Institute for
Chemical Technology
of Organic Materials

Chemistry 4 Climate

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Overview

- Setting the scene
- Chemistry and the chemical industry
- Sustainable production of chemicals
- Resources and resource availability
- Demand & availability gap
- Summary - Outlook

Linz Chemistry site

TIME

Climate is Everything

In New York for Climate Week? Your Three-Star Meal Could Be A Climate-Change Write Off

BY ARYN BAKER
Senior Correspondent

A 50% reduction in the world's overall meat and dairy consumption could really help fight climate change. According to a new study published Sept. 12 in *Nature Communications*, plant-based alternatives could reduce greenhouse gas emissions from agriculture 31% by 2050. The finding joins a long list of reports linking meat and dairy consumption to climate change and is likely to have about as much impact as its predecessors. Which is to say, not much at all. Americans consume more meat than anyone else,

How We Talk About Climate Change Has Evolved Over The Years

With over 231,000 mentions by the press and public in 2007, 'global warming' was once the main way to talk about our overheating planet. But "climate change" has since quickly taken over as the most popular term.

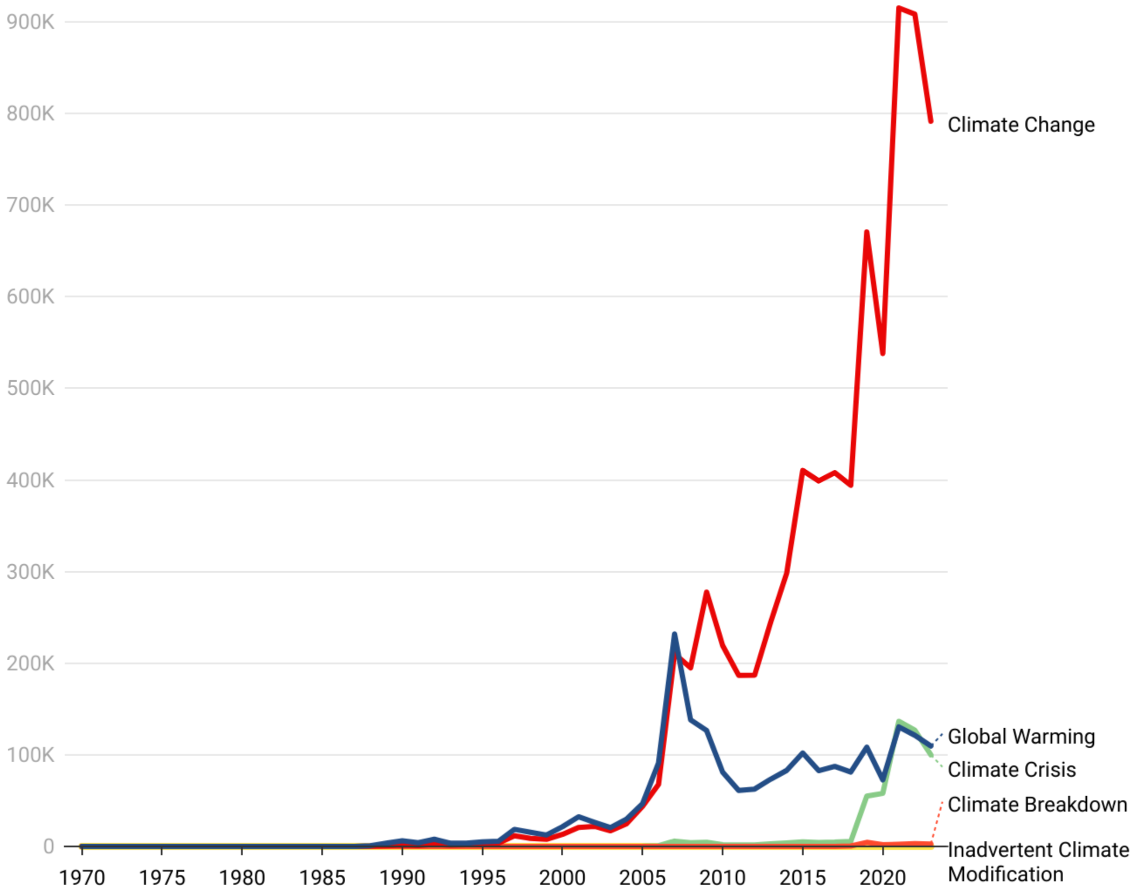

Chart: Kyla Mandel • Source: LexisNexis

TIME

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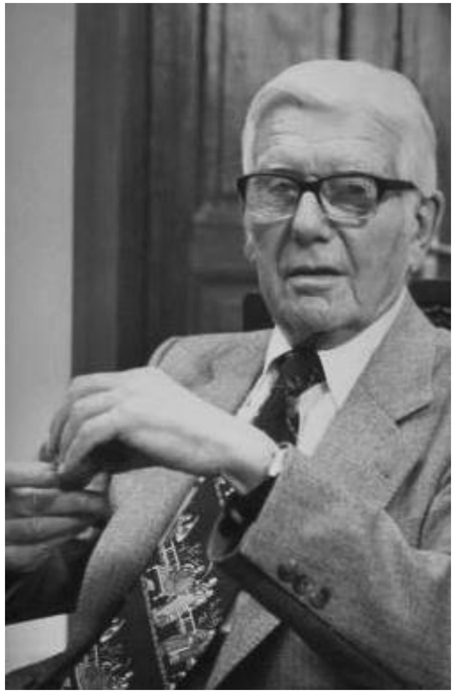
TIME climate newsletter, 21.09.2023

Hermann Franz/Francis Mark



Als Marks Vermächtnis an die Menschheit kann folgende Mahnung aus dem Jahr 1982 gelten, die heute aktueller denn je ist:

„Auf der Erde besteht ein Gleichgewicht zwischen den Pflanzen, das sind sonnenbetriebene chemische Fabriken, und den Tieren, das sind Verbrennungsmotoren. Die Pflanzen nehmen CO_2 aus der Atmosphäre und geben Sauerstoff ab, die Tiere nehmen Sauerstoff aus der Atmosphäre und geben CO_2 ab […] und zwischen diesen Dingen hat sich eben im Lauf von drei-, vierhundert Millionen Jahren auf der Erde ein gewisses Gleichgewicht eingependelt. Und jetzt, durch die gegenwärtige massenweise Verwendung von fossilen Brennstoffen […], das heißt von CO_2-erzeugenden Materialien für Wärme, für Transport, für Automobile, für Elektrizität, also für alles, erhöht sich der CO_2-Gehalt der Atmosphäre merklich. Und das hat dieselben Folgen wie das Ausströmen der fluorinierten Kohlenwasserstoffe aus den Spraydosen: Die Einstrahlung der Sonne wird gefiltert, weil CO_2 wie Fluorkohlenwasserstoff einen Teil des Sonnenlichtes absorbiert. […] Es käme entweder zu einer Eiszeit oder zu einer Wüstenbildung (= Treibhauseffekt, Red.) der gesamten Erde. […] Das Schreckliche ist, daß wir tatsächlich auf einem Vulkan leben. Wenn sich die durchschnittliche Temperatur der Erde nur um ein oder zwei Grade hinauf oder hinunter verändert, ist alles aus.“
(Kreuzer 1982, 61-62)

