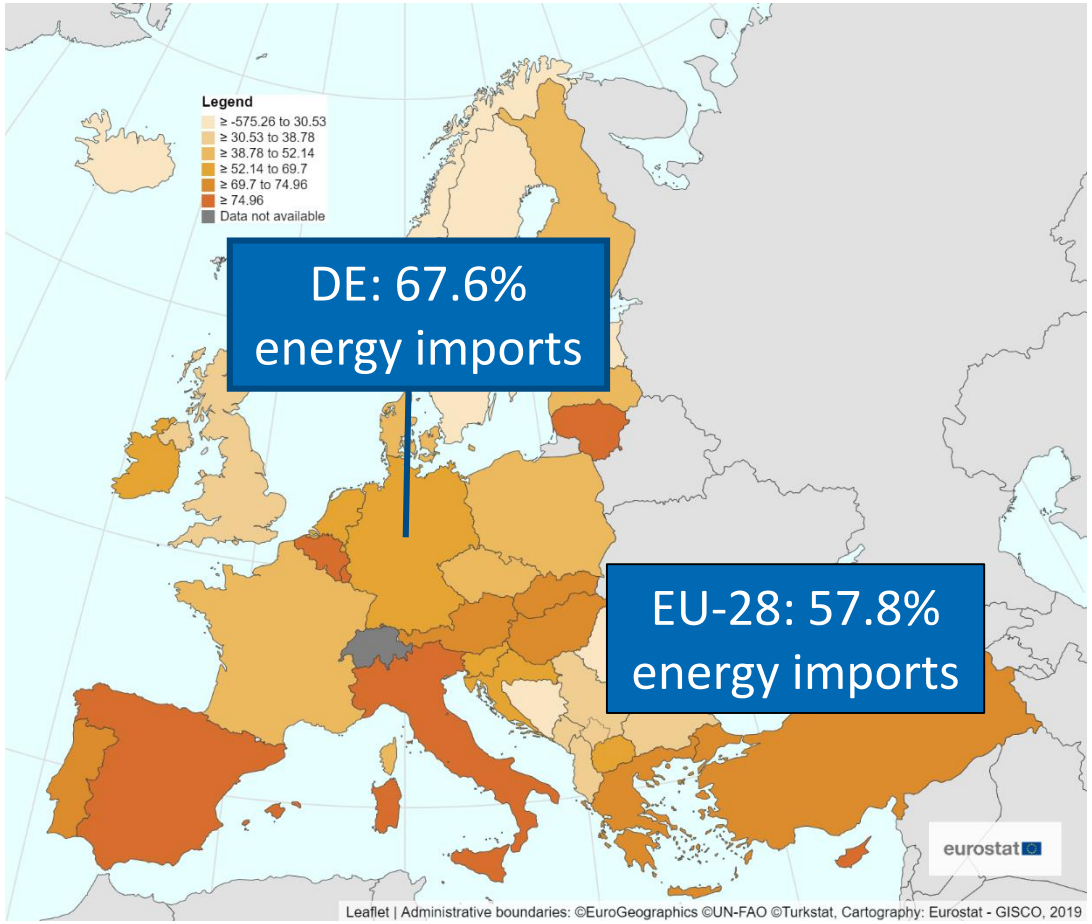
Johannes Hampp <johannes.hampp@zeu.uni-giessen.de> | Center for International Development and Environmental Research (ZEU)

Import options for chemical energy carriers from renewable sources to Germany

EU energy supply dominated by imports



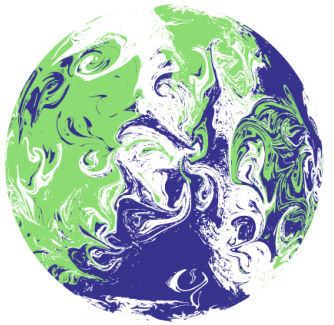
- Majority of EU energy import from outside
- Fossil chemical energy carriers (gas, oil, coal)
- Domestic renewable potentials limited
- Import situation unlikely to change soon

Energy Import Dependency: Share in % of energy imports from outside EU relative to total energy demand in 2019

via ec.europa.eu/eurostat/databrowser/view/sdg_07_50/default/map .

