



SOEC Enabled Biogas Upgrading

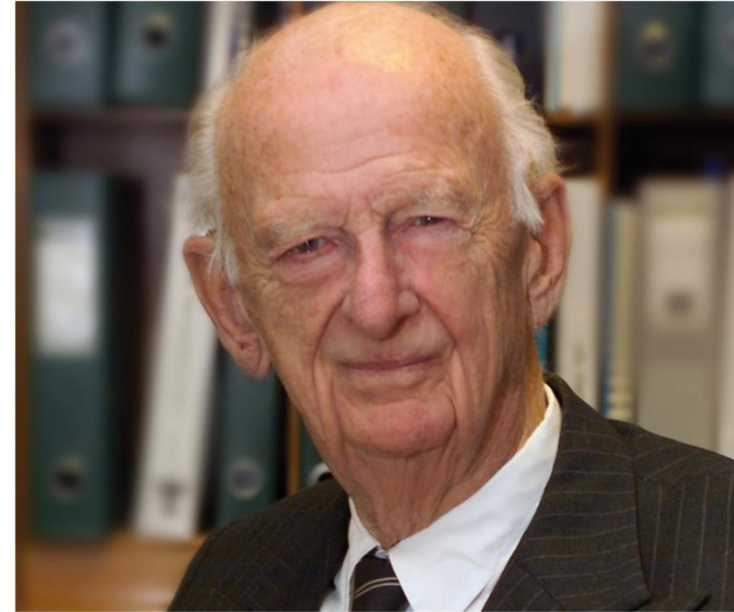
RESEARCH | TECHNOLOGY | CATALYSTS

John Bøgild Hansen, Haldor Topsøe A/S

Riga, December 7, 2017

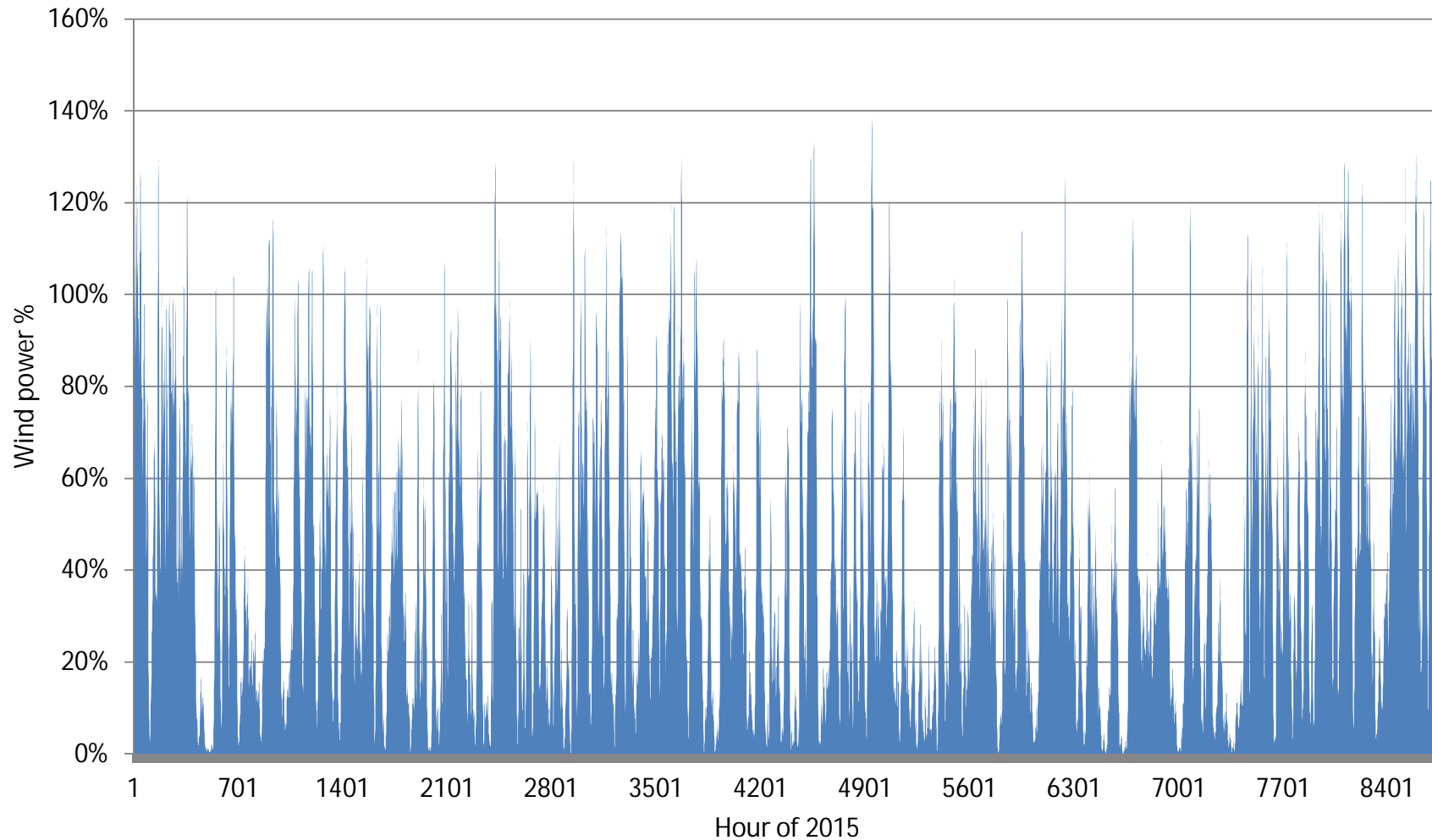
We have been committed to catalytic process technology for more than 70 years

- Founded in 1940 by Dr. Haldor Topsøe
- Revenue: 700 million Euros
- 2400 employees
- Headquarters in Denmark
- Catalyst manufacture in Denmark and the USA



