April 12, 2023

Zooming in Zooming Out

Telescoping to Accelerate the Energy Transition

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TU Delft

Sixth Assessment Report
WORKING GROUP III – MITIGATION OF CLIMATE CHANGE

ipcc

> **Unless there are immediate and deep emissions reductions across all sectors, 1.5°C is beyond reach.**

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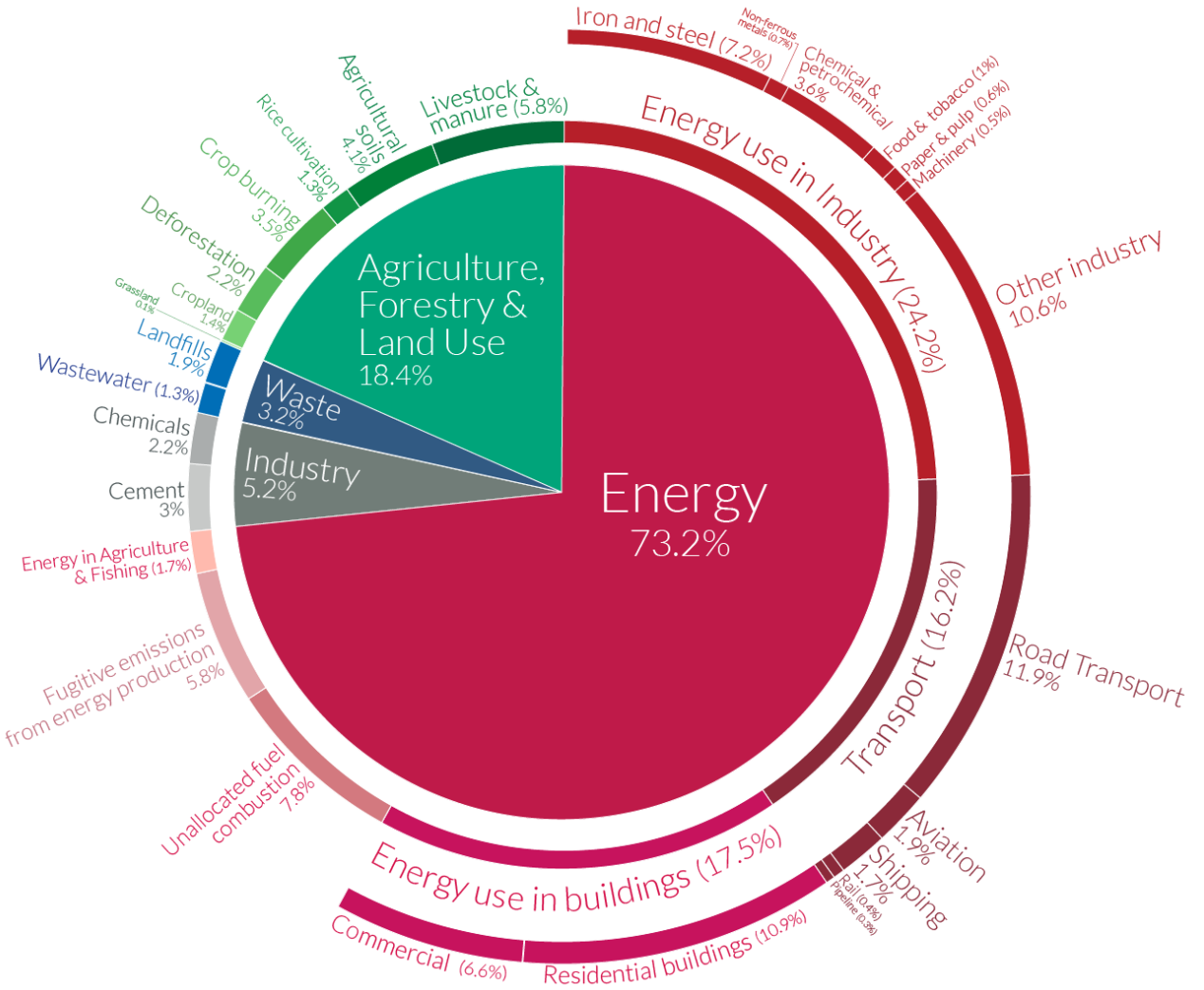
Description of sectors are based on the IPCC 5th Assessment Report

Global greenhouse gas emissions by sector

This is shown for the year 2016 – global greenhouse gas emissions were 49.4 billion tonnes CO_2eq.

Our World in Data



OurWorldinData.org – Research and data to make progress against the world's largest problems.
Source: Climate Watch, the World Resources Institute (2020).

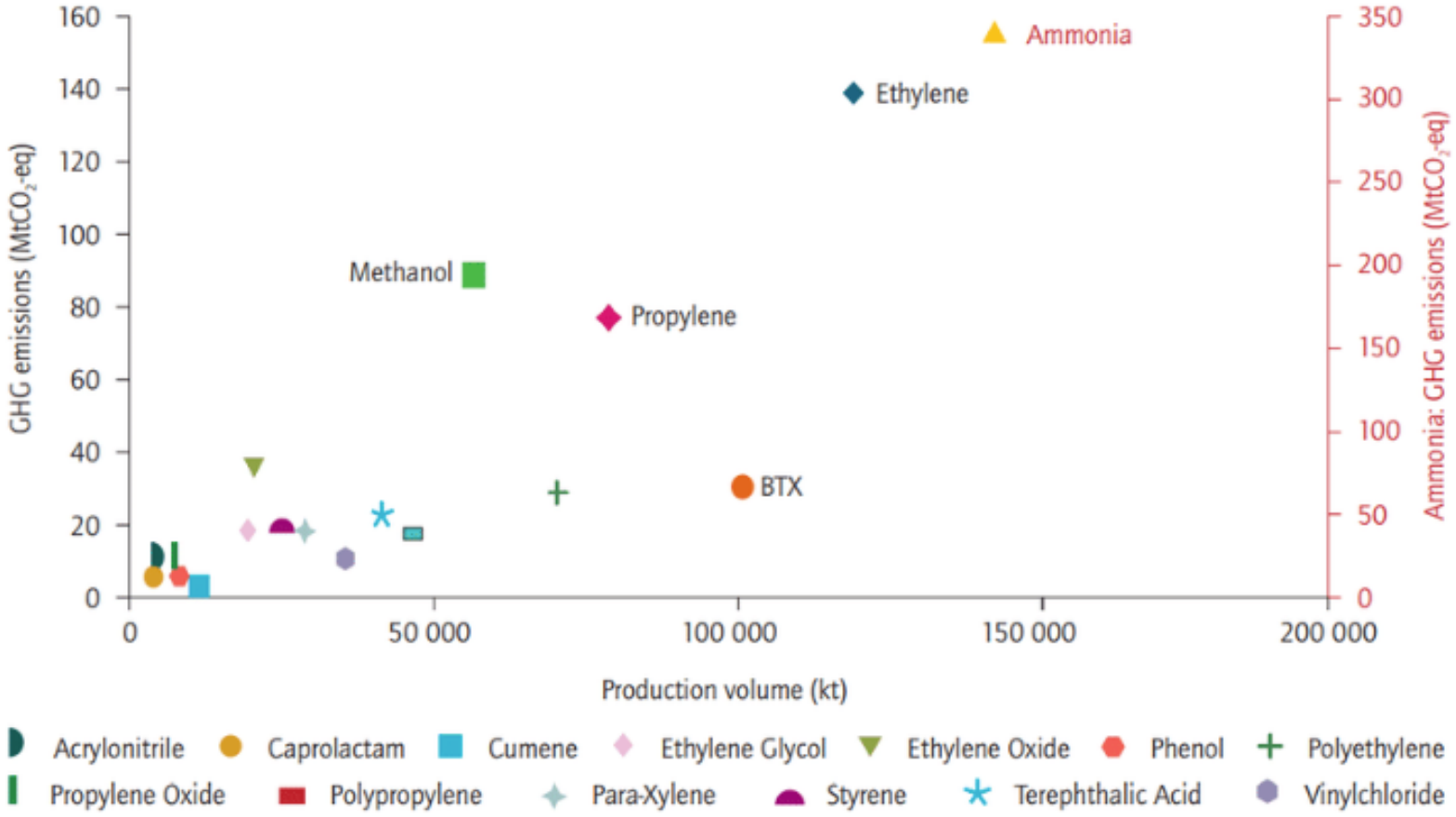
Image: No silver bullet by @bryanMMathers

Energy uses	Type of fossil fuels	Non-energy uses
Heat Electricity	Kerosene	Normal paraffins used in the production of detergents
	Naphtha, gas oil, ethane, propane, butane, NGL	Feedstocks for steam cracking, intermediates, plastics, rubber, solvents, paints, soaps, detergents, food additives, etc.
	Natural gas	Ammonia, methanol, carbon monoxide
	Residual fuel oil	Ammonia, methanol, propylene, carbon black

Zooming OUT there are 3 key strategies:

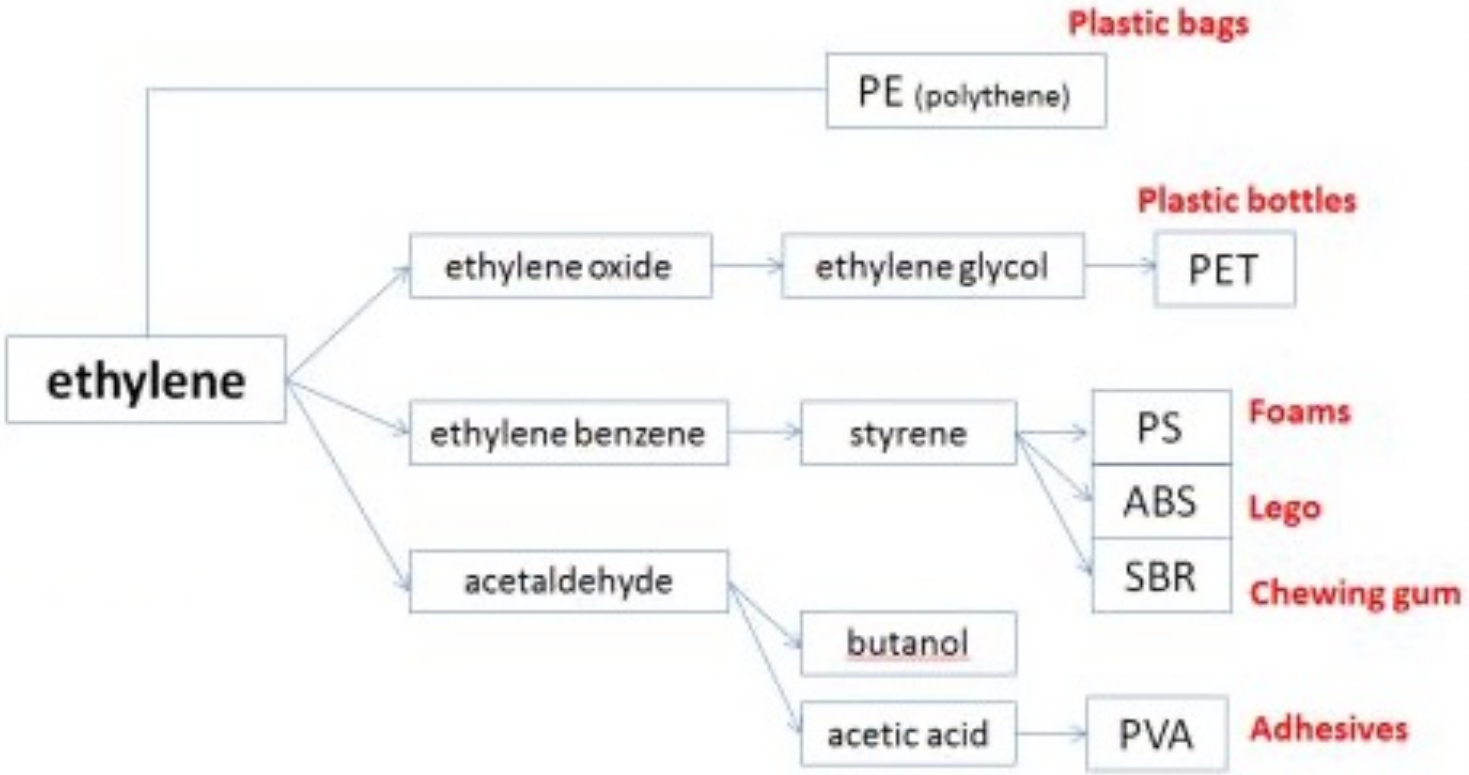
- Use less resources
  - Increase efficiency
  - Reuse
  - Recycle
  - Degrowth
- Decarbonize energy sources
- Replace fossil fuels with alternative feedstocks:
  - Waste
  - Biomass
  - CO_2