ORF 1978 series “Alles Leben ist Chemie”

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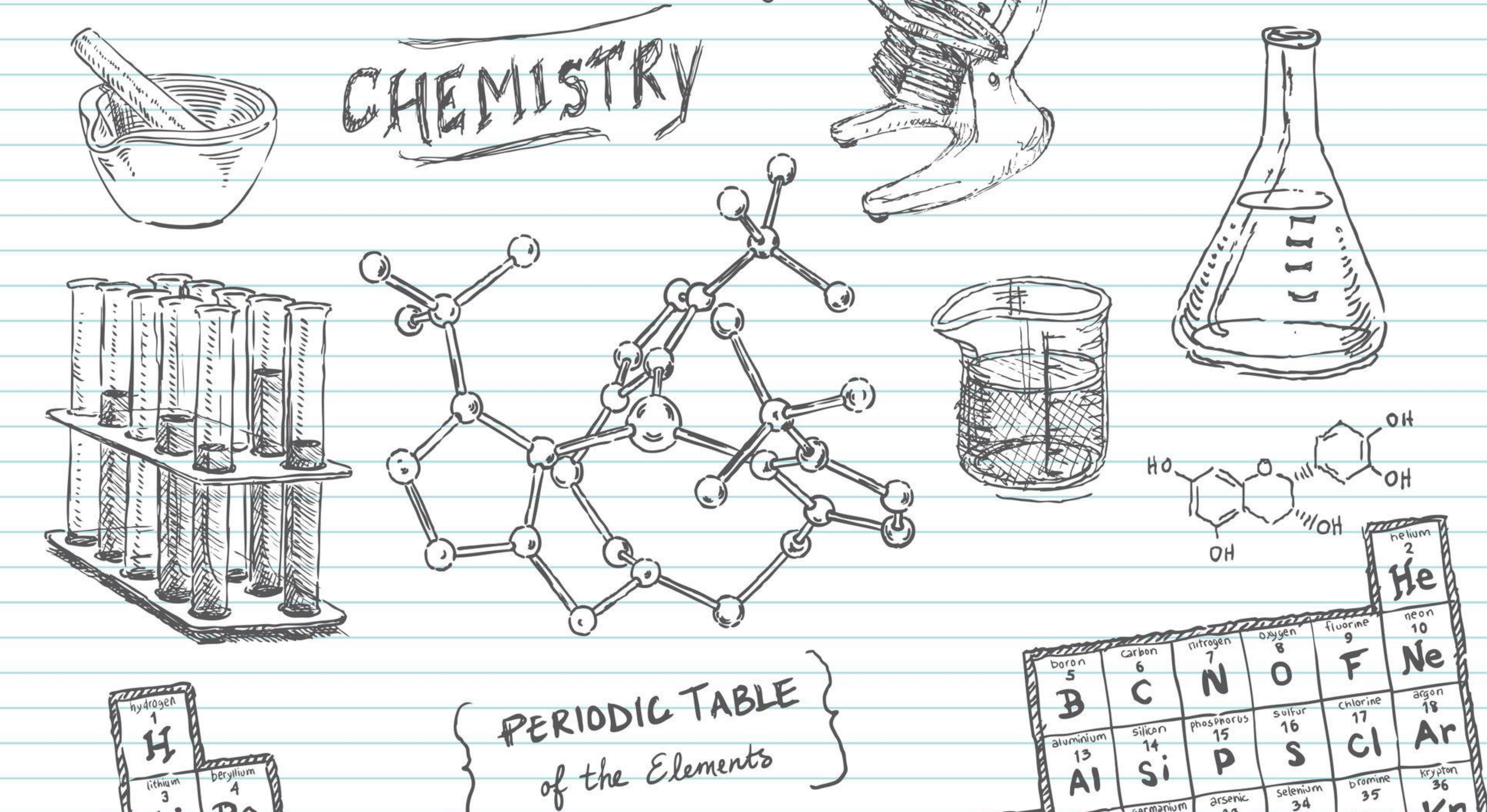
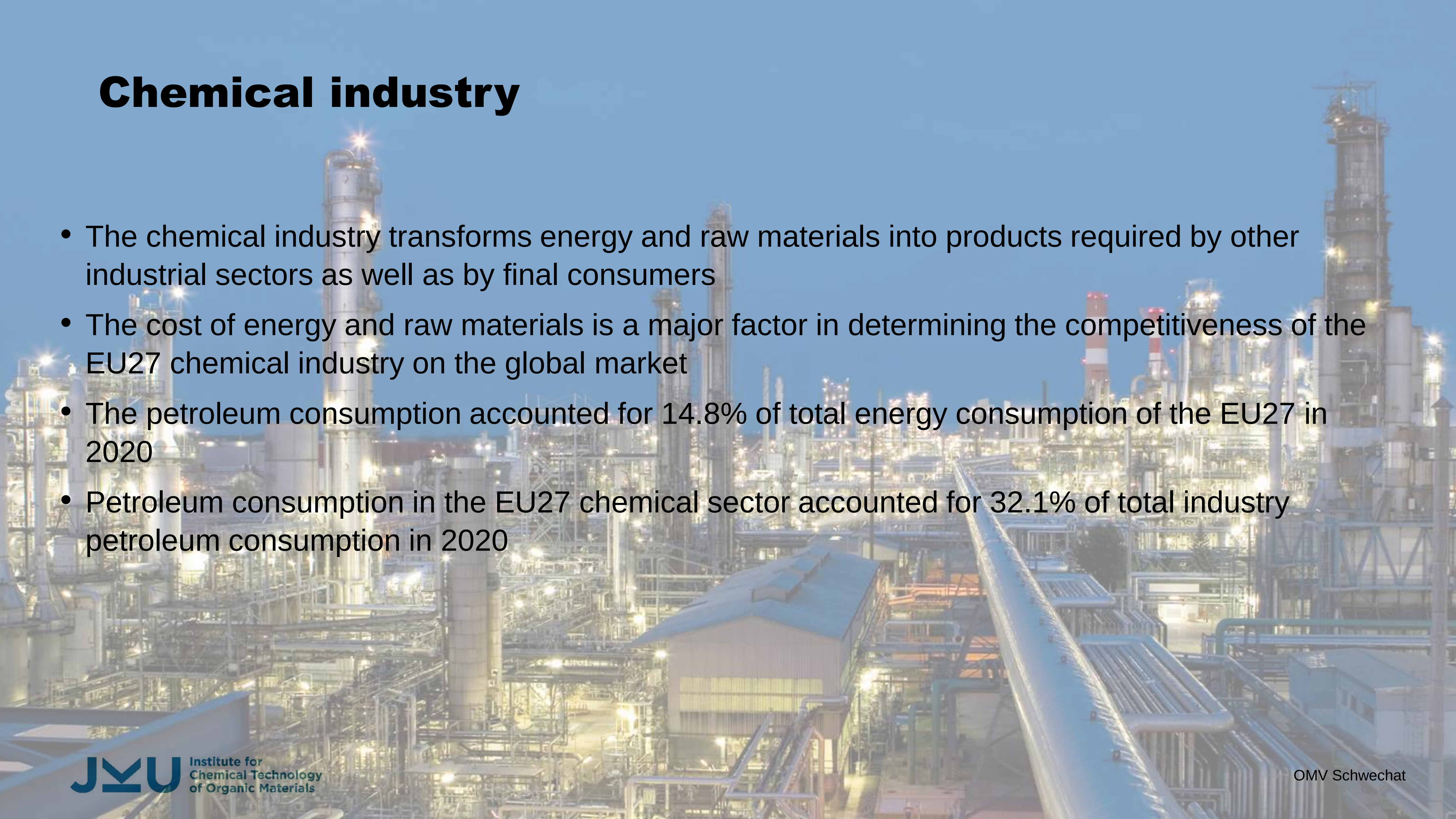
https://www.brainscape.com/academy/why-chemistry-central-science/



