Emerging Opportunities for Natural Gas Treatment and CO_2 Capture

J.F. Vente
W.G. Haije

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ECN
Your energy. Our passion.

Emerging Opportunities for Natural Gas Treatment and CO_2 Capture

Jaap Vente and Wim Haije

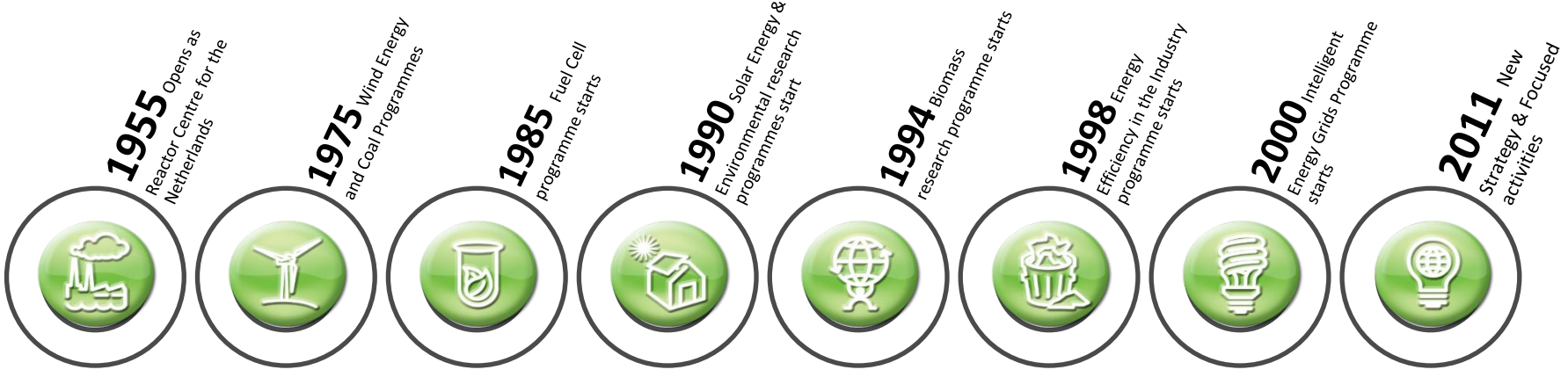
4th International Gas Processing Symposium

Doha, Qatar
October 26–27, 2014

ECN : A rich and evolving history

~500 employees

~110 patents



ECN technology can be found in

60% world wide solar modules

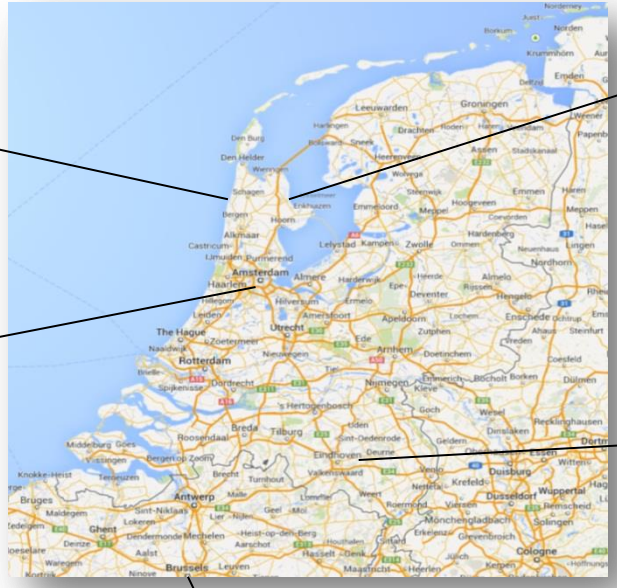
80% of EU off – shore wind farms

We are in our 60th year of pushing technology boundaries

Where we are

ECN
Petten
(head office)