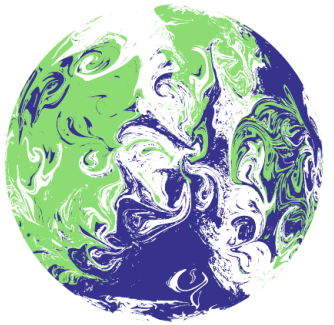
Strategies for energy transition

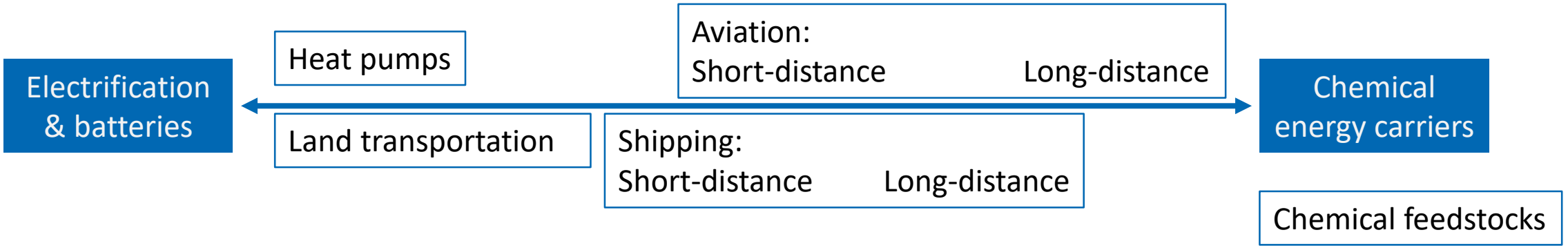
- Energy transition: Climate change mitigation
- Strategy:
  - 1st electrification (trivial physics) + clean energy sources



Strategies for energy transition

- Energy transition: Climate change mitigation
- Strategy:
  - 1st electrification (trivial physics) + clean energy sources
  - 2nd chemical energy carriers





How?

Pipeline for Nord Stream 2 © 2019 Gerd Fahrenhorst, licensed CC BY 4.0, via wikimedia.org.

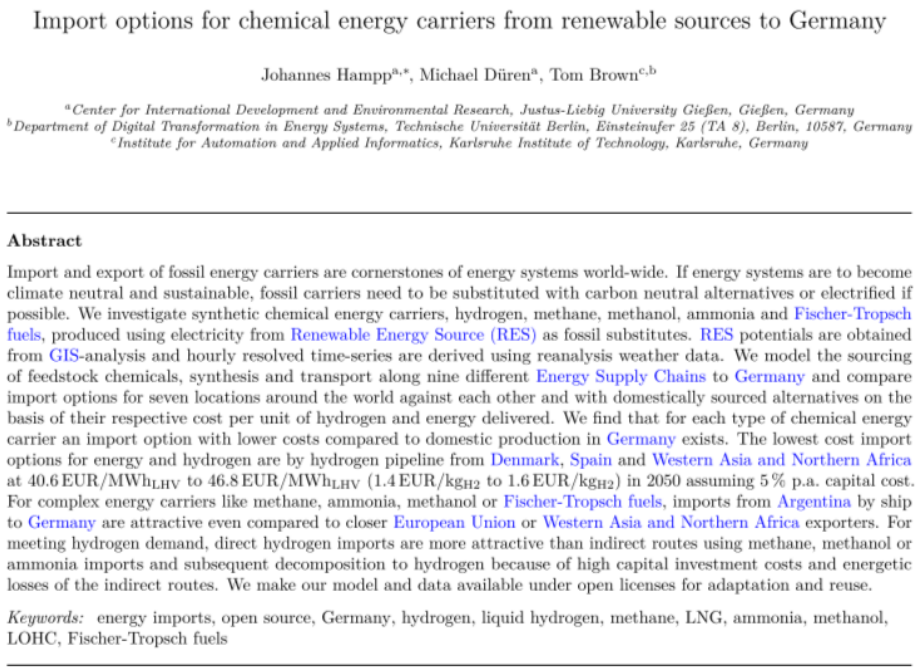
LNG carrier © 2014 FeZn, licensed CC BY SA 3.0, via wikimedia.org.

HVDC transmission line by TagsSanPedroAko, licensed CC0, via wikimedia.org.

Need sustainable & ready solution:

- Sustainable energy sources (wind, PV)
- Closed cycle for feedstock streams (CO2)
- Use existing technologies
- Quick deployment and scale-up
- Known chemical energy carriers

GIS analysis | RES availability | ESC modelling | System optimisation | Results analysis