Wind Power Generation as percentage of consumption in Denmark 2015

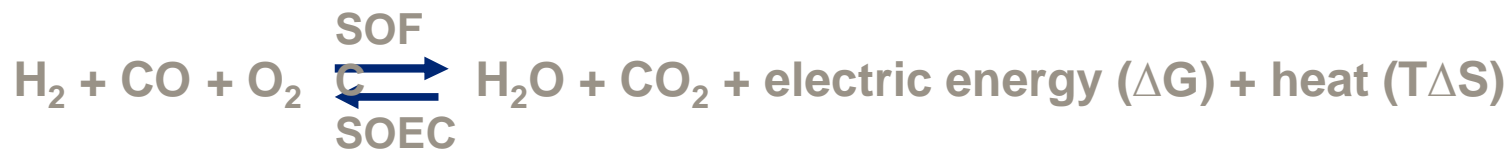
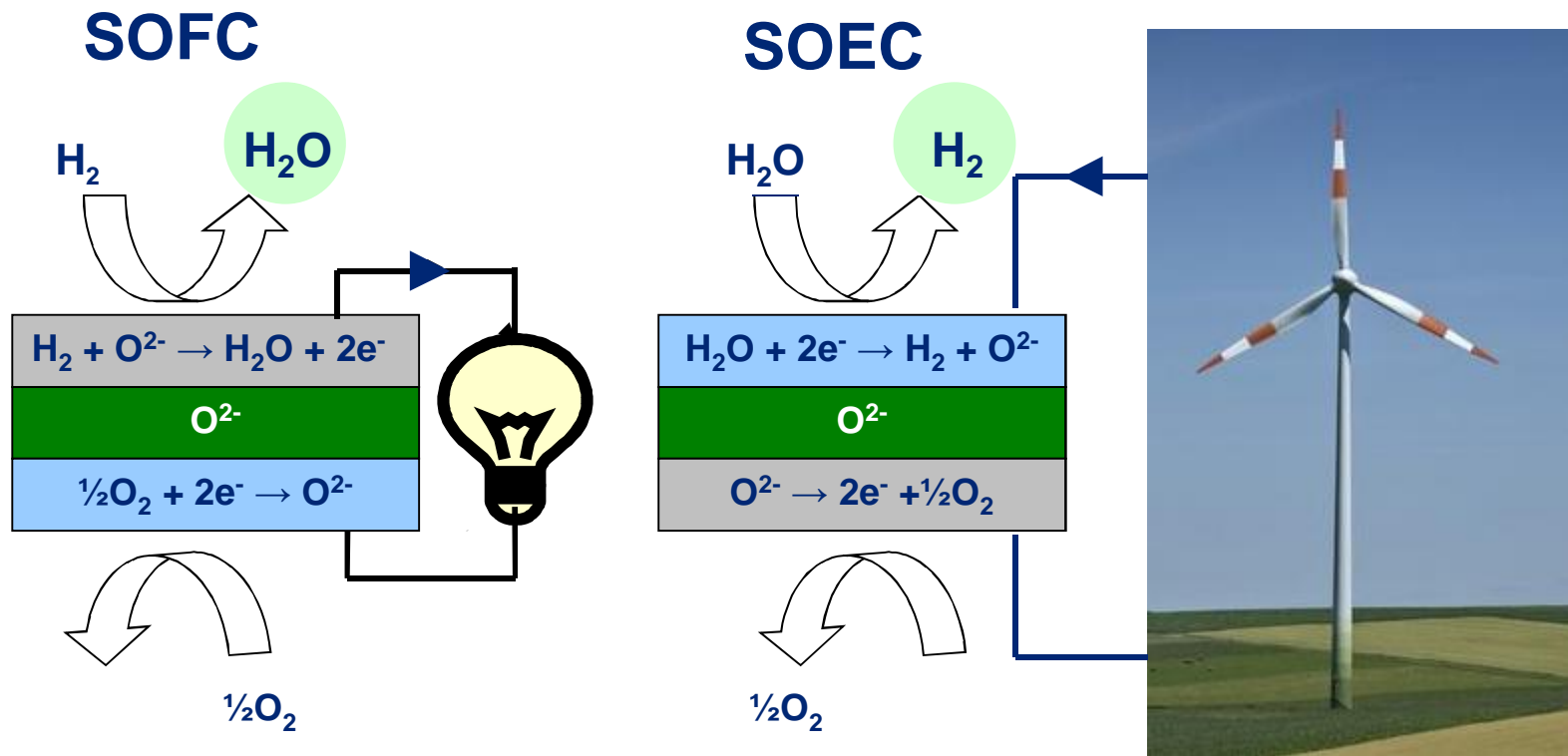
Wind power generation as % of total power consumption in Denmark 2015