ECN
Amsterdam

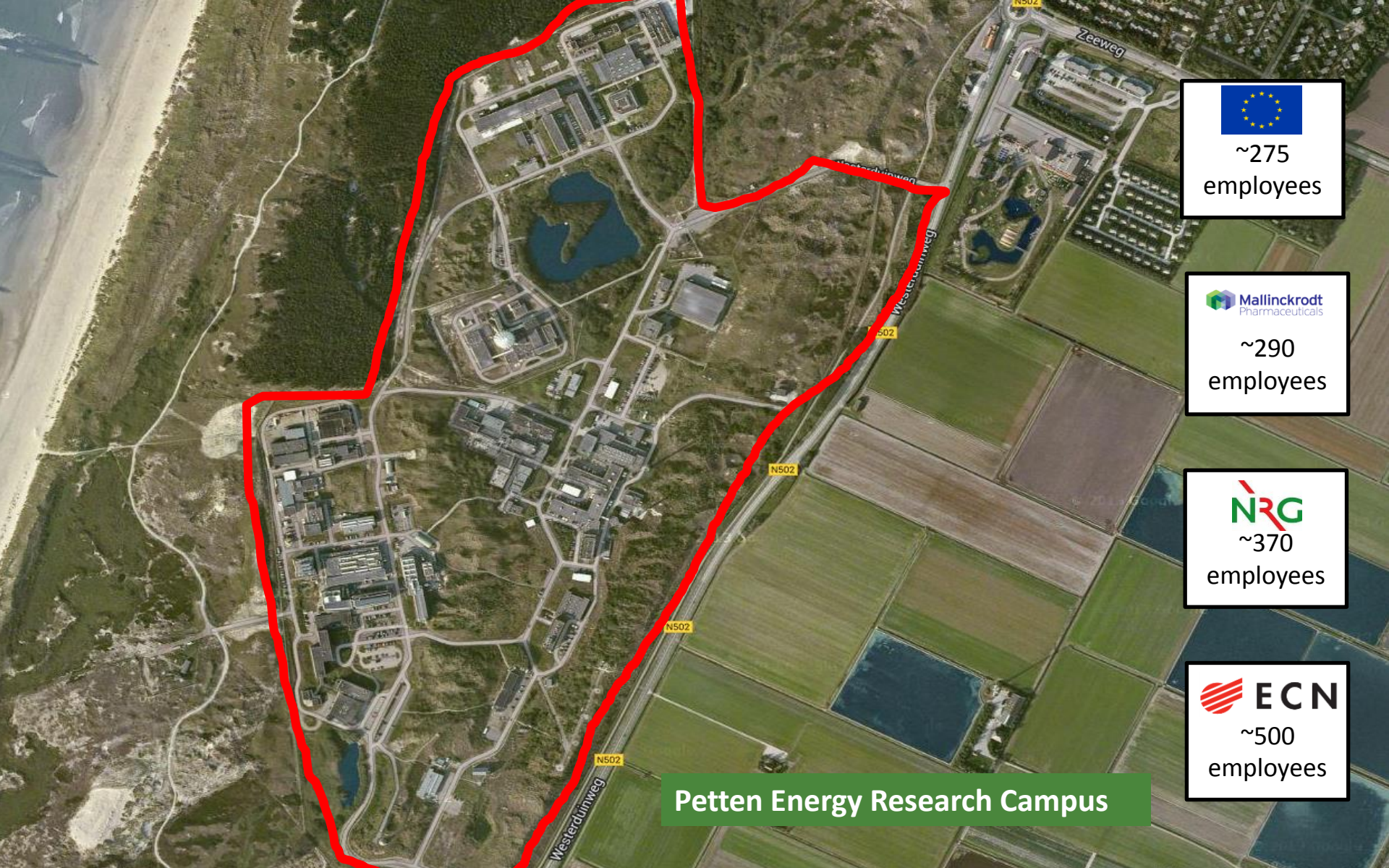


ECN
Wieringerwerf

ECN
Eindhoven

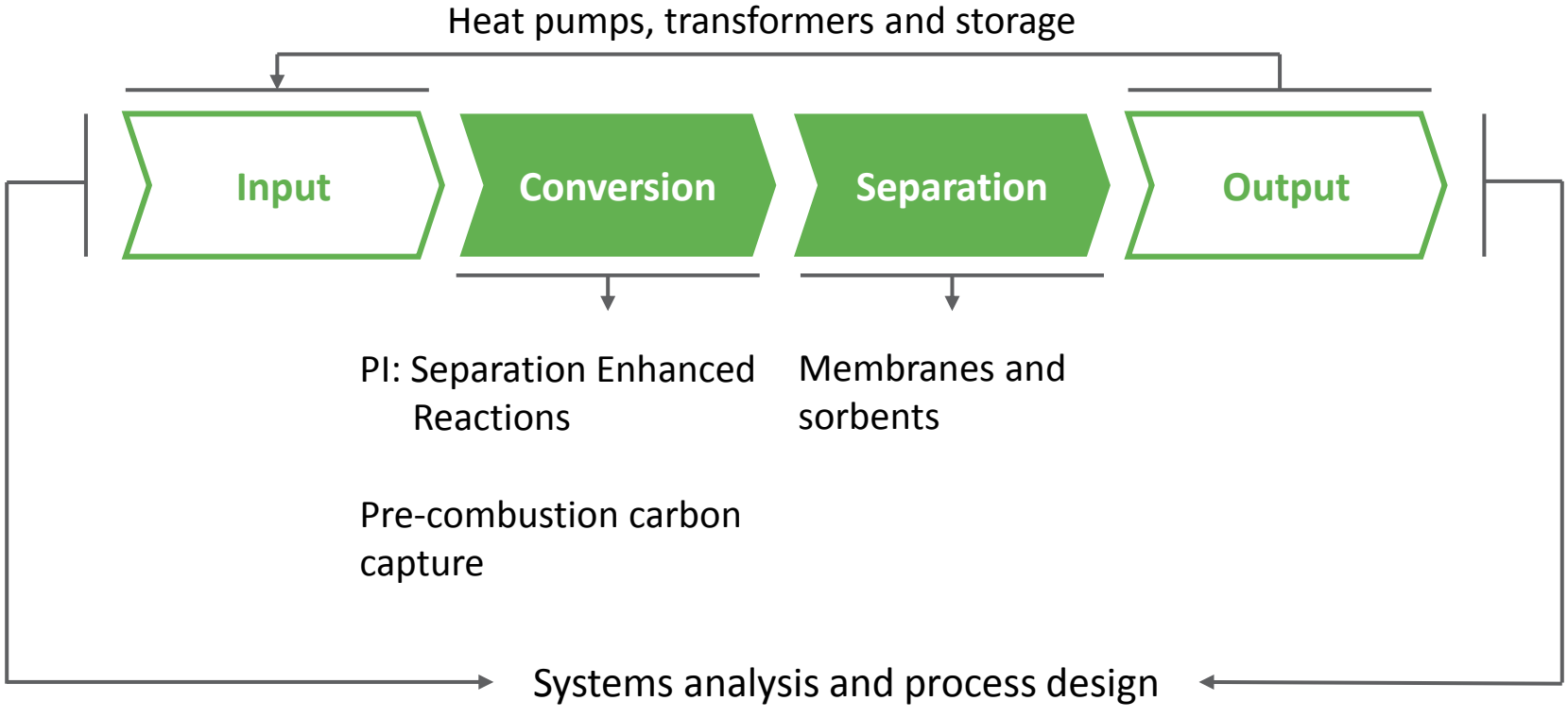
ECN
Brussels

ECN
Beijing


Zeeweg
Westerduinweg
N502
~275 employees
Mallinckrodt Pharmaceuticals
~290 employees
NRG
~370 employees
ECN
~500 employees
Petten Energy Research Campus

We strive to increase the energy efficiency in selected industrial processes by 30% in 2020

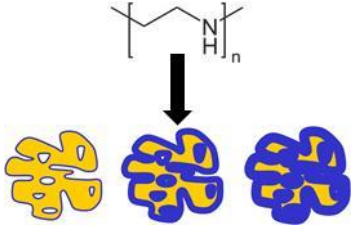
