Universiteit Utrecht

KNCV

Energie en materialen voor de toekomst

Prof. Dr. Eelco Vogt
Universiteit Utrecht

9 november 2024

INORGANIC CHEMISTRY & CATALYSIS

Utrecht University

Institute for Sustainable & Circular Chemistry

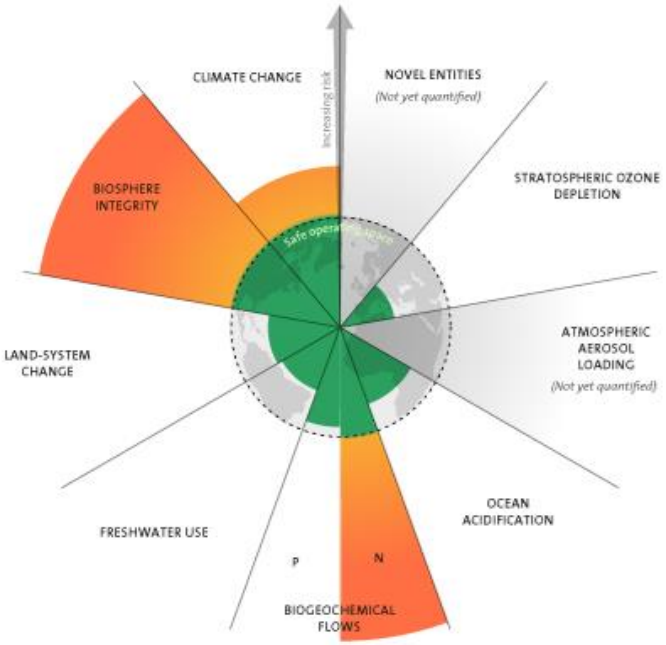
C3 Centrum JongerenCommunicatie Chemie

Grote Problemen: Grote oplossingen

Beeld: iFink, Plastic Soup Foundation, Mohamed Abdulraheem, World Bank

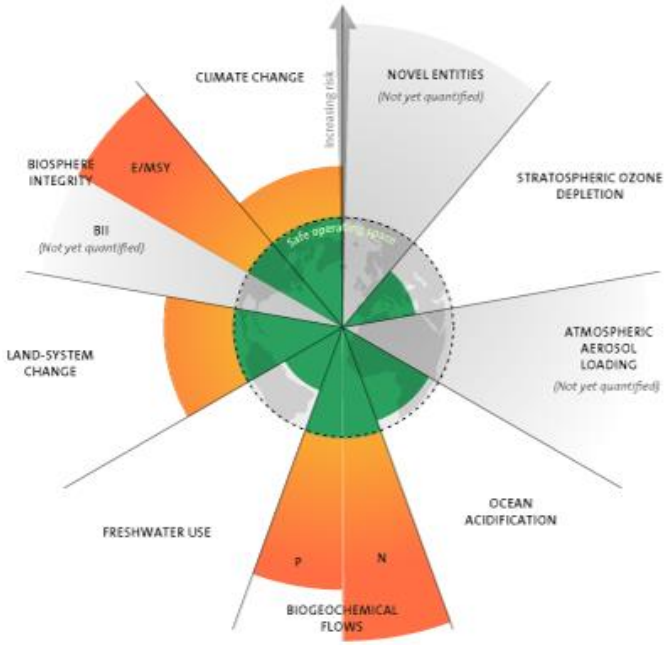
Planetary Boundaries

2009



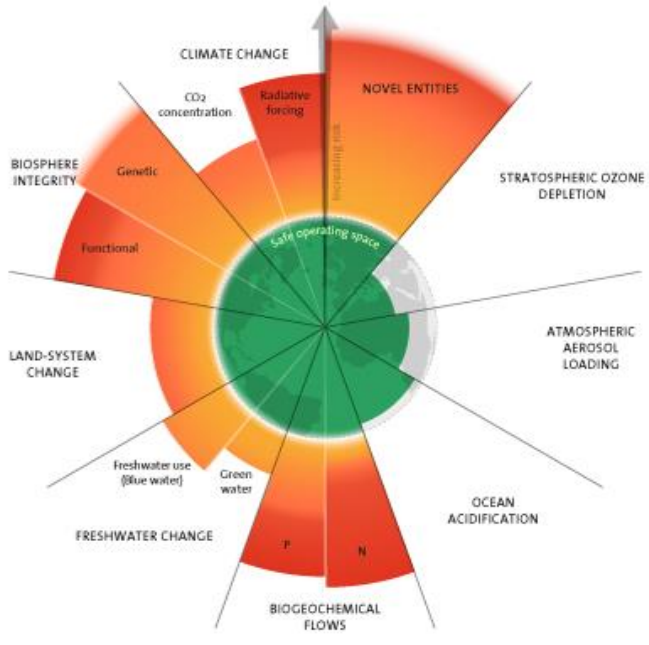
3 boundaries crossed

2015



4 boundaries crossed

2023



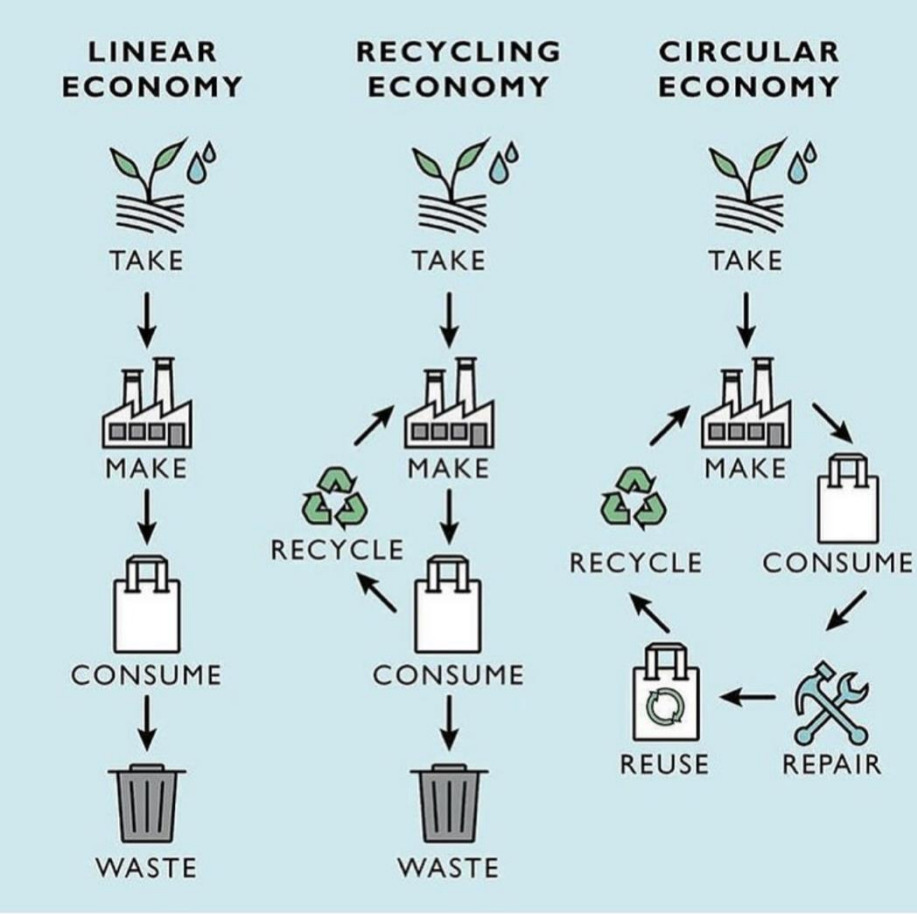
6 boundaries crossed

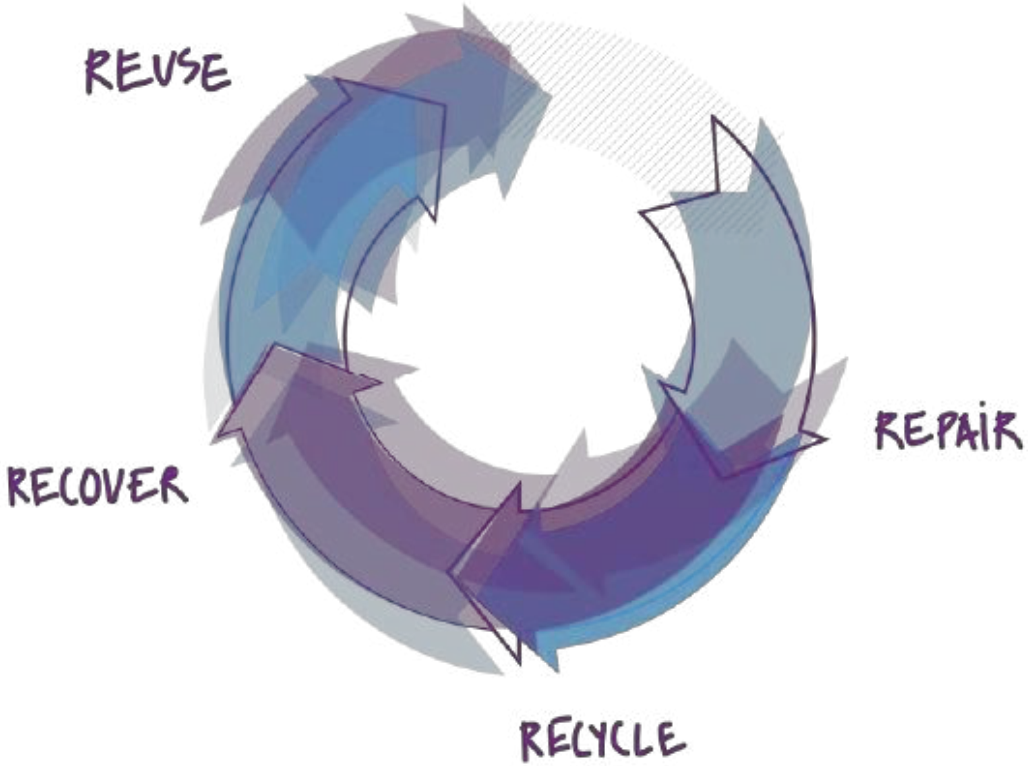
Credit: Azote for Stockholm Resilience Centre, Stockholm University.
Based on Richardson et al. 2023, Steffen et al. 2015, and Rockström et al. 2009

Groene chemie?

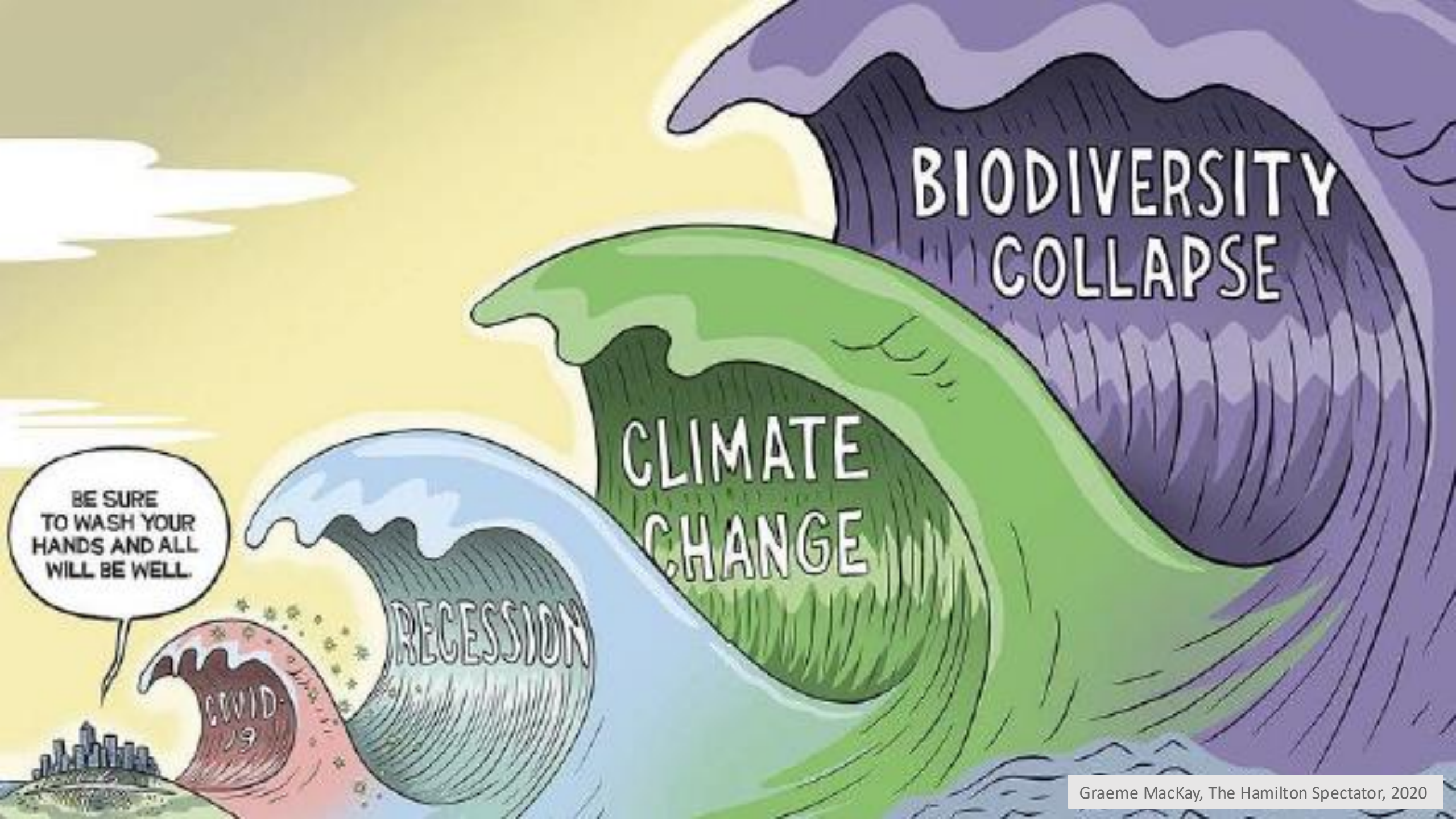
- LimnoTech, Aerial Associates

Lineair of circulair?





