# Potential and risks of hydrogen-based e-fuels in climate change mitigation

Dr. Falko Ueckerdt, head of National Energy Transitions Team at
Potsdam Institute for Climate Impact Research
HEC WEBINAR, January 10th, 2022

*Based on:*

***1)* Ueckerdt, F., Bauer, C., Dirnaichner, A., Everall, J., Sacchi, R., Luderer, G. (2021).**
***Nature Climate Change, https://doi.org/10.1038/s41558-021-01032-7***

*2) Ariadne Project Scenario Report for Germany,* „Deutschland auf dem Weg zur Klimaneutralität 2045."
https://ariadneprojekt.de/publikation/deutschland-auf-dem-weg-zur-klimaneutralitat-2045-szenarienreport/

3) Ariadne Project Policy Brief: „Cornerstones of an adaptable hydrogen strategy"
https://ariadneprojekt.de/publikation/eckpunkte-einer-anpassungsfaehigen-wasserstoffstrategie/

4) Odenweller, A., Ueckerdt, F., Nemet, G.F., Jensterle, M., Luderer, G., in preparation. Growth of electrolysis required to make green hydrogen a substantial climate change mitigation option

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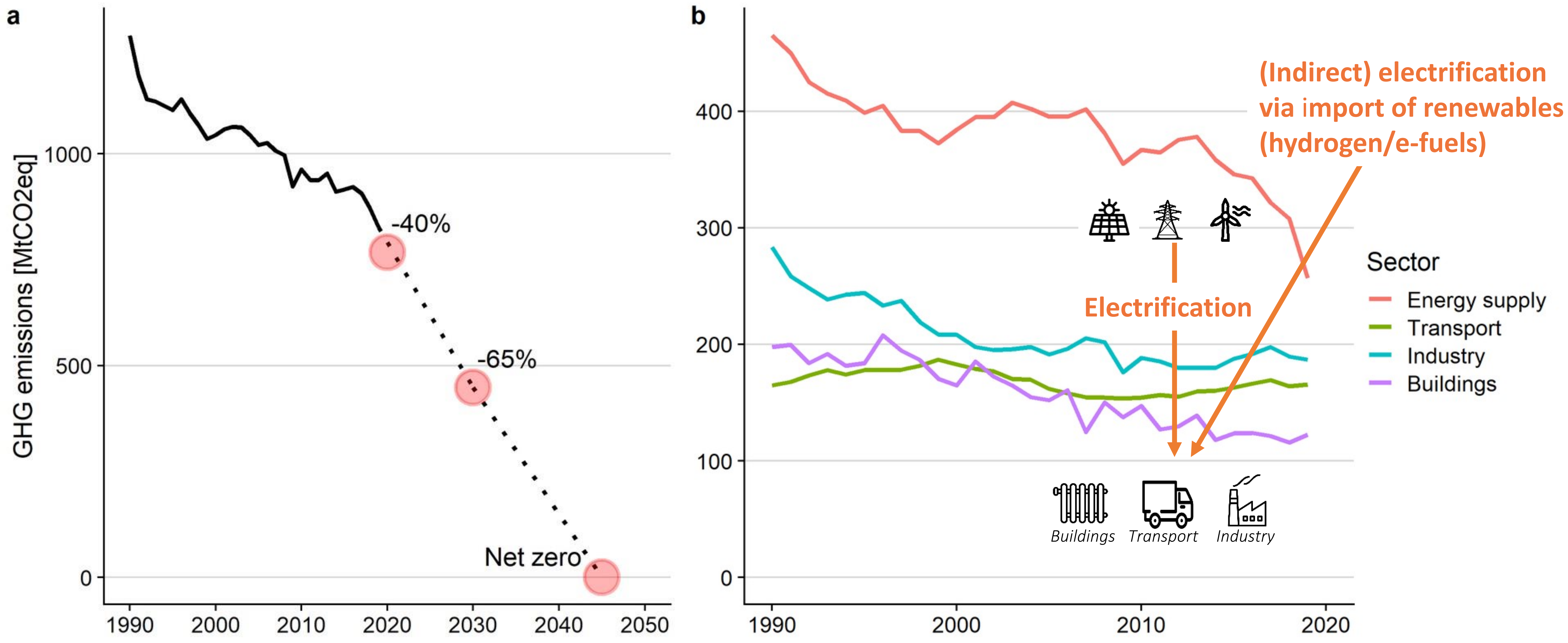
***4. Q&A, joint discussion***
transfer to Quebec/Canada

# Next phase of the energy transition: rapid and deep.




New consensus on main strategy (at least in Germany/EU):
renewable electricity and electrification

Figures by Adrian Odenweller

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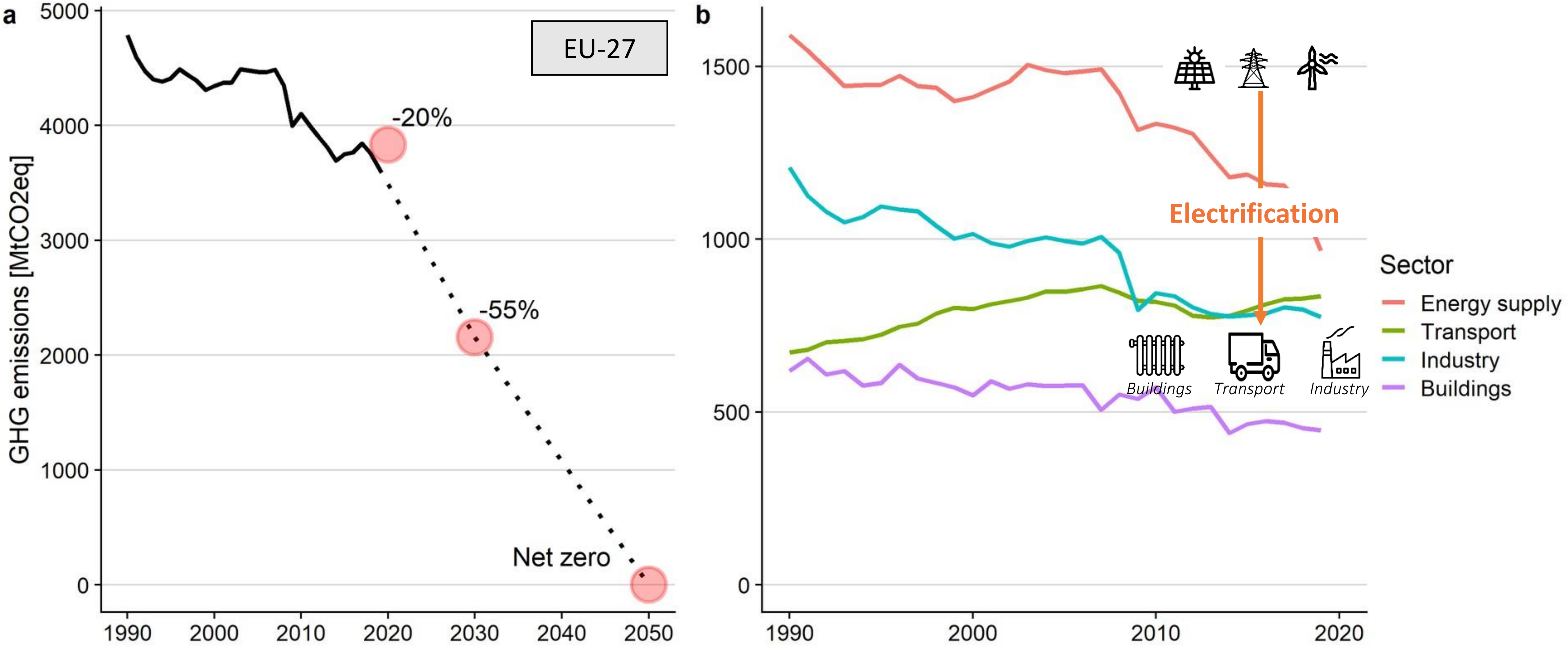


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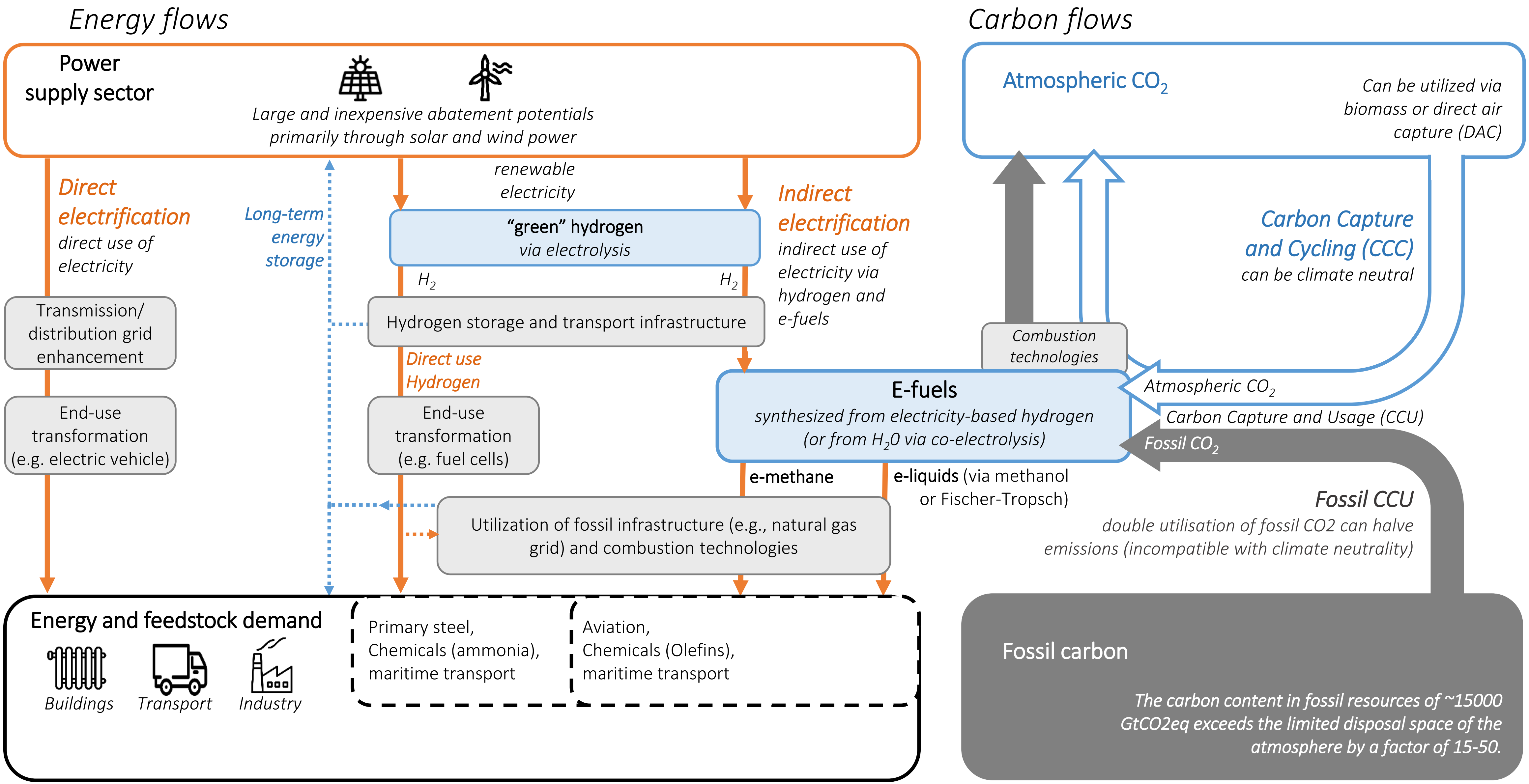


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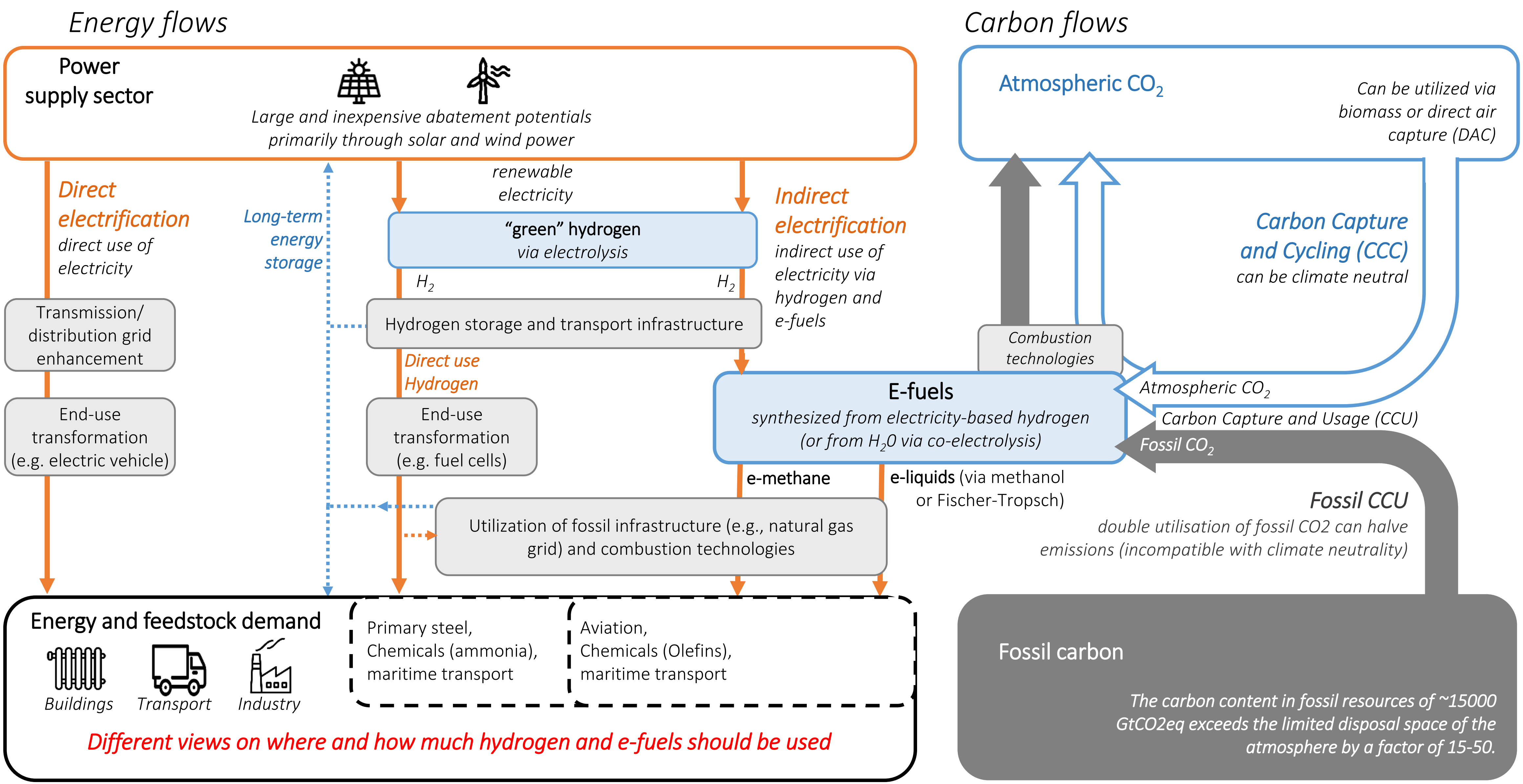


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# Two dimensions in the debate

*More **domestic** renewable expansion*

*More **direct** electrification*

*More renewable **imports***

*More **indirect** electrification*

***H2 demand side: which applications?***

**Focused prioritize hydrogen for „no-regret sectors“ (consensus)**
primary steel, ammonia, aviation, shipping, olefins (huge markets)