Import options for chemical energy carriers from renewable sources to Germany

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Abstract

Import and export of fossil energy carriers are cornerstones of energy systems world-wide. If energy systems are to become climate neutral and sustainable, fossil carriers need to be substituted with carbon neutral alternatives or electrified if possible. We investigate synthetic chemical energy carriers, hydrogen, methane, methanol, ammonia and Fischer-Tropsch fuels, produced using electricity from Renewable Energy Source (RES) as fossil substitutes. RES potentials are obtained from GIS-analysis and hourly resolved time-series are derived using reanalysis weather data. We model the sourcing of feedstock chemicals, synthesis and transport along nine different Energy Supply Chains to Germany and compare import options for seven locations around the world against each other and with domestically sourced alternatives on the basis of their respective cost per unit of hydrogen and energy delivered. We find that for each type of chemical energy carrier an import option with lower costs compared to domestic production in Germany exists. The lowest cost import options for energy and hydrogen are by hydrogen pipeline from Denmark, Spain and Western Asia and Northern Africa at 40.6 EUR/MWh_{LHV} to 46.8 EUR/MWh_{LHV} (1.4 EUR/kg_{H2} to 1.6 EUR/kg_{H2}) in 2050 assuming 5 % p.a. capital cost. For complex energy carriers like methane, ammonia, methanol or Fischer-Tropsch fuels, imports from Argentina by ship to Germany are attractive even compared to closer European Union or Western Asia and Northern Africa exporters. For meeting hydrogen demand, direct hydrogen imports are more attractive than indirect routes using methane, methanol or ammonia imports and subsequent decomposition to hydrogen because of high capital investment costs and energetic losses of the indirect routes. We make our model and data available under open licenses for adaptation and reuse.

Keywords: energy imports, open source, Germany, hydrogen, liquid hydrogen, methane, LNG, ammonia, methanol, LOHC, Fischer-Tropsch fuels

Preprint:

Hampp, J., Düren, M., and Brown, T. (2021):

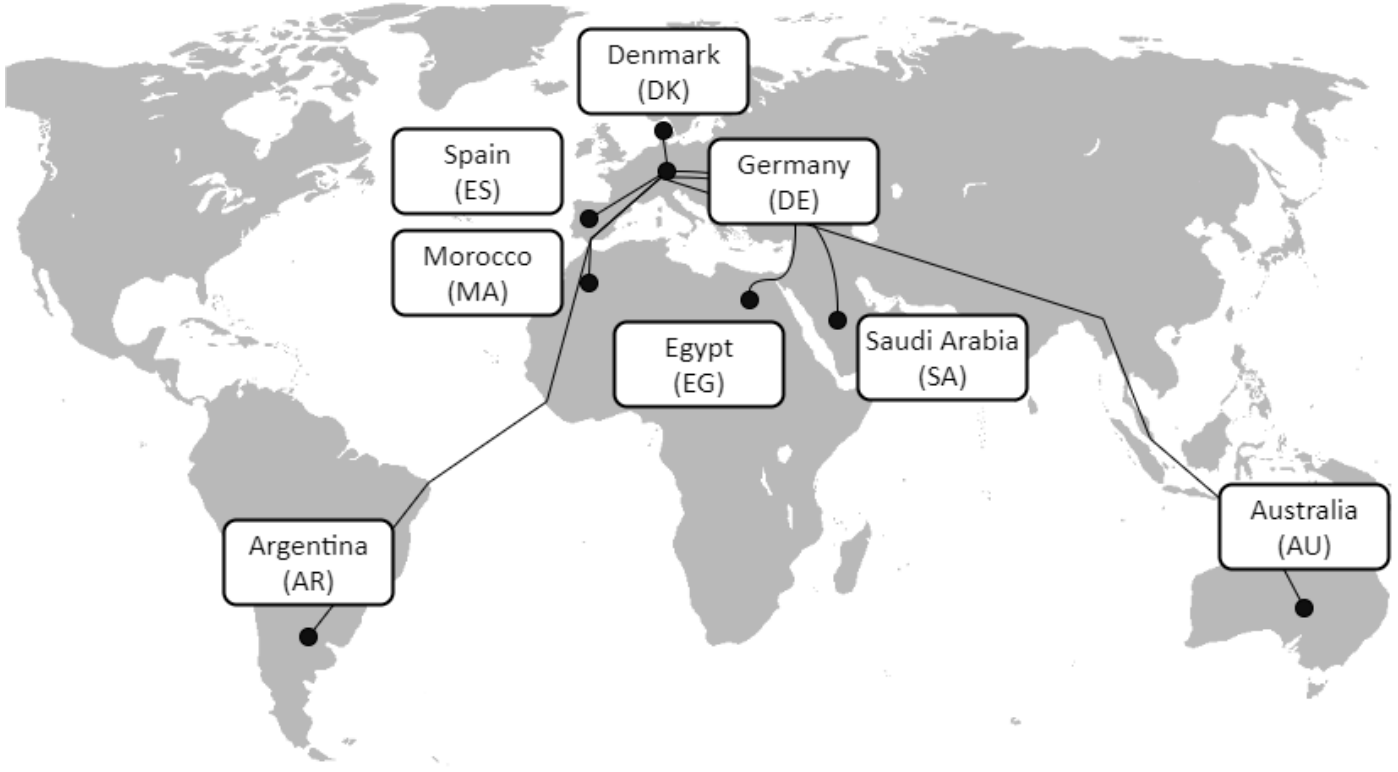
Import options for chemical energy carriers from renewable sources to Germany.