Source figure: Gordon Walmsley et al., 2019 (doi: 10.016/j.rser.2019.03.039)

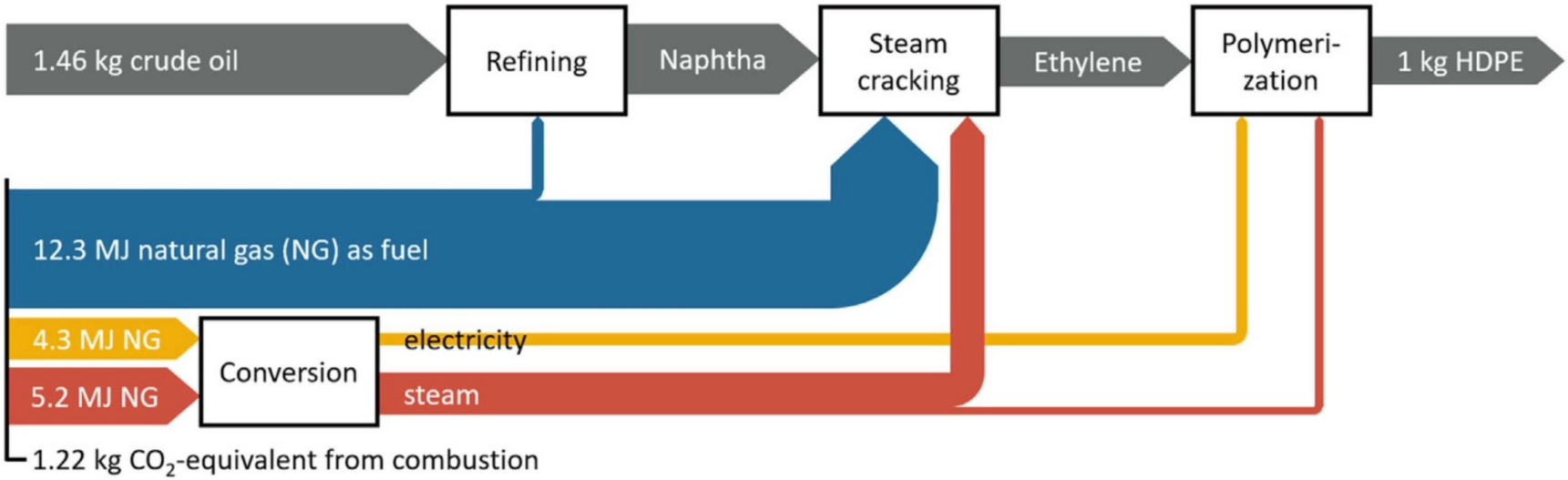


Source: IEA, 2013

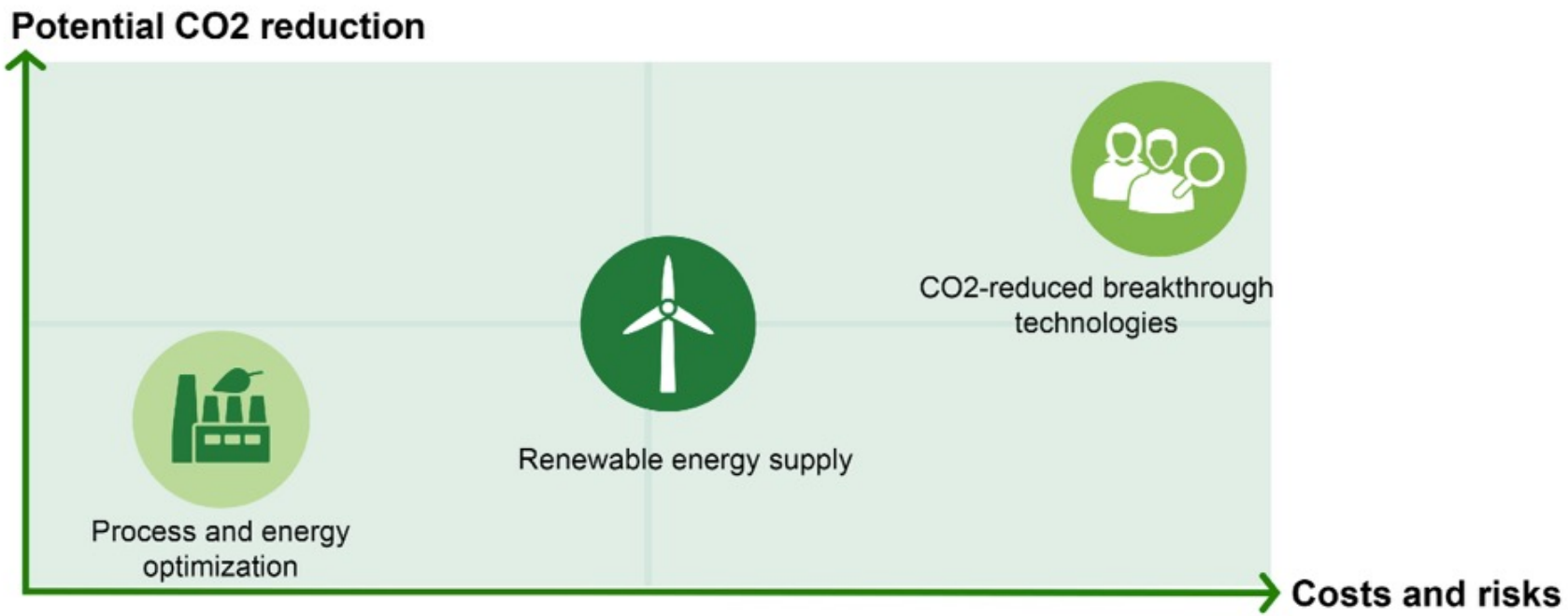
In 2022, we produced about 163 million tonnes of ethylene worldwide



Energy use in the production of high density Poly-ethylene

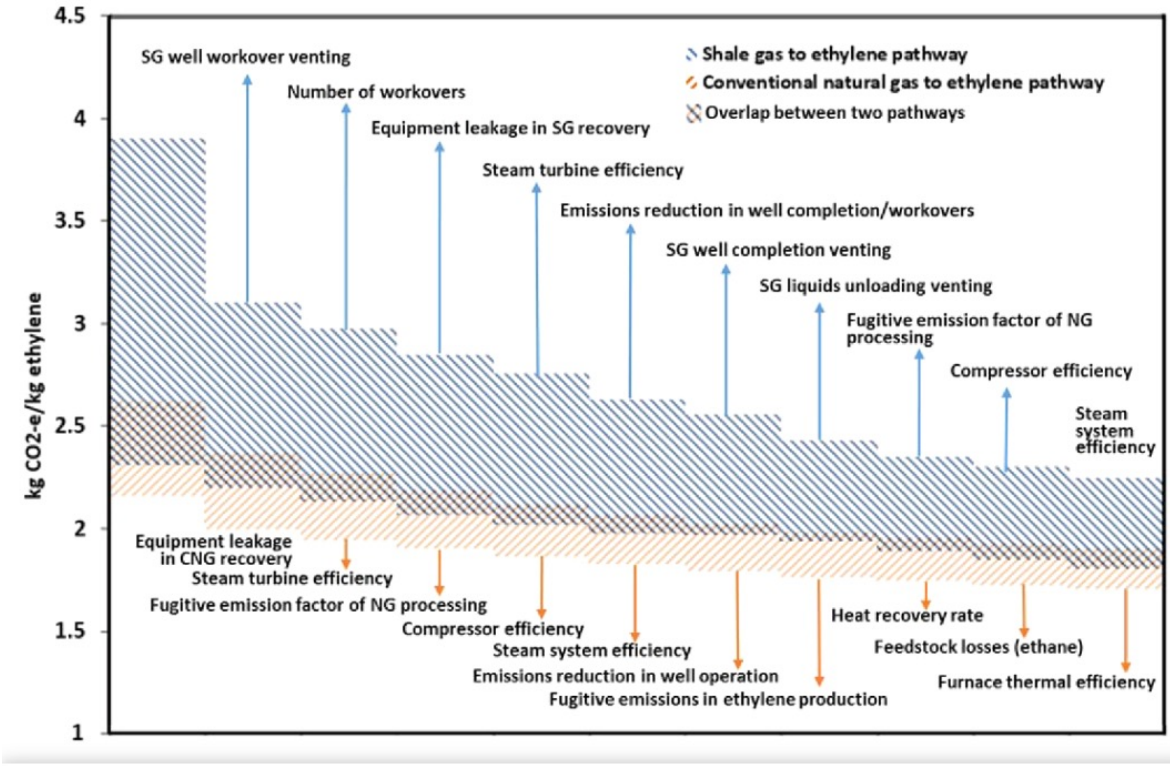


Source: Bauer et al., 2023



Three areas of focus for the chemical industry Image: BASF

Changes in GHG intensity by changing current to best practice efficiency values in the ethylene value chain