Biogas upgrade by means of SOEC

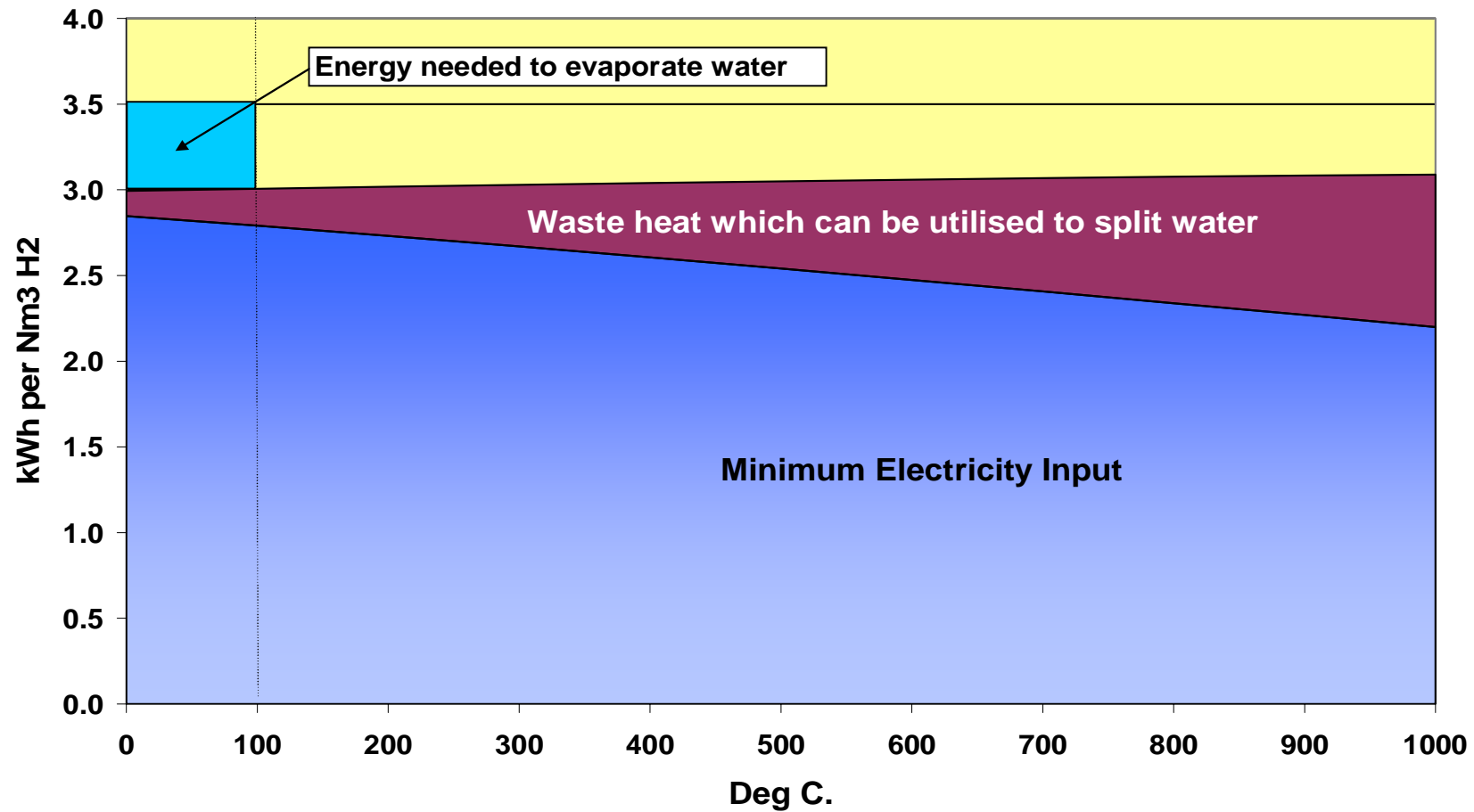


Fuel Cell and Electrolyser



SOEC more efficient than present Electrolysers

Internal waste heat used to split water



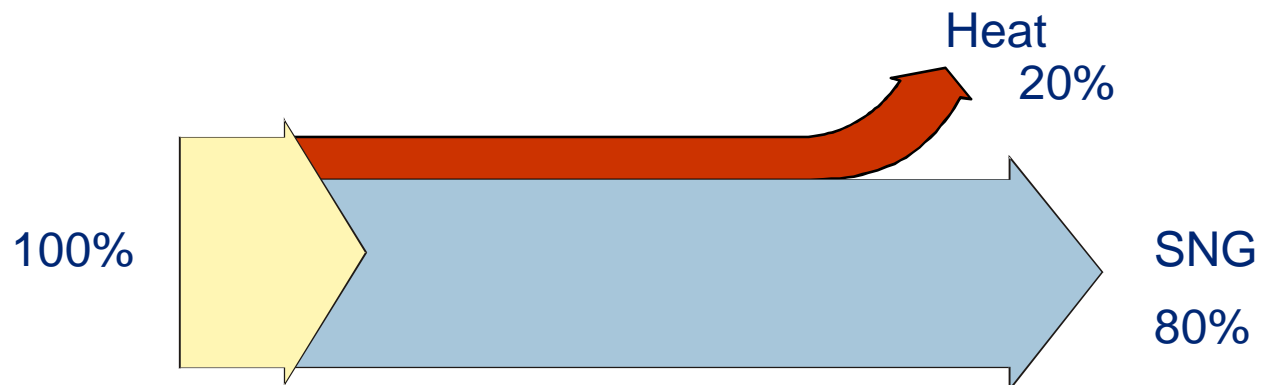
SNG Technology

Methanation generates a lot of heat

