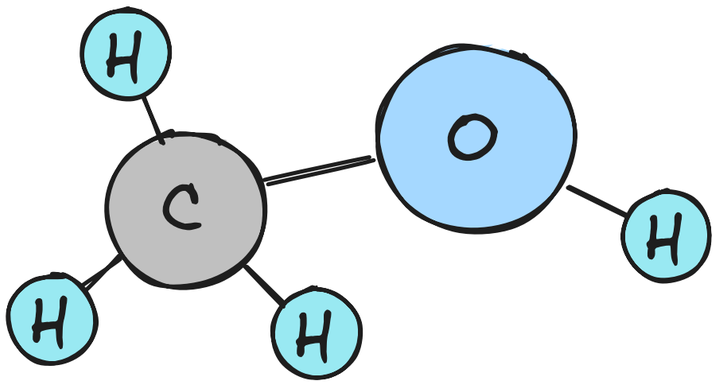
Is Green Methanol the missing piece for the Energy Transition?



industrydecarbonization.com

Hanno Böck

Climate Change

Refinery: İsa Karakuş, Public Domain, Flood: Czach, CC0

Technologies to fix our emission problem

Step 1

Clean Electricity

Step 2

Electrify (almost) Everything



Step 3

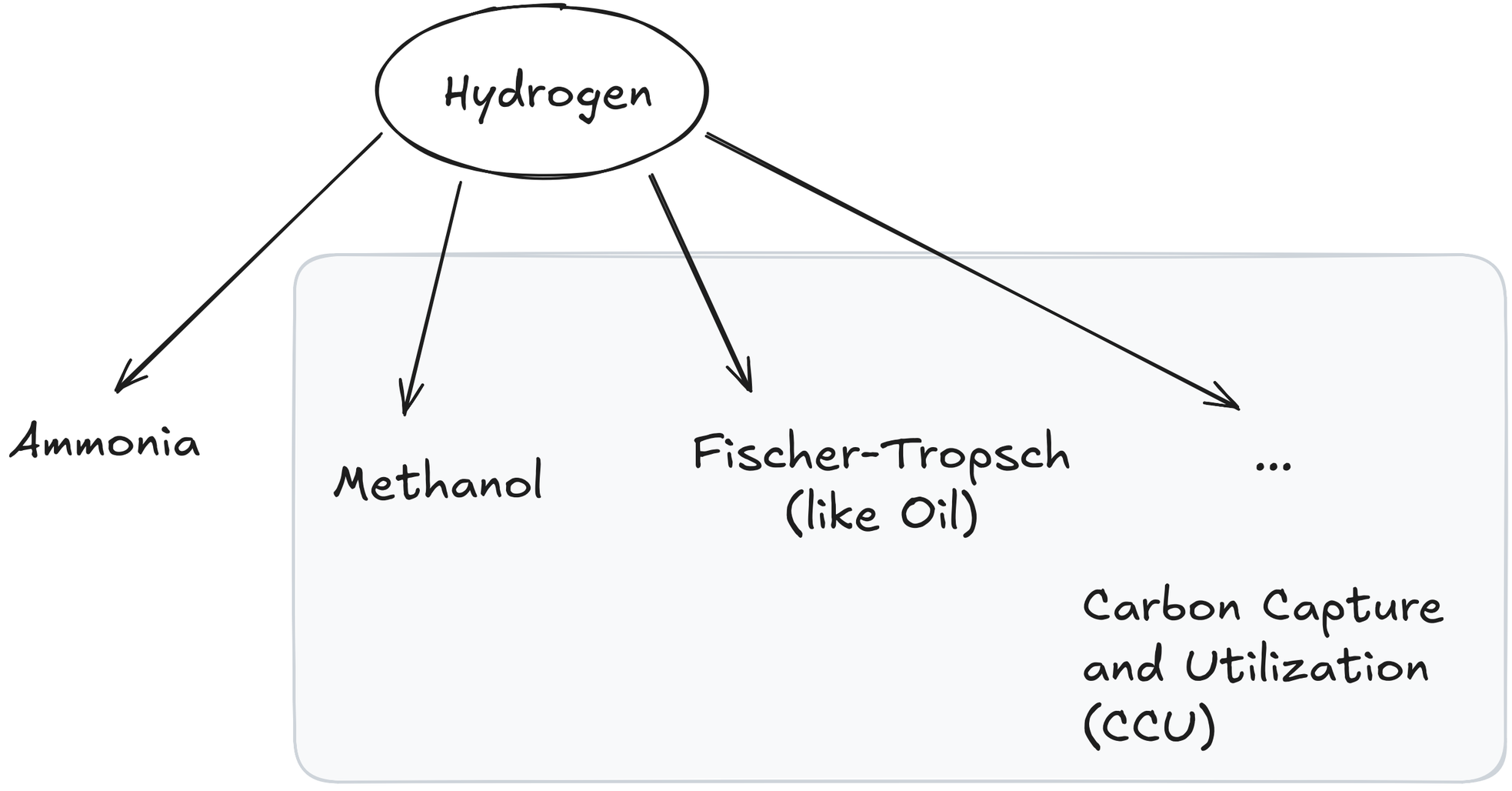
Deal with the rest

Steel plant: Aimelaime/Public Domain, Ship: Bernard Spragg, Public Domain, Plastics: stevepb, CC0

Green Hydrogen

Problems with Hydrogen (incomplete)

- **Today, almost entirely made from fossil fuels**
- **Green Hydrogen requires lots of clean energy**
- **Difficult to transport and store**


Hydrogen
Ammonia
Methanol
Fischer-Tropsch
(like Oil)
...
Carbon Capture
and Utilization
(CCU)