Chemical industry

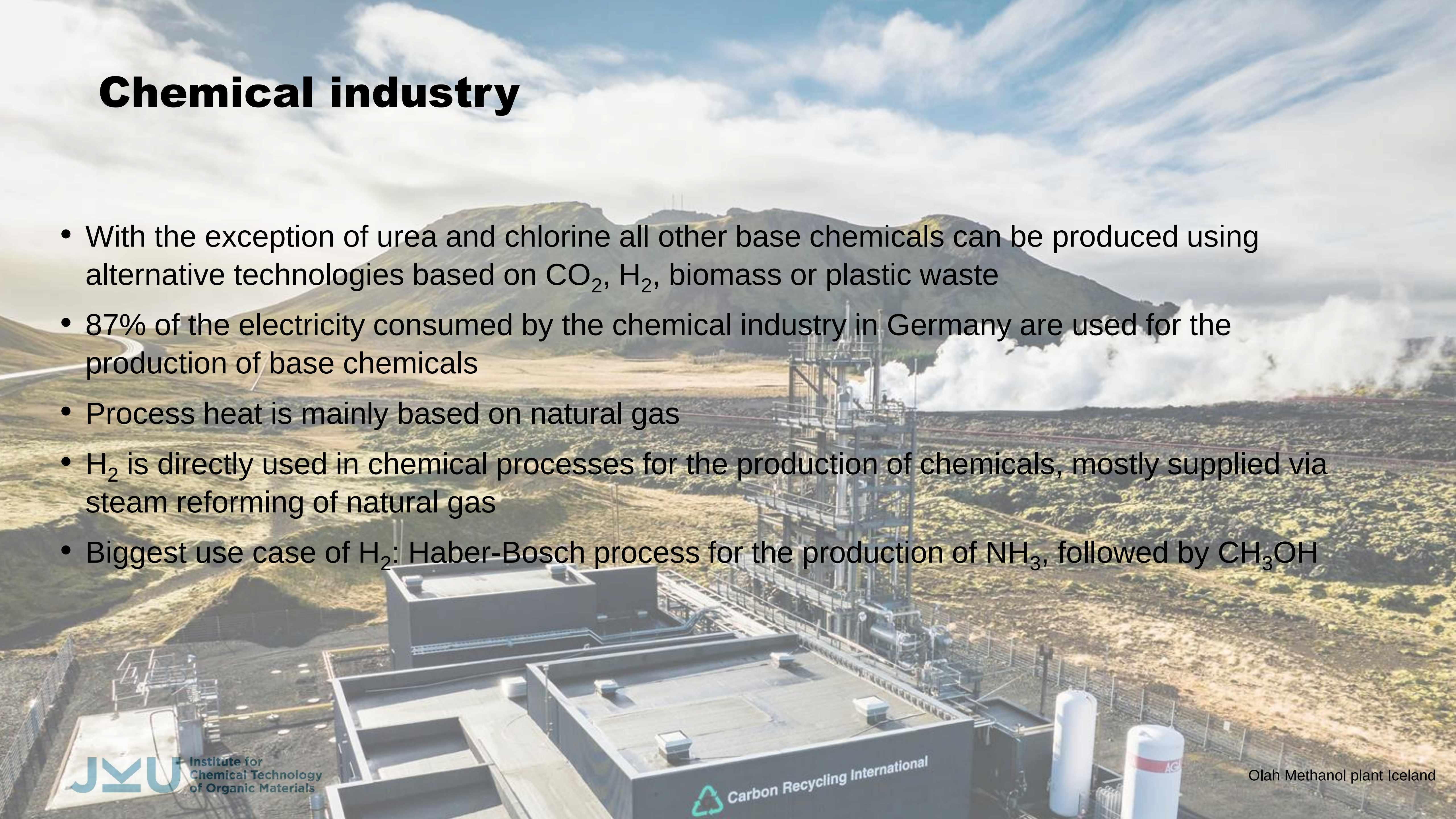
- The chemical industry transforms energy and raw materials into products required by other industrial sectors as well as by final consumers
- The cost of energy and raw materials is a major factor in determining the competitiveness of the EU27 chemical industry on the global market
- The petroleum consumption accounted for 14.8% of total energy consumption of the EU27 in 2020
- Petroleum consumption in the EU27 chemical sector accounted for 32.1% of total industry petroleum consumption in 2020



OMV Schwechat

Chemical industry

- With the exception of urea and chlorine all other base chemicals can be produced using alternative technologies based on CO_2, H_2, biomass or plastic waste
- 87% of the electricity consumed by the chemical industry in Germany are used for the production of base chemicals
- Process heat is mainly based on natural gas
- H_2 is directly used in chemical processes for the production of chemicals, mostly supplied via steam reforming of natural gas
- Biggest use case of H_2: Haber-Bosch process for the production of NH_3, followed by CH_3OH