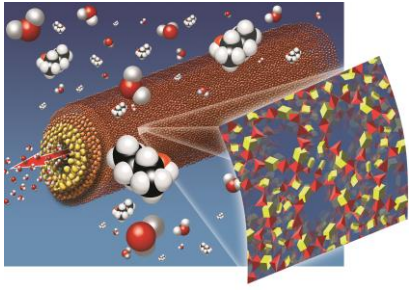
A process approach to improving energy efficiency



Markets
Clients & Partners

- Gas Processing, Syngas Tuning, Refinery, Steel production
- End users, component manufacturers, system integrators
- Public Private Partnerships

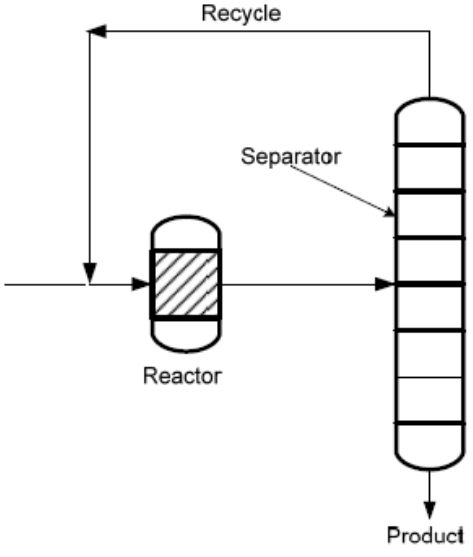
Industrial gases
Membranes and sorbents

	T ≤ 150 °C	T ≥ 300 °C
Advanced sorbents	 Immobilized amines	 Alkasorb®
Advanced membranes	 HybSi®	 HySep®