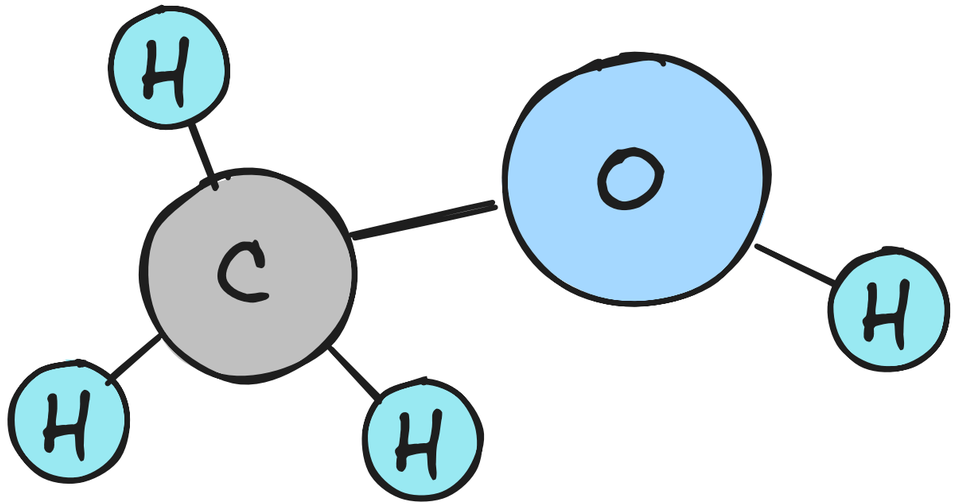
The Hydrogen Economy and its Difficulties

Whereas it is indeed clean burning to form water, its generation is a highly energy-consuming process, which itself is not necessarily clean. [...]

The volumetric power density of liquid hydrogen is also a drawback at only one-third of that of gasoline [...]

Beyond Oil and Gas: The Methanol Economy (George A. Olah, 2005)

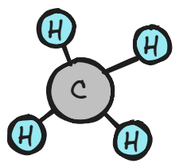
Methanol (CH_3OH, MeOH)



- **Simplest carbon-containing liquid**
- **Primarily used as a chemical feedstock**

Methanol Production Today

Methane (Fossil Gas)

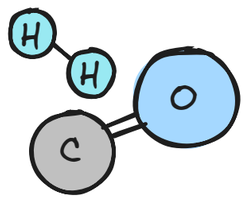


→

Steam Reforming

→

Syngas (Hydrogen, Carbon Monoxide)



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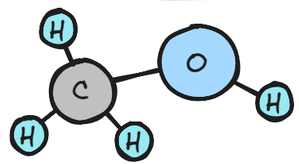
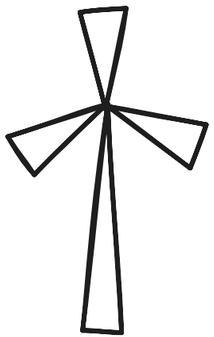
Methanol

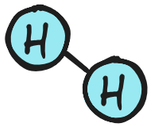


CO_2 emissions during production and after use

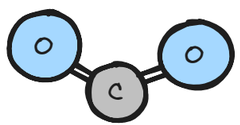
E-Methanol



Electrolyzer

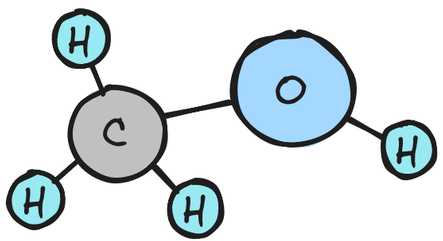


Hydrogen



CO_2

Methanol



George Olah Renewable Methanol Plant (Iceland, since 2009)
Carbon Recycling International

What could we do with E-Methanol?

