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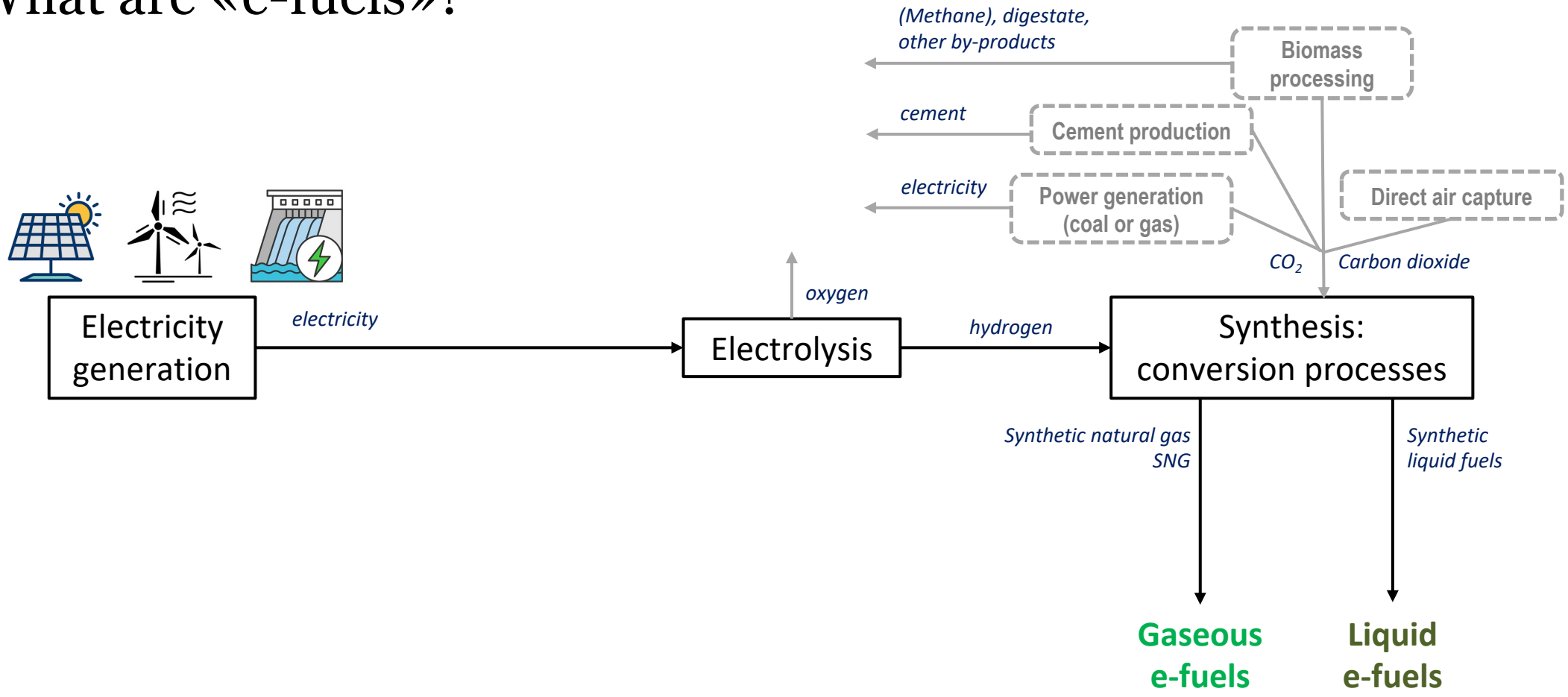
Hydrogen-based e-fuels in climate change mitigation: the environmental and economic perspectives

ETHZ DARCH «What counts?», 20.09.2022

What are «e-fuels»?



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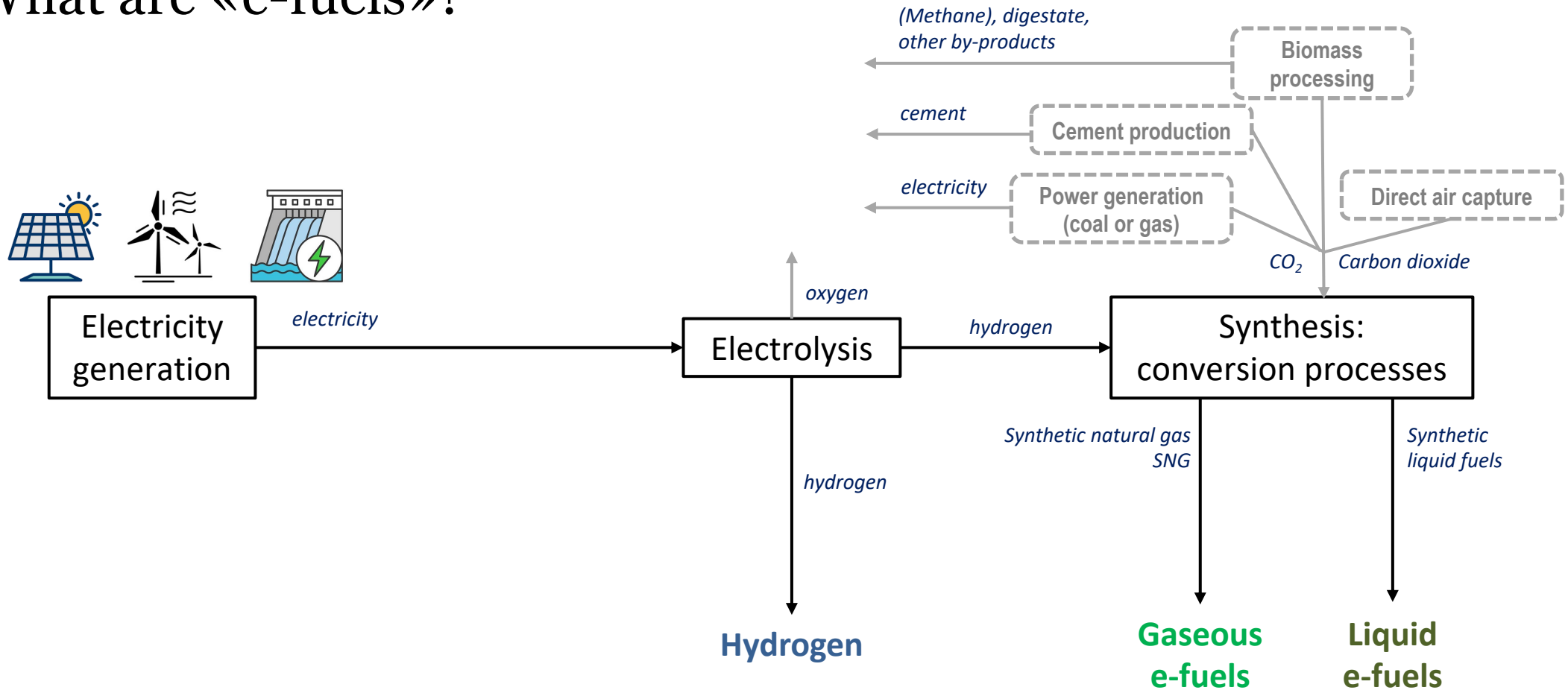