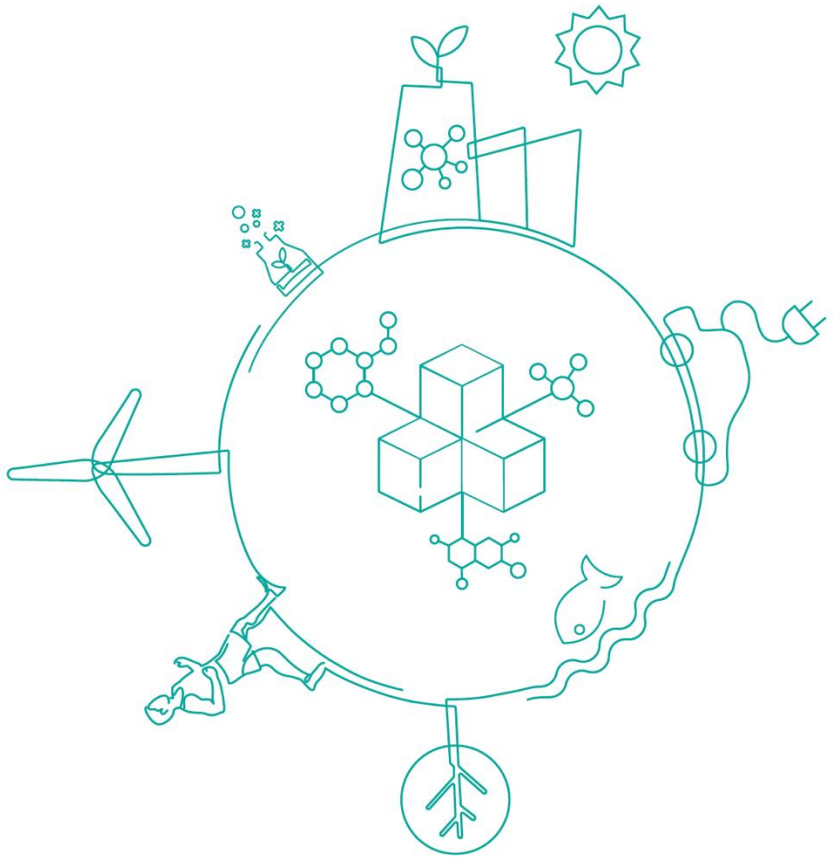
Chris Slootweg, UvA



Graeme MacKay, The Hamilton Spectator, 2020

3 transities

Energie	• Alternatief voor olie, gas en kolen
Materialen	• Alternatief voor beton/cement, staal, glas
Grondstoffen	• Alternatief voor opgraven – gebruiken - dumpen



CEFIC

Energie-Transitie

Oil and Gas IQ,
Energy industry review


Materiaal-Transitie
Area Iron and Steel
Stevenage Glass
Science ABC


Grondstoffen-Transitie
iStockphoto ID:1213299014

3 transities

Energie	• Alternatief voor olie, gas en kolen
Materialen	• Alternatief voor beton/cement, staal, glas
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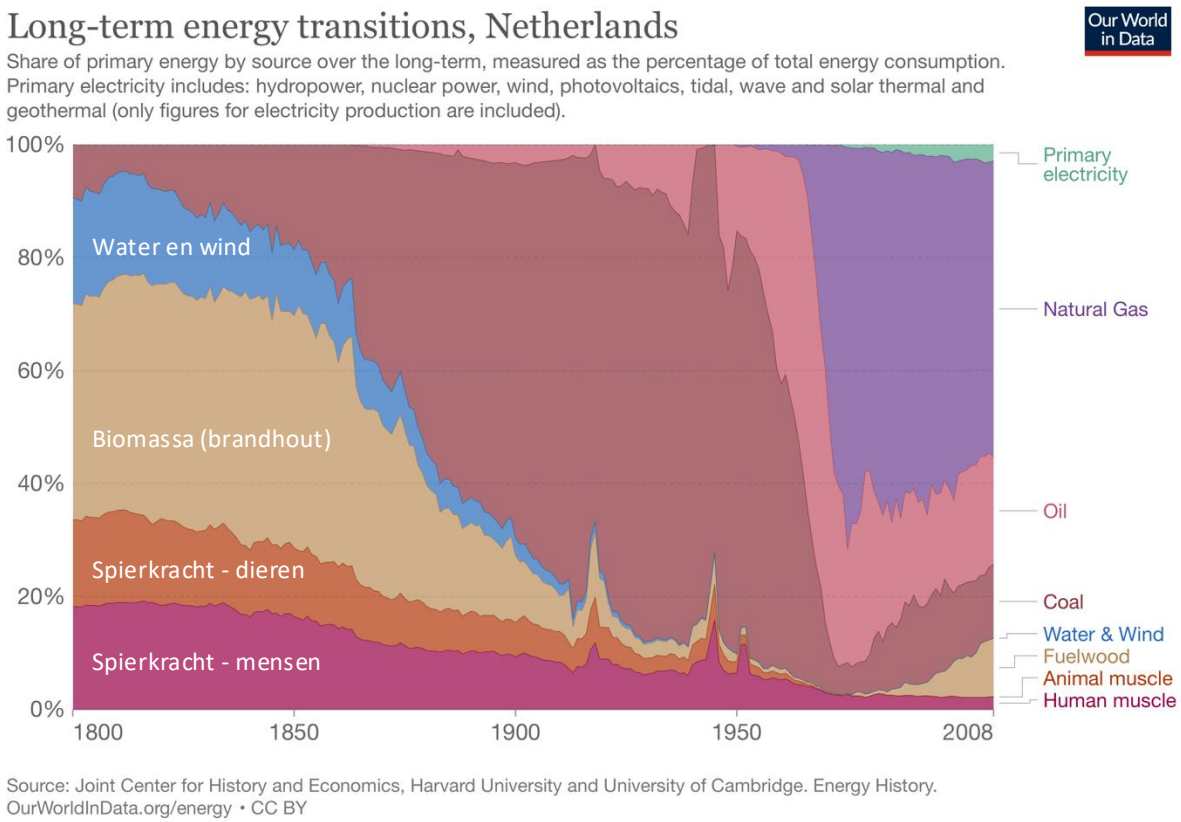
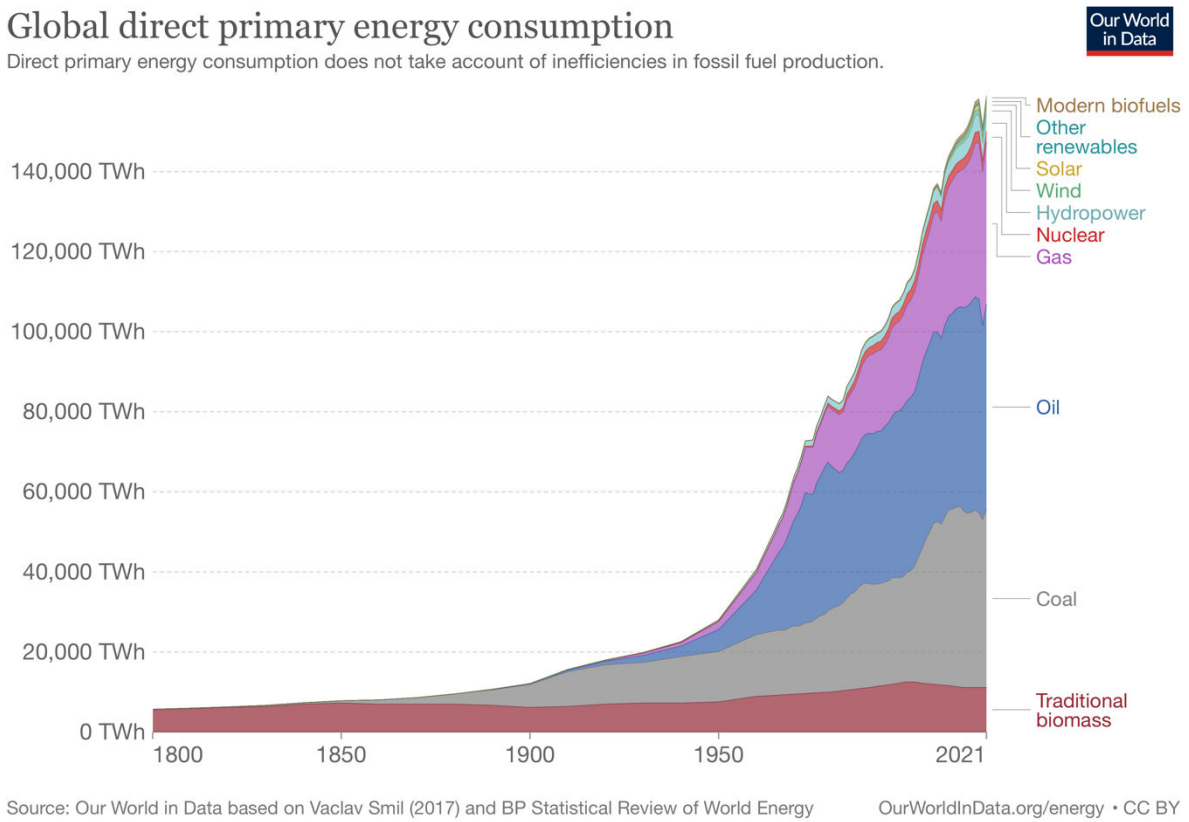
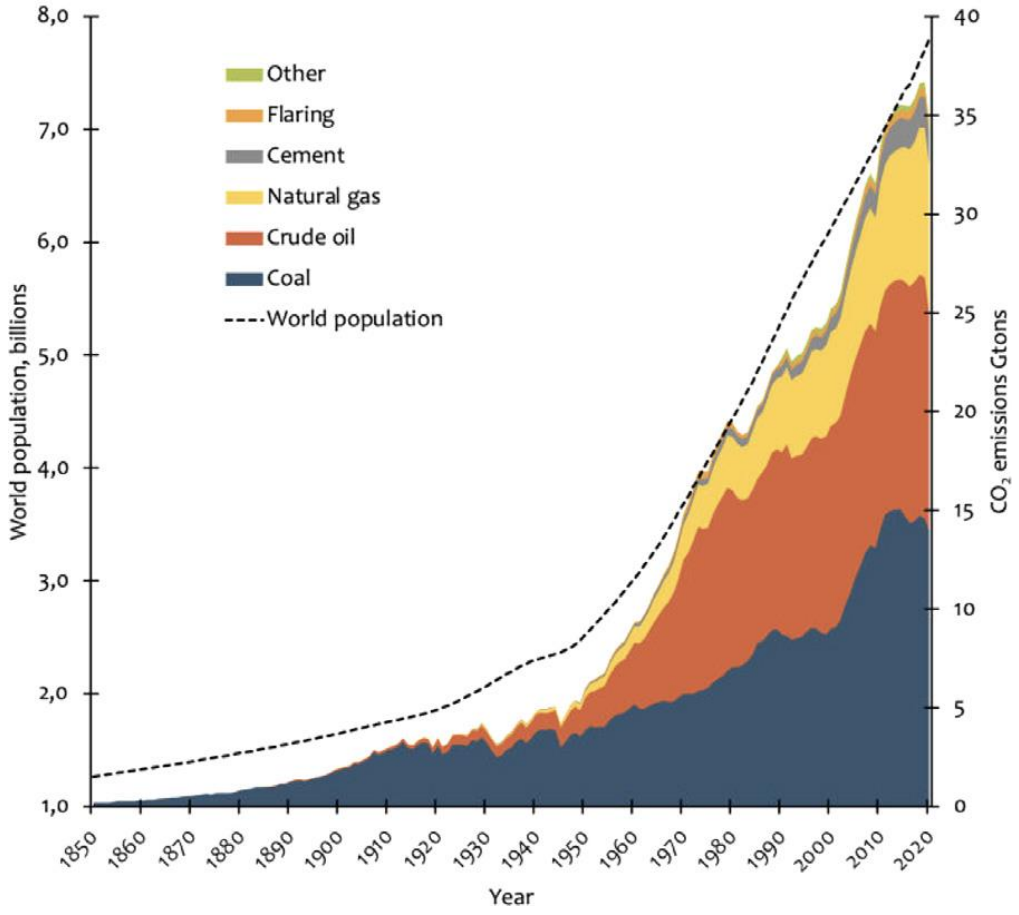
Circulaire economie