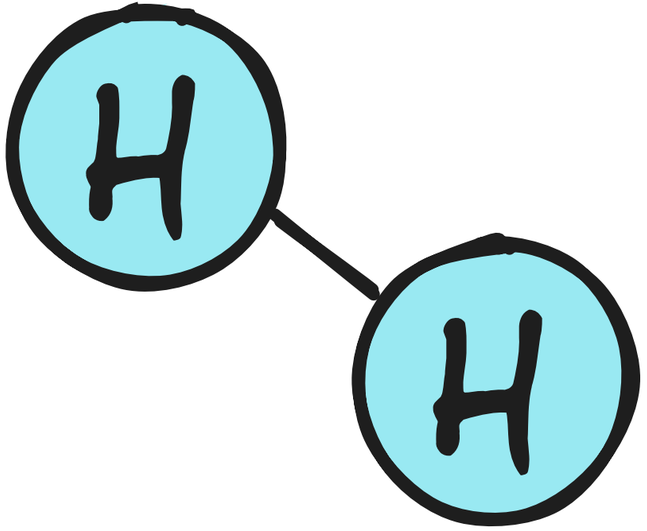
Renewables and Intermittency

Storage

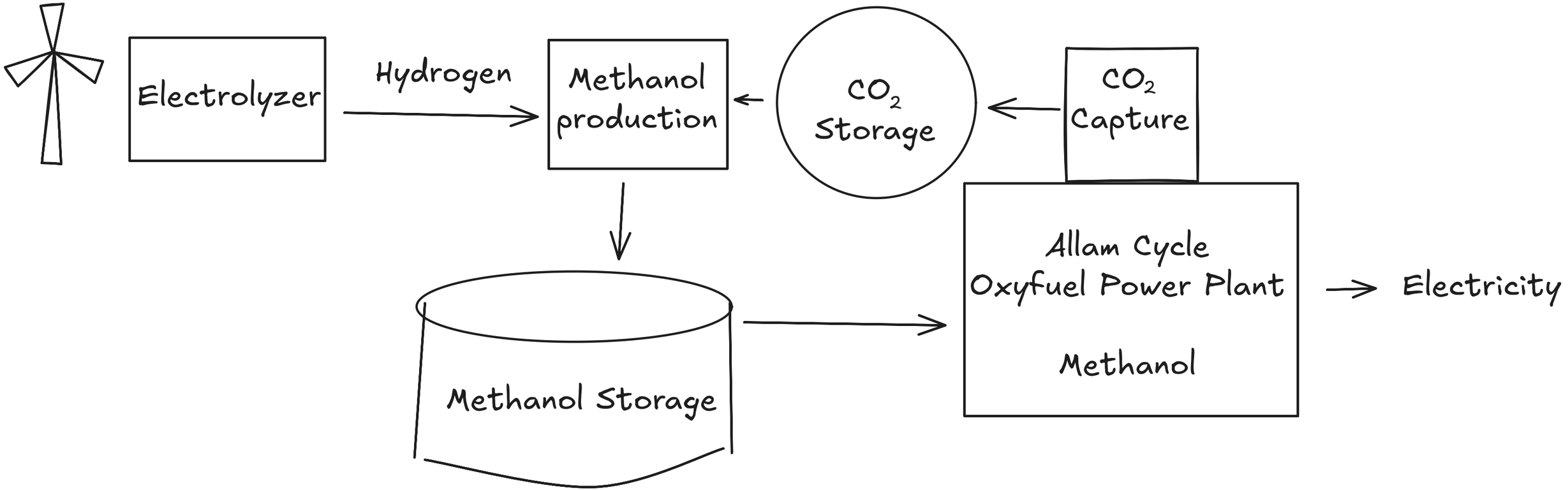
Established technologies (pumped hydro, batteries) not suitable for long-duration storage

Long-Duration Energy Storage

Hydrogen?



Remember: Hydrogen is difficult to store and transport



Ultra-long-duration energy storage anywhere: Methanol with carbon cycling (Tom Brown, Johannes Hampp, Joule, 2023)

Long-Duration Energy Storage with Methanol and Carbon Cycling

- **Slightly less efficient than hydrogen, but sometimes cheaper**
- **Multi-year storage possible**
- **Based on Open-Source model (PyPSA)**

https://github.com/PyPSA/methanol-uldes

NOAA, Public Domain

Shipping

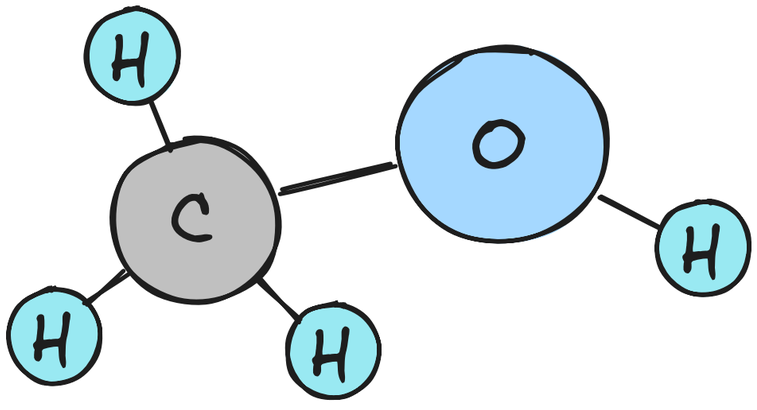
Around 4% of CO_2 emissions

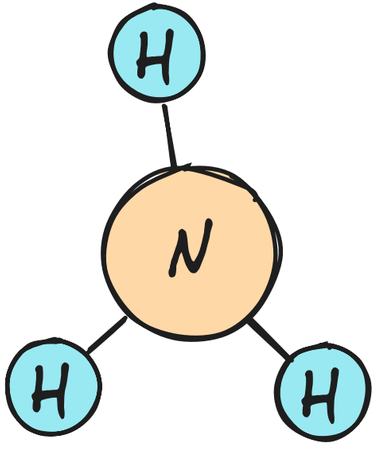
Nor-Shipping, CC-by 3.0

Battery-electric ships are great, but not for long distances

Climate-neutral shipping fuels

E-Methanol or E-Ammonia





Ammonia

No carbon needed, but very toxic/dangerous

Masur, Public Domain

Shipping with Methanol

Stena Line, CC-by 3.0

Alf van Beem, Public Domain

Maersk has ordered Methanol/dual-fuel ships and has invested in multiple companies developing Green Methanol technology

In 2024, Maersk started ordering LNG-powered ships again (fossil gas)

