ENGIE Research

Loving the Alien:

CO_2 deserves our affection but save a seat for some other surprising climate change allies

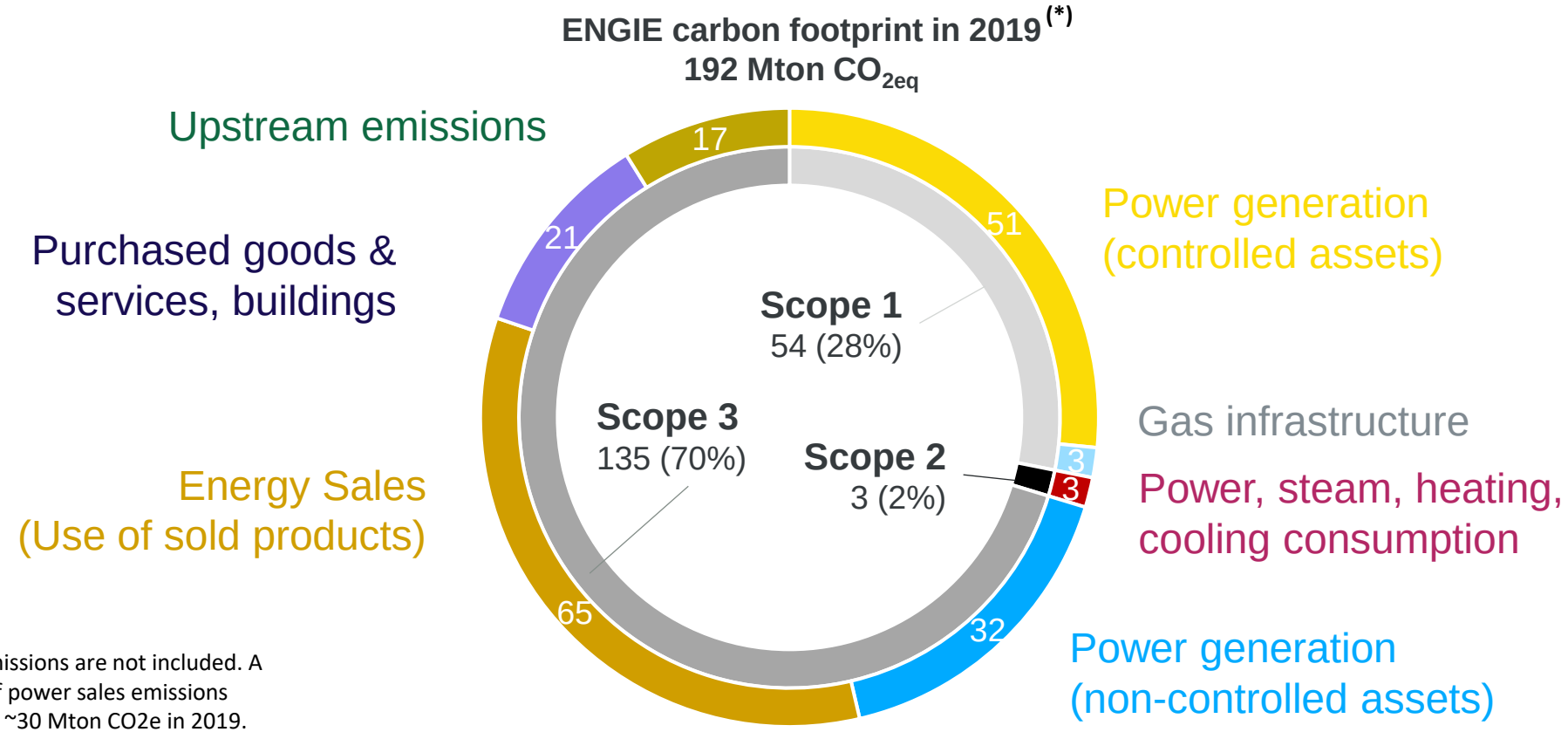
Jan Mertens

Chief Science Officer @ENGIE

Visiting Professor @ Ugent

4th IERE Webinar: 'Towards a Carbon Neutral Energy Future'
18 November 2021

ENGIE's ambition covers all 3 scopes, including direct emissions as well as all indirect emissions



(*) power sales emissions are not included. A first assessment of power sales emissions estimates these at ~30 Mton CO2e in 2019.

Proposed net zero ambition by 2045 covers all scopes including procurement and upstream emissions, but intermediate targets are limited to energy generation and sales, the two most important sources of emission

Pilot projects with academic, industrial and government partners are important to co-develop, test and demonstrate new solutions

Pilots are key for ENGIE and a large part of the research budget

Biomass gasification Gaya

gaya

France

Battery Storage

Belgium

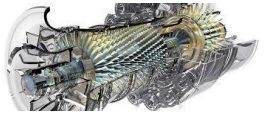
Bifacial Solar testing

Chile

Decentralized Energy System for Islands

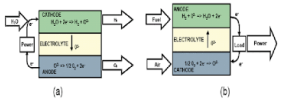
Singapore

H_2 co-combustion in gas turbine



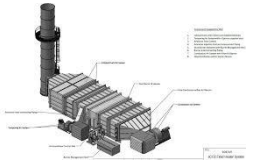
Belgium

High temperature SOEC/SOFC



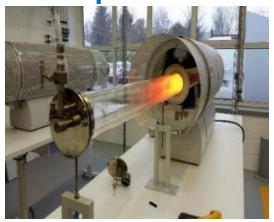
France

Supercritical CO_2 cycle



US

Solar-H_2 panels



France

OPV for Buildings Heliatek

Heliatek

HeliaFilm®

Global

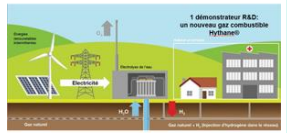
Floating Wind turbine

Portugal

High Altitude Airborne Wind

Germany

H_2 injection in natural gas grid



France

Power to methane

France

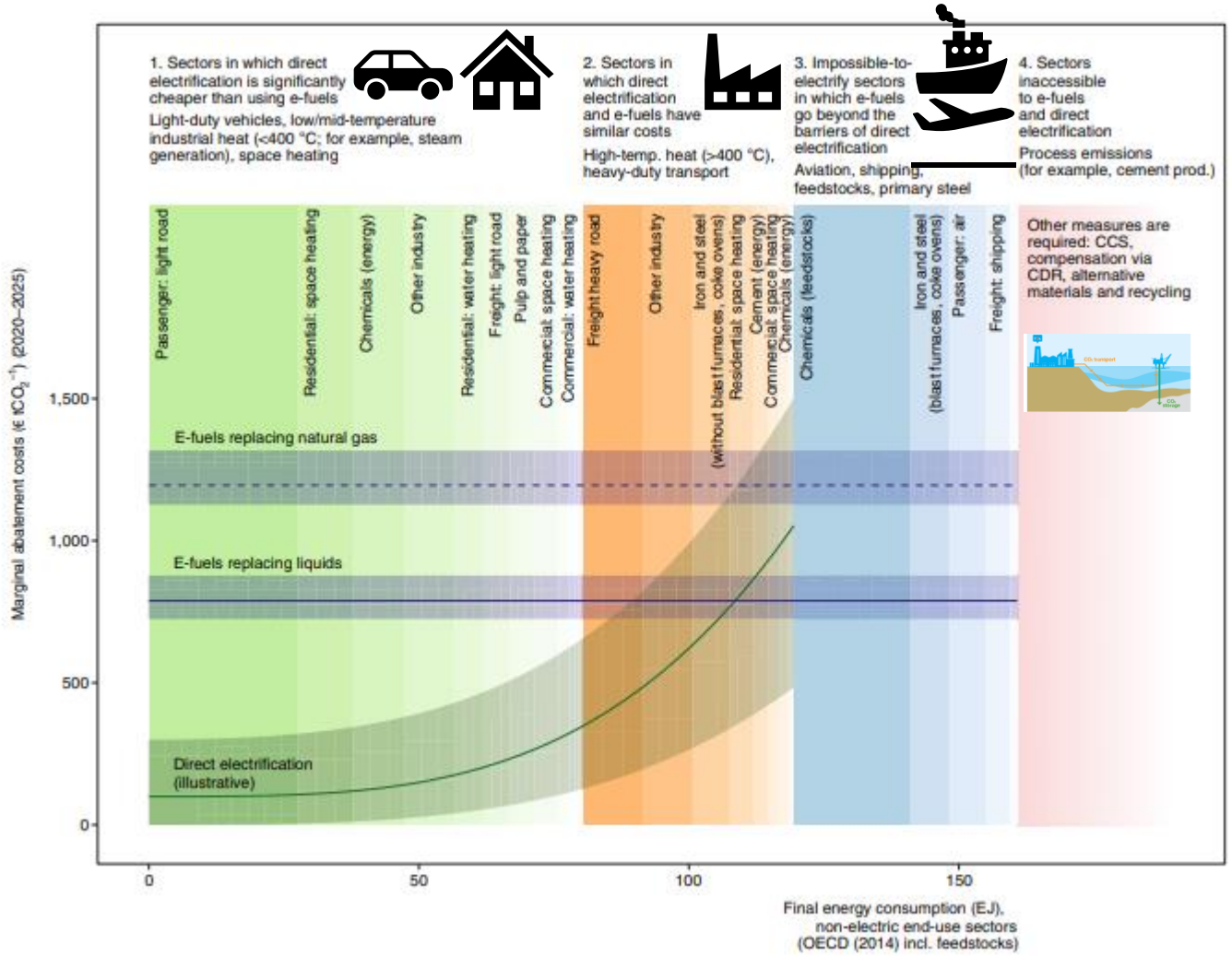
Solar cooling

France

Marginal abatement costs differ as a function of the industry for the different pathways towards carbon neutrality