Primair Energieverbruik



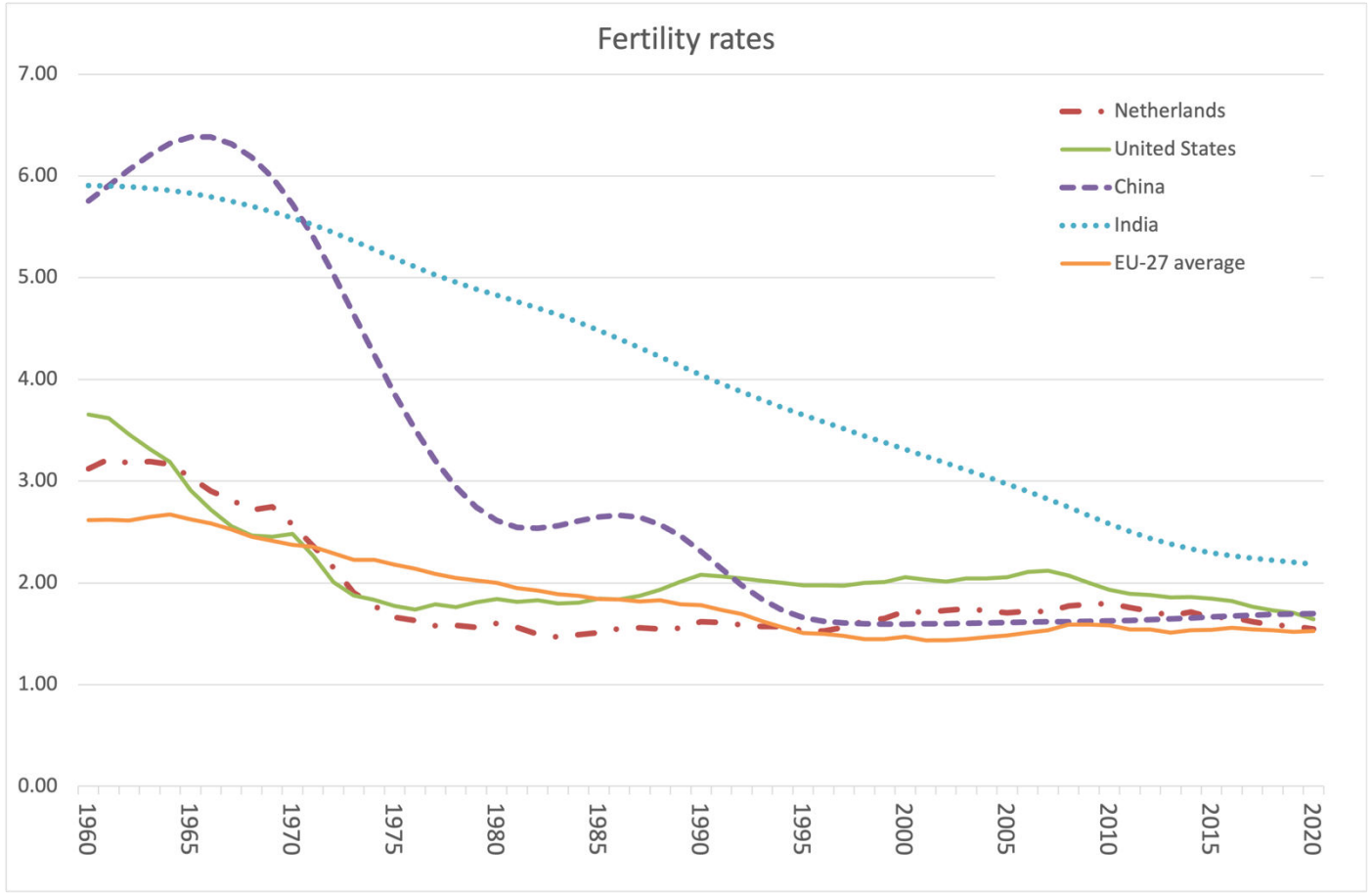


Wereldbevolking en Energieverbruik



The Guardian, OECD

Aanwas wereldbevolking



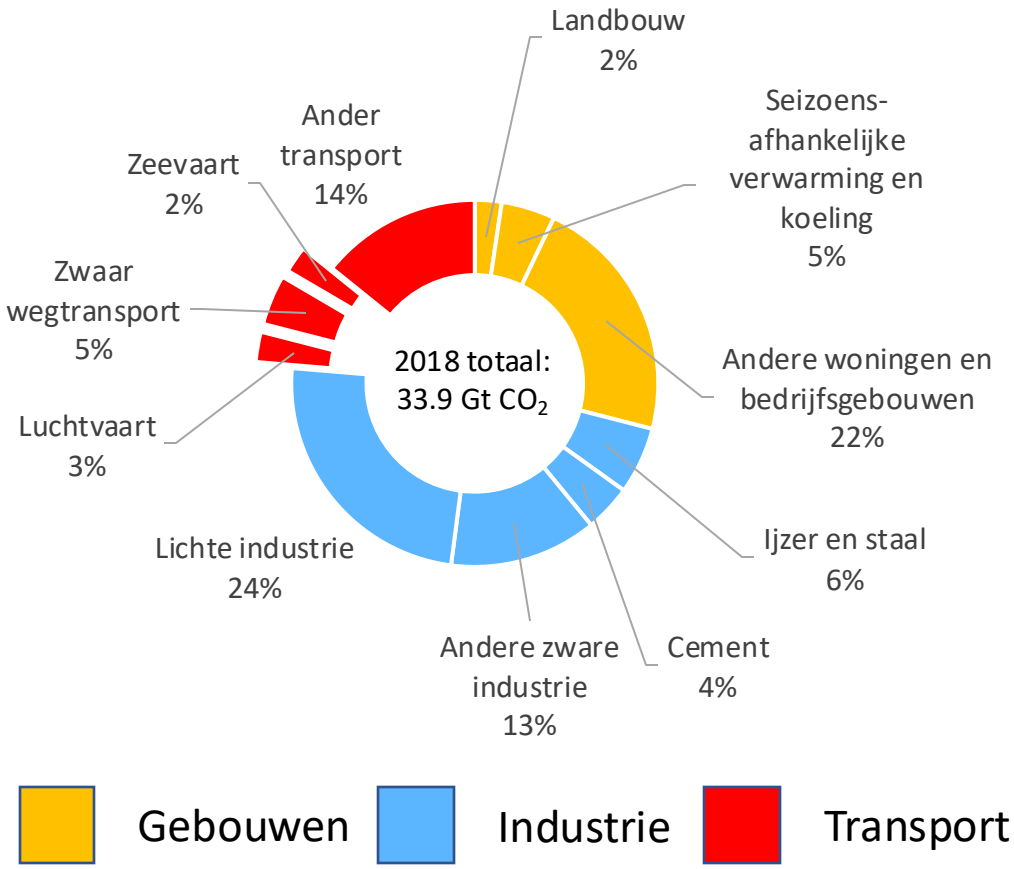
Data OECD

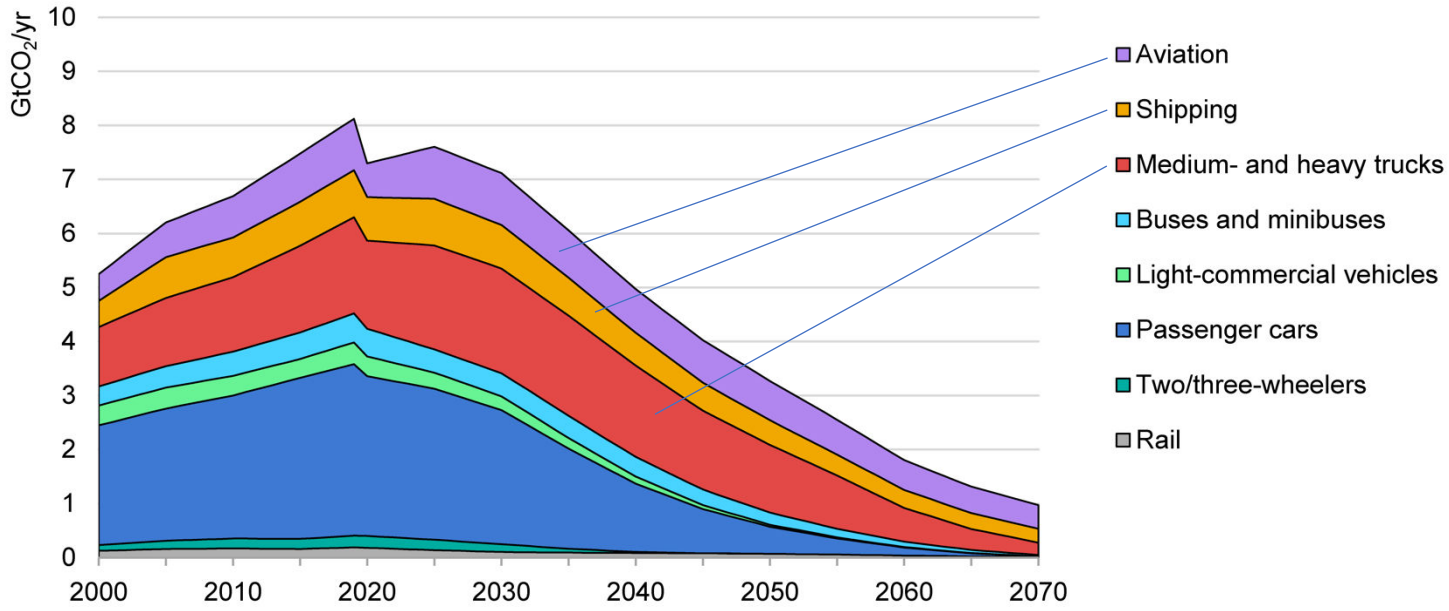
Energie en Materiaal transitie

2024

2050

Brandstoffen in 2050?

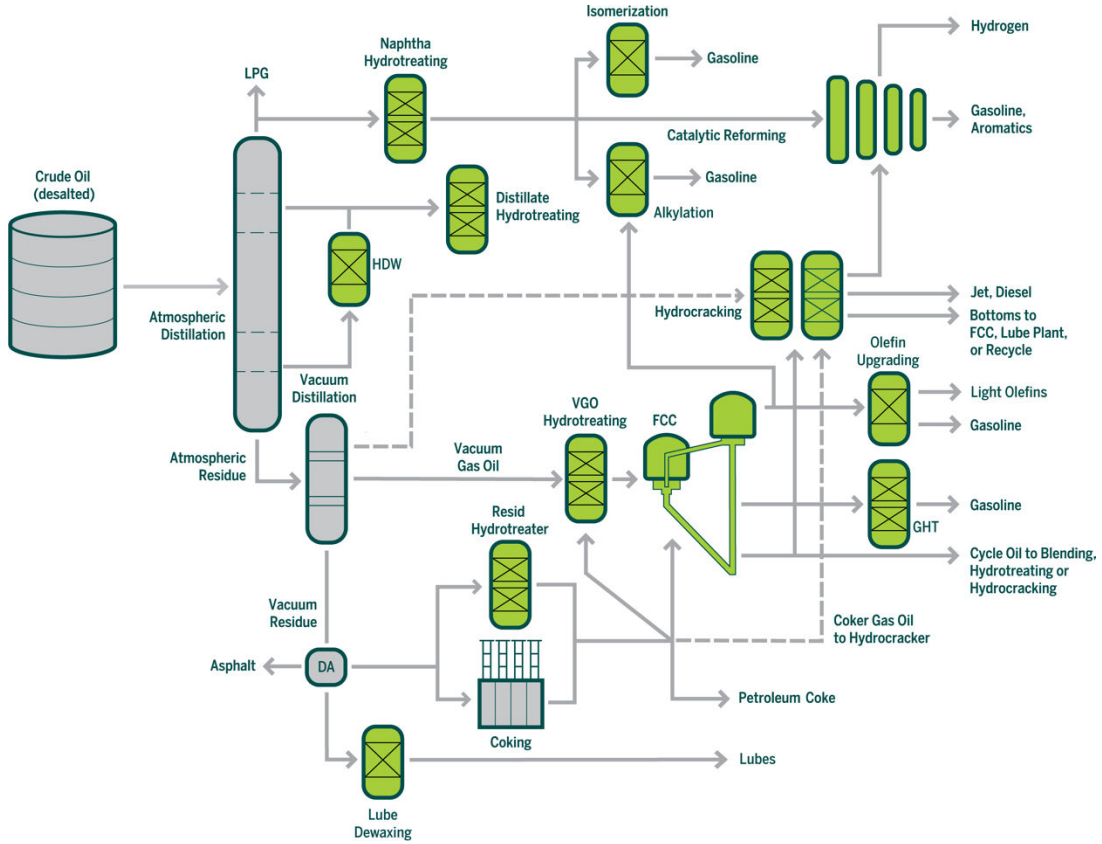


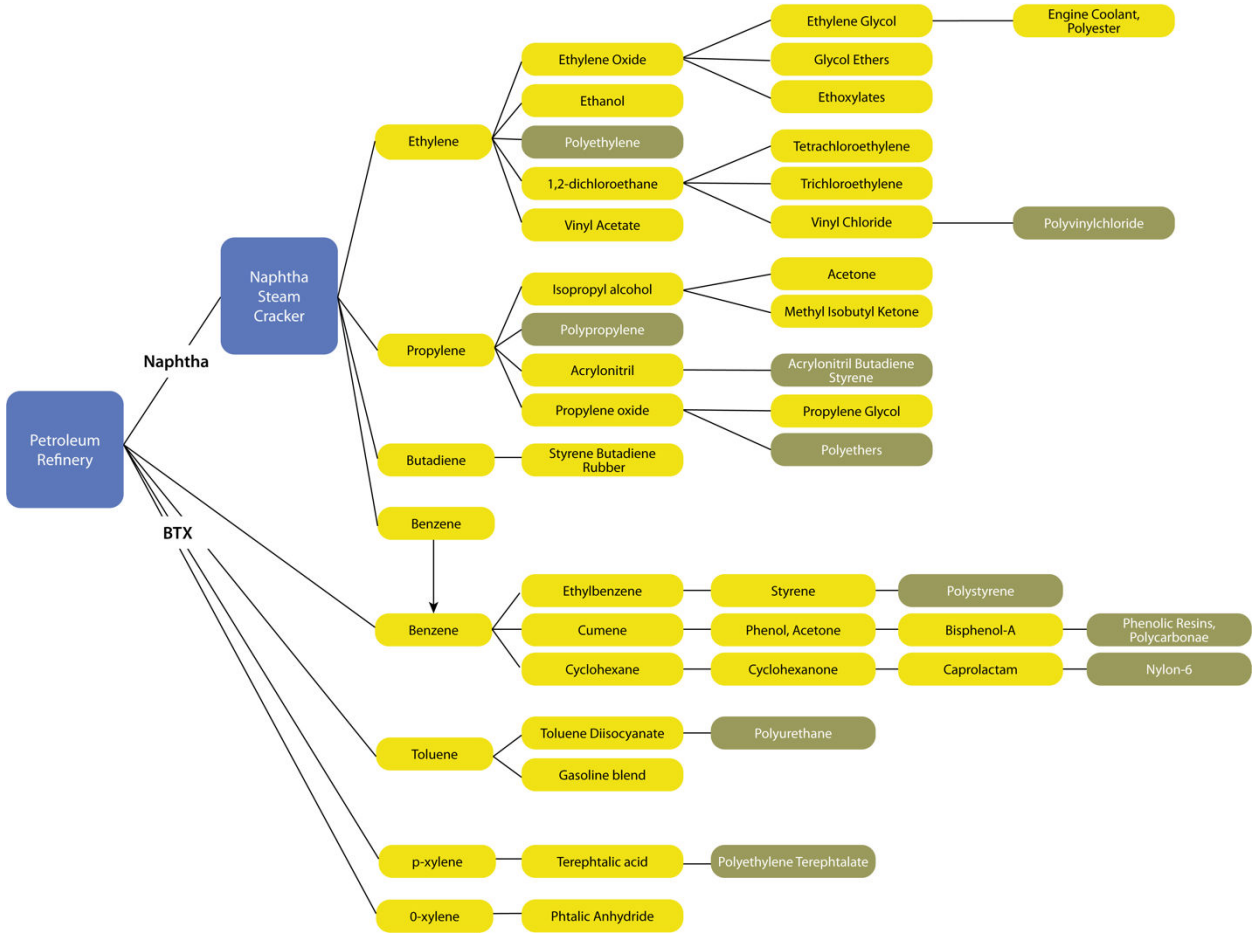


79% van bronnen is stationair
1/3 van transportbrandstoffen hebben echt nog even koolwaterstoffen nodig

Brandstof en chemie voor de toekomst

Raffinaderij en petrochemisch complex





Olieraffinaderij: Schaal en Impact van Petrochemie (NL)

Capaciteit : 404,000 vaten olie per dag
Oppervlakte: 5 km^2
(FCC unit Shell, Pernis)

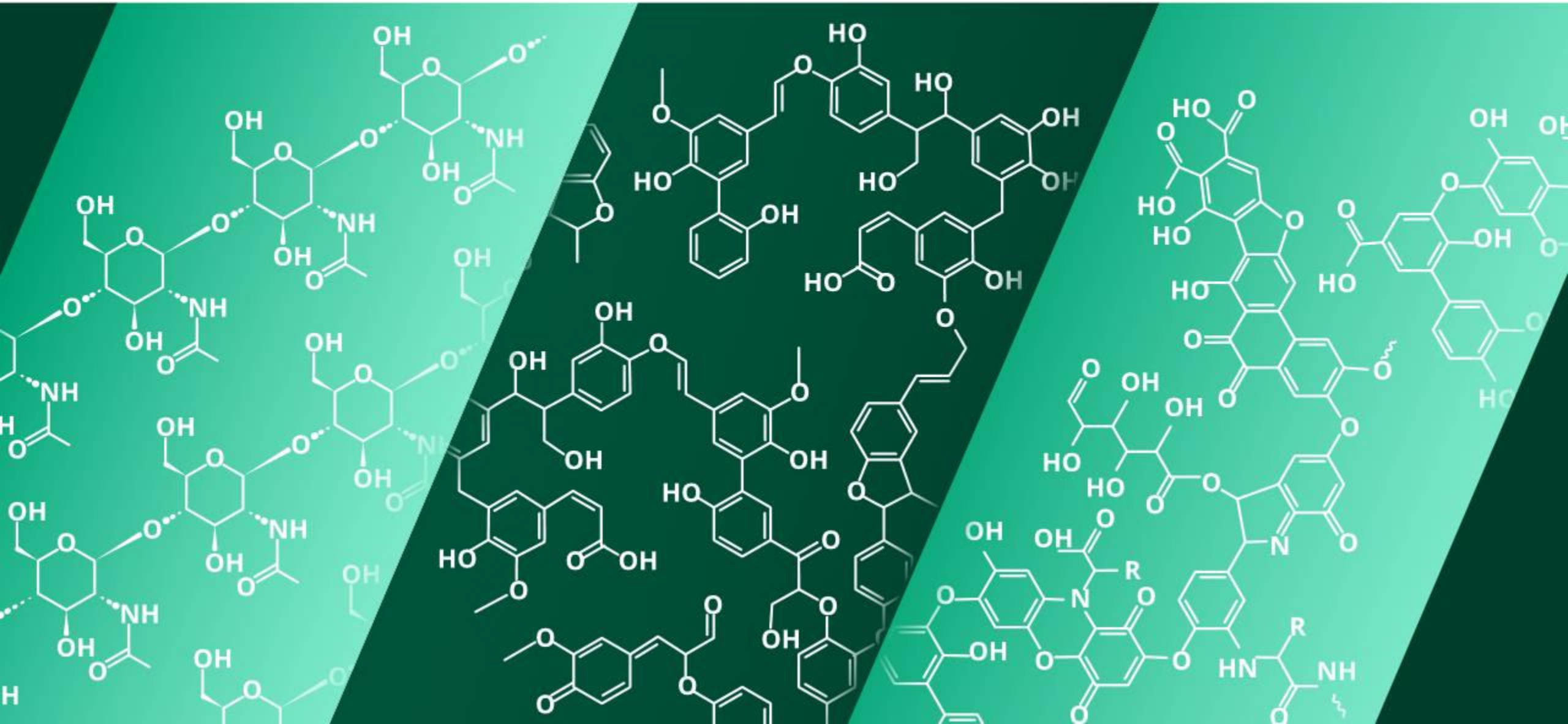

~ 600 Olieraffinaderijen, Capaciteit ~ 100 Miljoen bpd

Waar halen we de koolstof vandaan ?