**Grey area middleground**
- low-temp. heat industry (steam making)
- high-temp. heat (e.g. glass making, or cement)
- long-haul freight transport (trucks)

**Broad**
all sectors, including passenger car, buildings

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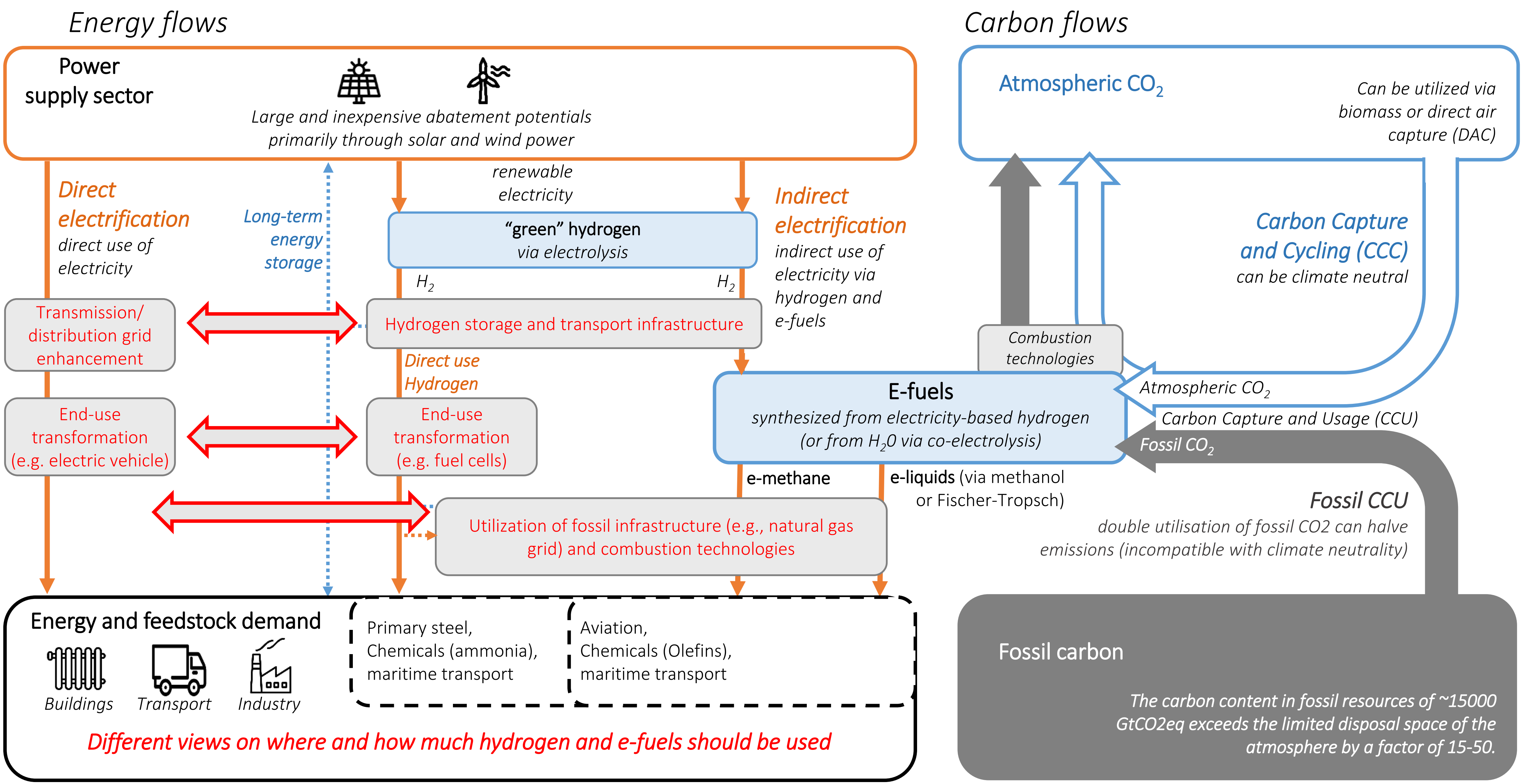


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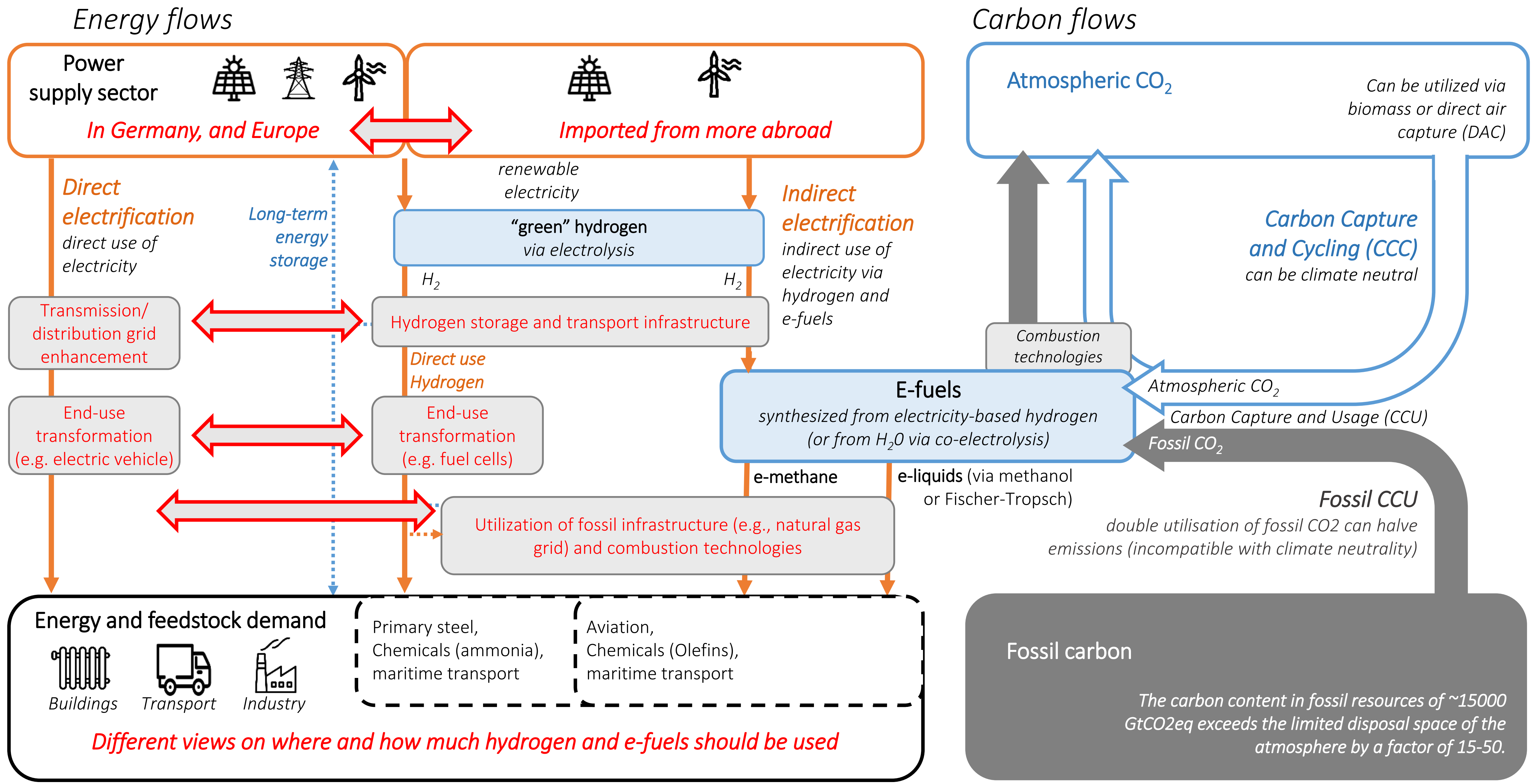
# Underneath the hydrogen debate: Competing visions of the future energy system

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***2nd dimension of the debate?***

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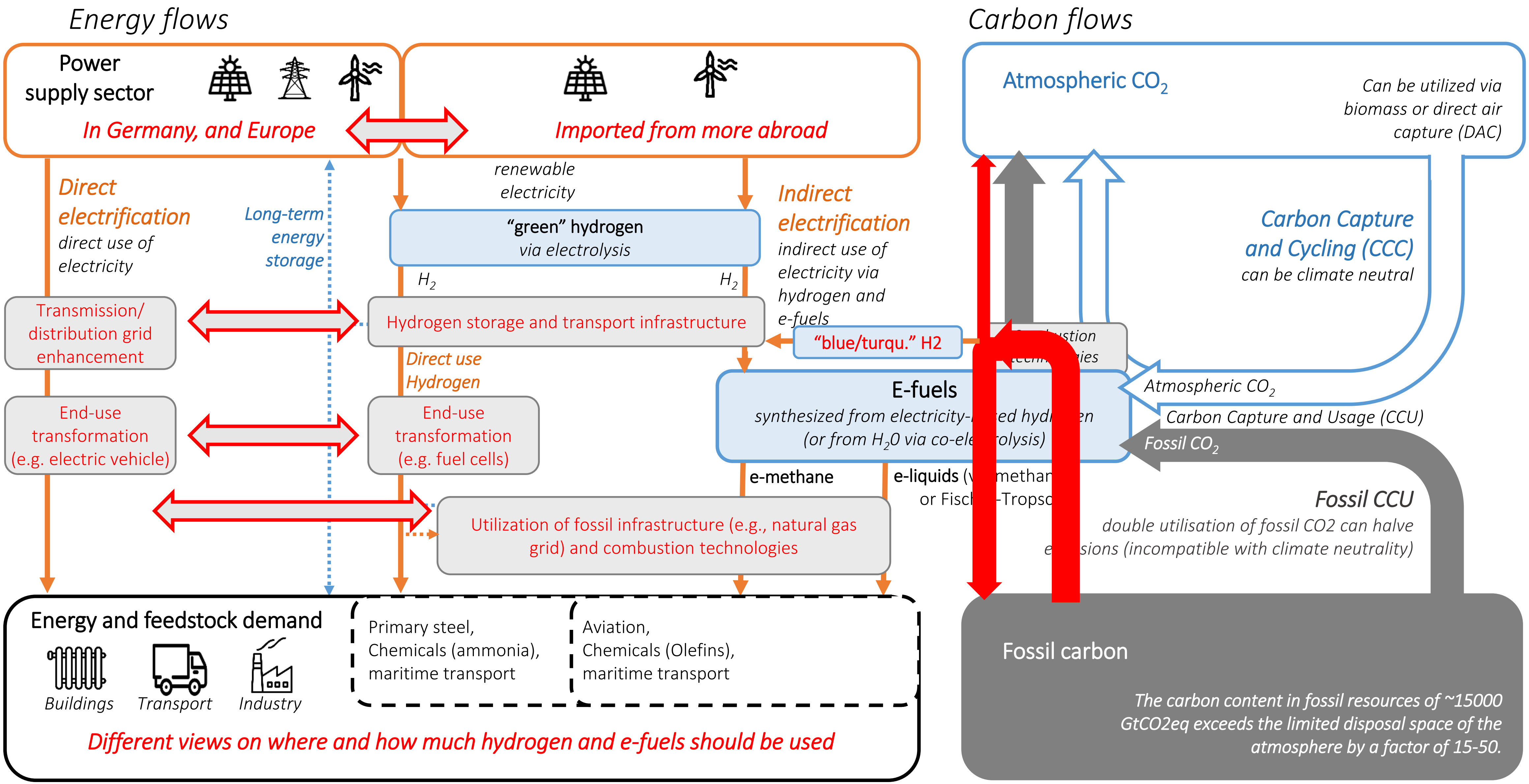


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# Two dimensions in the debate

***H2 supply side***
***(hydrogen colors and other bridging solutions)***

Entirely
**green**
hydrogen

*„Hydrogen:*
*the **champagne** of the energy transition!“*

***H2 demand side:***
***which applications?***

Short bridge
of **blue** hydrogen

Longer and broad
contribution of **blue and turquoise** hydrogen

**Focused**
**prioritize hydrogen for „no-regret sectors“ (consensus)**
primary steel, ammonia,
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*„Hydrogen:*
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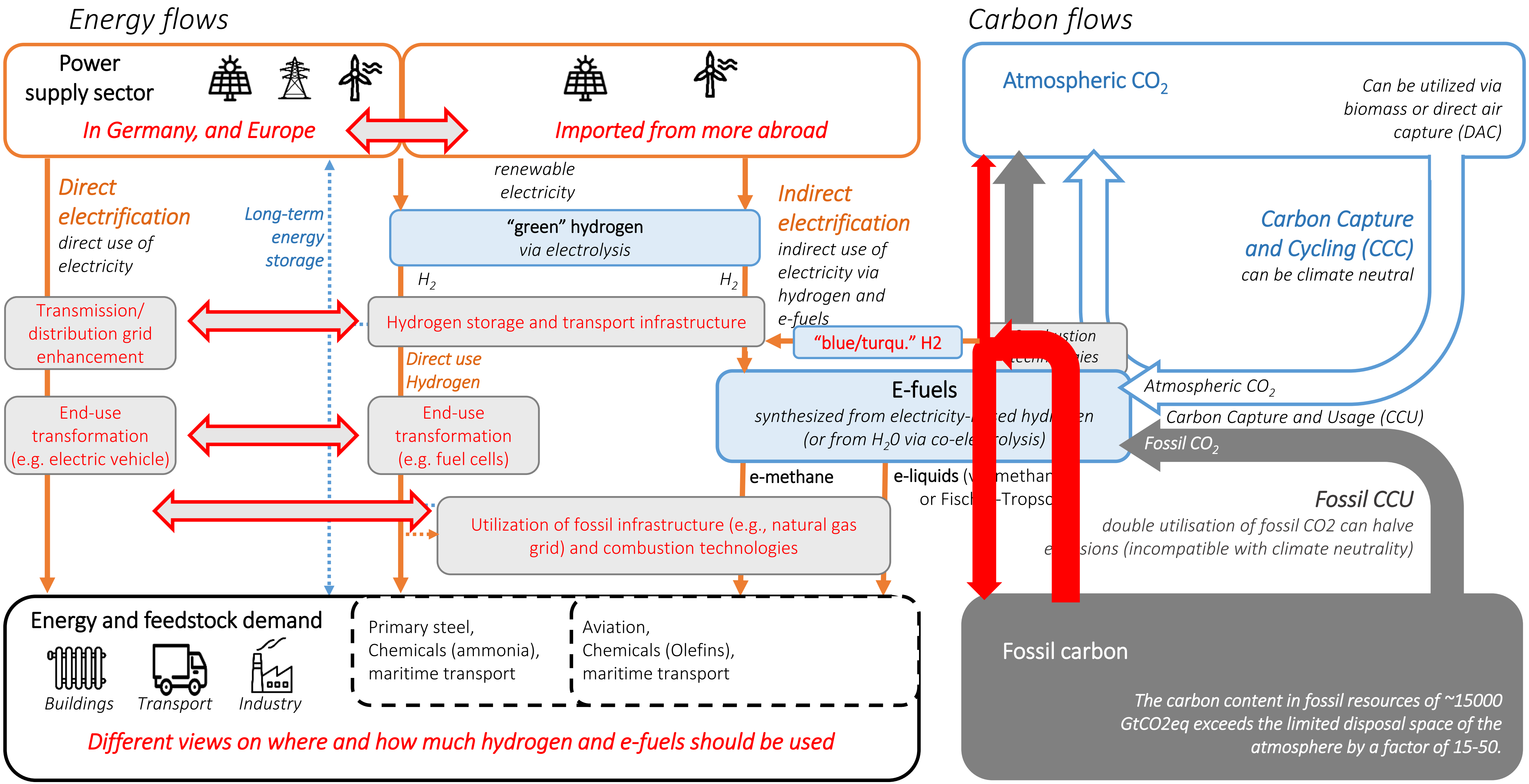