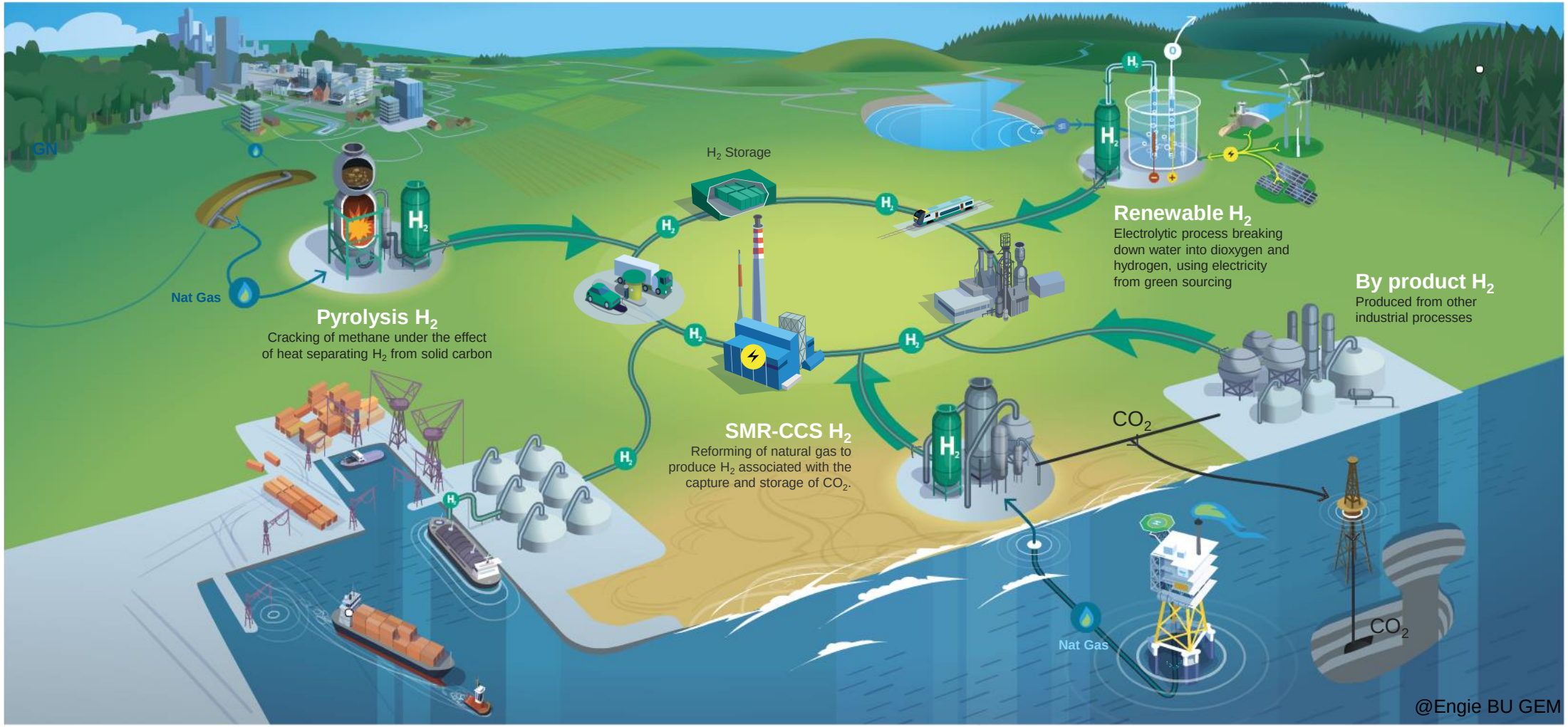
3 pathways towards carbon neutrality (order is important!):

1. Increase efficiency
2. Electrify what is possible
3. Need for molecules



Falko Ueckerdt, Christian Bauer, Alois Dirnaichner, Jordan Everall, Romain Sacchi, Gunnar Luderer. **Potential and risks of hydrogen-based e-fuels in climate change mitigation**. *Nature Climate Change*, 2021; DOI: 10.1038/s41558-021-01032-7

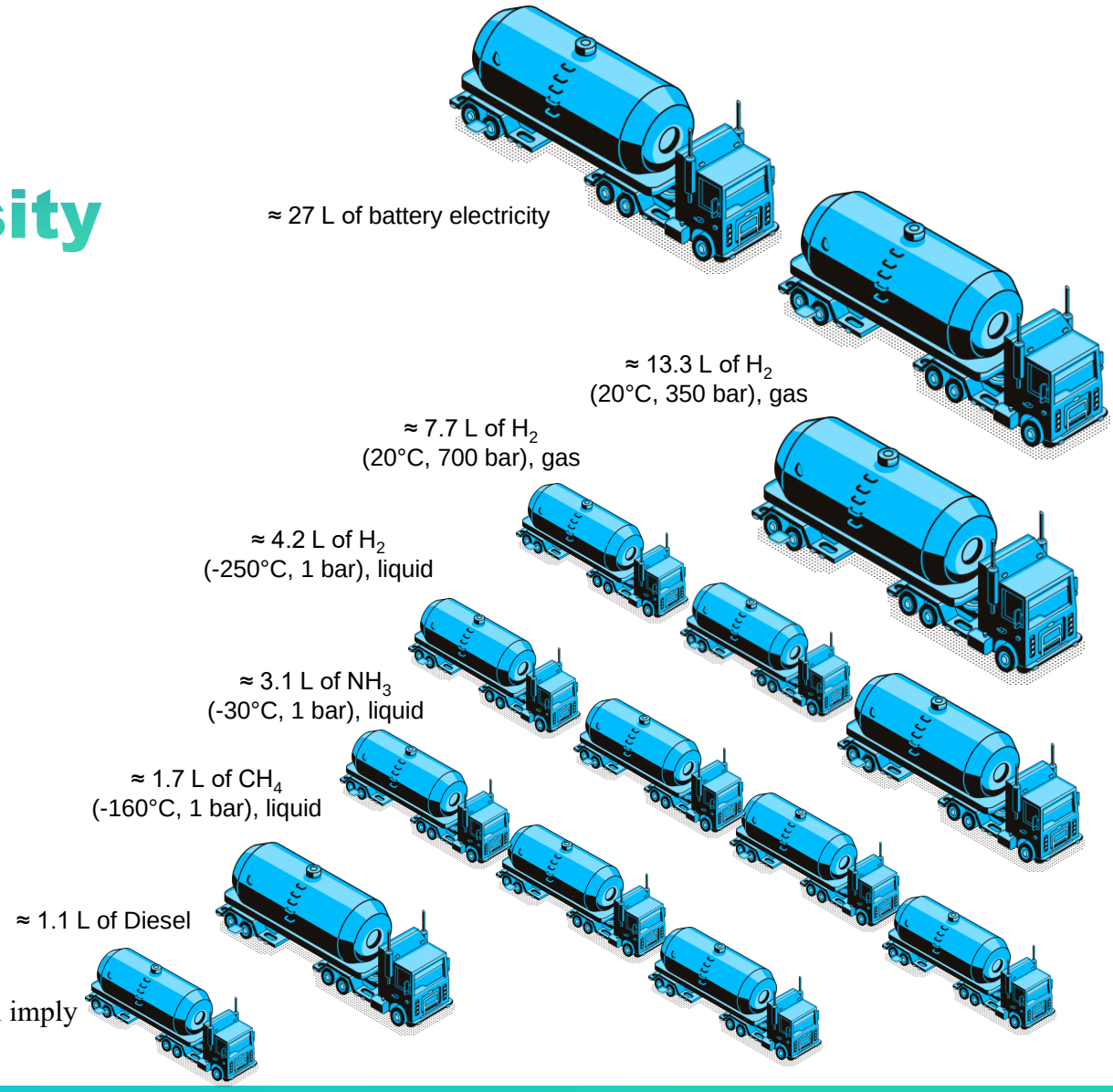
Hydrogen is a low carbon energy solution with a lot of potential but ...



but

Has a very low energy density and is thus extremely hard and expensive to store and move around

→ Need for synthetic hydrocarbons!*

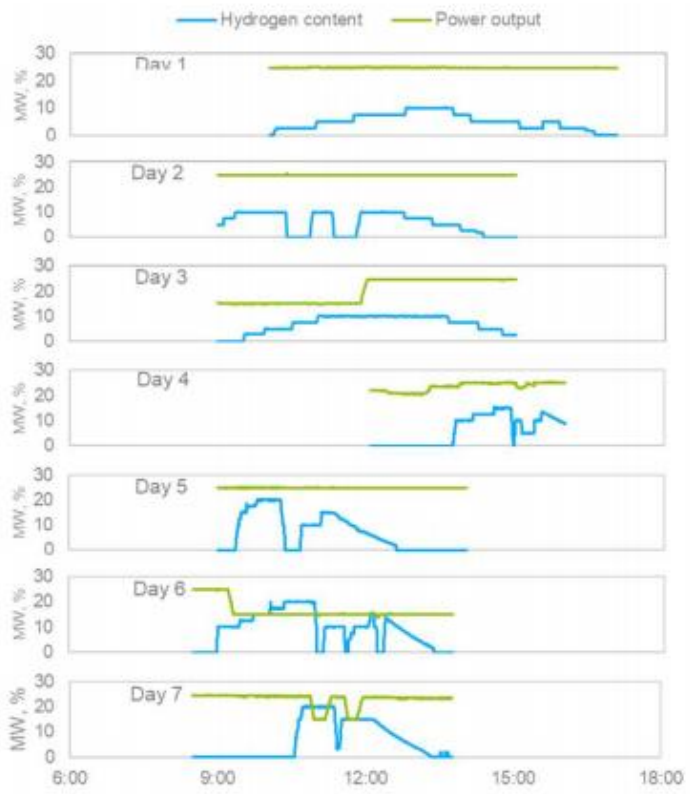


* Mertens, J., R. Belmans and M. Webber, 2020. Why the carbon neutral transition will imply the use of lots of carbon. *C-Journal of Carbon research*, 6 (39), 1-8

Technically, co-combustion of H_2 in CCGT is feasible: proven by ENGIE at INEOS phenol in Antwerp and upgrade in NL for H_2 up to 60 %!