Chitine

Lignine

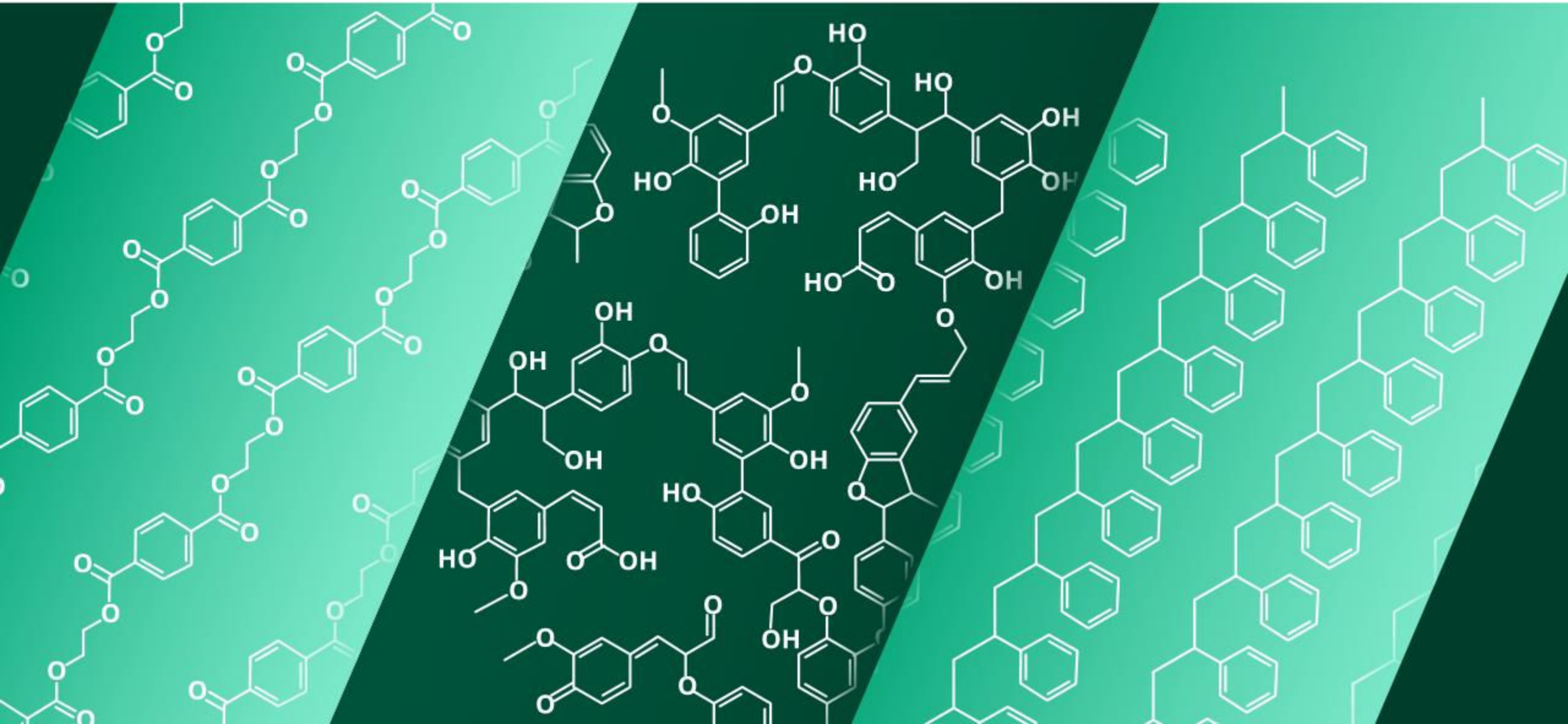
Humus



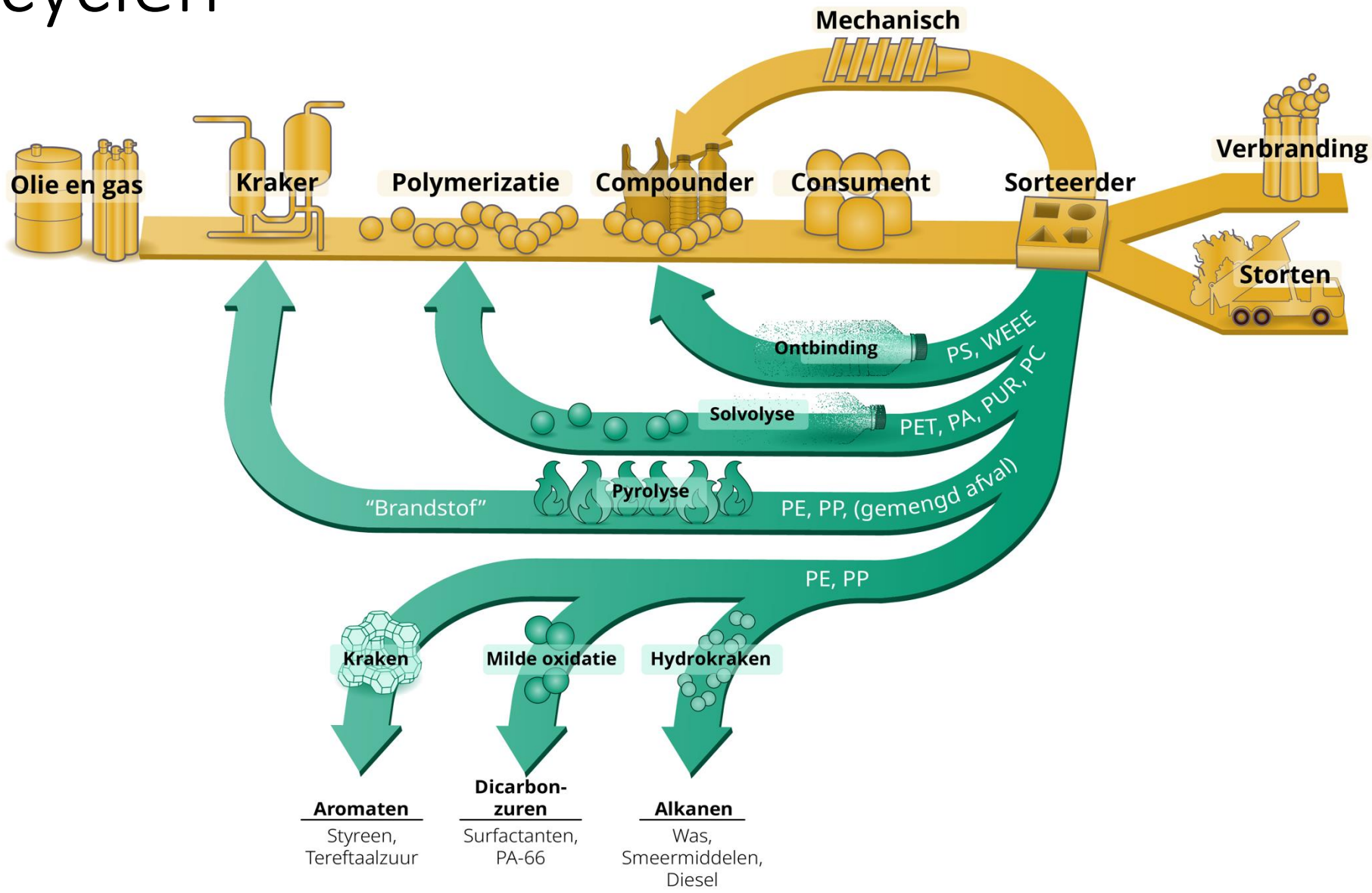
PET

Lignine

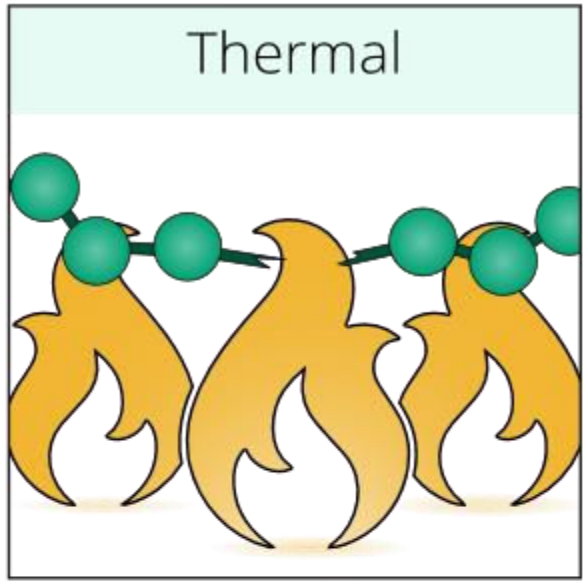
PolyStyreen

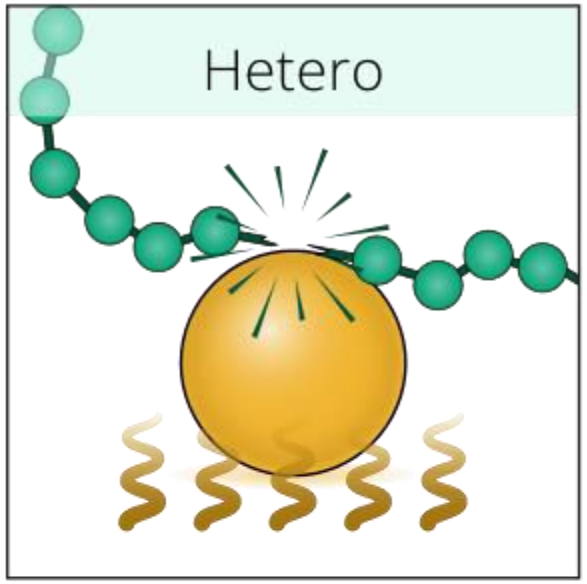


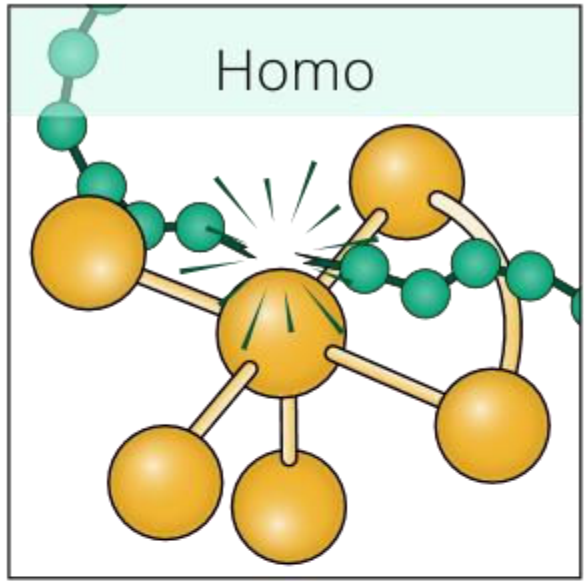
Plastic Recyclen

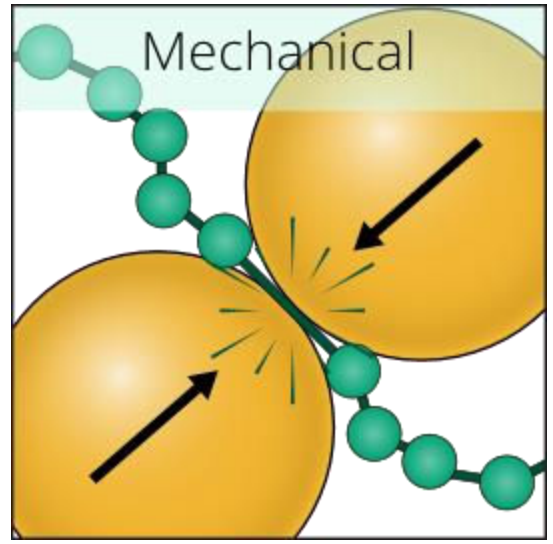


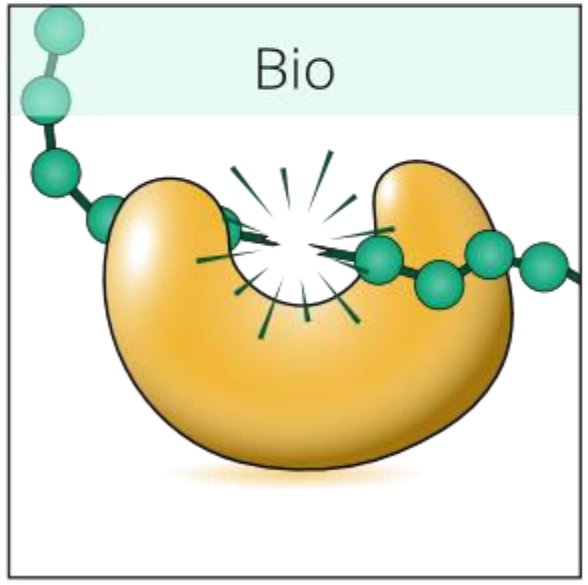
Conversie-technologiën

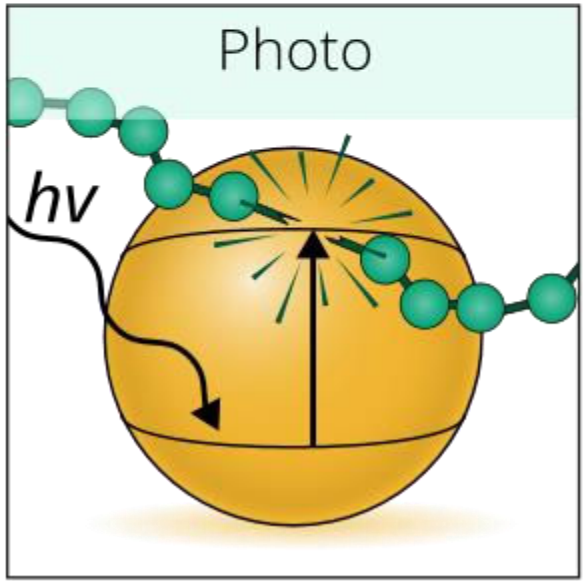


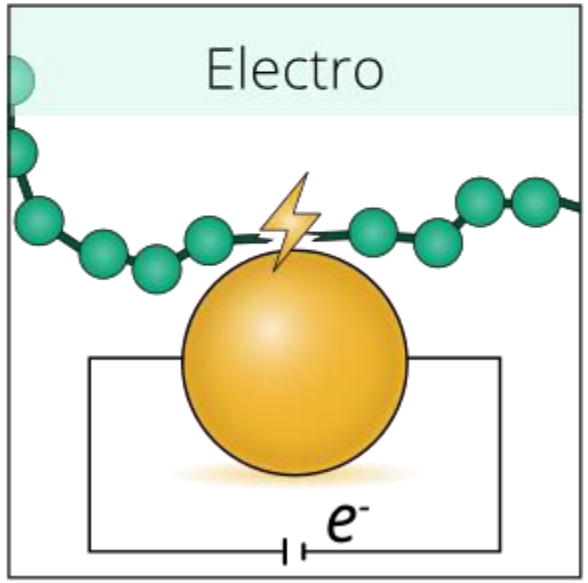


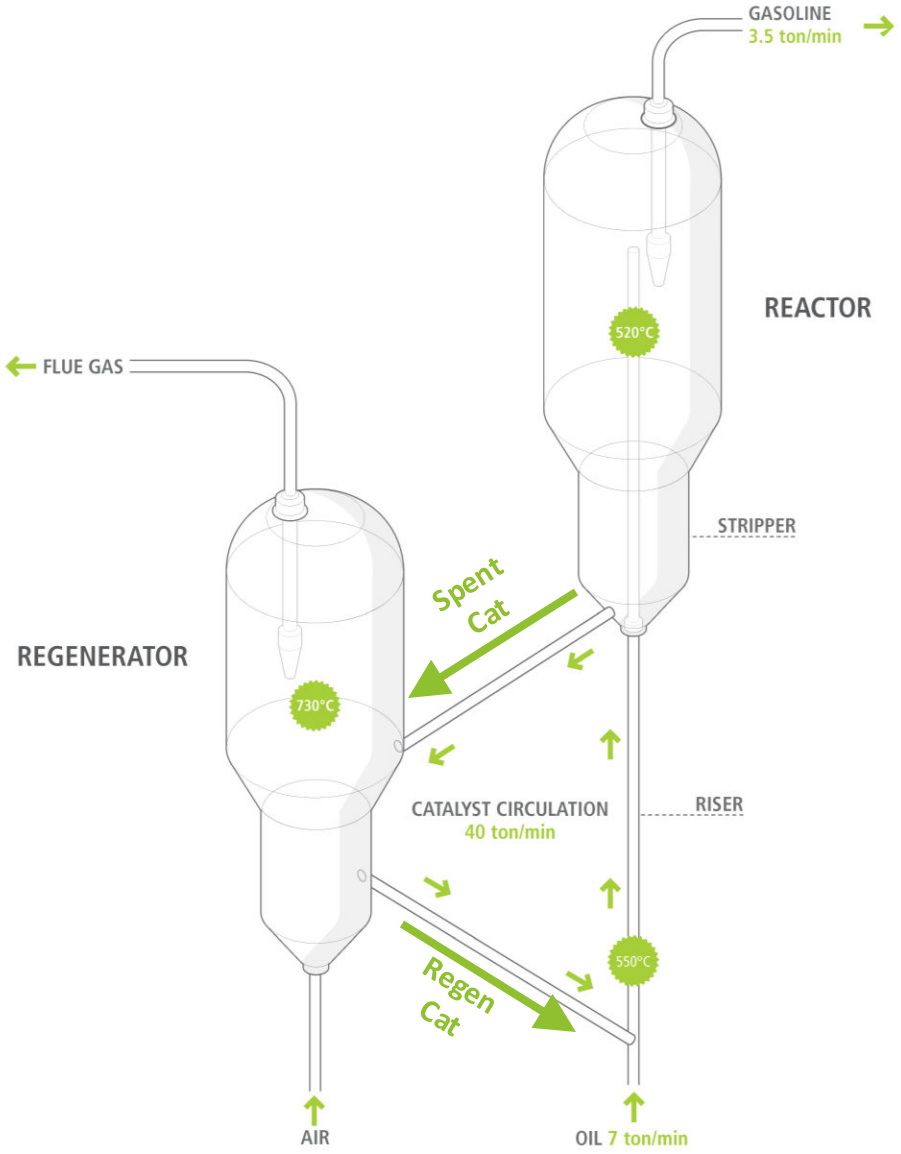











GASOLINE
3.5 ton/min