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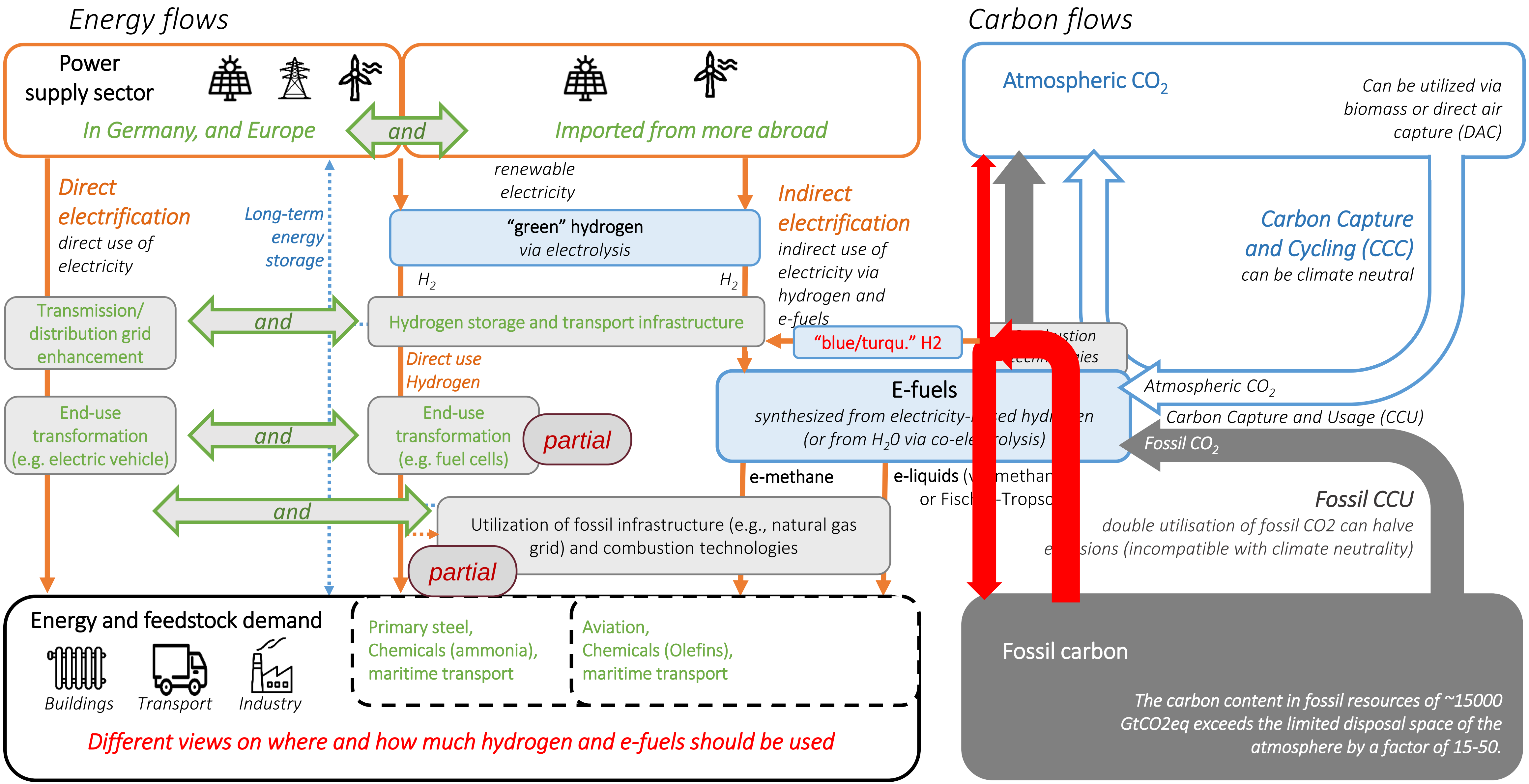
# Many robust "no-regret" options. How to make decisions on competing options?

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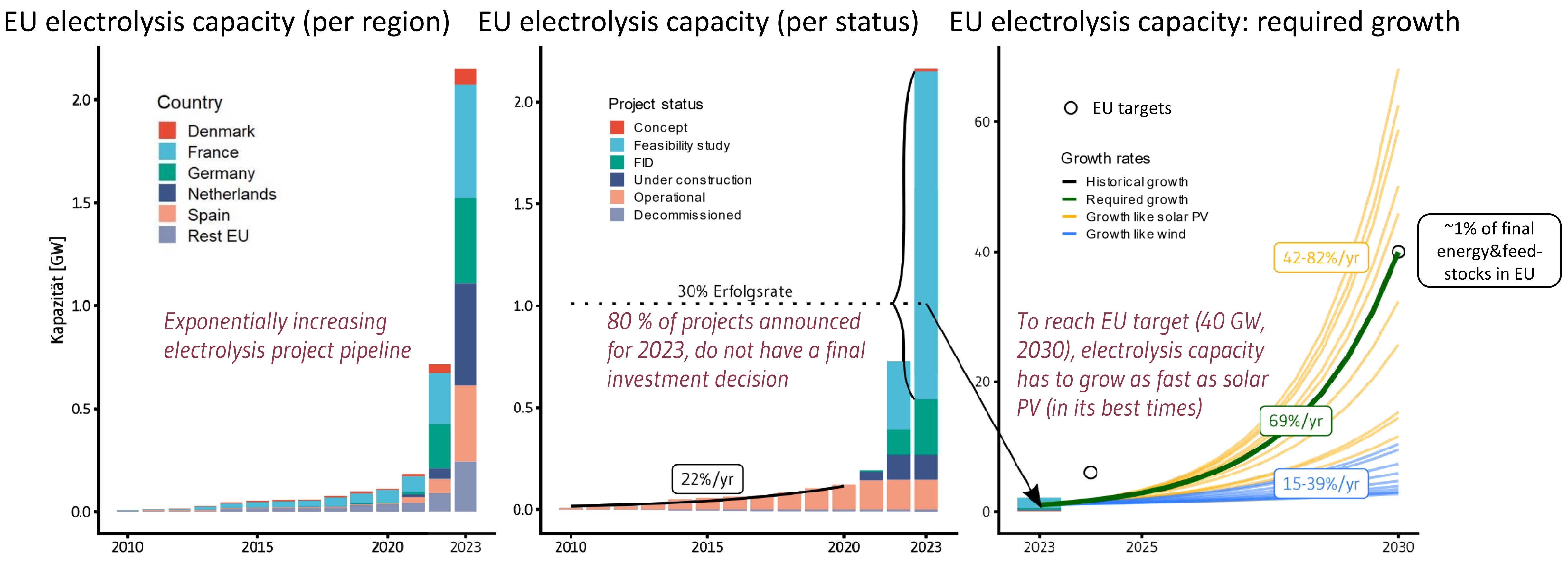
# Bottleneck and indicator: Electrolysis capacity expansion

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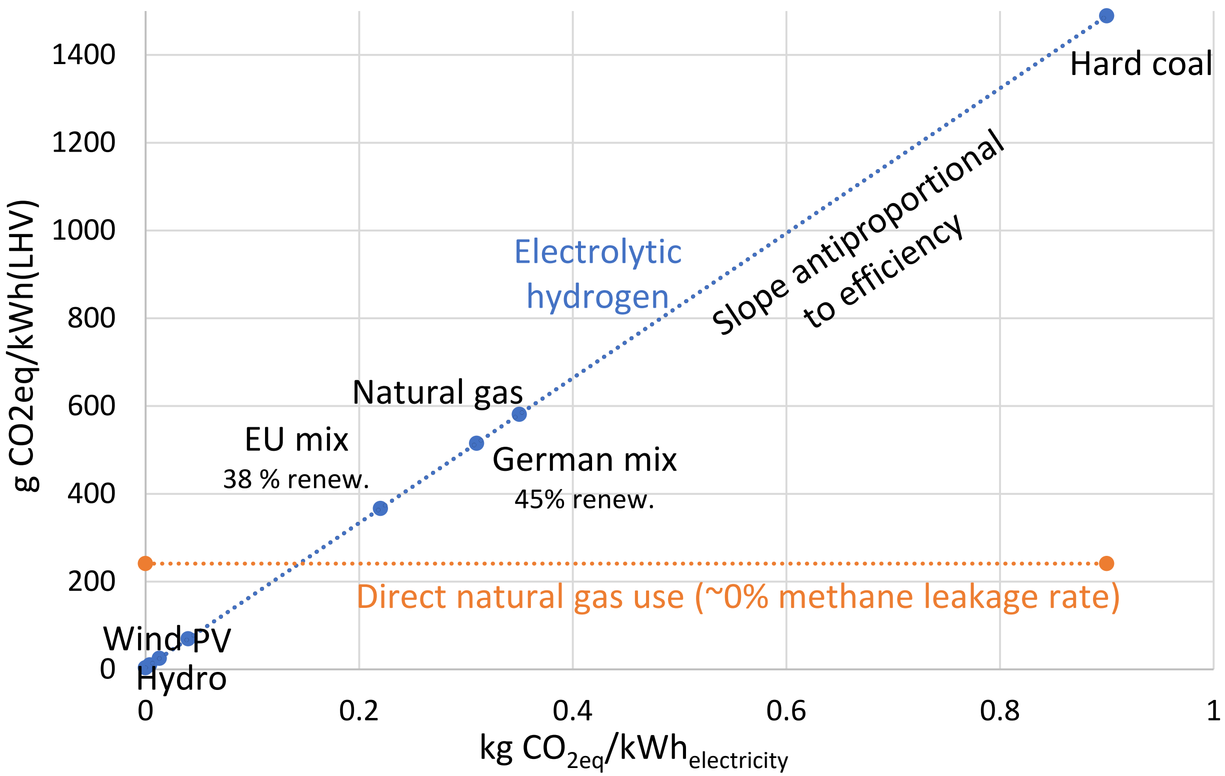
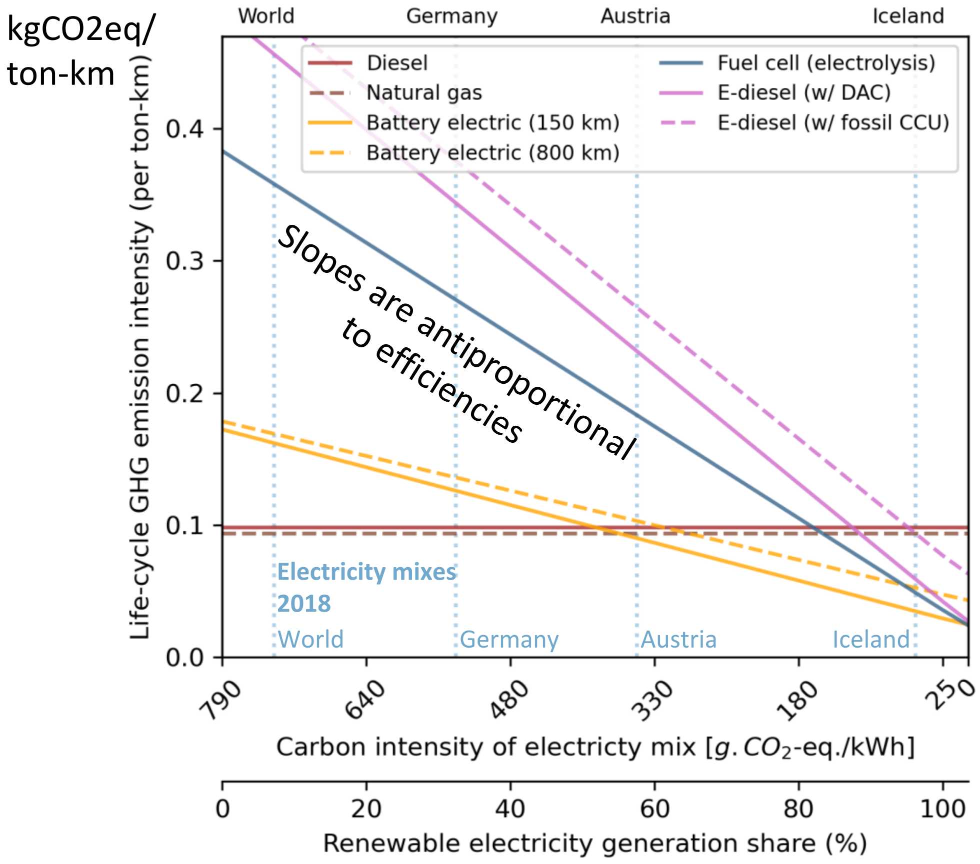
# Climate effectiveness of hydrogen highly depends on the CO2 intensity of electricity

**>80 % renewable electricity required to reduce emissions with hydrogen compared to natural gas**
(based on LHV for e.g. heating applications)




**>80 % renewable electricity required to reduce emissions with a fuel-cell truck compared to diesel**
(semi-trailer trucks, 40t weight, 10t load)

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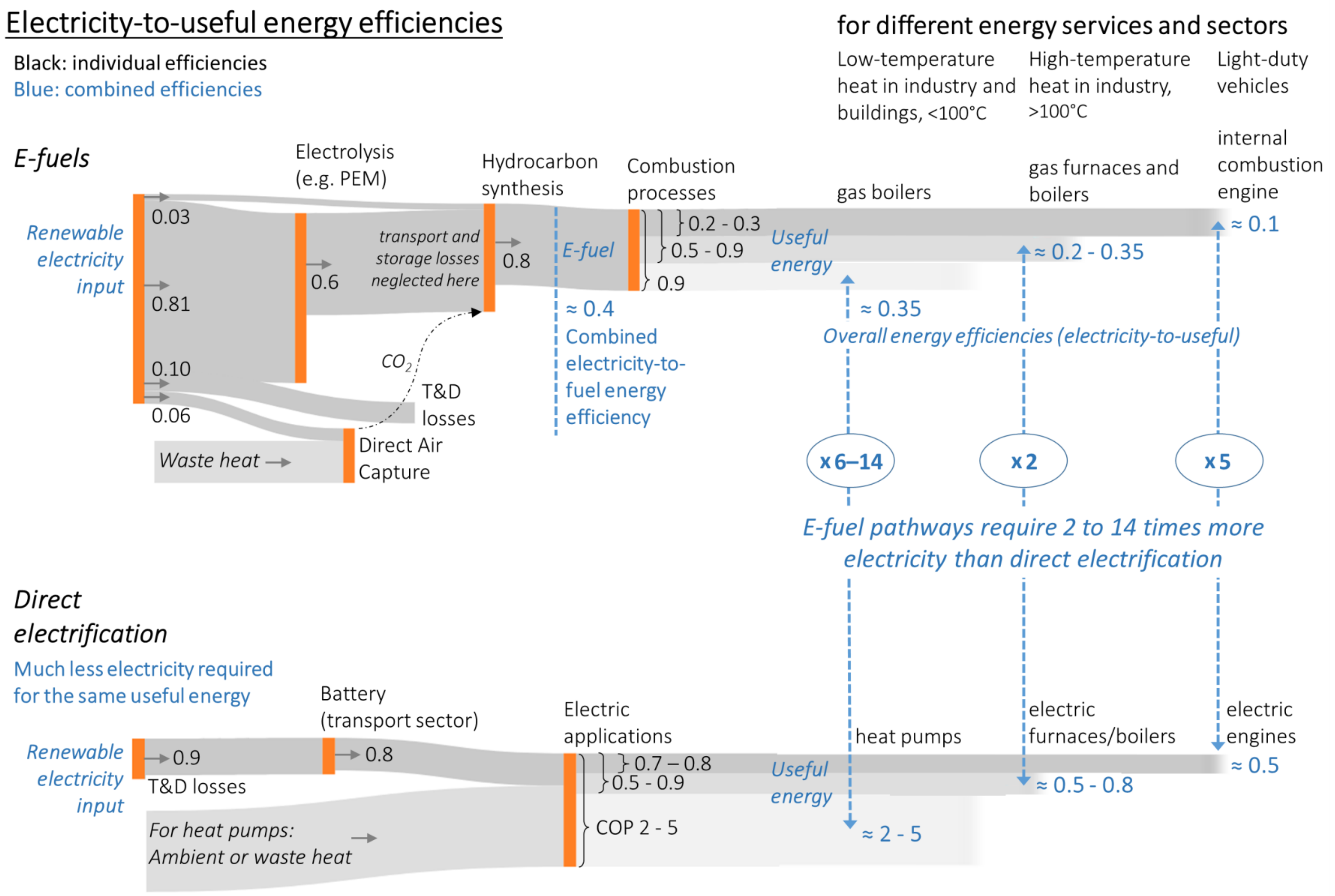
# E-fuels require two to fourteen times more electricity than a direct electrification