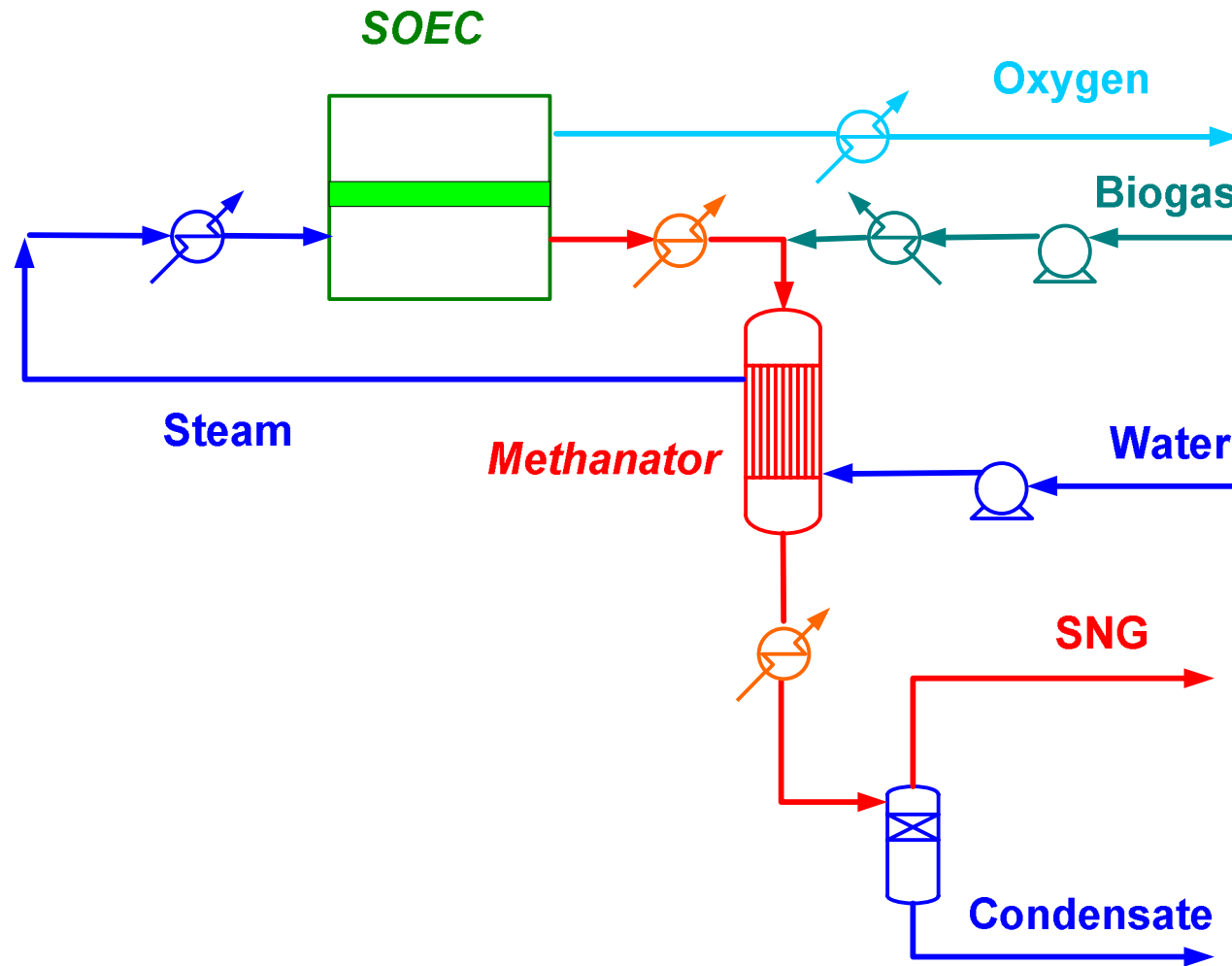


Syngas = SNG + heat

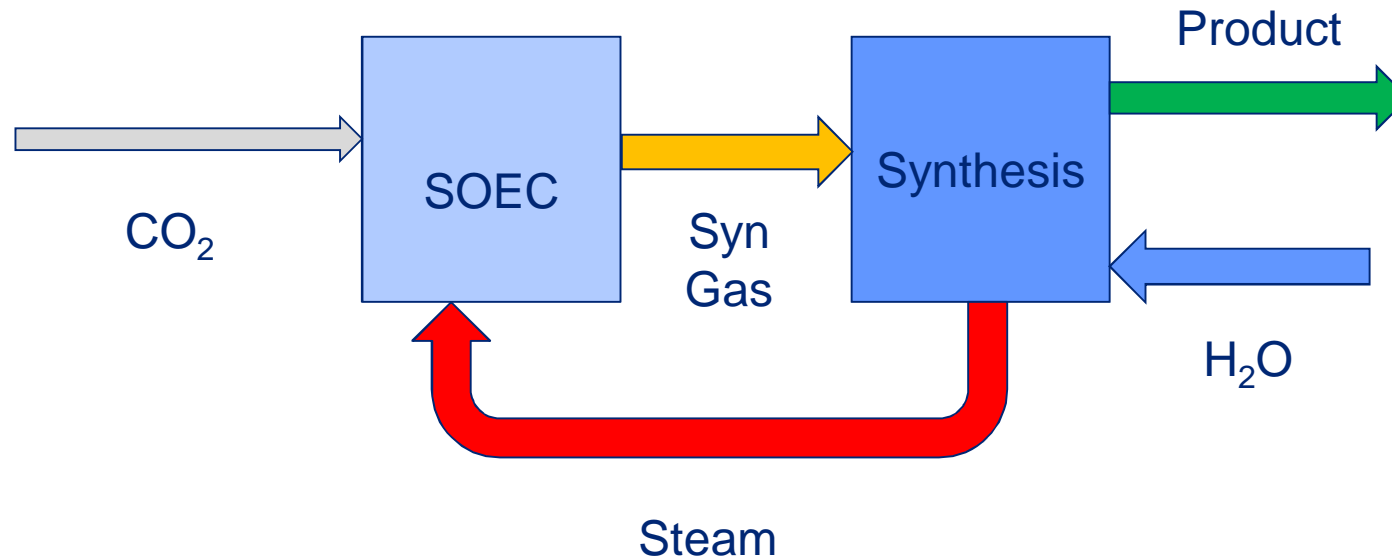
Energy: 100% = 80% + 20%



Biogas to SNG via SOEC and methanation of the CO₂ in the biogas

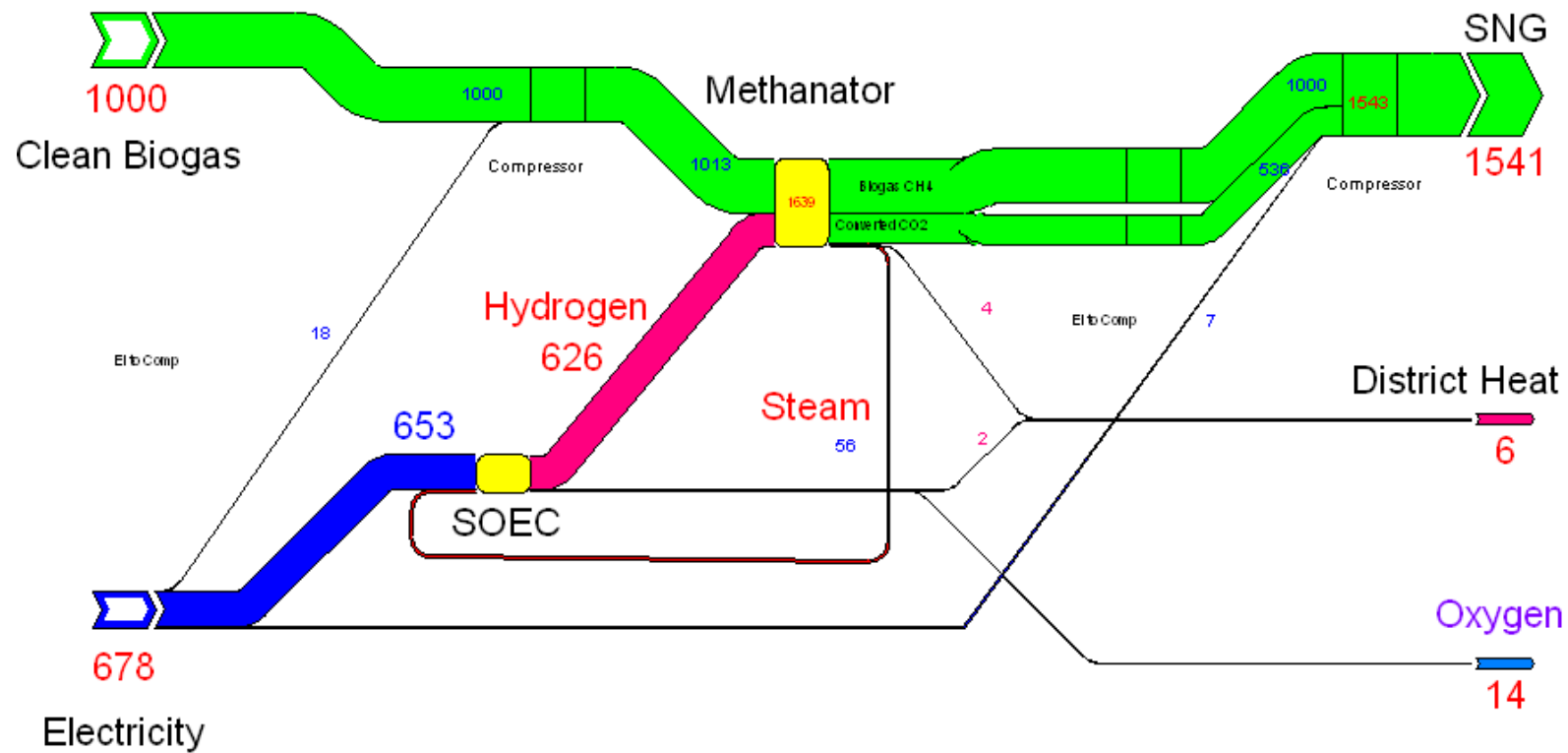


Synergy between SOEC and fuel synthesis



Exergy Flows in CO₂ case

Power to Gas Exergy Efficiency 79.8 %



New EUDP project

50 kW SOEC and 10 Nm³/h methane



Participants:
Haldor Topsøe A/S
Aarhus University
HMN Naturgas
Naturgas Fyn
EnergiMidt
Xergi
DGC
PlanEnergi
Ea Energianalyse

