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

Ueckerdt, F., Bauer, C., Dirnaichner, A., Everall, J., Sacchi, R., Luderer, G.

(2021). *Nature Climate Change*

Strommarkttreffen, 18th May 2021

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KOPERNIKUS Ariadne PROJEKTE Die Zukunft unserer Energie
GEFÖRDERT VOM Bundesministerium für Bildung und Forschung

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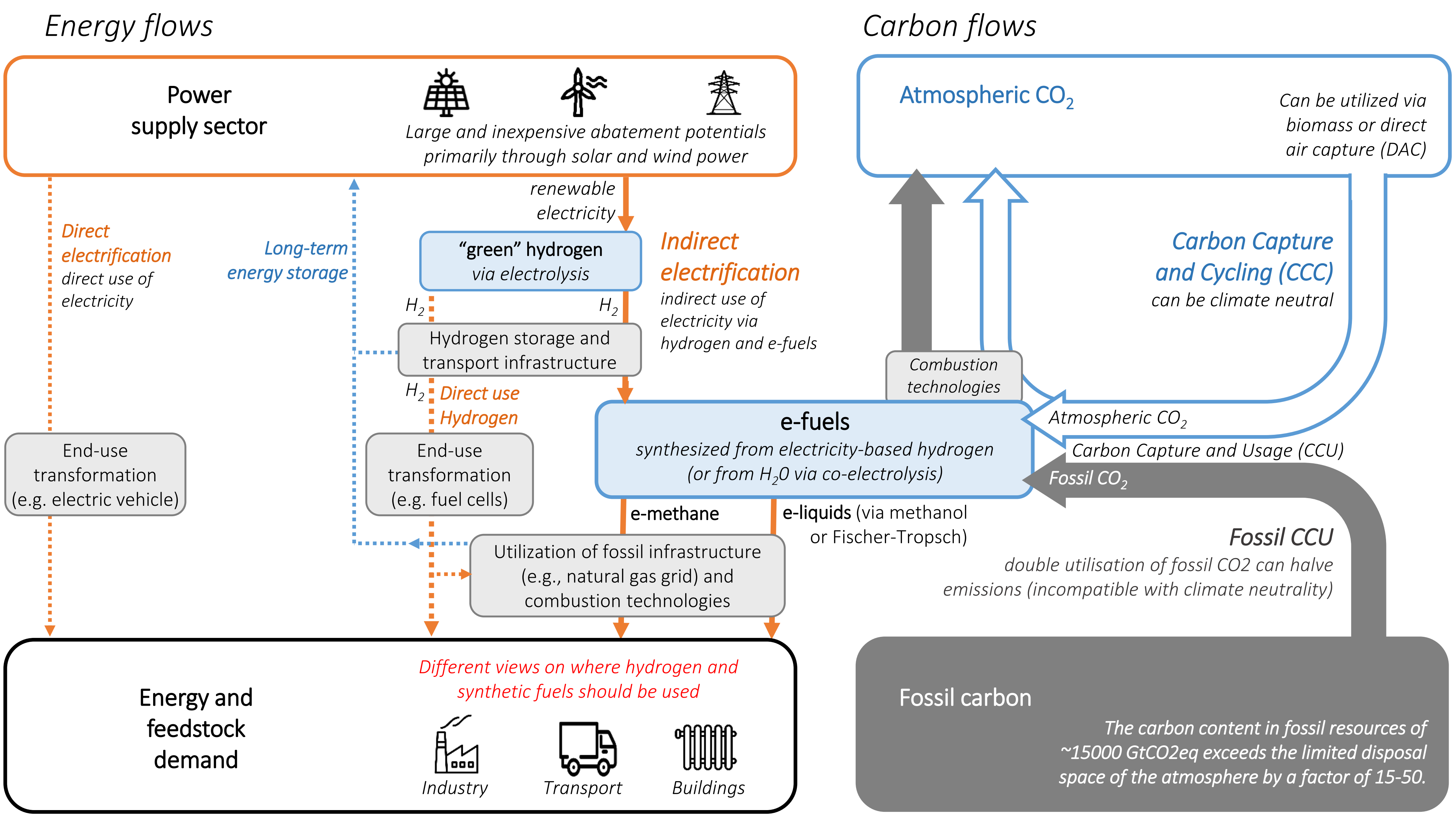
At the crossroad of different electrification pathways