ArXiv:2107.01092 [Physics].
https://arxiv.org/abs/2107.01092

Twitter thread:

https://twitter.com/euronion42/status/1412329081027371008

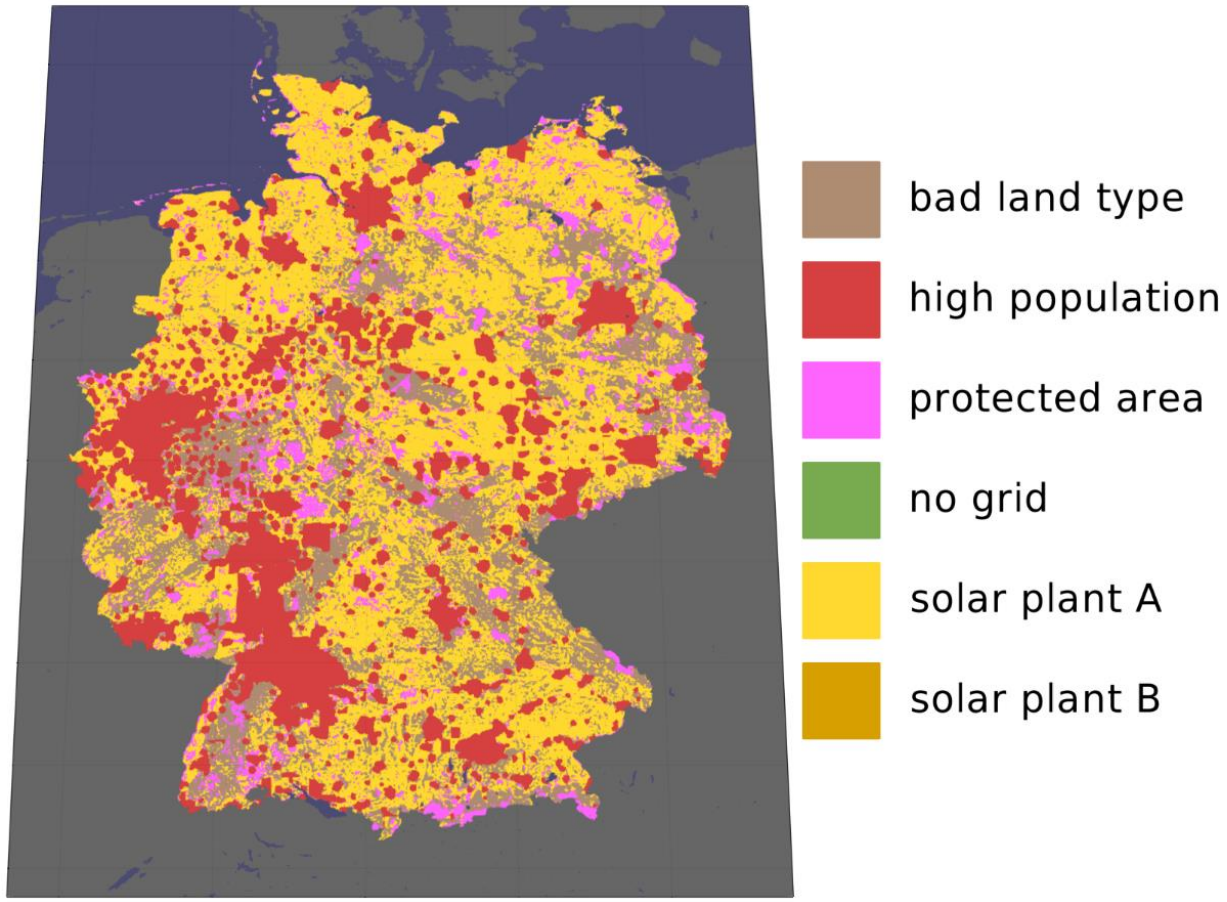
GIS analysis | RES availability | ESC modelling | System optimisation | Results analysis



Criteria for export regions:

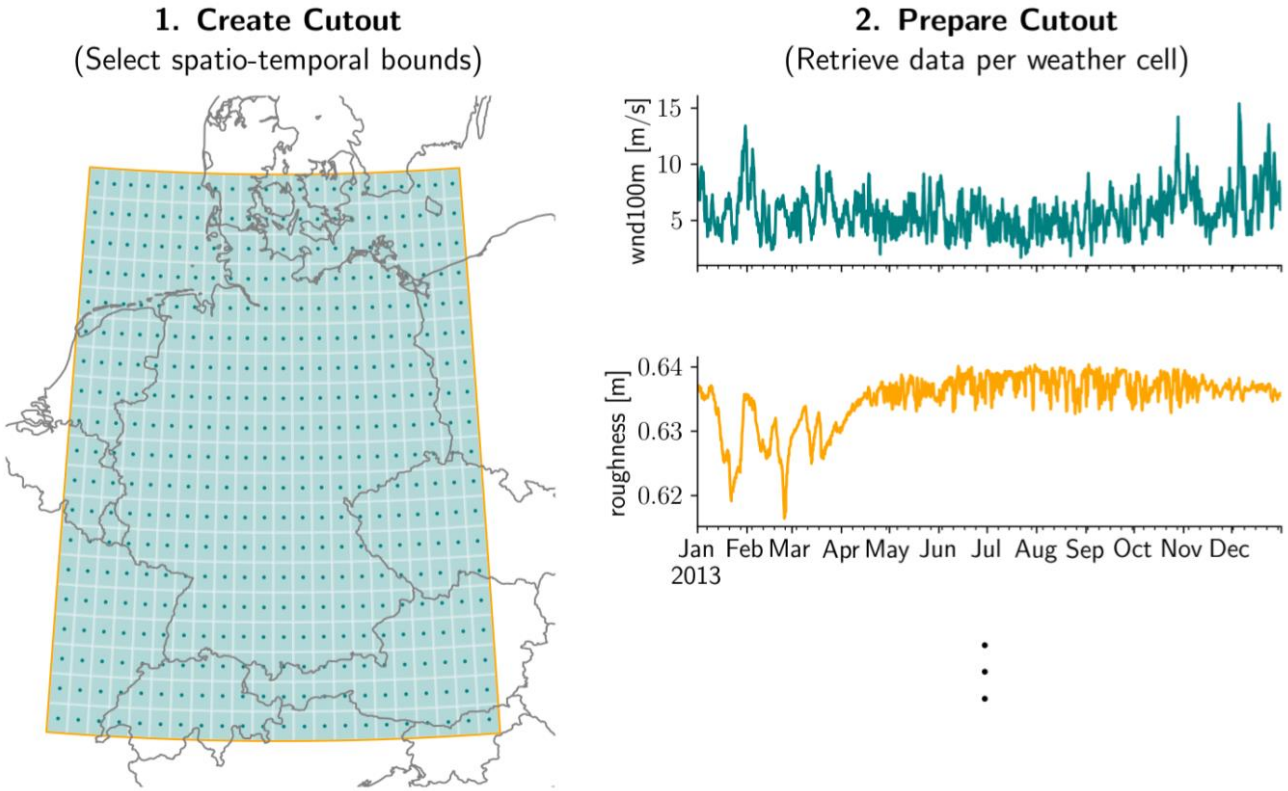
- Proximity
- EU & non-EU member
- Suitability: PV / wind

GIS analysis | RES availability | ESC modelling | System optimisation | Results analysis



- Determine available locations

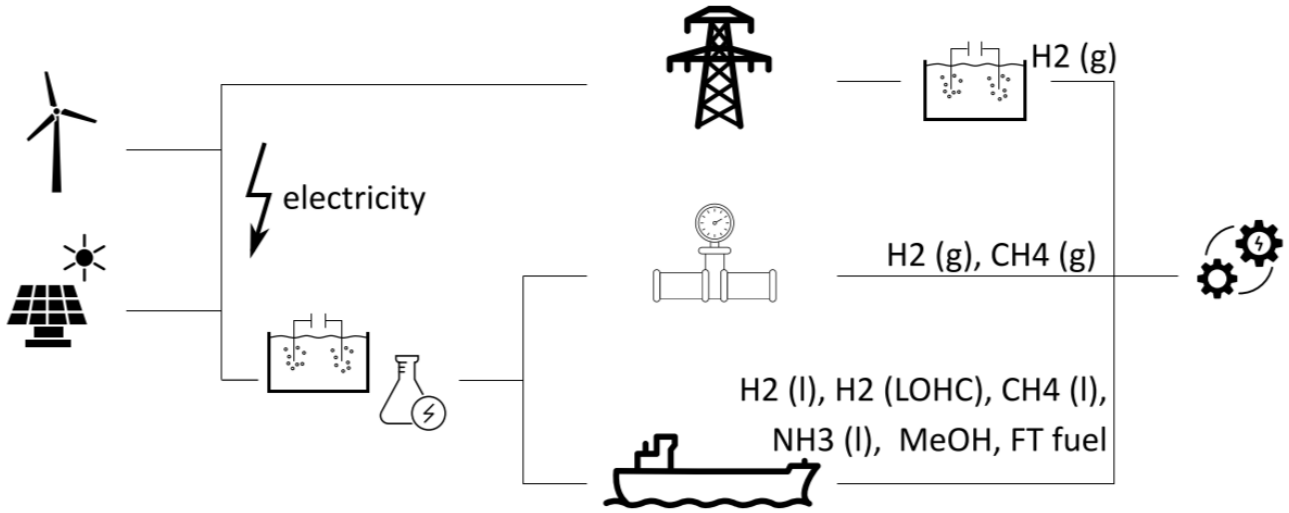
GIS analysis | RES availability | ESC modelling | System optimisation | Results analysis



Hofmann et al. (2021), licensed CC BY 4.0, https://joss.theoj.org/papers/10.21105/joss.03294 .

