From a pilot solar reactor to an industrial plant, Process analysis and cost issues

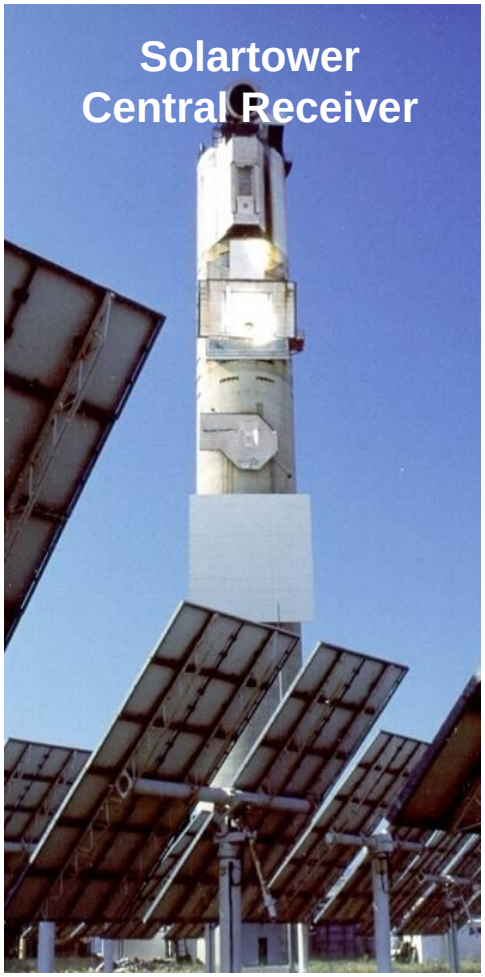
SOLHYCARB Event, Odeillo, 28 September, 2009

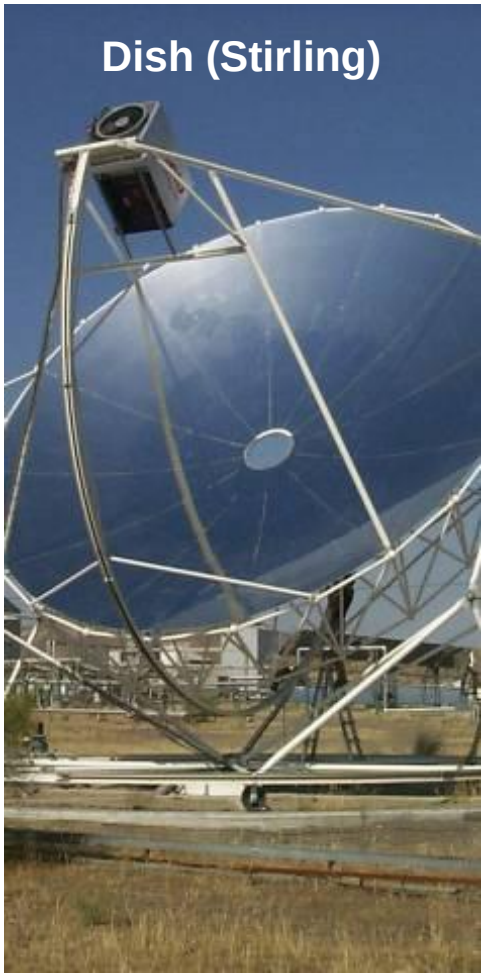
Deutsches Zentrum
für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

Overview

- CSP Options – How to achieve very high temperatures
- SOLHYCARB Pilot Reactor as basis for Scale-up
- Preliminary Economic Analysis
  - Invest
  - O&M
  - Revenues
  - Hydrogen Production
- Summary and Outlook

CSP - Concentrating Solar Power





Parabolic Trough - State of the art: SEGS-Plants

Heat transfer medium:

Thermal oil (Therminol VP1)

Live steam parame

ar

Cycle ef ncy

37%

Backup tions:

Thermal ener orage
Auxill vessel

Fuels

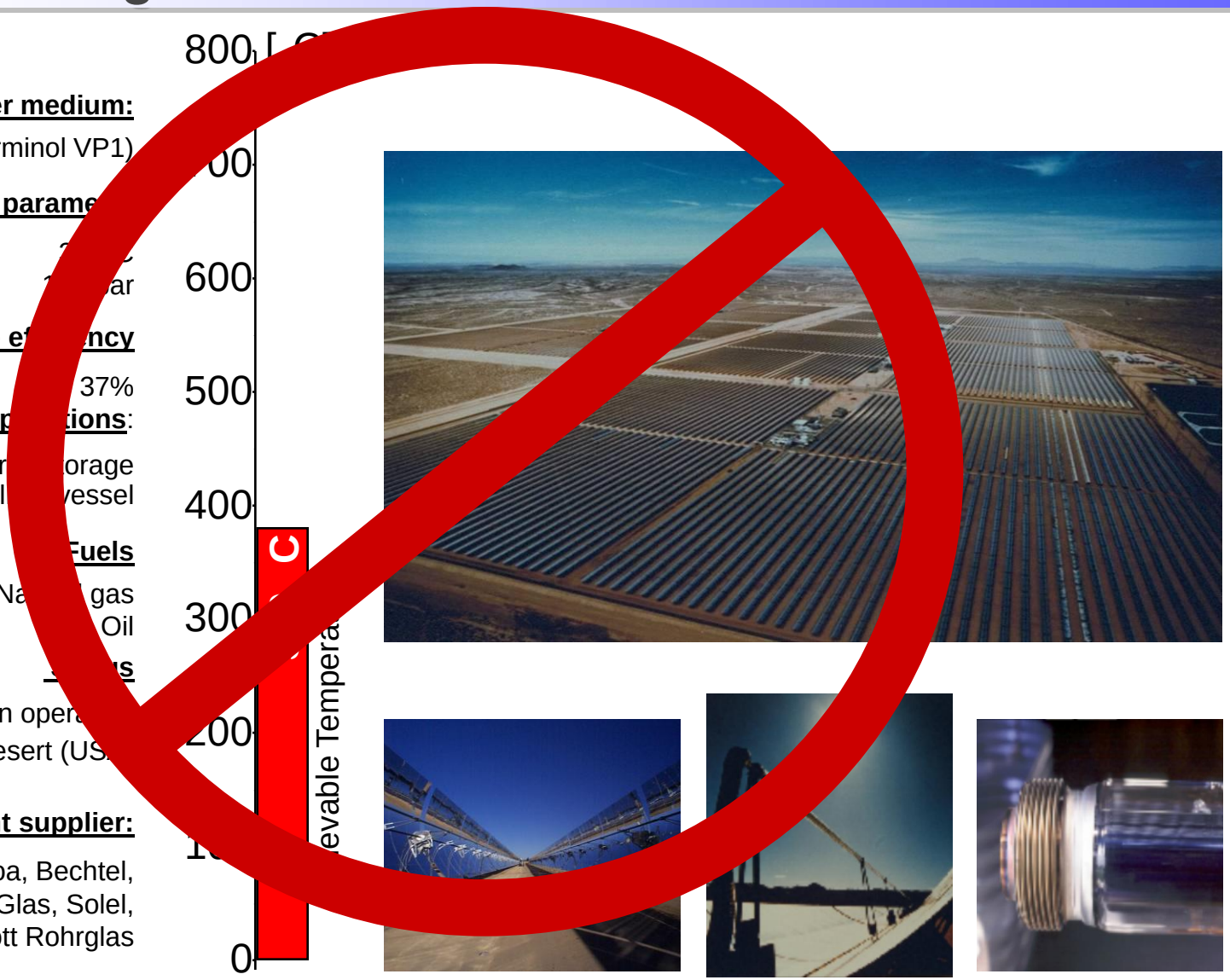
Na gas
Oil

s

354 MW in opera
in Mojave desert (US

Component supplier:

Abengoa, Bechtel,
Centrosolar Glas, Solel,
Schott Rohrglas



Central Receiver Plants: Molten salt receiver

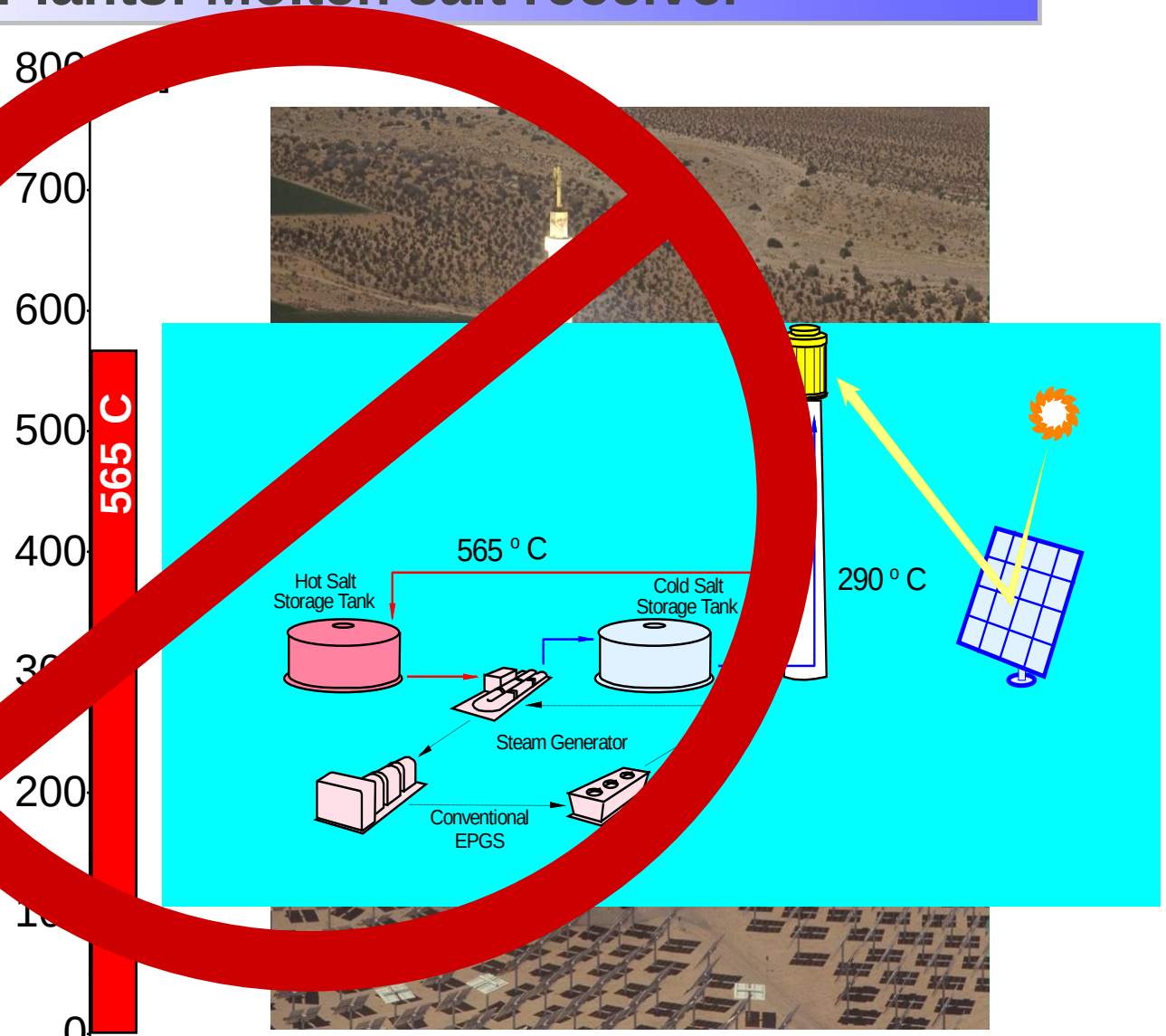
Receiver heat transfer flui
Molten nitrate