Olah Methanol plant Iceland

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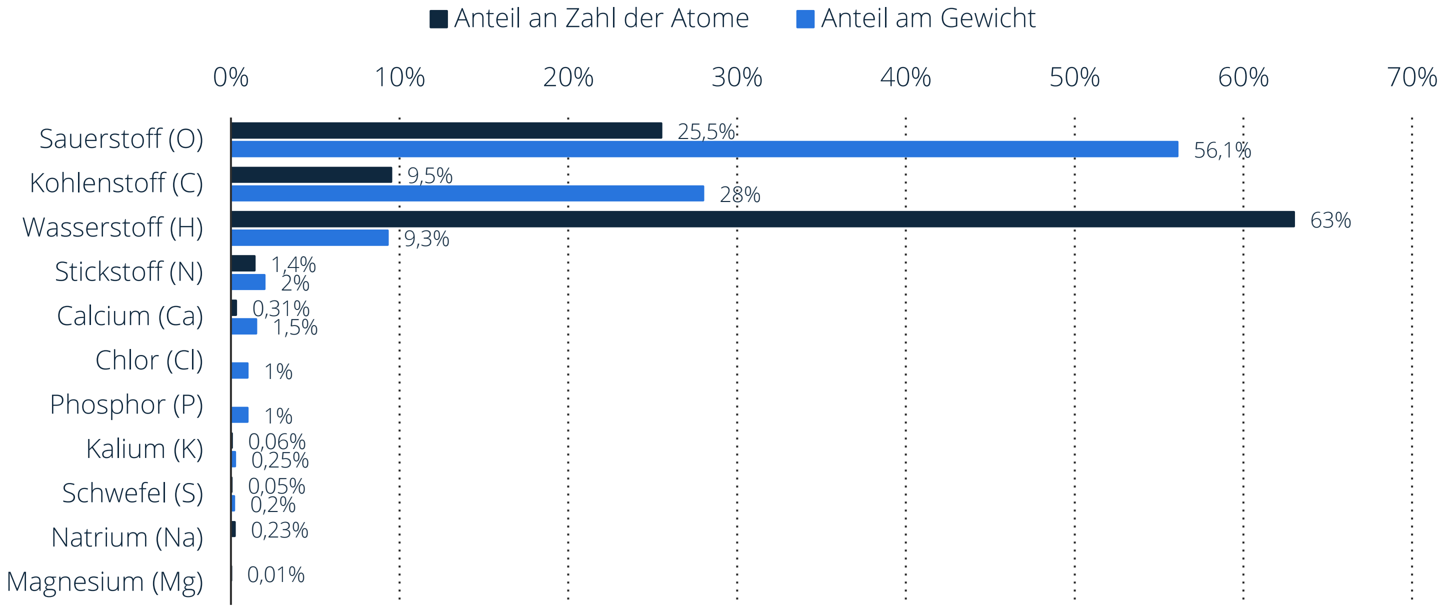
6
C
Carbon
12.011

- How can the transformation of chemistry toward sustainability succeed
- Our life, and therefore also chemistry, only works with carbon
- CO_2 is not only a problem
- It will become one of the most important carbon sources of the future
- This makes CCU a core element of the transformation strategy for chemistry

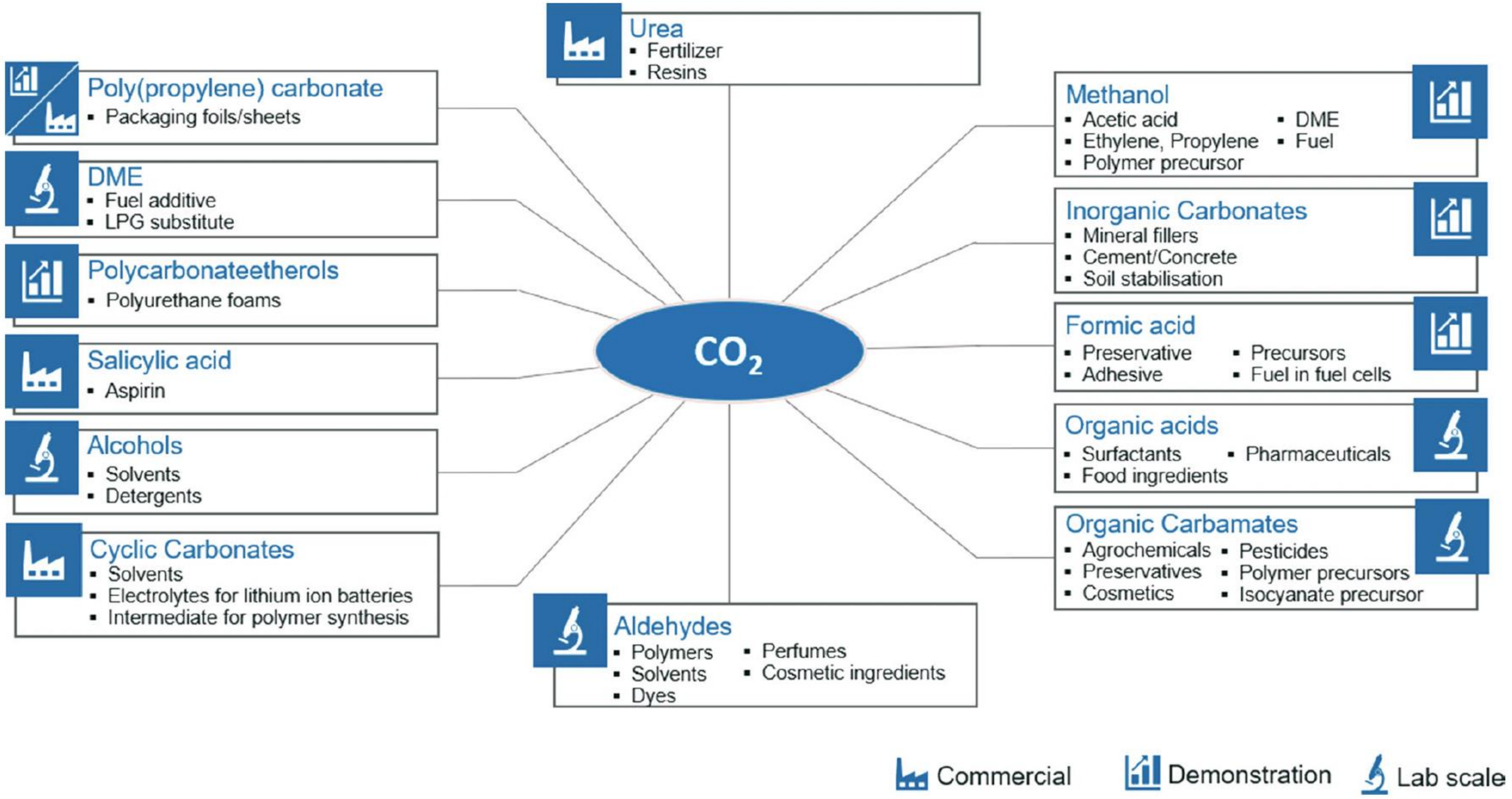
Proportions of chemical elements in the human body by weight and quantity of atoms