25 vol% H_2 was mixed with CH4 (no hardware changes)

No significant impact on power output and efficiency



NOx emissions increase slightly but tuning allows to reduce the NOx emissions to the base emission levels

Nieuws

Technische upgrade maakt de ENGIE Maxima-centrale geschikt voor waterstof en de toekomst.

dinsdag 22 juni 2021

Ansaldo Energia en ENGIE hebben een contract getekend voor een technische upgrade van de Maximacentrale in Lelystad. De technische upgrade zorgt voor verbeterde prestaties waardoor de CO2 uitstoot afneemt. De centrale krijgt een hoger rendement, meer vermogen, hogere flexibiliteit en zal ook geschikt worden voor het gebruik van waterstof. Hiermee wordt een belangrijke stap gezet voor de toekomstige rol van de centrale als CO2-vrij regelbaar vermogen in aanvulling op zon en windenergie.

Fueling a gas turbine with 100 % H_2 seems practically 'challenging'

9000HL: How much H_2 onsite storage is needed?

SIEMENS energy

1 HOUR = 4km 1.4m pipeline

1.4m dia pipe @100bar

1 DAY = 4x

NASA Tank ~230 Tons

1 WEEK = 9x

Teesside Salt Cavern ~810 tons

1 MONTH = 2,500km 1.4m pipeline

1.4m dia pipe @100bar

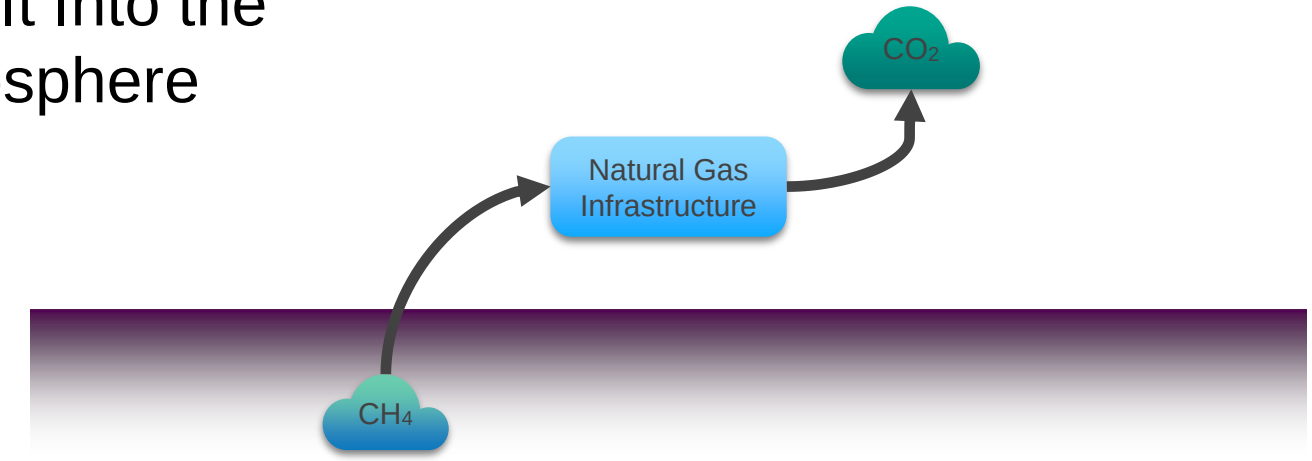
41.5 tons H_2/hr

870 MW* 63% eff *CCGT

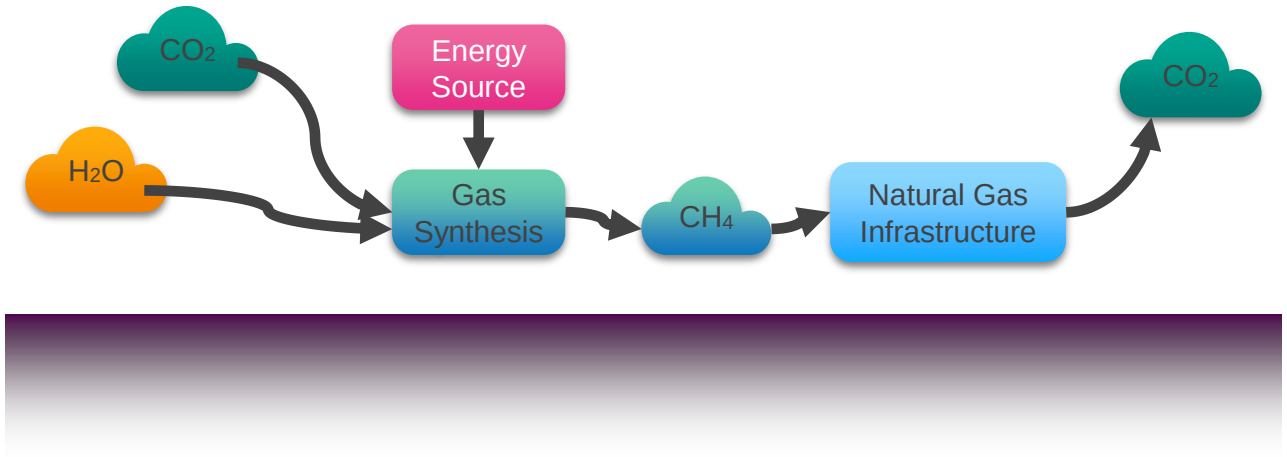
Assumptions: Tube trailer = 500 kg H_2, Pipeline[1]: 1.4 Diameter pipeline at 100 bar (12 ton H_2/km), NASA Spherical Liquid Cryogenic Tank[1]: 230 tons H_2, Teeside Salt Caverns[2] 810 tons (210,000 m^3 at 45 bar)

1. J. Andersson and S. Gronkvist, "Large-scale storage of hydrogen," *International Journal of Hydrogen Energy*, vol. 44, pp. 11901-11919, 2019.
2. E. Wolf. "Large-scale hydrogen energy storage," J. Garche (Ed.), *Electrochemical energy storage for renewable sources and grid balancing*, Elsevier, Amsterdam (2015), pp. 129-142

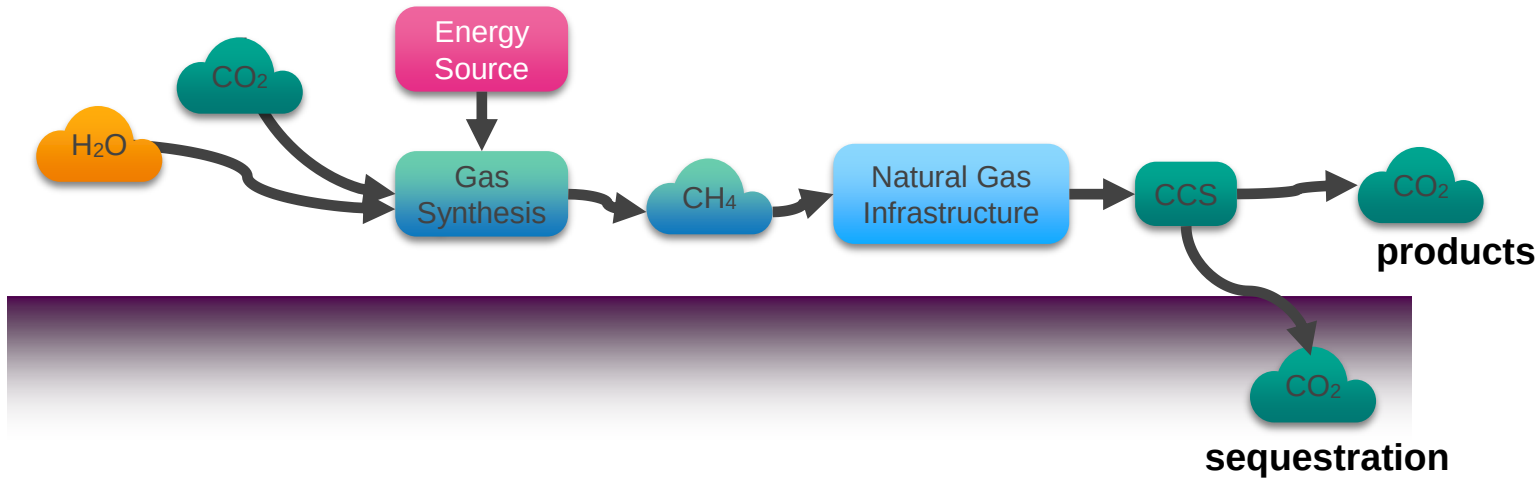
Today's Gas System Takes C From The Earth's Crust and Puts It Into the Atmosphere