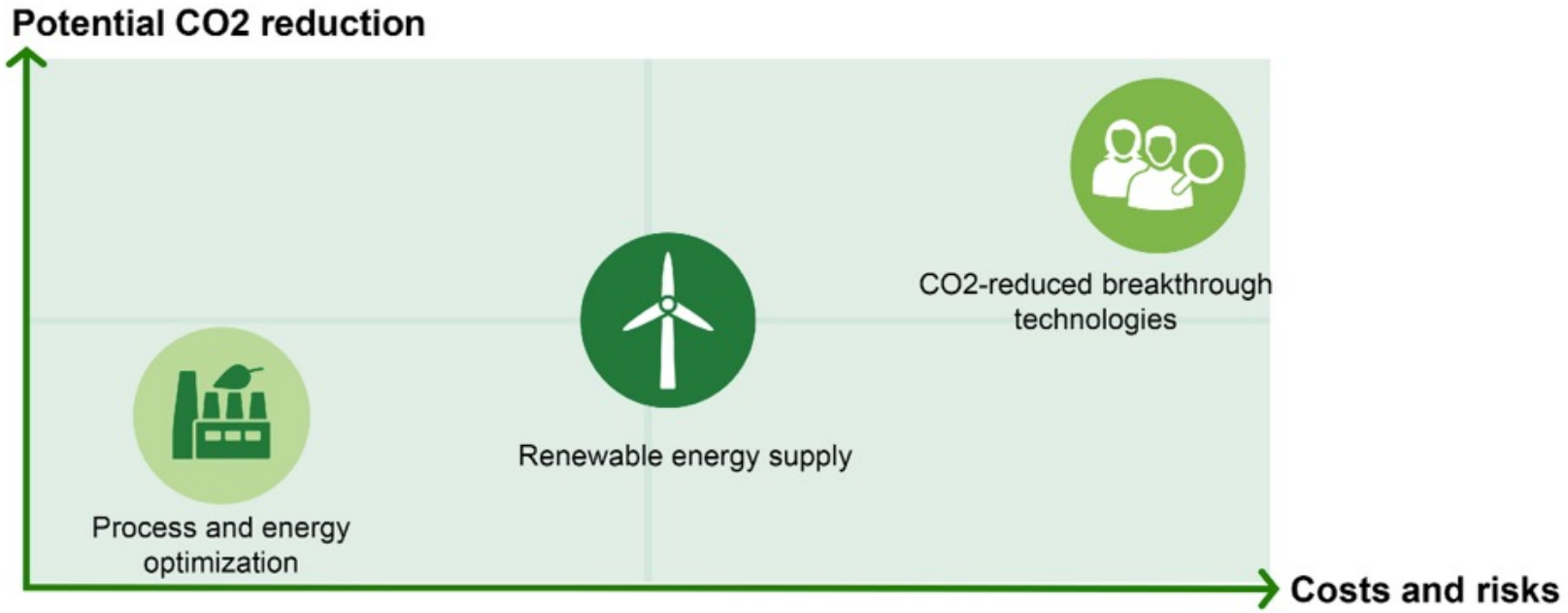
Source: Yao et al., 2015

Door Jeroen Kraan

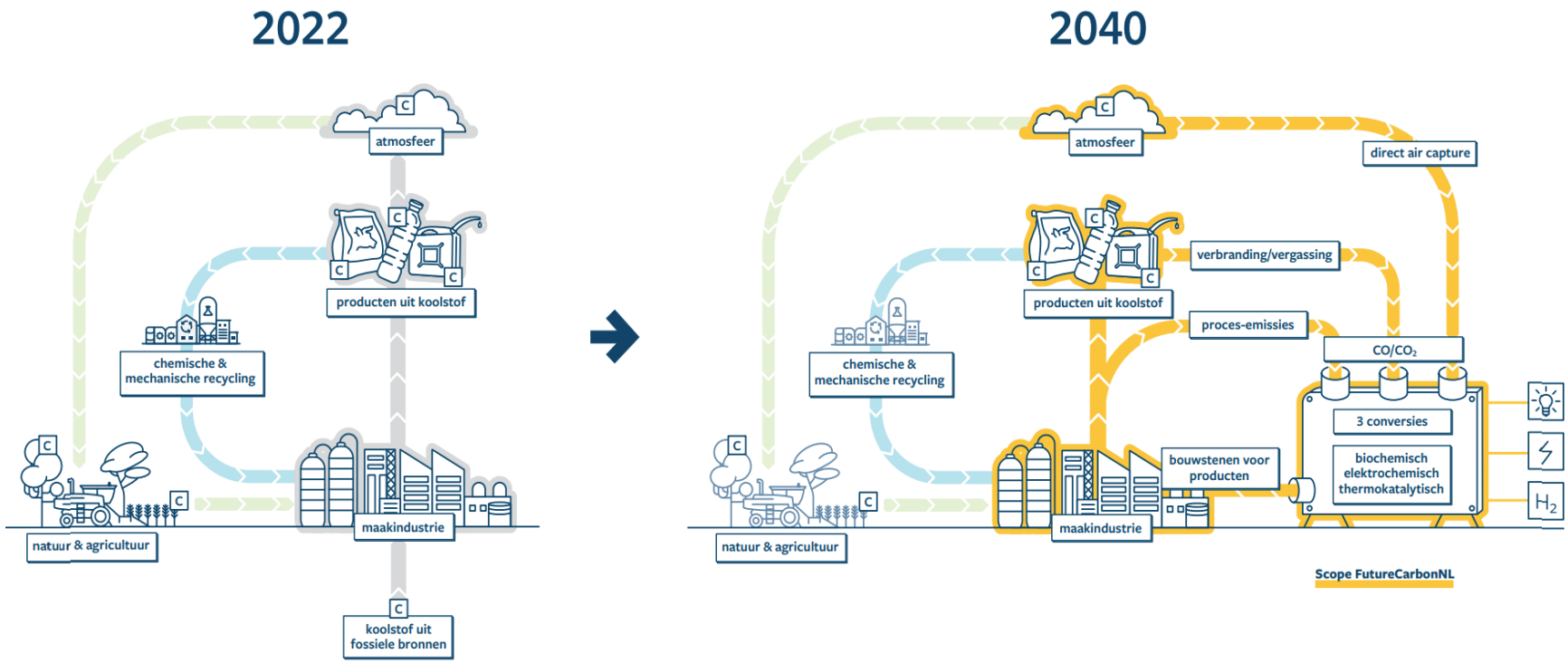
24 mrt 2023 om 05:06
Update: 2 dagen geleden

1.2K reacties

Industriële giganten als Shell, BP en chemiebedrijf Dow hebben een veel grotere klimaatimpact dan hun concurrenten. De bedrijven produceren minder efficiënt, waardoor ze jaarlijks vele honderdduizenden extra tonnen CO2 uitstoten. Dat blijkt uit onderzoek van NU.nl.



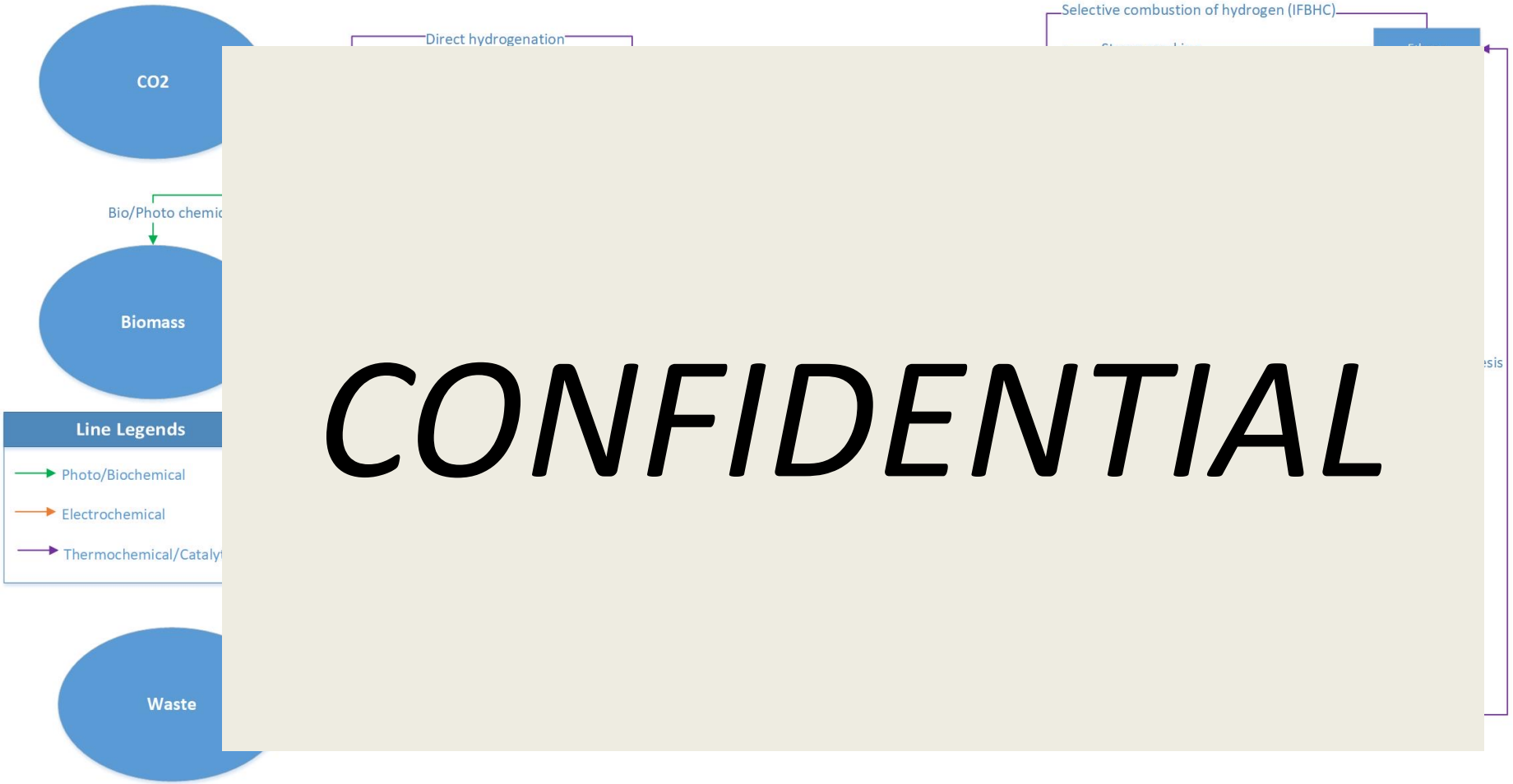
Three areas of focus for the chemical industry Image: BASF



Source: FutureCarbonNL

Possible pathways to make Ethylene (at different TRL)

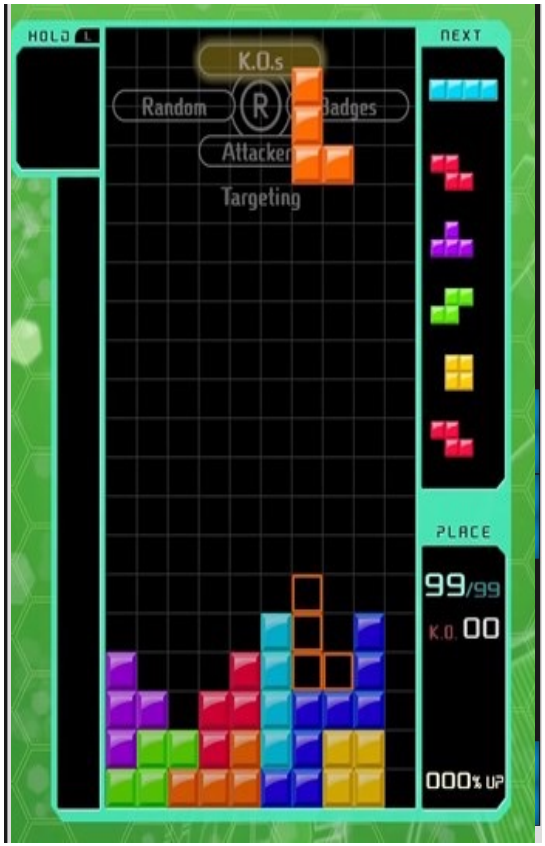
54 possible pathways identified (3-step routes)

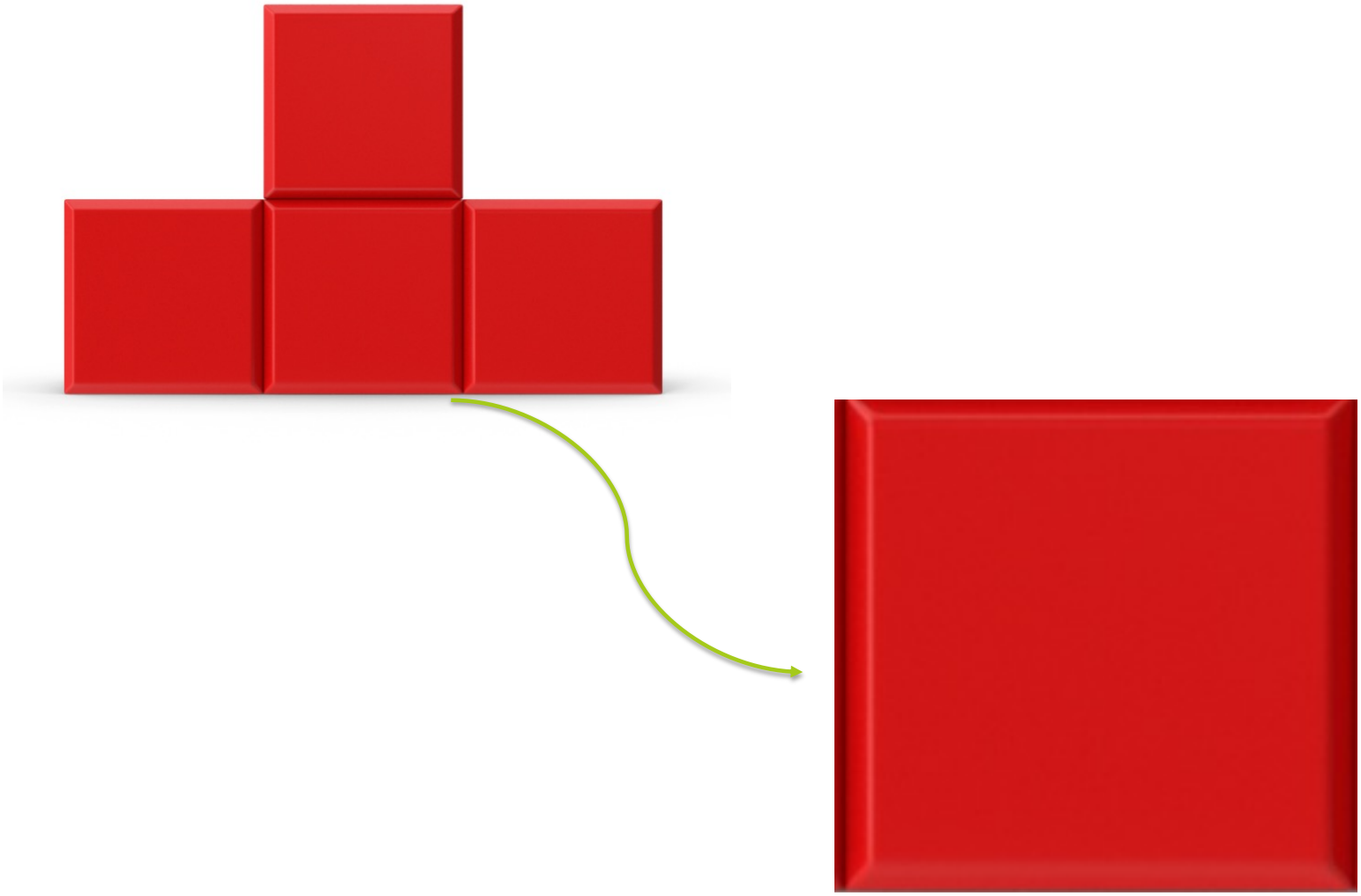


Source: Manalal T., Ibarra P, Perez-Fortez M., Ramirez A (2023, in preparation).