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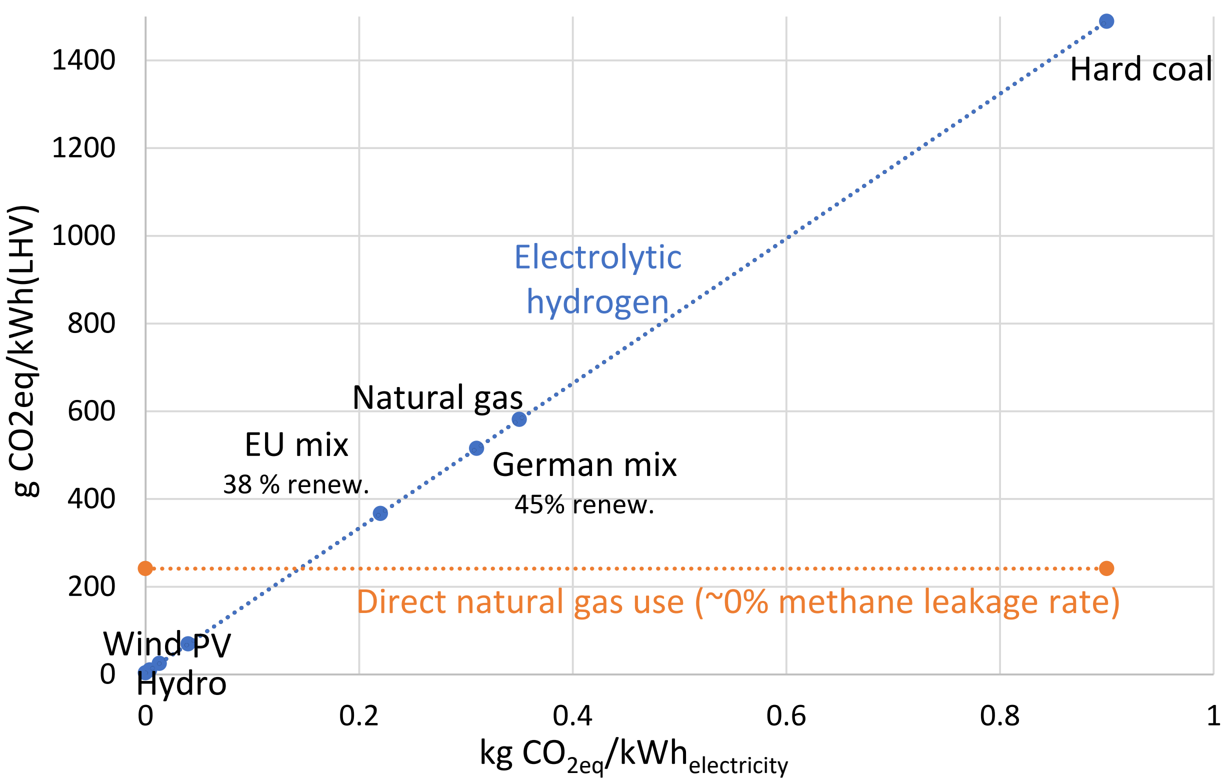


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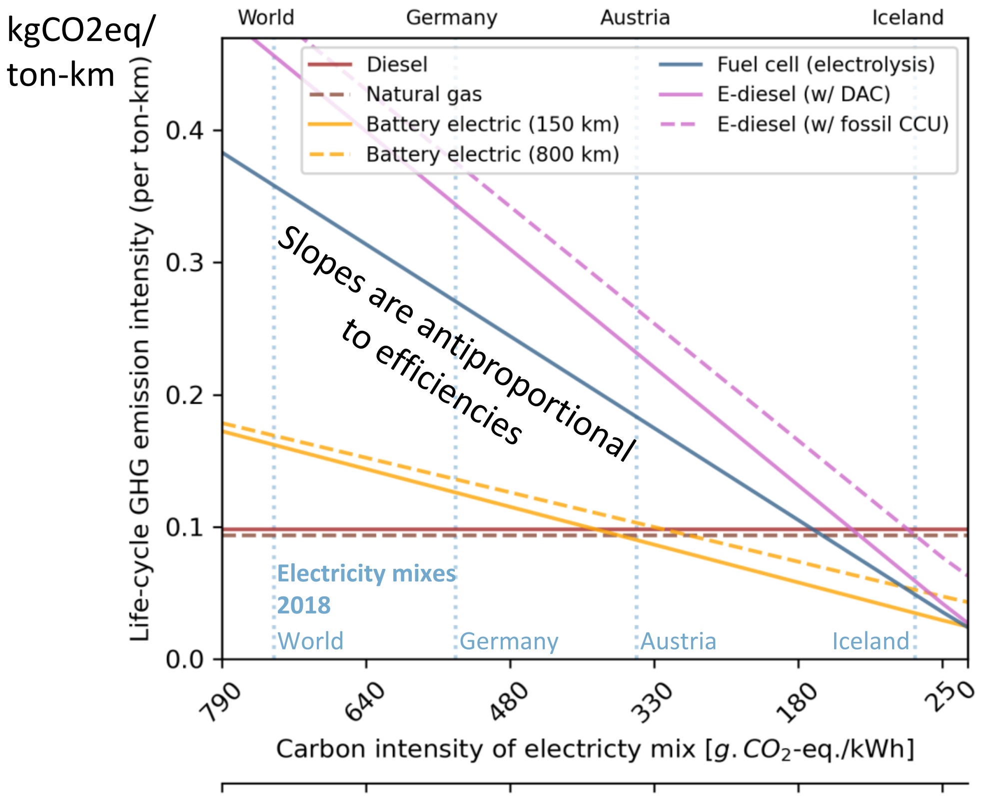


***Fierce debate around EU delegated act on RFNBOs. Environmentalists: „Additionality*** **of renewables is required because“**

i) despite substantial shares, renewable electricity is and will remain scarce

ii) diverting renewable electricity away from more efficient and thus more effective direct use increases emissions

**→ trade-off between short-term mitigation and (green) hydrogen scale up. What phase-in period of strict criteria?**

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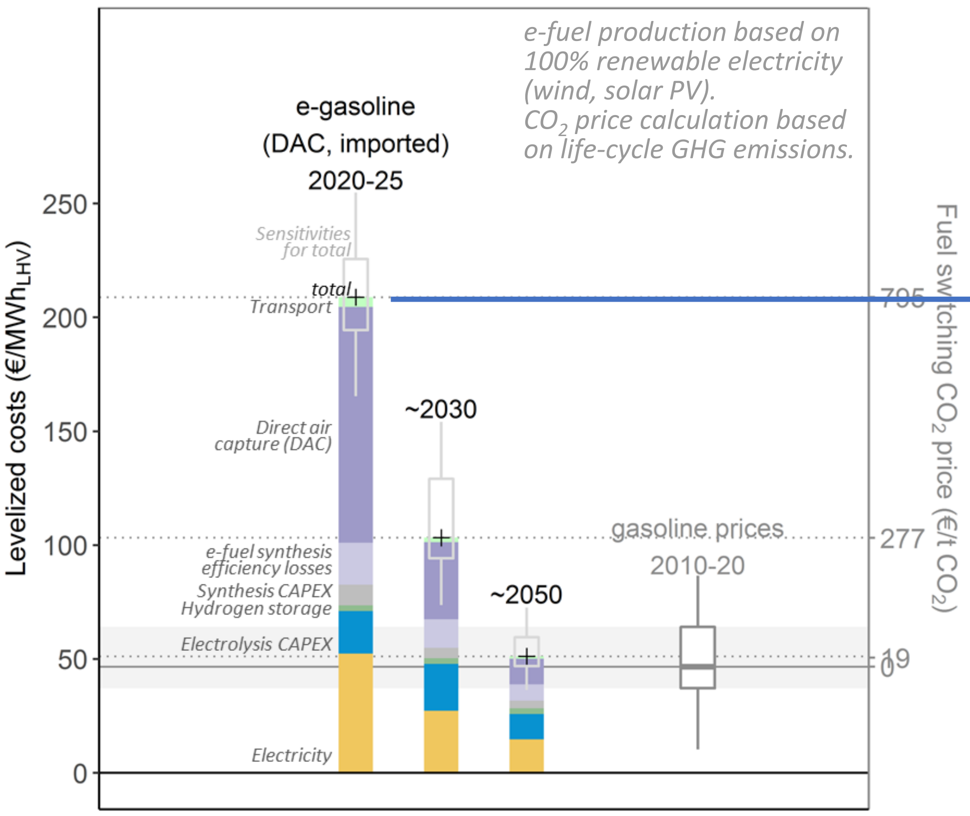
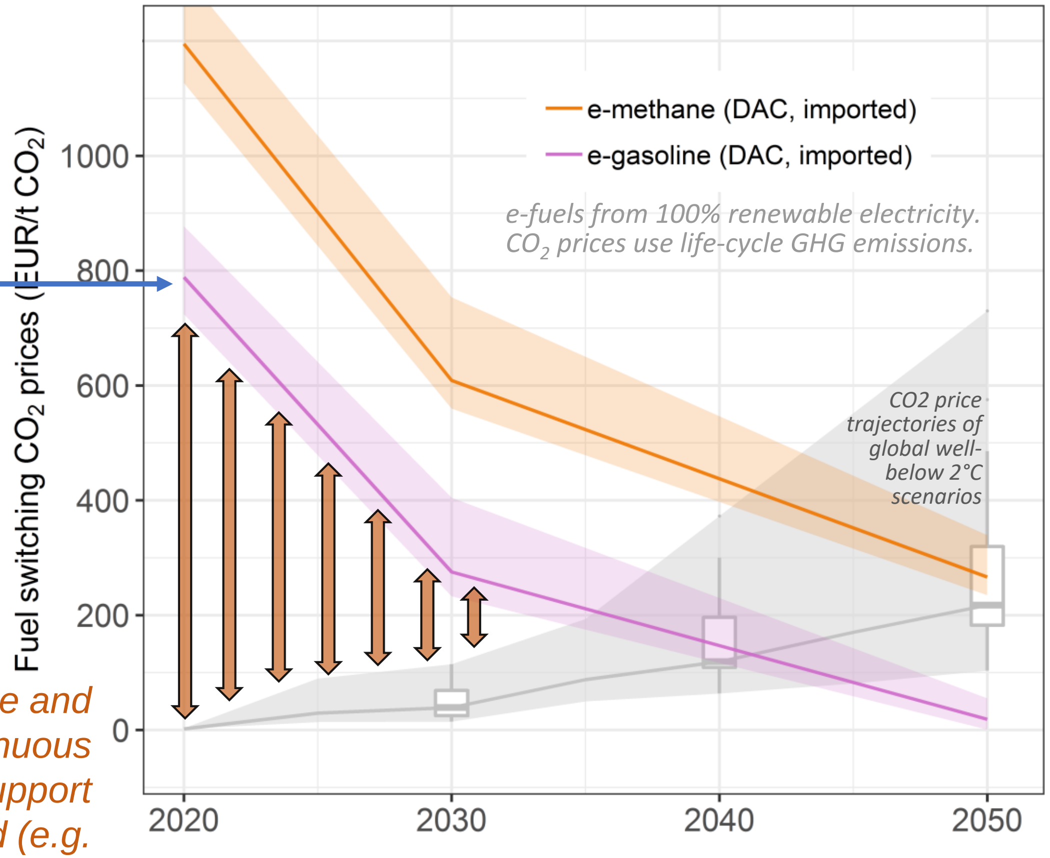
# E-fuels not competitive in the next 1-2 decades. Immense policy support required.

High today‘s costs, high CO2 prices required.
Future innovation possible in case of massive scaling.




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




*Immense and continuous policy support required (e.g. subsidies such as CCfDs)*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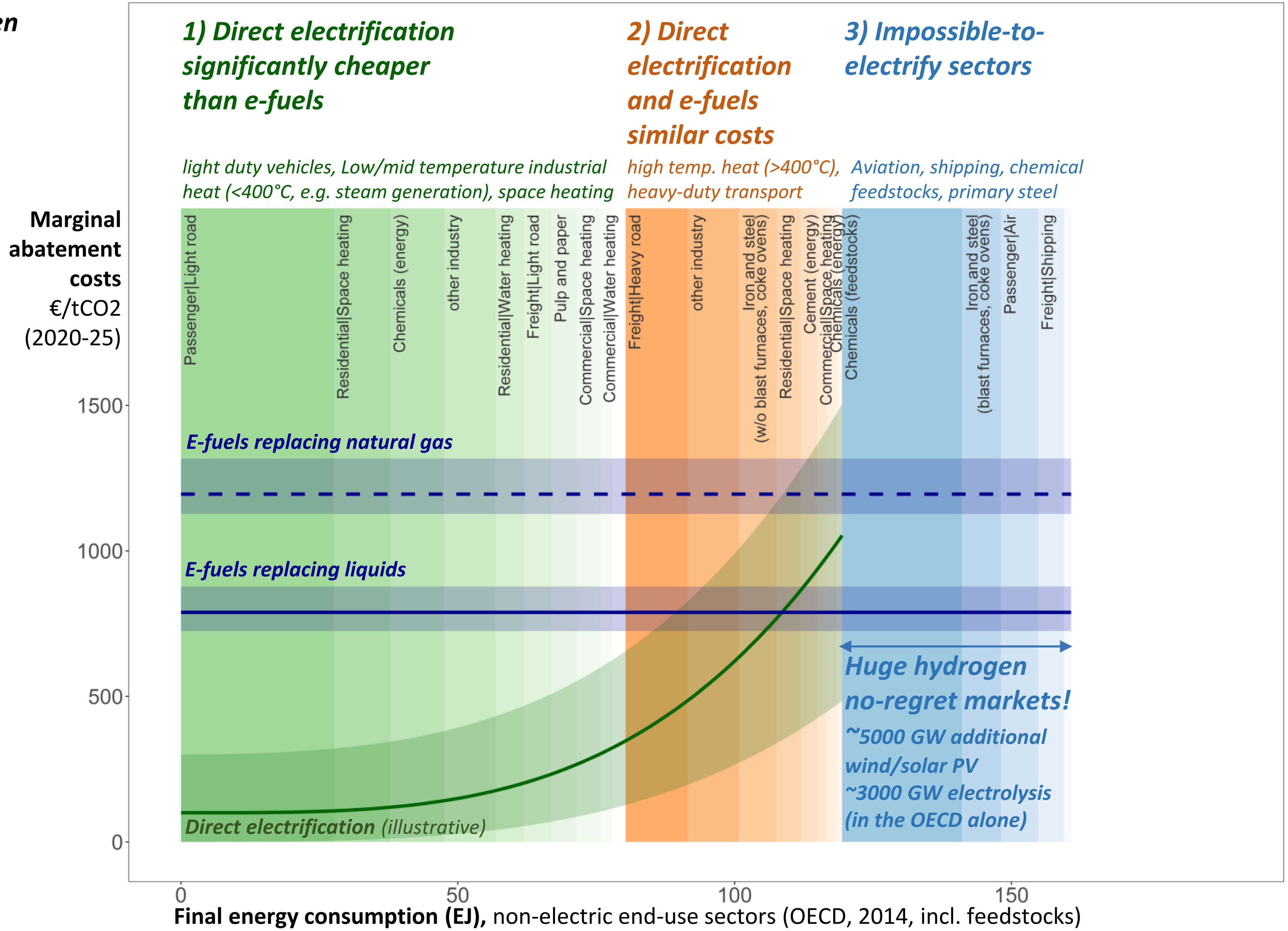
***Merit order of hydrogen and e-fuel demands***

