



# Defossilizing Petrochemical Clusters under a Regional Perspective: Evolution or Revolution?

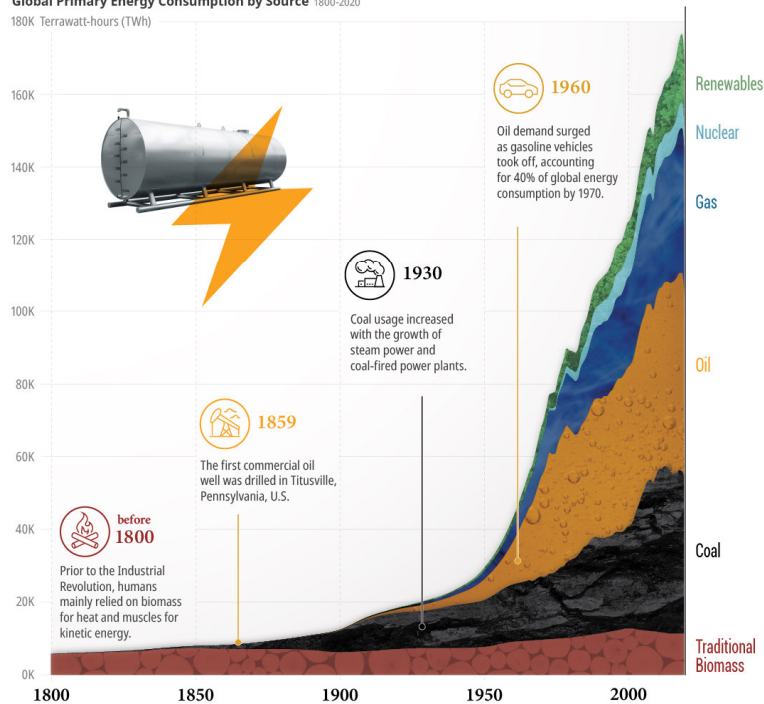
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Chair Low Carbon Systems and Technologies  
Delft University of Technology

## THE HISTORY OF Energy Transitions

The economic and technological advances over the last 200 years have transformed how we produce and consume energy.

Here's how the global energy mix has evolved since 1800.

**Global Primary Energy Consumption by Source 1800-2020**  
180K Terrawatt-hours (TWh)



Source: Vaclav Smil (2017), BP Statistical Review of World Energy via Our World in Data

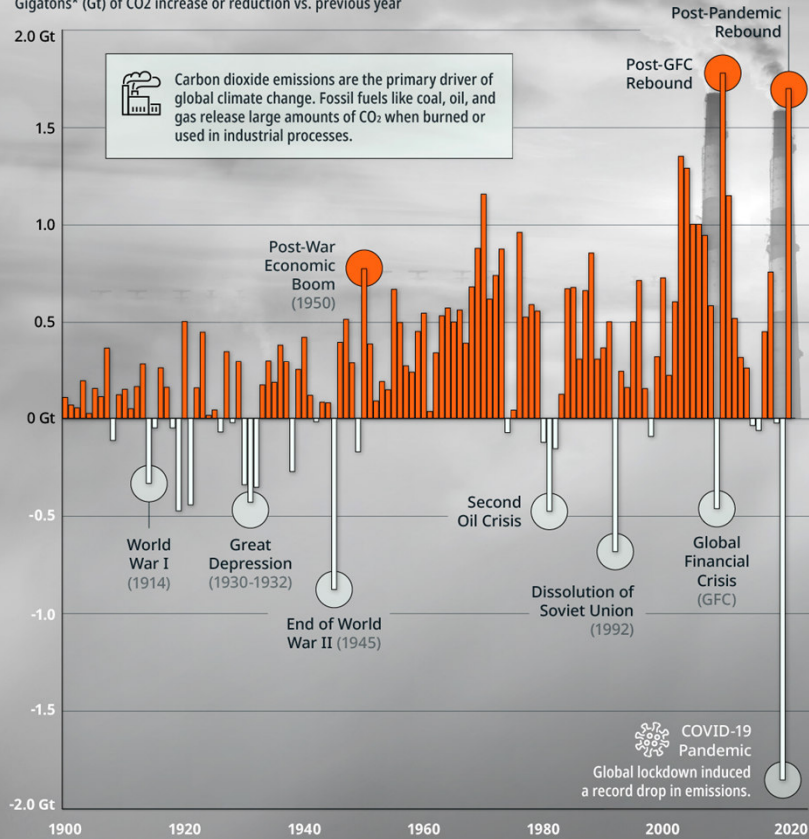
ELEMENTS

ELEMENTS.VISUALCAPITALIST.COM

## CO<sub>2</sub> EMISSIONS SINCE 1900

The COVID-19 pandemic lockdowns led to the biggest drop in CO<sub>2</sub> emissions. The level of CO<sub>2</sub> emissions has, however, risen since the pandemic.

**GLOBAL FOSSIL CO<sub>2</sub> EMISSIONS Annual Changes**  
Gigatons\* (Gt) of CO<sub>2</sub> increase or reduction vs. previous year

