Accelerating industrial electrification

Strategies for integrating CO_2 capture and conversion

Maartje Feenstra, Elena Perez, Anca Anastasopol, Earl Goetheer, **Reinier Grimbergen**

“BRIDGING SCIENCE WITH TECHNOLOGY”

KNOWLEDGE TRANSFER

Knowledge exploitation by spin-offs, licences, in partnership with other companies

DEVELOP FUNDAMENTAL KNOWLEDGE

Together with universities

CLIENTS & PARTNERS

KNOWLEDGE APPLICATION

Contract research for and with clients

KNOWLEDGE DEVELOPMENT

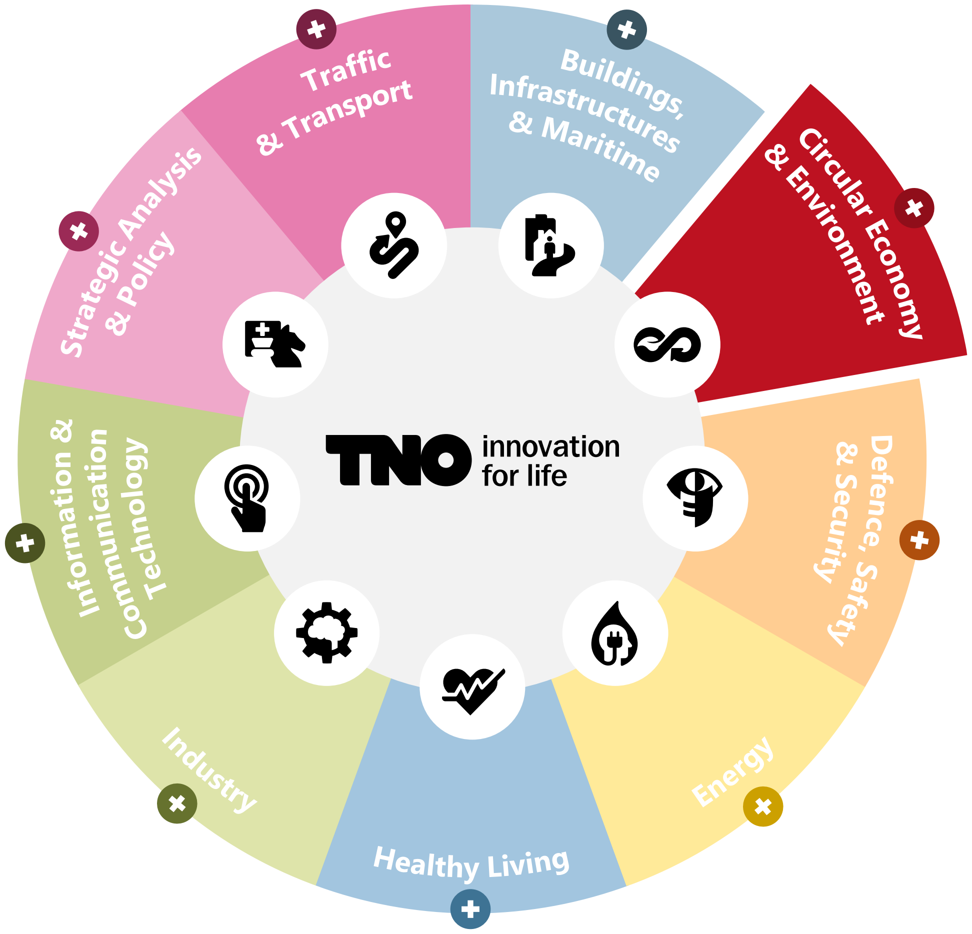
In public-private partnership with partners from the triple helix