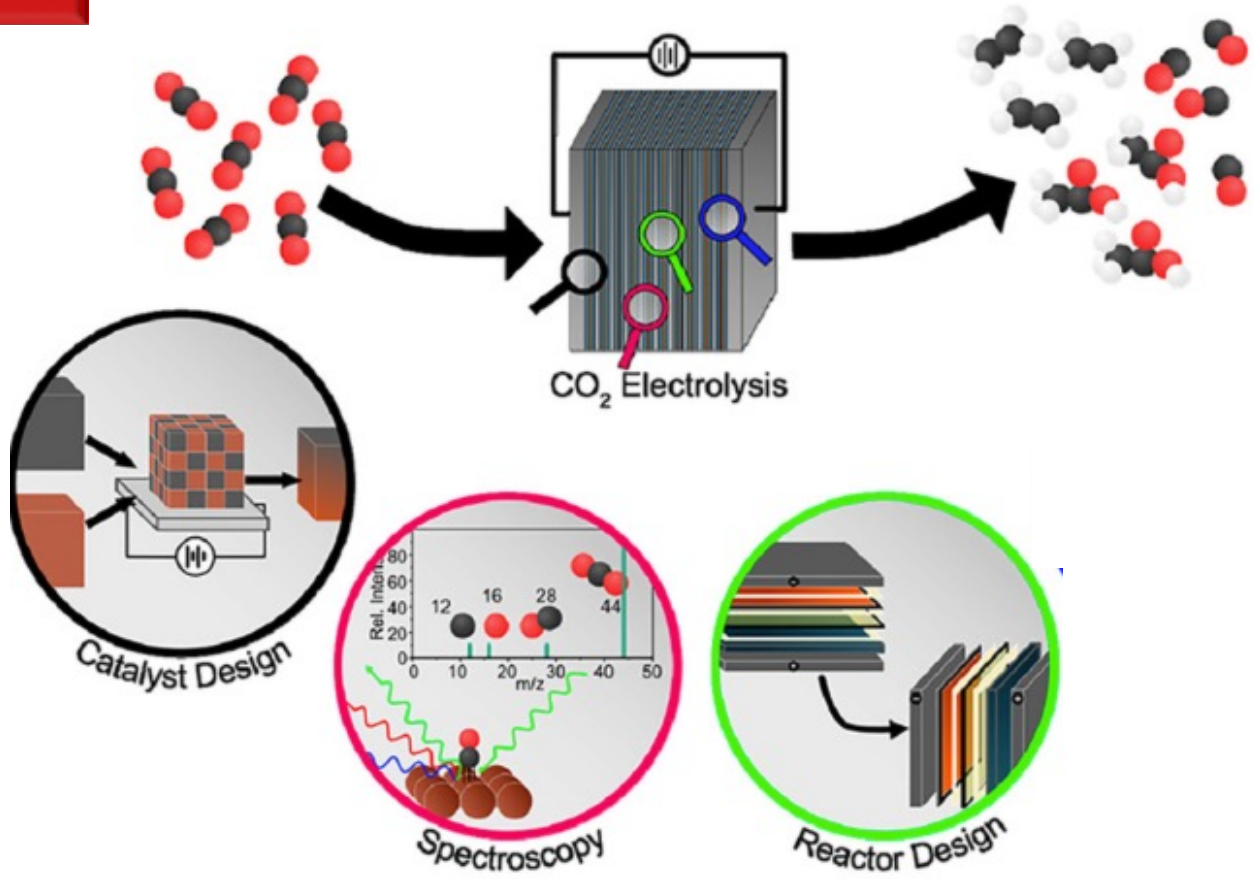
A TETRIS-like problem…

- Technologies
- Chains
- Systems

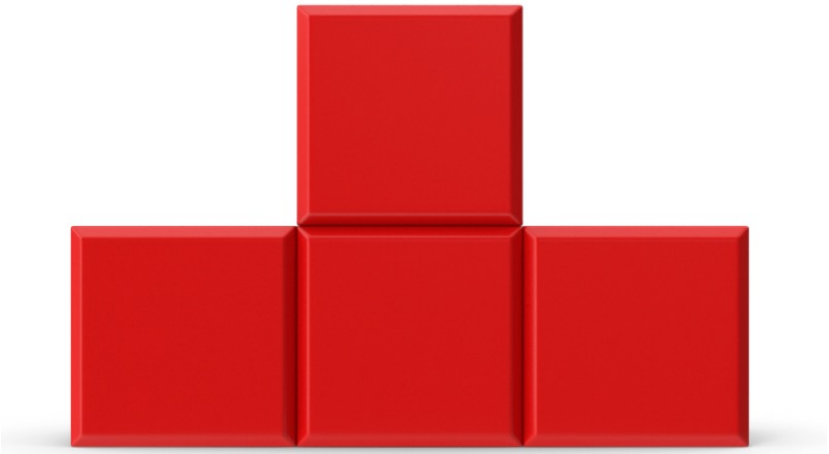


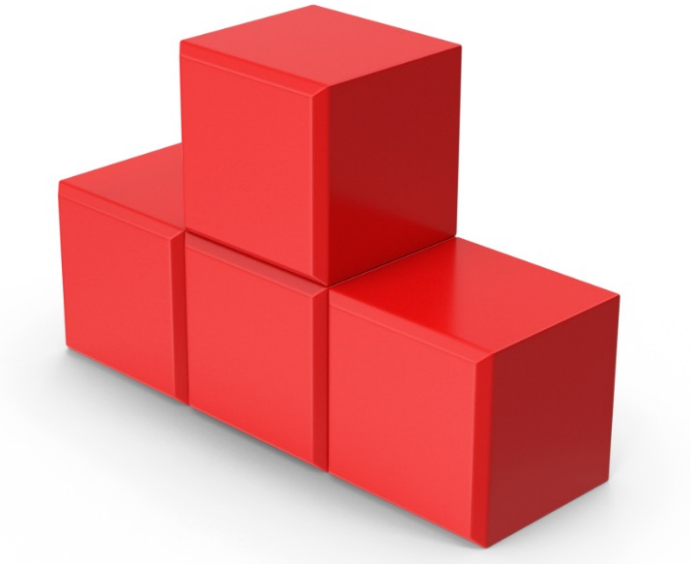


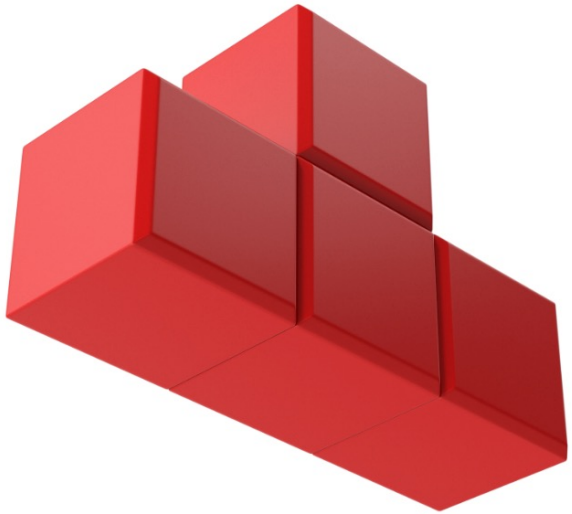
Zooming In

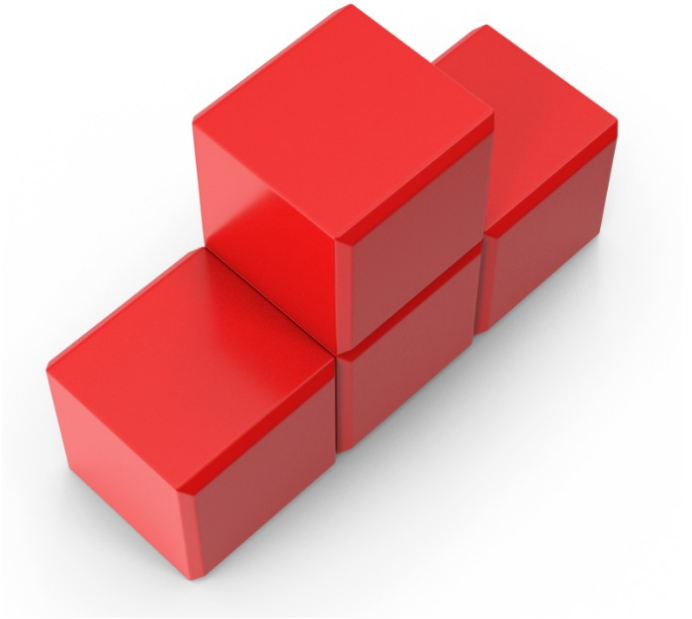


Modified from : Overa et al., 2022

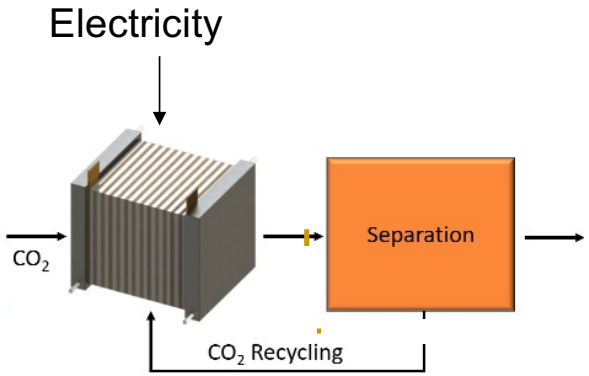




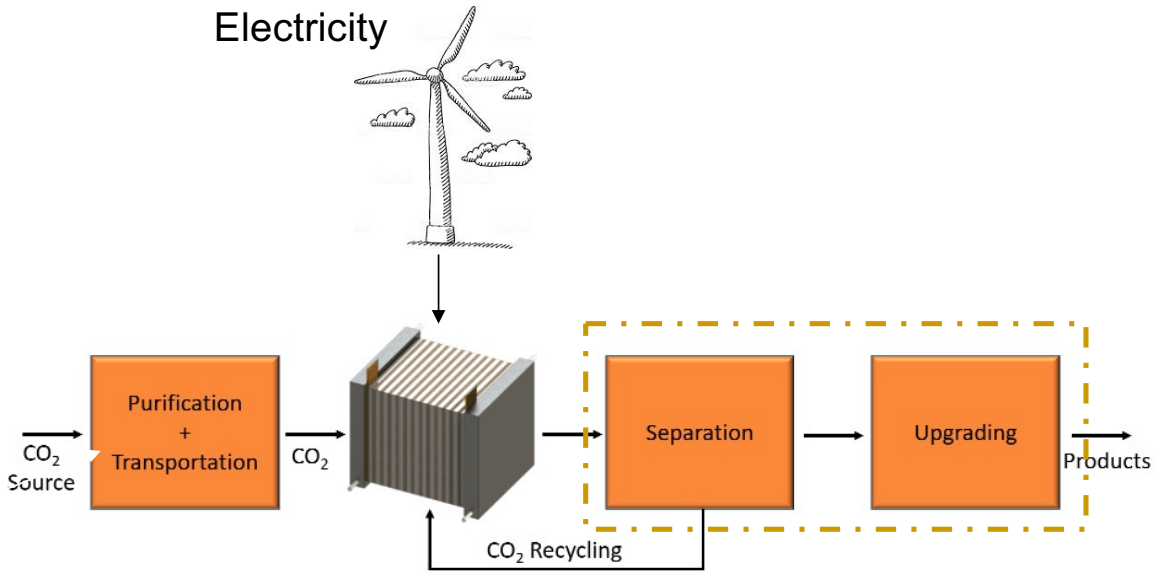




The assessment of novel technologies requires zooming out from the core aspect of the technology……