Maximum live steam par er:
35 C
00 bar

Backu ptions:
Thermal storage is an gral part
of concept

Technolo tatus
10 MW_e System demons n at
Solar
Operated from1996 to

Companies:
Bechtel, Boing, Ghersa



Central Receiver Plants: Atmospheric air receiver

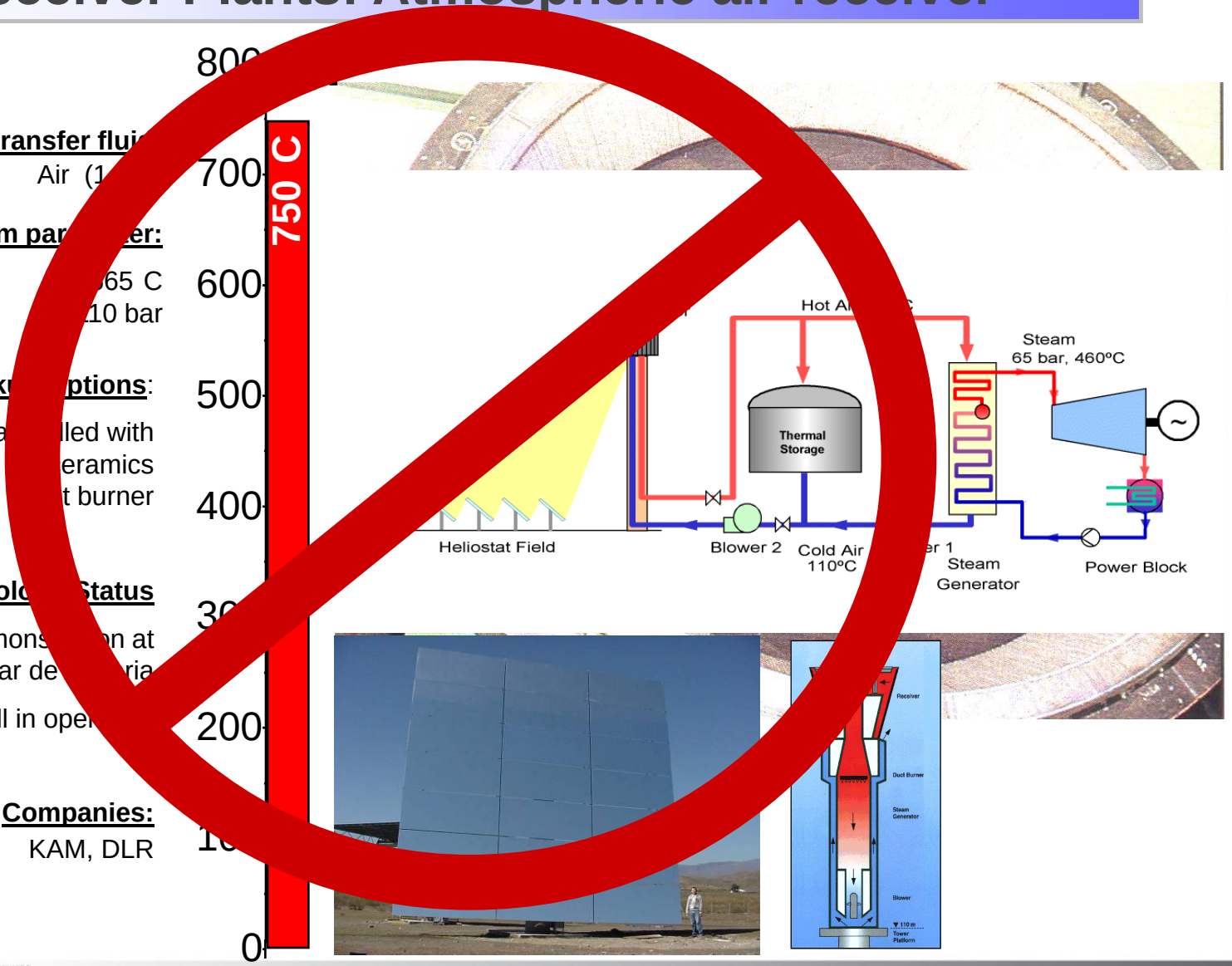
Receiver heat transfer flui
Air (1

Maximum live steam par er:
65 C
10 bar

Backu ptions:
Thermal stora lled with
eramics
t burner

Technolo Status
3 MW_{th} air loop demons n at
Plataforma Solar de ria
still in oper

Companies:
KAM, DLR



Central Receiver Plants: Pressurized air receiver

Receiver heat transfer fluid:
Air (10-16 bar)

Hybrid system:

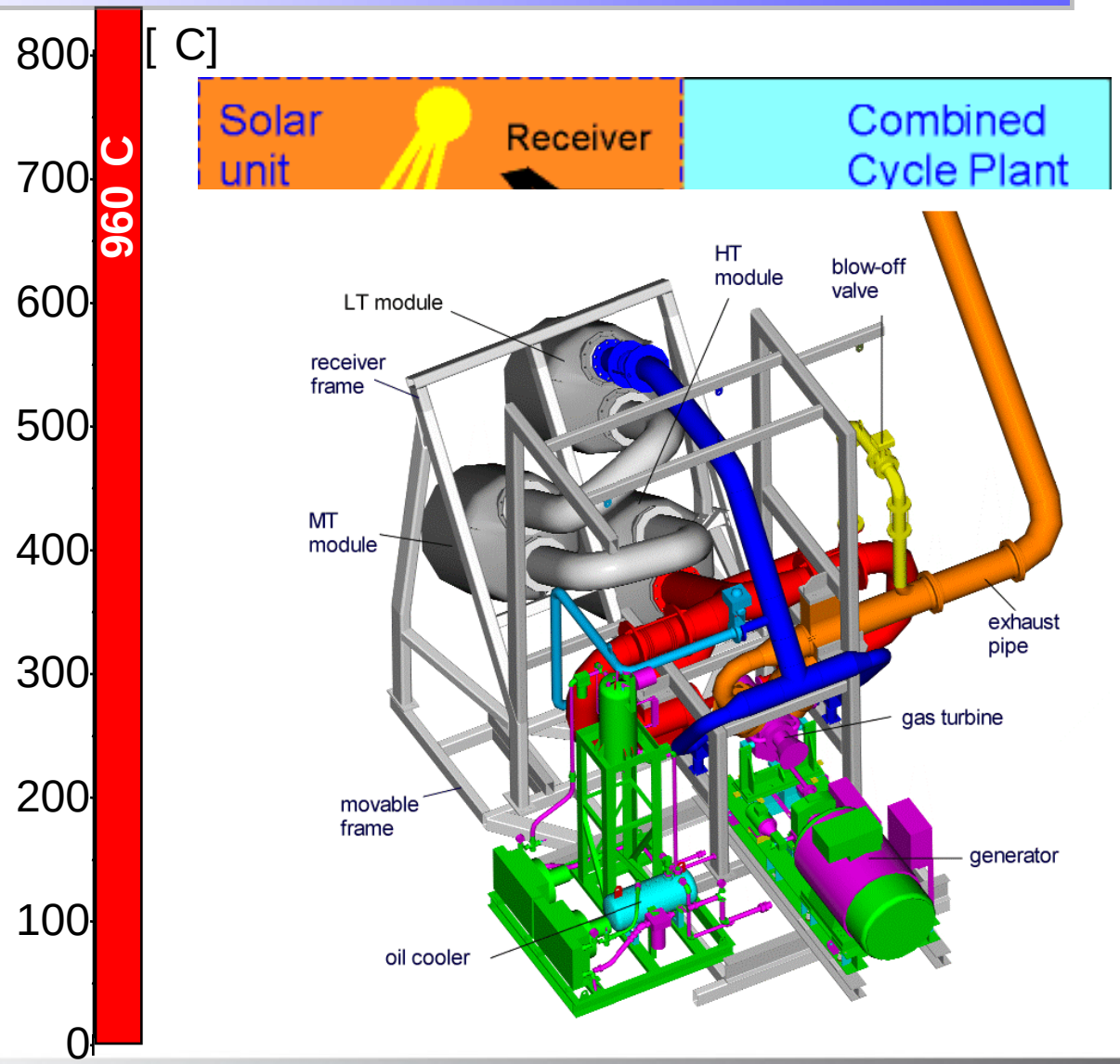
The maximum temperature acievable in solar operation is currently limited to 1000 C.