REACTOR
520°C
FLUE GAS
STRIPPER
Spent
Cat
REGENERATOR
730°C
CATALYST CIRCULATION
40 ton/min
RISER
550°C
Regen
Cat
AIR
OIL 7 ton/min

Raffinaderij van de toekomst: Niemand weet het precies

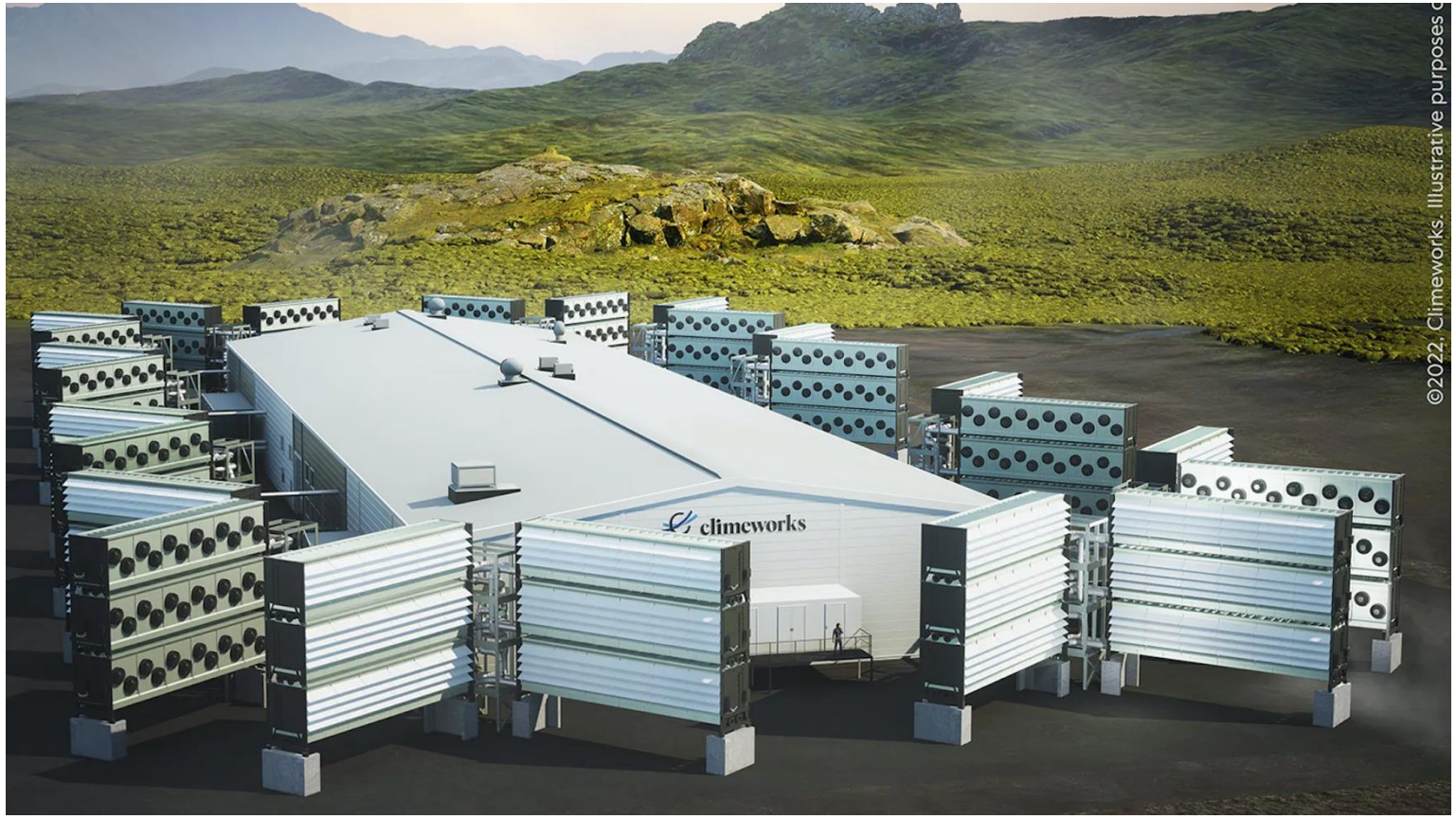
Grootte-orde berekeningen

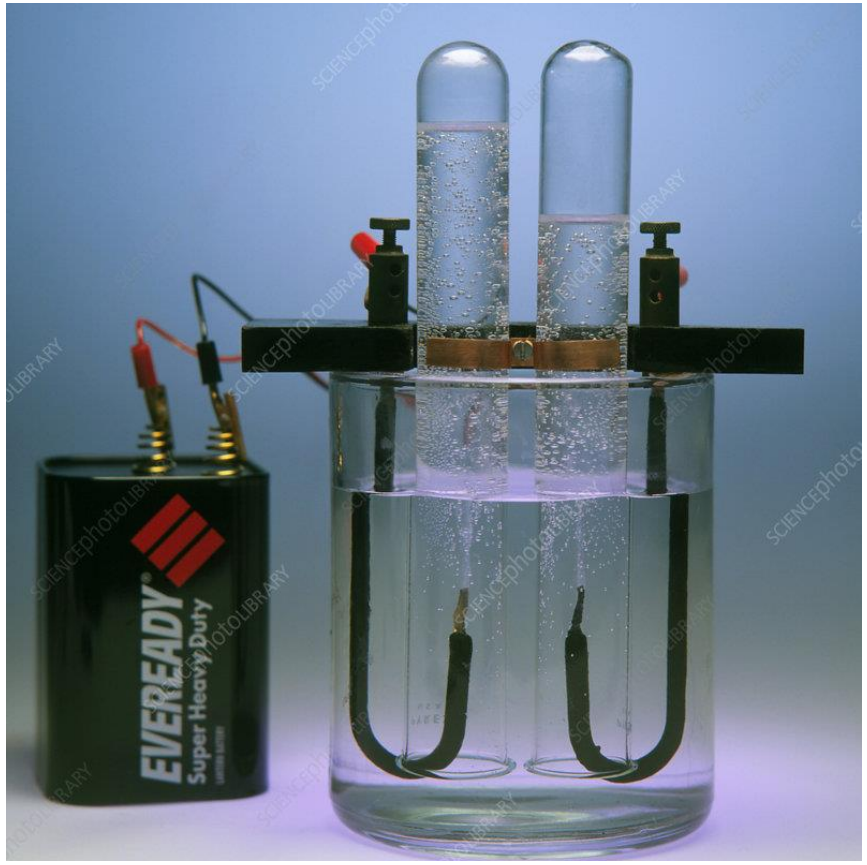
~ 80.000 vaten per dag - equivalent

Produceert:
5,6 kton/dag diesel en kero
2,8 kton/dag chemicaliën
2,8 kton/dag plastic

Vogt, Weckhuysen, Nature, 2024, 629, 295-306

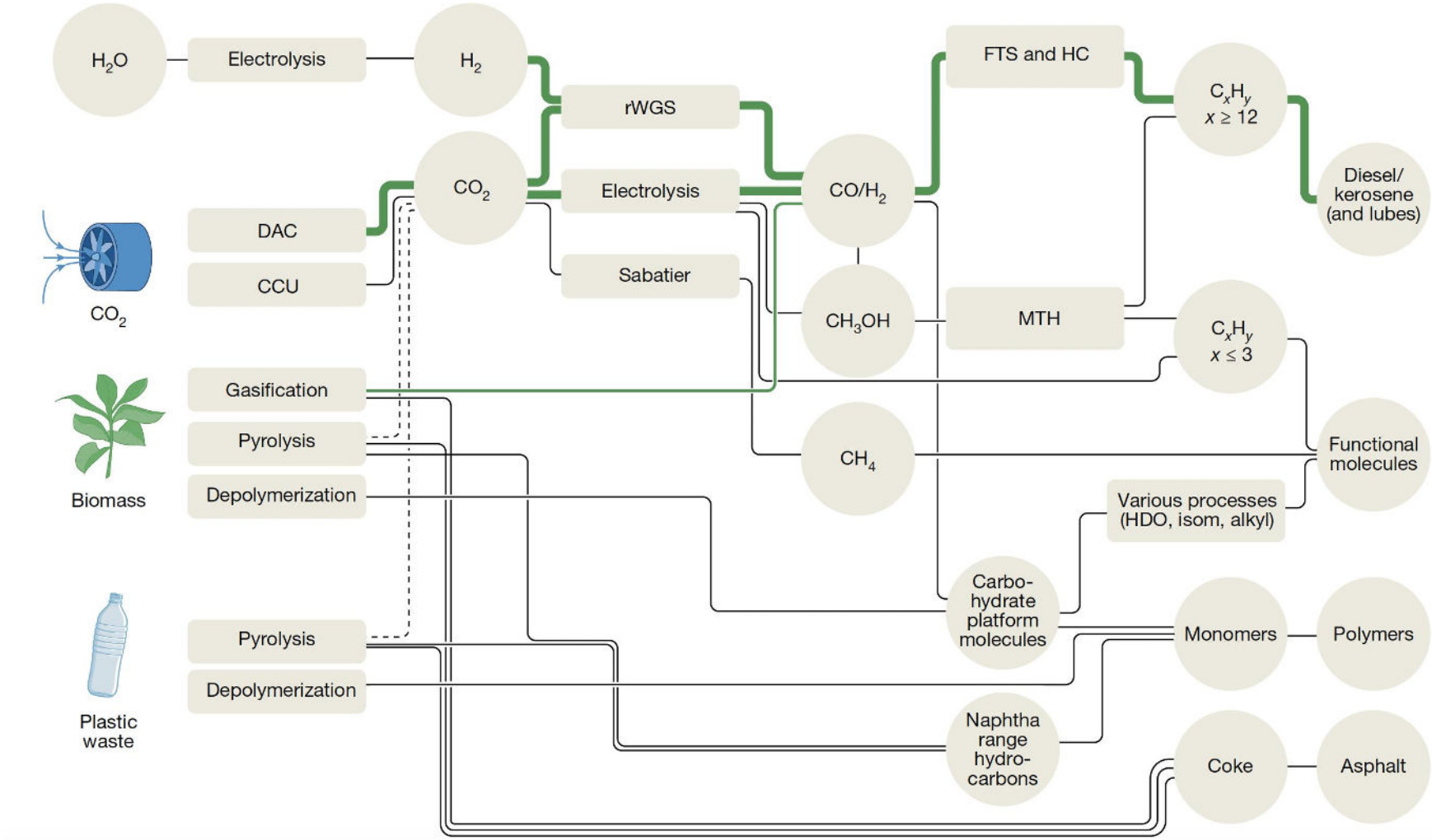
Carbon Capture and Use (CCU)