Plastics

stevepb, CC0

Plastics are (made from) fossil fuels

Olefins

Ethylene and Propylene

Olefins / Plastics production

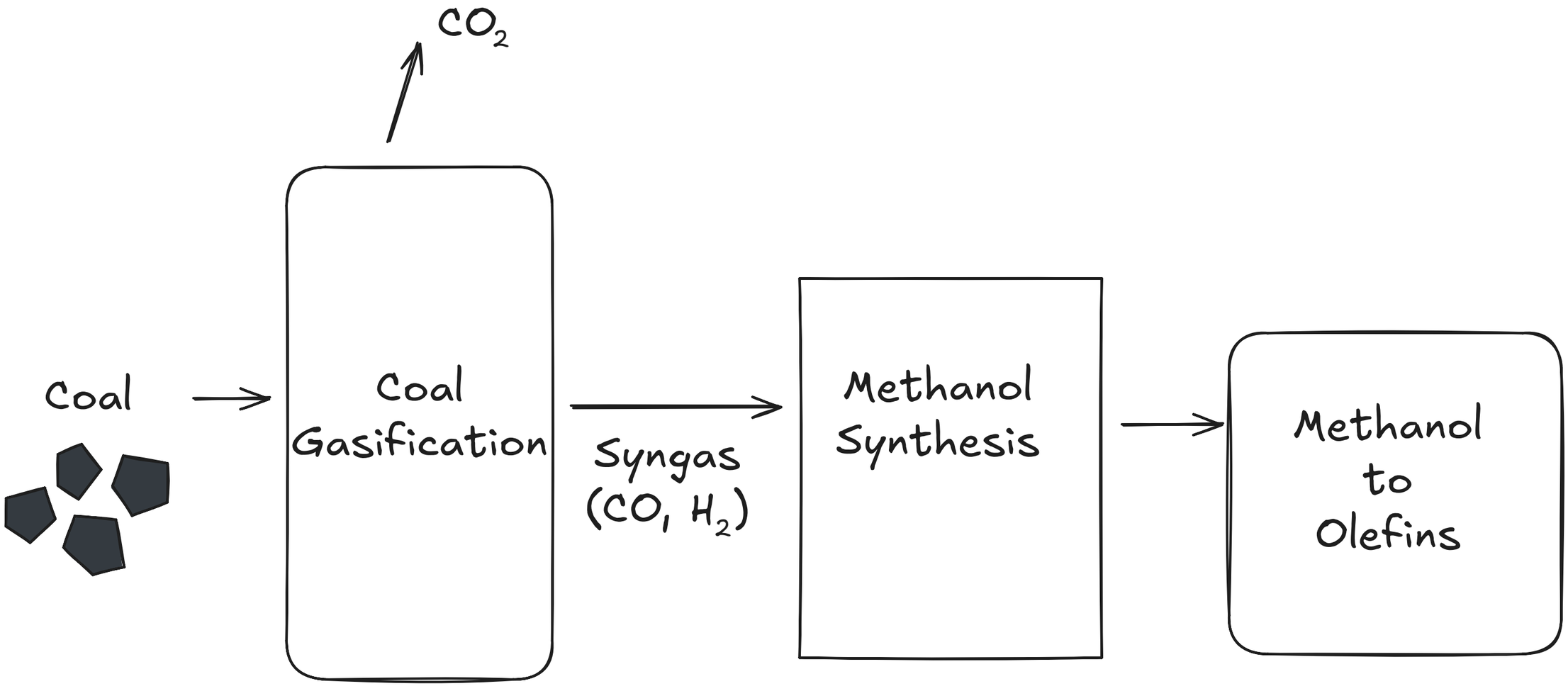
Mark Dixon, Public Domain

Steam Cracker (Oil/Gas)

There is another way to make plastics

Olefins/Plastics from Coal

Mao Ye et al, CC-by 2.0


CO_2
Coal
Coal Gasification
Syngas (CO, H_2)
Methanol Synthesis
Methanol to Olefins

Green Plastics

Option 1: Steam Cracker with Green Naphtha (e.g., from Fischer-Tropsch)

Option 2: Methanol-to-Olefins with Green Methanol

Steam Cracker or Methanol-to-Olefins

With green feedstocks, Methanol-to-Olefins is more efficient and requires less hydrogen, CO_2, and energy

Chemistry4Climate, 2023, VCI (German Chemical Industry Association)

30 SEPTEMBER 2024

A.P. Moller Holding launches Vioneo to pioneer fossil-free plastics production

CARBON RECYCLING INTERNATIONAL

CRI AND JIANGSU SAILBOAT START UP WORLD'S MOST EFFICIENT CO_2-TO-METHANOL PLANT

Carbon Recycling International, September 2023

So we can use Green Methanol to store energy, clean up shipping, and make fossil-free plastics.

Sounds great, right?

Let's talk about some downsides

None of this is going to be easy

Ørsted/Liquid Wind

FlagshipONE (Ørsted)

50,000 t/a E-Methanol

Cancelled in August 2024

Green Methanol at scale is not going to happen without strong policy support

Energy

Turning low-energy molecules like water and CO_2 into a high-energy molecule like Methanol requires a lot of energy