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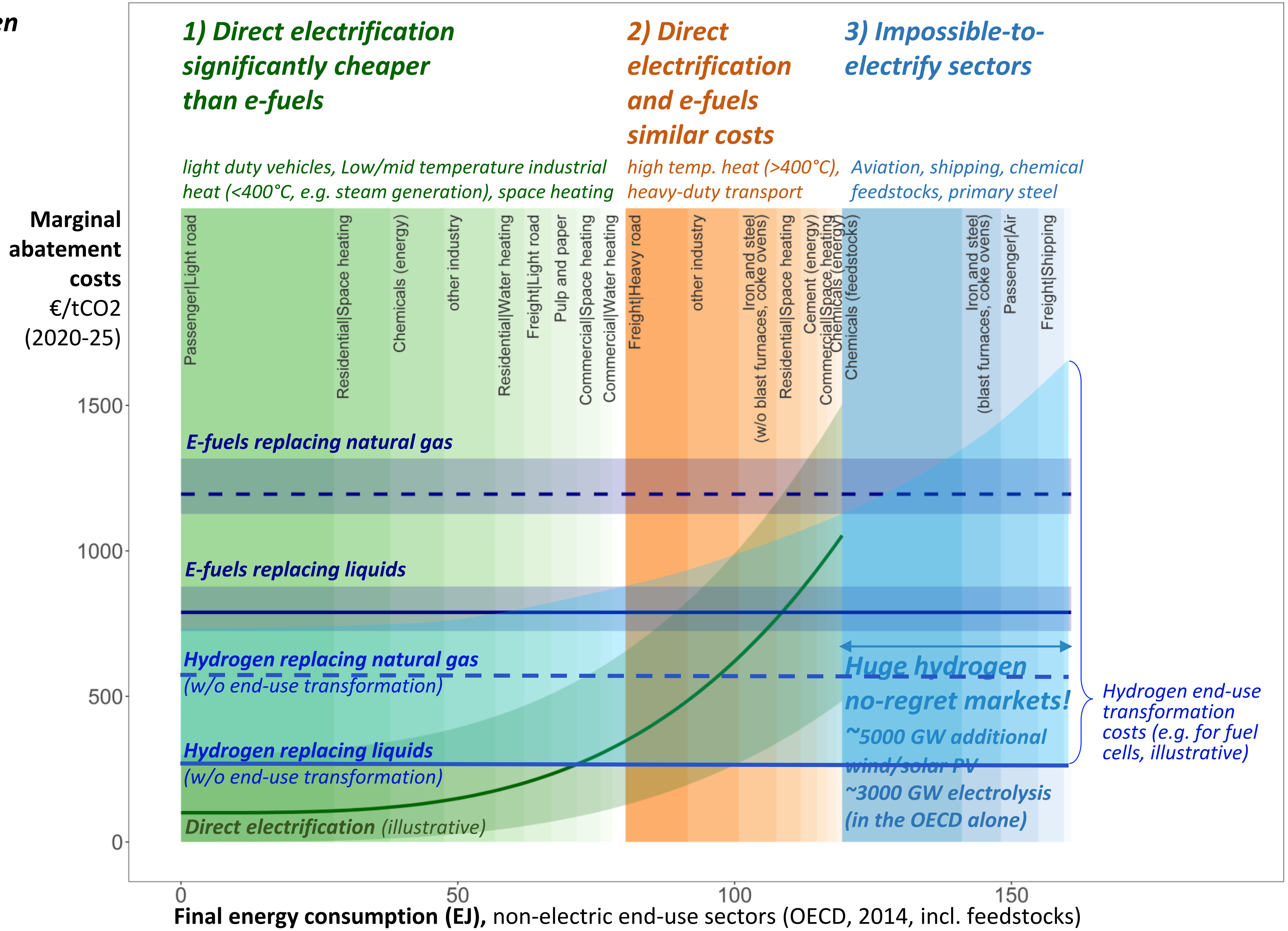


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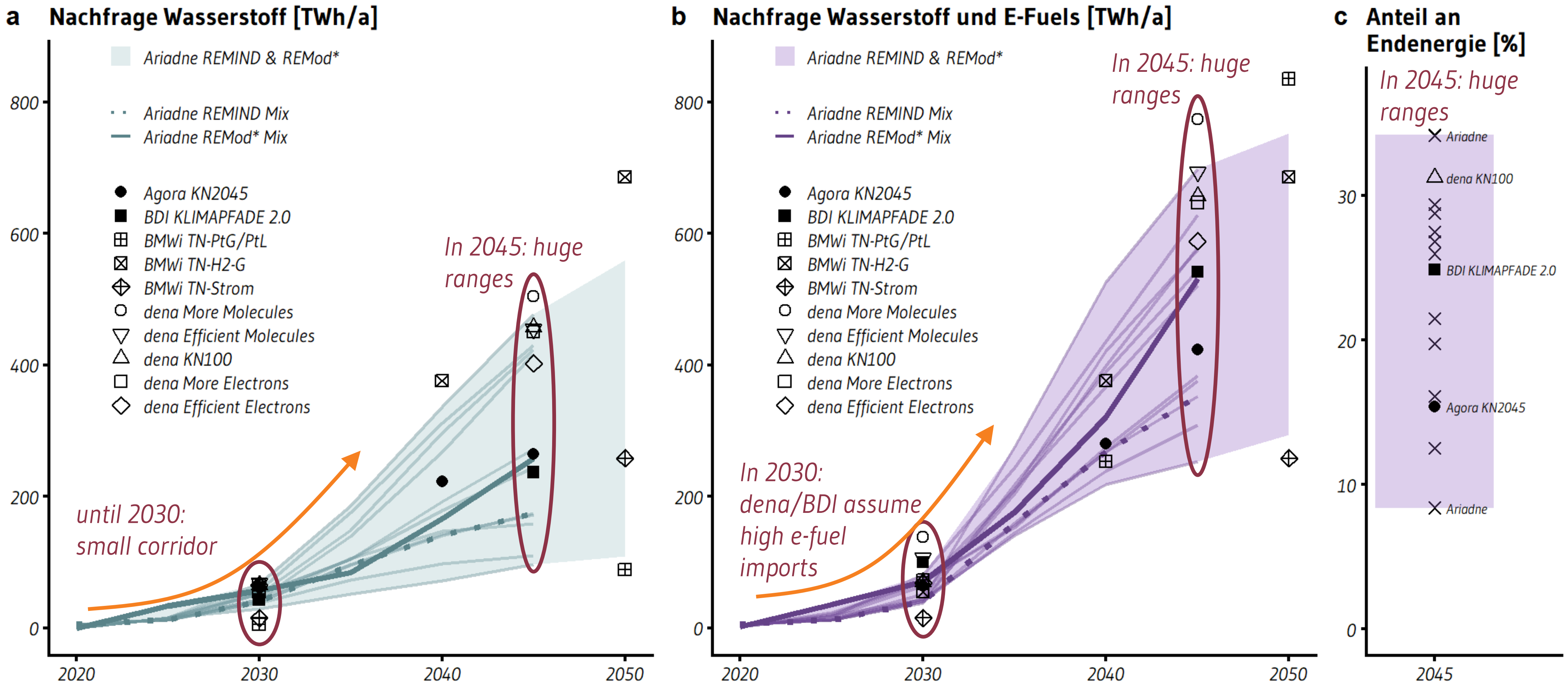
# Scenarios: What do the "big 5" say about hydrogen and e-fuels?




HYDROGEN SUPPLY EXPANSION?

SCENARIO RANGES ? ≠ POLITICAL OPTION SPACE

TECHNO-ECONOMIC UNCERTAINTIES!

**WITH BOTH INDIRECT AND DIRECT ELECTRIFICATION**

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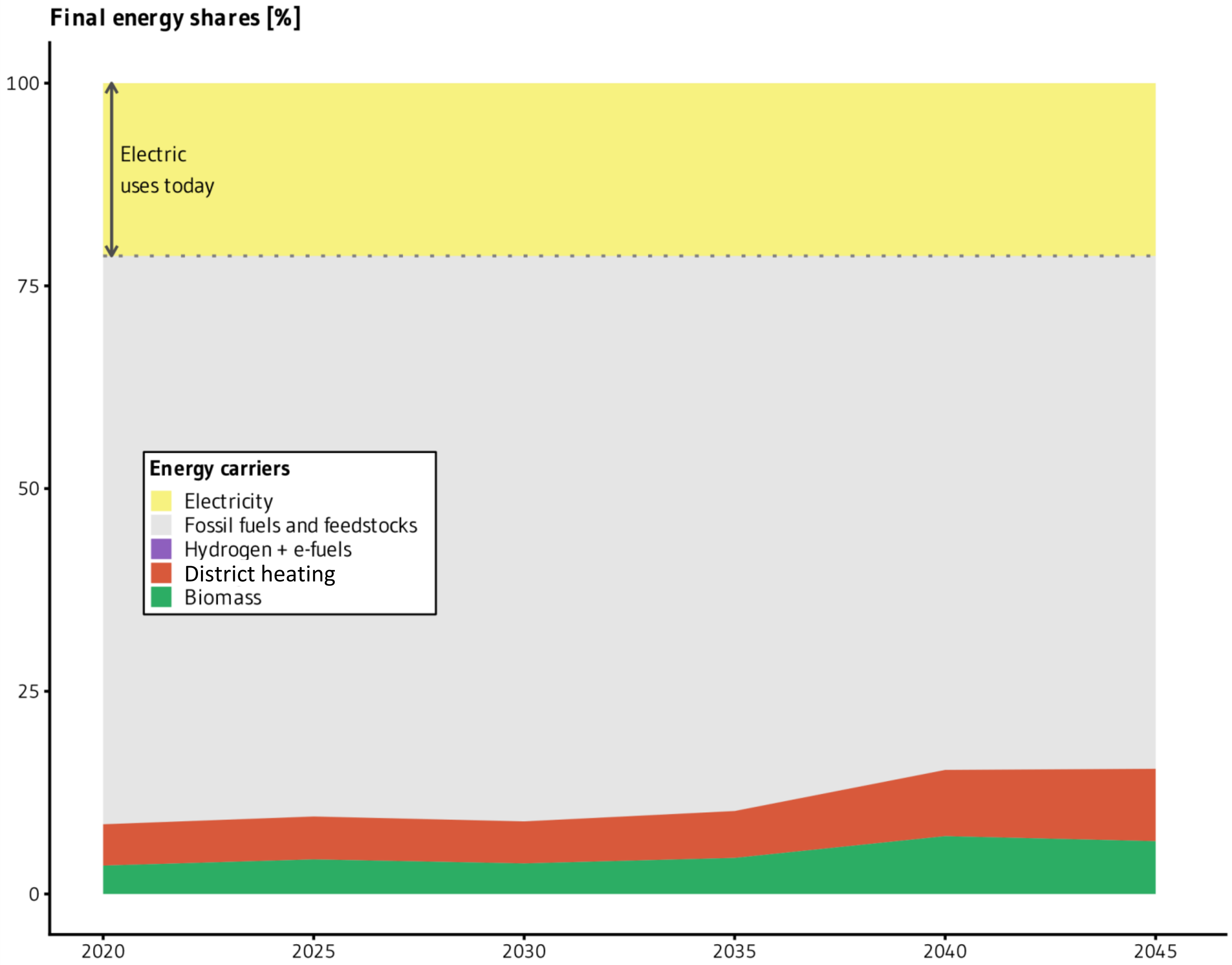
# Scenarios climate neutrality Germany:
# Significant techno-economic uncertainties → Do not pick and impose one pathway




Ariadne scenarios for
Germany climate neutrality 2045

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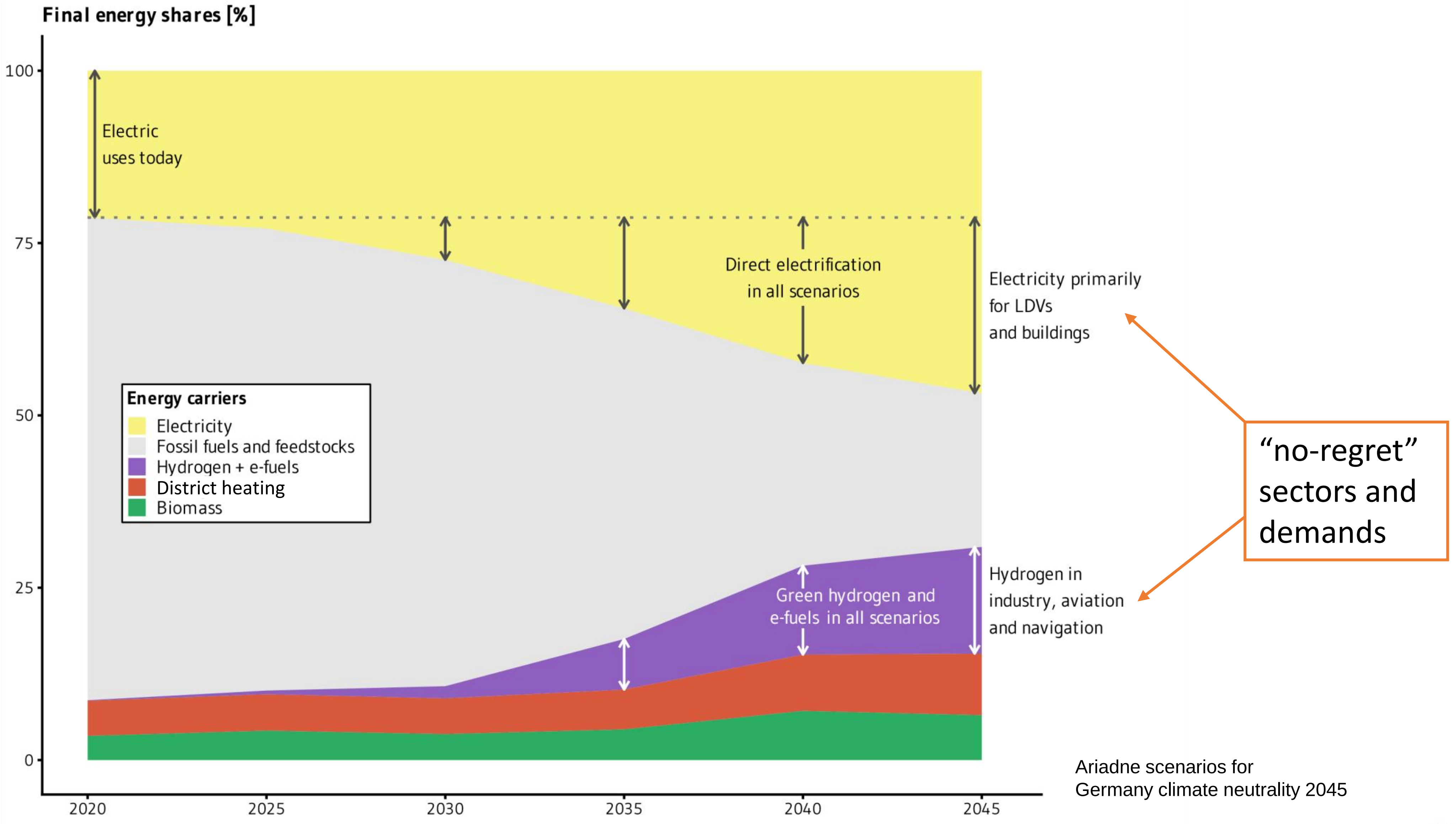