FU Berlin, Sept. 2014

Pathways for a sustainable production of chemicals

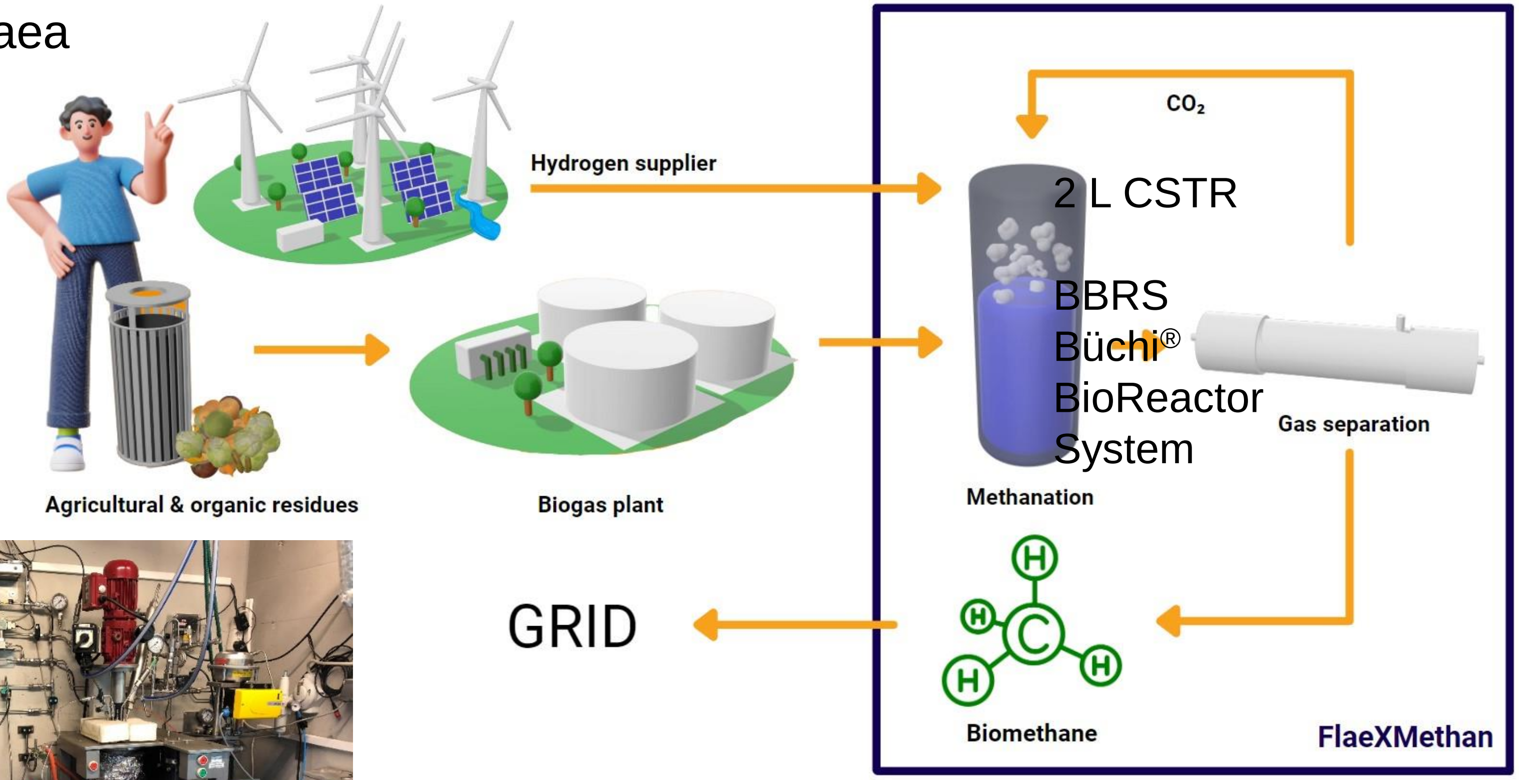
- Processes based on the use of climate neutral H_2 and CO_2:
  - Affording base chemicals such as NH_3, CH_3OH, BTX, via Fischer-Tropsch also higher hydrocarbons and olefins are possible
- Processes based on plastic waste leading to synthetic crude oil (naphtha)
- Processes based on biomass



Berg Huettenmaenn Monatsh 165, 221–226 (2020)

Bio methanization

- Hydrogenotrophic methanogenic archaea
- 37 - 85 °C / up to 15 bar
  (Extremophiles 50 bar)
- In-situ and ex-situ
- Limited gas-liquid mass transfer of H_2