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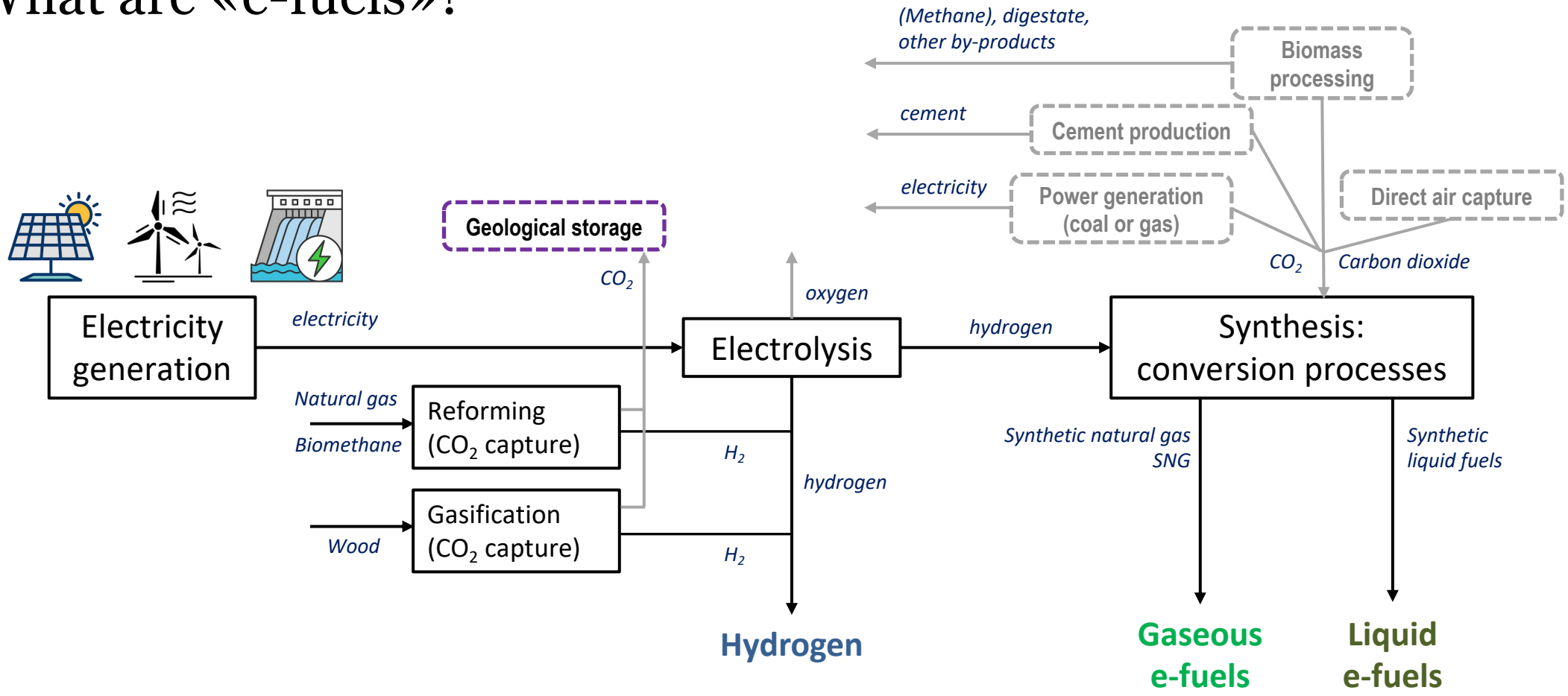

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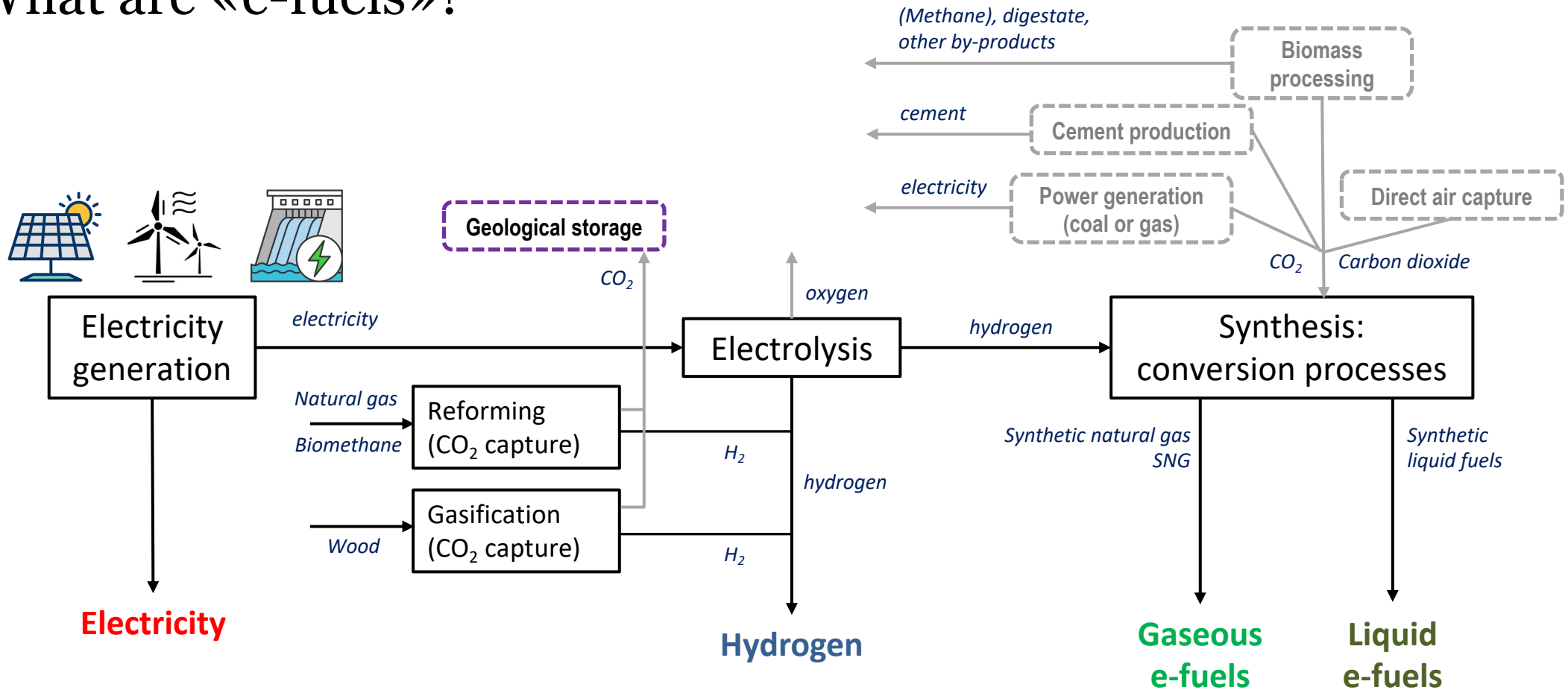