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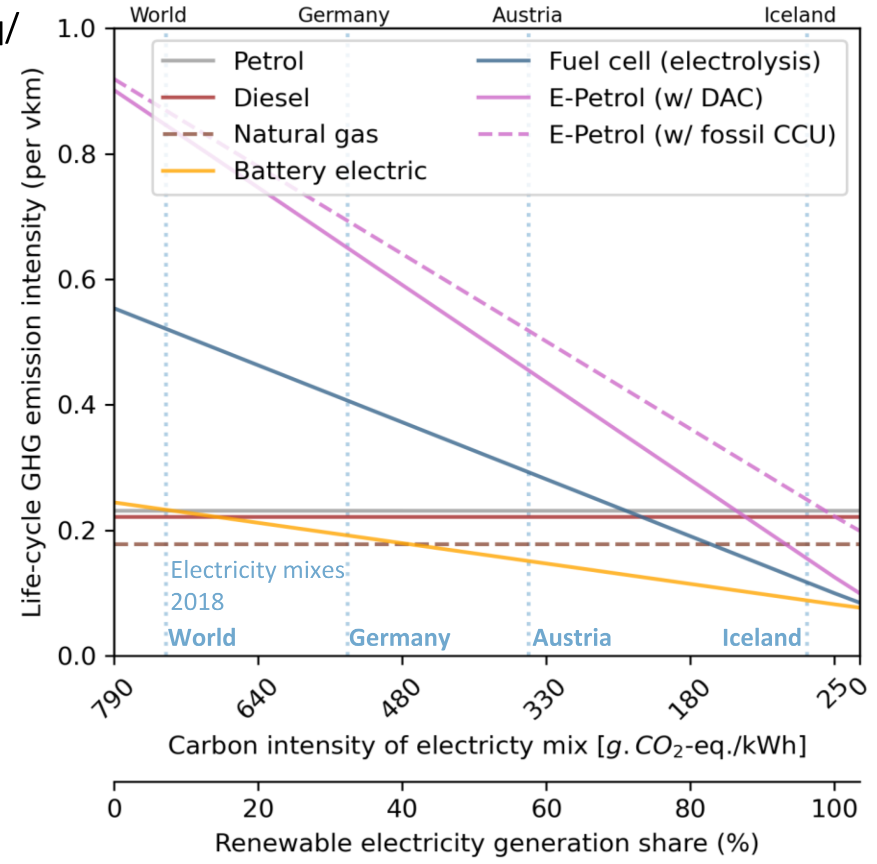
Climate change mitigation ***effectiveness***

E-fuels require ~100% renewable electricity, and atmospheric CO2. Battery electric cars and trucks can save emissions already today/soon

Life-cycle GHG emission intensities for transport applications (*2030 technology*)

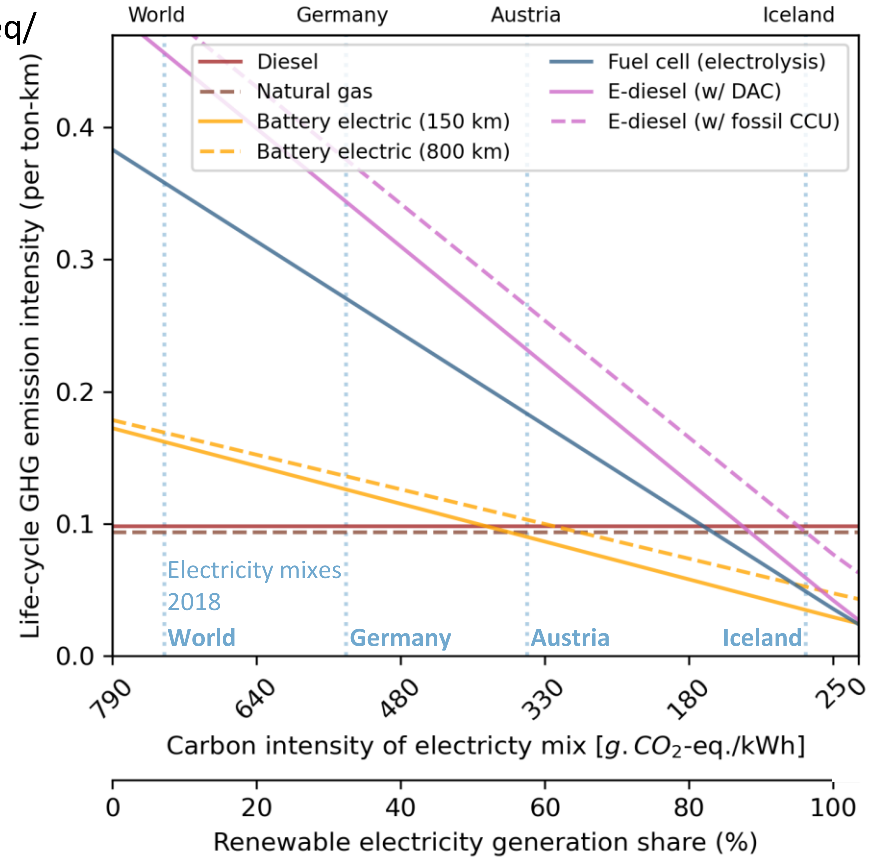
Light-duty vehicles (lower-medium size passenger car)