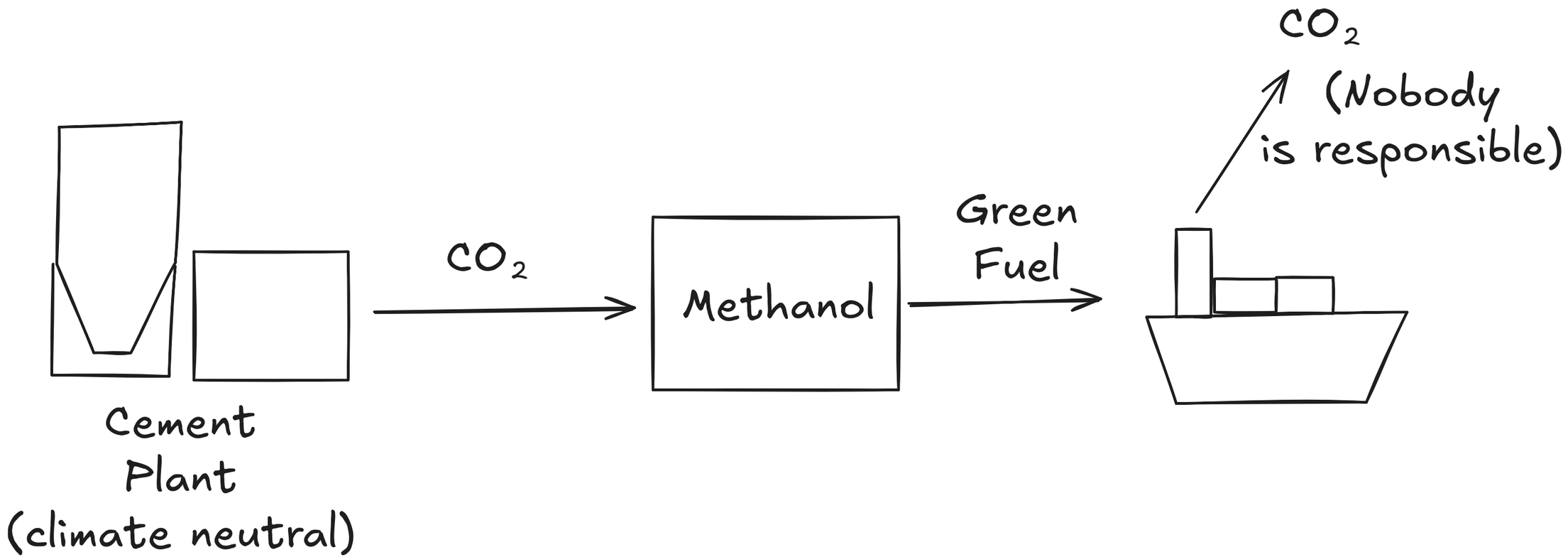
Chemical Industry based on E-Methanol

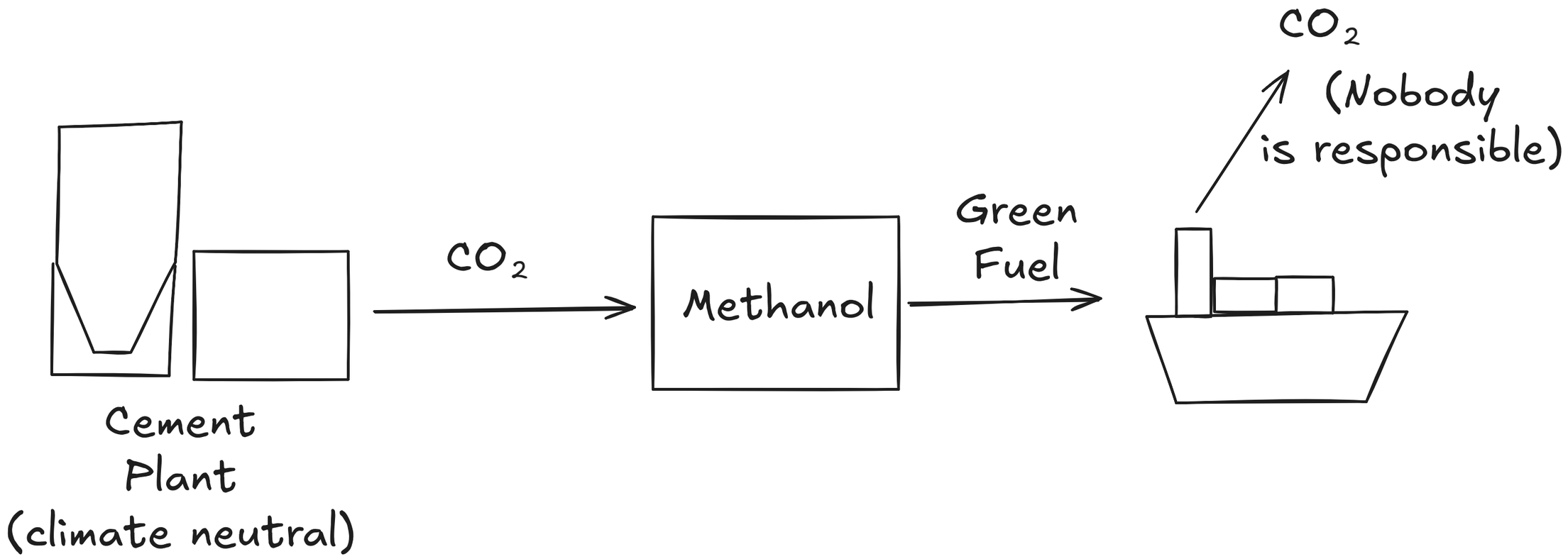
17 - 32 Petawatt hours ⚡

(🌎⚡ 29 Petawatt hours)

Kätelhön et al, PNAS, 2019

CO_2 Source


CO_2
(Nobody is responsible)
Green Fuel
CO_2
Methanol
Cement Plant (climate neutral)



I also call it the "Holcim model"

(plan for Lägerdorf cement plant)