Coordinator:
HALDOR TOPSØE 
CATALYSING YOUR BUSINESS

Duration:
June 2013 -
December
2017

Project sum:
5.3 mio €
Location:
Foulum

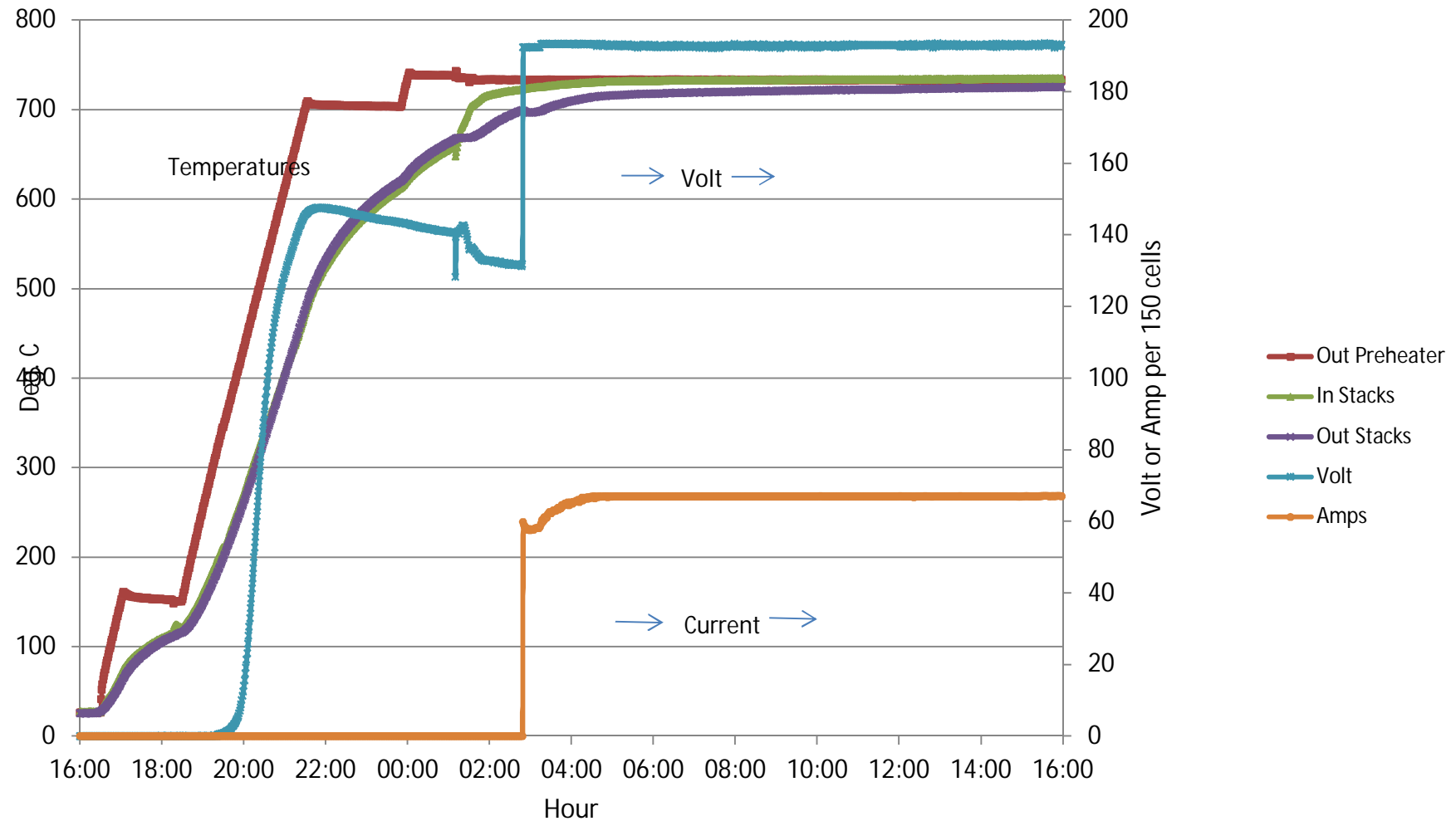


Methanation and SOEC at Foulum

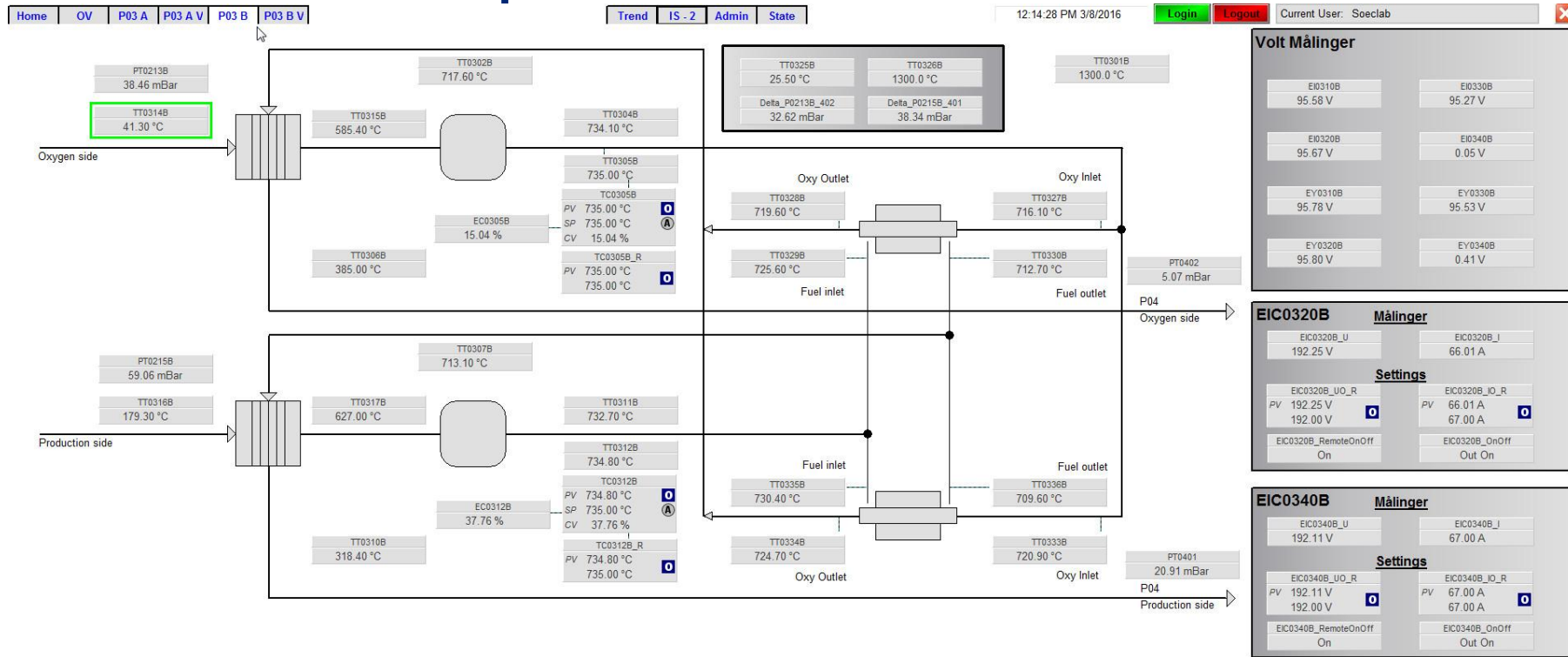


Heat up of SOEC unit from cold