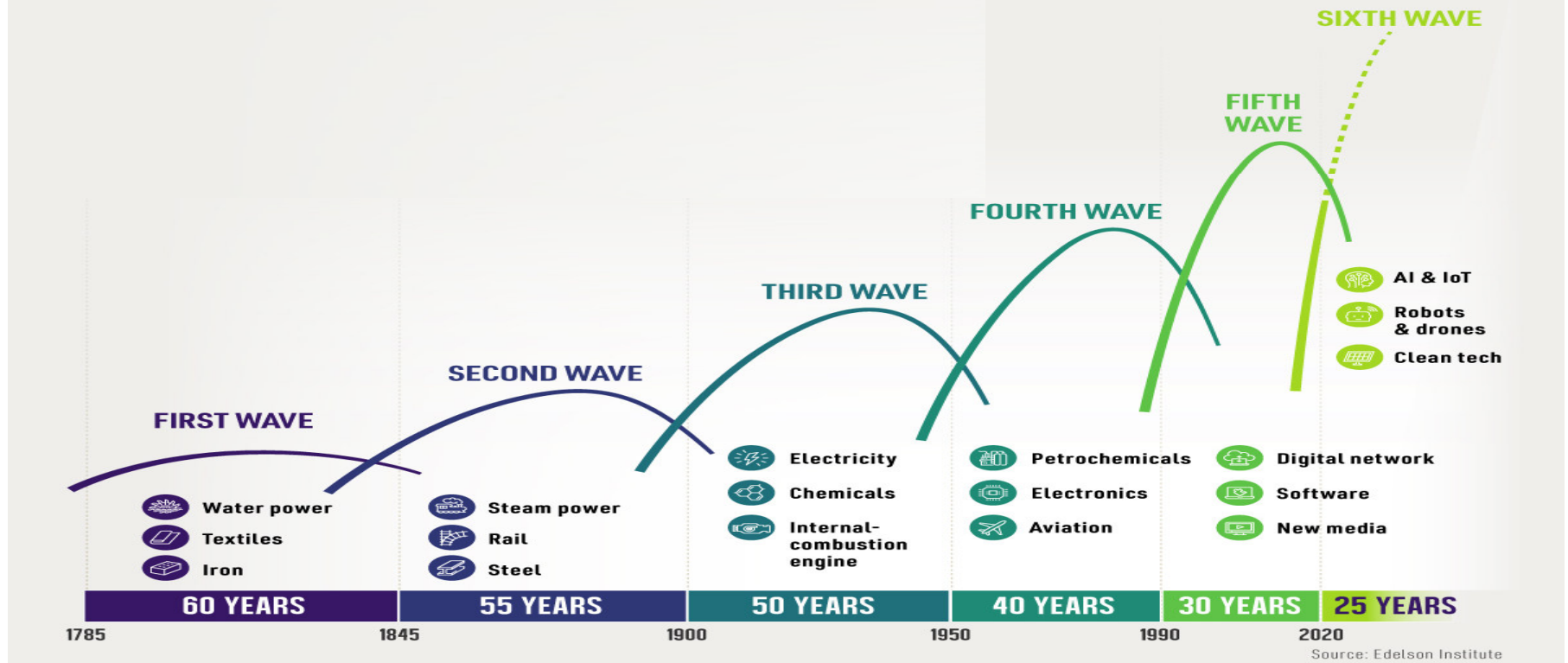


\*Equivalent to one billion metric tons

The History of

# INNOVATION CYCLES

Below, we show waves of innovation across 250 years, from the Industrial Revolution to sustainable technology.





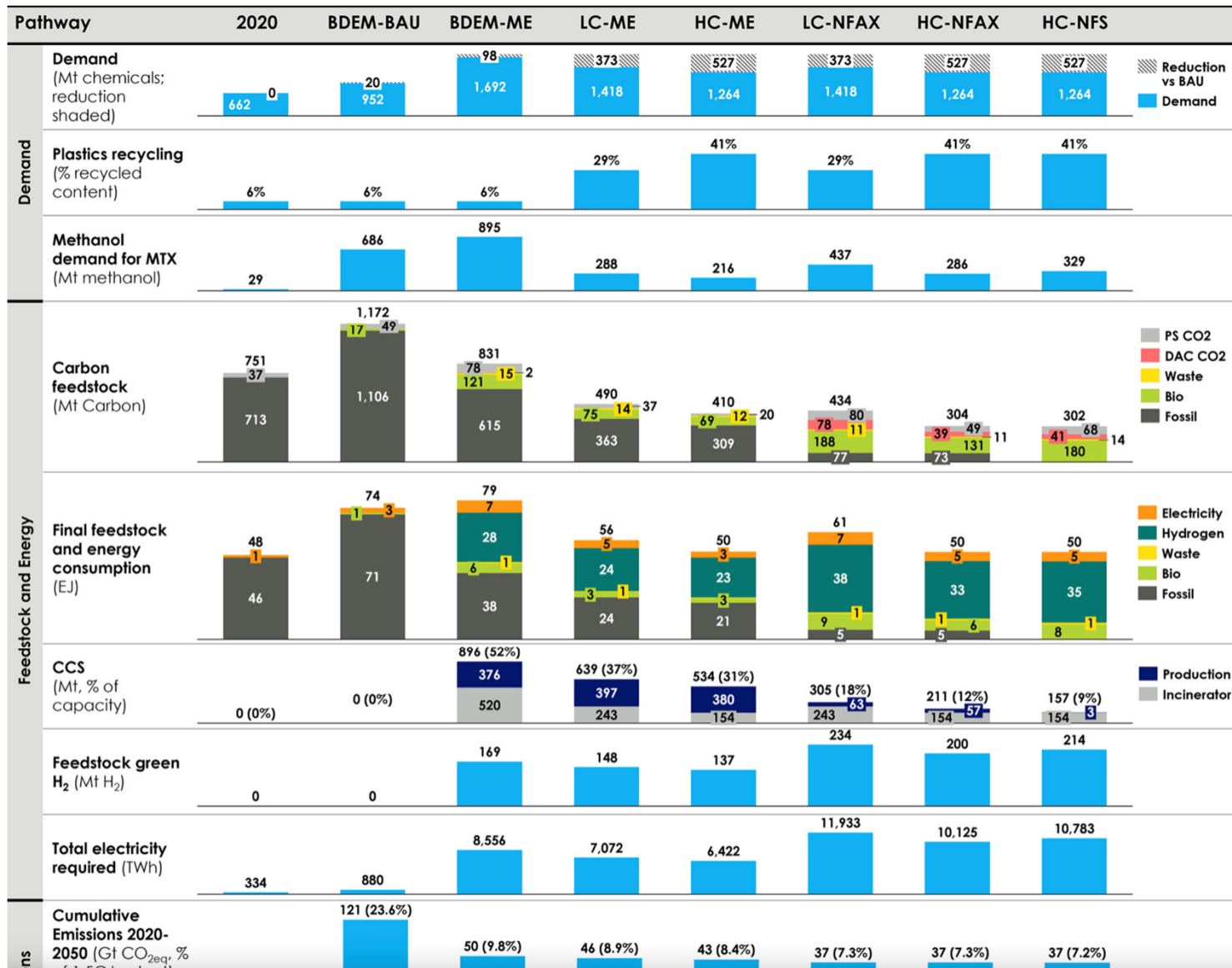
A creative picture about the defossilisation  
of the chemical industry Generated with AI  
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# Zooming OUT there are 3 key strategies:

- Use less resources
  - Increase efficiency
  - Reuse
  - Recycle
  - Degrowth
- Decarbonize energy sources
- Replace fossil fuels with alternative feedstocks in industrial sector:
  - Waste
  - Biomass
  - CO<sub>2</sub>

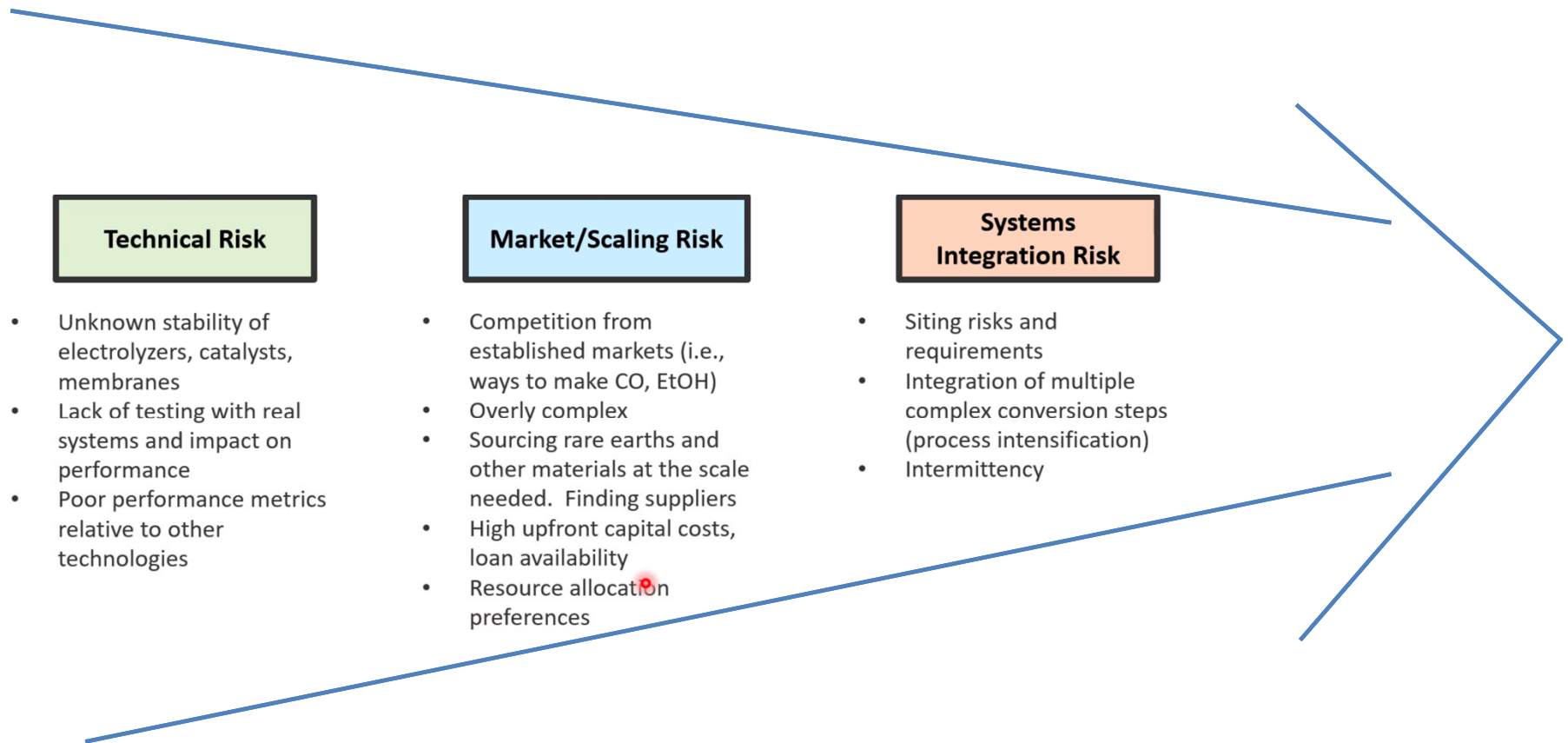




Source: Meng et al., 2023. Planet-compatible pathways for transitioning the chemical industry PNAS 120 (8)