TNO innovation for life

WE DO THIS BY TAKING A MULTIDISCIPLINARY APPROACH

1379
PUBLICATIONS

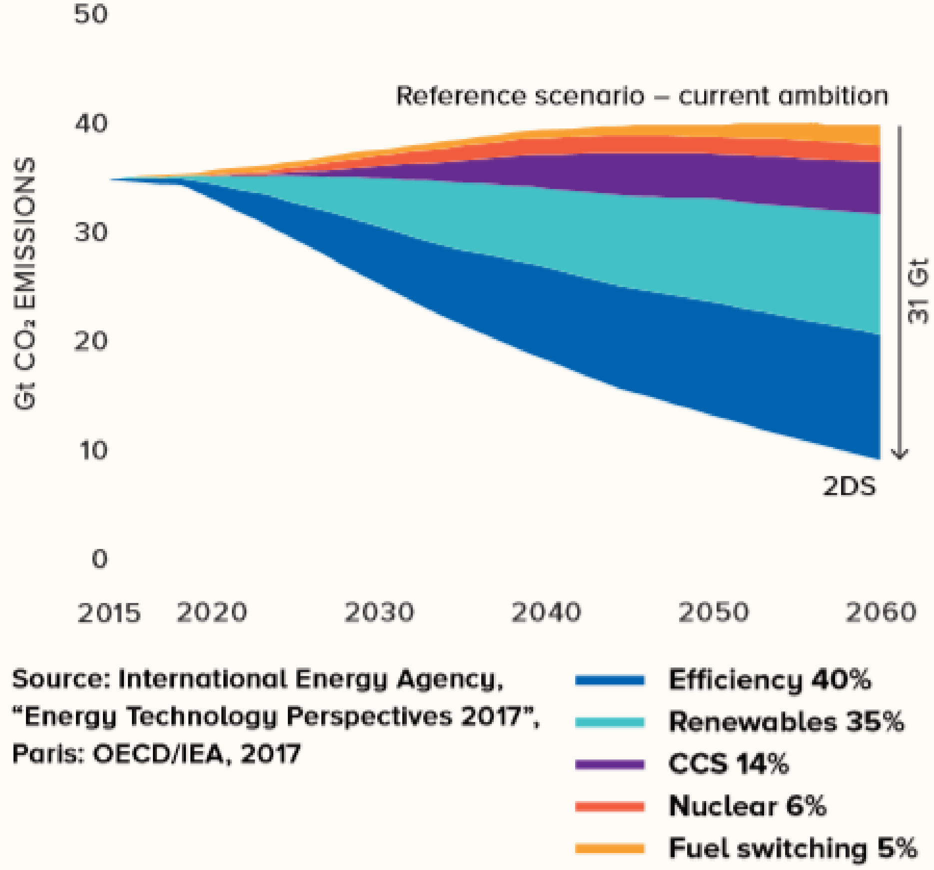
958
PATENTS



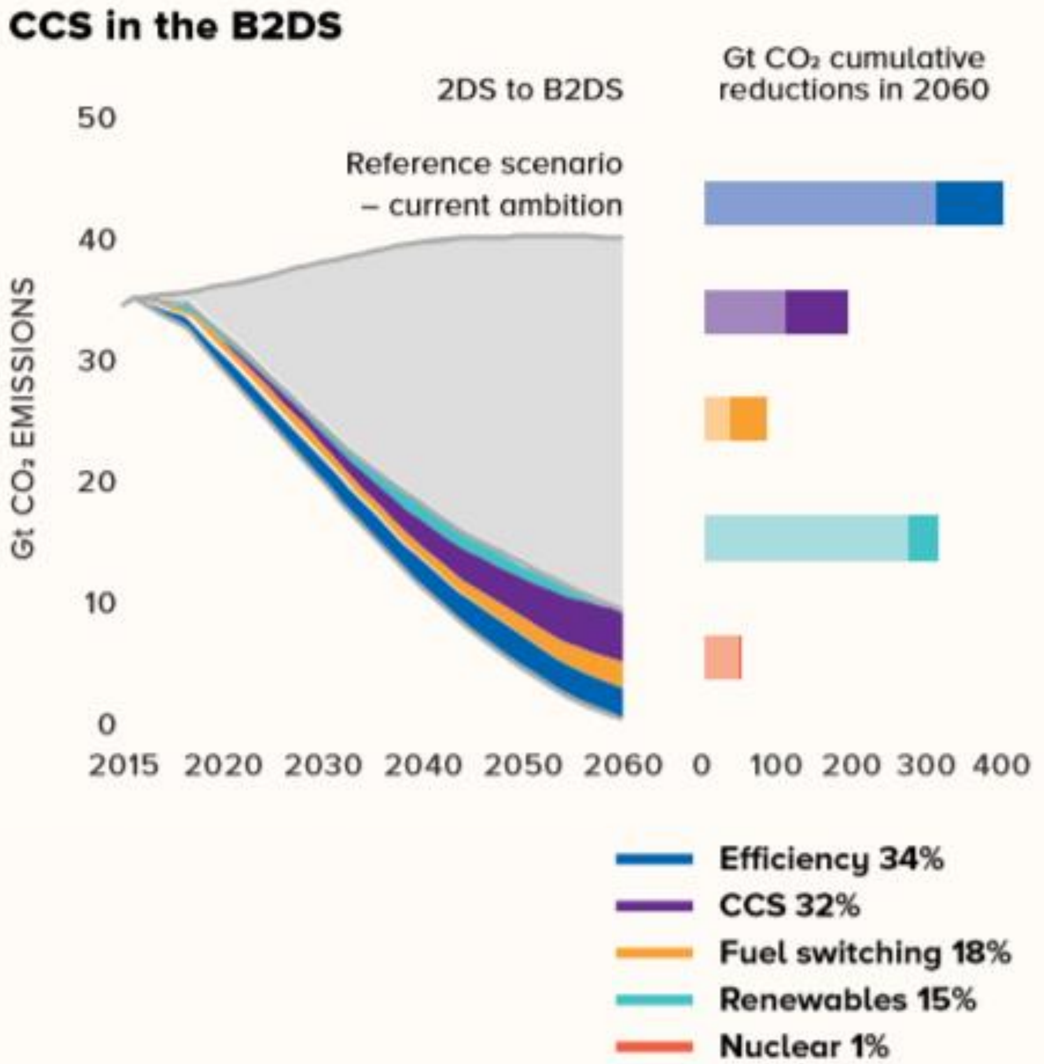
58
PROFESSORS

MORE THAN
2900
FTE RESEARCH

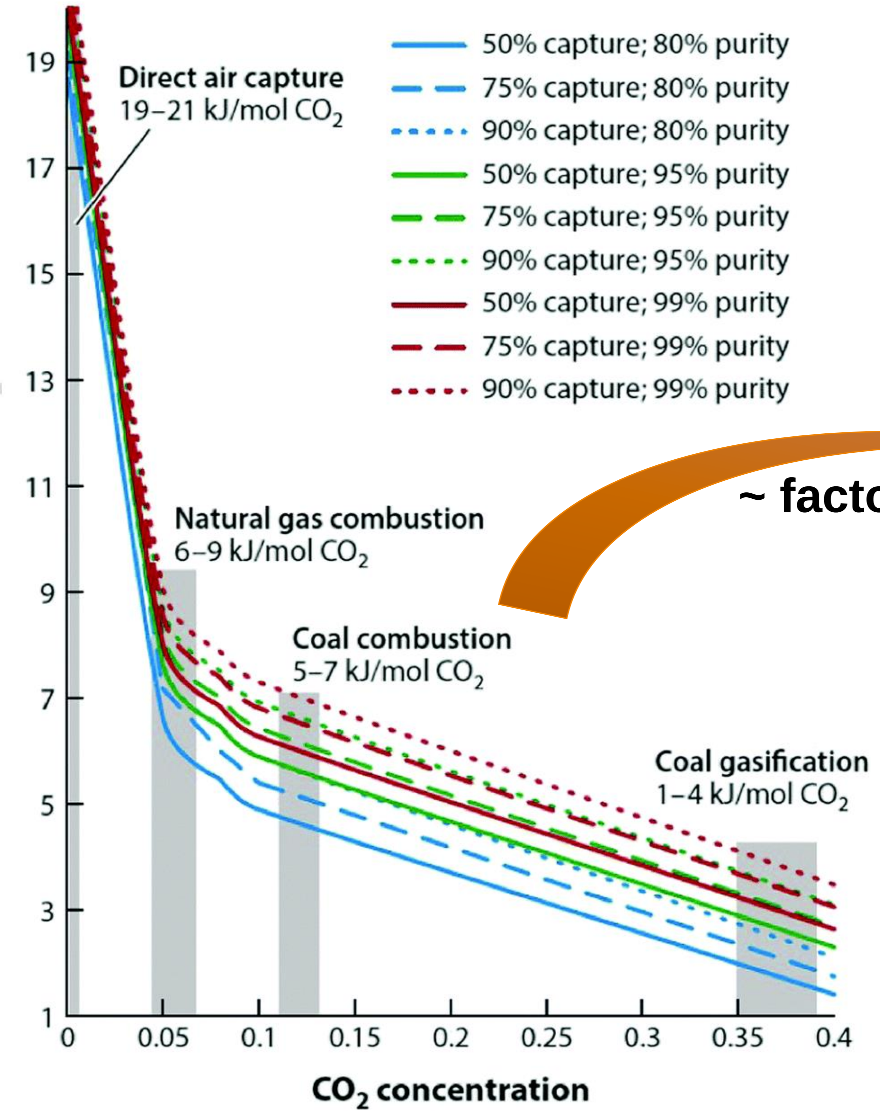
IMPORTANCE OF CCS



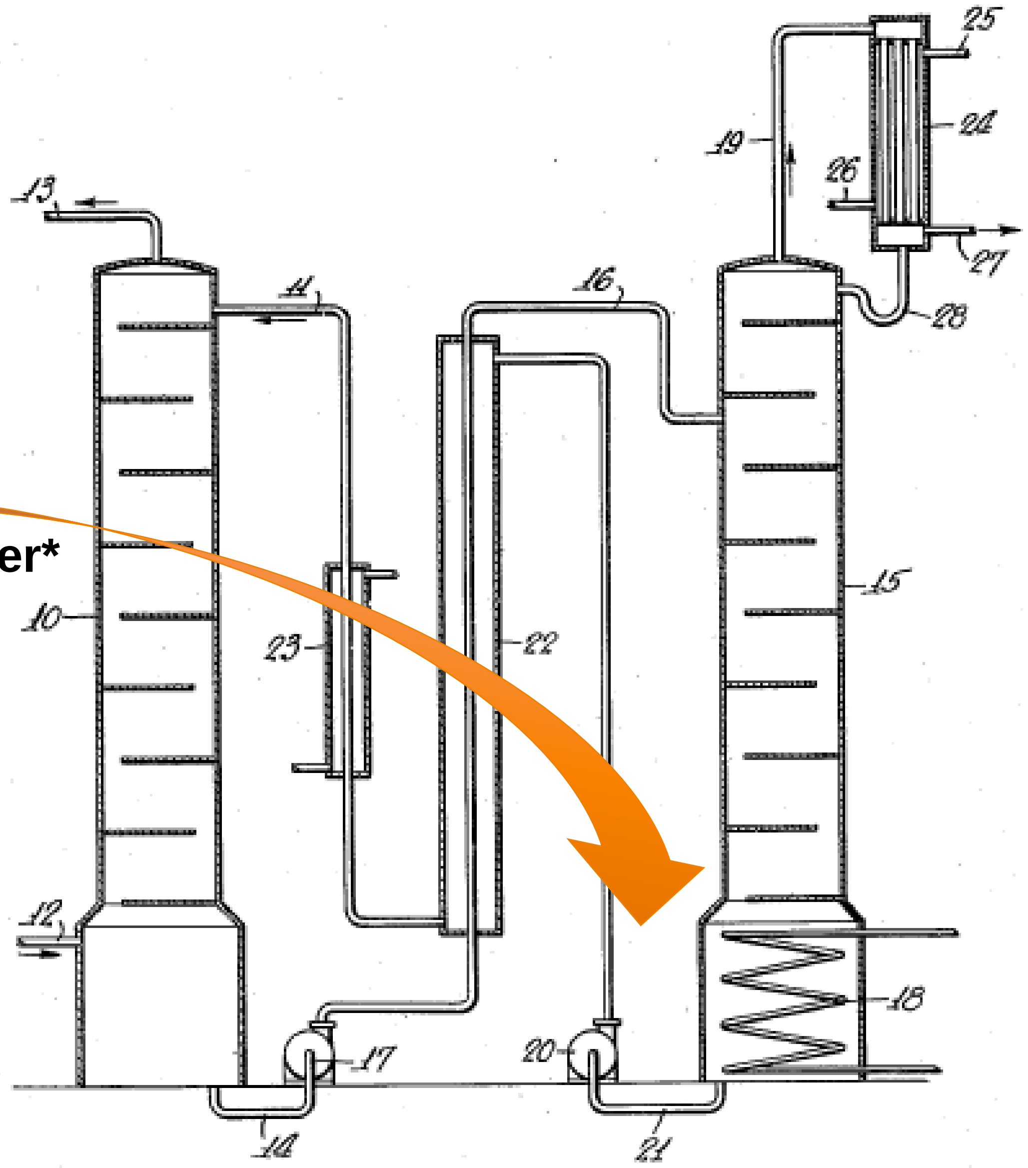
Source: International Energy Agency, "Energy Technology Perspectives 2017", Paris: OECD/IEA, 2017



