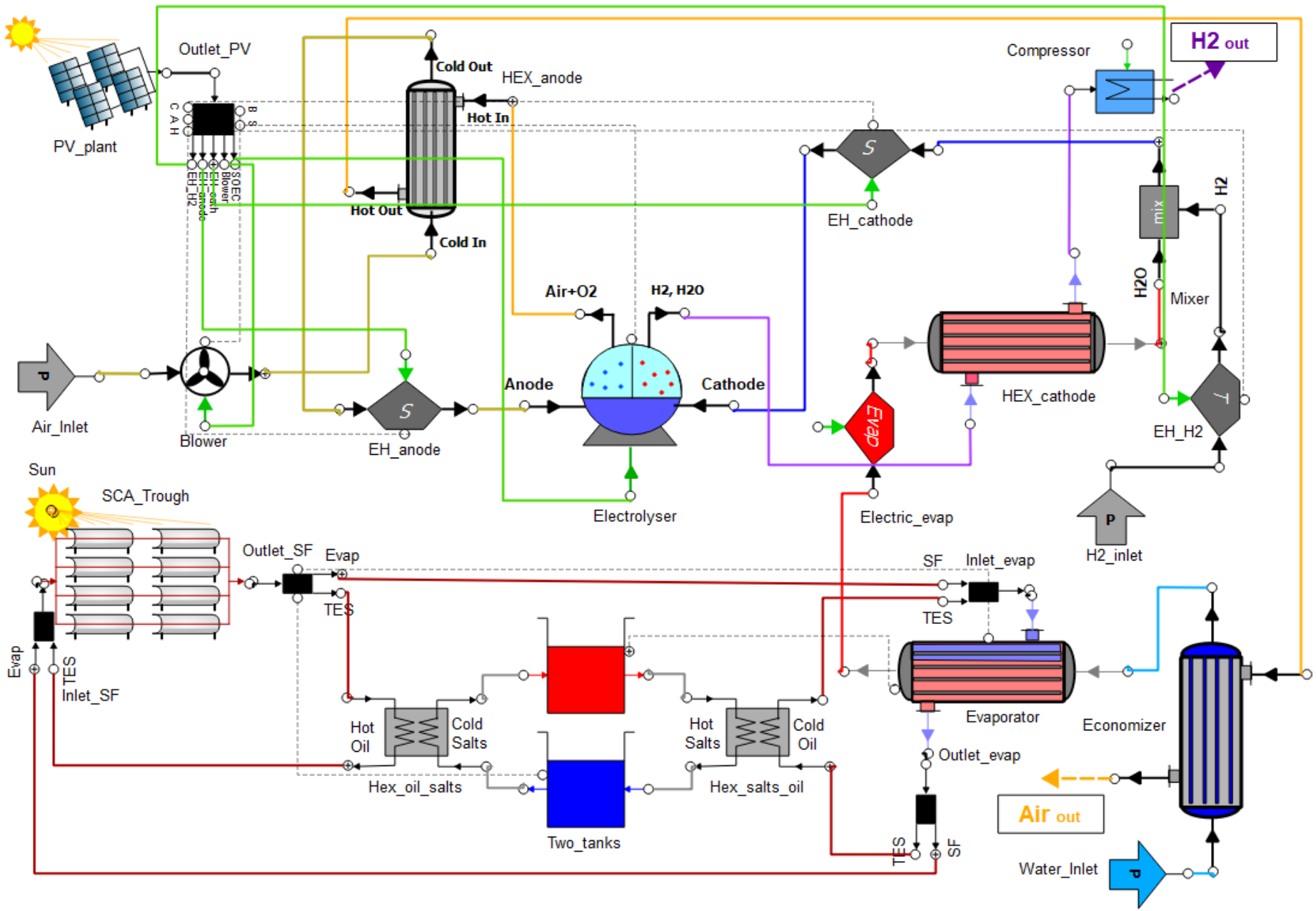


3. Component Modelling : SOEC

Variable	Assumed value
ASR	SP data used to obtain α = 0.51
Sweep gas flow rate	26.7 kg/h
SOEC hot surface	75x54x74cm (HxWxL)
SOEC insulation width	12cm
SOEC heat capacity (Ks)	96.86 J/K
SOEC insulation material	Microtherm 240 kg/m3 (Microtek International Ltd.)
Number of cells	80
Cell active area	320 cm2
Full power	25kW