Graphic: Courtsey dr Tom Burdyny (TUD)



Graphic: Courtsey dr Tom Burdyny (TUD)

Ex-ante Technology Assessment

- provides a means to EXPLORE the FUTURE performance of technologies at low TRL level
- uses a combination of process modelling, economics and life cycle assessment
- takes a value chain approach to vertically expand the boundaries of assessment (from cradle to grave)

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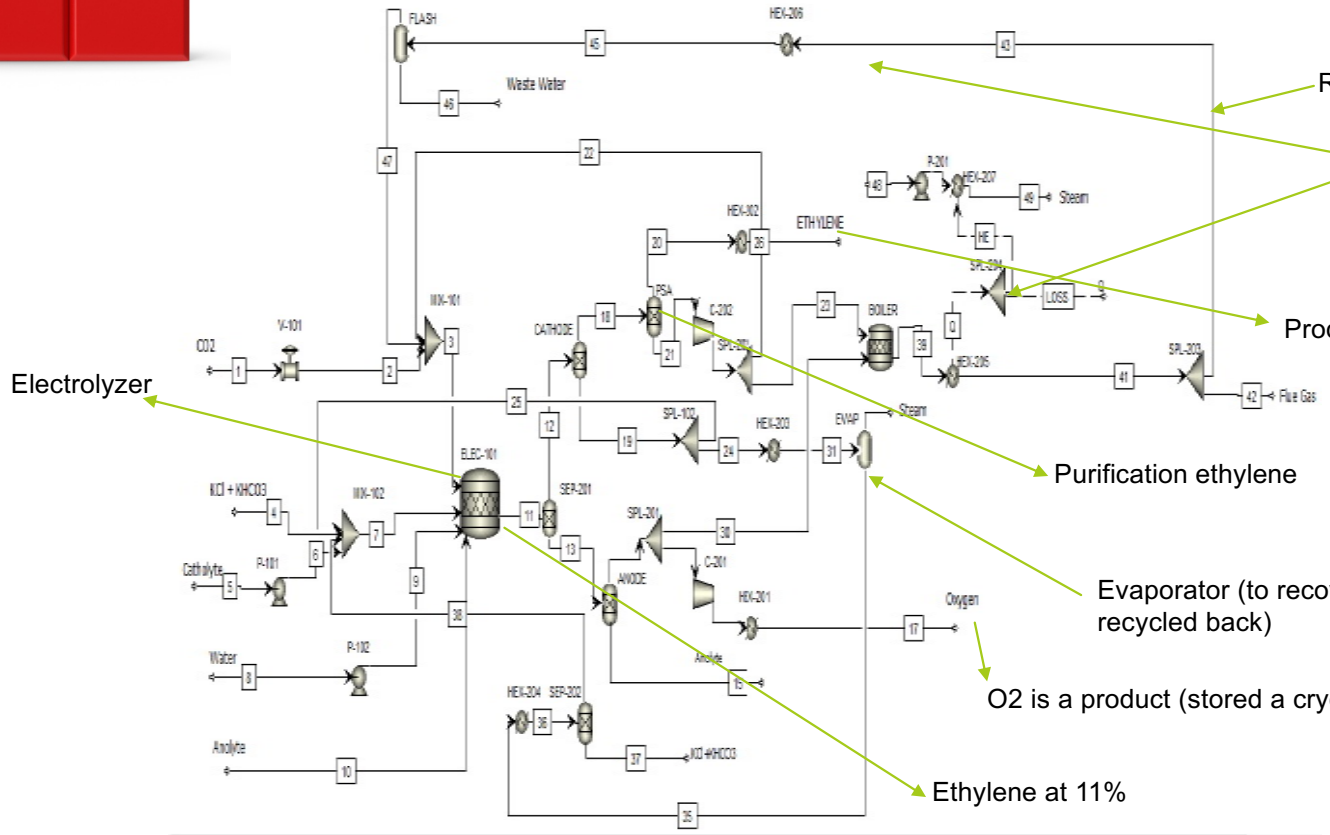


Recycling of CO_2

Heat integration

Product

Electrolyzer

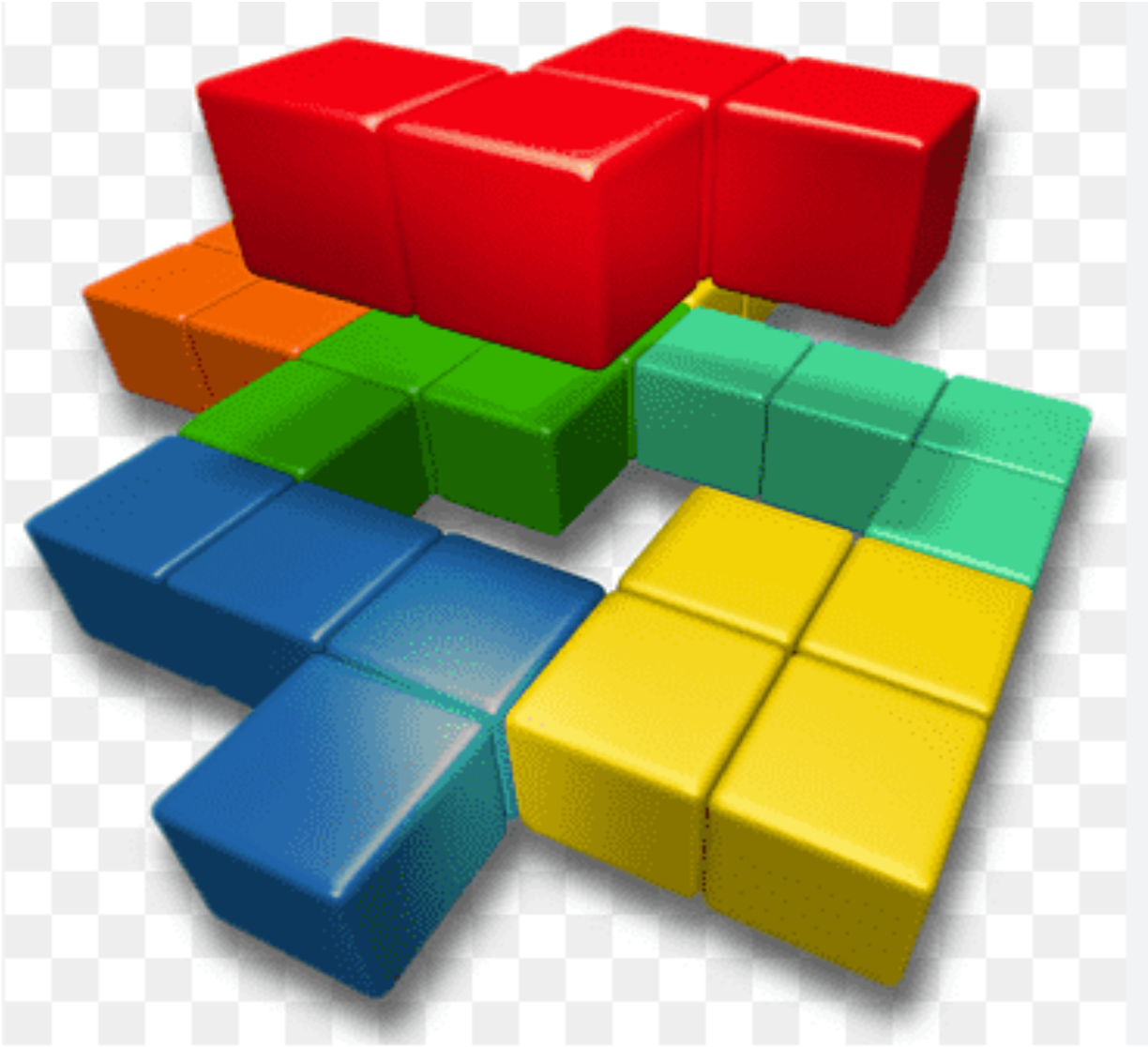
Purification ethylene

Evaporator (to recover inorganics and recycled back)

O2 is a product (stored a cryogenic temperature)

Ethylene at 11%

Source: Moncada, Torri, Eger, Burdyni, Smith and Ramirez (under preparation)



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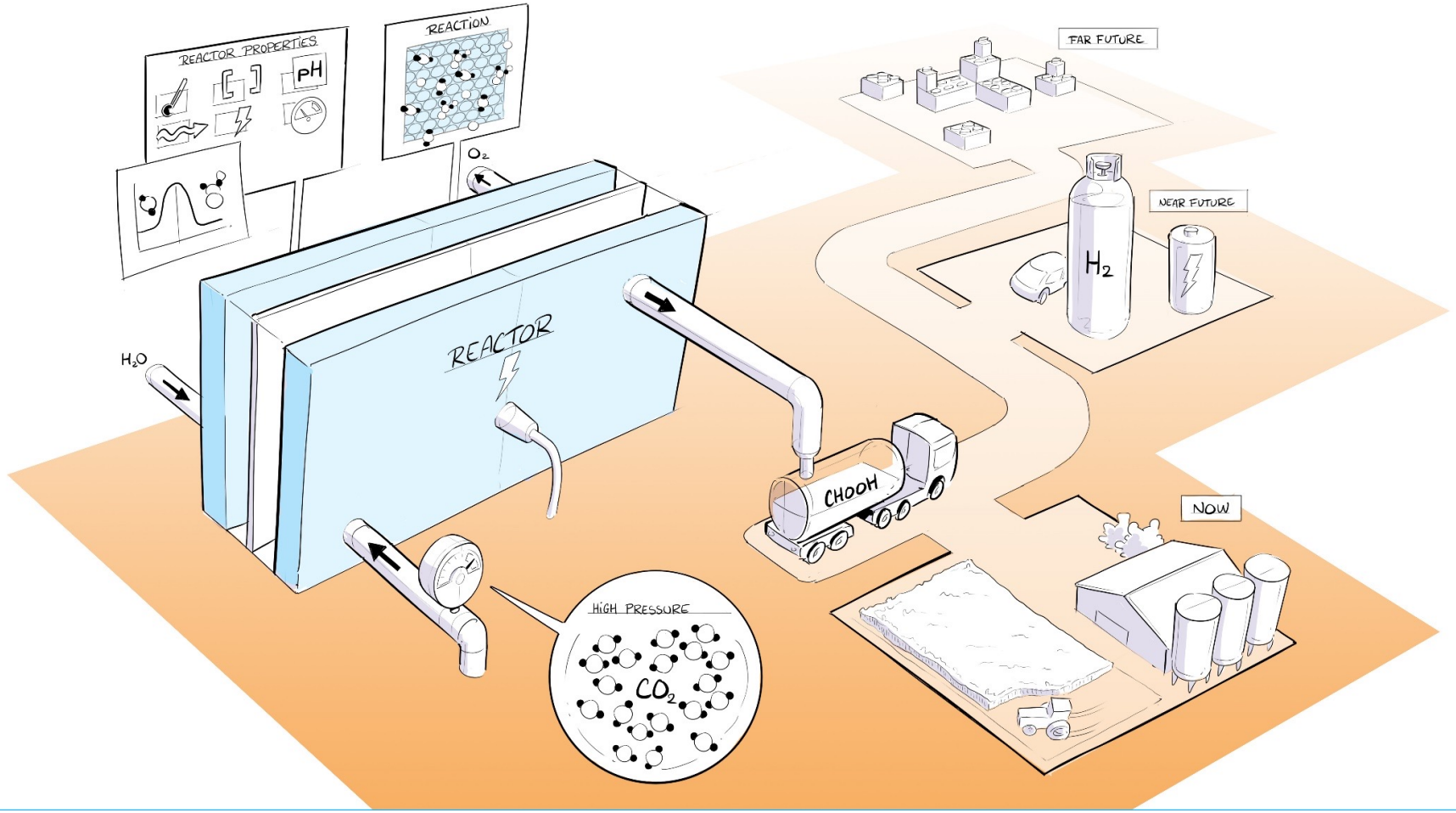
e:Refinery