Therefore natural gas firing is always needed for operation

Technology Status

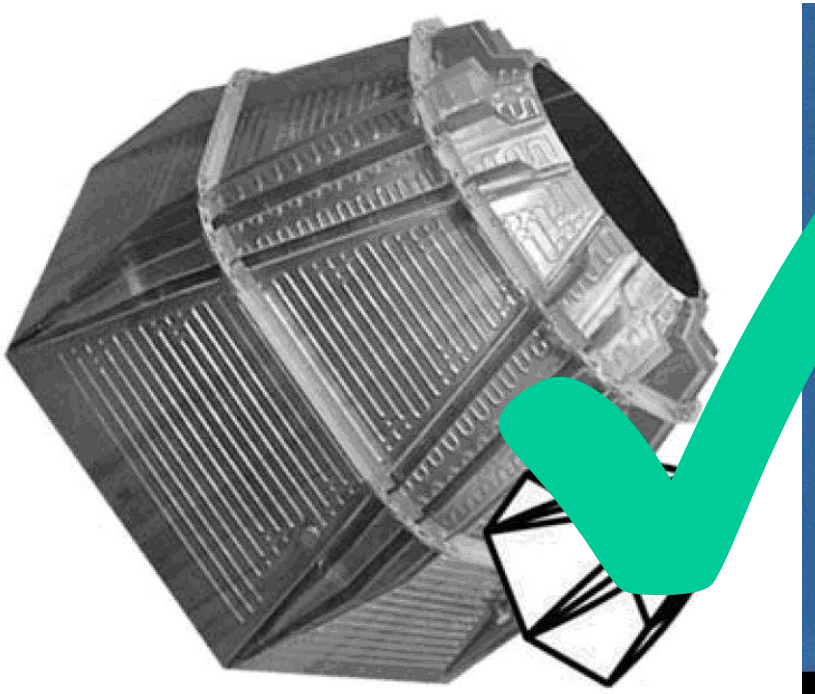
250 kWe (6.5 bar) demonstration at Plataforma Solar de Almeria

Companies:
DLR



Secondary Optics

- T > 1600 °C must be proven!



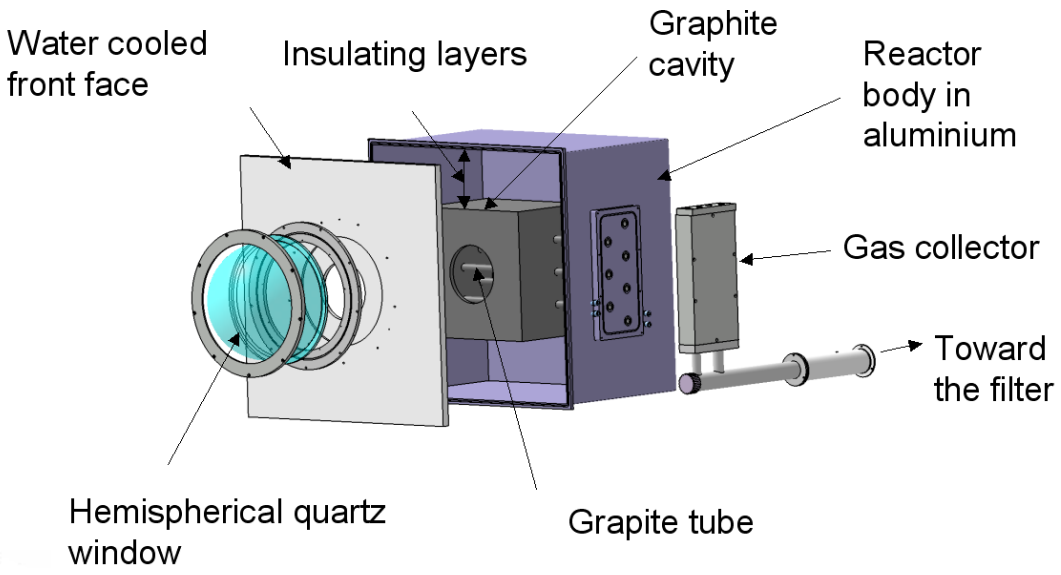
CESA-1, PSA, Spain. Receiver in operation.

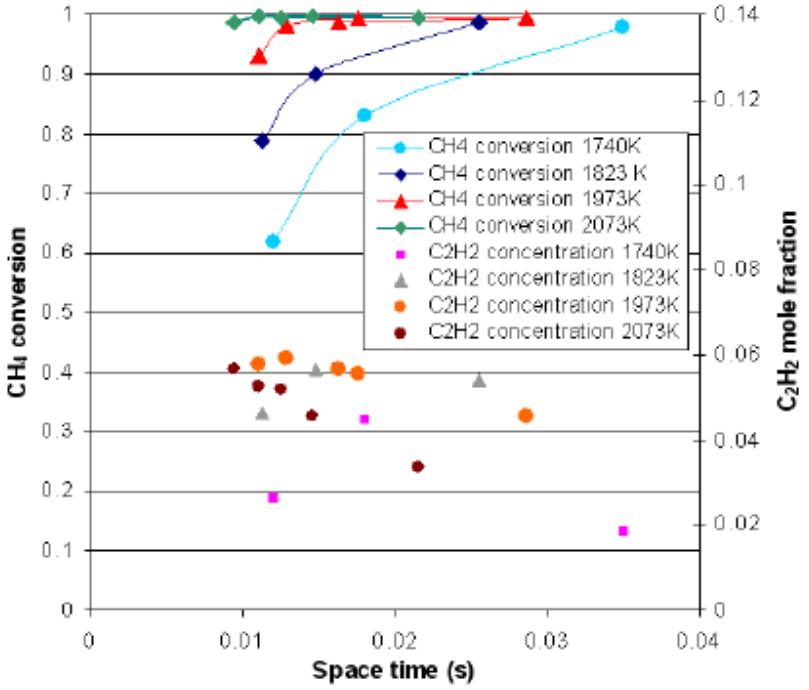
Scale-up Study

- Design point determination
- Component lay out
- Flow-sheet optimisation
- Economic calculation
  - Investment
  - O&M
- Economic evaluation