kgCO2eq/
vkm



Heavy-duty freight (semi-trailer trucks, 40t weight, 10t load)

kgCO2eq/
ton-km



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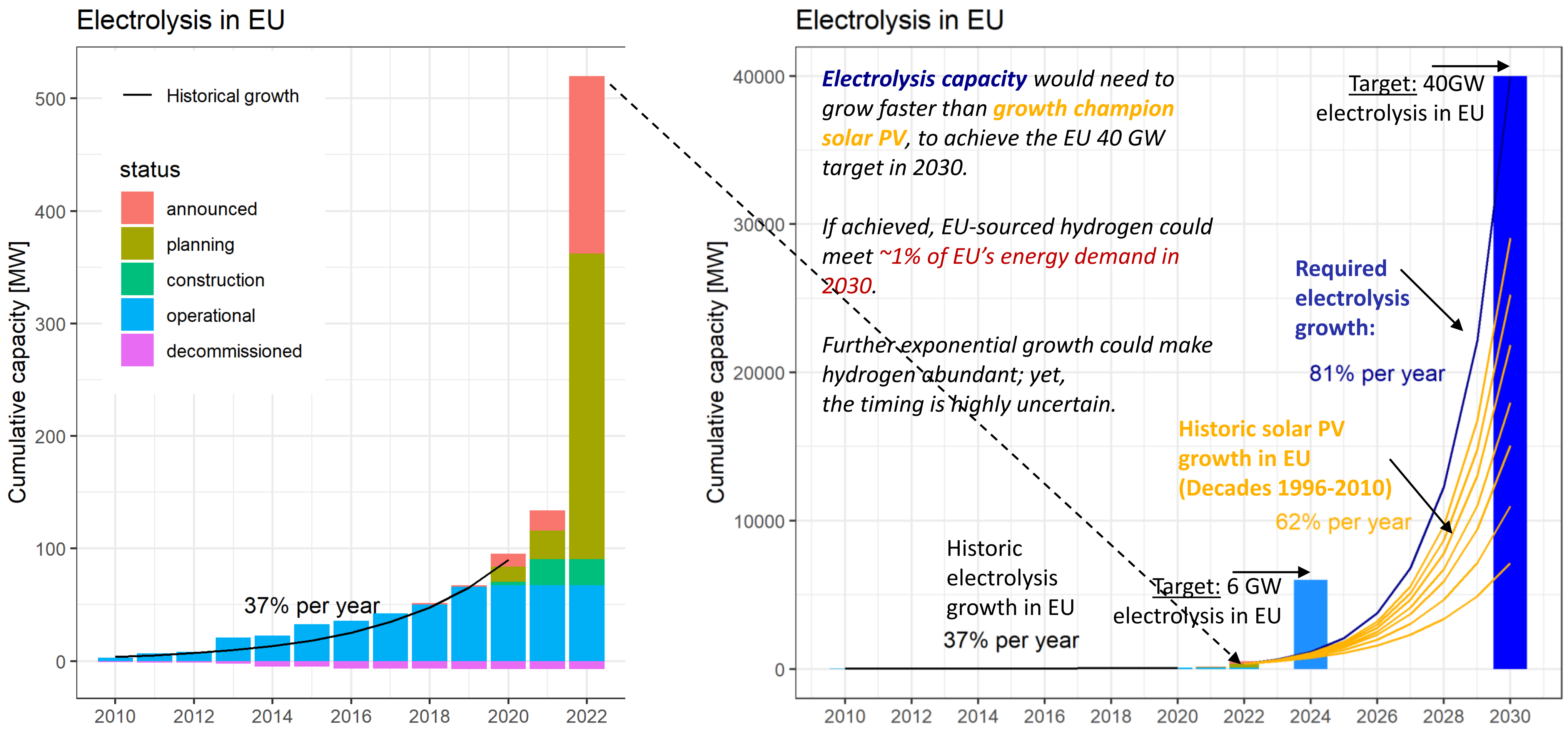
The life-cycle analysis for passenger cars and trucks can be reproduced with the open-source tools carculator and carculator_Truck (https://carculator.psi.ch). The modified version of ecoinvent used in this analysis is generated from ecoinvent 3.7.1 (https://github.com/romainsacchi/premise). The modified version is available from the authors on reasonable request.