10-11 hours, but full production on/off within seconds



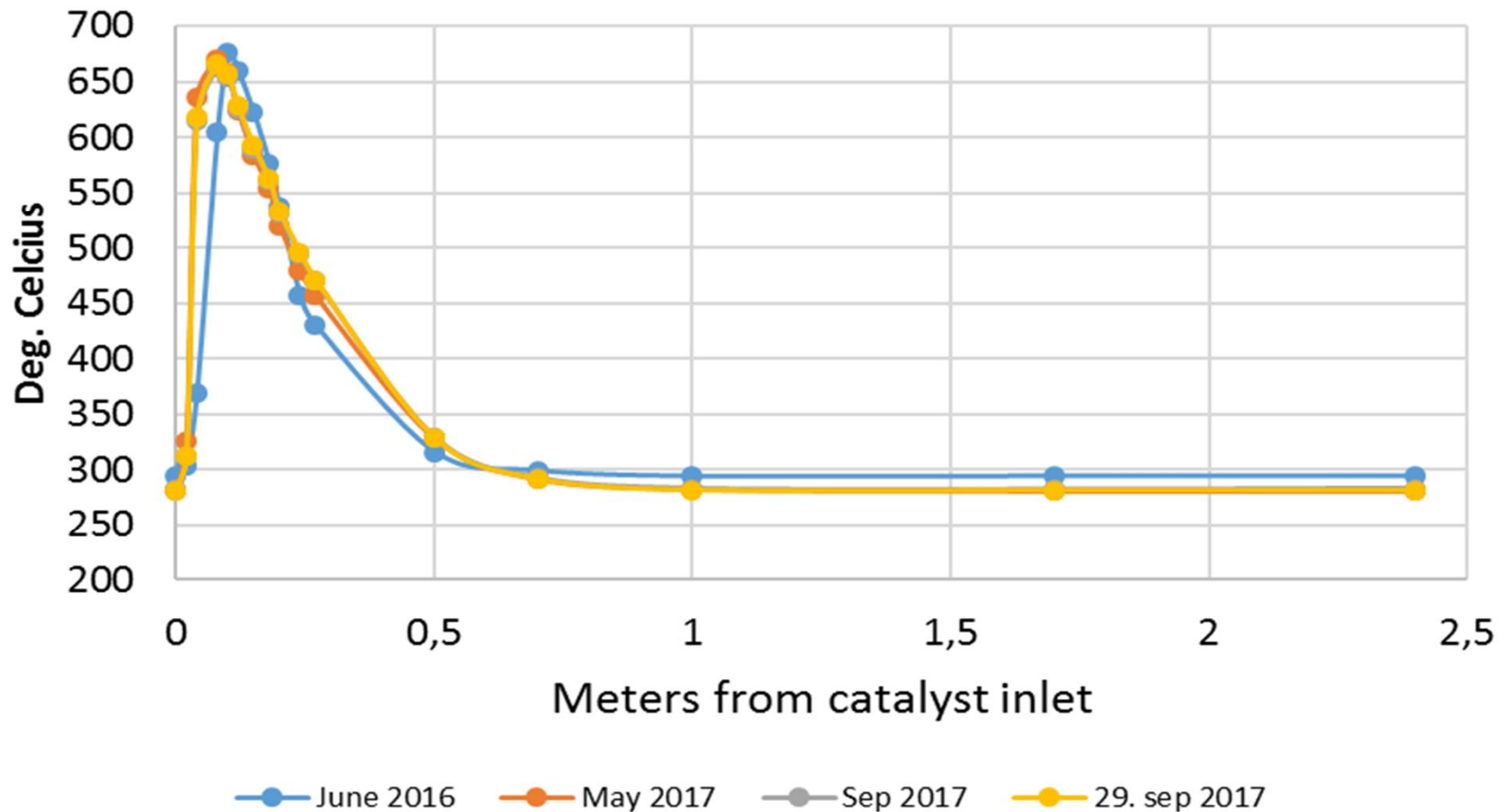
Screen dump from Cores



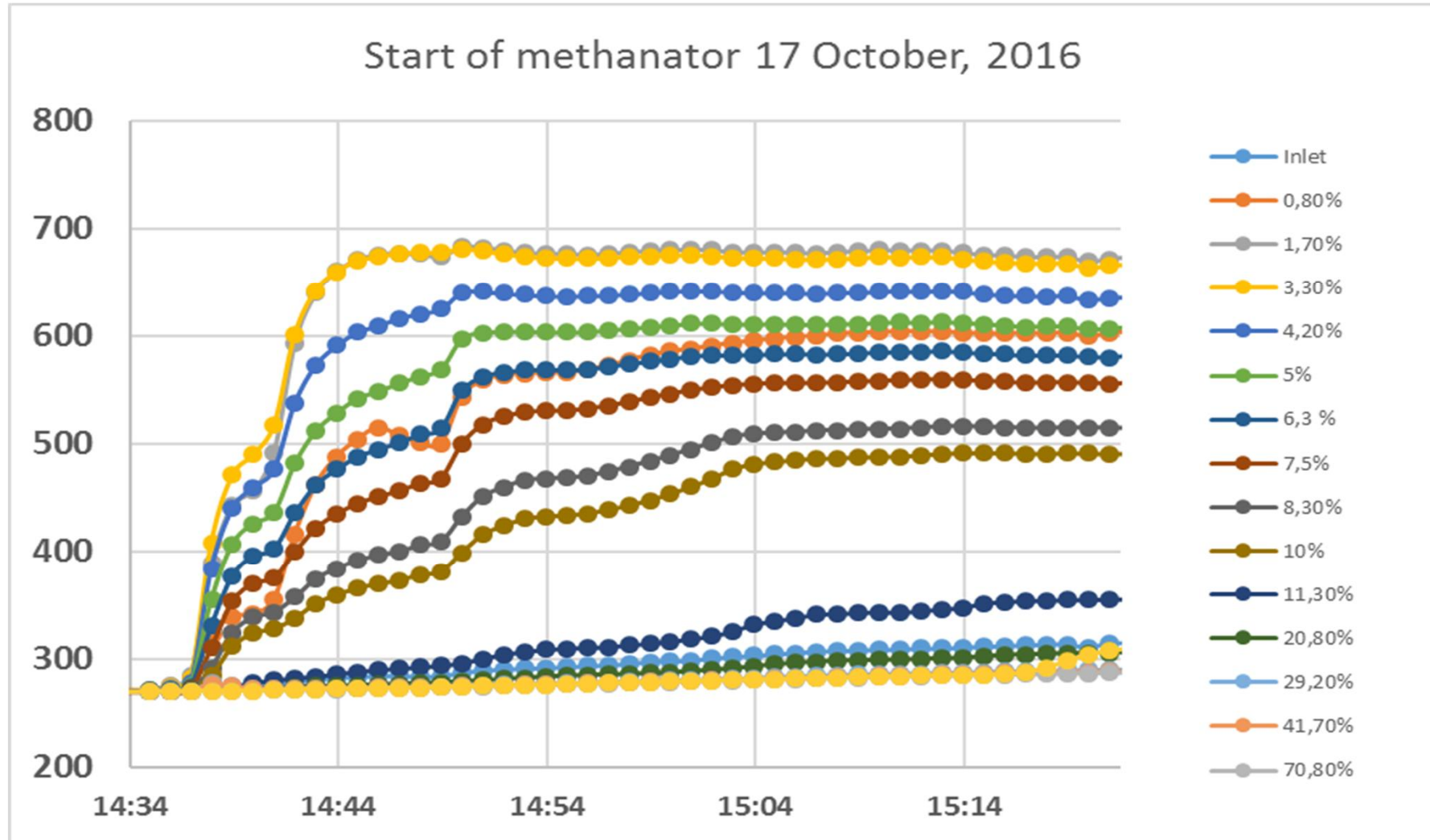
8 Stacks of 75 cells
 1.28 V per cell, 65 A = 50 kW
 Hydrogen production = 16.3 Nm³/h
 3.06 kWh/Nm³
 Tinlet = 726 °C