Scale-up Starting point

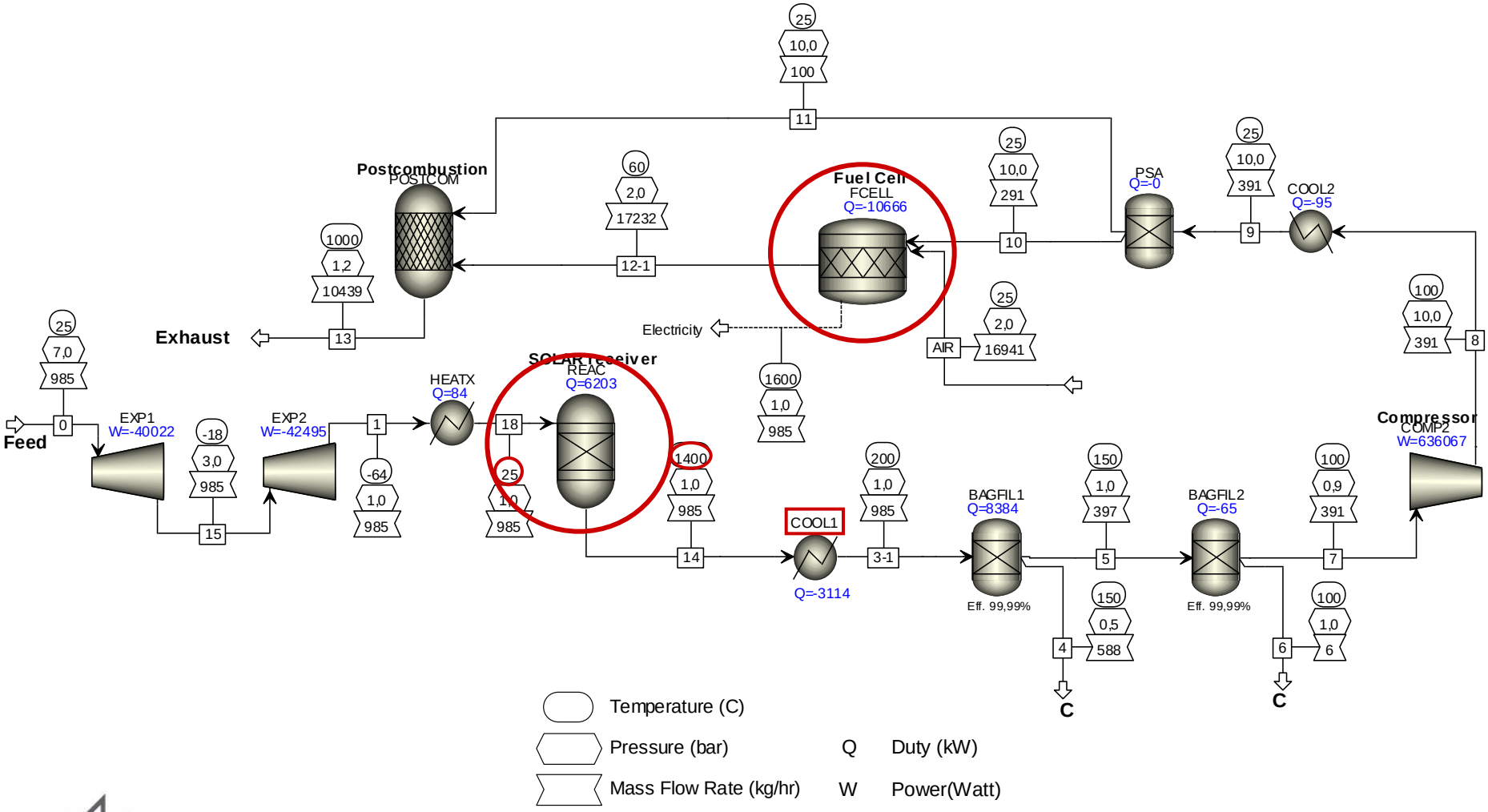
50 kW solar reactor operating up to 2100K