Towards sustainable production of chemicals and fuels



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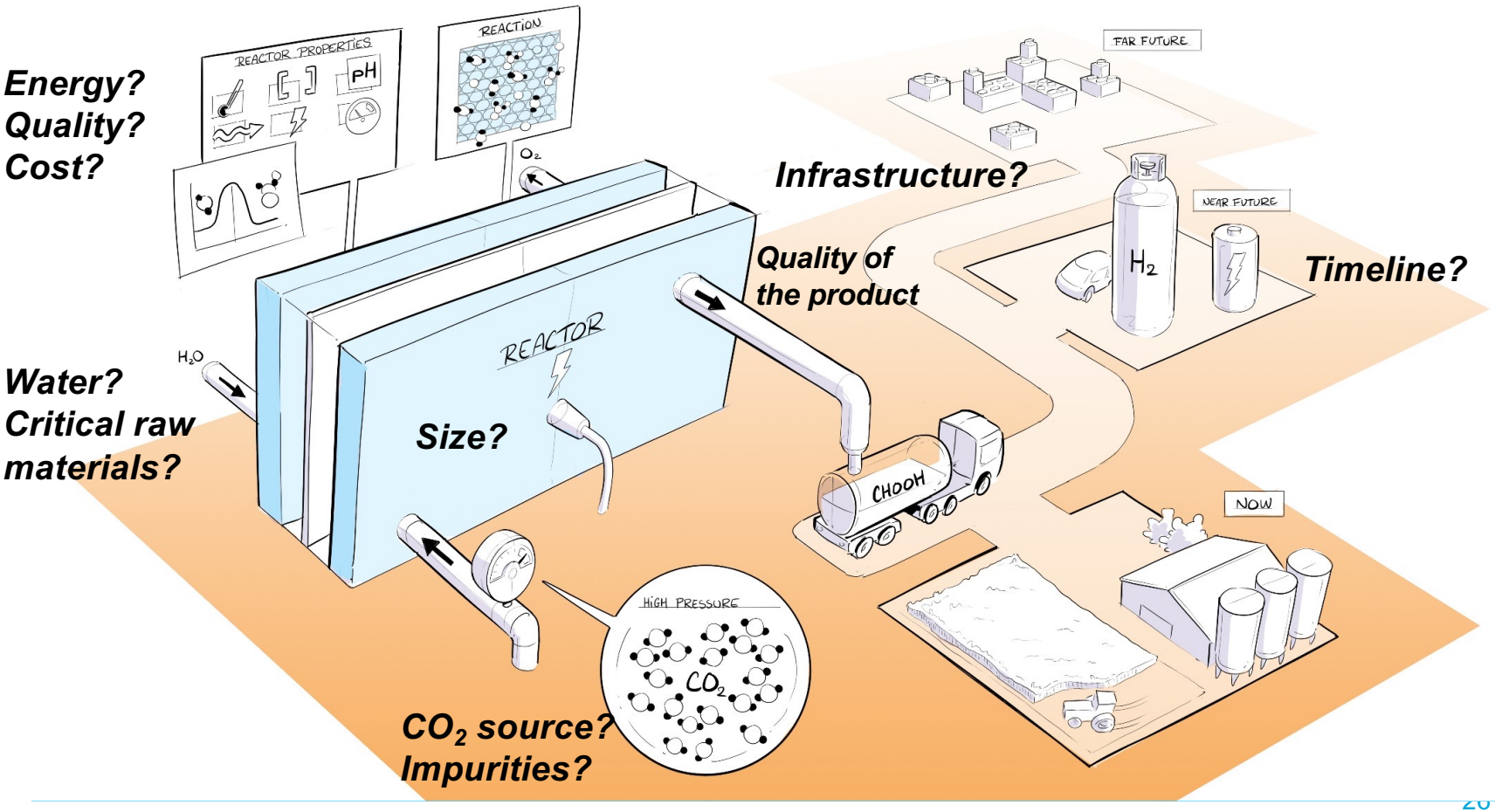
e:Refinery
Towards sustainable production of chemicals and fuels



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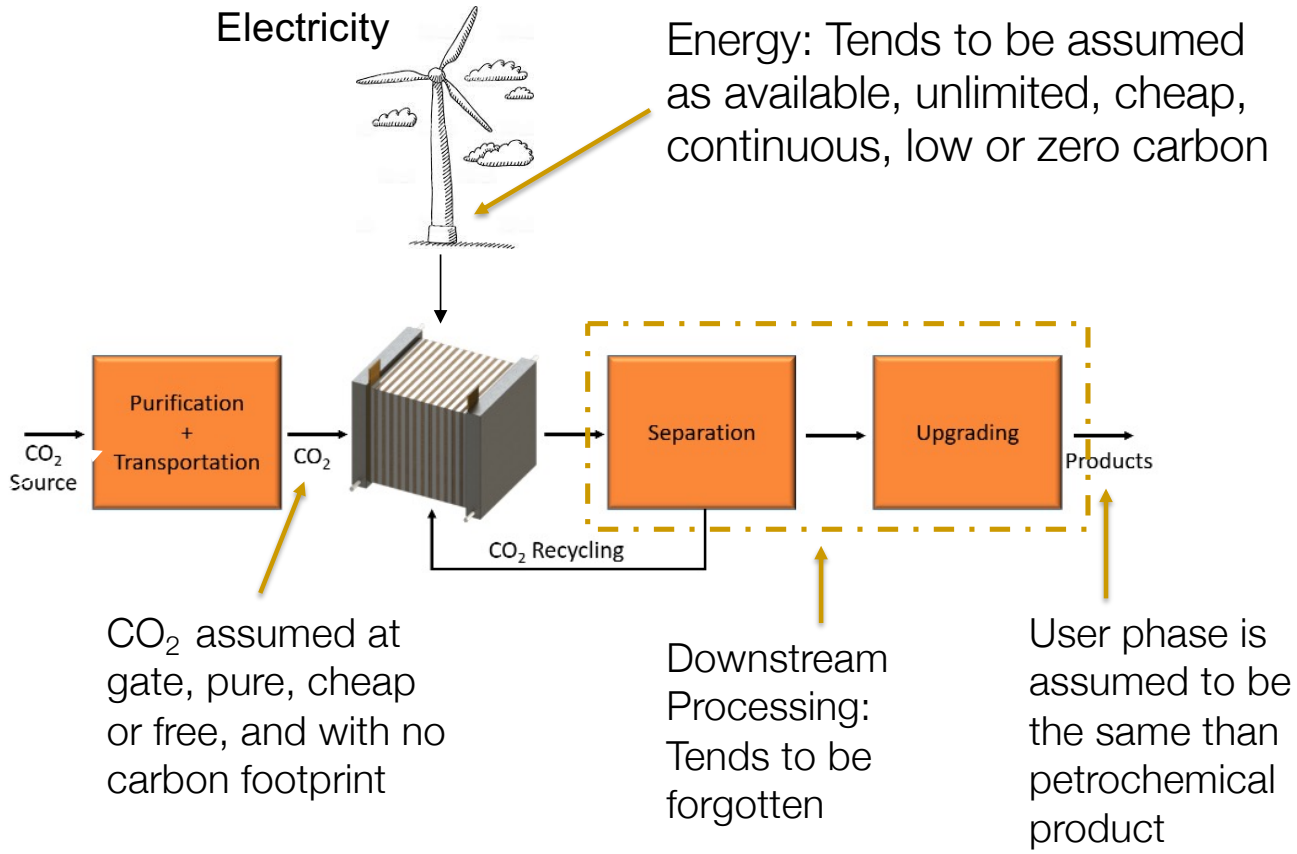
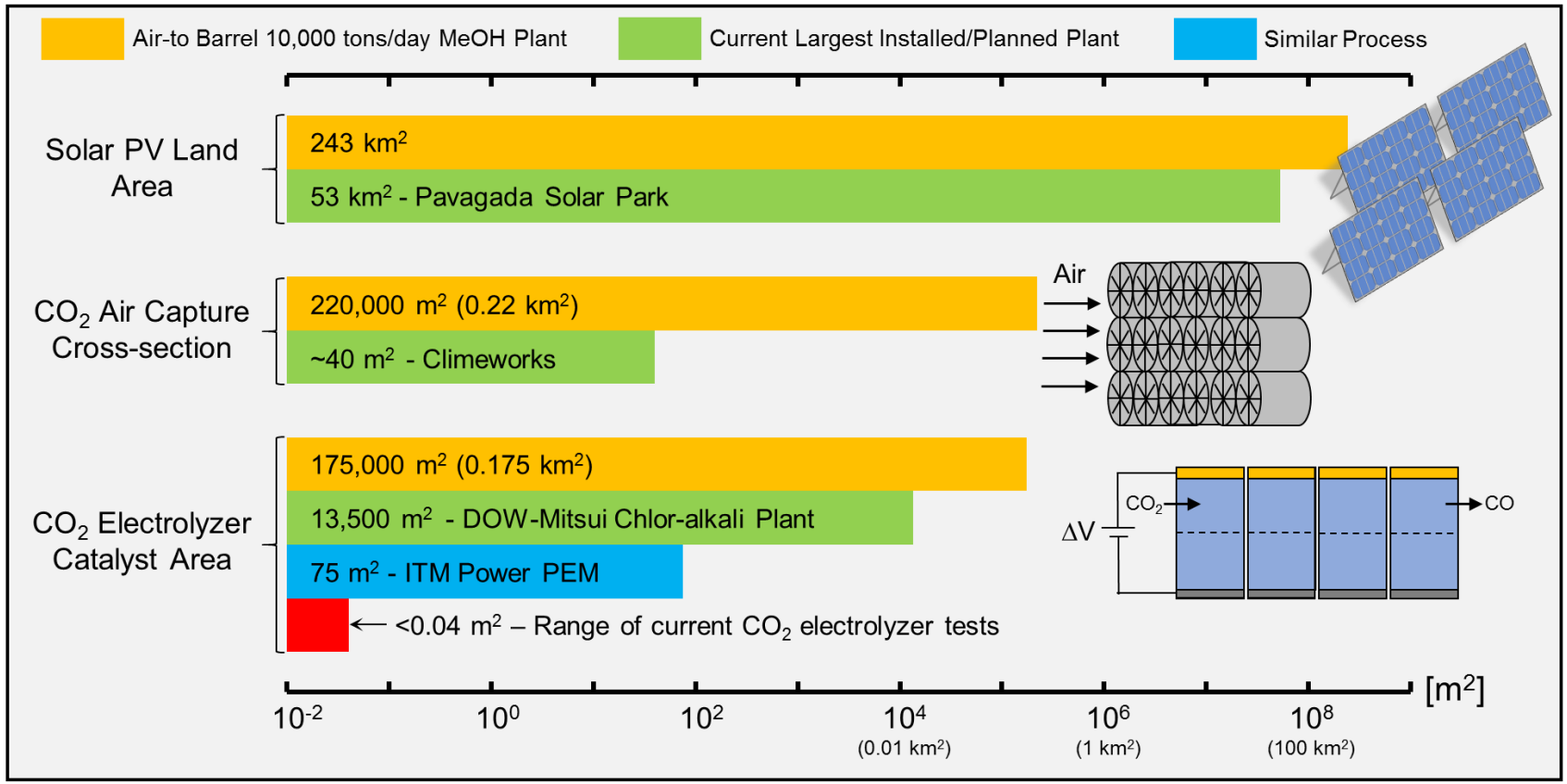