# Where are we today?

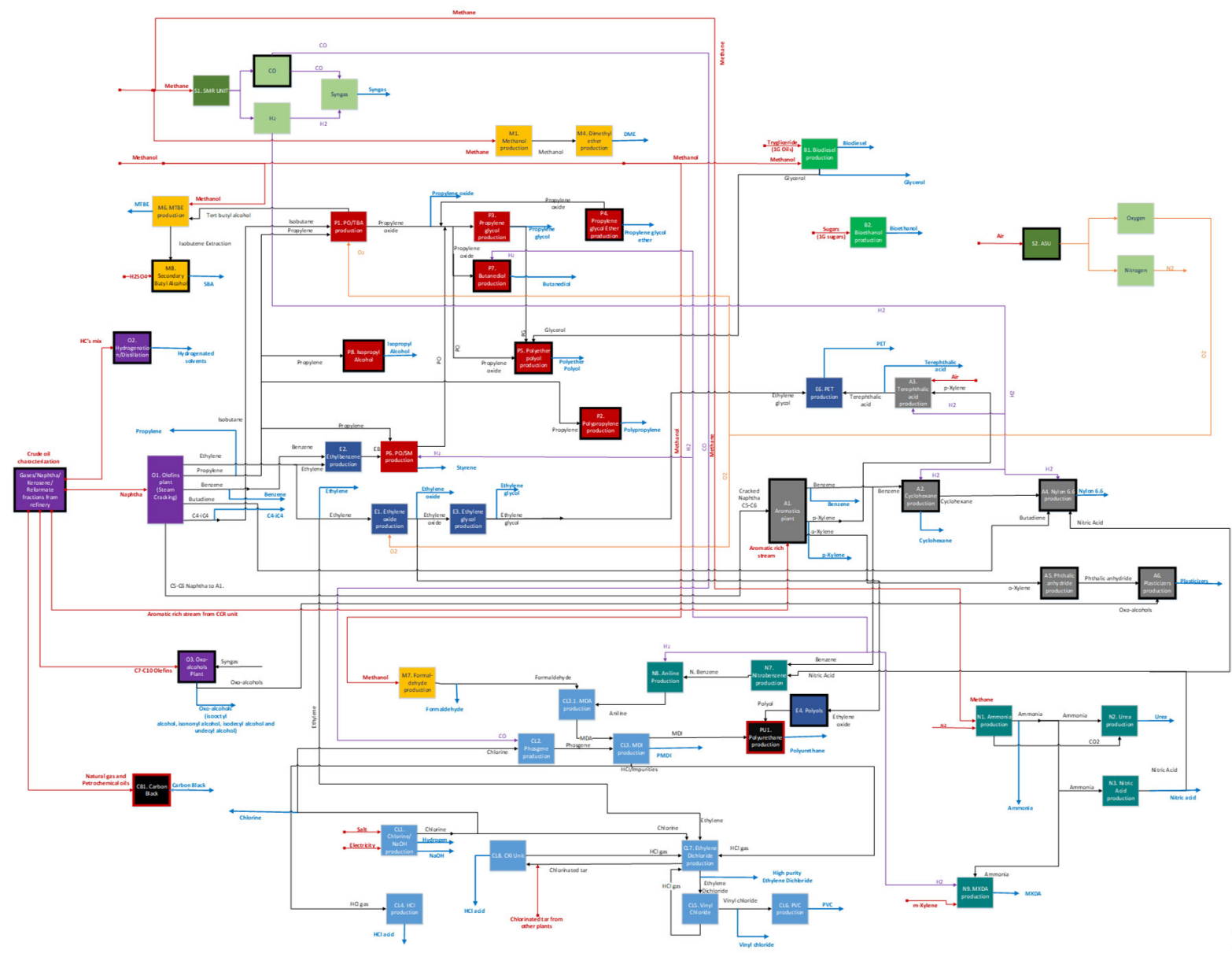
- Increase commitment to decrease CO<sub>2</sub> emissions by governments and companies
- Higher CO<sub>2</sub> emission abatements **cannot** be reached without deployment of breakthrough technologies (BAT will not take us past 30-50% max)
- **A diverse portfolio** of measures with recurrent options (electrification, BtX, WtX, CCU, CCS)
- **High dependence** on system conditions (availability of (green) electricity, H<sub>2</sub>, CO<sub>2</sub>, biomass, policies, etc)