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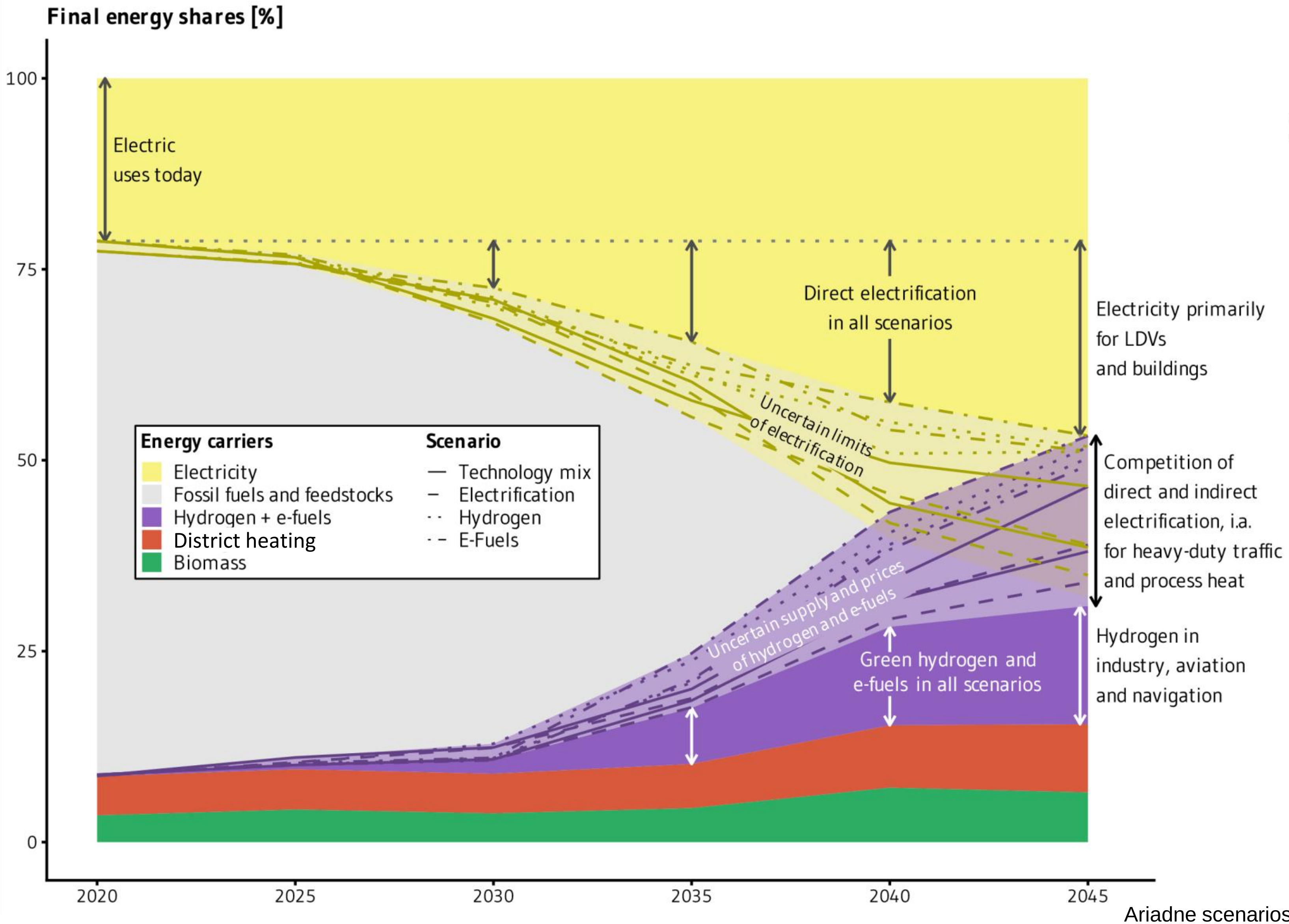
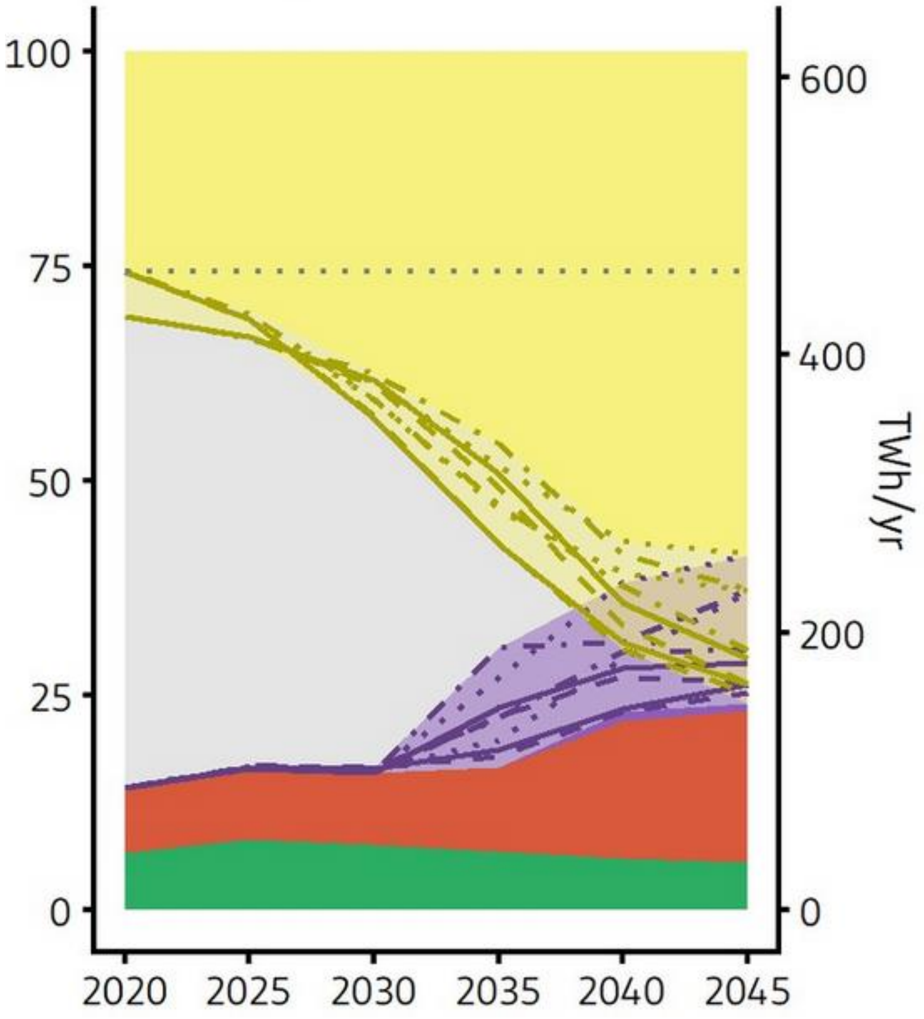



**Final energy in buildings**

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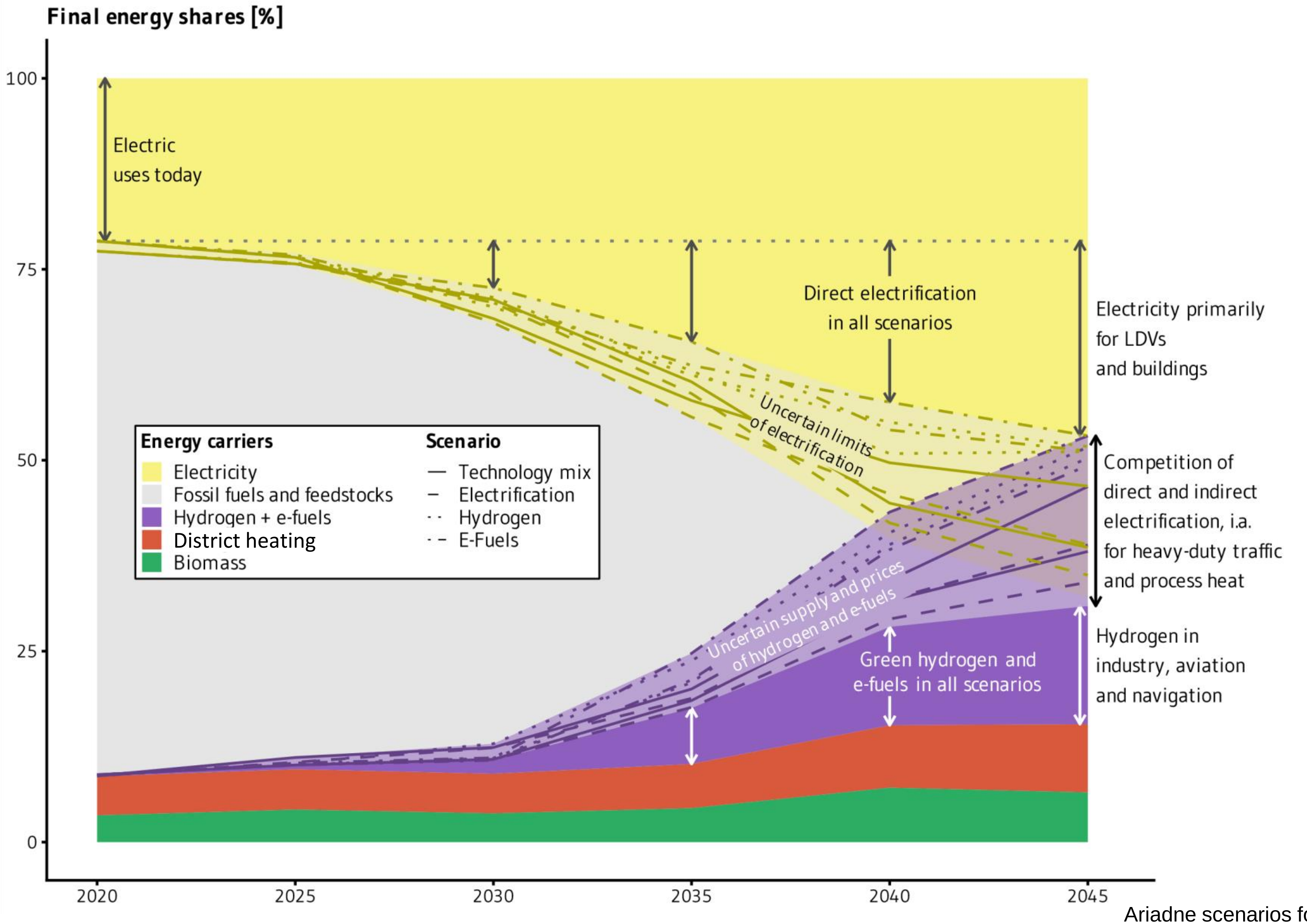


## An adaptive hydrogen strategy

1. Do not pick and impose one pathway. e.g. no betting on broad availability of low-cost hydrogen, as it risks to lockin fossil fuel dependence
2. Foster robust options: efficiency/electrification, domestic renewables, hydrogen supply (imports) and backbone infrastructure for least-regret applications

Ariadne scenarios for Germany climate neutrality 2045

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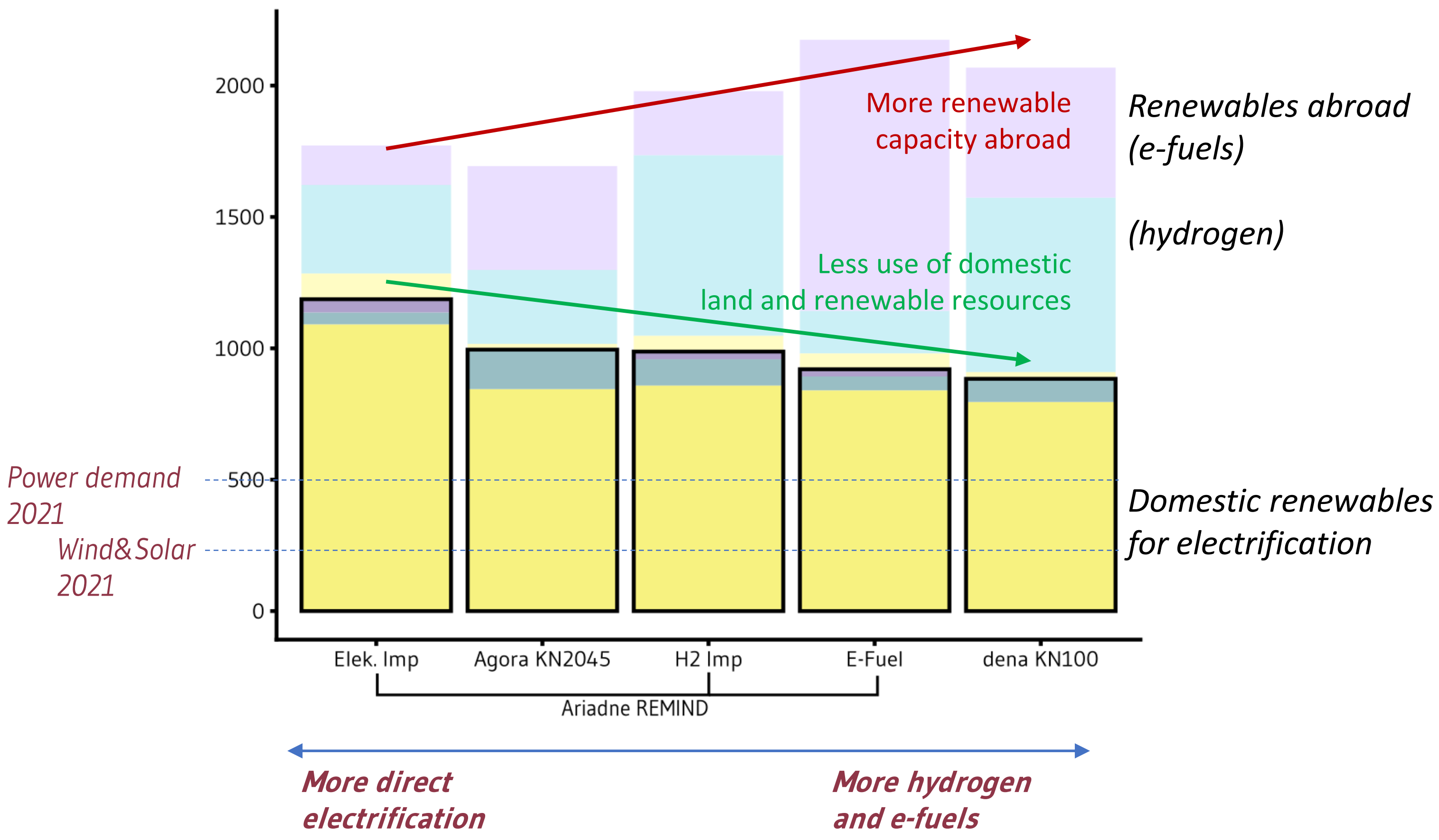
# No-regrets: all scenarios show 1) dramatic expansion of domestic renewables & 2) substantial hydrogen/e-fuel imports