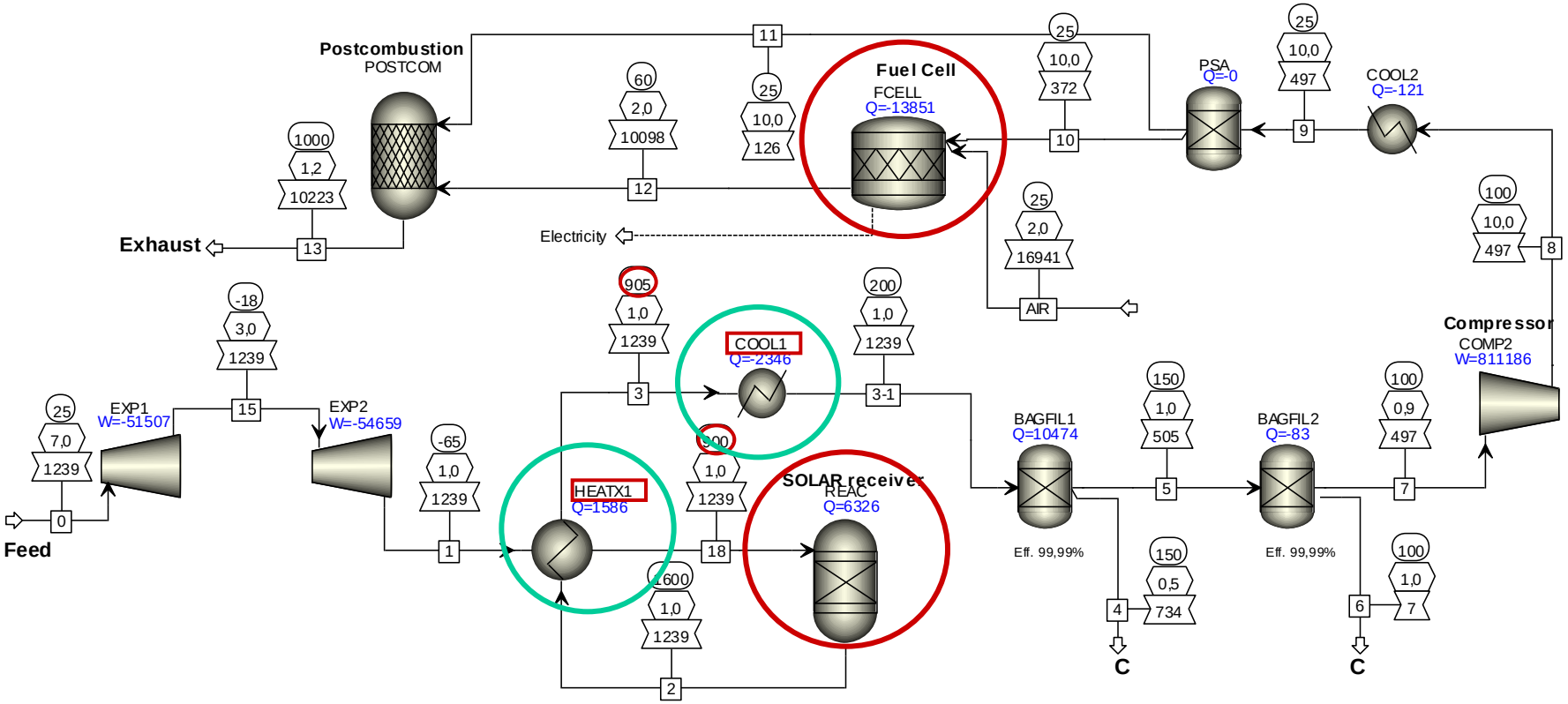


Source: S. Rodat et al., CNRS, France

Reference Flow Sheet (N-GHY)



Flow Sheet with Preheating



Economical approach – Investment (1)

- **Solar System**

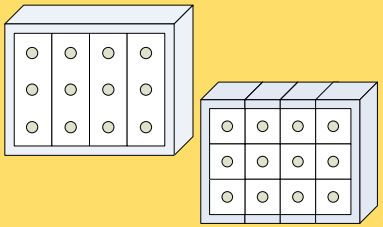
  - Heliostats

137 á 121m² = 16.400m²
Investment: 200 €/m²
Land area: 12ha
[Abengoa]

  - Tower

Hight: 40m
Investment: 1 M€
[Abengoa]

  - Receiver



Non modular: 4 M€
Modular: 5.6 M€
[CNRS]

Preliminary Economic Evaluation

Boundary Conditions

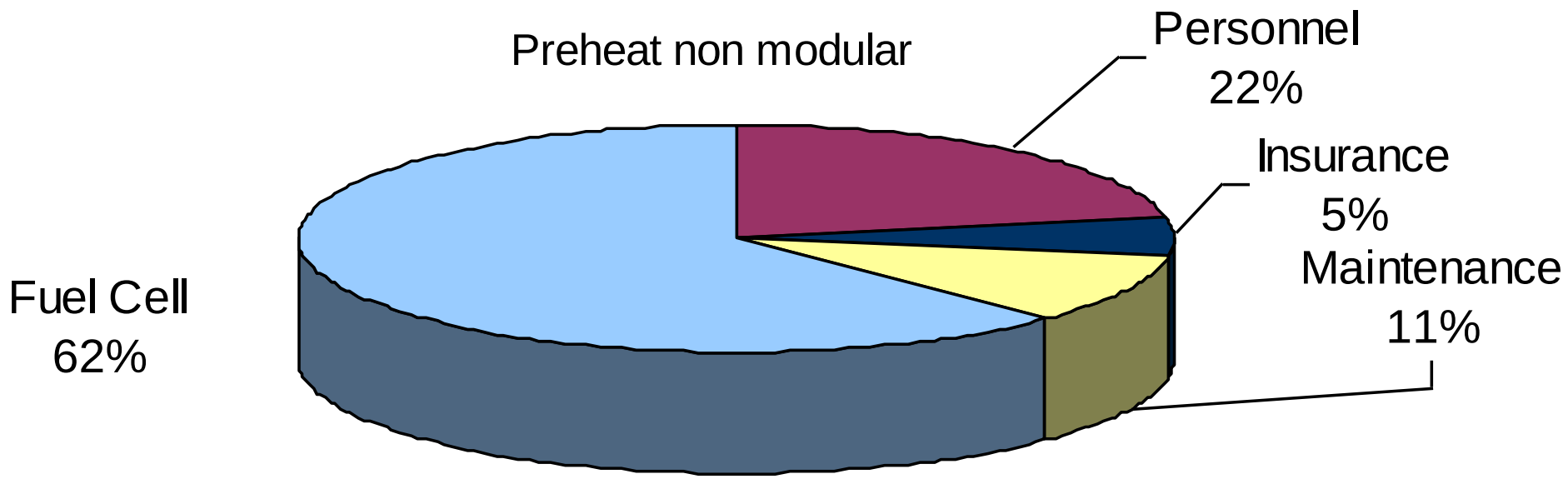
Site	Assuan	Egypt
Operation life time	20	yrs
Load factor	80	%
Discount rate	0.08	
Operation time	2,938	h/yr
Interest factor	1.12	