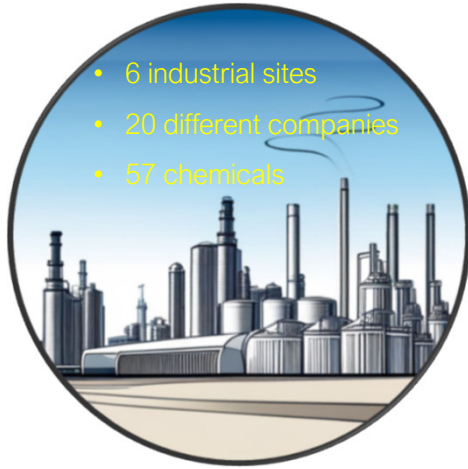




# What to change?

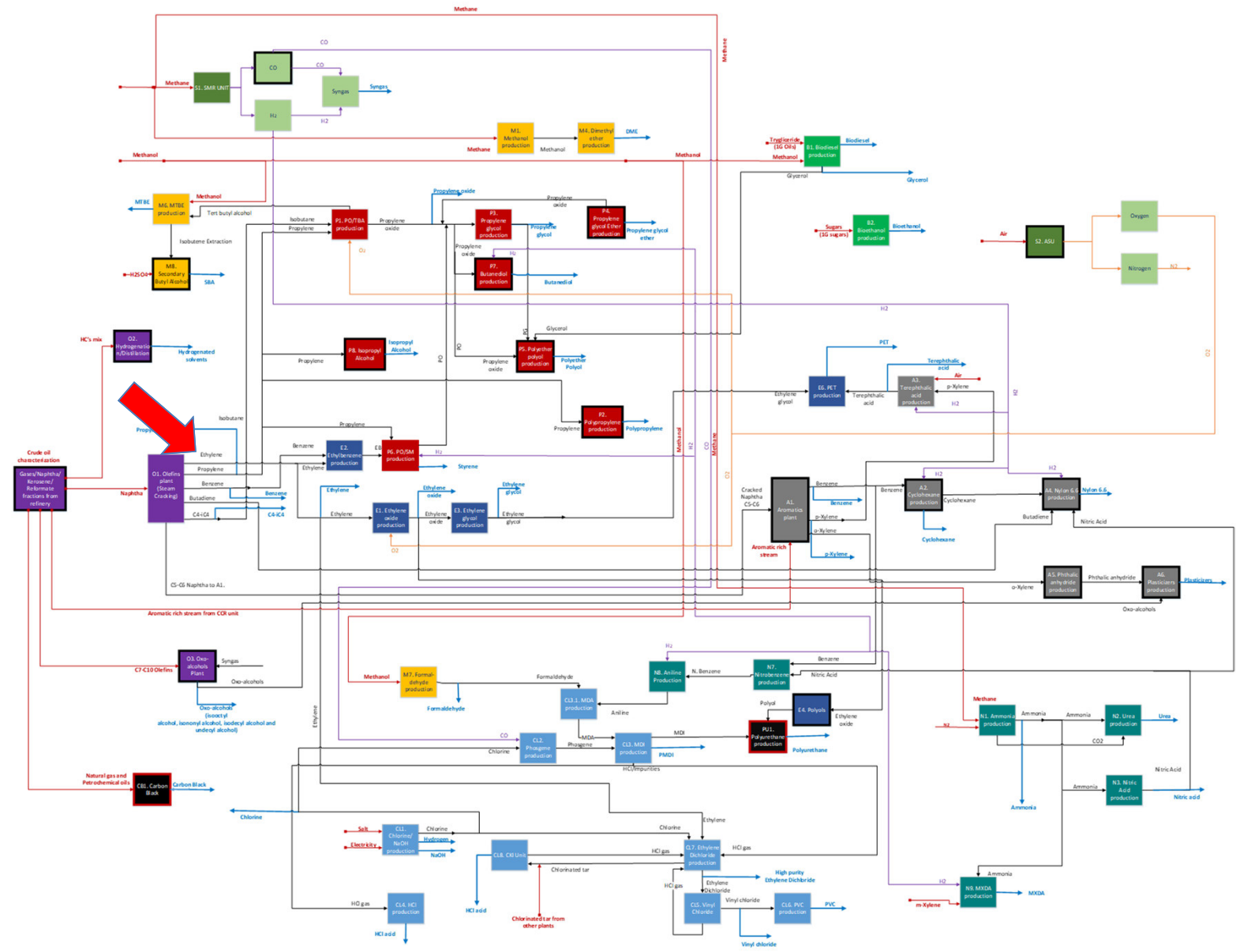
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- 6 industrial sites
  - 20 different companies
  - 57 chemicals





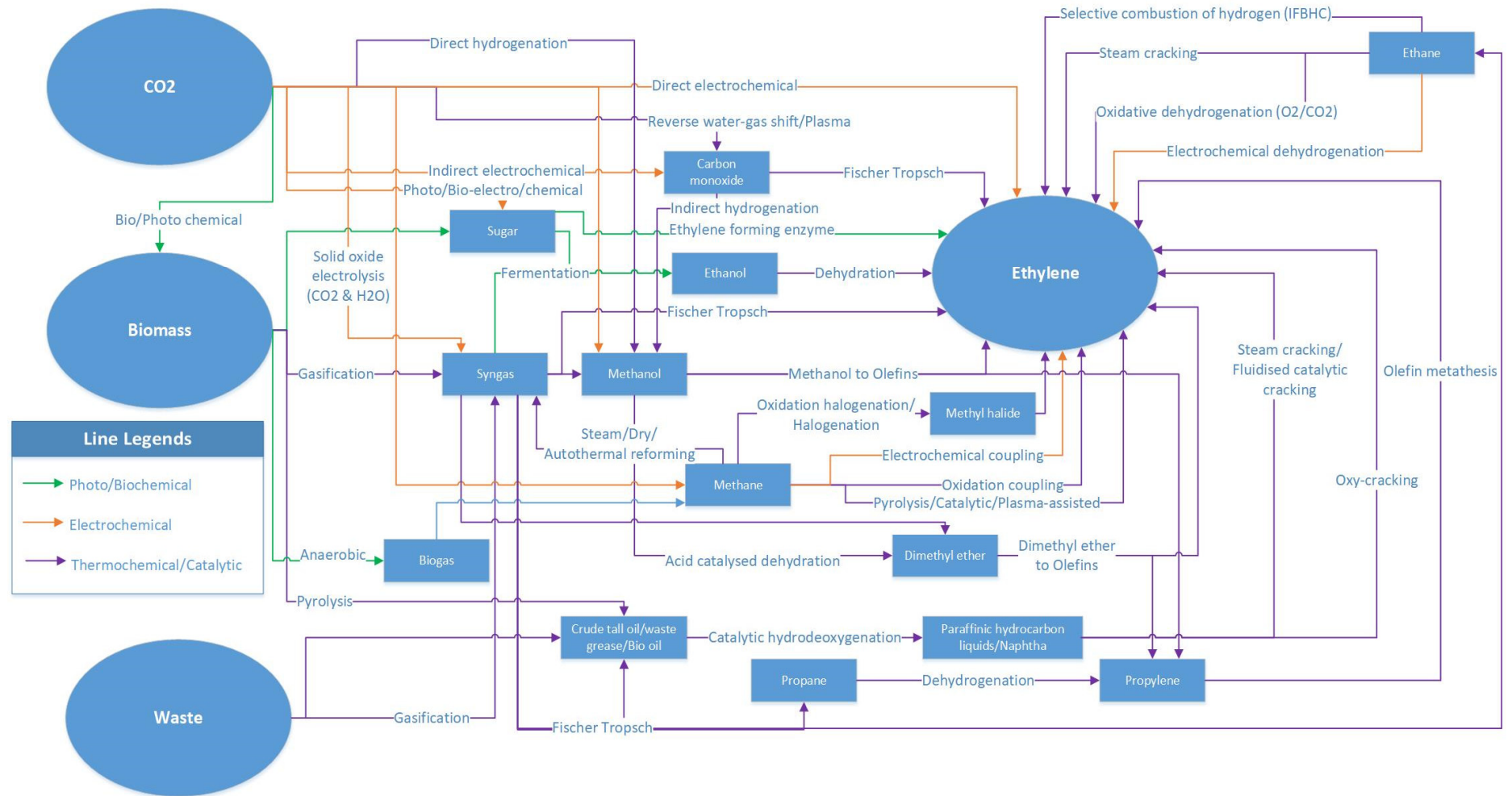
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In 2022, we produced about 163 Mt of ethylene worldwide. In Rotterdam c.a. 800Kt