Methanator catalyst very active and stable

Temperatures profile in Methanator



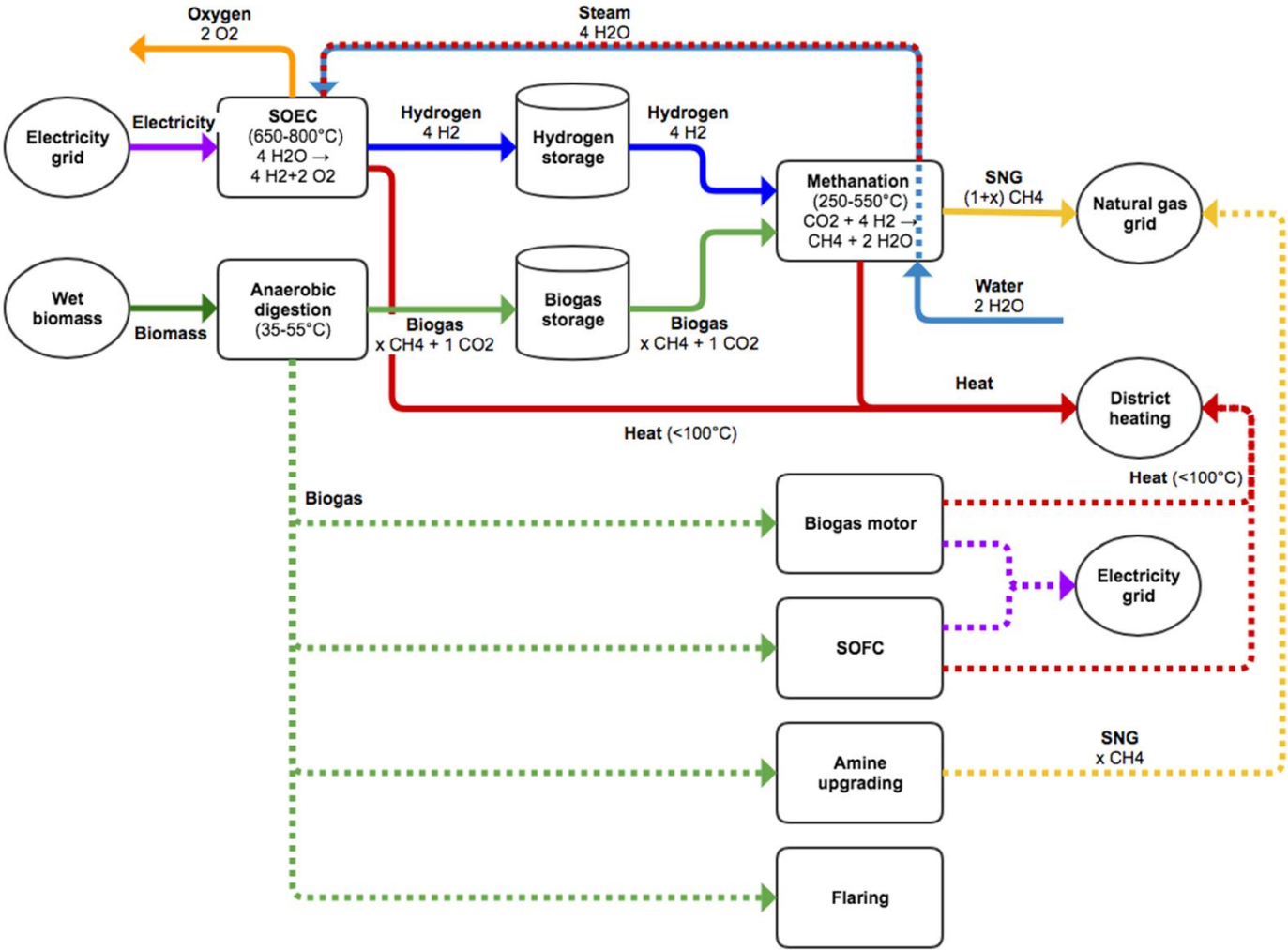
Transient operation of methanator



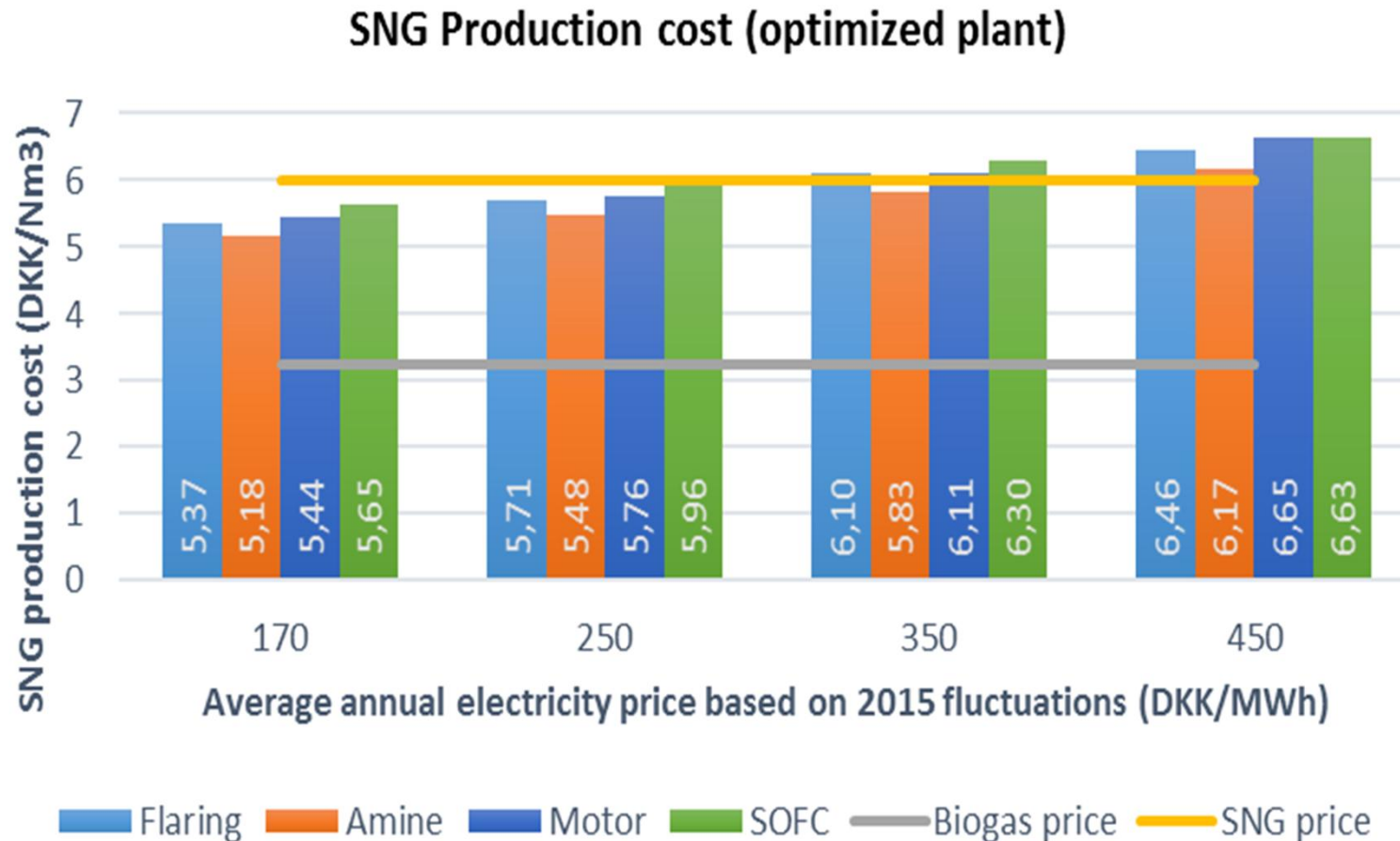
Average gas compositions June 2, 2016

Position	CH ₄	CO ₂	N ₂	H ₂
Inlet	56	43	1	0
Exit 1 st stage	94.58	0.27	0.91	4.23
Product gas	97.69	0.00	0.95	1.36

Economic model



Calculated BNG prices vs scenario



Demonstration Plant - Conclusions

- Process values very close to design simulations
- Better than SNG quality:
- Catalyst for CO₂ methanation have high activity and durability
- Boiling water reactor design robust and flexible
- SOEC close to 100% efficiency (LHV)
- Hot start and stop within seconds
- Integration of SOEC and methanation unit
- Completely automated including all utilities
- Operating Strategy:
 - Thermoneutral Voltage – Full Production
 - Increase Temperature to Counteract Degradation

Key numbers

Denmark

- Final energy consumption: 673 PJ
- Biogas potential: 40 PJ
- If upgraded by SOEC: 67 PJ ~ 10 %
- NG used for power plants: 73 PJ
- NG used in household, industry and service: 76 PJ
- Saved CO₂ ~ 1 MT/capita