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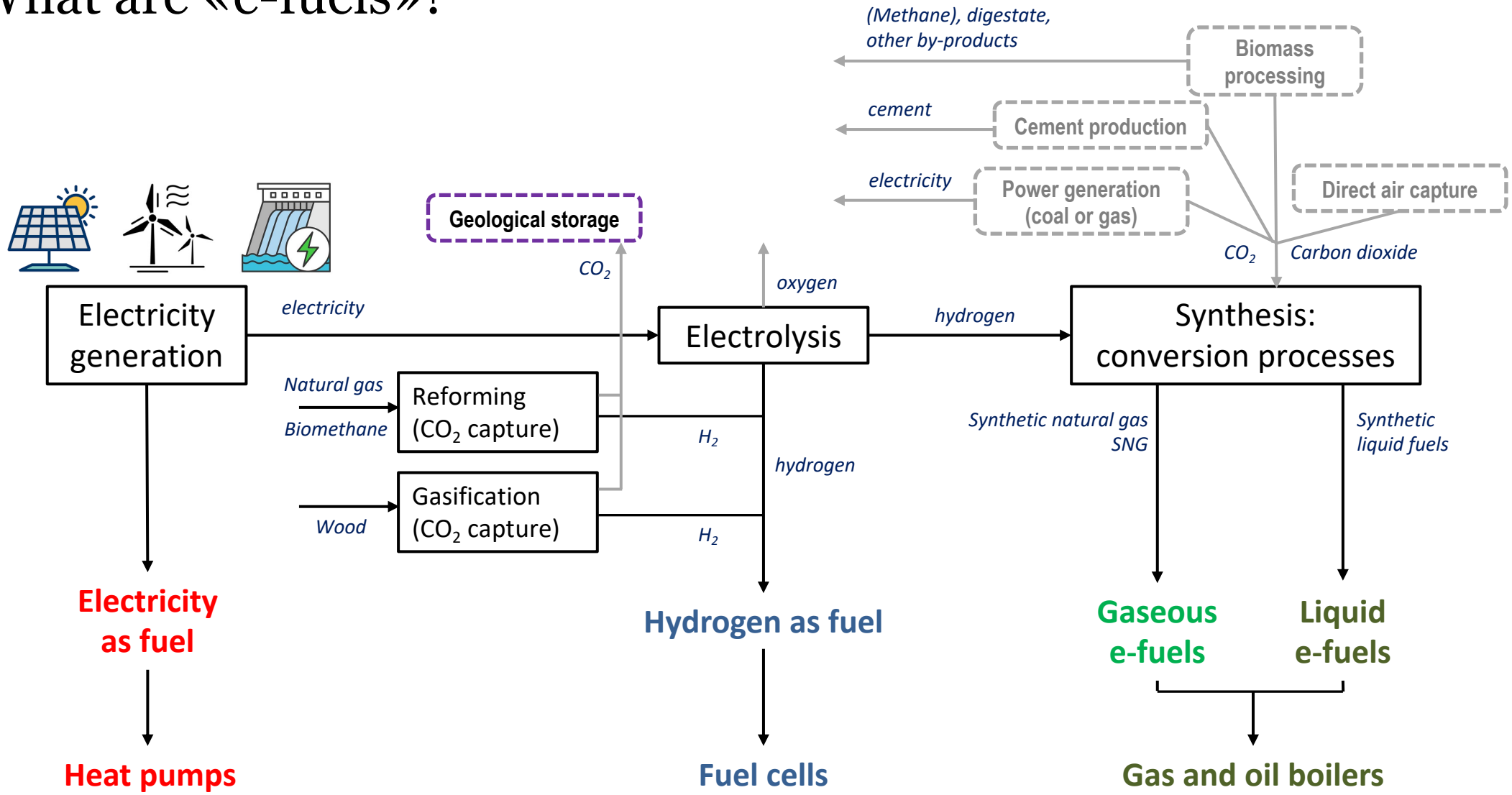

What is the promise of H_2-based e-fuels for the energy transition?

Atmosphere

Electricity

2020:
~20% hydro
~10% nuclear
~10% wind/solar

Fossil fuels (coal, natural gas, oil-based fuels)

Combustion technologies

Fossil fuel infrastructure

~20% of final energy use

~30% of energy CO2 emissions

Combustion technologies

Energy demand sectors

Industry *Transport* *Buildings*

Fossil carbon

The carbon content in fossil resources of ~15'000 Gt CO_{2eq} exceeds the limited disposal space of the atmosphere by a factor of 15-50.

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Electricity

2020:
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Indirect electrification

Hydrogen

Direct electrification

Fossil fuels (coal, natural gas, oil-based fuels)

E-fuels (e-methane, e-gasoline, e-kerosene)

Combustion technologies

Fossil fuel infrastructure

Combustion technologies → *Electric technologies*

Energy demand sectors

Industry *Transport* *Buildings*

Fossil carbon

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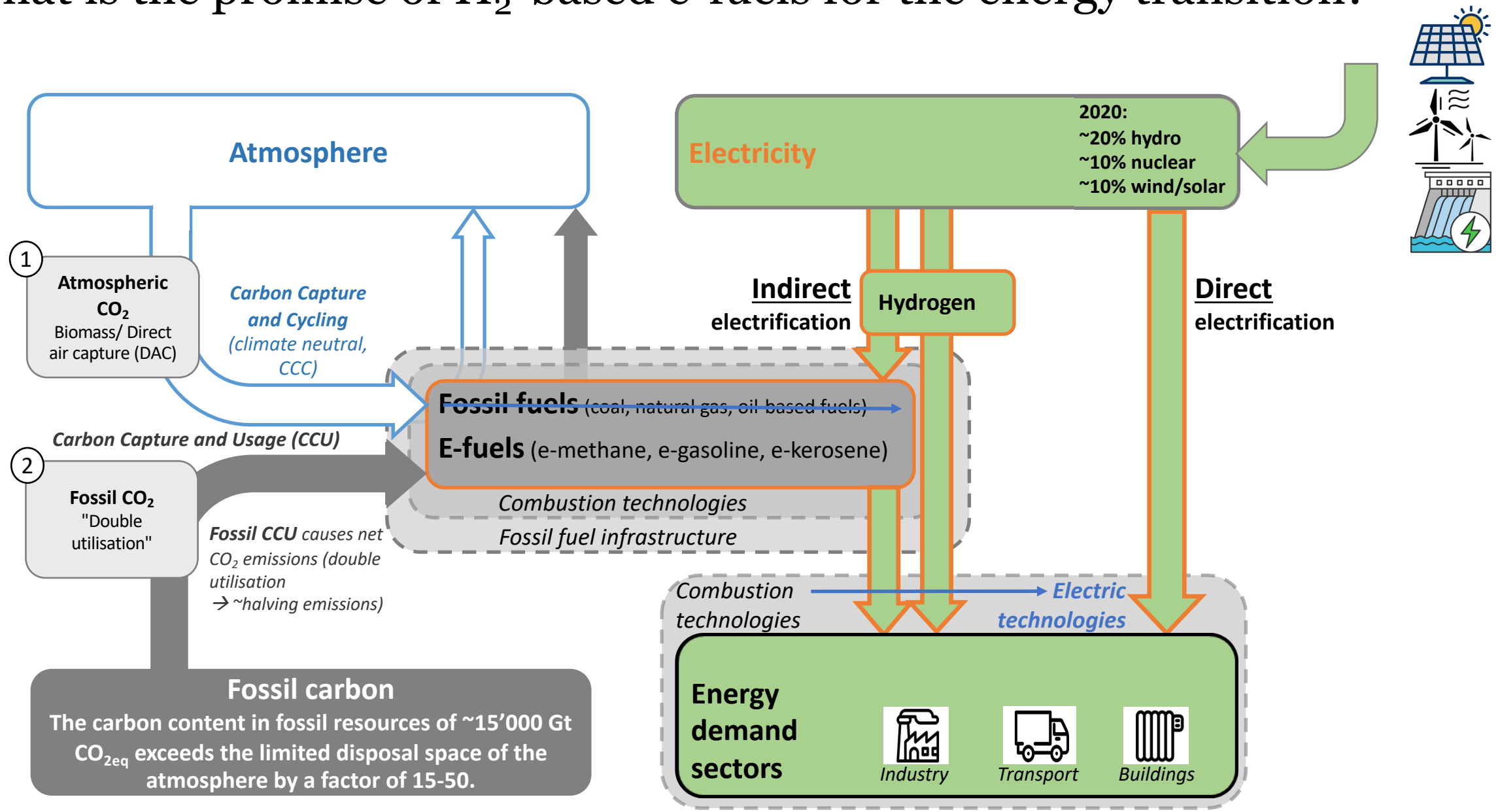


What is the promise of H_2-based e-fuels for the energy transition?