Thermodynamic limitations

- Conversions hindered chemical equilibria
  - Large recycle streams
  - Complex separator
  - Low conversions
  - Mediocre single pass yields
  - Poor energy efficiency
  - High costs

- Solution: *in-situ* removal of one of the products



Ammonia – Methanation – Water-Gas Shift – Reverse Water-Gas Shift – Methanol – Steam Reforming – Condensation Reactions - Dehydrogenation

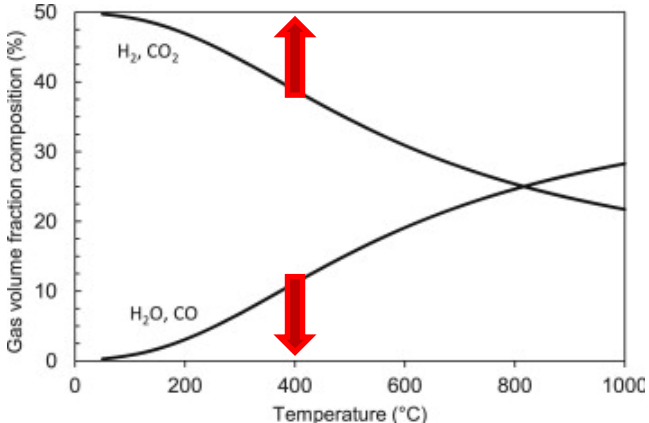
Separation promoted Water-Gas Shift

- Applications in Carbon Capture and hydrogen production

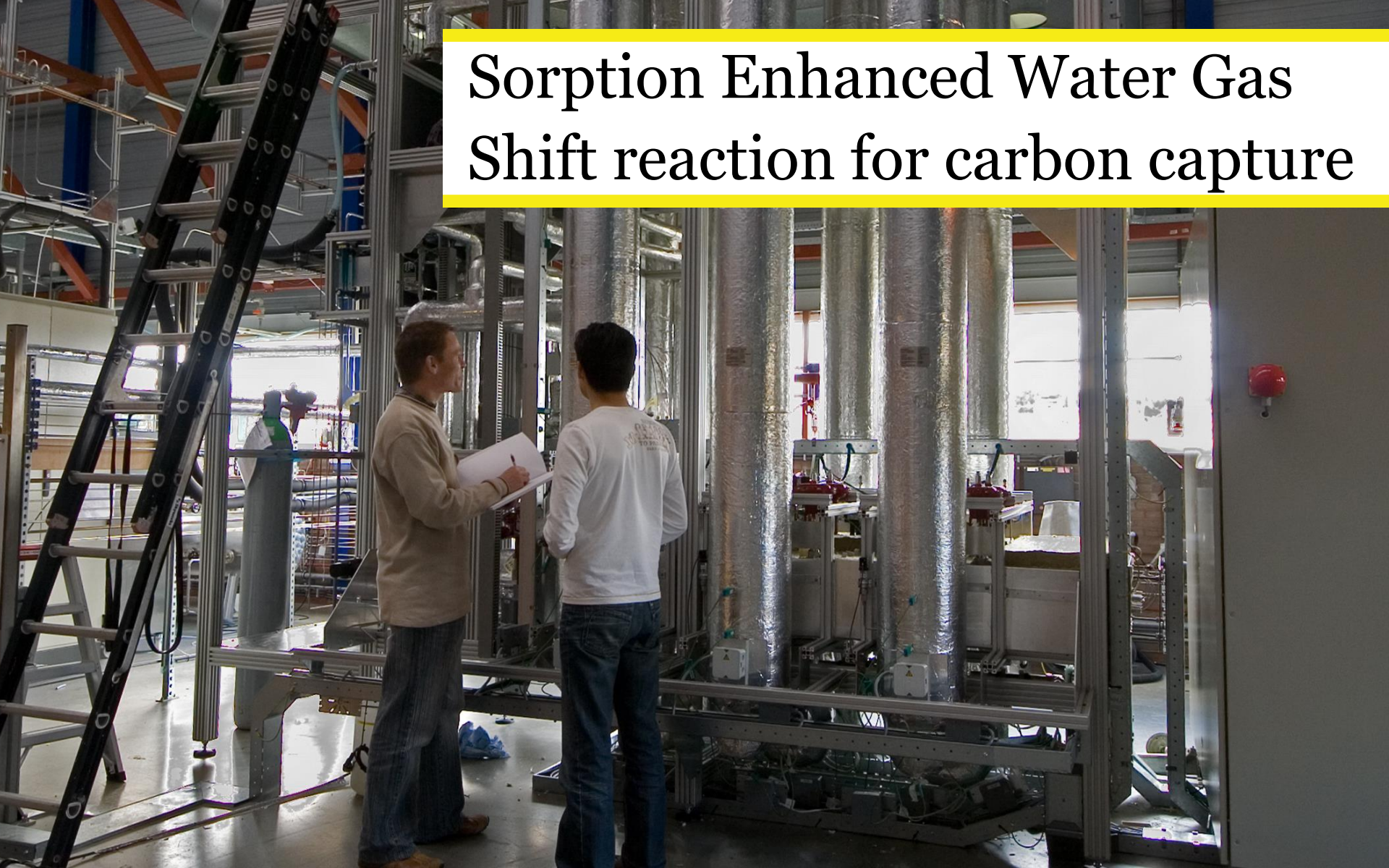
$$CO + H_2O \leftrightarrow CO_2 + H_2 \qquad \Delta H = -41\ kJ/mol$$