Electrolysis would need to be scaled up faster than growth champion solar PV



Adapted from Adrian Odenweller, PIK
(based on IEA hydrogen database and additions by Adelphi)

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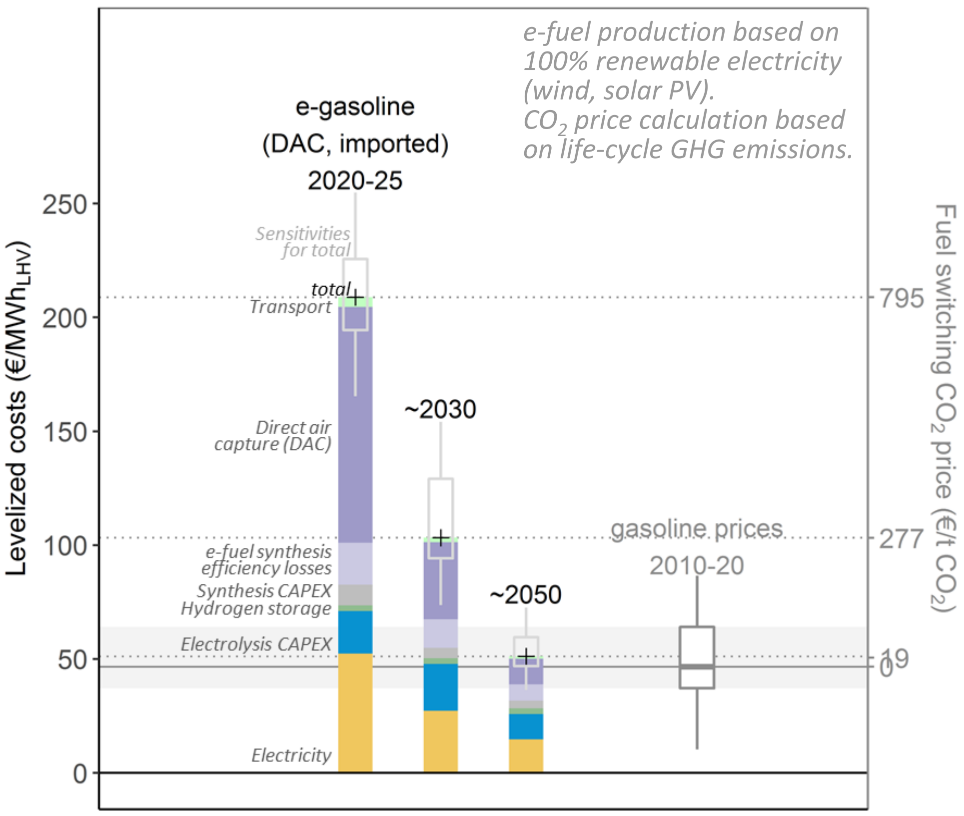
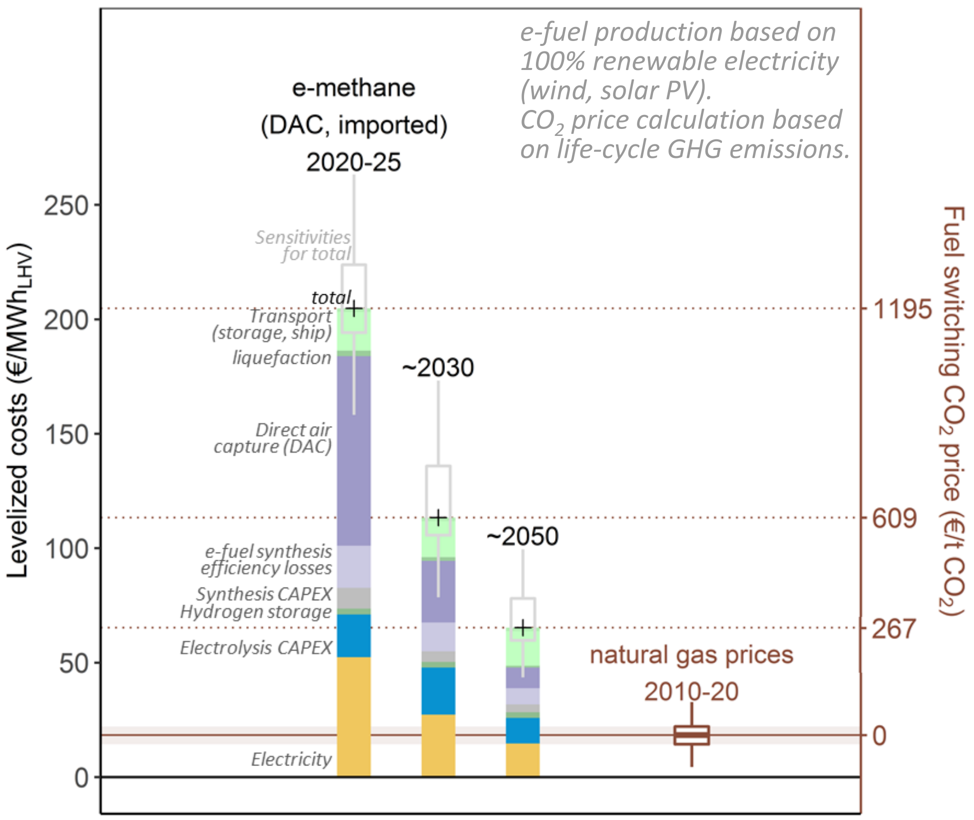
Climate change mitigation ***cost efficiency*** *or* ***competitiveness*** *with fossils and direct electrification*