1. Broadly replacing fossil fuels without an end-use transformation.
   “Greening” fossil fuel infrastructures and combustion technologies.
2. Spatial matching of renewable energy supply and demand: global e-fuel trade
3. Temporal matching of electricity supply and demand: seasonal energy storage

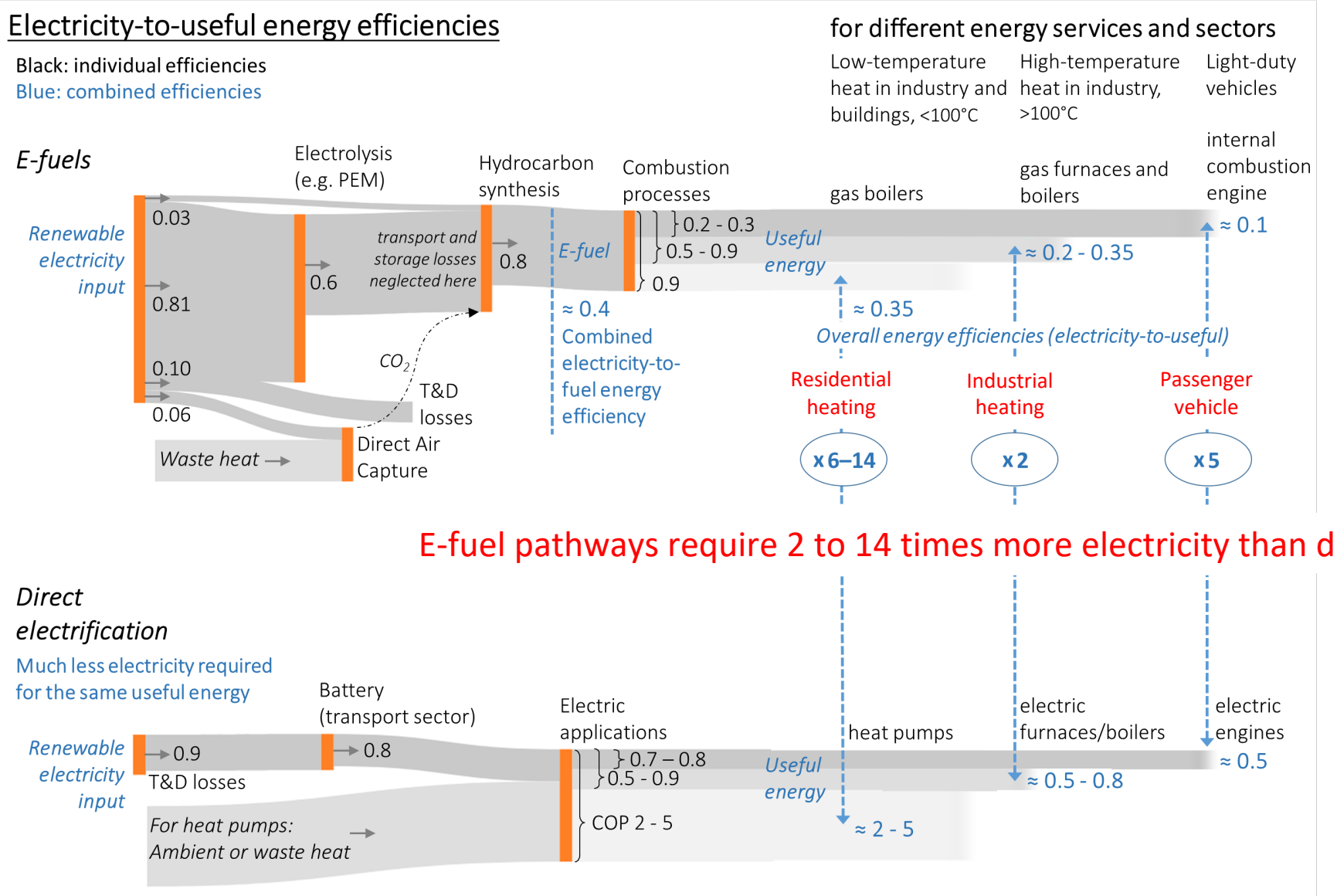
What are the shortcomings of H_2-based e-fuels?

1. Inefficient use of primary energy
2. Shaky climate benefits
3. Very high CO_2 abatement costs
4. Uncertain scale up and availability

H_2-based e-fuels – overall energy efficiency (production to use)

E-fuels

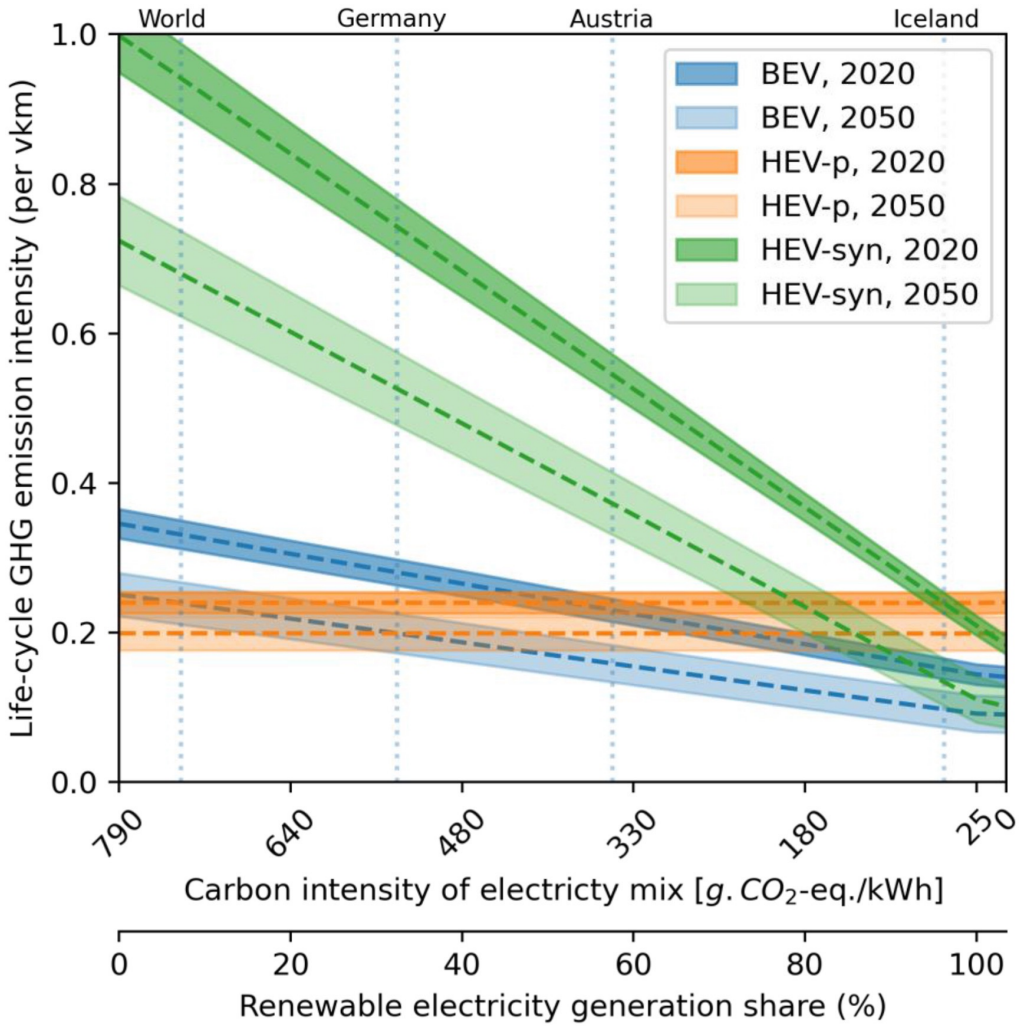
Direct electrification



Ueckerdt, F., et al. (2021) Potential and risks of hydrogen-based e-fuels in climate change mitigation