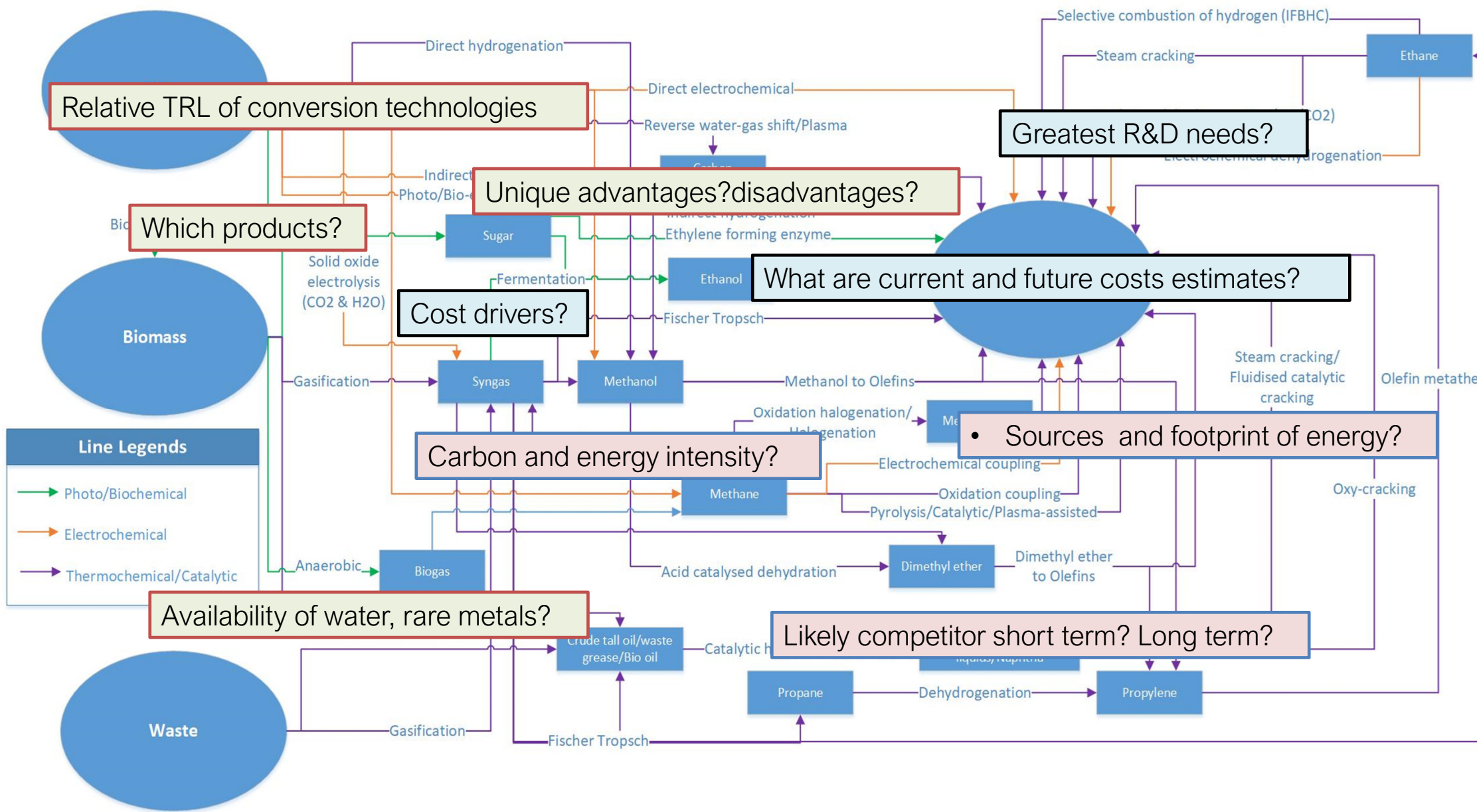


From which  
technologies/feedstock?