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.





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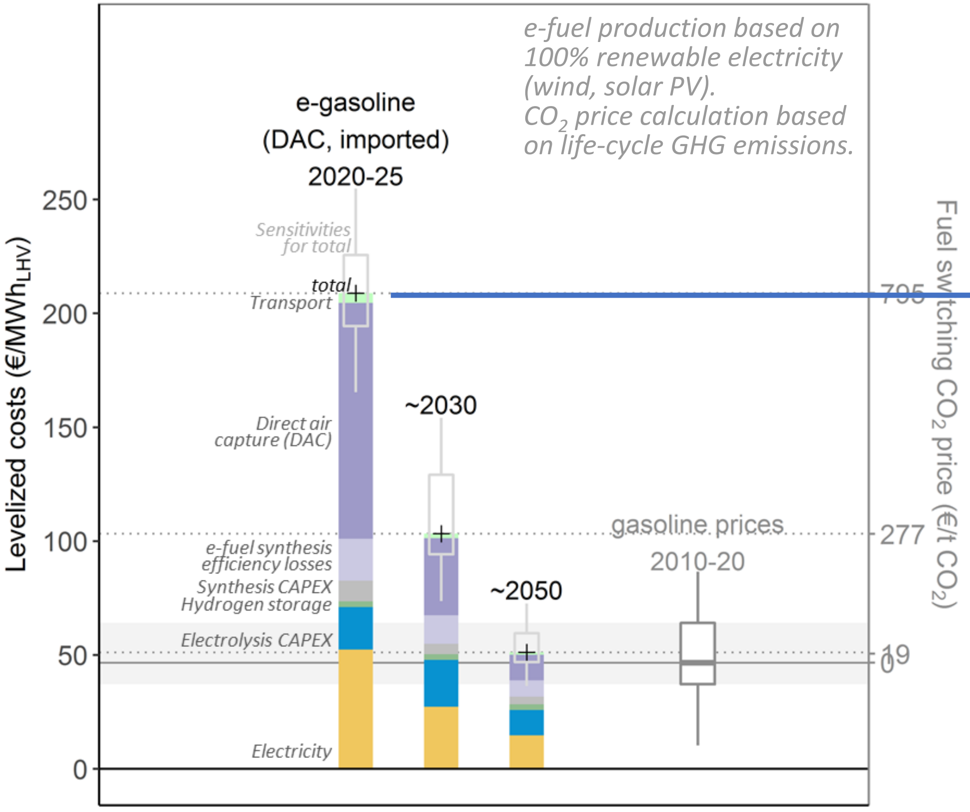
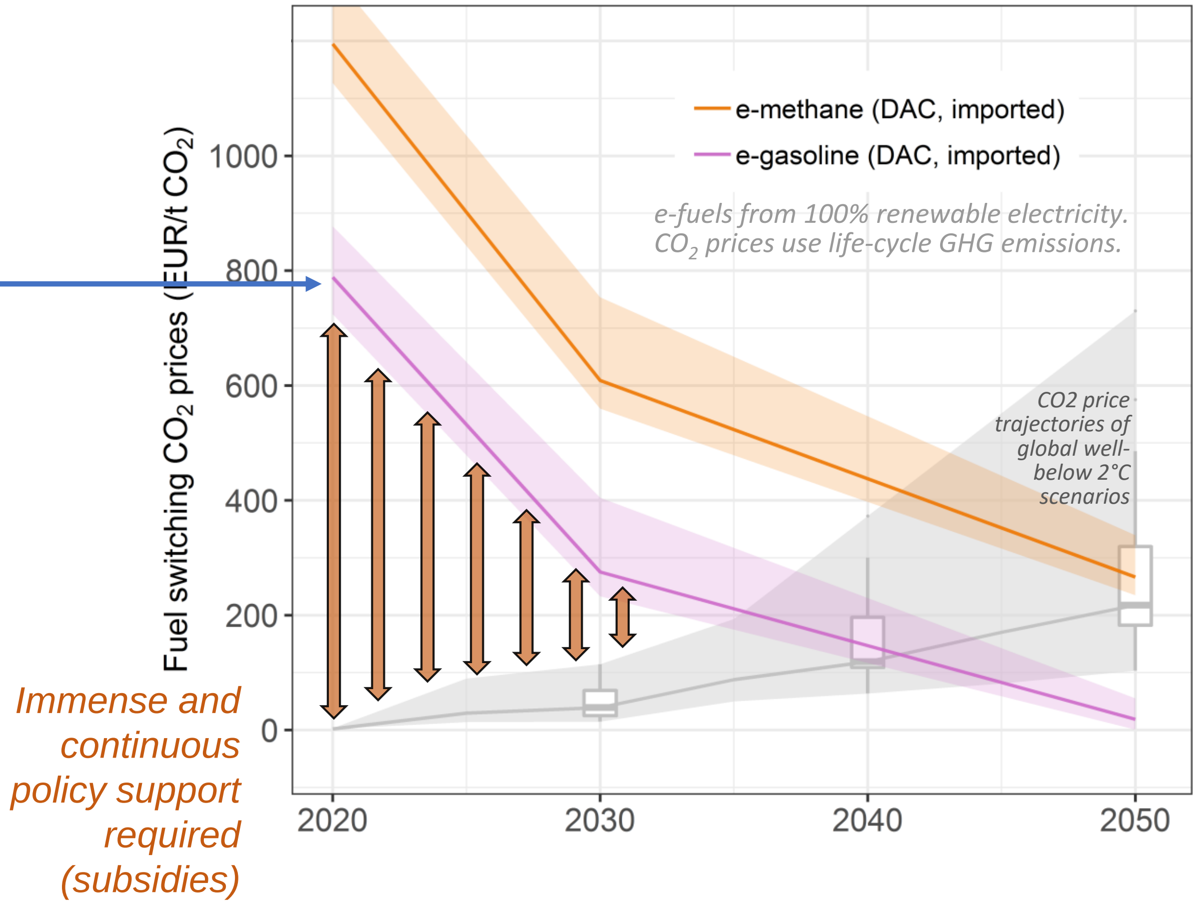