H_2-based e-fuels – Climate impacts

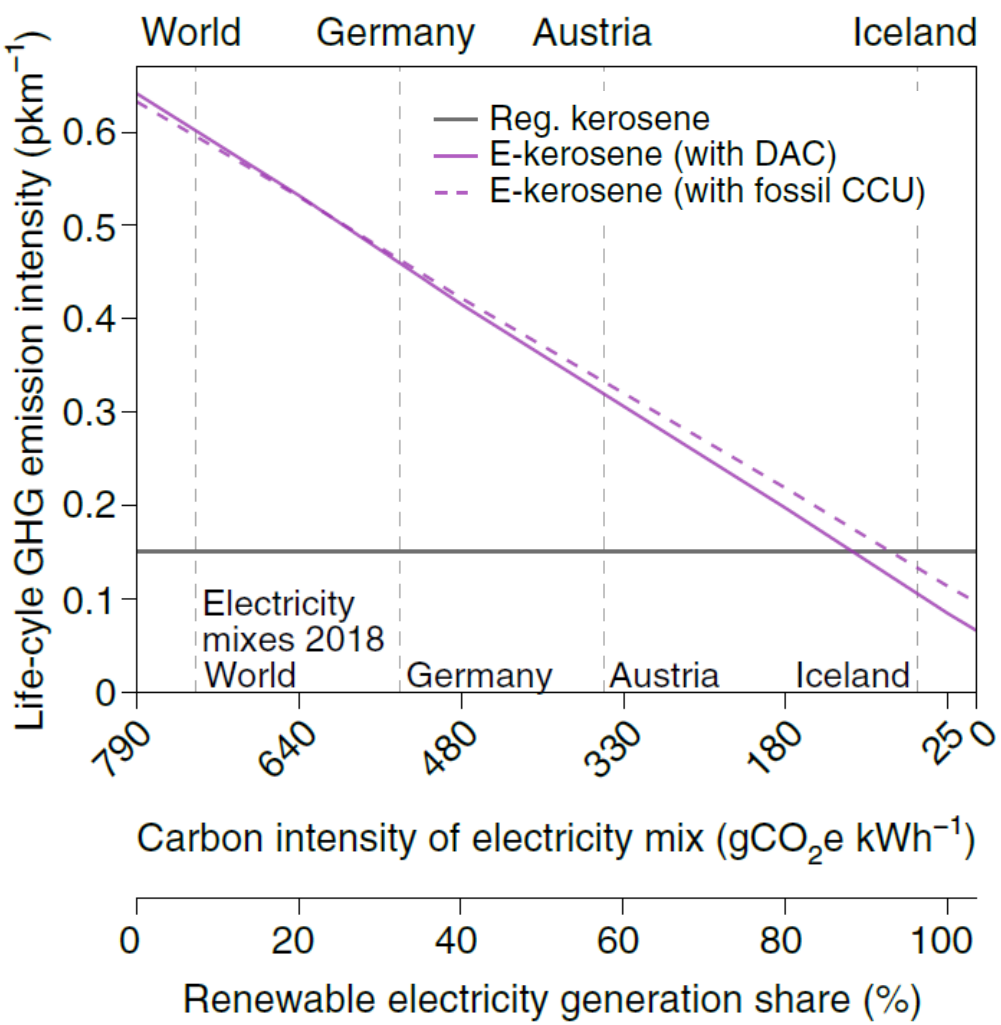
Mid-size passenger vehicle



BEV: Battery Electric Vehicle **HEV: Hybrid Electric Vehicle** **-p: petrol** **-syn: e-fuel**

Sacchi, R., et al. (2022) When, where and how can the electrification of passenger cars reduce greenhouse gas emissions?

Long-distance aviation



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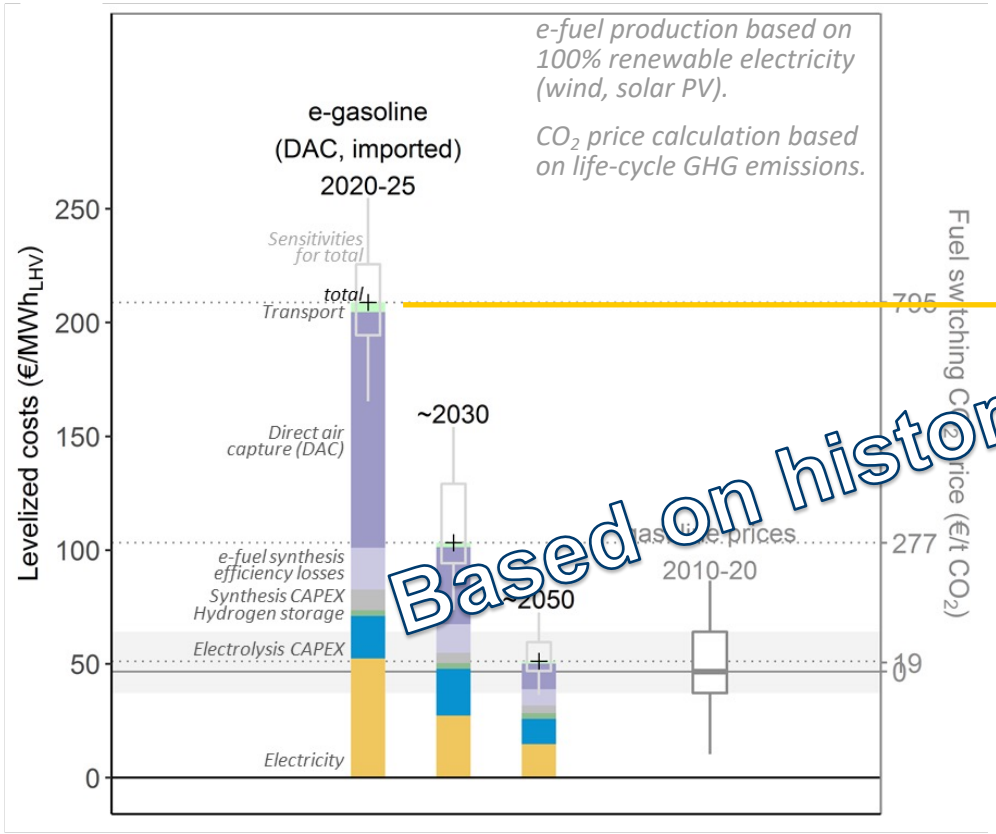
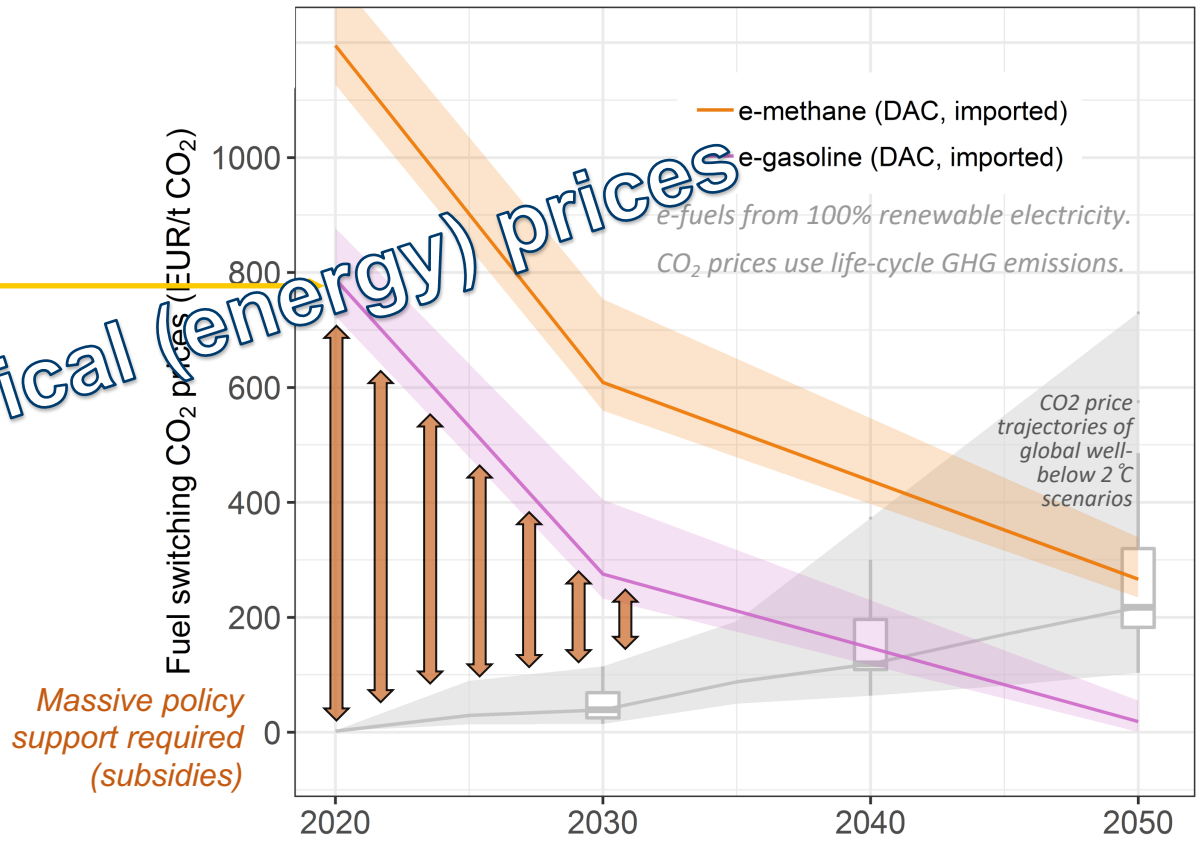
H_2-based e-fuels – high CO_2 abatement costs