Fossil or otherwise "new" CO_2 emission sources are not climate-neutral

Biogenic CO_2

Yes, with caveats

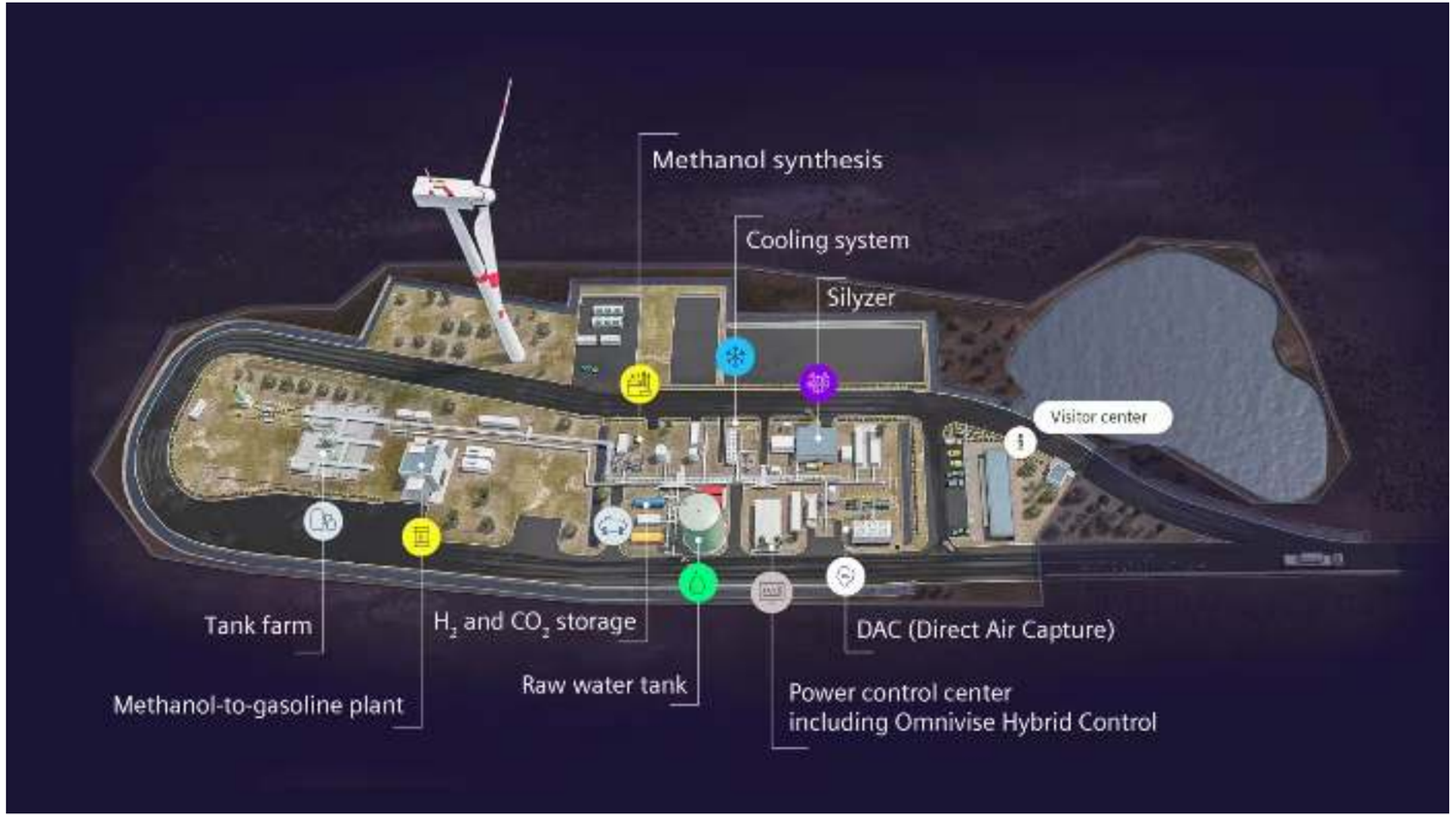
Direct Air capture

Expensive

Green Methanol will remain scarce and expensive, don't waste it when better alternatives exist

Inefficient use of Green Methanol

Even more inefficient use of Green Methanol



Siemens, Porsche, HIF

Do we have other ways to make Green Methanol?

Tom Brown
@nworbmot.bsky.social

+ Follow

All your carbon shall be methanol

Arguments for mopping up all carbon in wastes and residues into methanol; use it to supply sectors that can't be electrified

TL,DR: methanol is a liquid; easier to transport/store than CH4/H2/CO2; costs scale down nicely to multi-MW size