Graphic: Courtsey dr Tom Burdyny (TUD)

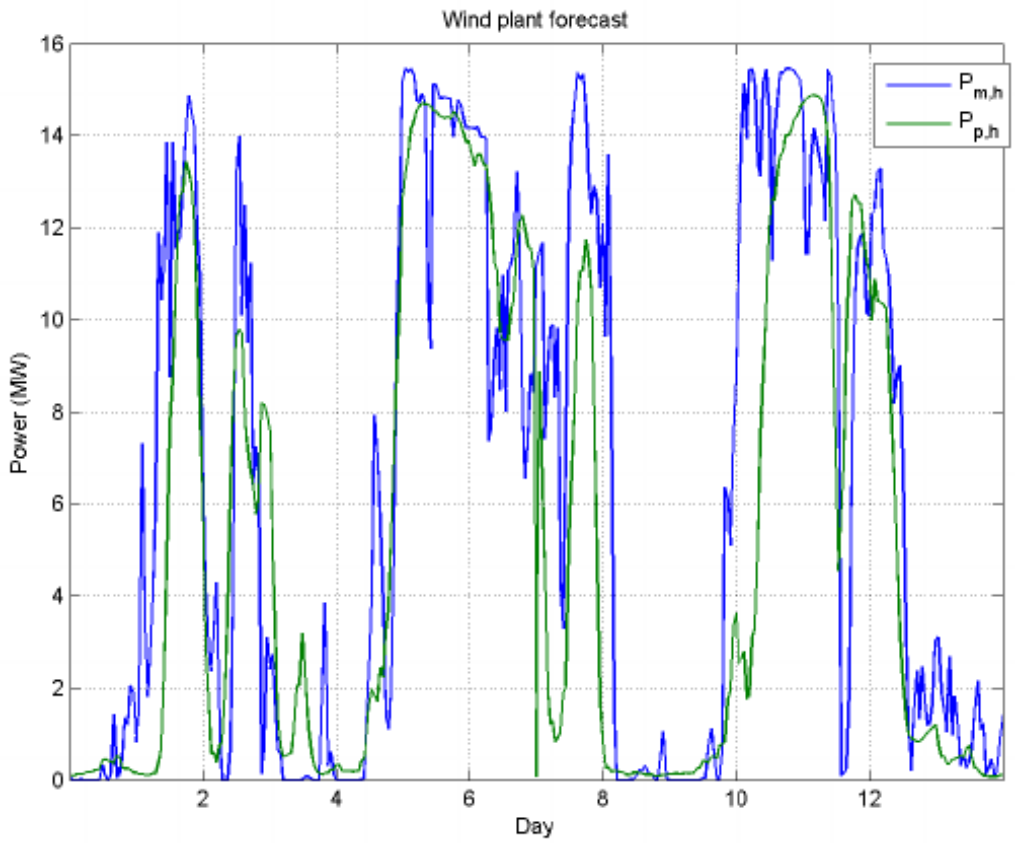
Imagining a global-sized CO_2 electrolyzer for methanol



Nel water electrolysis plant is ~37,500 m²

Smith, Burdyny, Vermaas, Geerlings. (2019) *Joule, 10.1016/j.joule.2019.07.009*

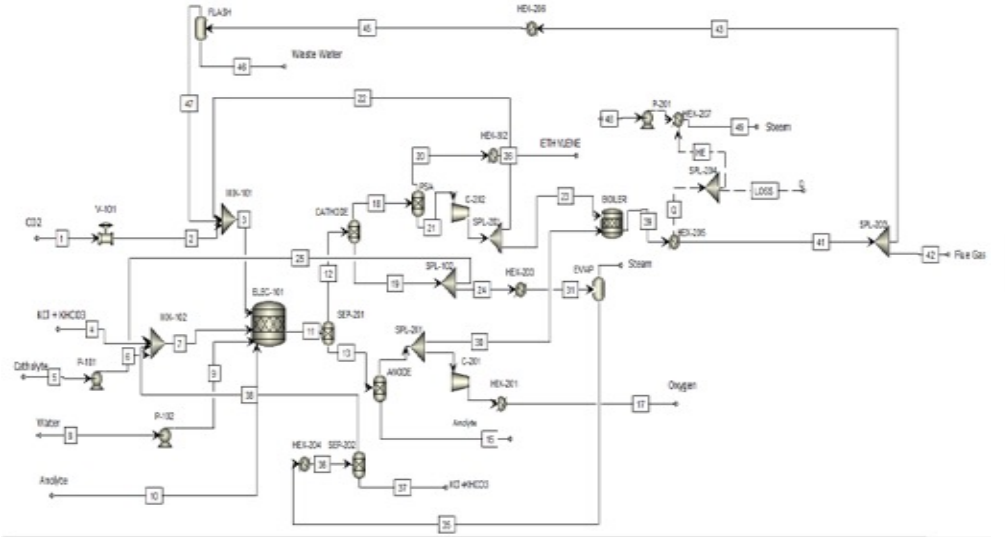
What about intermittency?

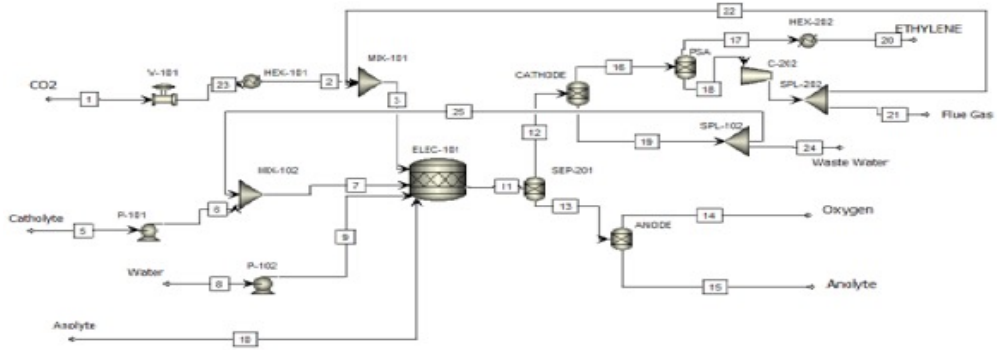


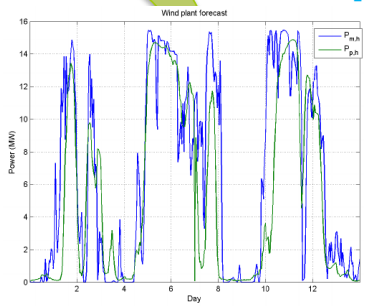
e:Refinery
Towards sustainable production of chemicals and fuels

Impact of intermittency in plant design

Example: electrochemical conversion of CO_2 ethylene







to allow flexibility:
-Changing heat integration
-Reduced Size
-Temporal storage

The plant layout, capacity, mass and energy balances are now different!

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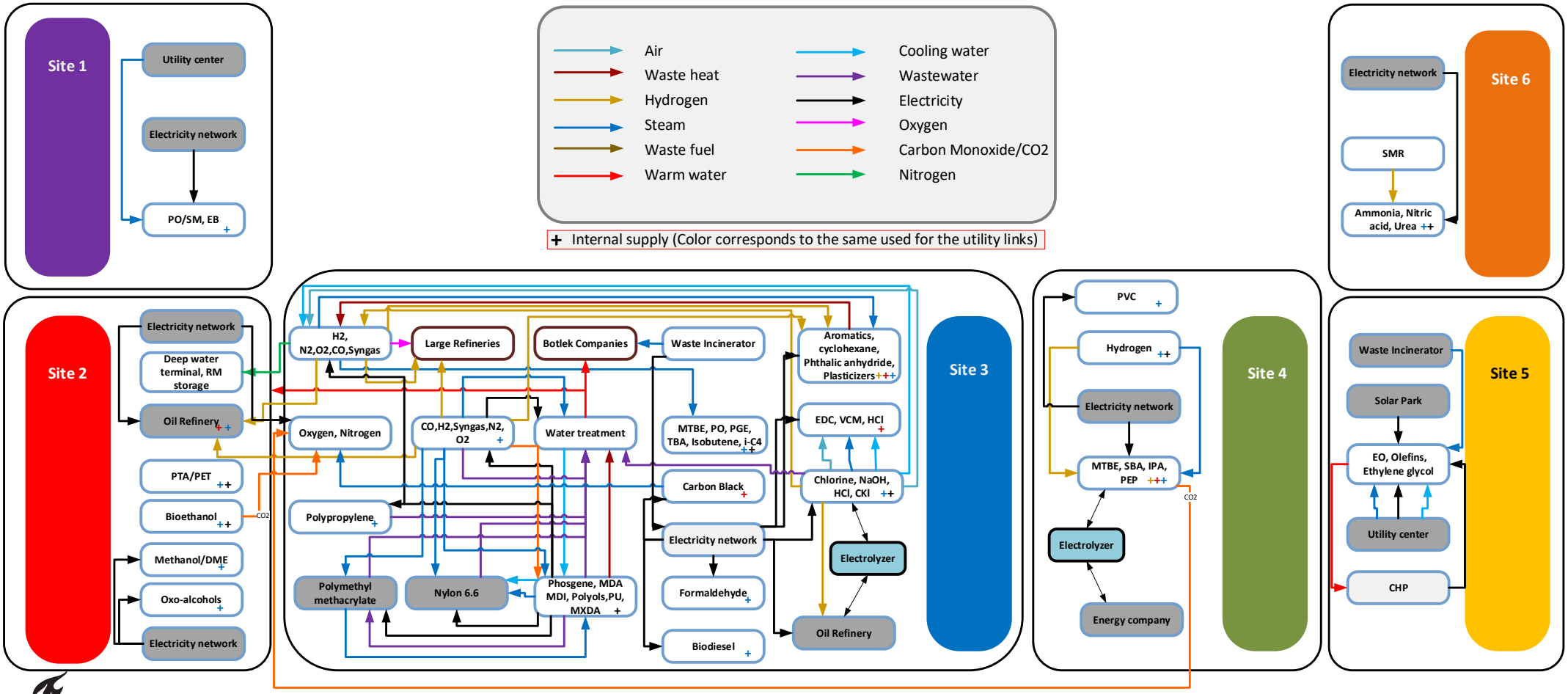
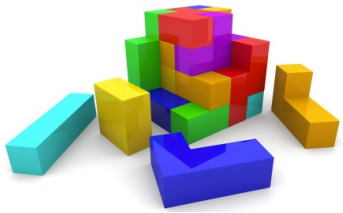
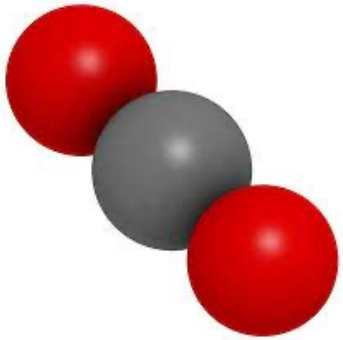
- Mapping of current utilities exchanges based in the Port of Rotterdam