Tomorrow's Gas System Could Take Carbon From The Atmosphere To Make The Gas



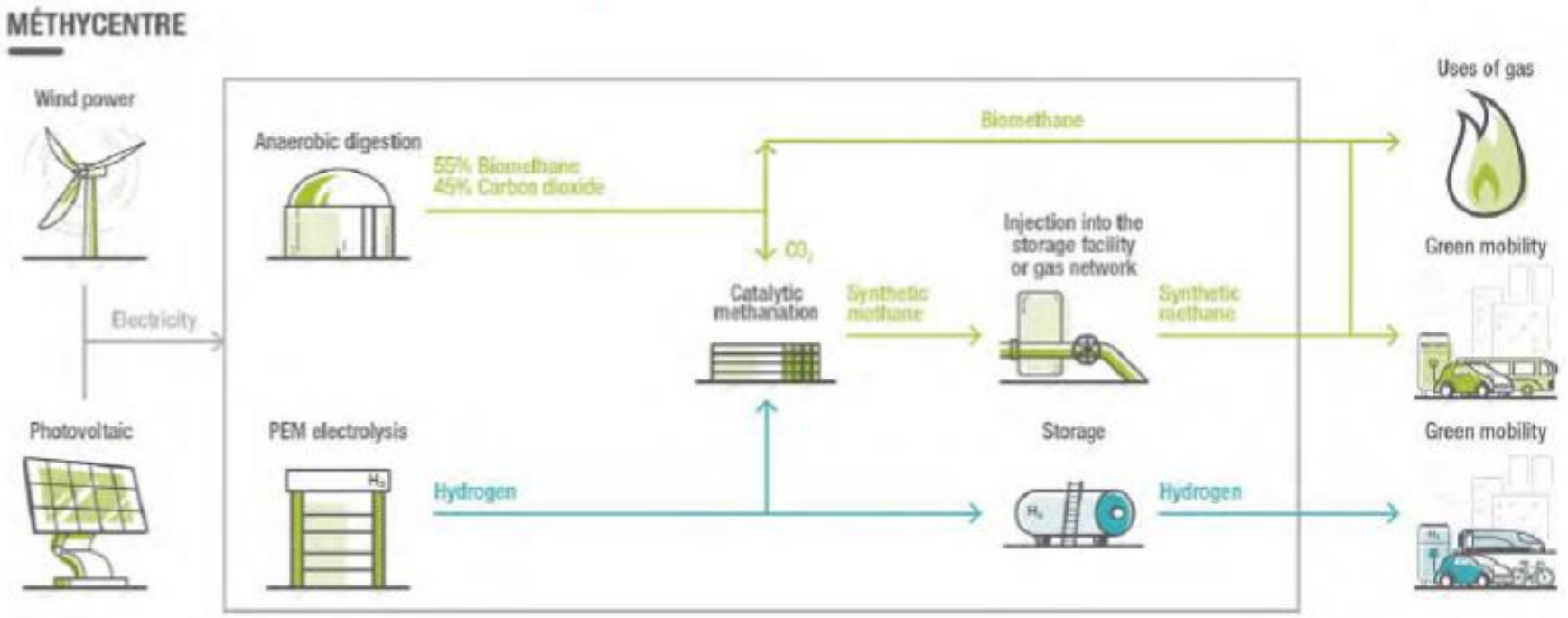
The Day After Tomorrow's Gas System Could Take Carbon From The Atmosphere And Put It Into Products or The Crust



Power – to – e-methane: example of Methycentre

storengy
Une société de ENGIE

MÉTHYCENTRE



It will be AND hydrogen AND methane AND methanol AND FT fuels AND ....

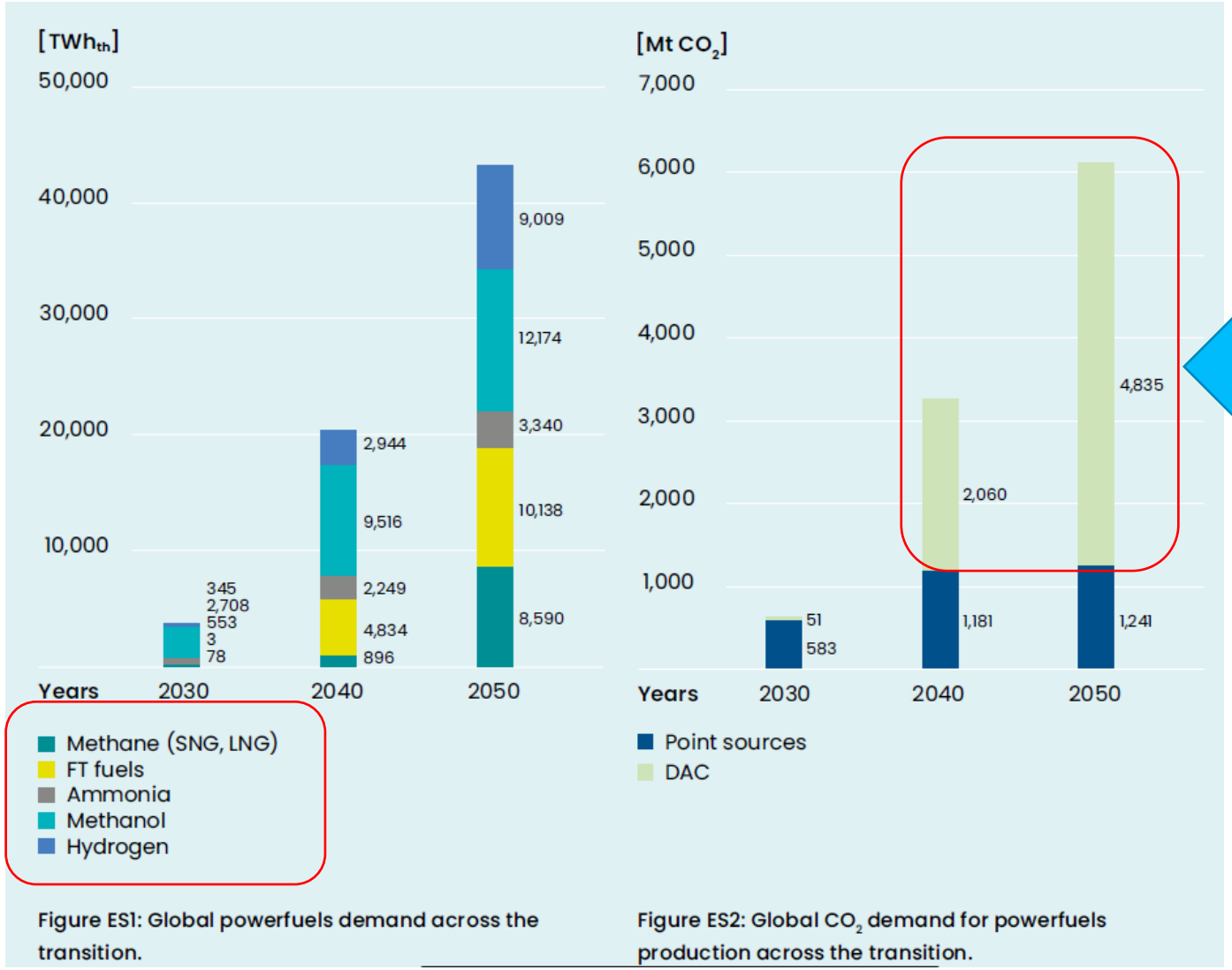


Figure ES1: Global powerfuels demand across the transition.

Figure ES2: Global CO_2 demand for powerfuels production across the transition.

Mix of molecules!

Main source of CO_2 will come from DAC (Direct Air Capture)

Ram M., Galimova T., Bogdanov D., Fasihi M., Gulagi A., Breyer C., Micheli M., Crone K. (2020). Powerfuels in a Renewable Energy World - Global volumes, costs, and trading 2030 to 2050. LUT University and Deutsche Energie-Agentur GmbH (dena). Lappeenranta, Berlin.

E-fuels high on the agenda of many ENGIE's BU's: From R&D over pilot to demo

Engie ecosystem

BU-GEN, BU-H_2, BU-MESCAT
STORENGY — AXIMA
ENGIE Impact — ENGIE Disruption
GRTgaz — TRACTEBEL
ELENGY — GEM
GRDF — ENGIE Research

R&D

ENCO2RE
BIOCON-CO2
wetsus
EnAlgae
power to PROTEIN
Sunrise
SUN ERGY
CO2 VALUE EUROPE

Pilot

Jupiter 1000 — **E-methane** — GRTgaz

(2014 - …)
Thermocatalytic hydrogenation
H_2 electrolyser (2 * 0.5 MWe)

C2FUEL — ENGIE Lab — **Formic acid DME**

Thermocatalytic hydrogenation
H_2 electrolyser (1 Nm_3/h -15 bar)