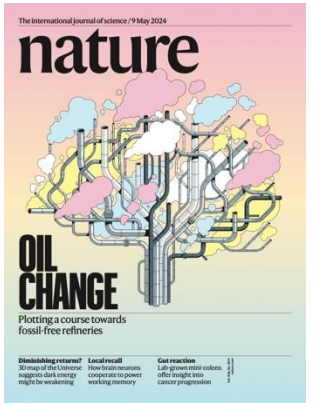




Climeworks

Het grote plaatje





E.T.C. Vogt, B.M. Weckhuysen, Nature, 2024, **629**, 295-306

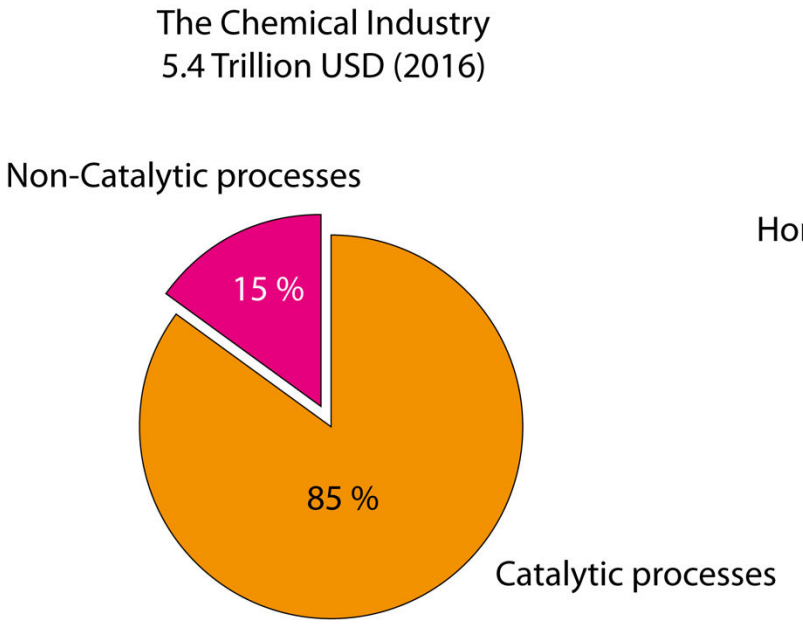
Katalysator – definitie

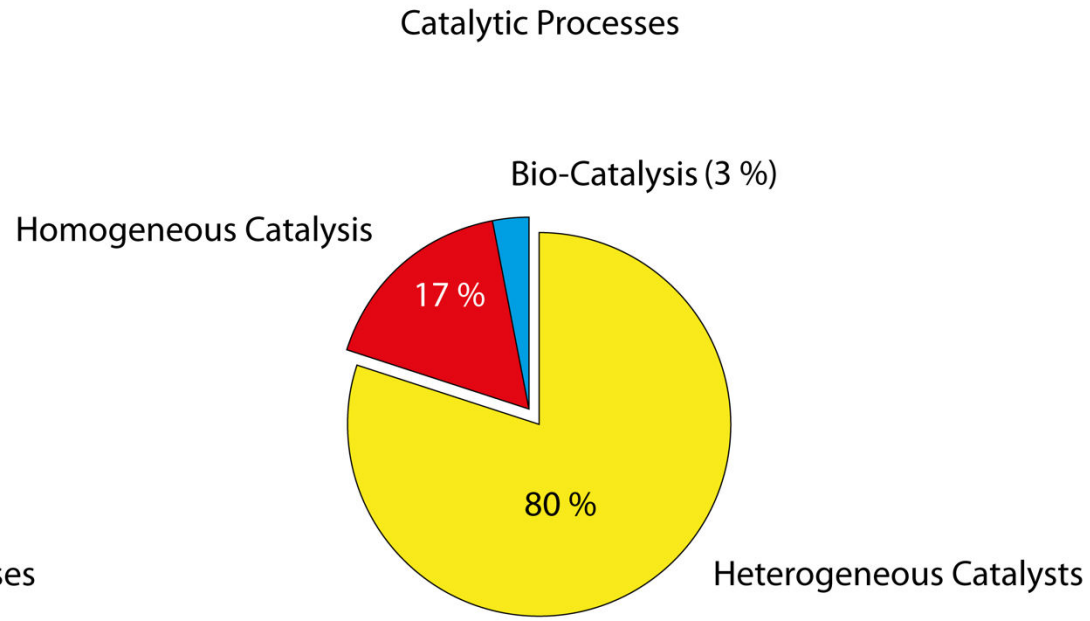
- Een katalysator is een hulpstof die het verloop van een chemische reactie beïnvloedt en daarna weer in de uitgangstoestand terugkeert, dus zonder daar zelf bij verbruikt te worden
  - Dus niet stoechiometrisch mee-reageren
  - Maar ook niet het evenwicht veranderen
  - Alleen een snellere/alternatieve weg vinden om één of meerdere gewenste reactiepaden te bevoordelen

  - En over dat verbruik: er wordt jaarlijks minimaal 900.000 ton katalysator gebruikt

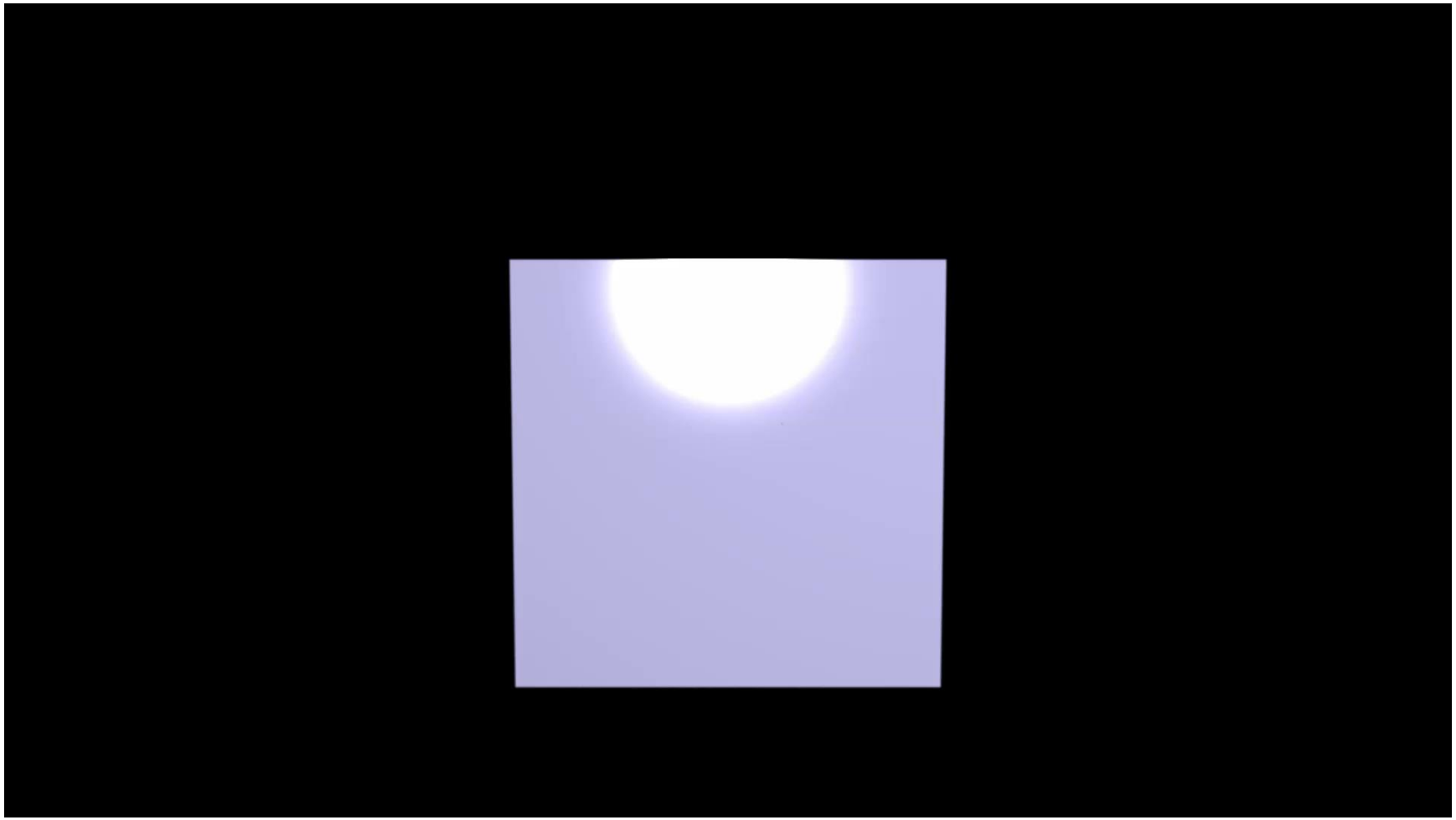
Katalyse: Wat kun je daar mee?

De rol van katalyse

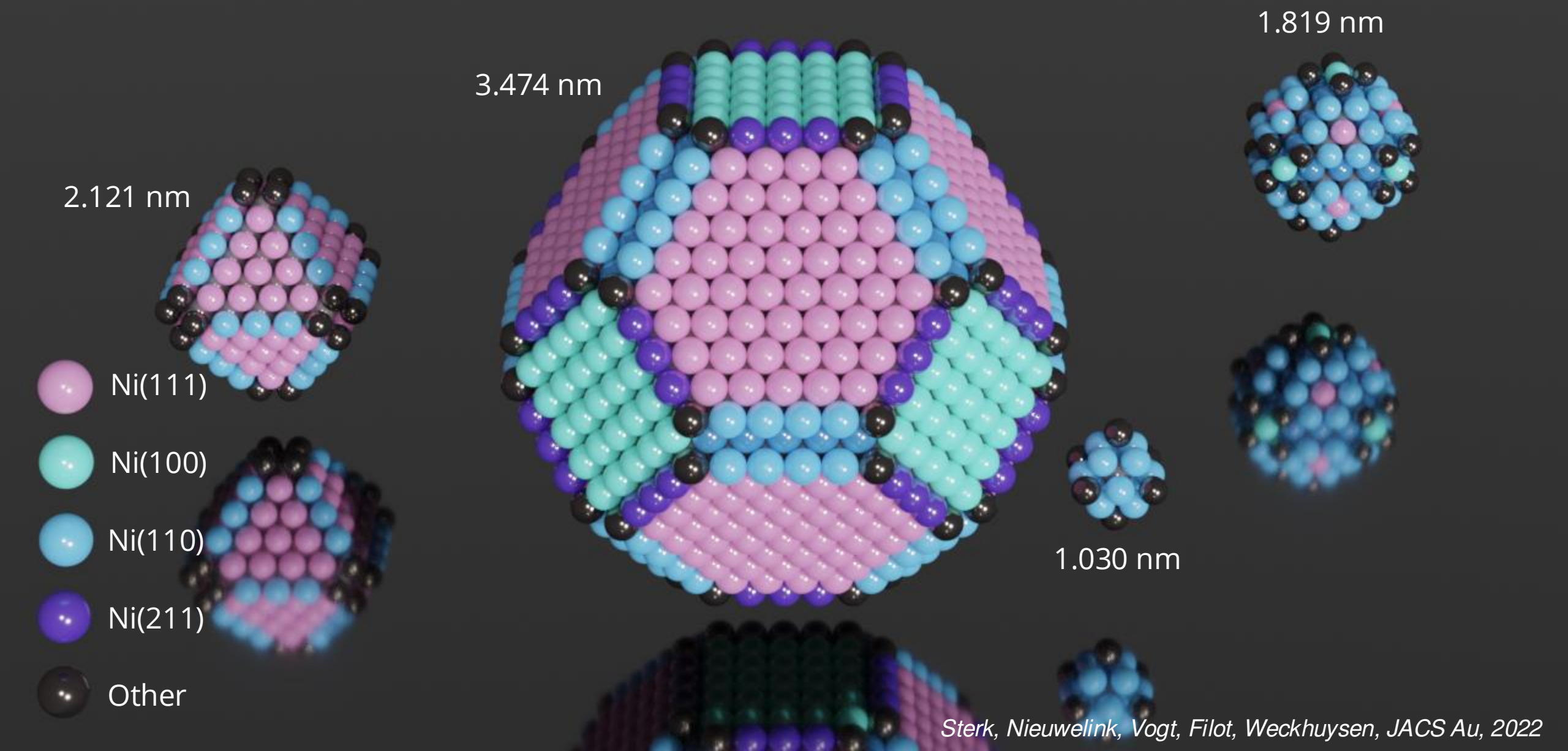




Steeds kleiner



Structuur-Afhankelijkheid: Micro-Kinetische Simulaties

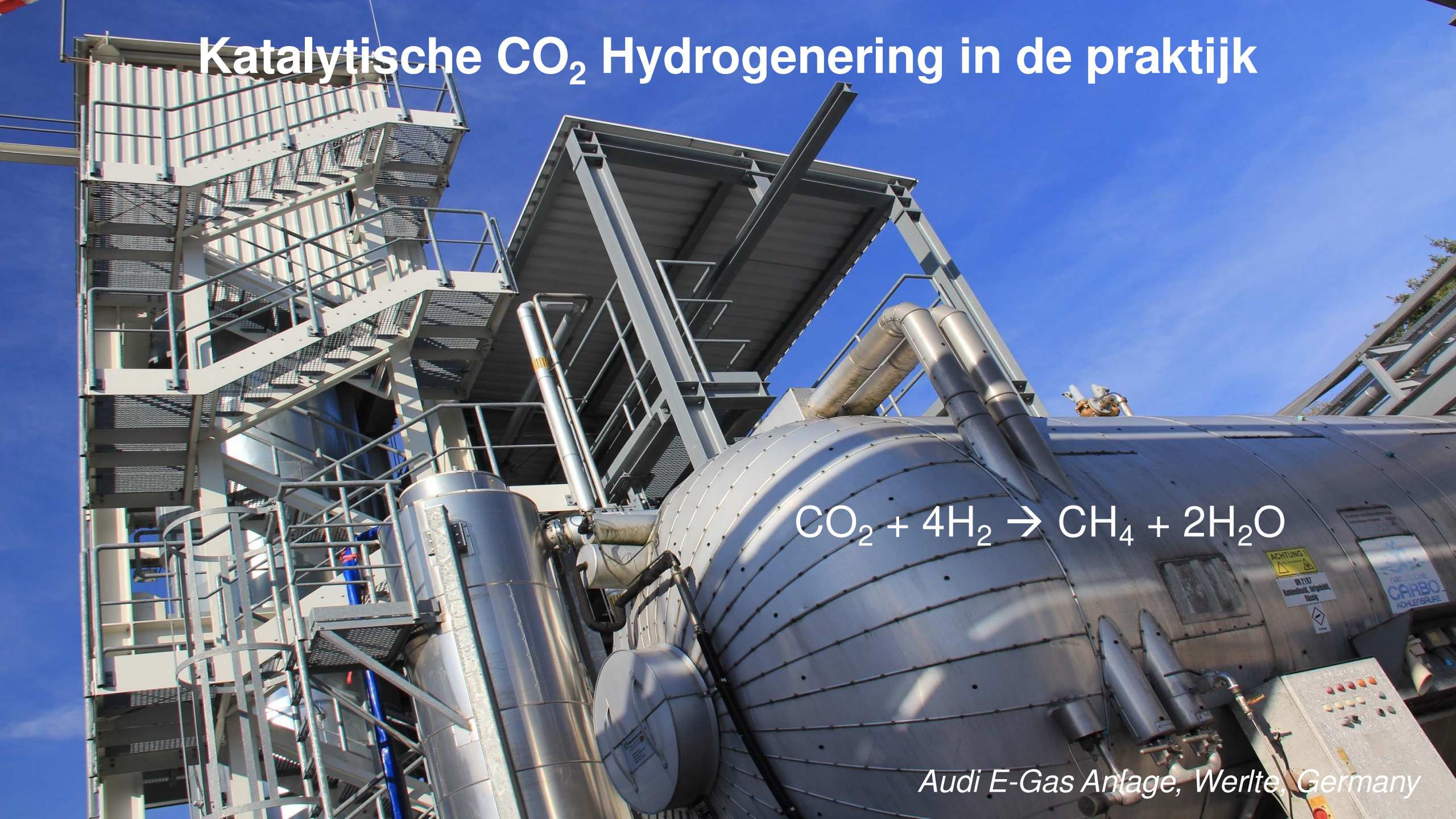


Sterk, Nieuwelink, Vogt, Filot, Weckhuysen, JACS Au, 2022

Even naar moleculen kijken?