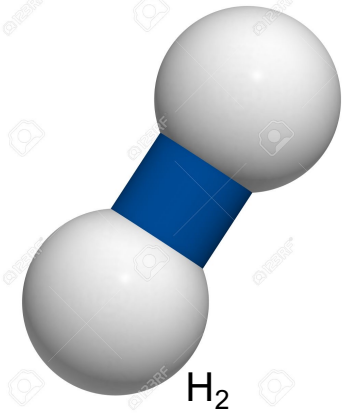


Enabling infrastructure

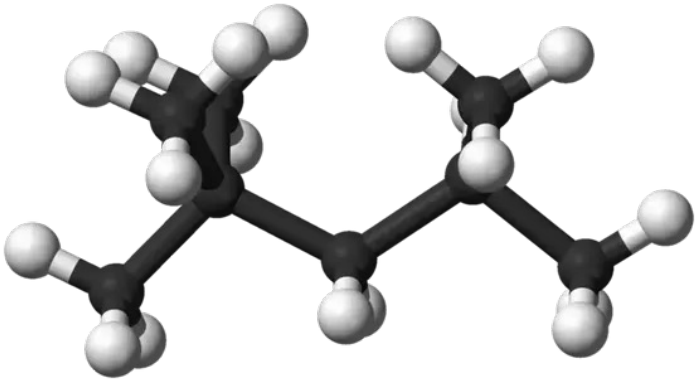




CO_2



H_2



- Capture of CO_2
- Transport of CO_2
- Temporal storage of CO_2

- Water
- Electricity
- Electricity storage
- Transport of H_2
- Temporal storage of H_2

- Fuel distribution

Centralized production (takes advantage of economies of scale) vs Decentralized production (takes advantage of economies of location/ number)

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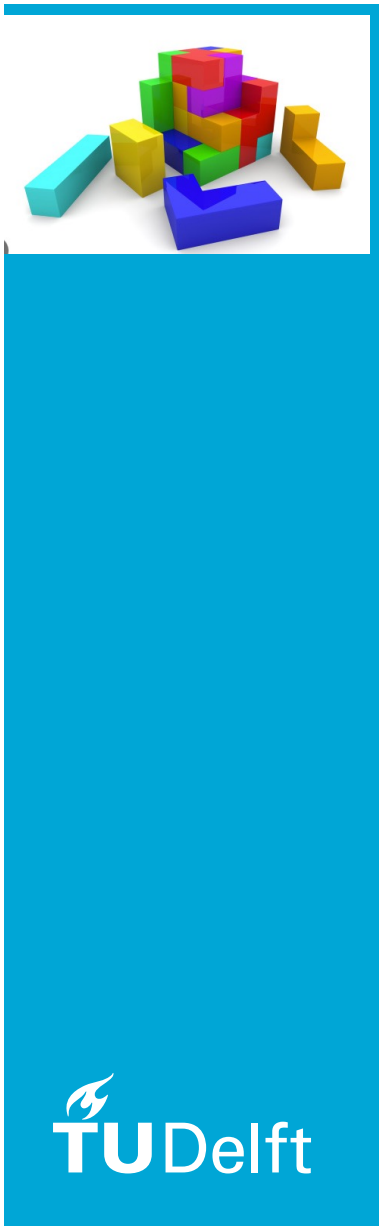


Industry Y

Flue gas

Air

CO2

Hydrogen

Purification

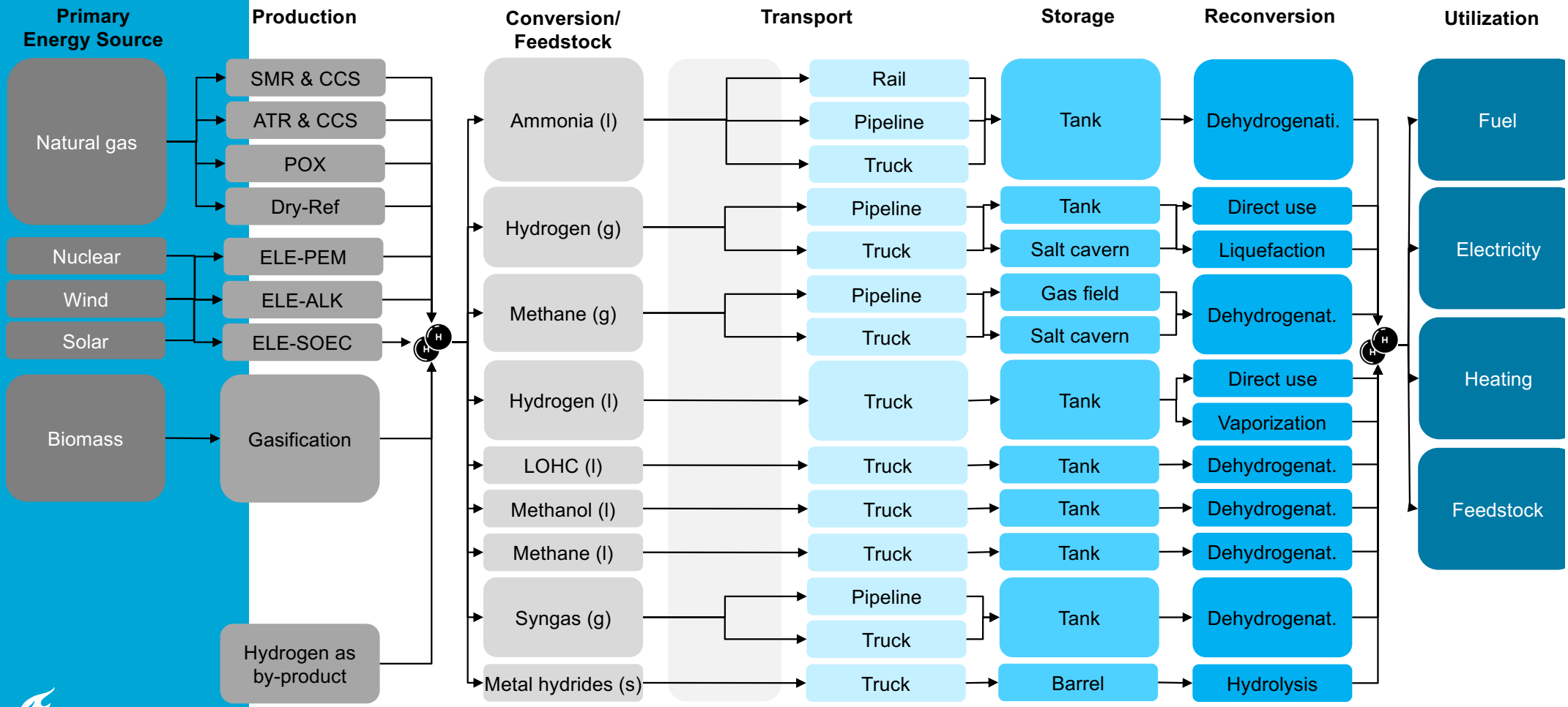
Storage

Technology X

Storage

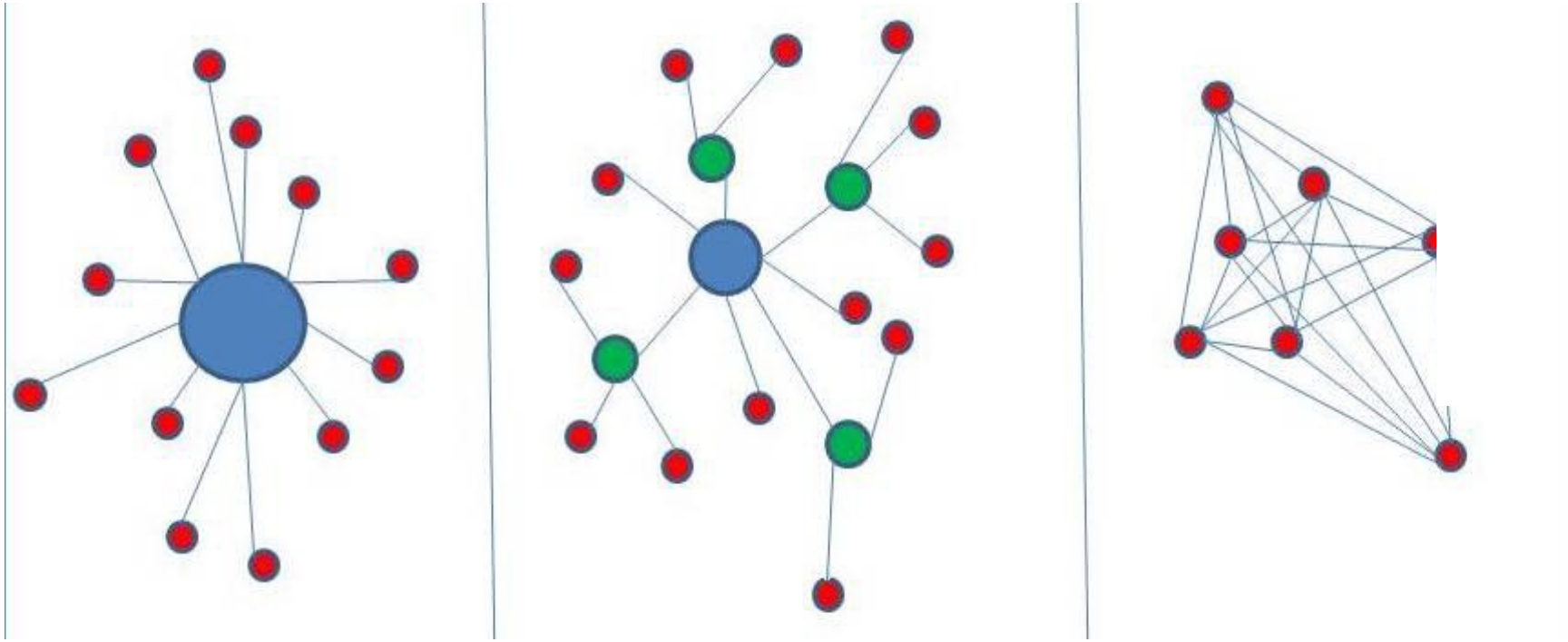
Hydrogen

Design not only process but also chains



Source: Hiestermann M., (2022).

Size matters!



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Adobe Stock | #467228413

Lack of understanding on how the system will develop	• lock-in situations • danger of stranded assets
Inadequate policy guidance	• unclear role in achieving climate targets • limited existing policy design • new policies needed to speed scaling -up
Challenging permitting environment	• numerous jurisdictions involved • variability in conditions for transport and storage regulations
Uncertain costs	• challenges aligning players, permitting and financing • long-term liability
Lack of public awareness and varying support	• low public awareness and varied opinions about infrastructure • historic inequities in infrastructure sitting • concern of continued fossil fuel use

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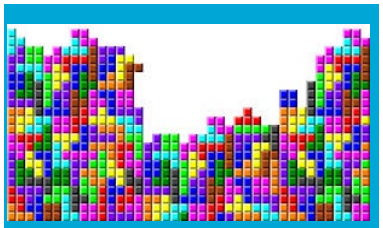

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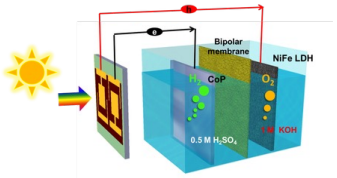
Zoom in

Zoom out

Feedstock (CO2)
Catalyst
Electricity



Lab scale

Resource consumption

Feedstock (e.g. flue gas)

Pretreatment

Photo/electro chemical Conversion

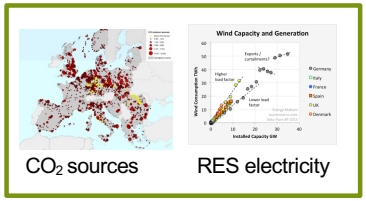
Downstream processing/ upgrading

Product
Coproduct

Waste and emissions

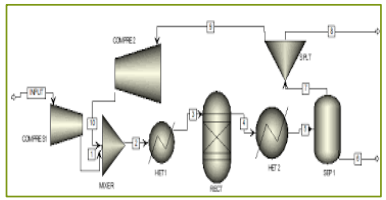
Process scale

Feedstock → Conversion & Upgrading → Distribution &end use



CO_2 sources

RES electricity



Supply chain

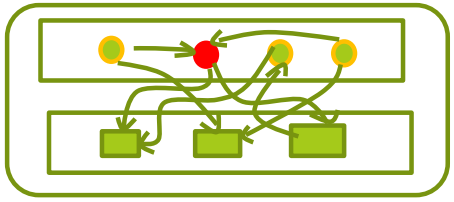
Lithosphere

Hydrosphere

Atmosphere

Biosphere

Ecosystems



Economy interconnections

Socio-economic system

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