Competitiveness of e-fuels only ~2040
Massive subsidies required until then.



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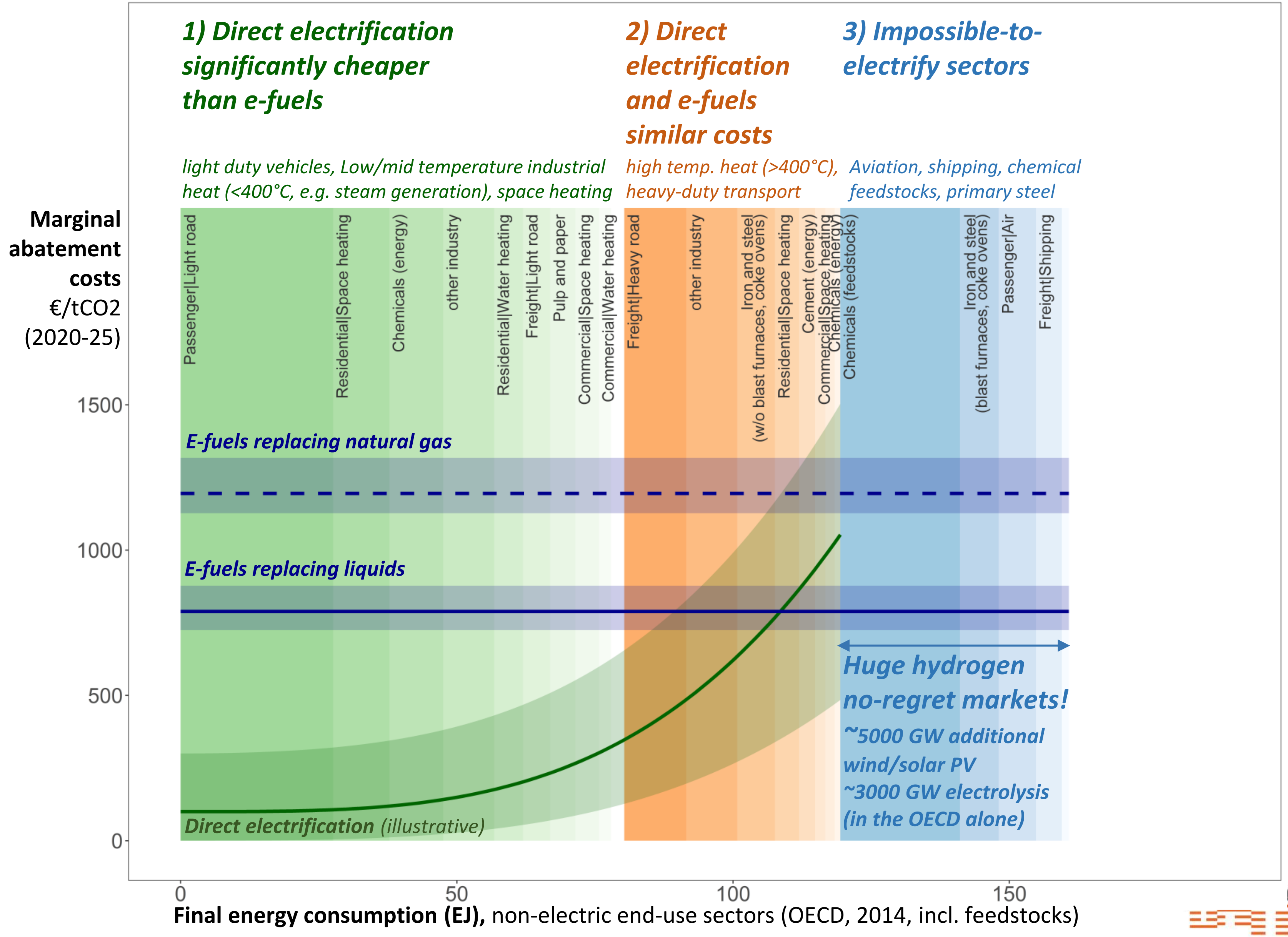
1) Direct electrification significantly cheaper than e-fuels
2) Direct electrification and e-fuels similar costs
3) Impossible-to-electrify sectors
light duty vehicles, Low/mid temperature industrial heat (<400°C, e.g. steam generation), space heating
high temp. heat (>400°C), heavy-duty transport
Aviation, shipping, chemical feedstocks, primary steel
Marginal abatement costs €/tCO2 (2020-25)
Passenger|Light road
Residential|Space heating
Chemicals (energy)
other industry
Residential|Water heating
Freight|Light road
Pulp and paper