Tom Brown on Bluesky, October 2023

Biomethanol

Multiple pathways (biogas, paper mills), usual caveats with bioenergy apply

We should talk about Trash

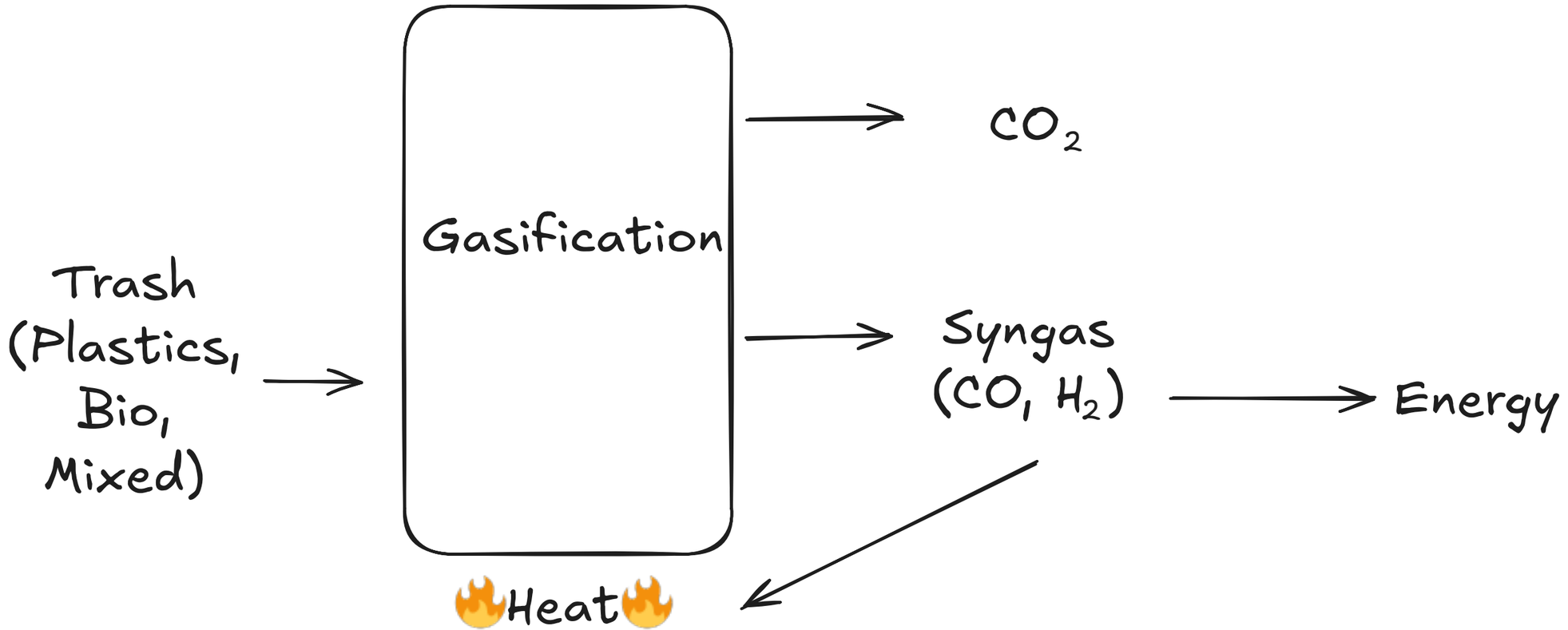
Albert Jankowski, Public Domain

Waste Incinerators are huge CO_2 emission sources

Fornaxianer, CC0

rainy day, CC0

Waste Gasification



Syngas could be used to make other chemicals (e.g. Methanol)

Waste-to-Methanol / Chemical Recycling

SVZ Schwarze Pumpe, Germany, 1995 - 2007 (coal/waste)

Enerkem Edmonton, Canada, 2015 - 2024

Waste Gasification could solve multiple problems

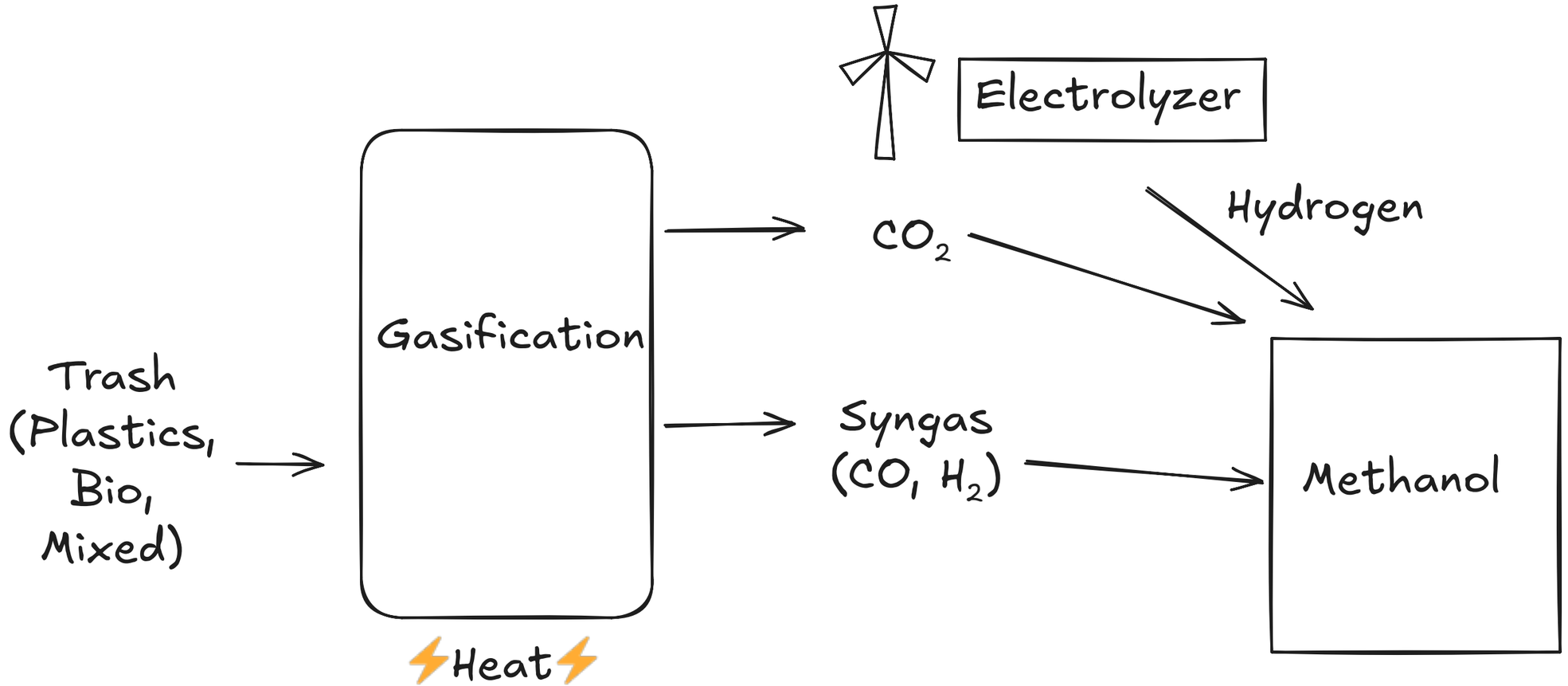
- **Avoid emissions / circular carbon use**
- **Recycling and upcycling of otherwise unrecyclable waste**
- **CO_2 source**