*2045 climate neutrality: renewable electricity demands Germany*

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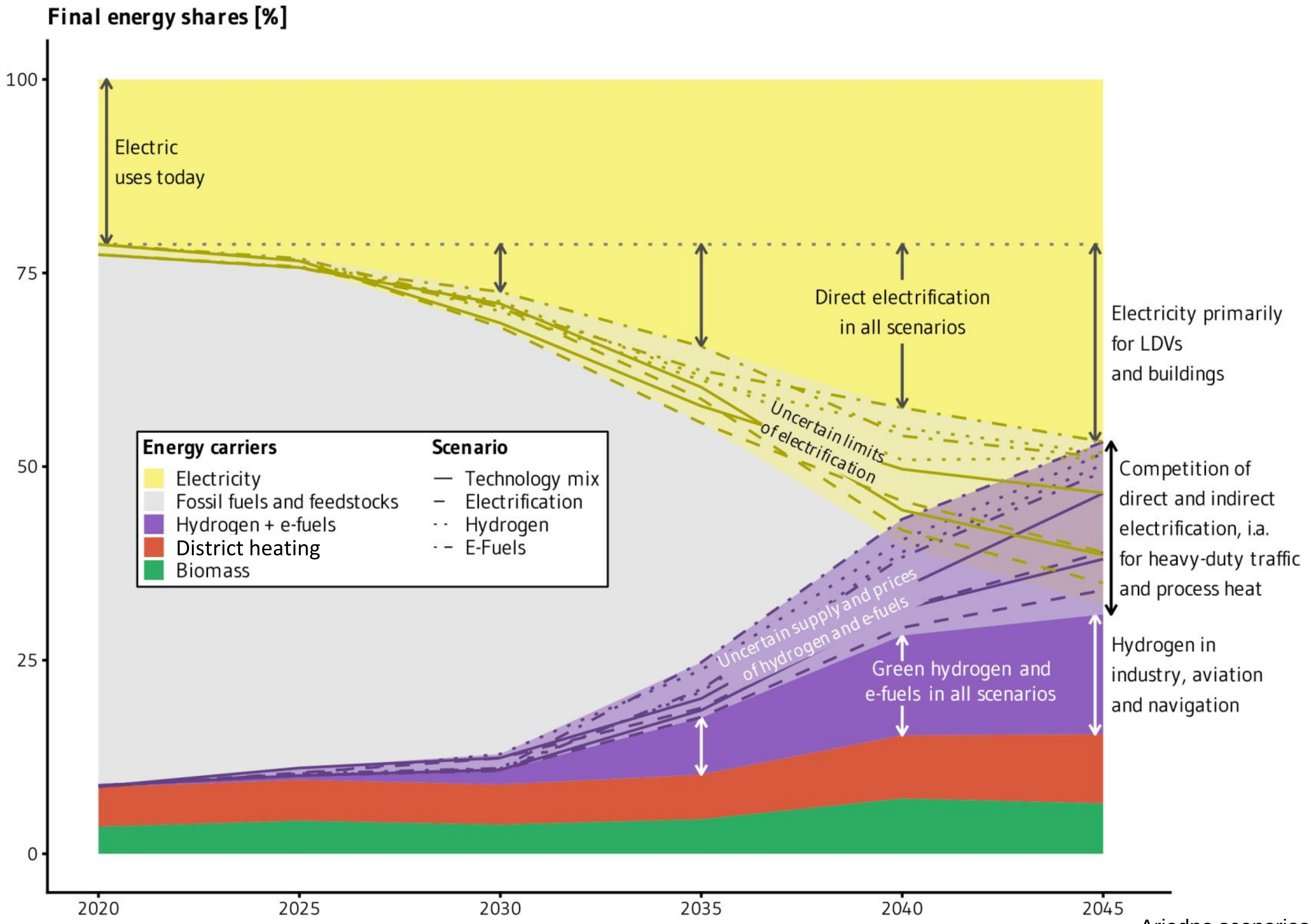
# Scenarios climate neutrality Germany:
# Significant techno-economic uncertainties → Do not pick and impose one pathway




## An adaptive hydrogen strategy

1. Do not pick and impose one pathway. e.g. no betting on broad availability of low-cost hydrogen, as it risks to lockin fossil fuel dependence
2. Foster robust options: efficiency/electrification, domestic renewables, hydrogen supply (imports) and backbone infrastructure for least-regret applications
3. Learn and adapt strategy: Learn about limits of direct electrification and hydrogen supply. Broaden the application of hydrogen, if availability and costs get more clear

Ariadne scenarios for
Germany climate neutrality 2045

Ueckerdt, F., Bauer, C., Dirnaichner, A., Everall, J., Sacchi, R., Luderer, G. (2021)
Potential and risks of hydrogen-based e-fuels in climate change mitigation. *Nature Climate Change*

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# Two dimensions in the debate

*More **domestic** renewable expansion*

*More **direct** elect*

*More renew*

**An adaptive hydrogen strategy**

**Start Focused**

**... learn and potentially broaden iteratively...**

**... do not bet on abundant and cheap hydrogen/e-fuels.**

***H2 demand side: which applications?***

**Focused prioritize hydrogen for „no-regret sectors“ (consensus)**
primary steel, ammonia, aviation, shipping, olefins (huge markets)

**Grey area middleground**
- low-temp. heat industry (steam making)
- high-temp. heat (e.g. glass making, or cement)
- long-haul freight transport (trucks)

**road**
all sectors, including passenger car, buildings

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# Overview

## *1. The debate* on hydrogen and e-fuels in Germany and the EU

- Background: climate targets
- 2 dimensions of the hydrogen debate
- Competing visions of the energy system

## *2. Evaluation* of hydrogen and e-fuels for climate mitigation

- Climate mitigation *effectiveness:*
  = quantity X specific emission reduction
- Climate mitigation *cost efficiency*
- Range of climate neutrality scenarios (for Germany)

## *3. Conclusion* an adaptable hydrogen strategy

- Do not pick and impose one pathway. e.g. no betting on broad availability of low-cost hydrogen, as it risks to lockin fossil fuel dependence
- Foster robust options: efficiency/electrification, domestic renewables, hydrogen supply (imports) and backbone infrastructure for least-regret applications
- Learn and adapt strategy: learn about limits of direct electrification. Broaden the application of hydrogen, if availability and costs get more clear

## *4. Q&A, joint discussion* transfer to Quebec/Canada

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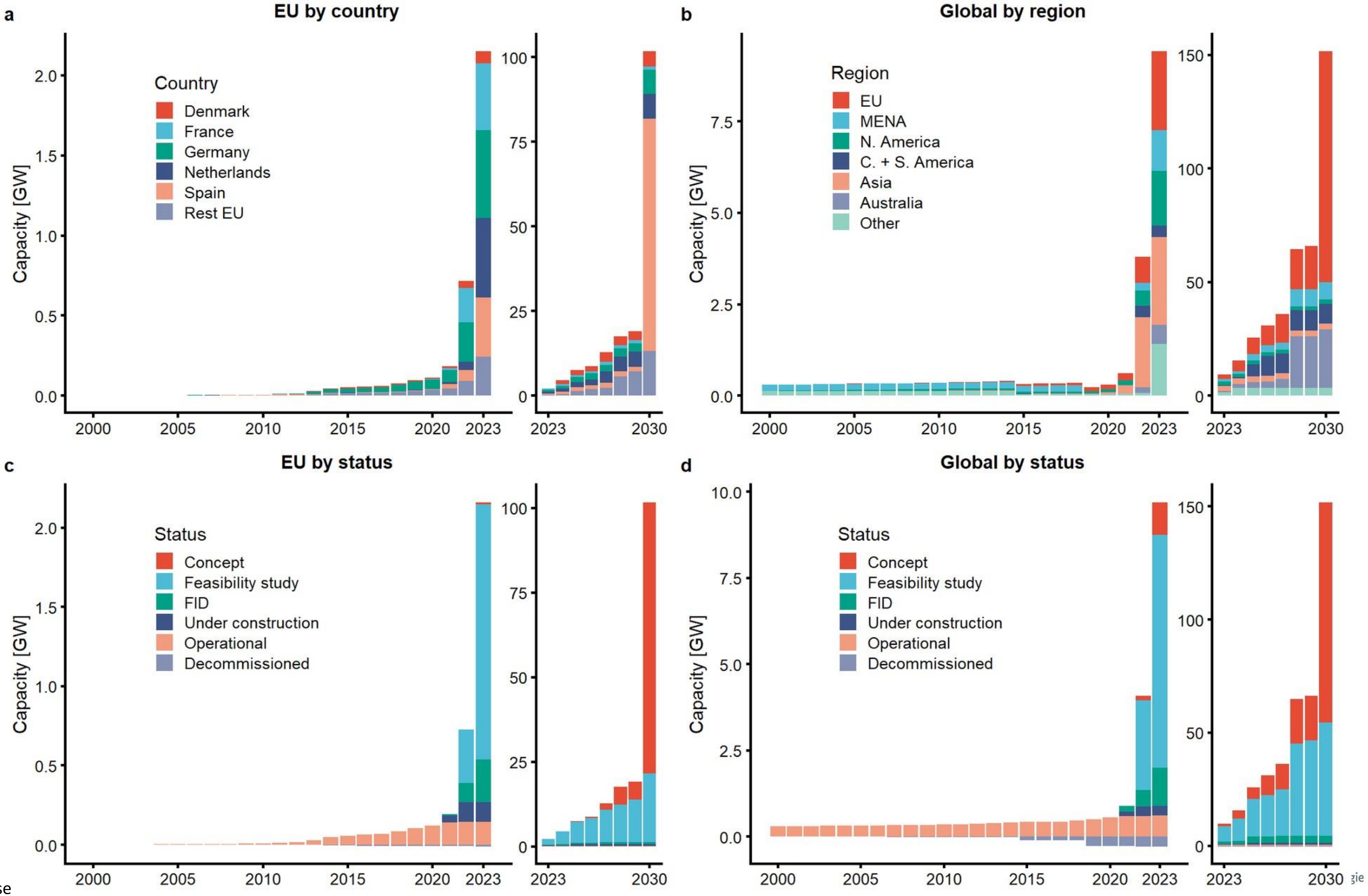
# ›BACKUP SLIDES

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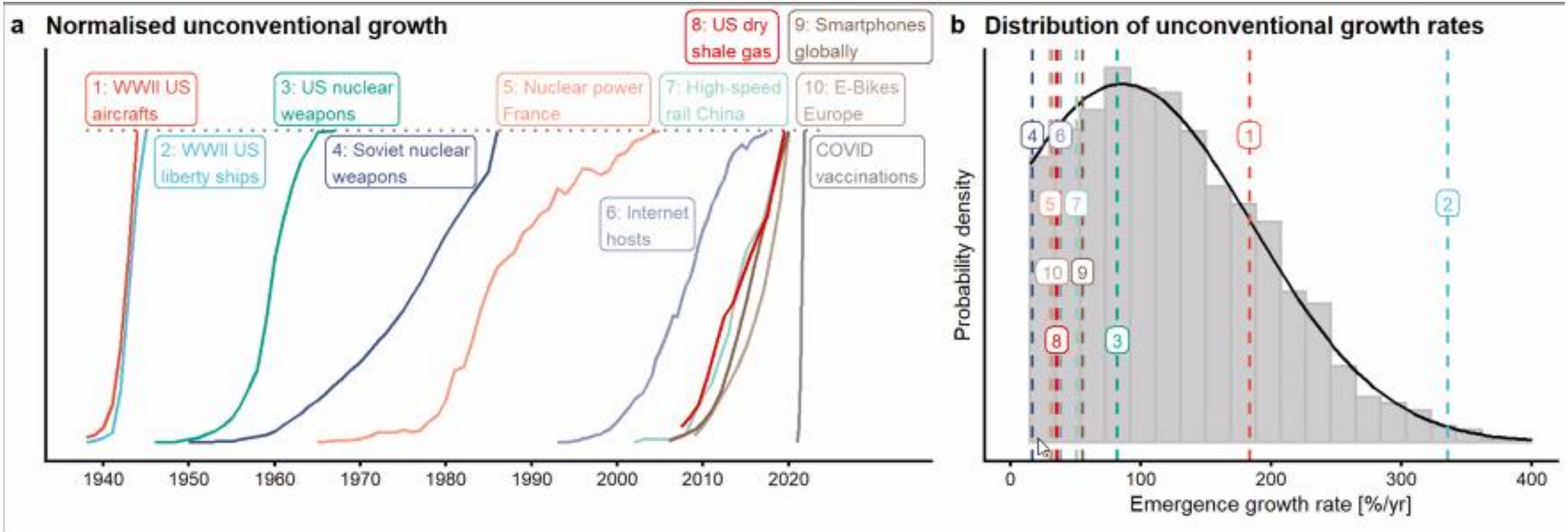
Daten: IEA hydrogen database

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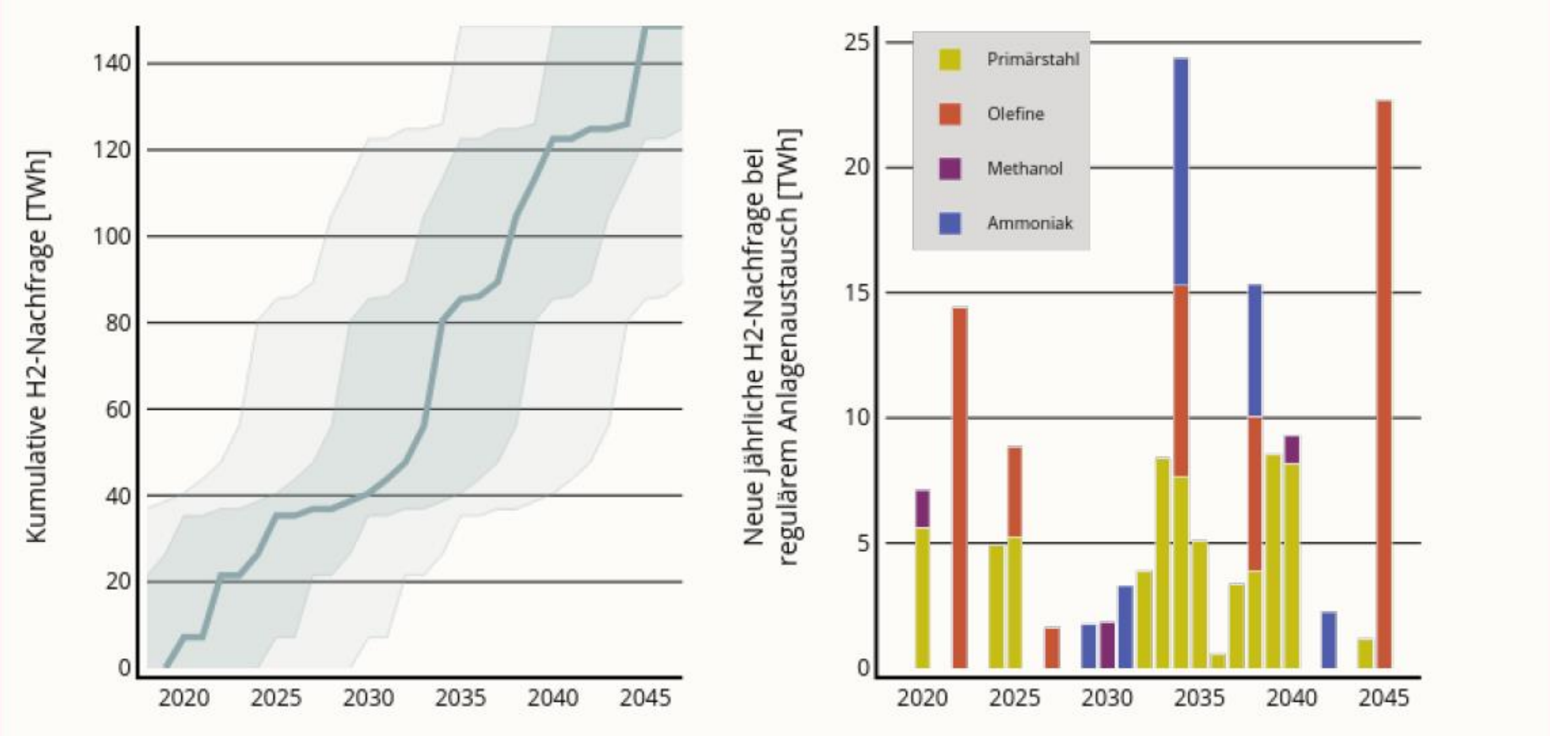
# NACHFRAGE IN INDUSTRIE UND FLUGVERKEHR IST BIS MINDESTENS 2030/35 GRÖßER ALS DAS ANGEBOT AN GRÜNEM WASSERSTOFF