Commercial|Space heating
Commercial|Water heating
Freight|Heavy road
other industry
Iron and steel (w/o blast furnaces, coke ovens)
Residential|Space heating
Cement (energy)
Commercial|Space heating
Chemicals (energy)
Chemicals (feedstocks)
Iron and steel (blast furnaces, coke ovens)
Passenger|Air
Freight|Shipping
1500
1000
500
0
E-fuels replacing natural gas
E-fuels replacing liquids
Huge hydrogen no-regret markets!
~5000 GW additional wind/solar PV
~3000 GW electrolysis
(in the OECD alone)
Direct electrification (illustrative)
0
50
100
150
Final energy consumption (EJ), non-electric end-use sectors (OECD, 2014, incl. feedstocks)
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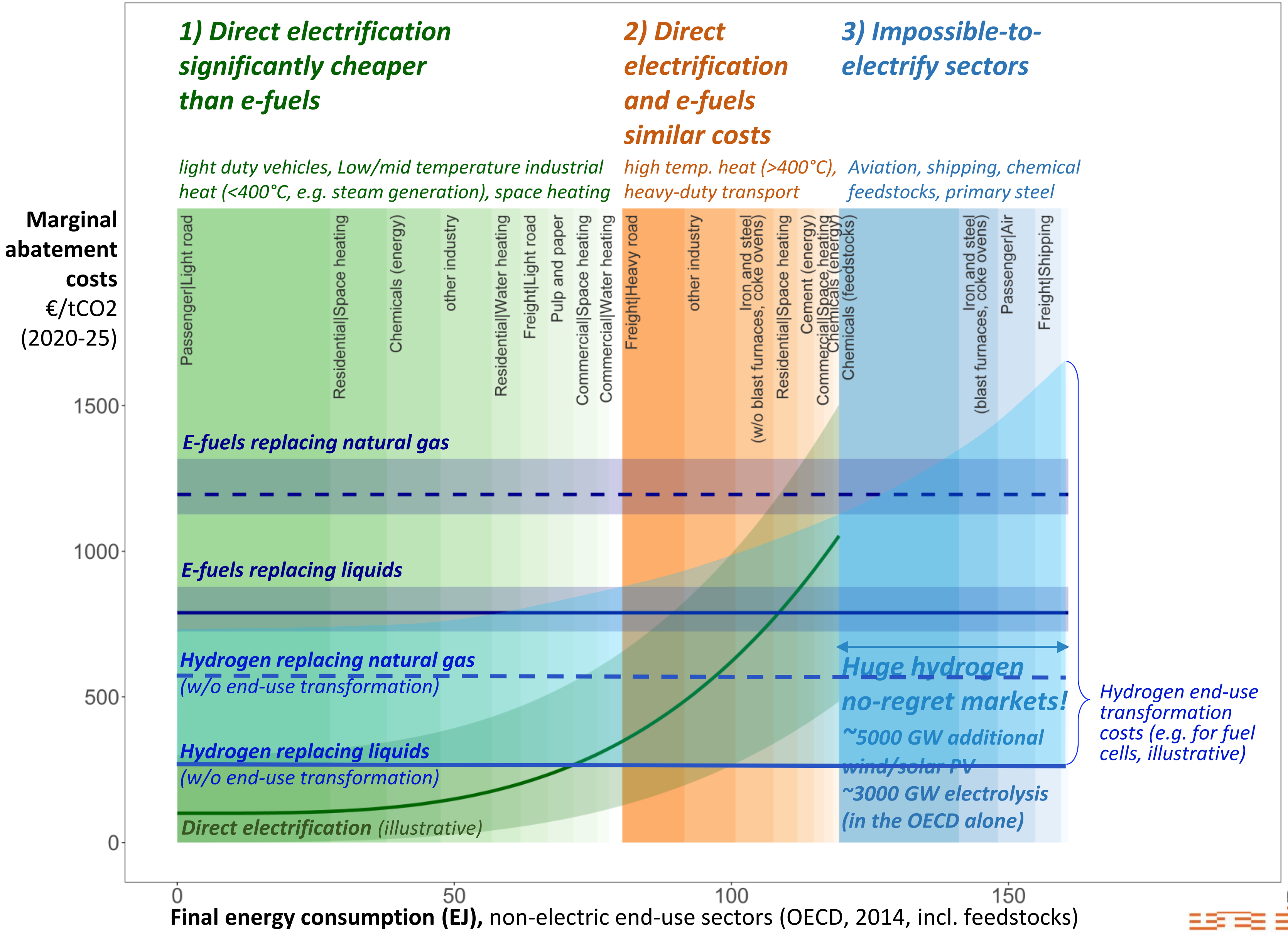