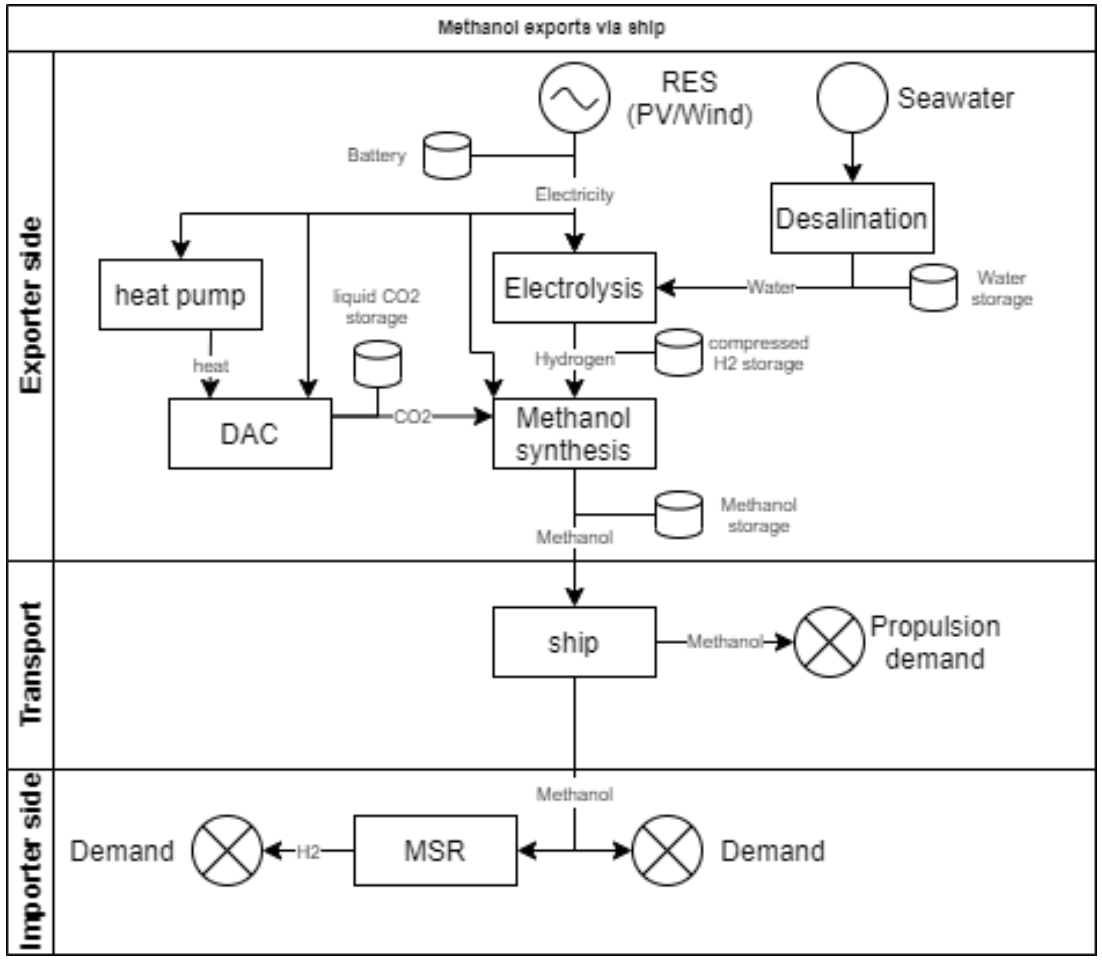
- Weather data for PV/wind time-series

GIS analysis | RES availability | ESC modelling | System optimisation | Results analysis



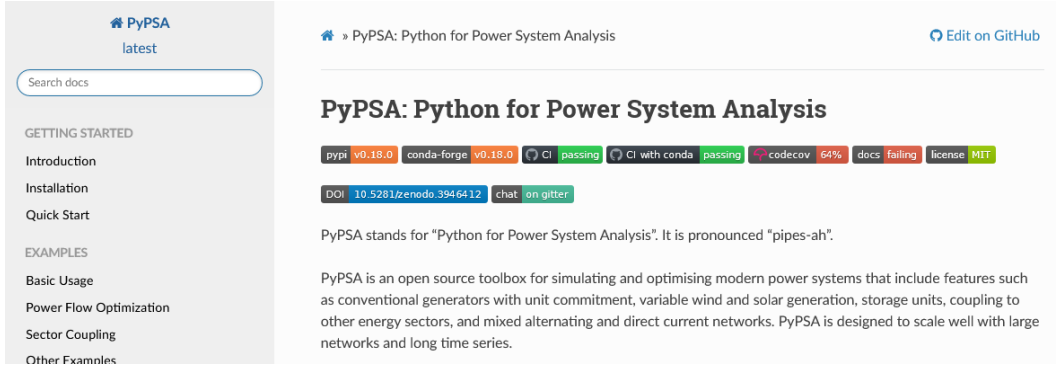
- 9 Energy Supply Chains
  - Electricity transmission + H2 electrolysis
  - Hydrogen H2: Gas, Liquefied, LOHC
  - Methane CH4: Gas, Liquefied
  - Ammonia NH3: Liquefied
  - Methanol MeOH: Liquid
  - Fischer-Tropsch fuels (Kerosene/Diesel)
- Energy sources: PV, Wind
- Conversion technologies
- Transportation routes