**Abbildung 8: Kumulativer Wasserstoffbedarf aus Produkten der Grundstoffindustrie (links) und zusätzlicher jährlicher Wasserstoffbedarf (rechts) aus der Produktion von Primärstahl, Olefinen (wie Ethylen), Ammoniak und Methanol bei regulärem Anlagenaustausch, gemäß Alter und Modernisierungszyklus bestehender Anlagen.**




*Betrachtet werden jährliche Gesamtkapazitäten von 30,7 Mt Primärstahl, 5,2 Mt Ethylen (und daran gekoppelt 6,2 Mt weitere Olefine) sowie 1,8 Mt Methanol und 3,1 Mt Ammoniak. Weitere Annahmen: 60 Jahre Lebensdauer für chemische Anlagen, Modernisierungszyklus Hochöfen 25 Jahre (ähnlich Agora, 2020). Schattierter Bereich links: Änderung bei Verschiebung des Anlagenaustausches (früher/später) um 5/10 Jahre.*

**Industrie:** Bei regulären Anlagenaustausch entstehen Wasserstoffbedarfe von **40 TWh in 2030 und 80 TWh in 2035**.
Um 5 bis 10 Jahre vorgezogene Investitionen erhöhen diese Menge auf **80 bis 120 TWh in 2030**

**Instrumente: IPCEI + CCfDs (nur für Industrie)**

**Im Fernflugverkehr** können bis zu **120 TWh E-Kerosin** verwendet werden. Dafür können E-Fuel-Quoten angehoben werden.

**Instrumente: (erhöhte) E-Fuel-Quoten im Flugverkehr**

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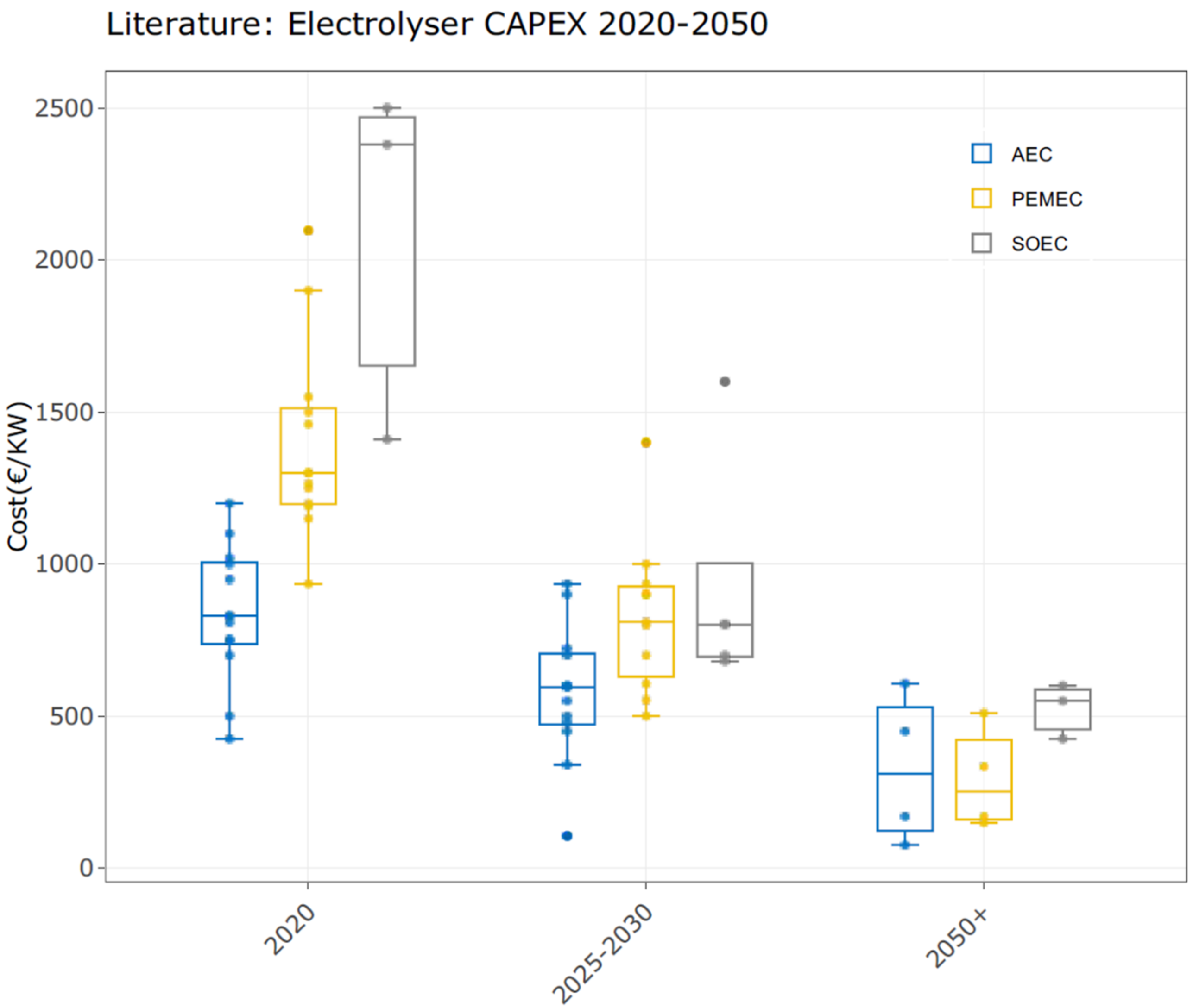


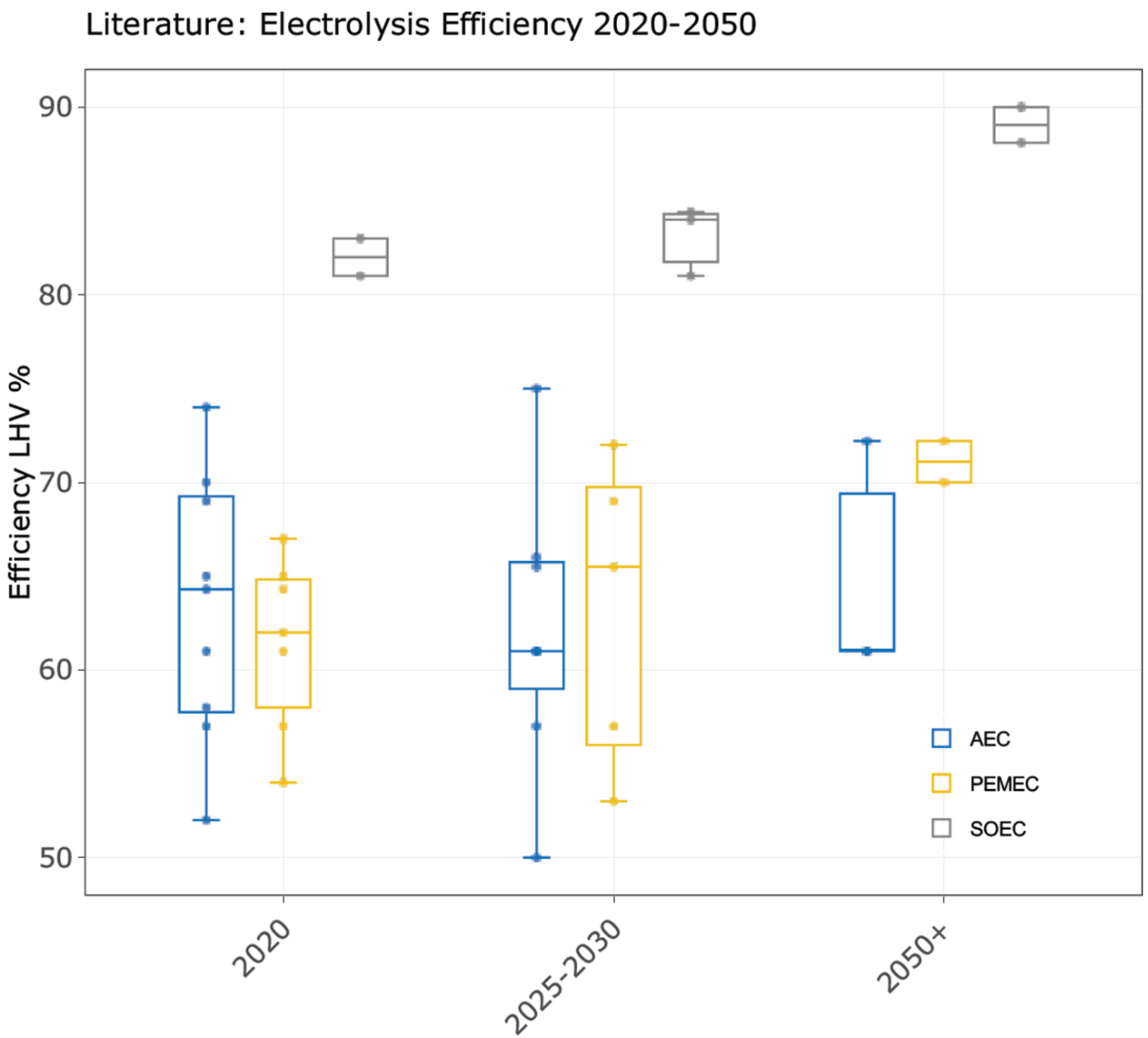


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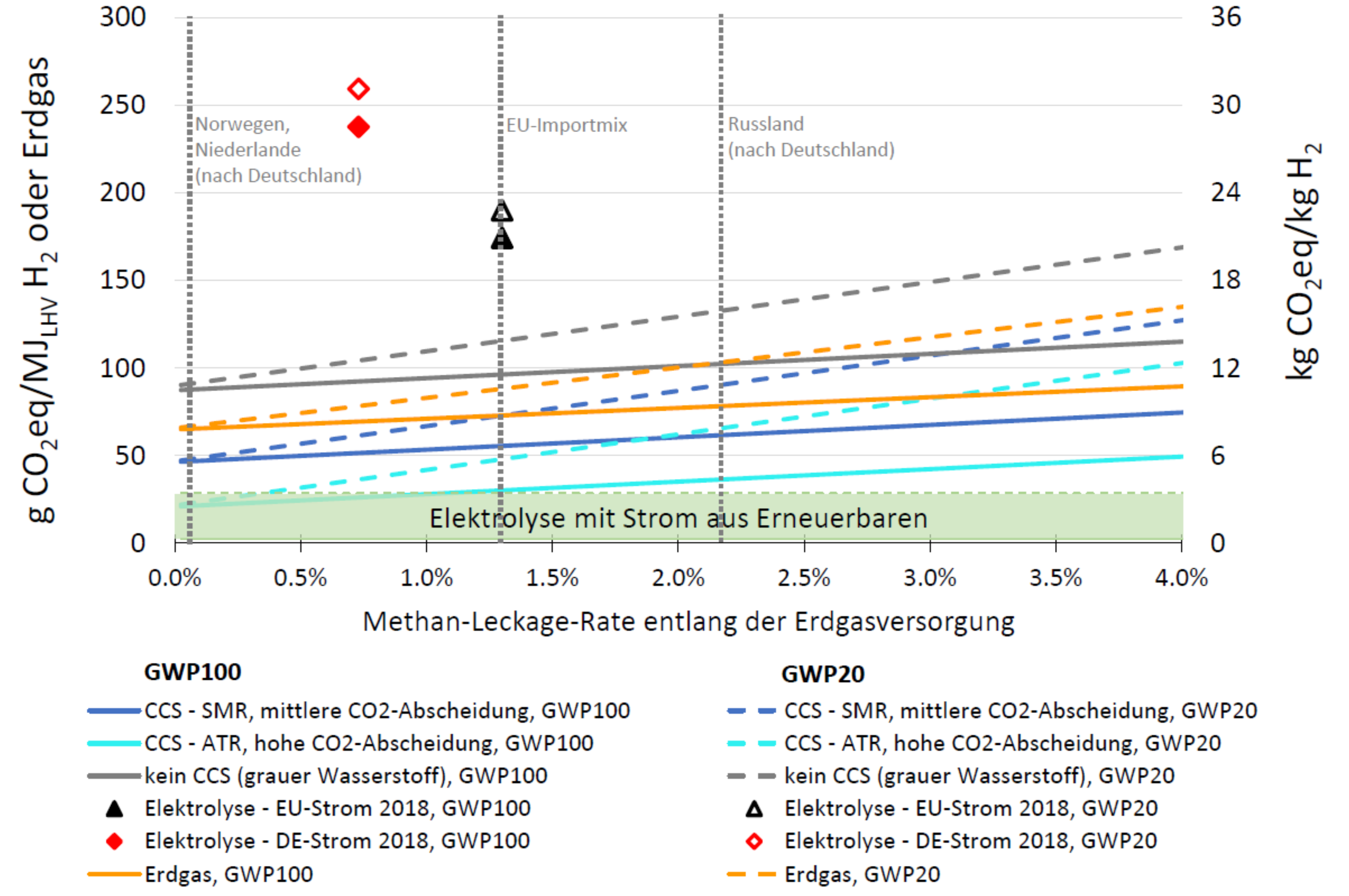
**Abbildung 9: Lebenszyklus-THG-Emissionen von blauem, grünem und grauem Wasserstoff im Vergleich zu Erdgas - als Funktion der Methan-Leckage-Rate bei Extraktion und Transport von Erdgas, und für GWP100 und GWP20[25].**




*Für blauen Wasserstoff werden zwei Technologien gezeigt: 1) CCS – SMR ($CO_2$-Abscheideraten insgesamt 55 %, im Capture-Schritt 90 %) und 2) CCS –ATR ($CO_2$-Abscheideraten insgesamt 93 %, im Capture-Schritt 98 %). Adaptiert von Bauer et al., 2021*

Ueckerdt, F., Bauer, C., Dirnaichner, A.,
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