In situ removal of ONE reaction product

- Normal Reaction Conditions
  - Two stage conversion of CO
    - 12% → 3% → 0.5%
    - 350-400°C → 180-250°C
  - 20-30 bar

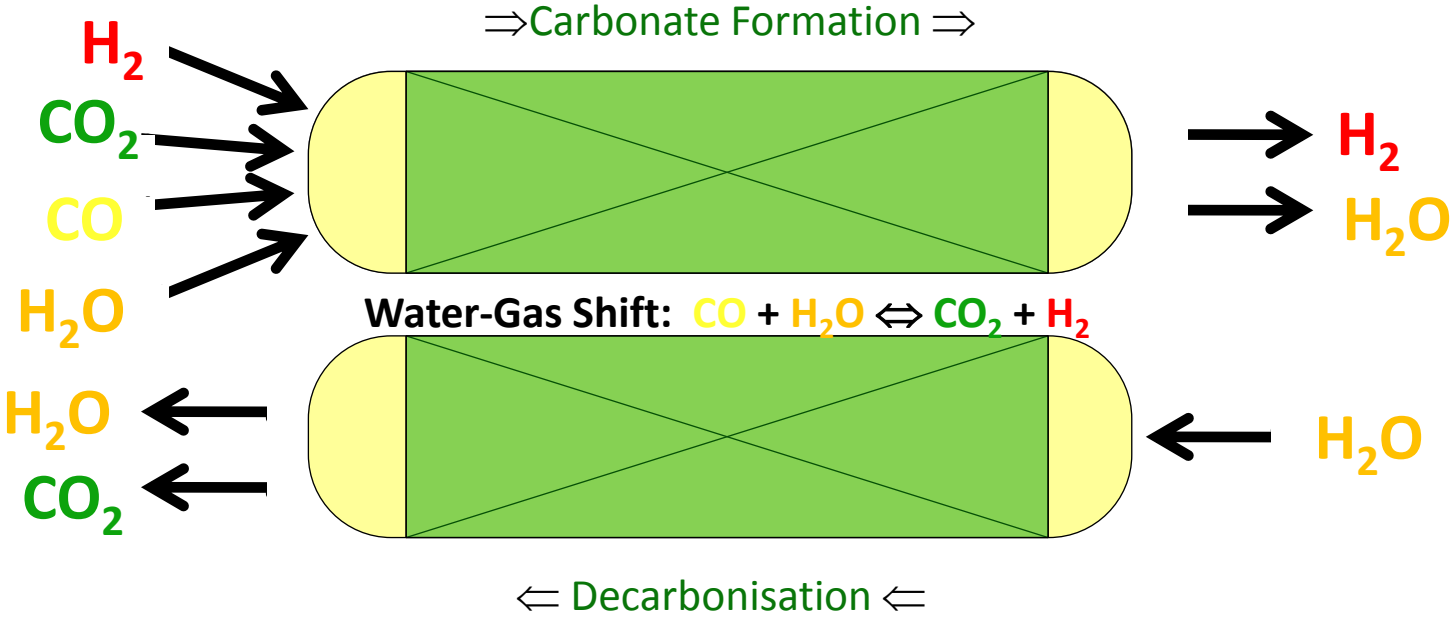


Sorption Enhanced Water Gas Shift reaction for carbon capture



The Intensification Step

- Combines the Water-Gas-Shift reaction with sorbent material to simultaneously produce H_2 at high temperature whilst also capturing CO_2