Waste Gasification has been tried again and again, and it usually fails

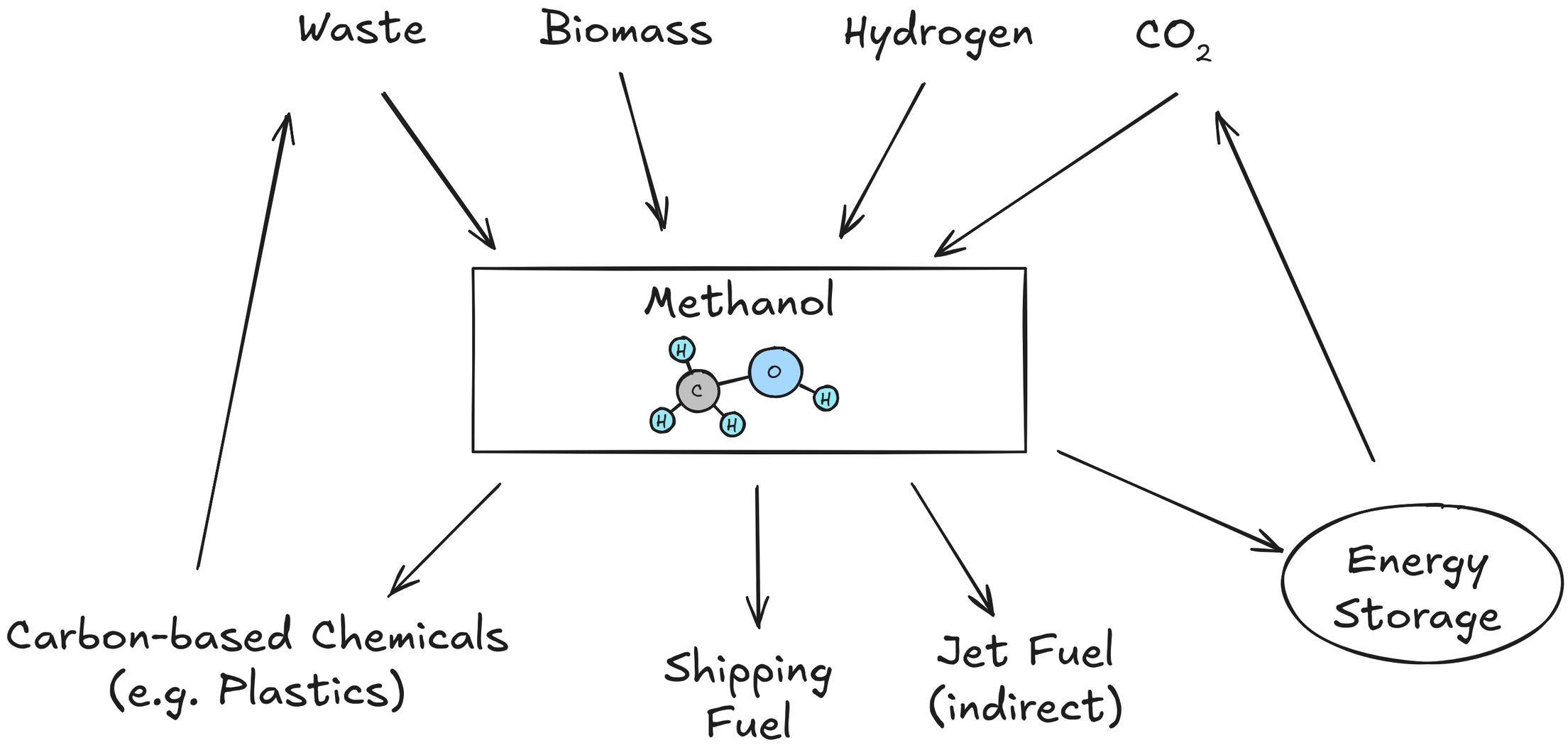
Waste Gasification only works in Japan

Gasification of biomass and waste could provide a less energy-intensive way to make Green Methanol

Waste Gasification optimized for Methanol Production



Bringing it all together


Waste
Biomass
Hydrogen
CO_2
Methanol
H
O
C
H
H
H
Carbon-based Chemicals
(e.g. Plastics)
Shipping
Fuel
Jet Fuel
(indirect)
Energy
Storage

How is Green Methanol doing today?

E-Methanol plant in Kassø, Denmark, by European Energy, under construction

32,000 t/a capacity

In other 2024 Green Methanol News

- **Goldwind broke ground for 500,000 t/a Bio/E-Methanol plant in Inner Mongolia (China), offtake agreement with Maersk**
- **Carbon Recycling International signs agreements for two E-Methanol plants in China (100,000 t/a, 170,000 t/a)**
- **Geely broke groud for a 100,000 t/a E-Methanol plant in Inner Mongolia (China), 500,000 t/a planned**
- **Clariant announces it will deliver catalyst for 250,000 t/a Biomass-Gasification-to-Methanol plant in China**
- **Hapag-Lloyd signs offtake agreement with Goldwind for 250,000 t/a Bio- and E-methanol**

Thanks for listening!

Missed my talk last year?
https://youtu.be/_DxD66qhazs

If you enjoyed this talk,
consider subscribing to my newsletter:
industrydecarbonization.com
Hanno Böck

Read more

- From Coal enabler to the Minimal Green Methanol Economy, September 2023
- Why no one wanted to buy the Green Shipping Fuel, August 2024
- How to make Plastics without Fossil Fuels, Aug 2023
- Unburning CO_2: The Problem with Fossil Carbon Capture and Utilization, Feb 2024
- E-Fuels and E-Chemicals may need multiple times the World's current Electricity Production, Feb 2024