High e-fuel costs, high CO_2 prices required.
Future innovation possible in case of massive scaling.

Competitiveness of e-fuels only ~2040
Massive subsidies required until then.



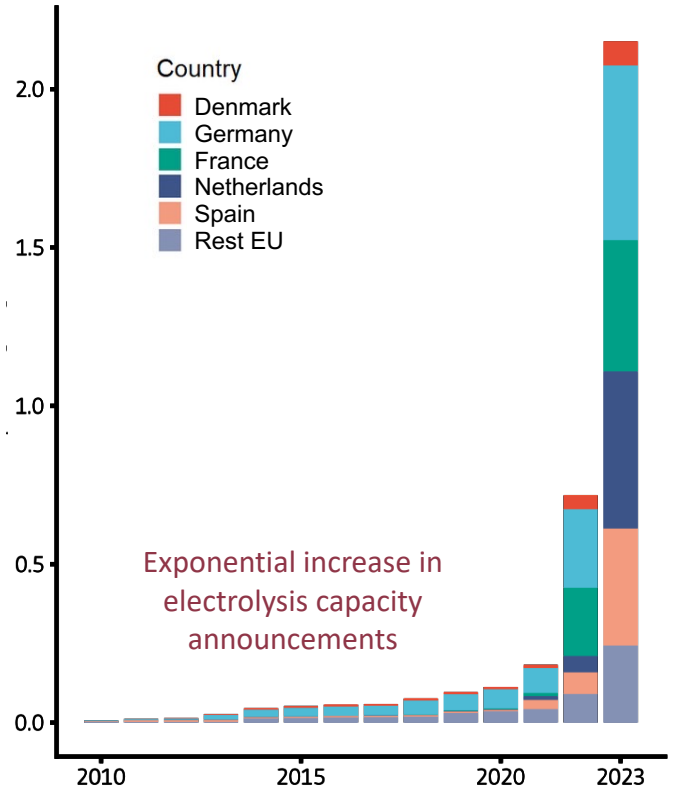


Recent increase in oil and gas prices will help closing the cost gap and might reduce policy support required.

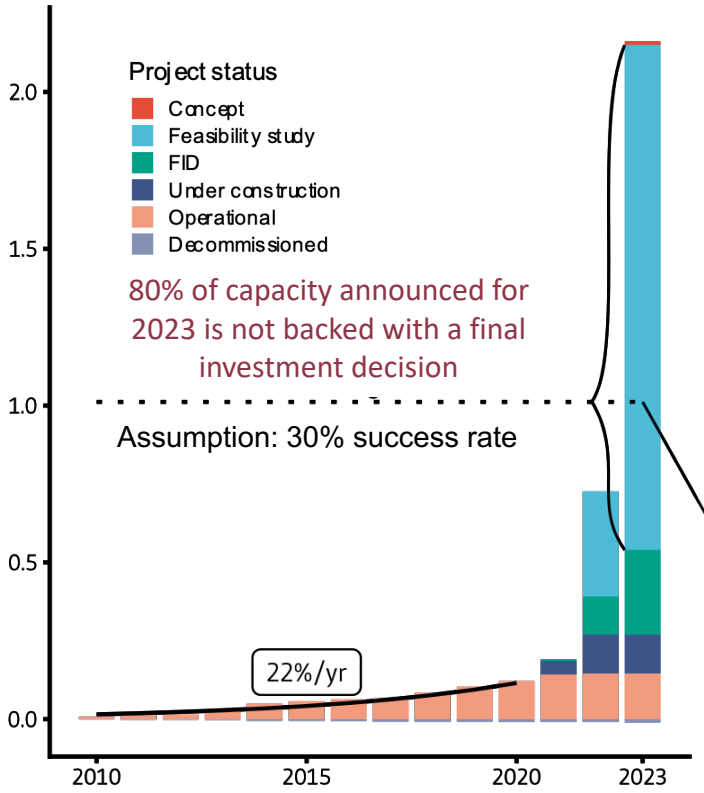
Ueckerdt, F., et al. (2021) Potential and risks of hydrogen-based e-fuels in climate change mitigation