CAPTURE EFFICIENCIES THEORY & PRACTICE



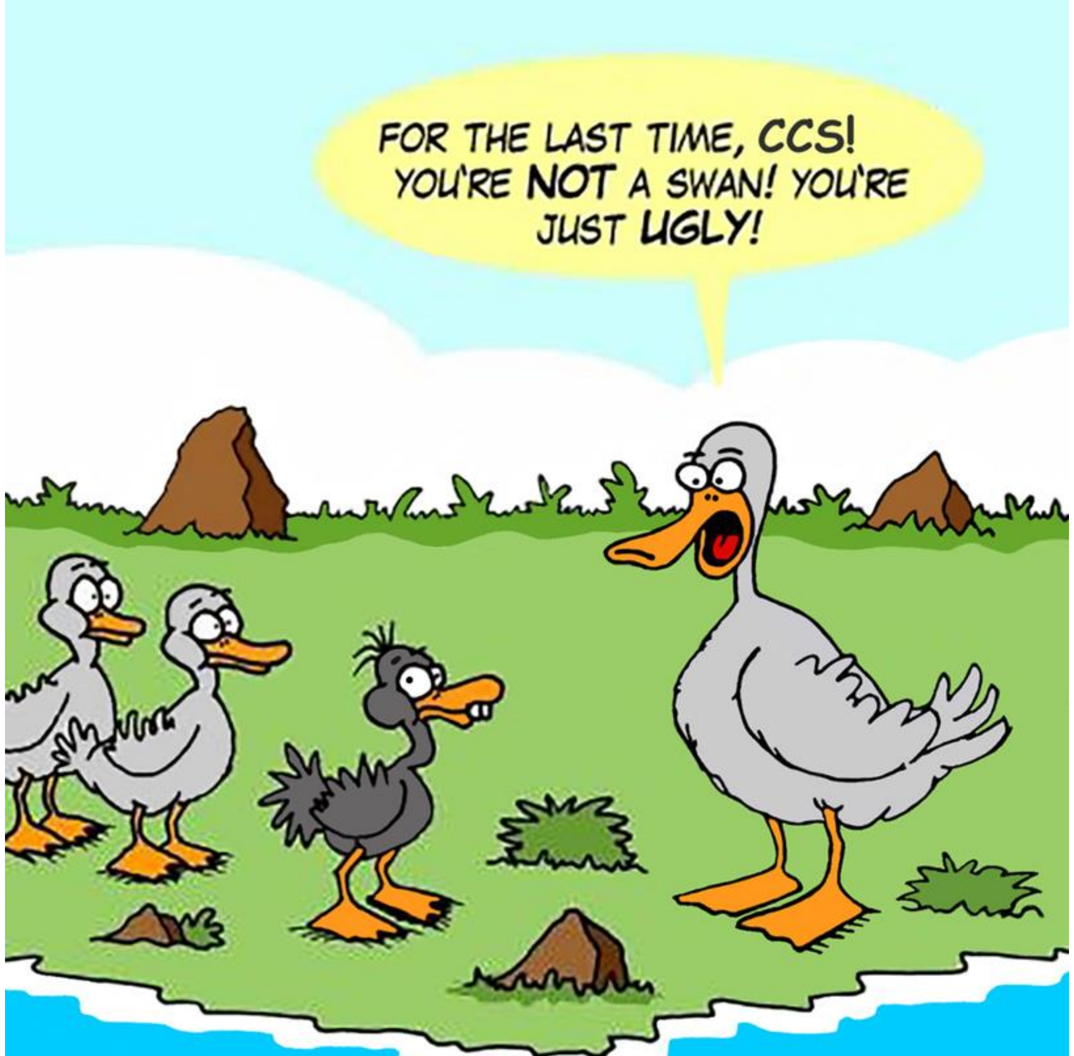
~ factor 20 higher*



Energy Environ. Sci., 2018, **11**, 1062-1176

*Highest energy cost is desorption of CO_2 at high T

CCS PROVEN TECHNOLOGY … PUBLIC PERCEPTION

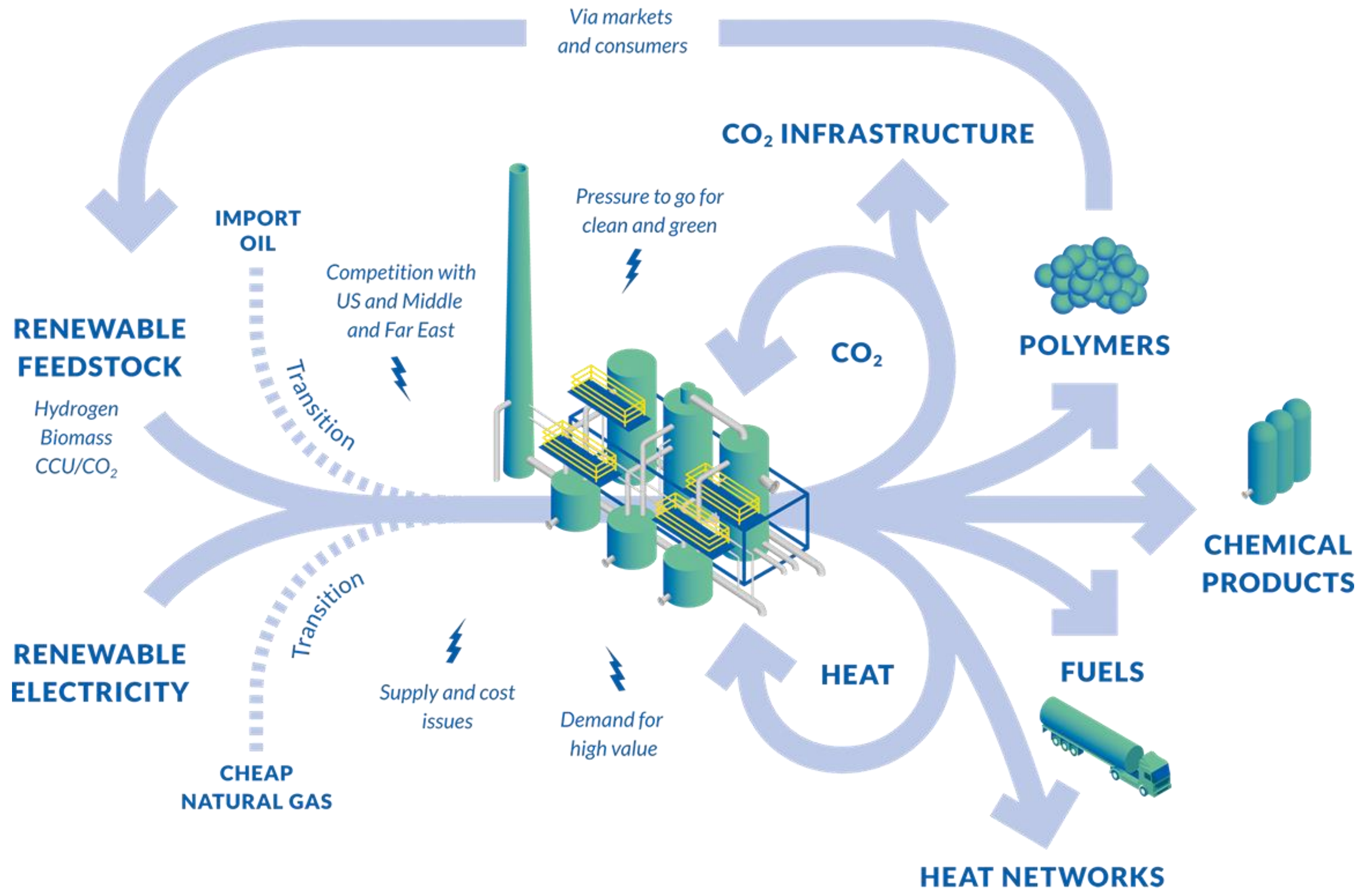


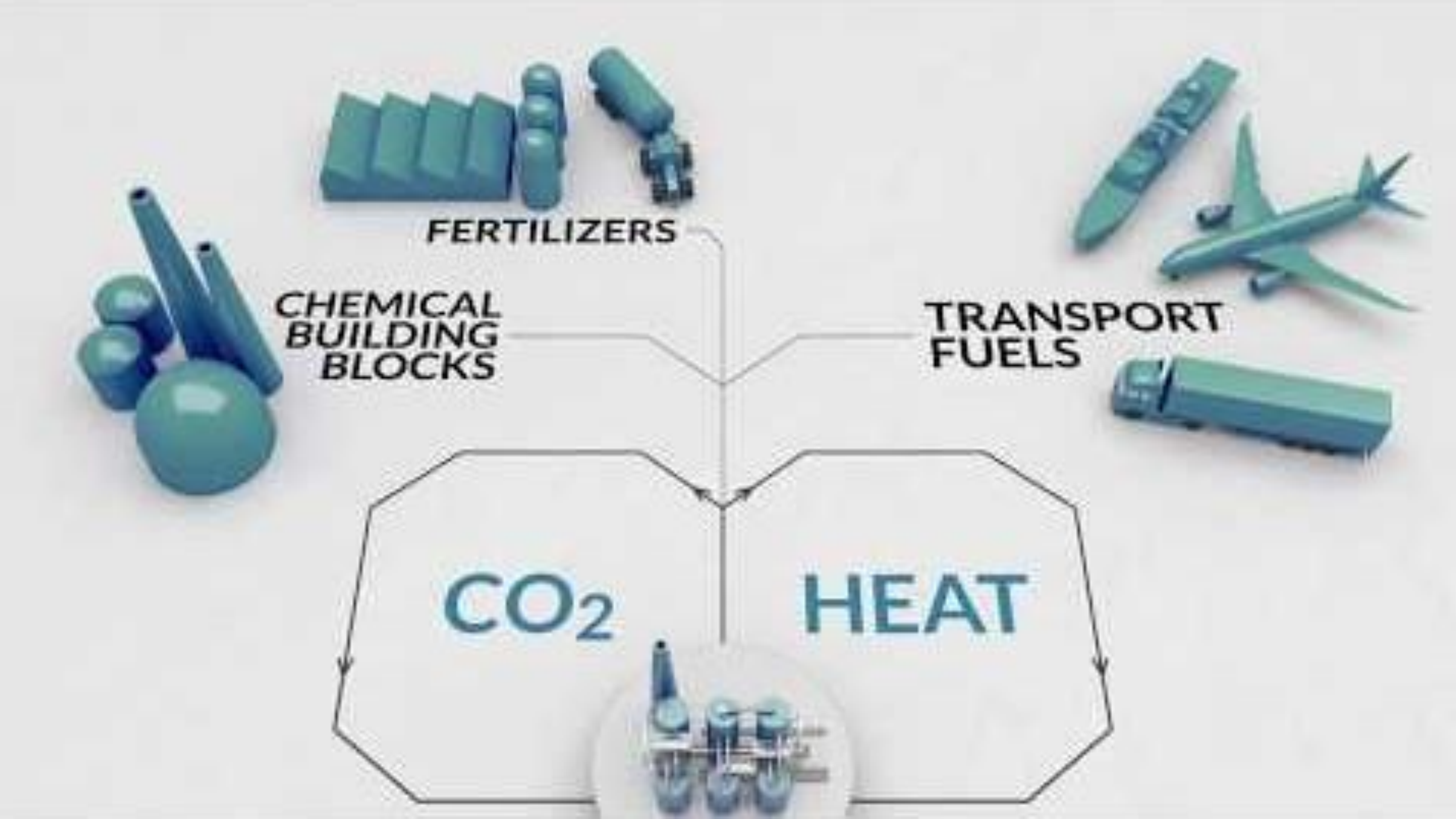
by: Andy Read & Mark Kombrink

TOWARDS A SUSTAINABLE CHEMICAL INDUSTRY

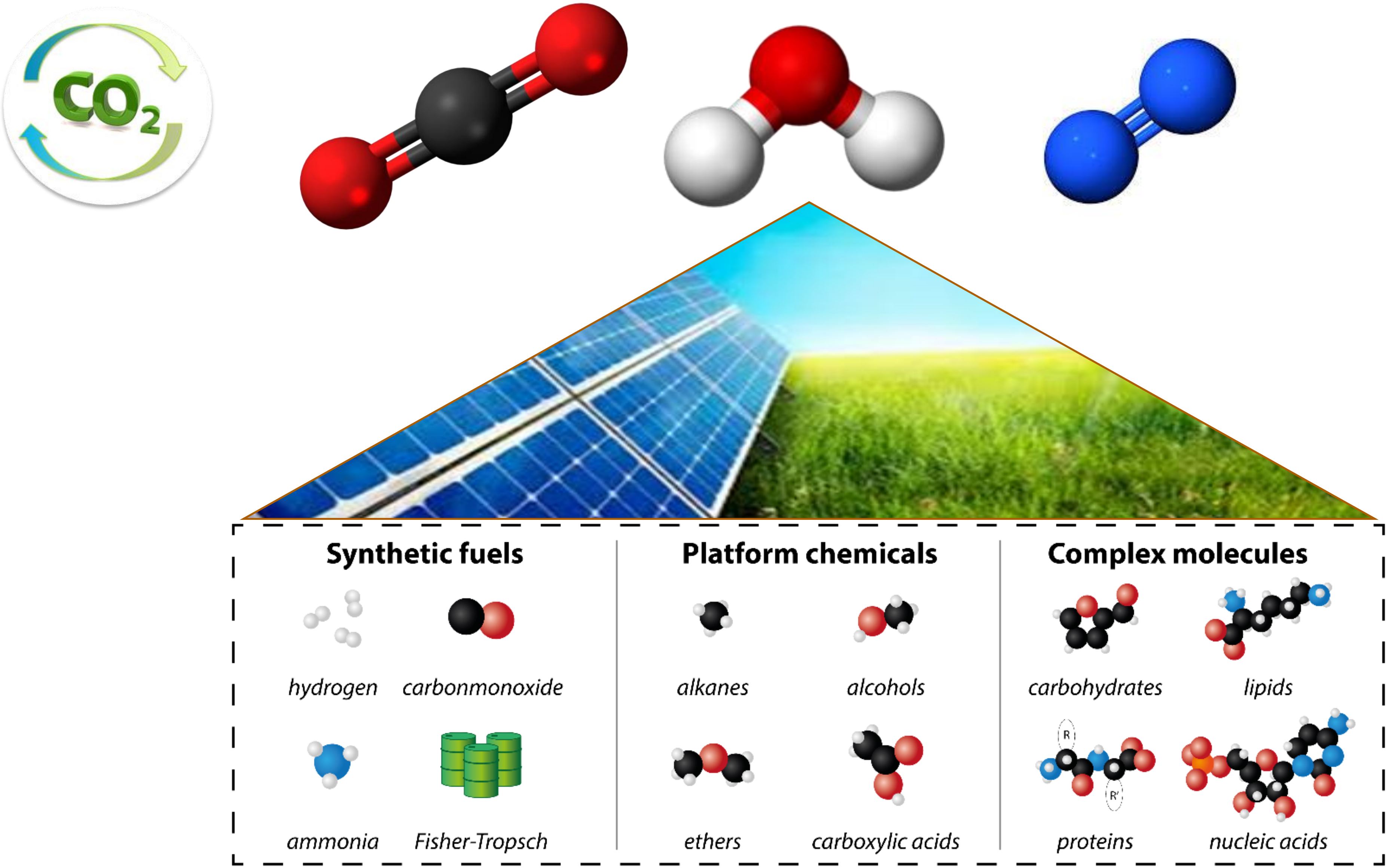
Feedstock
Recarbonization

Energy
Decarbonization




FERTILIZERS
CHEMICAL BUILDING BLOCKS
TRANSPORT FUELS
CO_2
HEAT

Grand challenge: *Our Man On The Moon*



Renewable production of fuels and (platform) chemicals from CO2, water and nitrogen based on photochemistry, electrochemistry, biotechnology