Demonstration

Port of Antwerp — **E-methanol**

Port of Antwerp

Thermocatalytic hydrogenation
H_2 electrolyser @ 3 MWe

Hycaunais — **E- methane**

Electrochaea — storengy

Bioconversion — ENGIE Lab
H_2 electrolyser @ 1MWe

Methycentre — **E-methane**

KHIMOD ALCEN — storengy

Thermocatalytic hydrogenation
H_2 electrolyser @ 250 kWe

CCU Hub Ghent — **E-methanol**

Thermocatalytic hydrogenation
H_2 electrolyser @ 63 MWe

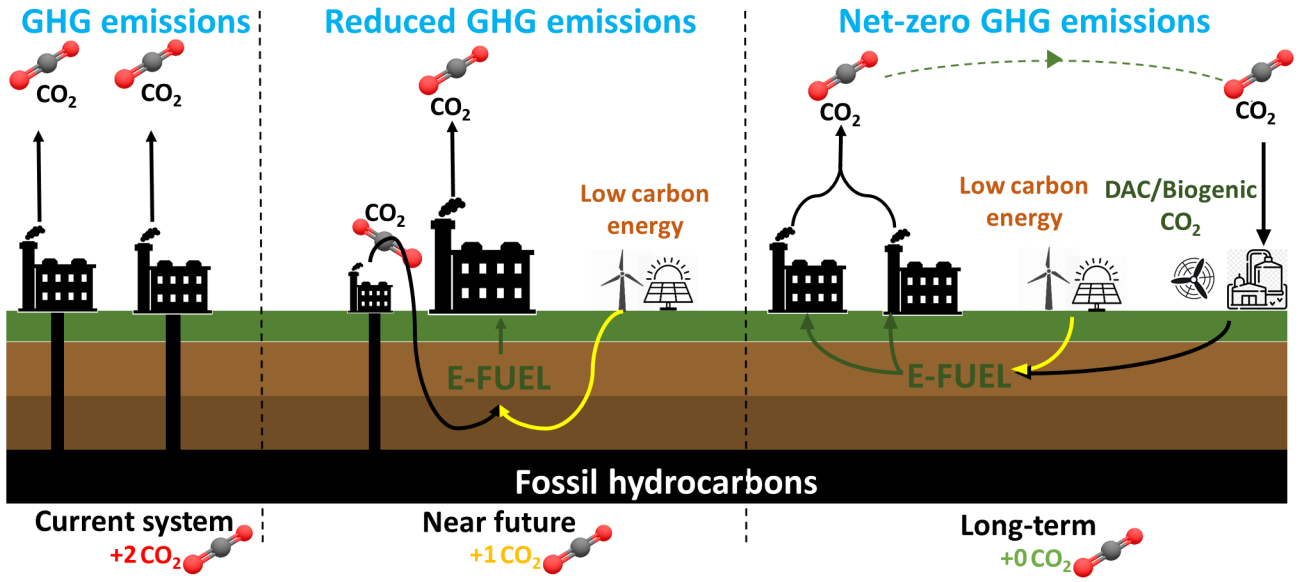
HyNetherlands

100 MW (2024/2025)

Charleroi — **E-methane**

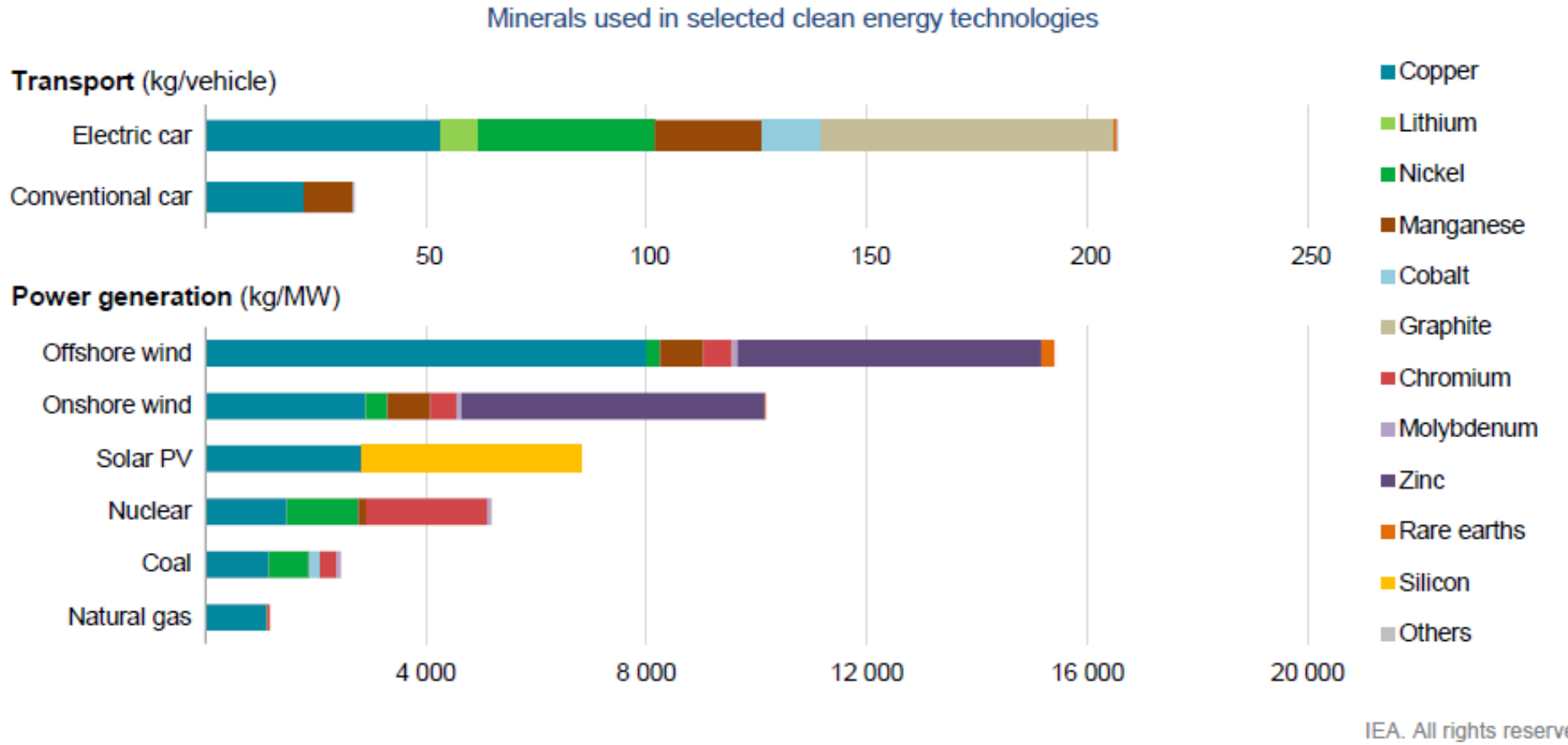
Bioconversion
H_2 electrolyser @ 75 MWe

So we should love the Alien:



And save a seat for?

The recent rapid deployment of clean energy technologies implies a significant increase in demand for minerals

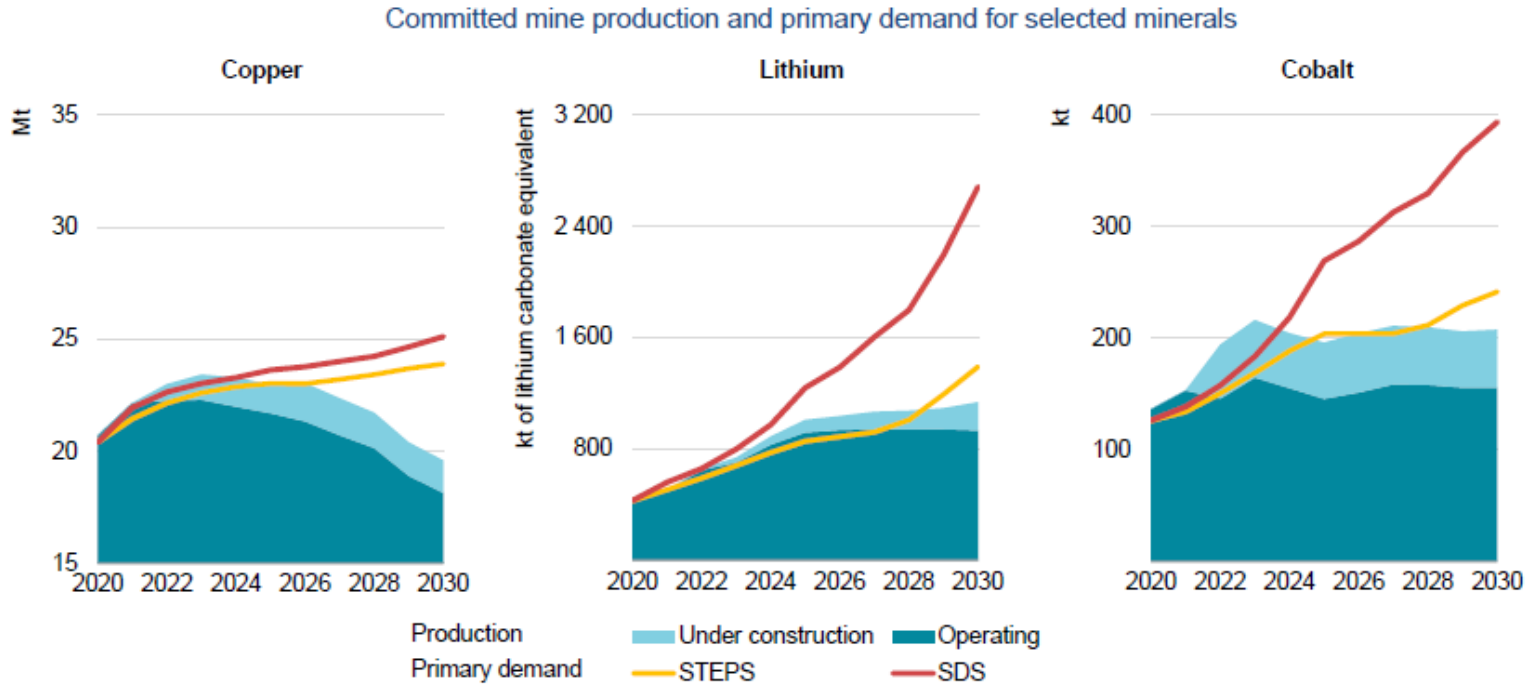


Notes: kg = kilogramme; MW = megawatt. Steel and aluminium not included. See Chapter 1 and Annex for details on the assumptions and methodologies.