E-fuels: uncertain scale-up and availability

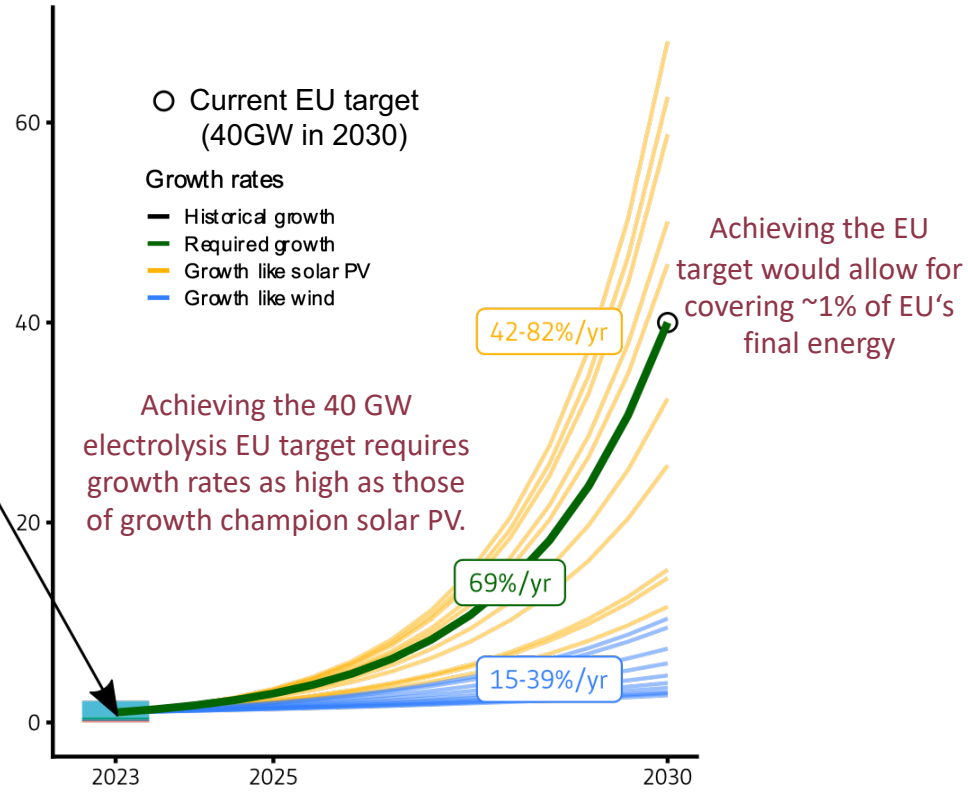
Electrolysis capacity EU [GW] per country



Electrolysis capacity EU [GW] per status

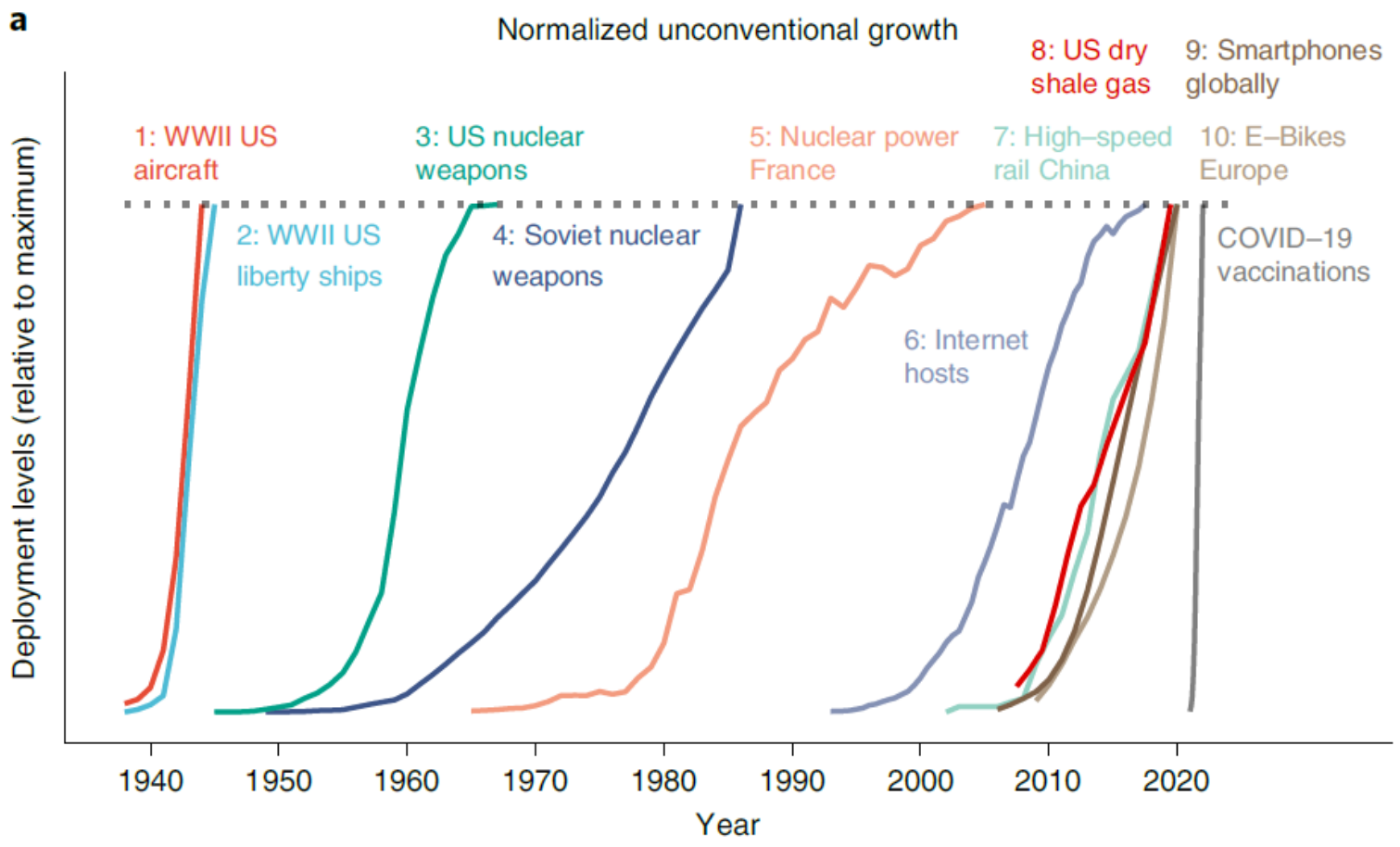


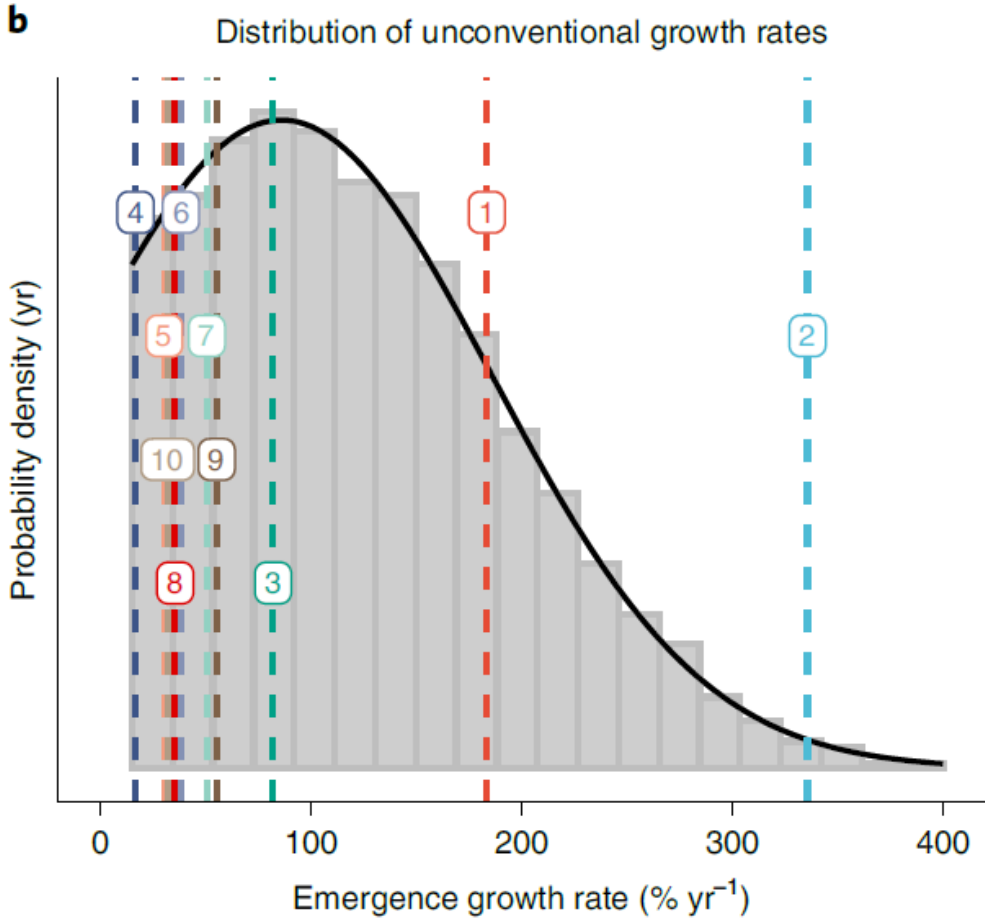
Growth rates required to achieve 40 GW electrolysis target



Ueckerdt et al. (2021) - Ariadne Kurzdossier, Eckpunkte einer anpassungsfähigen Wasserstoffstrategie.
Odenweller, A., et al., in preparation. Probabilistic feasibility space of scaling up green hydrogen supply.