* Modified from NWO solar fuel

CONVERSION TECHNOLOGIES

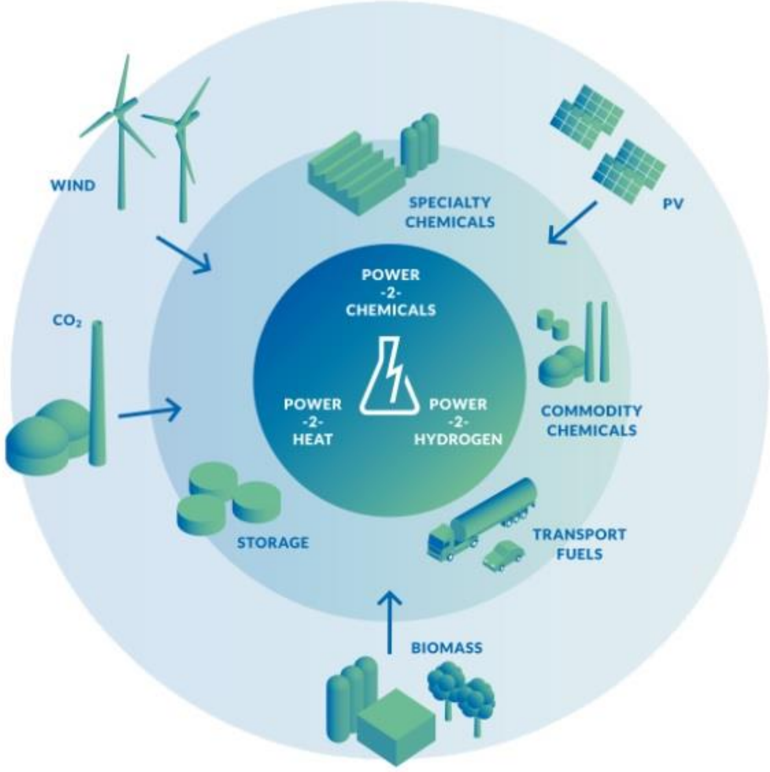
TNO innovation for life

1. Catalytic Hydrogenation
2. Direct Electrochemical

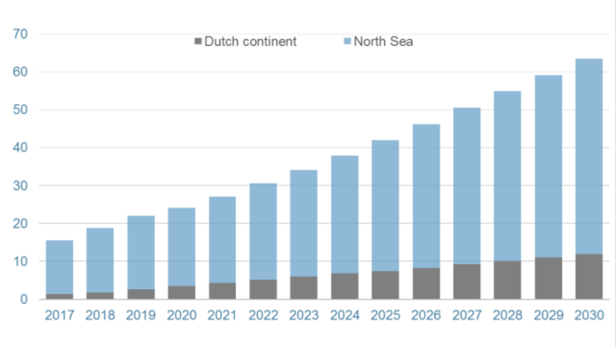
Electrification

3. Polymerization
4. Biochemical
5. Mineralization

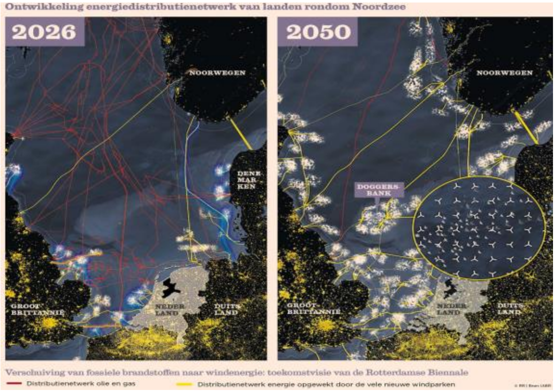
VOLTA CHEM

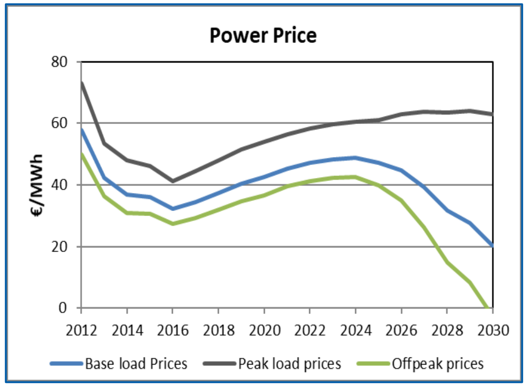


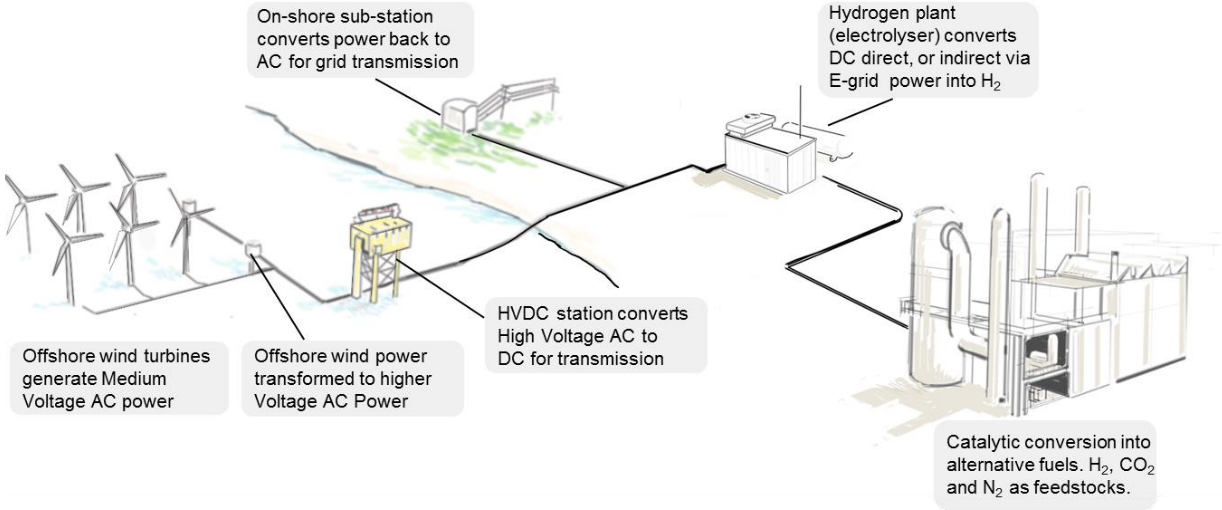
RENEWABLES WILL CREATE OPPORTUNITIES



0.9 GW (2016) → 4.5 GW (2023) → 250? GW (2050)







INDIRECT VERSUS DIRECT CONVERSION

$$H_2O \xrightarrow[e]{} H_2$$

products

CO_2

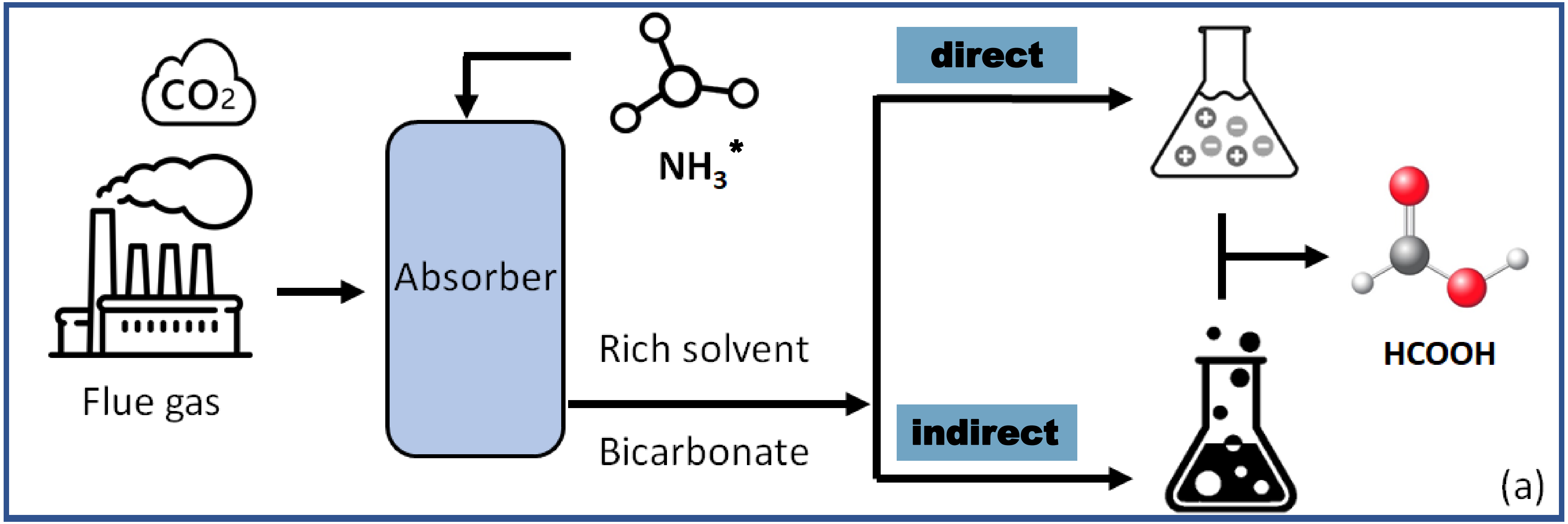
High TRL

siemens