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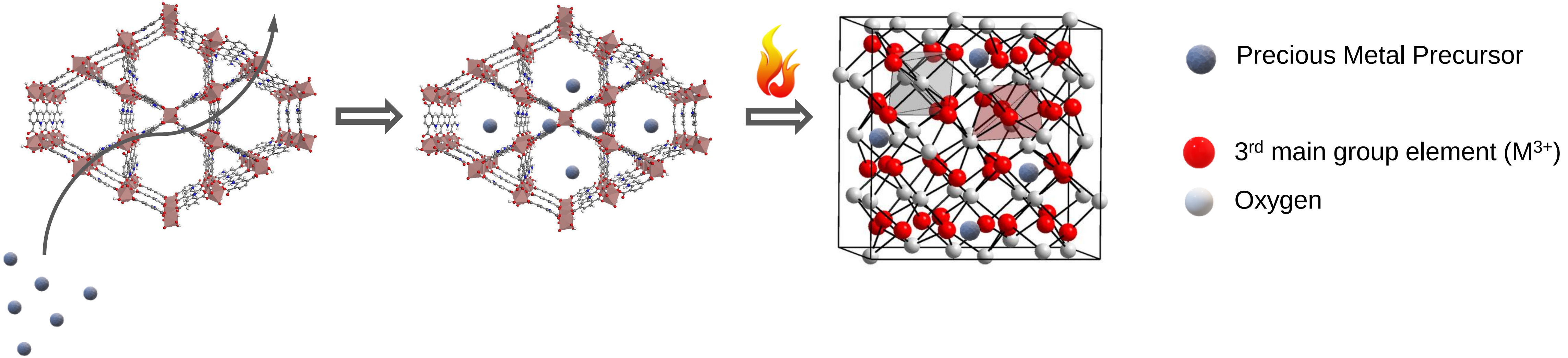
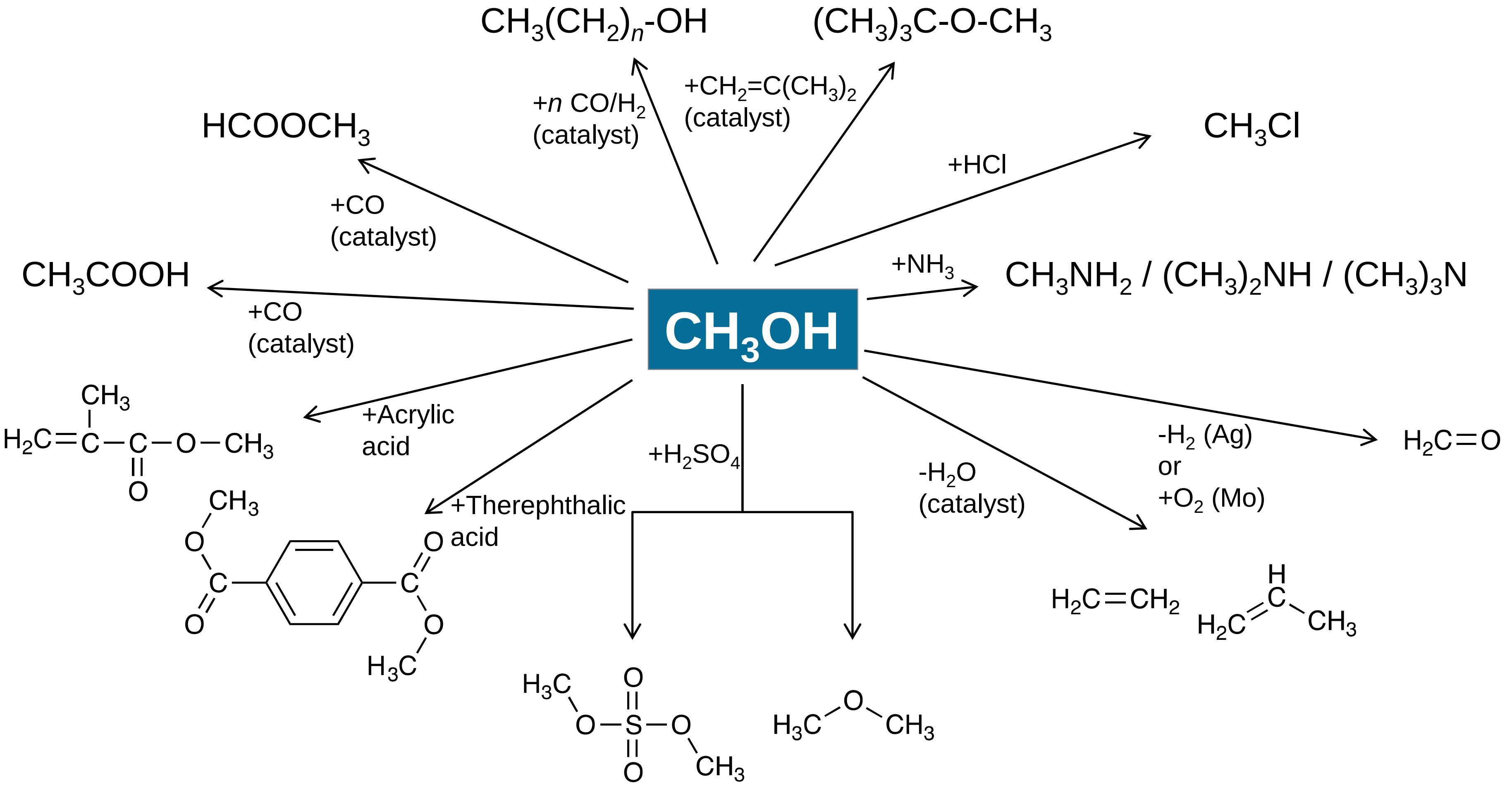
New approach for CO_2 to MeOH

- Project partner: CHASE, Heraeus, CTO
- Metal-organic frameworks (MOF) pores serve as means to achieve atomic dispersion of the noble metal promoter (Pd) after calcination
- Maximizes metal-support-interaction and abundance of catalytic facets/centers