Revenues

Electricity	320	€/MWh
Carbon black	800	€/t

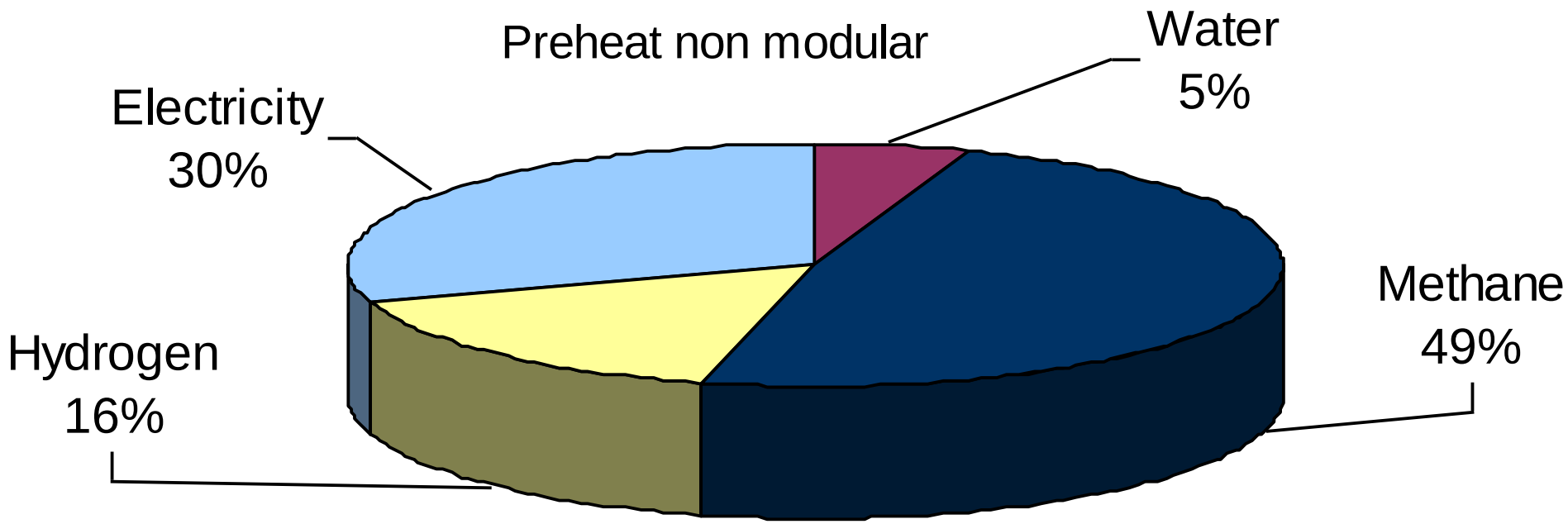
Preliminary Economical Approach – O&M Fix

- **O&M *Fix (non modular)***



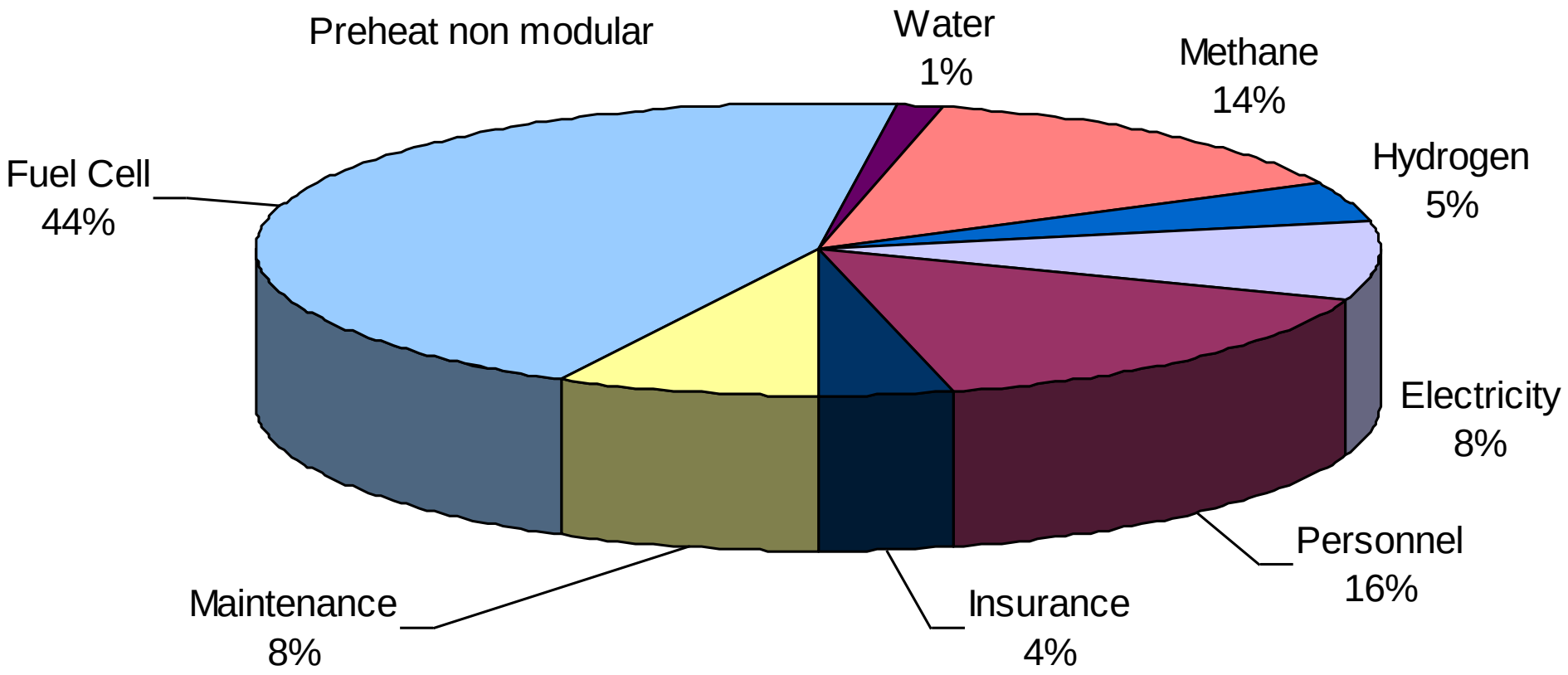
Preliminary Economical Approach – O&M Variable