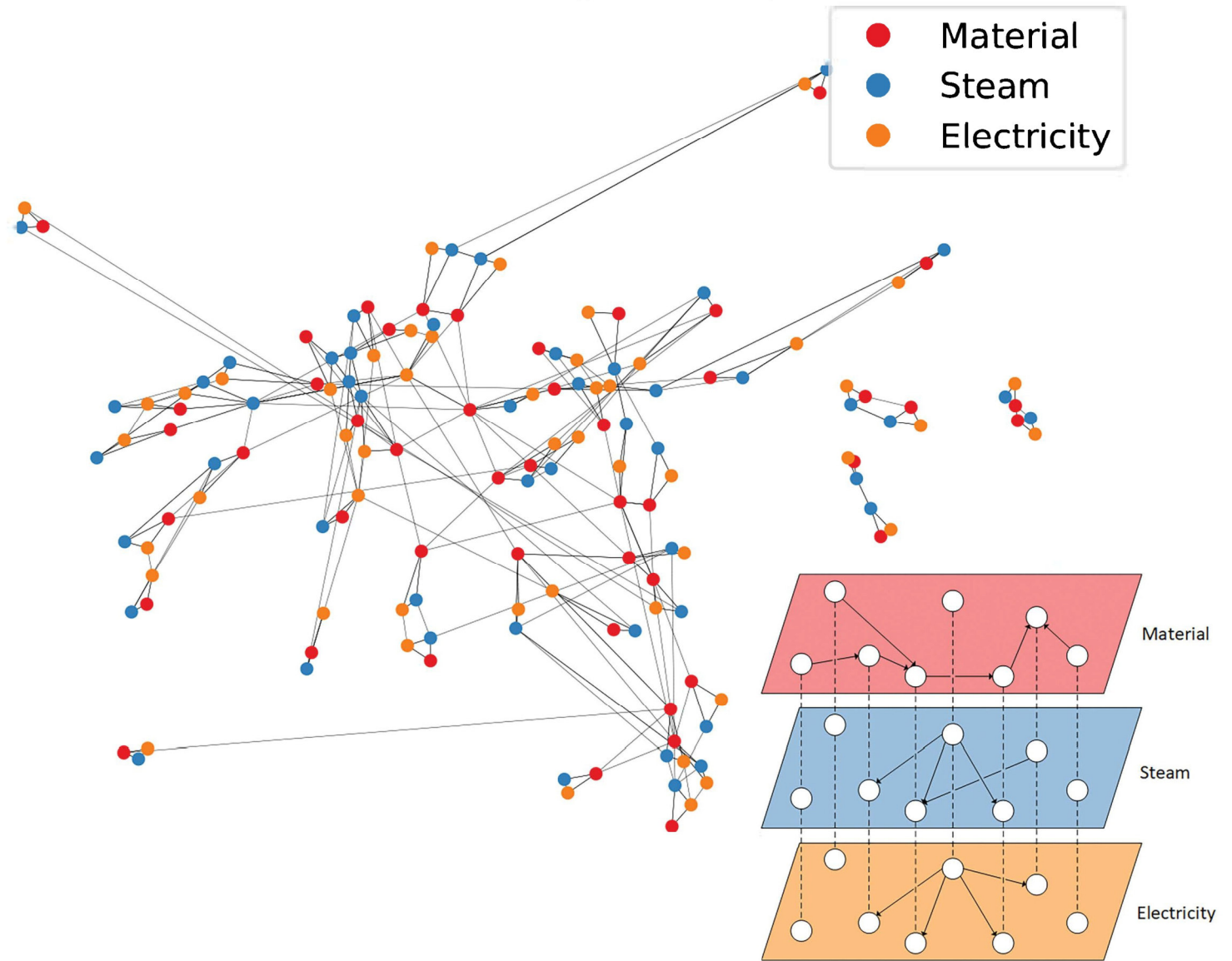
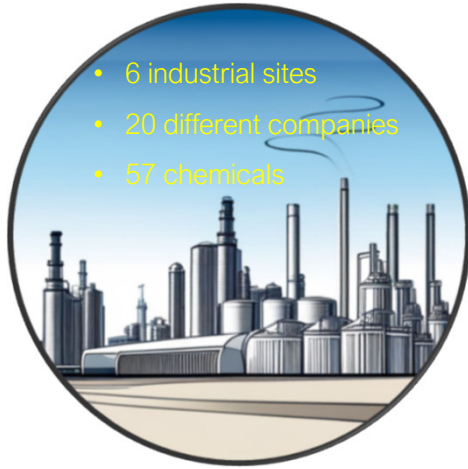
# >50 possible pathways to make Ethylene (at different TRL)







What would change in the cluster?



What is the future of  
(inter)national trade, markets  
and policies?



## EXCLUSIVE | Uniper delays major offshore-wind green hydrogen project to end of decade, hands back EU subsidies

The German energy company also tells *Hydrogen Insight* that while the updated Renewable Energy Directive has set strict H<sub>2</sub> targets in industry and transport, these have not yet been transposed into Dutch law — making it difficult to determine which sectors will specifically be pushed to use renewable hydrogen, and when penalties or support for potential offtakers will kick in.



## Government-backed green hydrogen-to-methanol pilot in Belgium scrapped due to 'escalating costs'

Consortium admits that no offtakers were willing to lock into long-term contracts at current prices

2 February 2024 11:00 GMT UPDATED 2 February 2024 11:07 GMT  
By **Polly Martin**

The Power to Methanol project at the port of Antwerp, an 8,000 tonne-per-year pilot originally scheduled to start operations in 2022, has been officially cancelled by its development consortium.

“Notably, the immaturity of the e-methanol market, coupled with pervasive uncertainties, has led to the reluctance of potential buyers to commit to long-term contracts in line with the project’s duration.”



Lack of understanding  
on how the system will  
develop

- lock-in situations
- stranded assets

Inadequate policy  
guidance

- limited existing policy design
- new policies needed to speed scaling –up & build supporting infrastructure

Challenging permitting  
environment

- Long time for permits
- numerous jurisdictions involved
- variability in conditions

Uncertain costs

- challenges aligning players, permitting and financing
- Uncertain market developments
- long-term liability

Lack of public  
awareness and varying  
support

- low public awareness and varied opinions about industry, technologies, infrastructure
- historic inequities in infrastructure sitting

Without a CLEAR direction, you may be going fast but going nowhere...but direction does not guarantee velocity nor speed