Sterk, Nieuwelink, Vogt, Filot, Weckhuysen, JACS Au, 2022

Katalytische CO_2 Hydrogenering in de praktijk



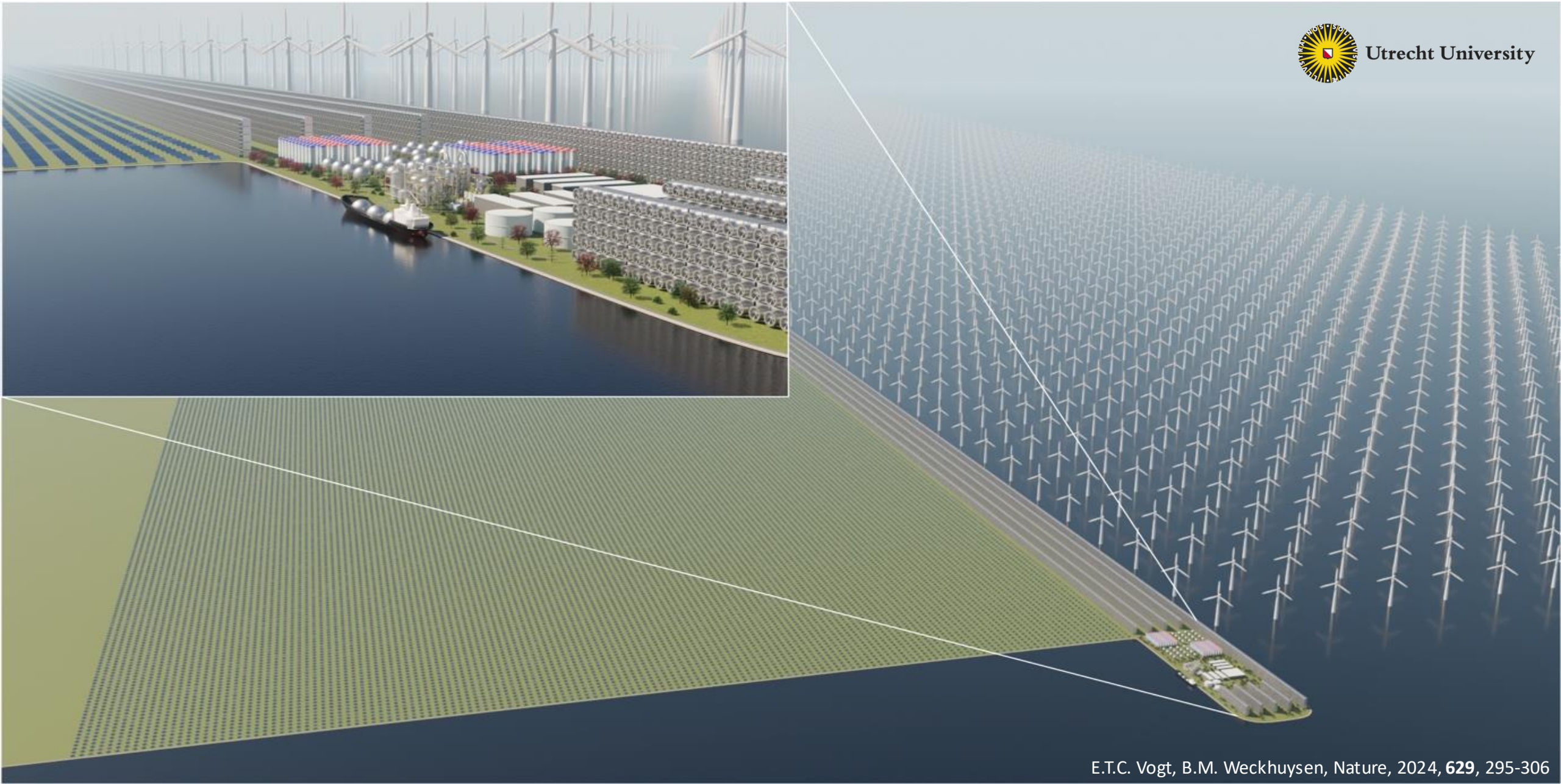
$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$$

Audi E-Gas Anlage, Werlte, Germany

Raffinaderij van de toekomst

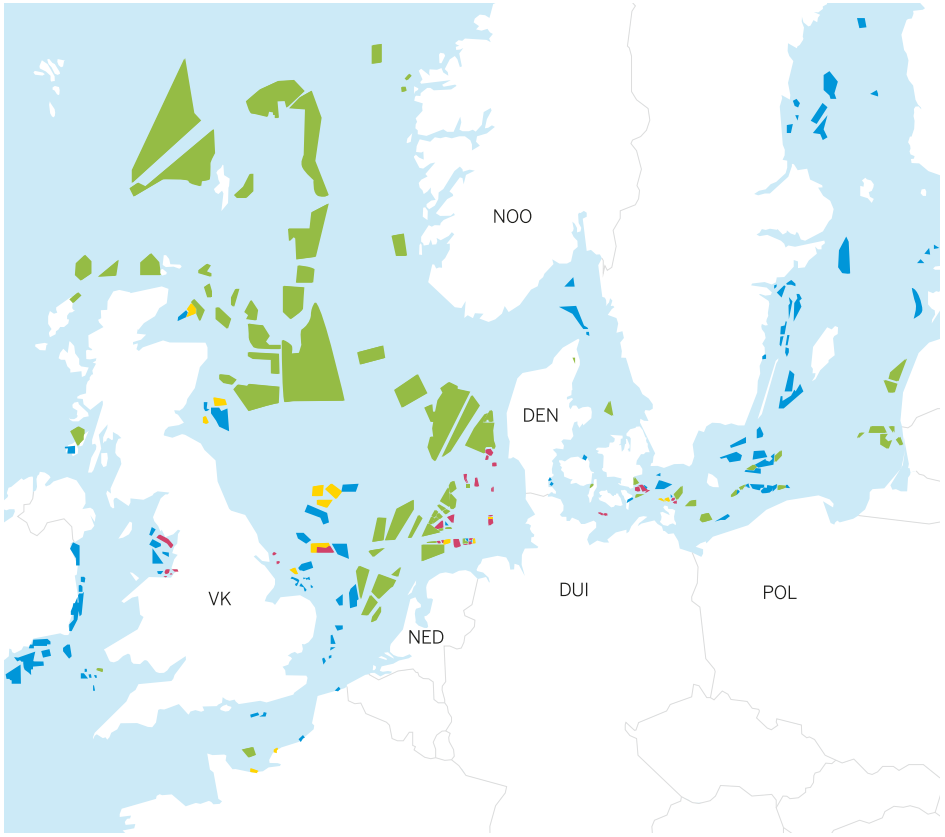
Utrecht University

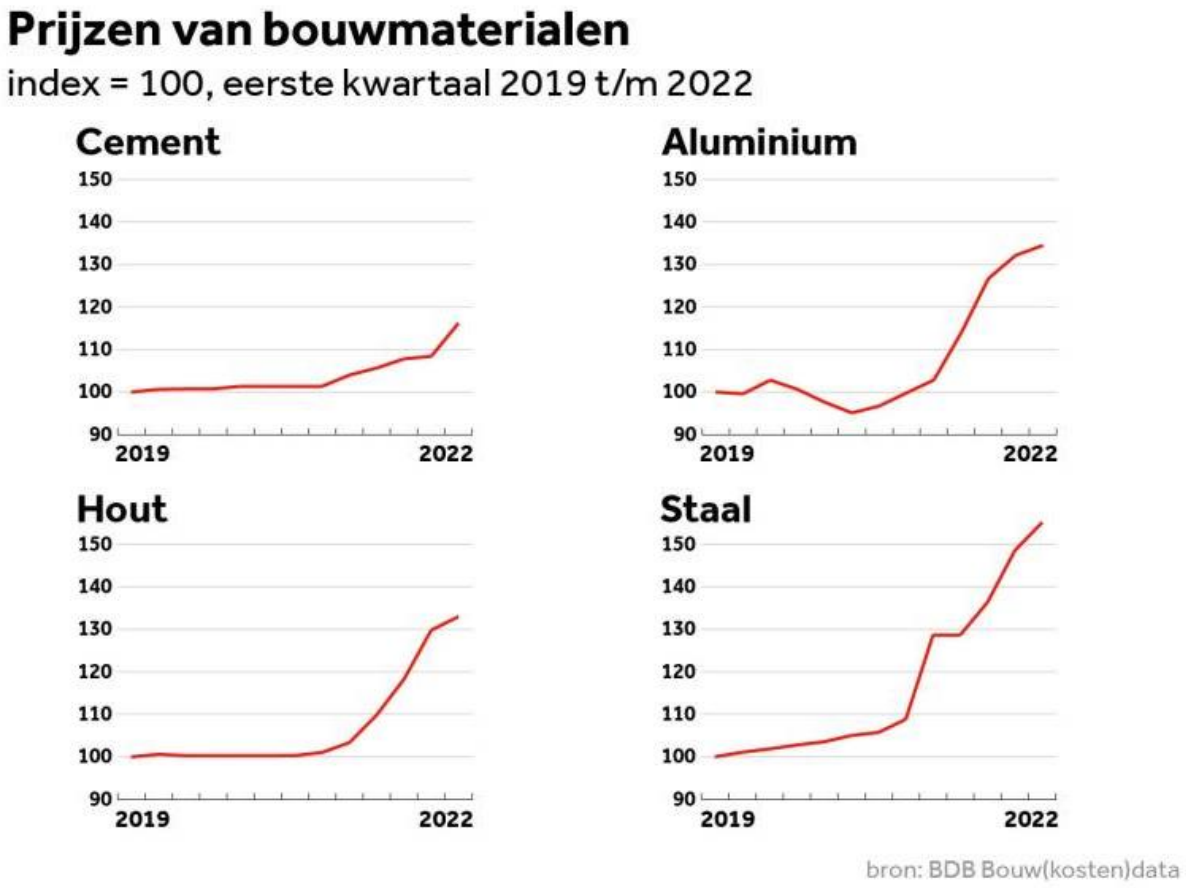
De raffinaderij van de toekomst: Impact



E.T.C. Vogt, B.M. Weckhuysen, Nature, 2024, **629**, 295-306

Infrastructuur





Bronnen: Volkskrant 11-01-2022
NOS.nl 26-03-2022

NEE!
HIER
GEEN
WINDPARK !!

Wet van behoud van ellende?

Vidal, Goffé, Arndt, Metals for a Low-Carbon Society, Nature Geoscience 2013, 6, 894

3 transities

Energie	• Alternatief voor olie, gas en kolen
Materialen	• Alternatief voor beton/cement, staal, glas
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Gaat dat lukken?

SCIENCE

SCALE

SOCIETY

Instituut voor duurzame en circulaire chemie ISCC

- Sterke fundering in chemie
  - Katalyse
  - Synthese
  - Analytische Chemie
  - Milieuchemie
- Over de grenzen van de discpline
- Maar steeds met chemie als basis
  - Systeemdenken
  - Weg van fossiele grondstoffen
  - Schone en efficiente processen
  - “Safe by design”

- Verplichte vakken
  - Chemie van de toekomst
  - Data science voor chemici
  - Basis van duurzaamheid
- Keuzevakken
  - Advanced Catalysis
  - Advanced Spectroscopy
  - Advanced Organic Synthesis
  - Advanced Molecular Characterization
  - Advanced Electrochemistry
  - Organometallic Chemistry and Homogeneous Catalysis
  - Synthesis of Catalysts & Energy Materials
  - Circular Polymers
  - Environmental Science and Safe-by-Design
  - Emerging Topics in Catalysis

Utrecht University

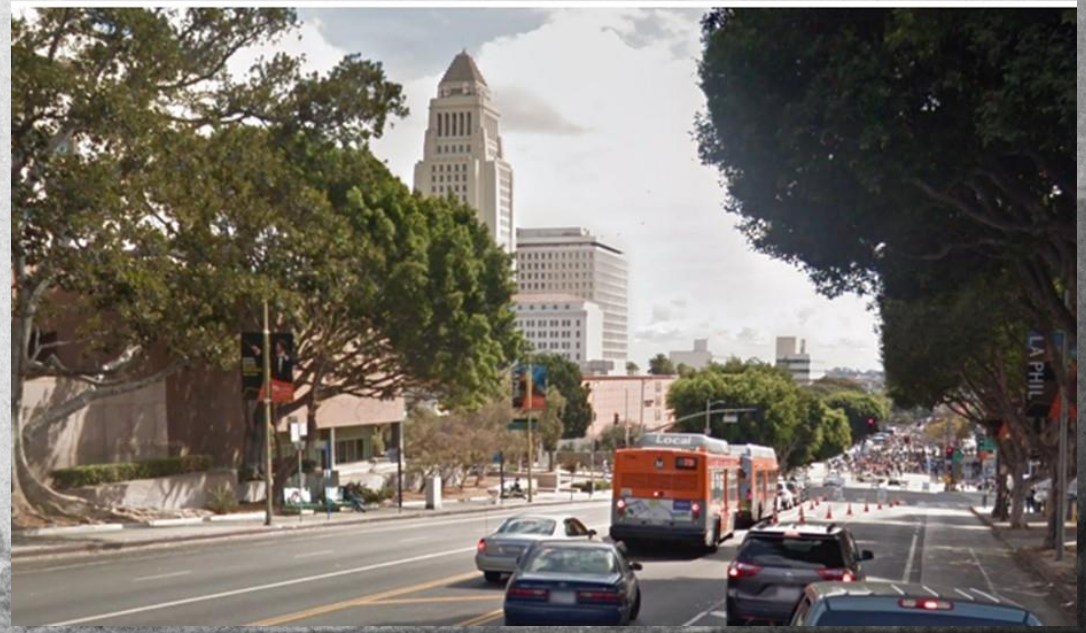
Institute for Sustainable & Circular Chemistry

Gaat dat lukken?