Testing and development on multiple scales

- Facilitating testing of new material and new conditions
- Scaling-up for manufacturing and full process simulations

8 x 2g

High Throughput Comparative Testing

10g

Adsorption Isotherms Realistic Conditions

2kg

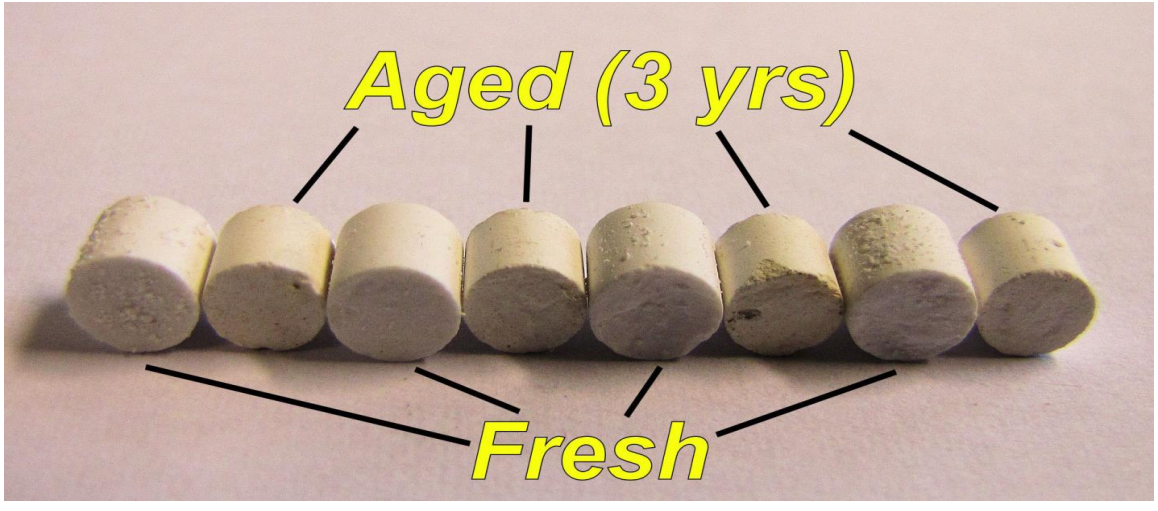
Industrially Relevant Materials

100kg

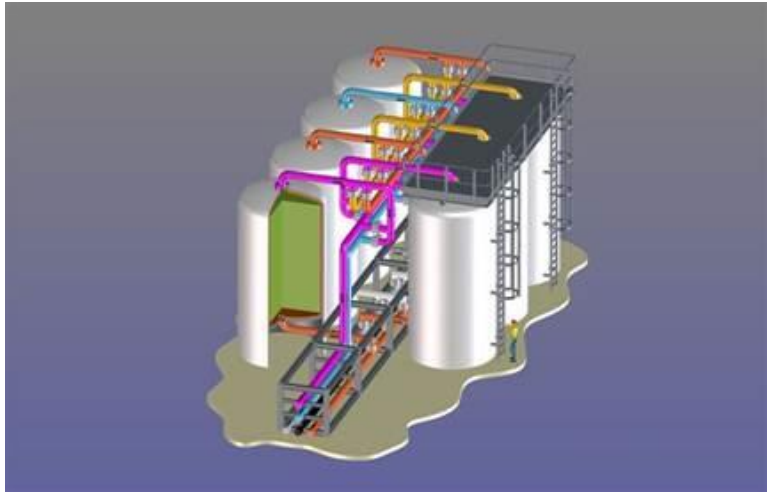
Pre-pilot Full-Cycles

Sorbent “stress test”

- Stability of the CO_2 sorbent ALKASORB
  - Combined adsorbing and catalytic activity of material for more than 5000 cycles
  - No deterioration was observed