GIS analysis | RES availability | ESC modelling | System optimisation | Results analysis



- Detailed Energy Supply Chains (ESCs) model
- Energy flows
- Material flows
- Conversions processes

GIS analysis | RES availability | ESC modelling | System optimisation | Results analysis



https://pypsa.readthedocs.io/en/latest/

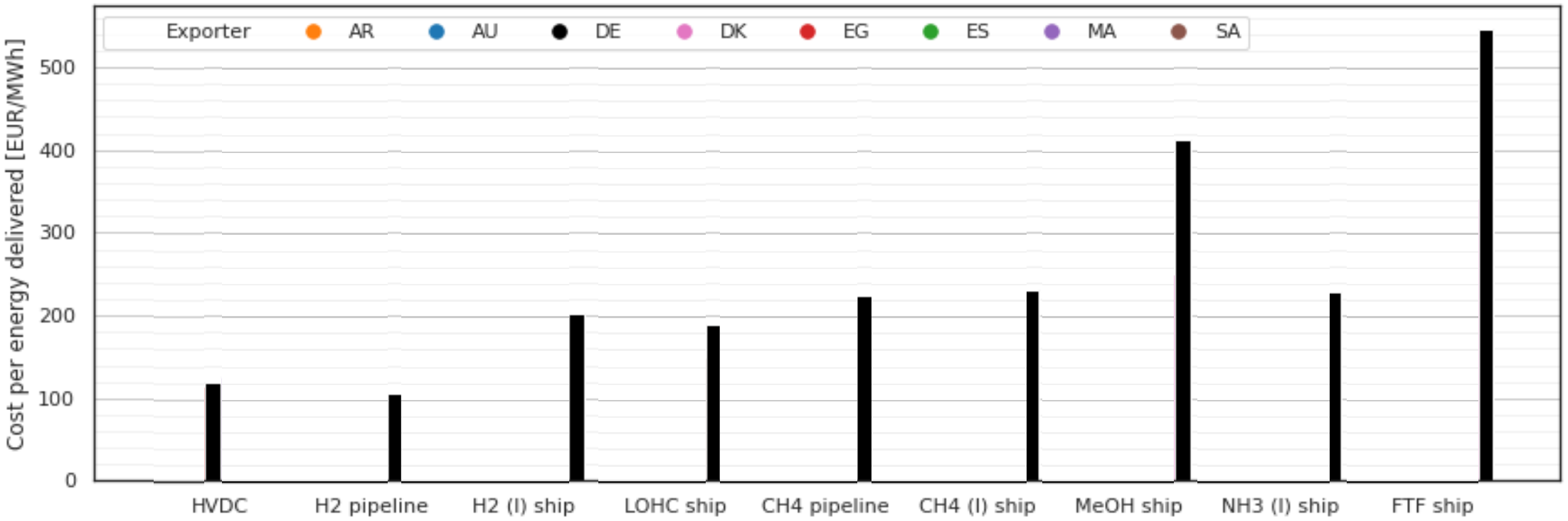
- Energy system model
- Linear programming
- Green field (no existing capacities considered)
- Capacity expansion model with least cost optimisation