IEA, WEO special report, 2021. The Role of Critical Minerals in Clean Energy Transitions.

IEA, 2021 alerts on a mismatch between the need of critical minerals to meet our climate ambitions and the predicted supply of some important critical metals

Meeting primary demand in the SDS requires strong growth in investment to bring forward new supply sources over the next decade

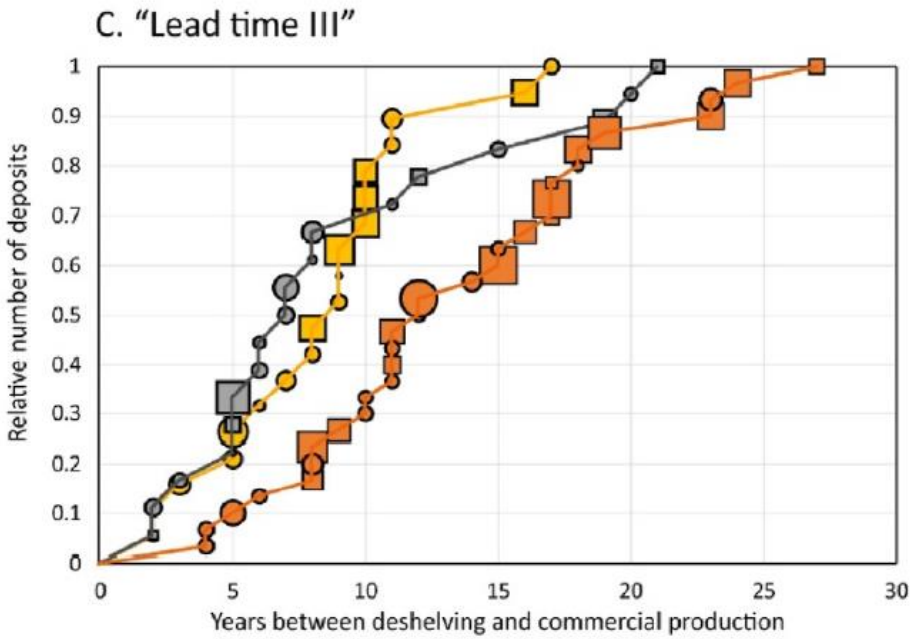


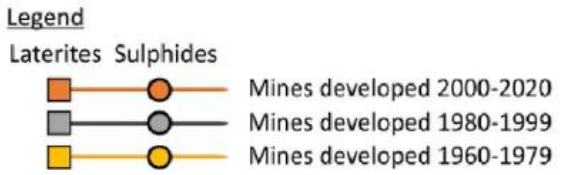
Notes: Primary demand is total demand net of recycled volume (also called primary supply requirements). Projected production profiles are sourced from the S&P Global Market Intelligence database with adjustments to unspecified volumes. Operating projects include the expansion of existing mines. Under-construction projects include those for which the development stage is indicated as commissioning, construction planned, construction started or preproduction. Mt = million tonnes.

Source: IEA analysis based on S&P Global (2021).

IEA, WEO special report, 2021. The Role of Critical Minerals in Clean Energy Transitions.

Lead time of 'new' mines increased over the last decades; supply gaps will exist for battery metals Nickel and Cobalt

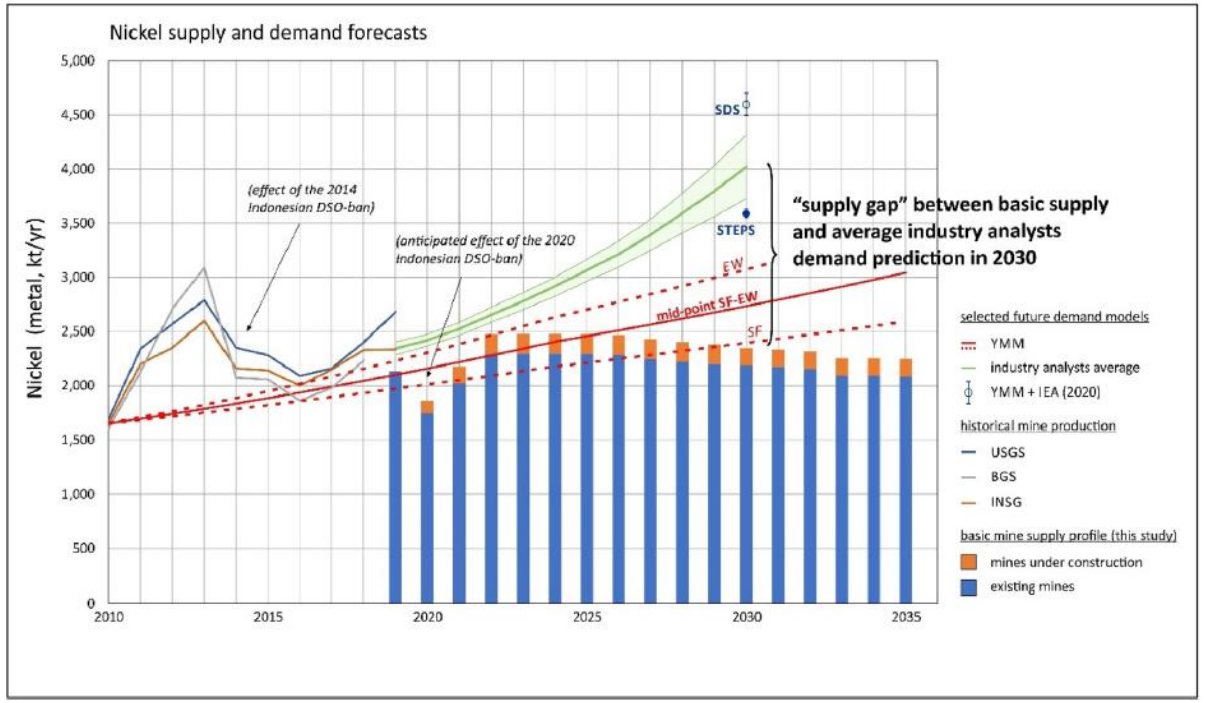




Assessing the adequacy of the global land-based mine development pipeline in the light of future high-demand scenarios: The case of the battery-metals nickel (Ni) and cobalt (Co).

Wouter Heijlen [a,*], Guy Franceschi [b], Chris Duhayon [c], Kris Van Nijen [c]

[a] Tercienco BV, Spijkstraat 105, B-9040, Ghent, Belgium
[b] GF Consult BV, Antwerpsesteenweg 644, B-9040, Ghent, Belgium
[c] Global Sea Mineral Resources NV, Slijkensesteenweg 2, B-8400, Ostend, Belgium



Material extraction accounts for half of the worlds carbon emissions and causes 80 % of the overall biodiversity loss

Chile, Atacama desert, Escondida Mine, 24°16'10.7"S 69°04'18.9"W

Resource extraction responsible for half world's carbon emissions

Extraction also causes 80% of biodiversity loss, according to comprehensive UN study

▲ Massive dump trucks by the Syncrude upgrader plant, Canada. The tar sands are the largest industrial project on the planet, and the world's most environmentally destructive. Photograph: Rex/Shutterstock

Extractive industries are responsible for half of the world's carbon emissions and more than 80% of biodiversity loss, according to the most comprehensive environmental tally undertaken of mining and farming.

While this is crucial for food, fuel and minerals, the study by UN Environment warns the increasing material weight of the world's economies is putting a more dangerous level of stress on the climate and natural life-

It is not only about environmental impact of the mining of 'critical' raw materials:

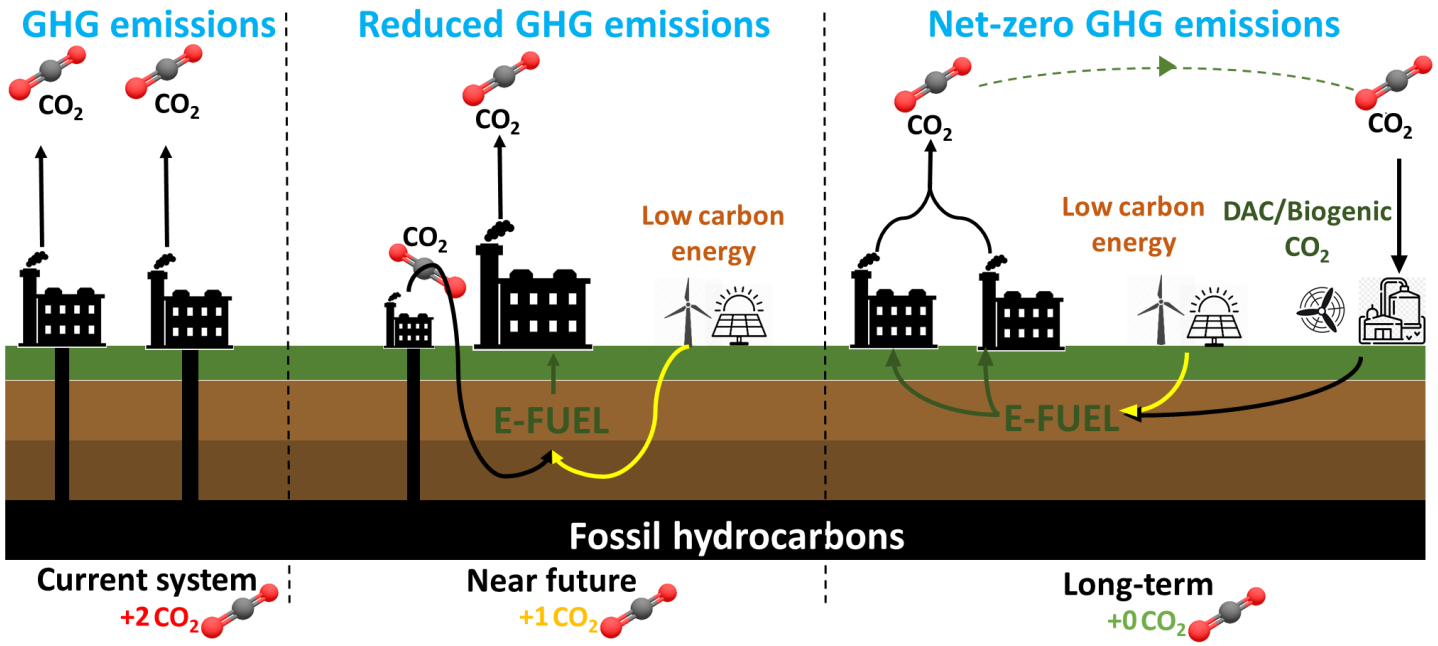
social and ethical issues are important

- Artisanal and small-scale mining:
  - Sapphires
  - Gold
  - Diamonds
  - Tantalum
  - Cobalt

- Small production volumes
  But extreme environmental (and social) impacts

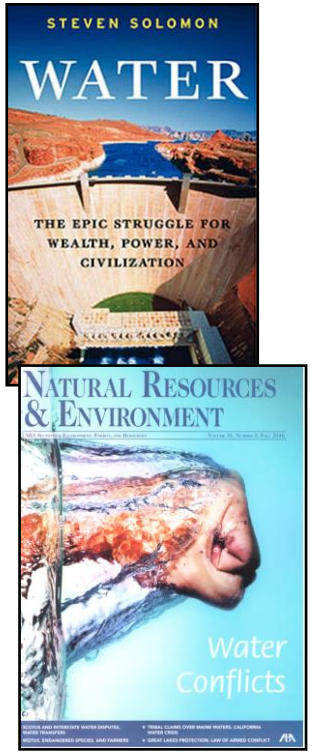
- Cobalt mining in Congo faces serious ethical and social issues

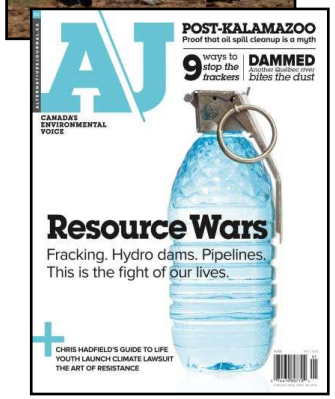
So we should love the Alien:

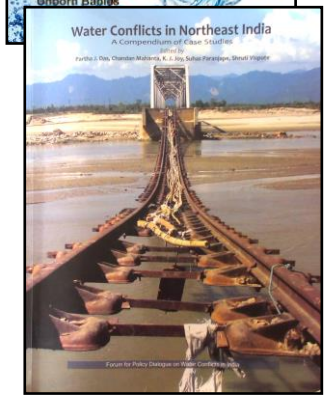


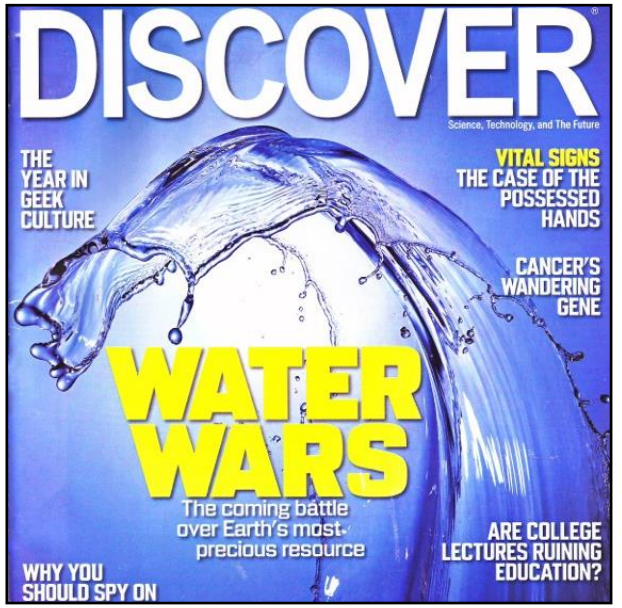
And save a seat for?

Water Will Be The Great Strategic Resource of the 21st Century









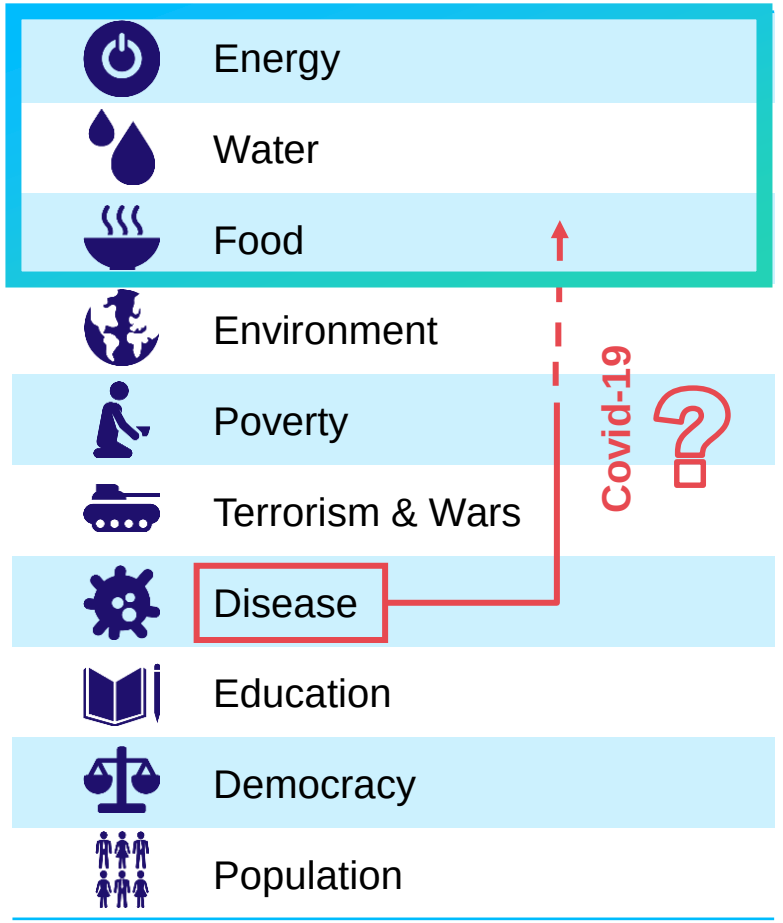
"Whiskey is for drinking,
Water is for fighting over."

American West Proverb

Energy and Water are at the top of Rick Smalley's list of humanity's ten grandest challenges

- Nobel Laureate
- Discovered 'Bucky balls'

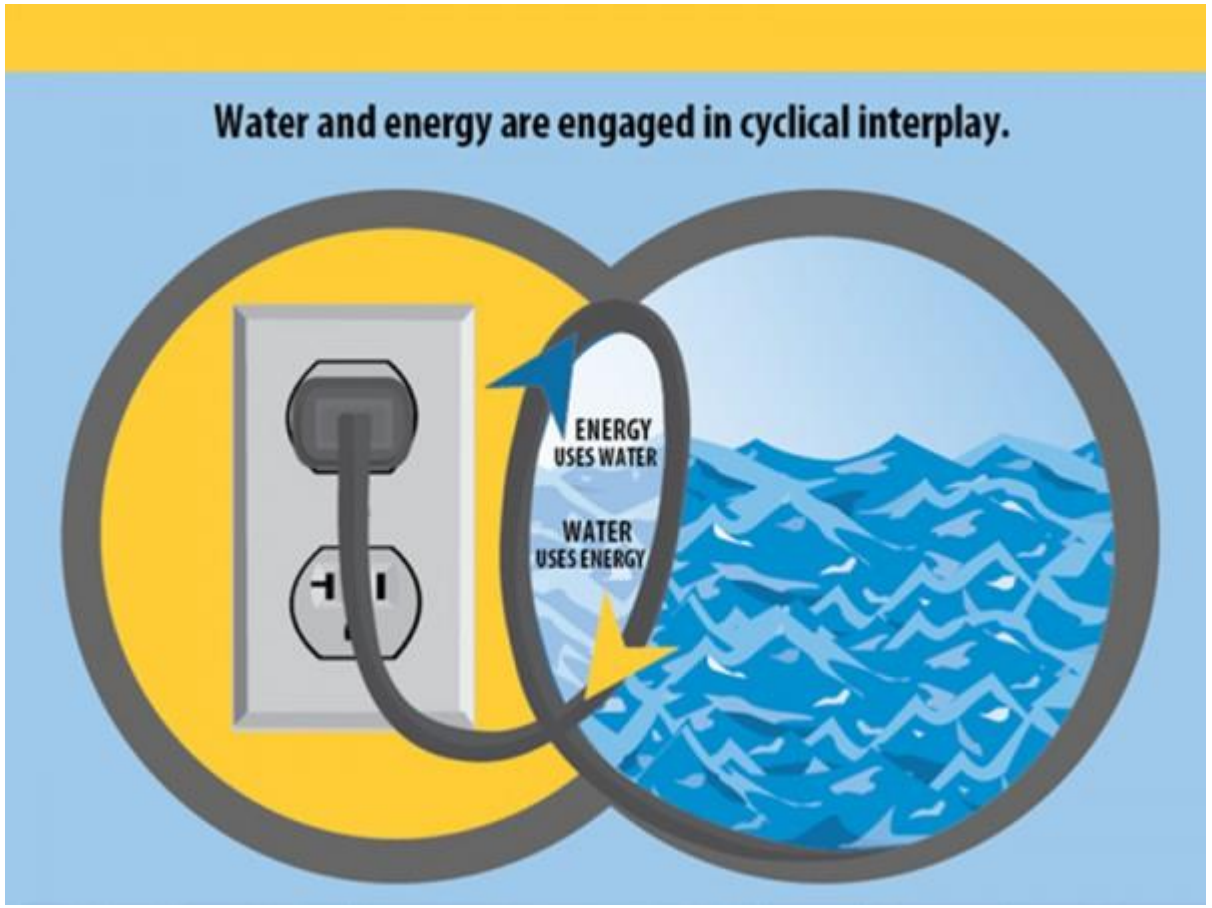
End of his life, many speeches with a list of the word's top 10 challenges!