SCIENCE

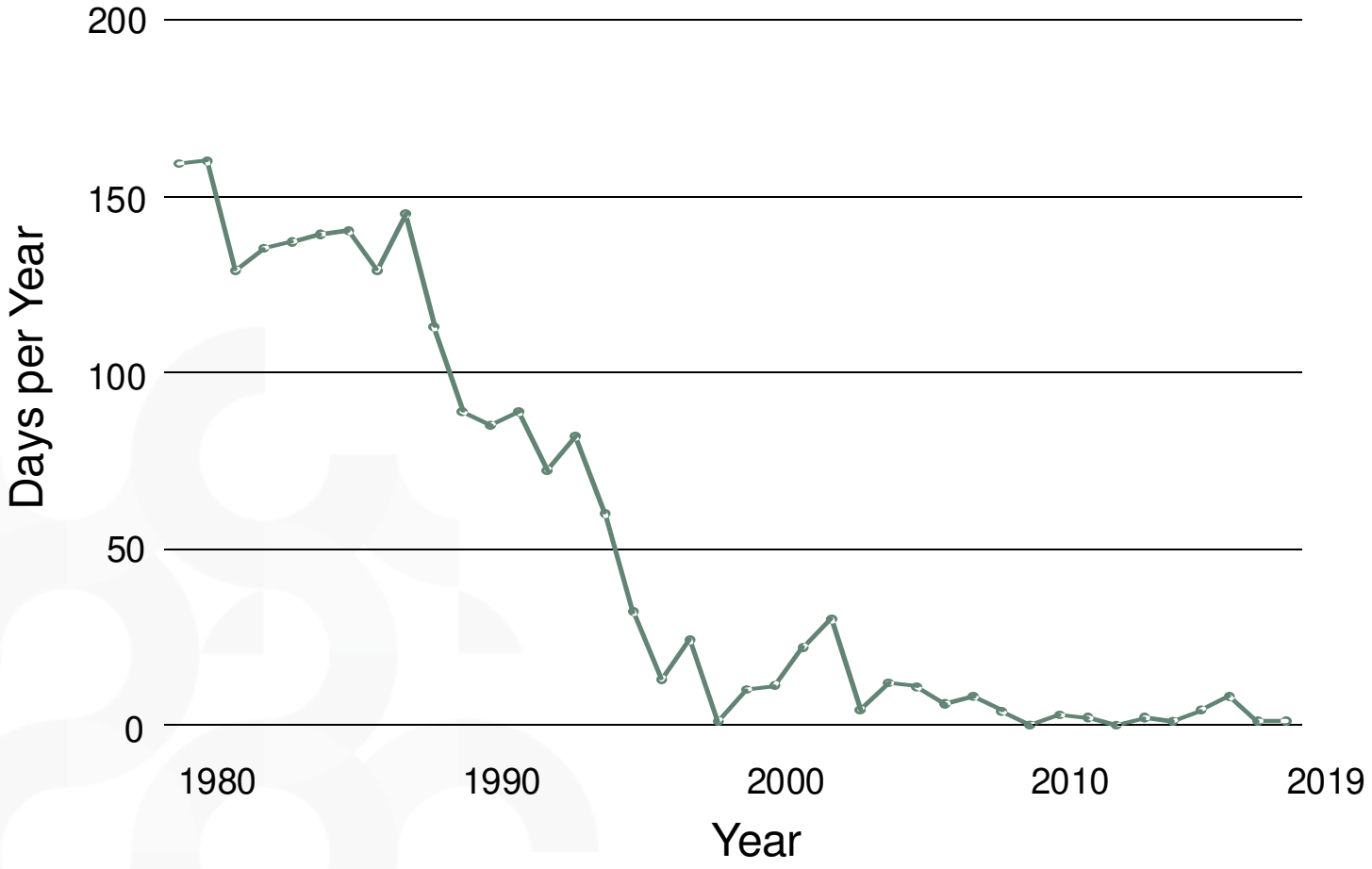
SCALE

SOCIETY



Water and power associates (waterandpower.org) and Smithsonian

“VERY UNHEALTHY OR HAZARDOUS AIR” DAYS IN LOS ANGELES

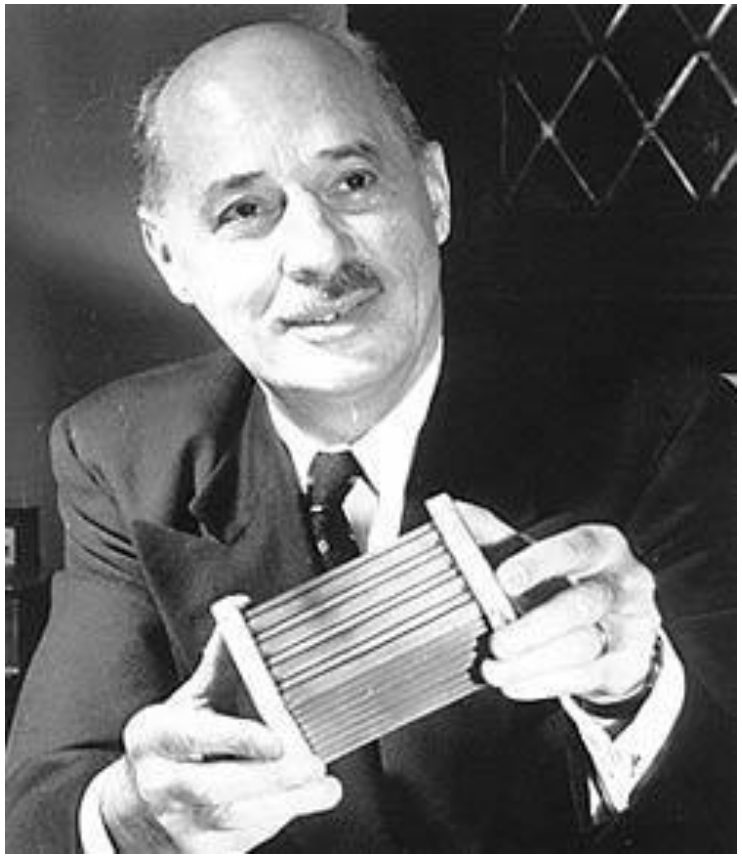


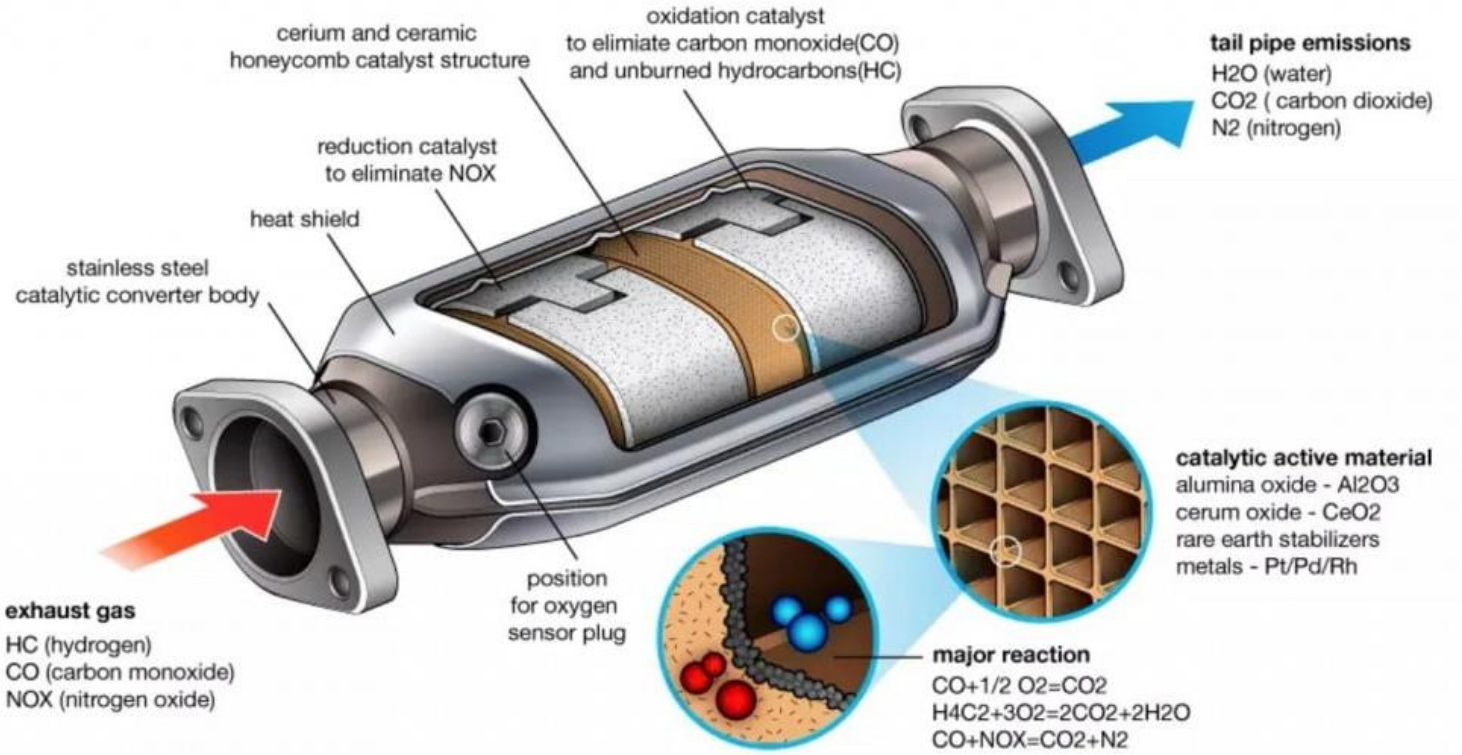
- Population tripled
- Number of automobiles quadrupled

What happened…?

The Air Quality Index Summary Report 1980-2023, Los Angeles Almanac.

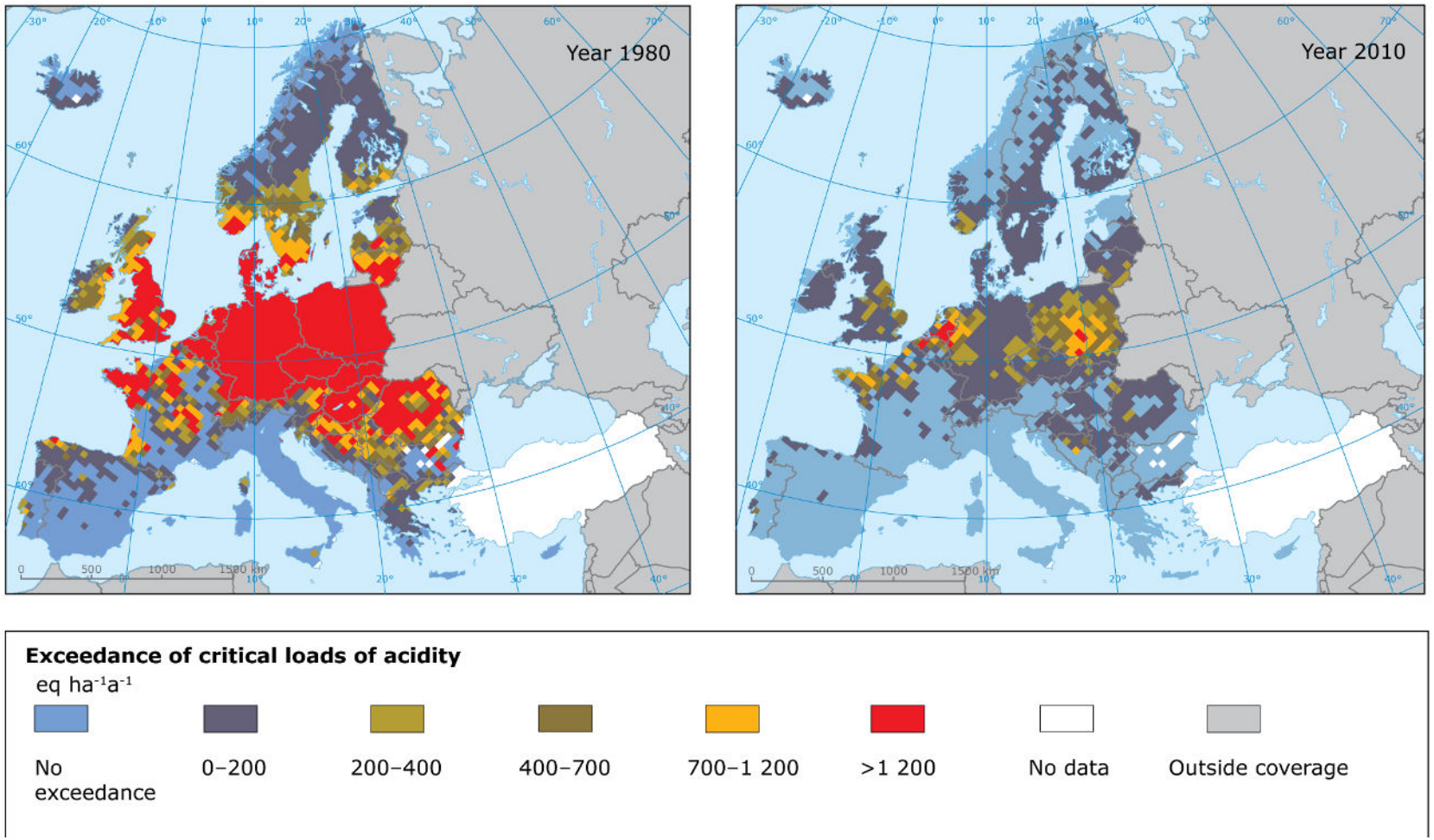
Katalyse!




cerium and ceramic
honeycomb catalyst structure
oxidation catalyst
to elimiate carbon monoxide(CO)
and unburned hydrocarbons(HC)
tail pipe emissions
H2O (water)
CO2 (carbon dioxide)
N2 (nitrogen)
reduction catalyst
to eliminate NOX
heat shield
stainless steel
catalytic converter body
catalytic active material
alumina oxide - Al2O3
cerum oxide - CeO2
rare earth stabilizers
metals - Pt/Pd/Rh
position
for oxygen
sensor plug
exhaust gas
HC (hydrogen)
CO (carbon monoxide)
NOX (nitrogen oxide)
major reaction
CO+1/2 O2=CO2
H4C2+3O2=2CO2+2H2O
CO+NOX=CO2+N2

Zure regen - 1970

Resultaten uit het verleden…



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