- **O&M *Variable (non modular)***



Preliminary Economical Approach – O&M

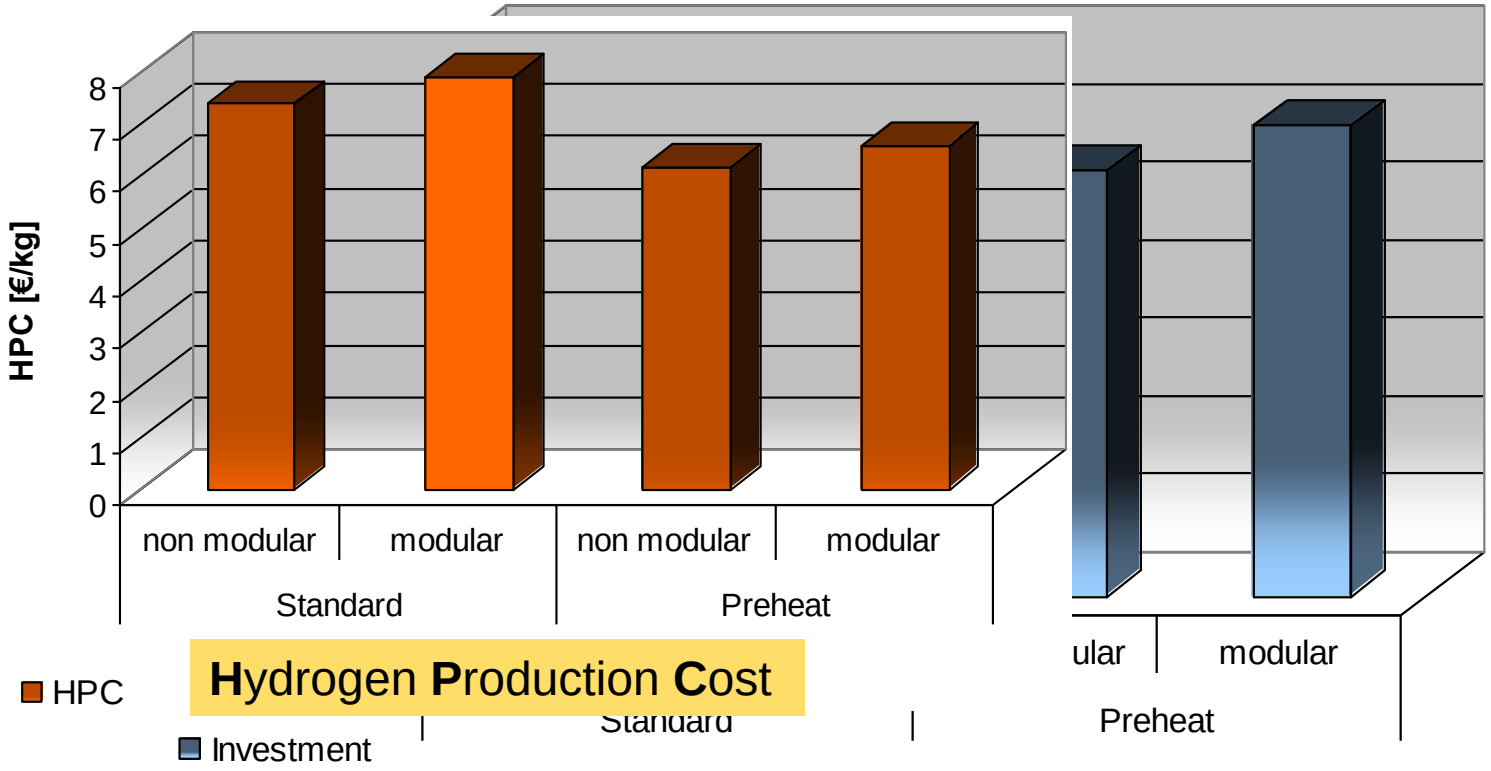
- **O&M overall *(non modular)***



Preliminary Economic Evaluation (2)

- **Summary**

Investment



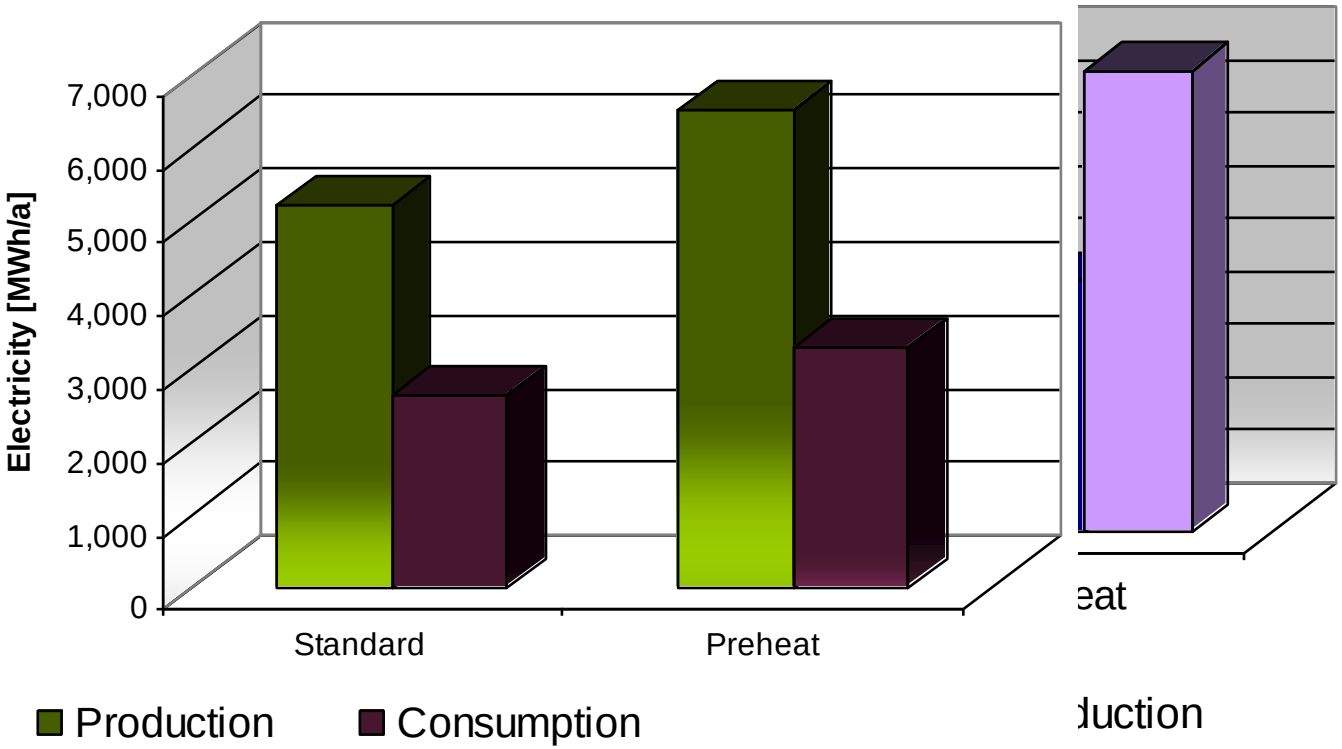
Hydrogen **P**roduction **C**ost

Preliminary Economic Evaluation (3)

- **Summary**

Electricity Production and Consumption

Production



Summary and Outlook

- SOLHYCARB is an interesting alternative to produce hydrogen with low CO_2 emission
- Additionally carbon is produced which has a high value itself
- Within the project reactor concepts have been realised up to 50 kW pilot scale
- A study for a 10 MW_{th} plant is in progress, components are presently fine tuned
- Hydrogen production cost are comparable to those of other renewable processes like thermochemical cycles or high temperature electrolysis, if the carbon can be sold

- **Acknowledgemet**
  We thank the European Commission for funding of the SOLHYCARB project under the 6th Research Framework Programme

Thank you very much for your attention!