1. Javier Sanz Bermejo el at. *Part load operation of a solid oxide electrolysis system for integration with renewable energy sources,* International Journal of Hydrogen Energy, 40 (2015), 8291-8303.
2. Floriane Petipas et al. *Model-based behavior of a high temperature electrolyser system operated at various loads,* Journal of Power Sources, 239 (2013), 584-595.


Outlet_PV
PV_plant
Cold Out
HEX_anode
Hot In
Hot Out
Cold In
Compressor
H2 out
EH_cathode
H2
mix
H2O
Mixer
Air+O2
H2, H2O
Anode
Cathode
HEX_cathode
Air_Inlet
Blower
EH_anode
Electrolyser
Evap
EH_H2
Sun
SCA_Trough
Electric_evap
H2_inlet
Outlet_SF
Evap
TES
SF
Inlet_evap
Inlet_SF
Hot Oil
Cold Salts
Hot Salts
Cold Oil
Hex_oil_salts
Hex_salts_oil
Two_tanks
Evaporator
Economizer
Outlet_evap
Air out
Water_Inlet

4. Design Point simulation results and PFD selection

	External Power Input [kW]	Number components	Evaporator heat requirement [kW]
Anode-Anode, Cathode-Cathode	2.22 kW (1.07+0.17 Anode and 0.9+0.08 Cathode)	3 Heat Exchangers 3 Electric Heaters 1 Evaporator 1 Blower Tot 8	5.7 kW
Anode supported	2.17 kW (1.02+0.17 Anode and 0.9+0.08 Cathode)	3 Heat Exchangers 3 Electric Heaters 1 Evaporator 1 Blower Tot 8	4.7 kW

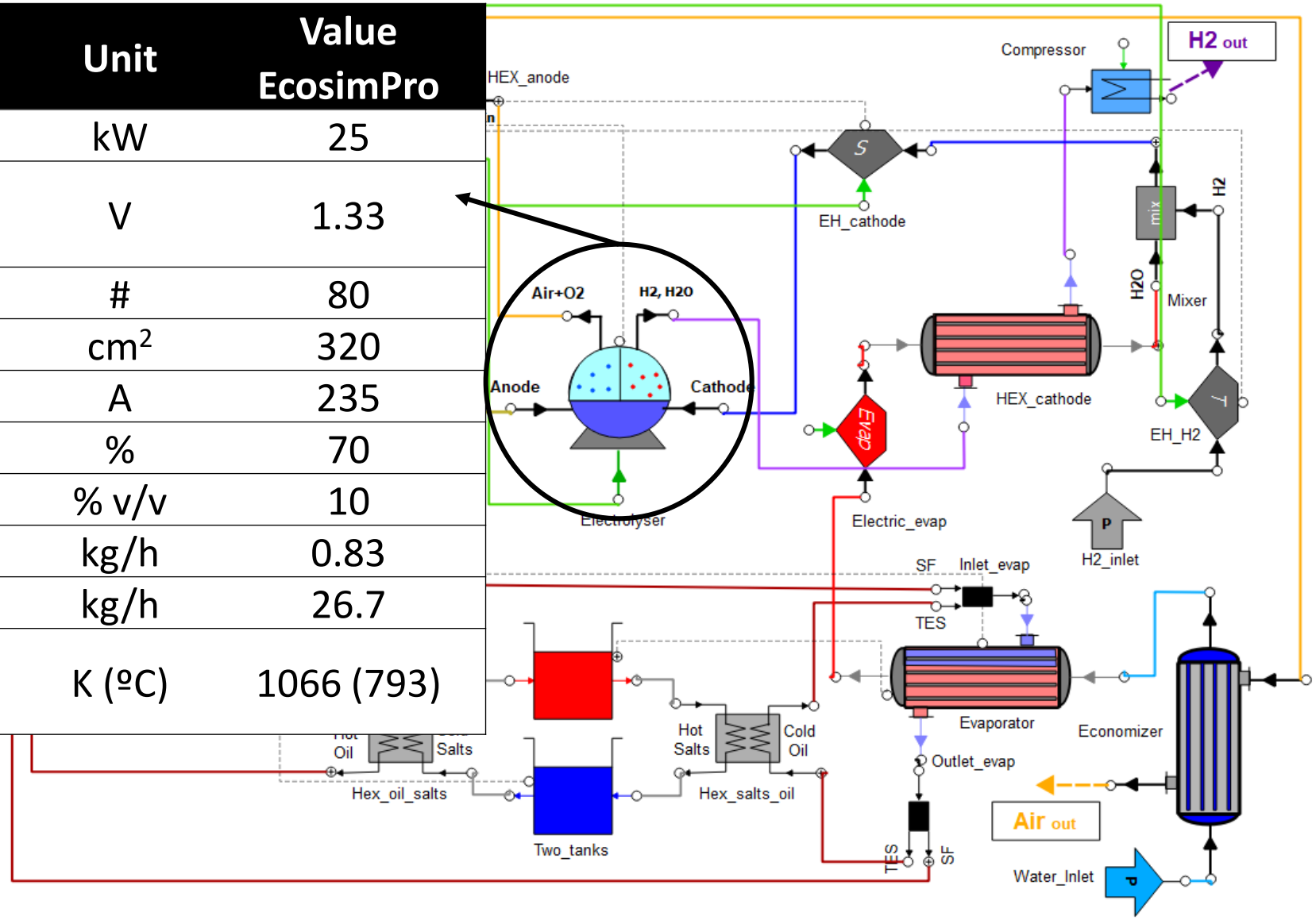
Constant values in both PFD:

- Blower power input = 0.17 kW
- Hydrogen inlet electric heater power input = 0.08 kW

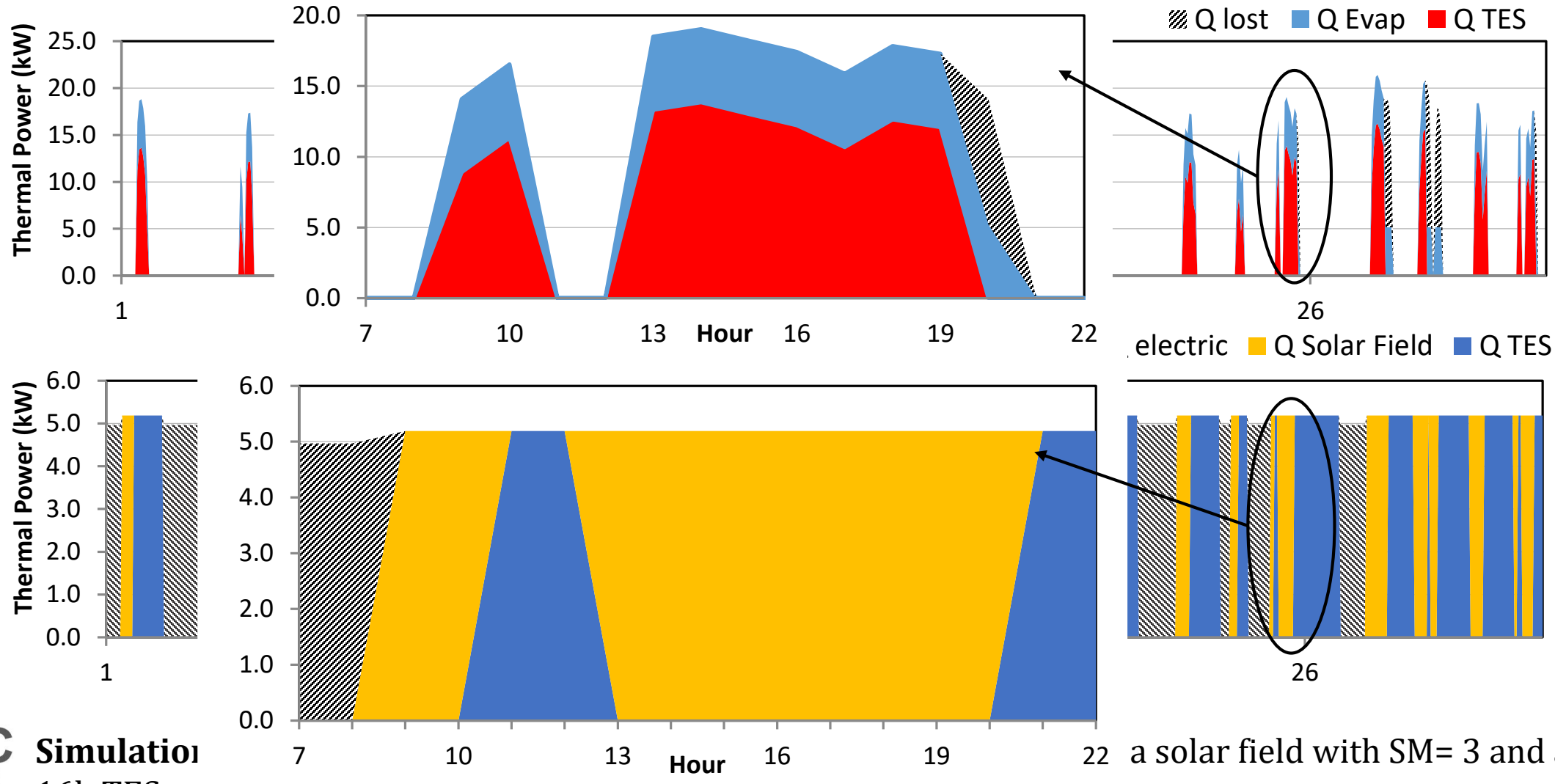
4. Design Point simulation results and PFD selection