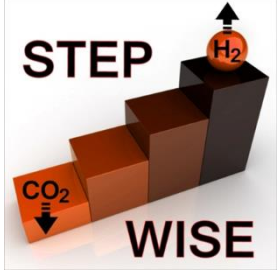


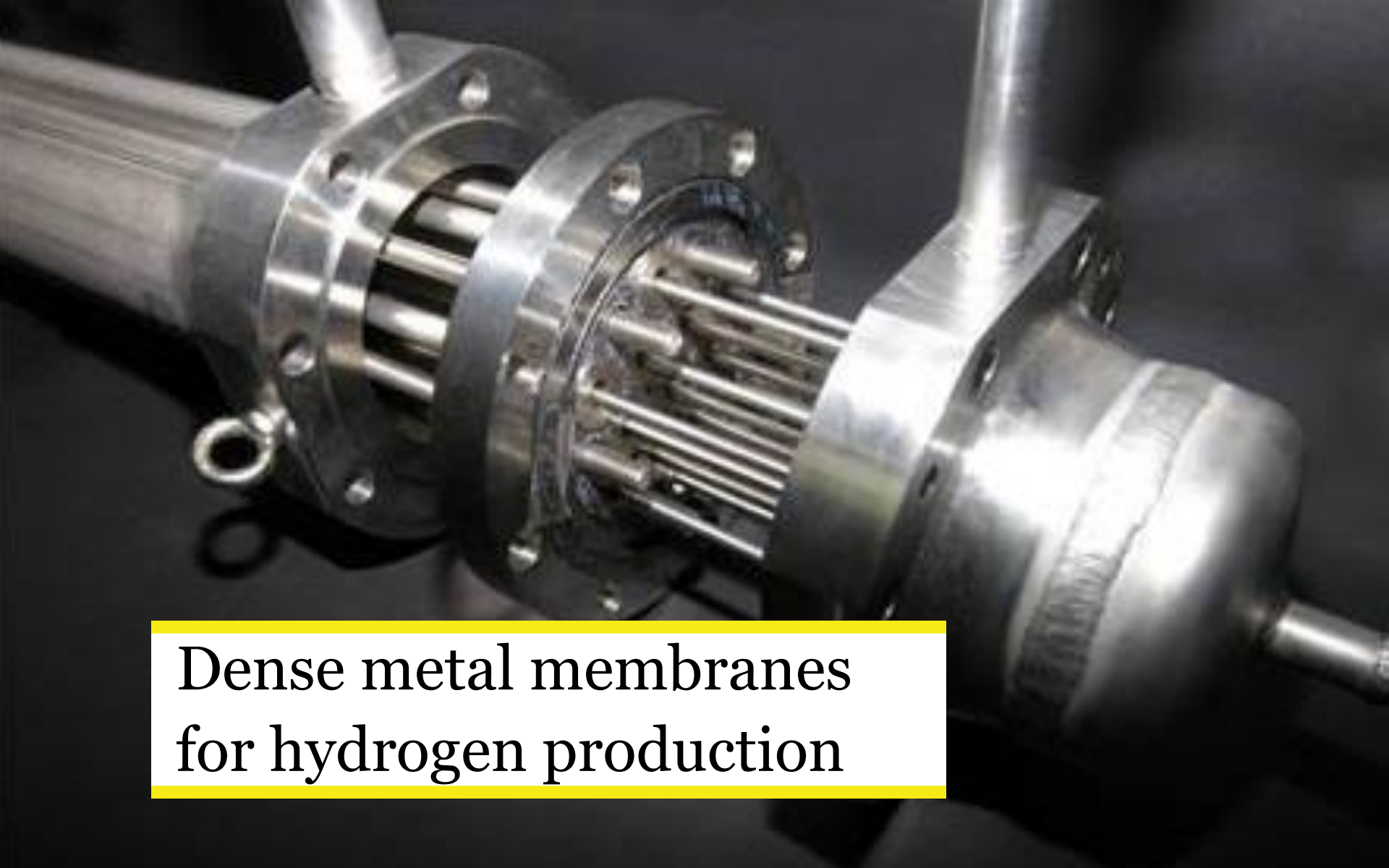
Near future ambition



- At ECN laboratory
- 100 kg of sorbents

- In the steel industry
- 4,000 kg of sorbents





Dense metal membranes for hydrogen production

Methane steam reforming at pre-pilot scale

Hydrogen membrane reactor

- Hydrogen production : 2 Nm^3/h
- Methane conversion increase > 30%
- 1000 hour long term testing at 7 bar

- Ambition
  - Continued testing at high pressure to increase methane conversion to >90%