Industrially important reactions of CH_3OH



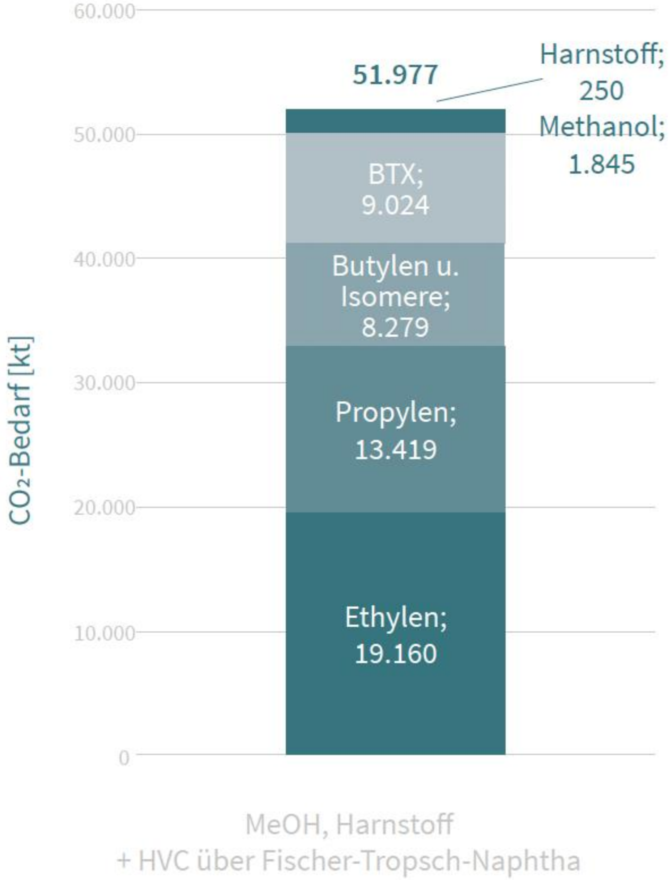
In addition: MTG, MTO, MTA

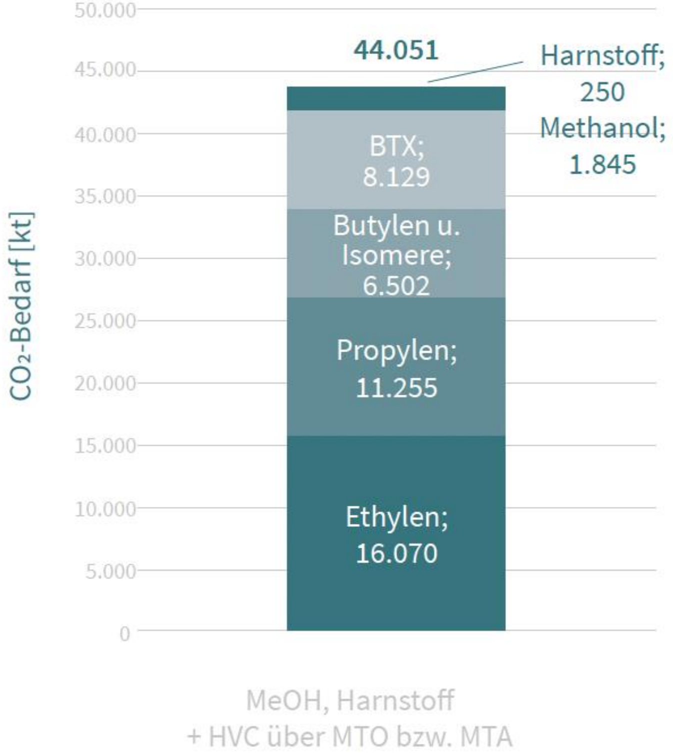
Resource availability

- No chemistry without Carbon - CO_2 is an important resource
- For a climate neutral chemistry based on CO_2 large amounts of H_2 and electricity are needed
- CO_2 sources will get a rare resource
- Availability of CO_2 from industrial sources, e.g., cement industry
- Plastic waste
- Biomass
- When our economy is CO_2 neutral also direct air capturing will be necessary (400 ppm) – high costs

https://taz.de/Analyse-zu-CO2-Emissionen-seit-1850/!5807527/

CO_2 need to cover German chemical production





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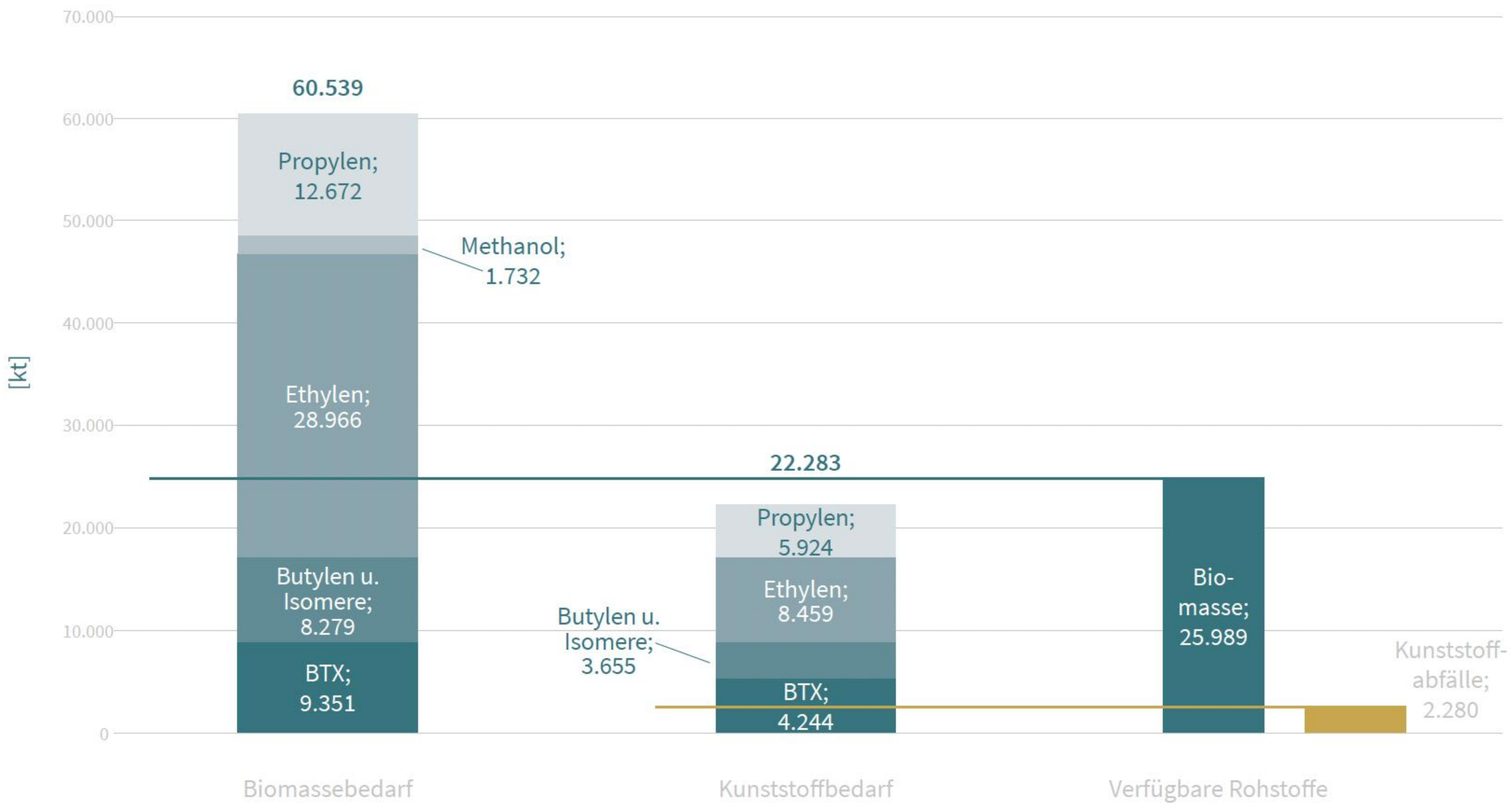
VCI Abschlussbericht 2023