Components of SOE	Unit	Value EcosimPro
SOE full power	kW	25
Voltage at full power (thermoneutral condition)	V	1.33
Number of cells	#	80
Surface area of the cell	cm^2	320
Current at full power	A	235
Steam utilization	%	70
Hydrogen inlet ratio	% v/v	10
Hydrogen production	kg/h	0.83
Airflow (dry air)	kg/h	26.7
Cell temperature (thermoneutral condition)	K (ºC)	1066 (793)

19.9 kg/day of H2

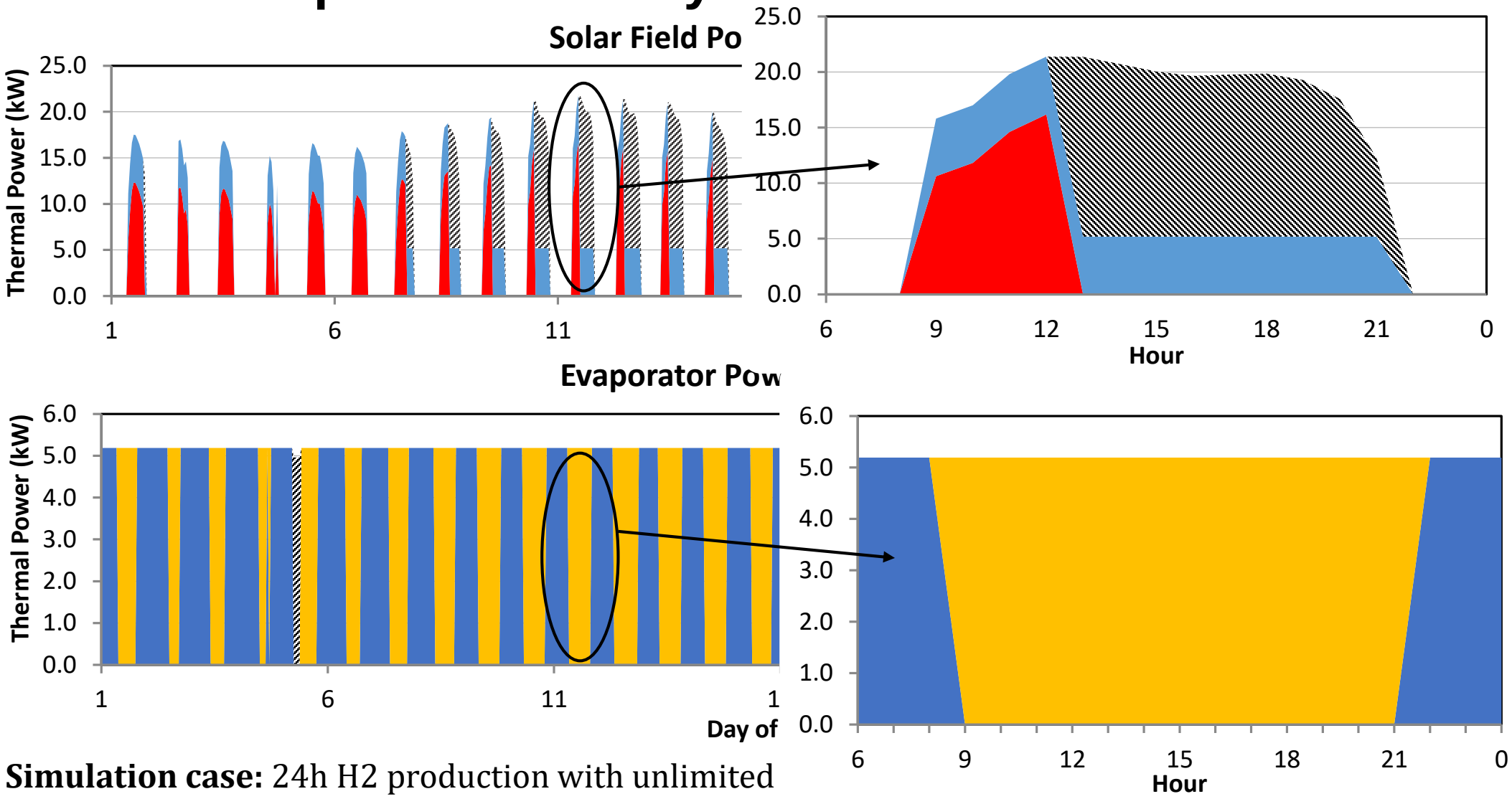


5. 1-Year Exploitation Analysis



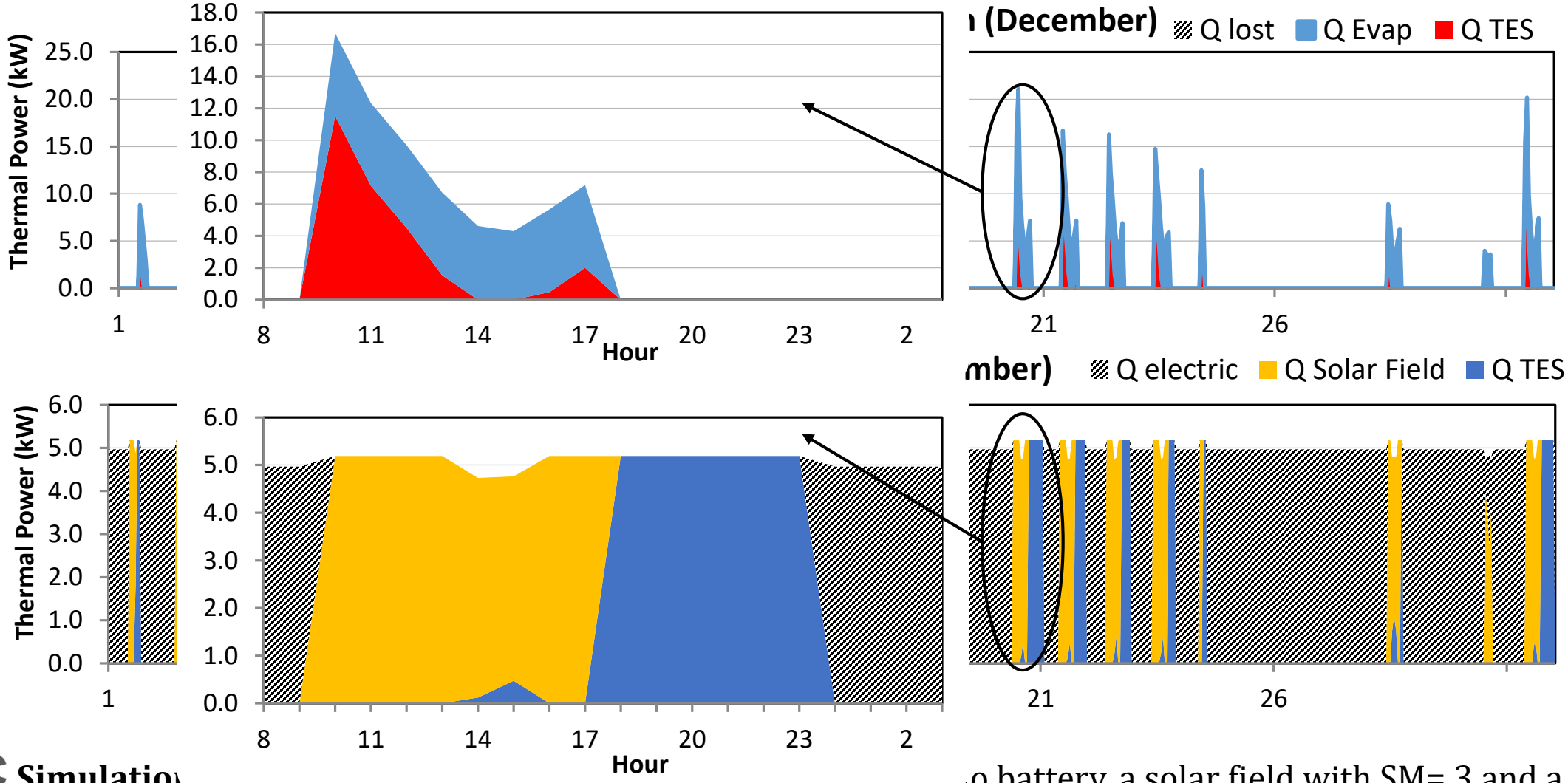
Simulation a solar field with SM= 3 and a 16h TES