HYSEP®
Hydrogen Separation Modules

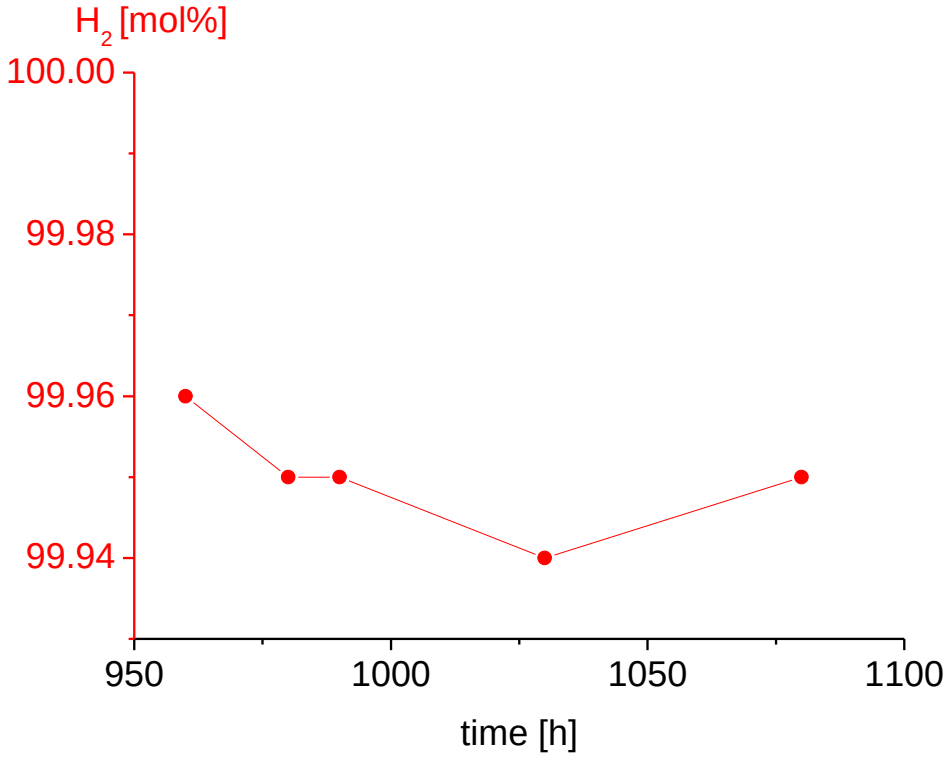
Pre-Pilot membrane testing

- Hysep module 1308
- Membrane area = 0.4 m^2
- 13 membranes, 26 seals, L = 70 cm

Designed parameter	Value
H_2 production[$Nm^3 \cdot h$]	4-6
H_2 max. recovery [%]	30
H_2 purity[%]	>95
T [°C]	450
P_{feed} [bar]	21

HYSEP®
Hydrogen Separation Modules

From 32% to 99.95% H2 purity

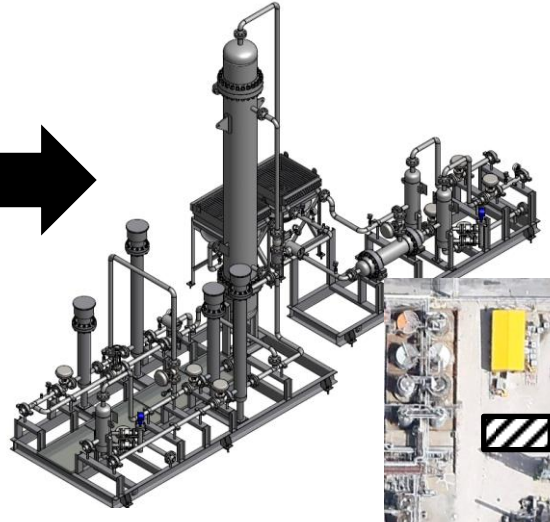


Feed

CO_2 ~ 6 mol%
CO ~ 2 mol%
H_2O ~ 50 mol%
H_2 ~ 32 mol%
CH_4 ~ 10 mol%

HYSEP® Hydrogen Separation Modules

Near future ambition



HYSEP®
Hydrogen Separation Modules

- Purposed built pre-pilot
- 4 Nm^3/h H_2

- Full on-site pilot,
- 50 Nm^3/h H_2

Membranes and sorbents to enhance your gas processes

Jaap Vente, vente@ecn.nl, +31 88 515 8615

ECN
Westerduinweg 3
1755 LE Petten
The Netherlands

P.O. Box 1
1755 LG Petten
The Netherlands

T +31 88 515 4949
F +31 88 515 8338
info@ ecn.nl
www.ecn.nl