SPEED

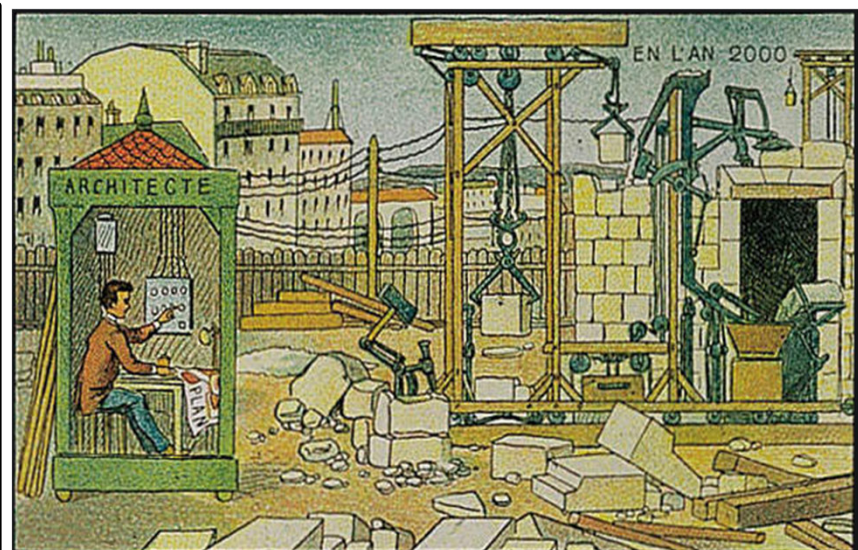
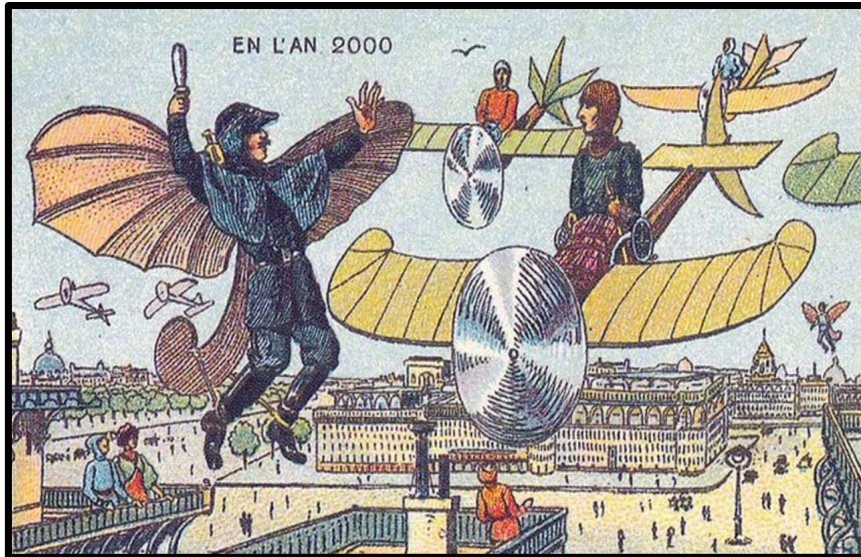
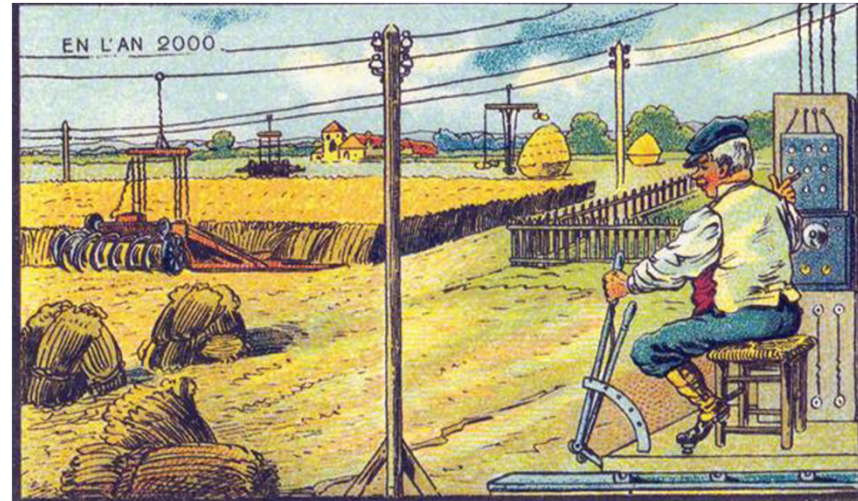
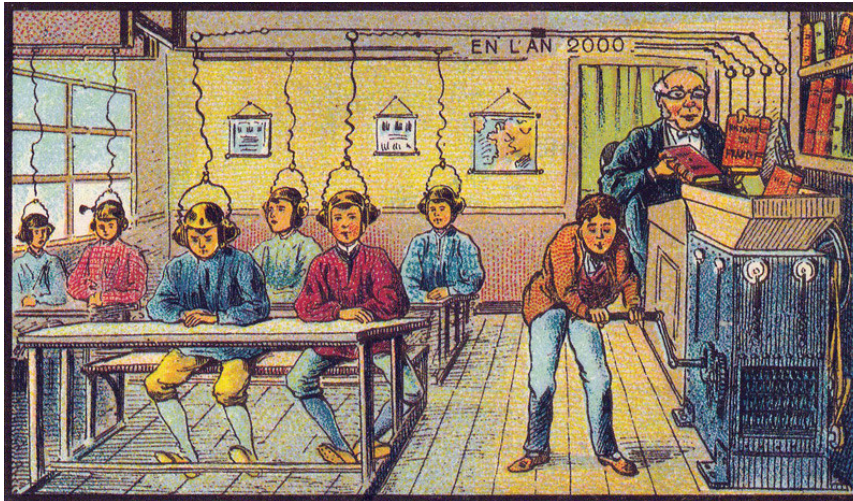


VELOCITY













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Thank you for your attention!

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