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E-fuels replacing natural gas
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Hydrogen replacing natural gas (w/o end-use transformation)
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~5000 GW additional wind/solar PV
~3000 GW electrolysis (in the OECD alone)
Hydrogen end-use transformation costs (e.g. for fuel cells, illustrative)
1500
1000
500
0
0
50
100
150
Final energy consumption (EJ), non-electric end-use sectors (OECD, 2014, incl. feedstocks)
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Conclusions

Techno-economic conclusions

1. **Scaling.** *Start* scaling hydrogen/e-fuels today. *Expect* large amounts only >2030/35. Still, uncertainty about when we achieve "efuel abundance".
2. **Risk.** Broadly betting on e-fuels risks further fossil lock-ins (and significant cost increases).
3. **No-regret sectors.** Focus hydrogen/e-fuels for steel, ammonia, aviation, olefins, shipping.
4. **Hierarchy of mitigation options.** Electrification is cheaper, available today, and makes more efficient use of scarce renewables.

Policy conclusions

1. **Policy action.** Hydrogen/e-fuel options require continuous and massive support and coordination.
2. **Develop e-fuels**, while hedging against their unavailability at large scale.
   1. A **merit-order of hydrogen end-uses** should guide all related policies
   2. Creating **dedicated hydrogen/e-fuel demand pulls** (e.g. focused CCfDs, e-kerosin quotas, bilateral import projects) rather then broad supply-side subsidies
3. **Direct electrification.** Foster direct use of electricity and an (increased) renewable electricity expansion.
4. **Mid-term level playing field.** Strengthen and broaden CO2 pricing schemes (and an energy tax reform)
5. **Carefully finding sensible bridges.** Start preparing no regret sectors for future hydrogen supply.
6. **Infrastrucure strategy.** Develop and implement robust hydrogen infrastructure roadmaps
7. **Future green value chains** will change!

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