"Clean water is a great example of something that depends on energy. And if you solve the water problem, you solve the food problem."

R. Smalley, 2005

The Nexus of Energy and Water is particularly important



https://ecoclean4ullc.com/resources-energy-and-water-efficient-products/

- Opportunity:
  Infinite energy gives infinite water, and vice versa
- Bad news: cross-cutting vulnerability
  Water problem becomes energy problem, and vice versa
- Good news: cross-cutting solutions

Our green hydrogen and e-fuels economy will require lots of clean water

To produce 1 kg of Hydrogen, we need 9 kg of pure, clean water!!!

$$H_2O_{(g)} \rightarrow H_{2\,(g)} + 1/2\ O_{2\,(g)}$$

Molecular weight (g/mol):

2x1 + 16 → 1x2 + ½ (16x2)

18 → 2 + 16

18 → 18

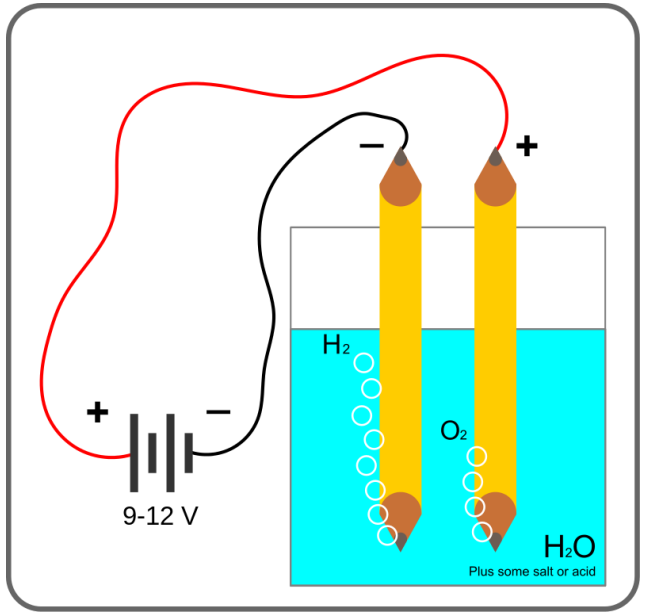
ELSEVIER

Journal of Cleaner Production

Volume 299, 25 May 2021, 126866

Assessing the environmental impacts of wind-based hydrogen production in the Netherlands using ex-ante LCA and scenarios analysis

Mathieu Delpierre [a], Jaco Quist [b], Jan Mertens [c, d], Anne Prieur-Vernat [c, d], Stefano Cucurachi [a]



Emerging Technologies such as Direct Air Capture (of CO_2 and water) can help !

- **If combined with DAC and e-fuels production:**

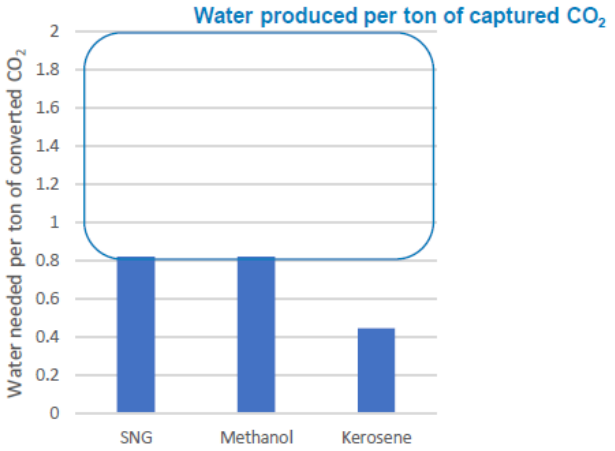
HEAT from e-fuels production → useful for DAC

Water from DAC → useful for e-fuels production

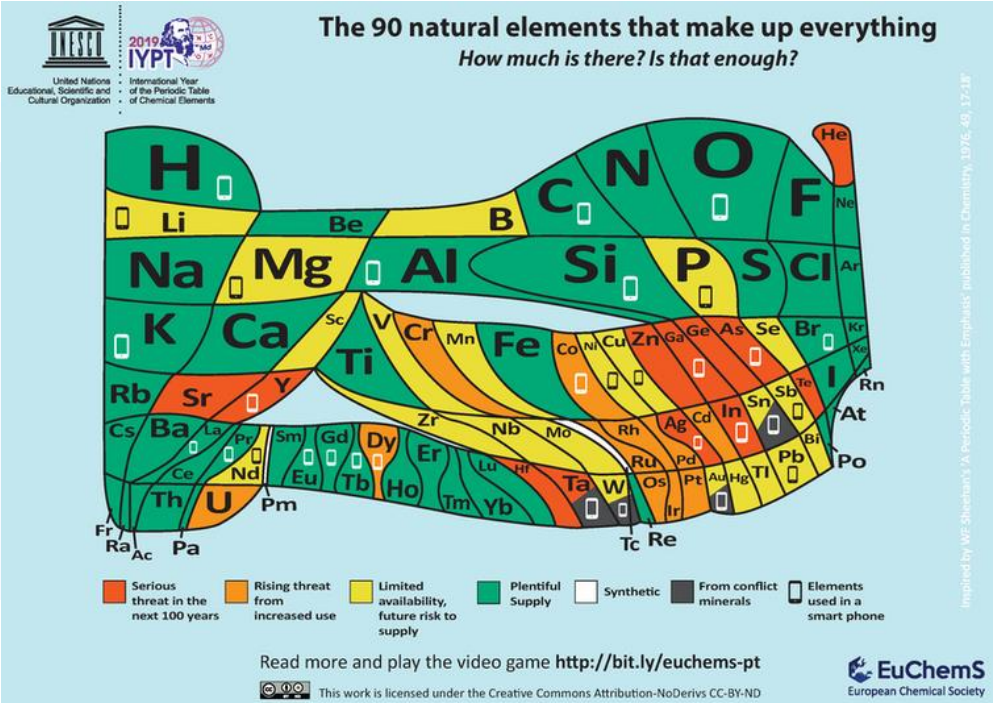
E-fuels synthesis is exothermic and produces water

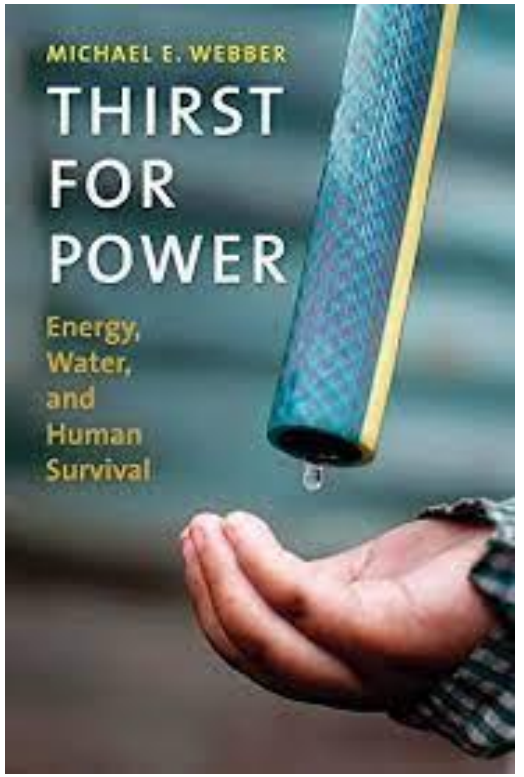
SNG	$CO_2 + 4H_2 \rightleftharpoons CH_4 + 2H_2O$	-164 kJ/mol of CO_2
Methanol	$CO_2 + 3H_2 \rightleftharpoons CH_3OH + H_2O$	-49.5 kJ/mol of CO_2

→ **Perfect circular system in terms of:**
Energy
Water
CO_2



So we should love the Alien but save a seat for raw materials and water !






Want to know more : download our latest version of our emerging sustainable technologies document:
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engie.com
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