5. 1-Year Exploitation Analysis



Simulation case: 24h H2 production with unlimited 16h TES

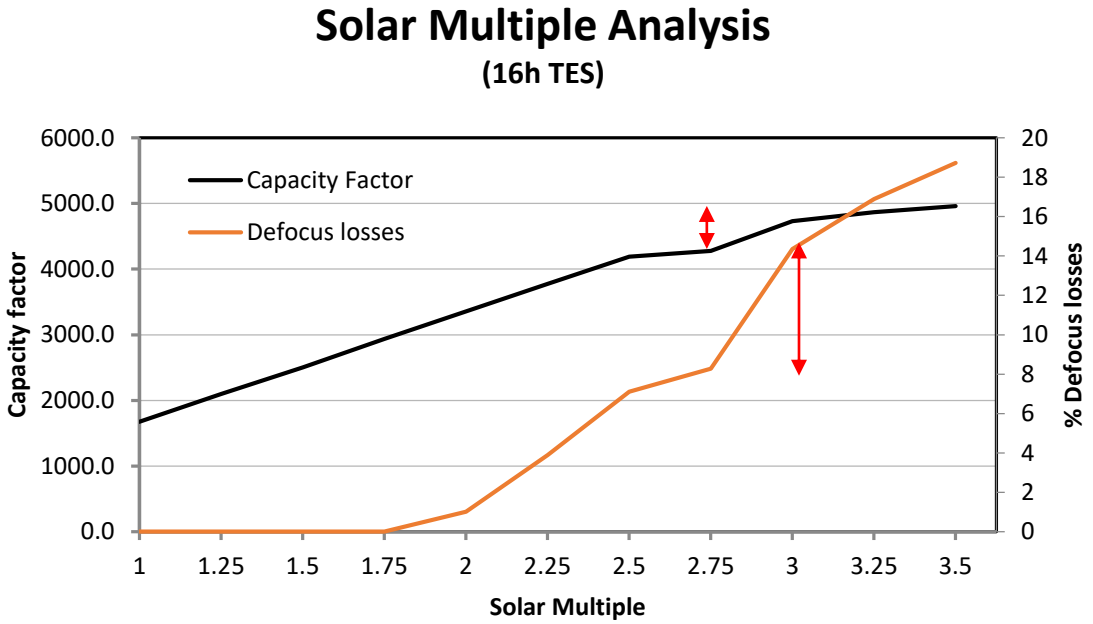
5. 1-Year Exploitation Analysis

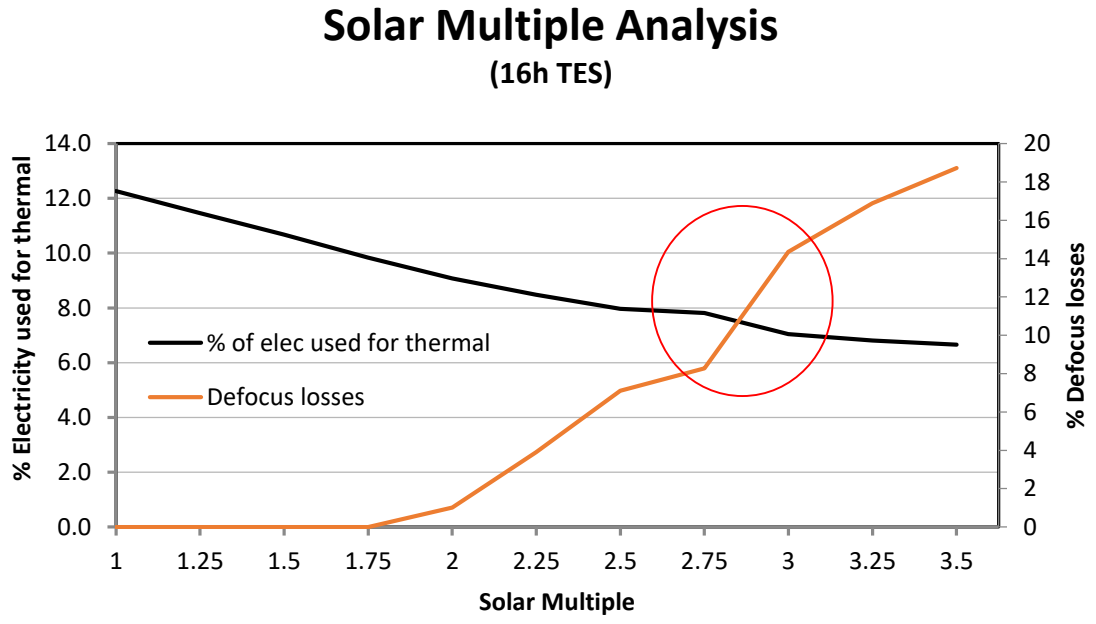


Simulation …o battery, a solar field with SM= 3 and a 16h TES

5. 1-Year Exploitation Analysis

For SM=0 (no solar field), the % of electrical energy dedicated to heat generation would be **16.1%**





According to the solar share and solar losses indicators, the optimum SM would be between 2 and 2.7 for 80kWh TES system.

6. Conclusions and Outlook

Conclusions:

- Identification of an efficient integration process flow diagram
- Develop a methodology tool based on EcosimPro software
- Develop a performance analysis (SM=3 and TES=16h):
  - 7% of electricity used for heat generation (instead of 16% without SCA)
  - Sun to Hydrogen efficiency: $\eta_{Sun \rightarrow H2} = \frac{HHV_{H_2} \cdot kg_{H2}}{P_{thermal}/\eta_{SCA} + P_{electric}/\eta_{PV}} = \mathbf{19.5\%}$

Outlook:

- Perform a techno-economic analysis and optimization of the upscaled prototype
- Integration analysis considering different downstream options:
  - Grid balancing
  - Operation in reverse mode SOEC/SOFC
  - Off-grid

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Thanks for the attention

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