Alternative sources

1 t Holz bzw. Stroh ergibt	1 t Holz bzw. Stroh spart	
0,78 t Methanol	0,07 bis 0,147 t Wasserstoff[40]	6,3 bis 7 MWh Strom
0,24 t Olefine		
0,235 t BTX-Aromaten	durch Ersetzen der alternativen Route über Wasserstoff aus erneuerbaren Energiequellen	
1 t Kunststoffabfall ergibt	**1 t Kunststoffabfall spart**	
0,41 t HVC (Olefine, Aromaten)	0,41 bis 0,58 t Wasserstoff	10,1 bis 14,3 MWh Strom
	durch Ersetzen der alternativen Route über Wasserstoff aus erneuerbaren Energiequellen	

Demand on alternative feed for 2045



VCI Abschlussbericht 2023

Plastic waste

- A part of the carbon feed for the chemical industry can be supplied through plastic waste
- However, circularity is key
  - Keep materials as long as possible in the loop
  - Energetic use only if no other possibility
  - Avoiding impurities
- Development of CCU technologies
- Recycling of plastics
  - Mechanical and chemical recycling

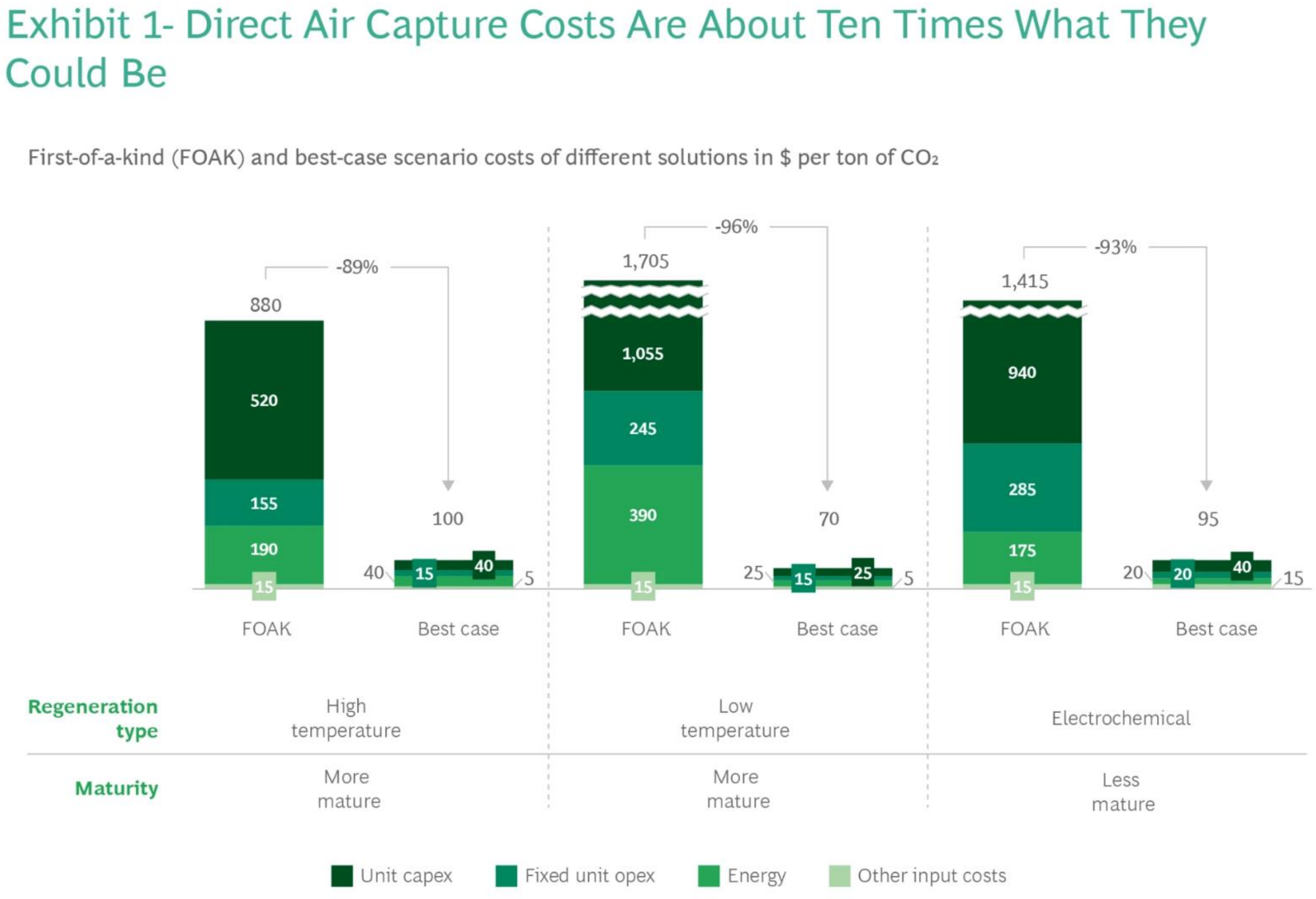
https://twitter.com/plasticsoupfoun/status/1069275124183040000

Biomass

- Sustainable production and use of biomass
- In accordance with regulations on biodiversity
- Use of bio based side- and wase streams but also cultivated biomass
- Primarily use as material source and only secondarily as energy source
- Chemical industry needs high volumes of homogenous quality
- Full replacement of fossil resources by biomass is not possible

https://physicsworld.com/a/biomass-energy-green-or-dirty/

Direct Air Capturing (DAC)



- DAC could play an important role in delivering on net zero
- Low-cost DAC is challenging but no more so than any other revolutionary technology
- Significant cost reduction (>75 %) necessary
  - From 1.000$ to 100$ per t CO_2
  - Solar is a role model
- Massive step up in investments, government support, collaboration models, industry engagement required
  - NASA spends > $20 billion on space research

https://www.bcg.com/publications/2023/solving-direct-air-carbon-capture-challenge/

Hydrogen

- H_2 will be absolutely necessary for sectors where transformations to other technologies will not be possible (e.g., steel, glass) or where an electrification will be difficult (e.g., shipping)
- Development of H_2 production technologies important with the focus on green H_2
- H_2 infrastructure is necessary (pipelines and storage facilities)

https://www.planet-wissen.de/sendungen/sendung-wasserstoff-100.html/

Summary

- CO_2 is a problem but also a resource
- Technologies to base the carbon need of the chemical industry on CO_2 are available
  - Indirect and direct conversion of CO_2 possible – economic models to be developed
  - CH_3OH is a versatile platform chemical - existing downstream usage models
- Plastic waste and biomass are important raw materials
- Frog leap in DAC technology necessary
- Electricity from renewable resources and green H_2 are of paramount importance

- Using the potential of digitalization → Digitainability

https://andreasgoller.photography/traumhafter-sonnenaufgang-auf-der-rotwand/

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Thanks for listening

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