$$CO_2 + H_2O \xrightarrow[e]{} \text{products}$$

Low TRL

INTEGRATION CAPTURE WITH CONVERSION



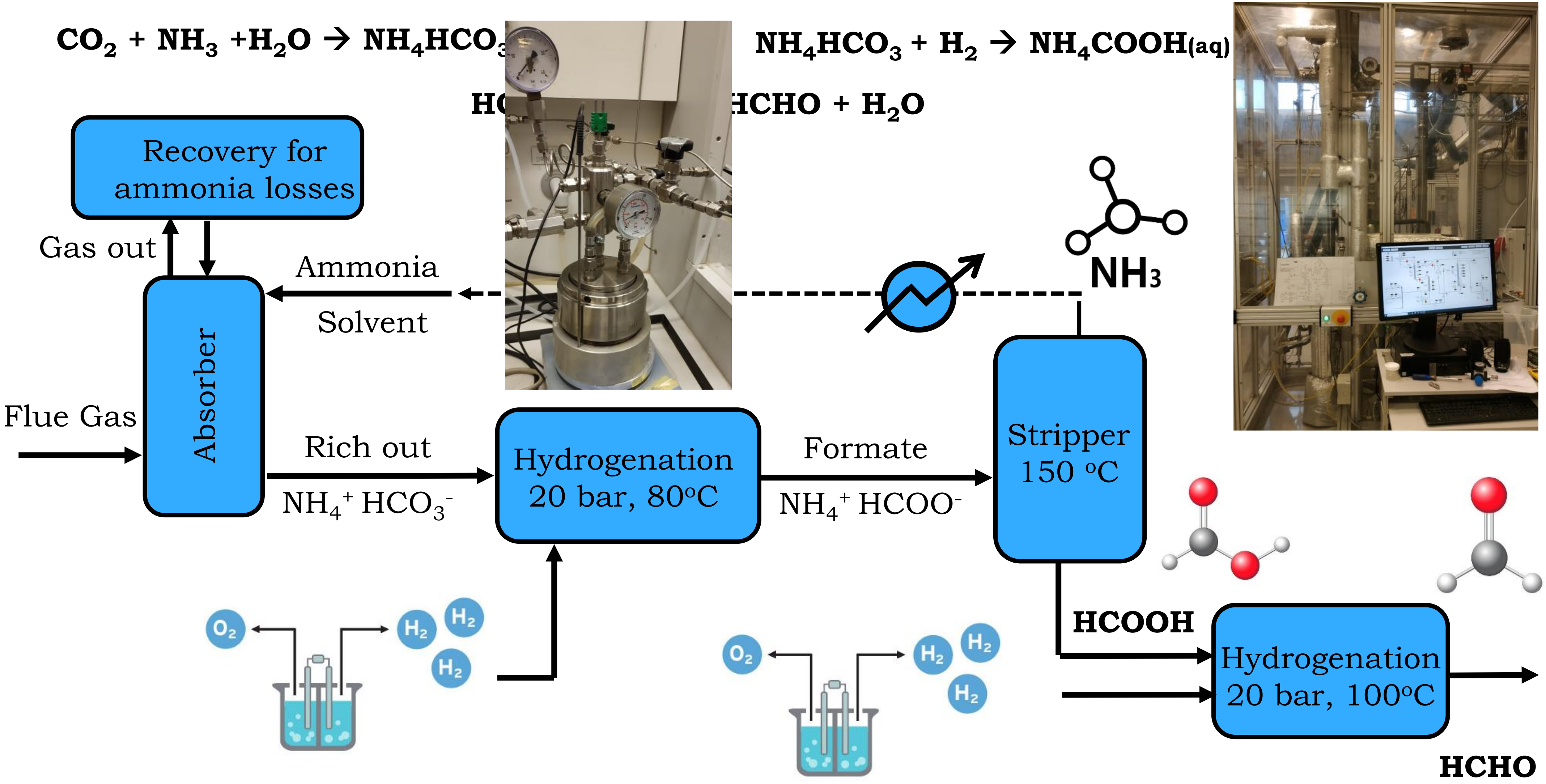
***Ammonia is just an example**

DESCRIPTION OF THE SYSTEM

$CO_2 + NH_3 + H_2O \rightarrow NH_4HCO_3$

$NH_4HCO_3 + H_2 \rightarrow NH_4COOH(aq)$

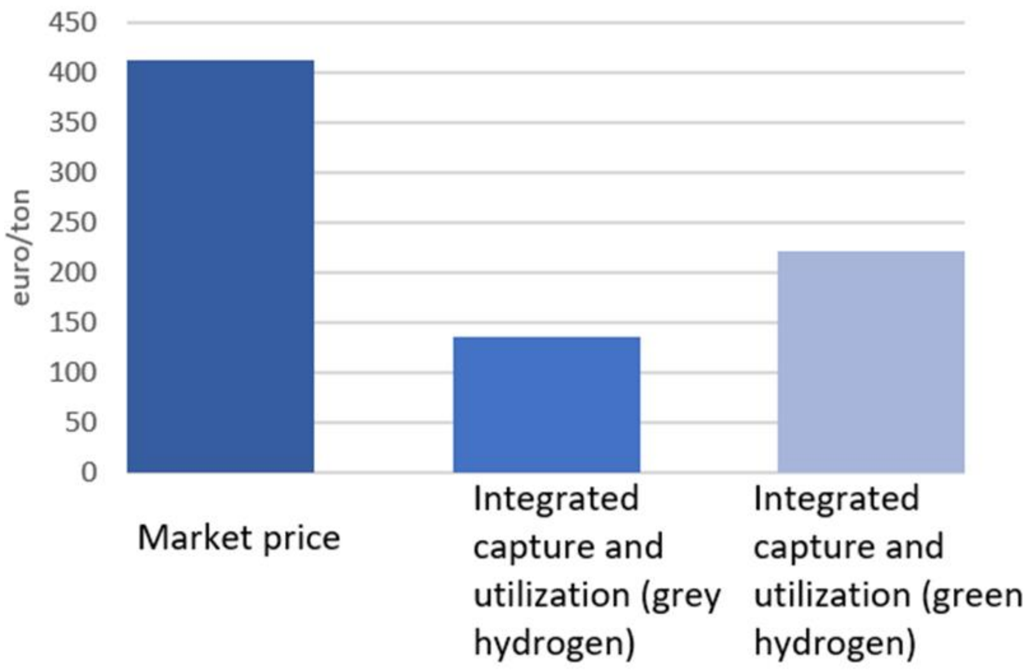
HC … $HCHO + H_2O$



COMPARISON OF PRODUCTION COST

- Comparison with formaldehyde market prices for a purity of 37%
- Interesting CO_2 utilization route from an economic and sustainable perspective

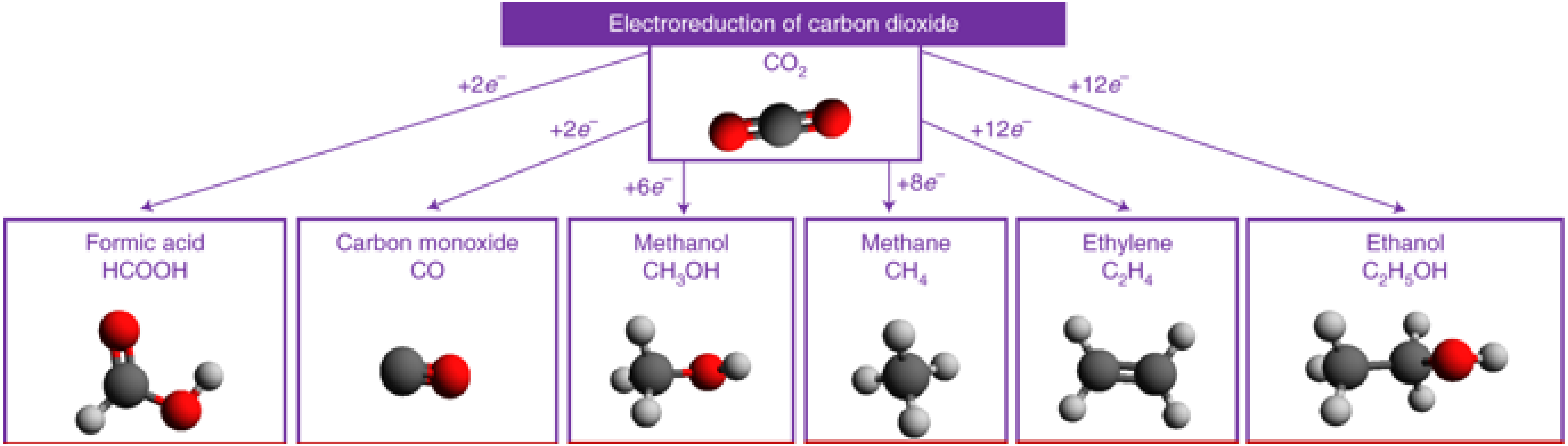
Comparison of formaldehyde (37%) produced by integrated capture and utilization:



H_2=1.5 €/kg

H_2=3.5 €/kg

DIRECT ELECTROCHEMISTRY

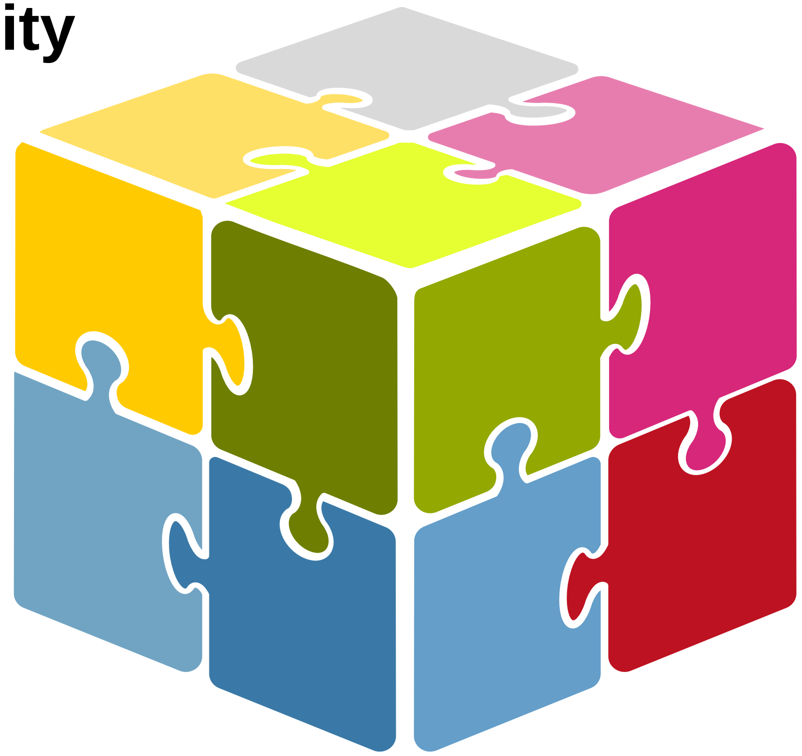


Sumit Verma, Shawn Lu & Paul J. A. Kenis, Nature Energy (2019)