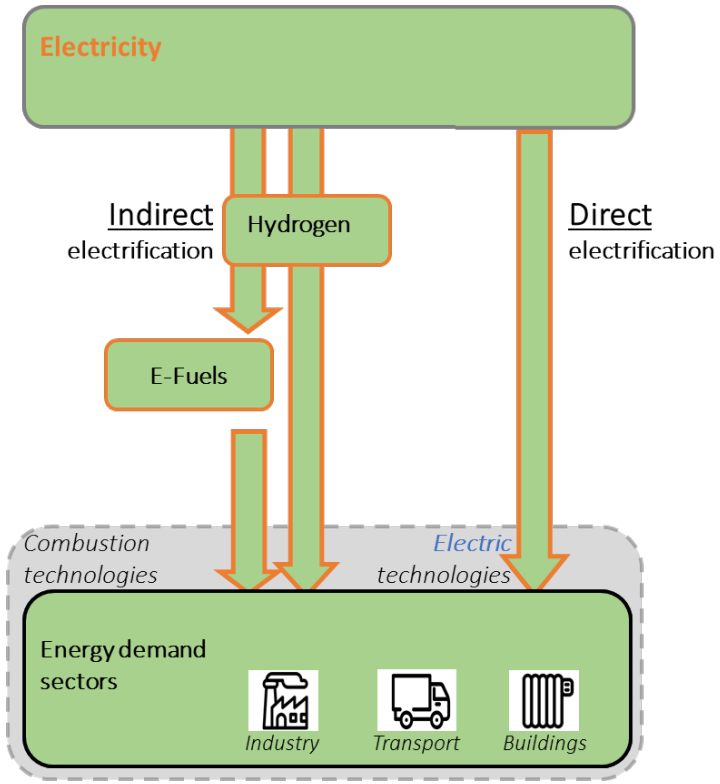
E-fuels: uncertain scale-up and availability

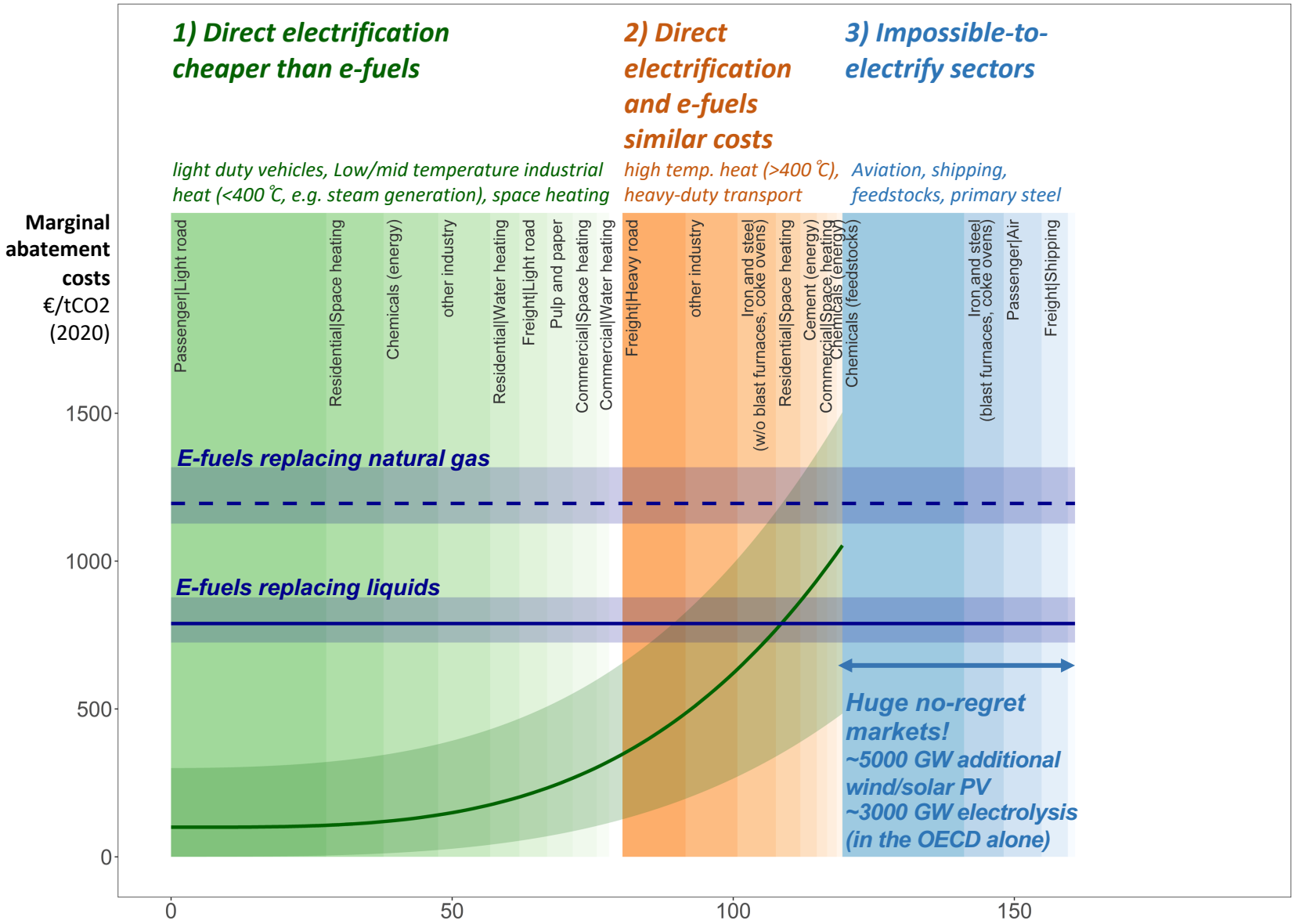




Odenweller et al. (2022) Probabilistic feasibility space of scaling up green hydrogen supply. Nature energy, https://doi.org/10.1038/s41560-022-01097-4

E-fuels vs. direct electrification: merit order of e-fuel demand





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Summary and take home messages

- E-fuels (as well as hydrogen) can (and hopefully will) be meaningful contributions towards net-zero GHG emissions
- BUT ONLY, if electricity with close to zero GHG emissions is available
- Due to e-fuel (and low-carbon H_2) scarcity, comparatively inefficient use of resources and thus also high costs and resource consumption, direct electrification should be preferred whenever possible
- Primary use cases for e-fuels: aviation and long-distance shipping, industry
- Primary use cases for (green) hydrogen:
  industry – feedstock and energy carrier; long-distance heavy-duty freight transport

Wir schaffen Wissen – heute für morgen

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Jordan Everall

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