MERIT IN ELECTROLYSIS

Current density

Selectivity

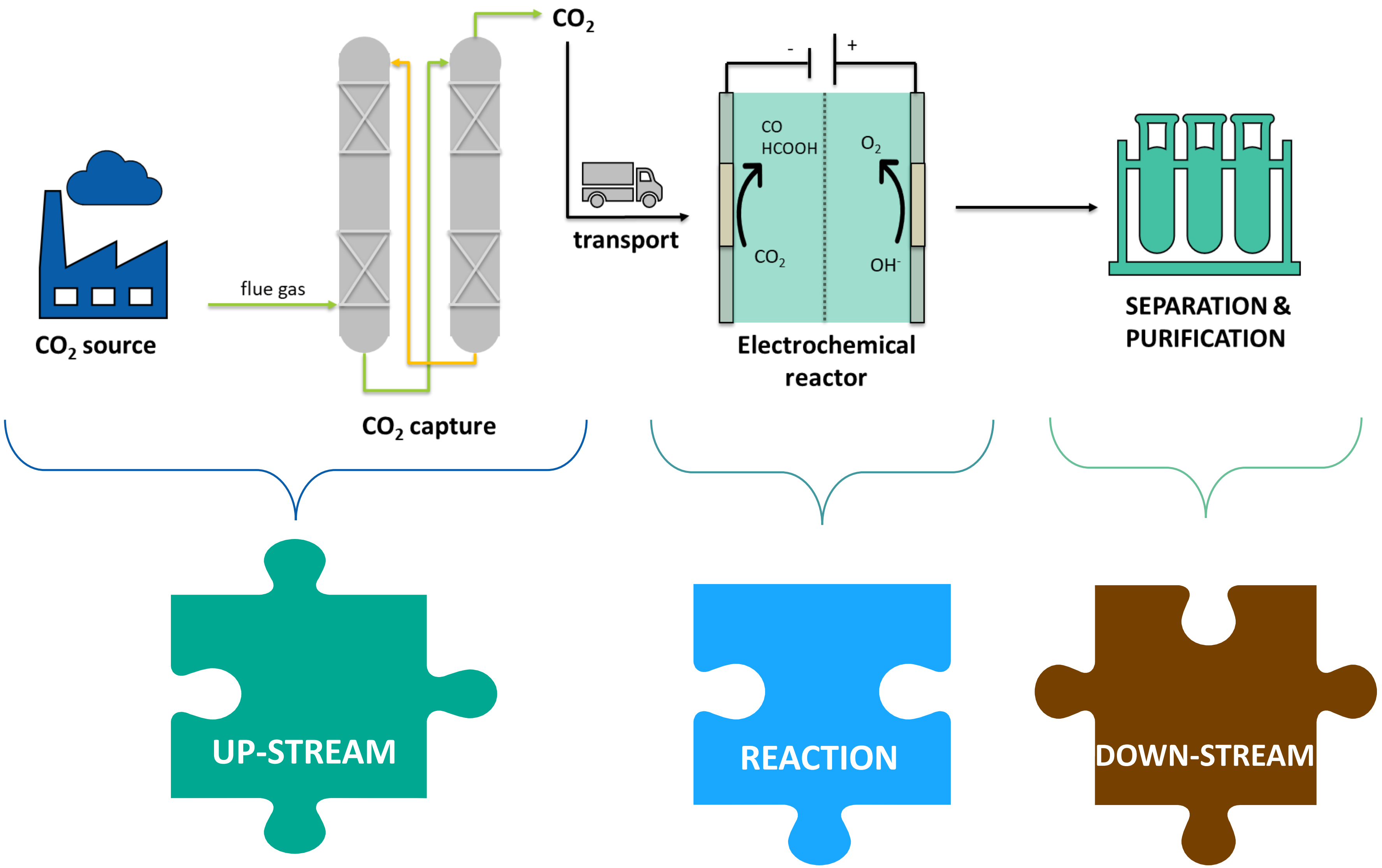


System design

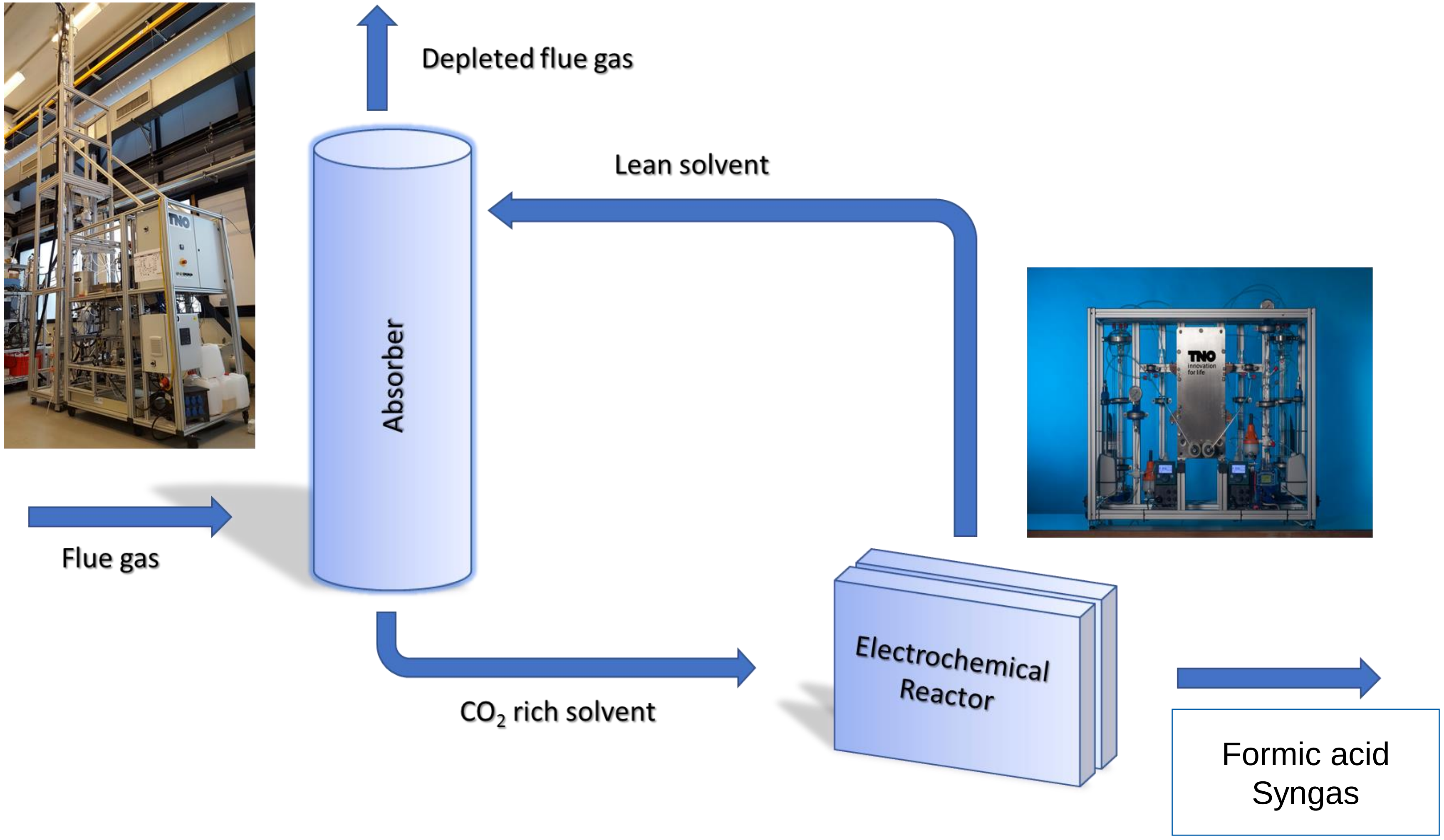
Stability

Internal resistance

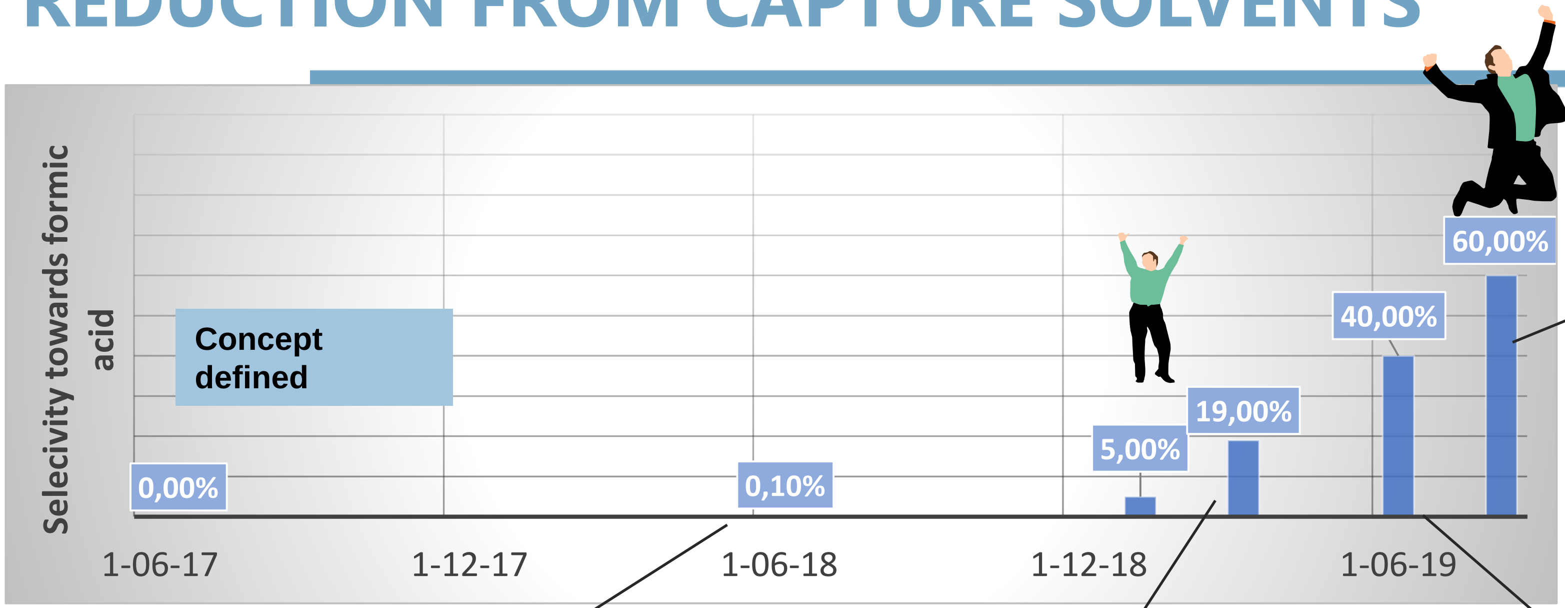
PROCESS AND SYSTEM INTEGRATION

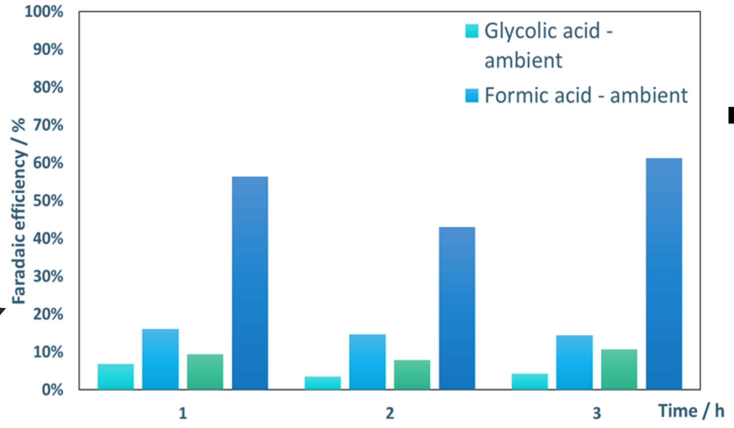


INTEGRATION OF CO_2 CAPTURE & CONVERSION

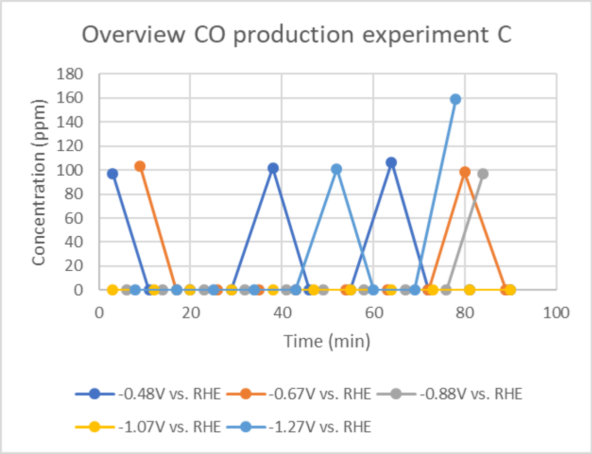


CO_2 REDUCTION FROM CAPTURE SOLVENTS

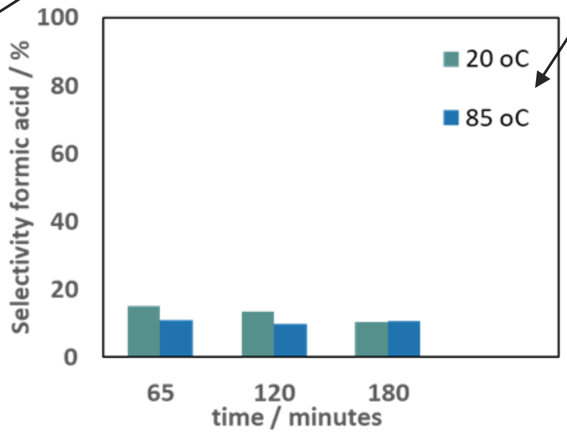




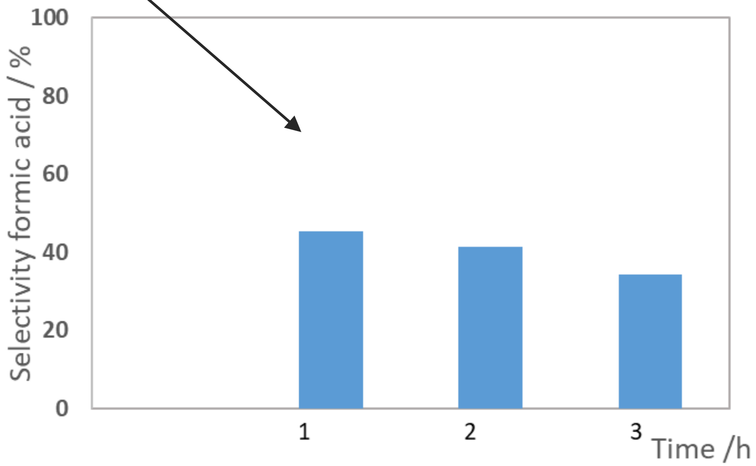
Organic capture solvent B



Aqueous capture solvent A

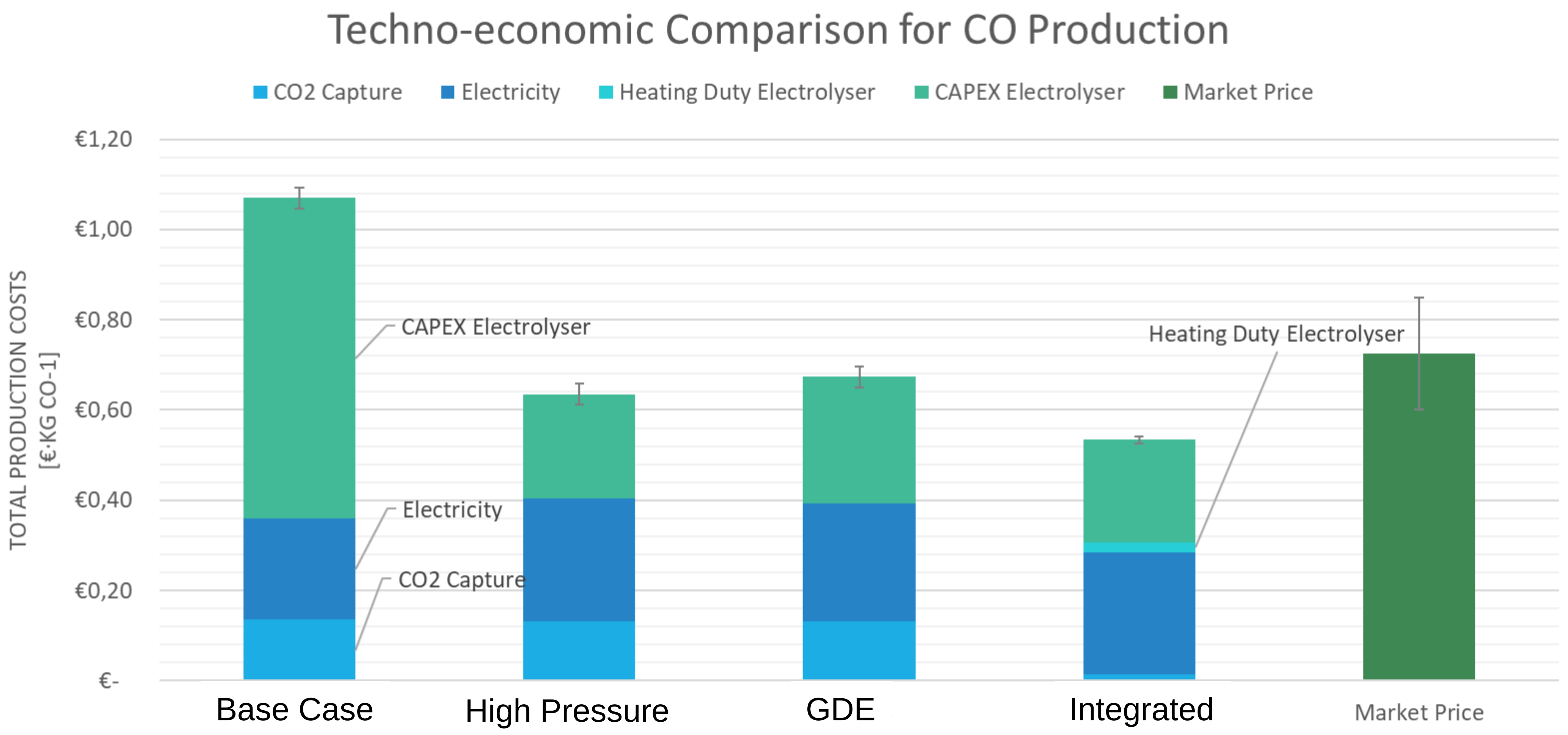


Aqueous capture solvent B

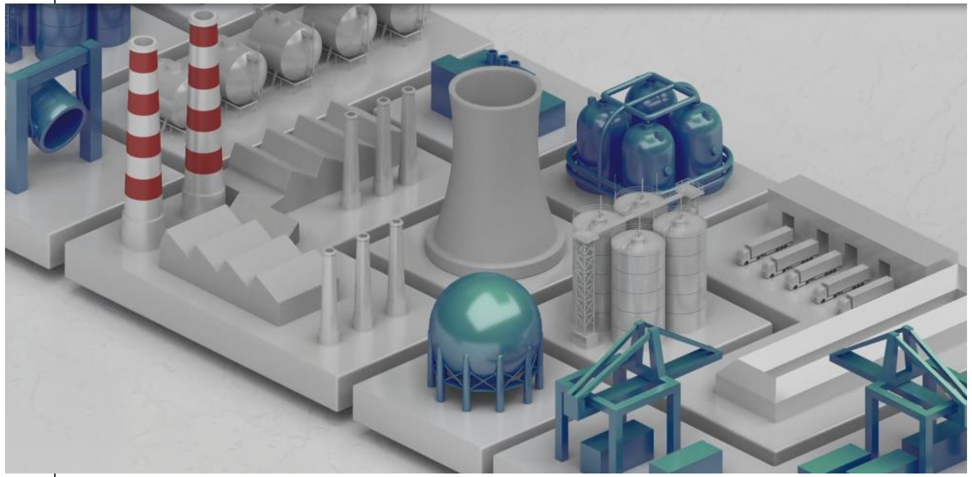


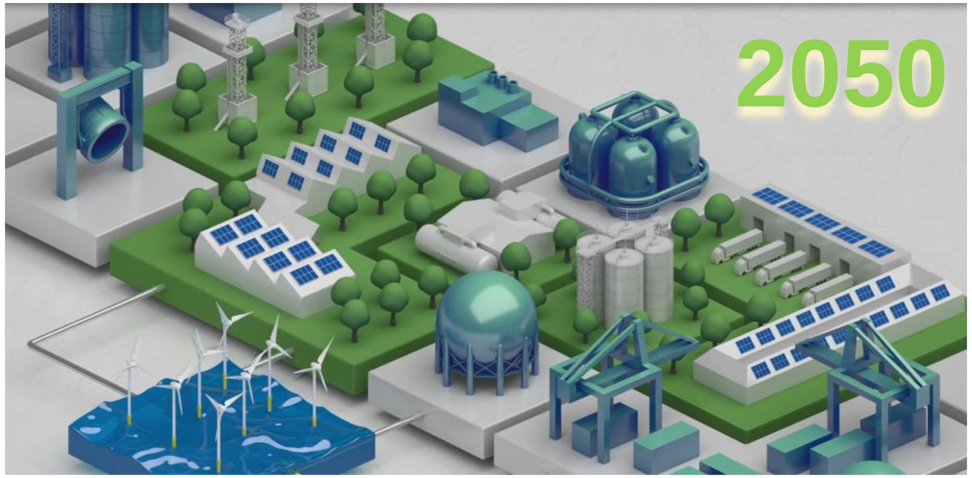
Low aqueous capture solvent B

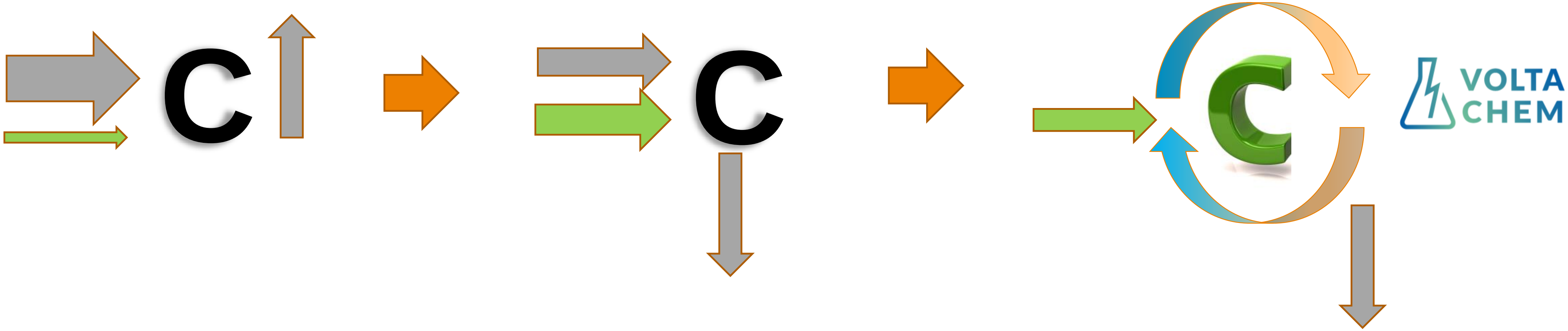
WHAT IF WE MAKE CO



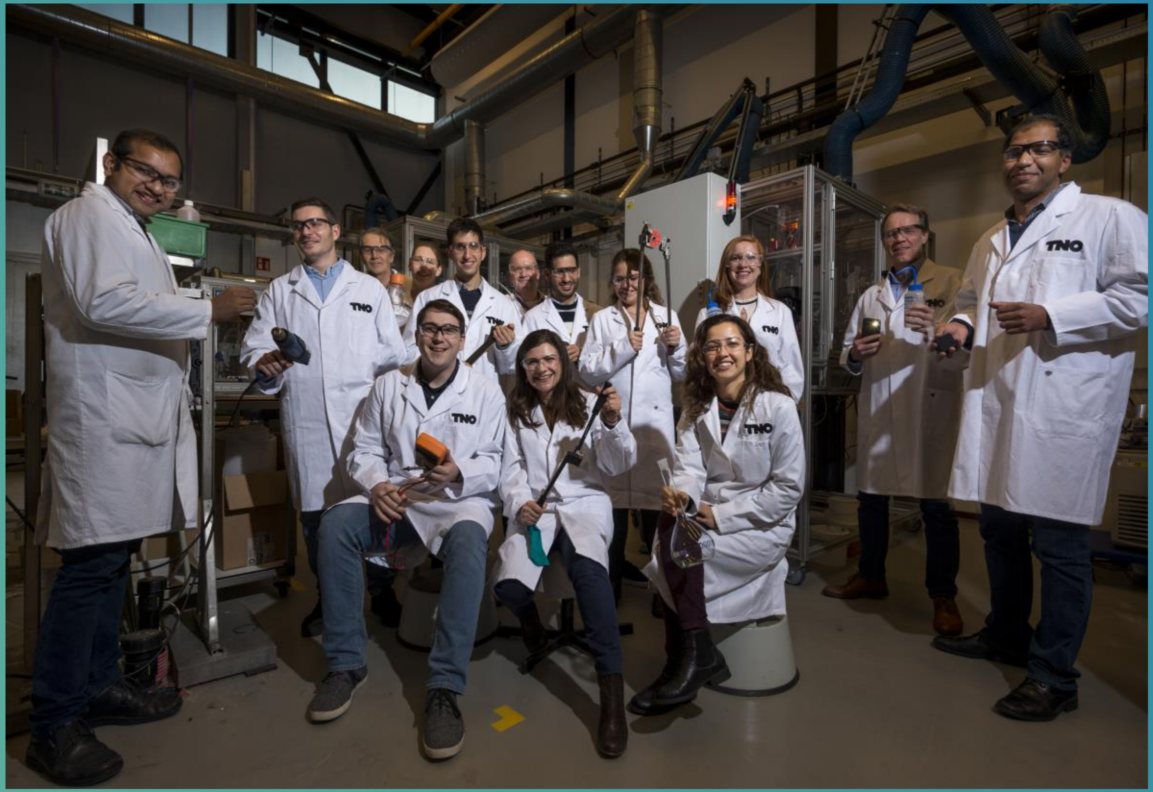
SUMMARY: THE FUTURE IS CIRCULAR







Let's energize innovation together!



www.voltachem.com

Dr. Reinier Grimbergen
Senior business developer
reinier.grimbergen@tno.nl

Prof. dr. ir. Earl Goetheer
Principal scientist
earl.goetheer@tno.nl

VOLTA CHEM

Powered by: TNO & ECN