openmod open energy modelling initiative

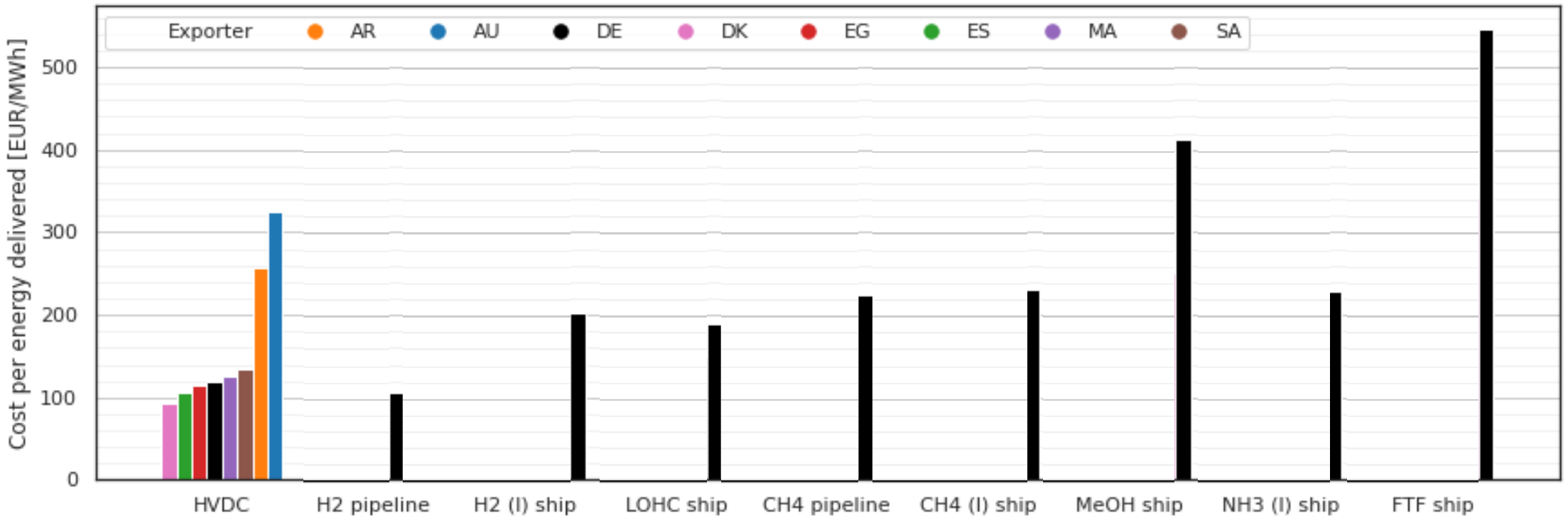
https://openmod-initiative.org/

- Open-ess & FAIR-ness
  → Acceptance
  → Open Source + Data + Access

GIS analysis | RES availability | ESC modelling | System optimisation | Results analysis



GIS analysis | RES availability | ESC modelling | System optimisation | Results analysis



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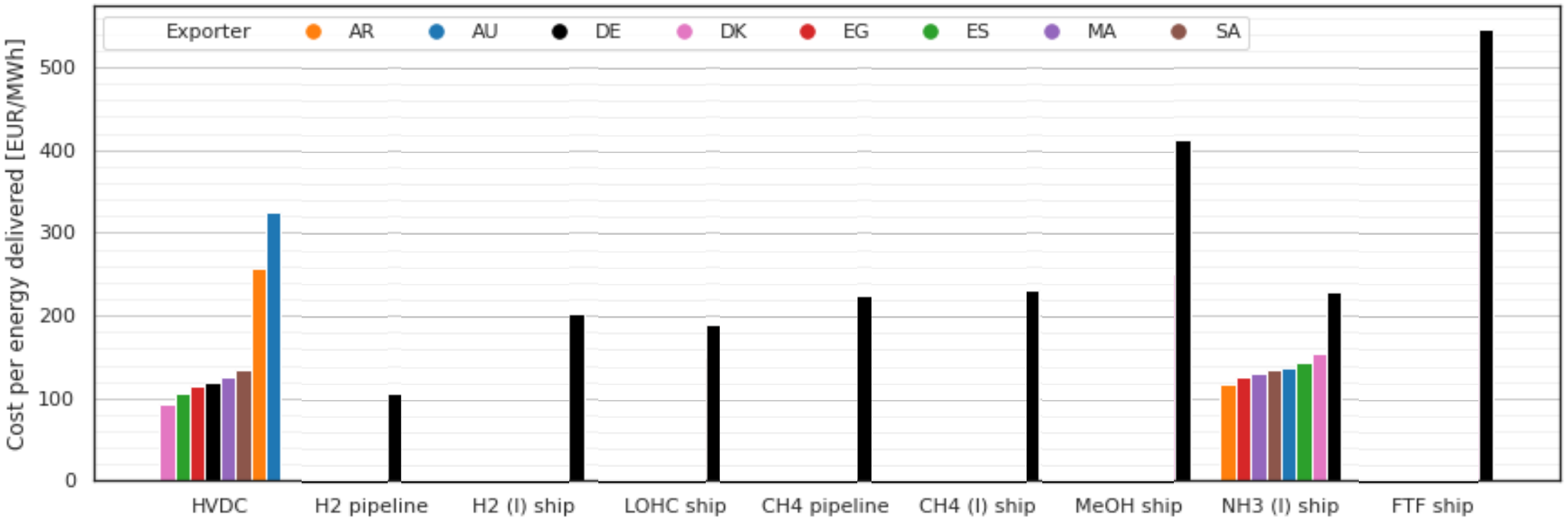

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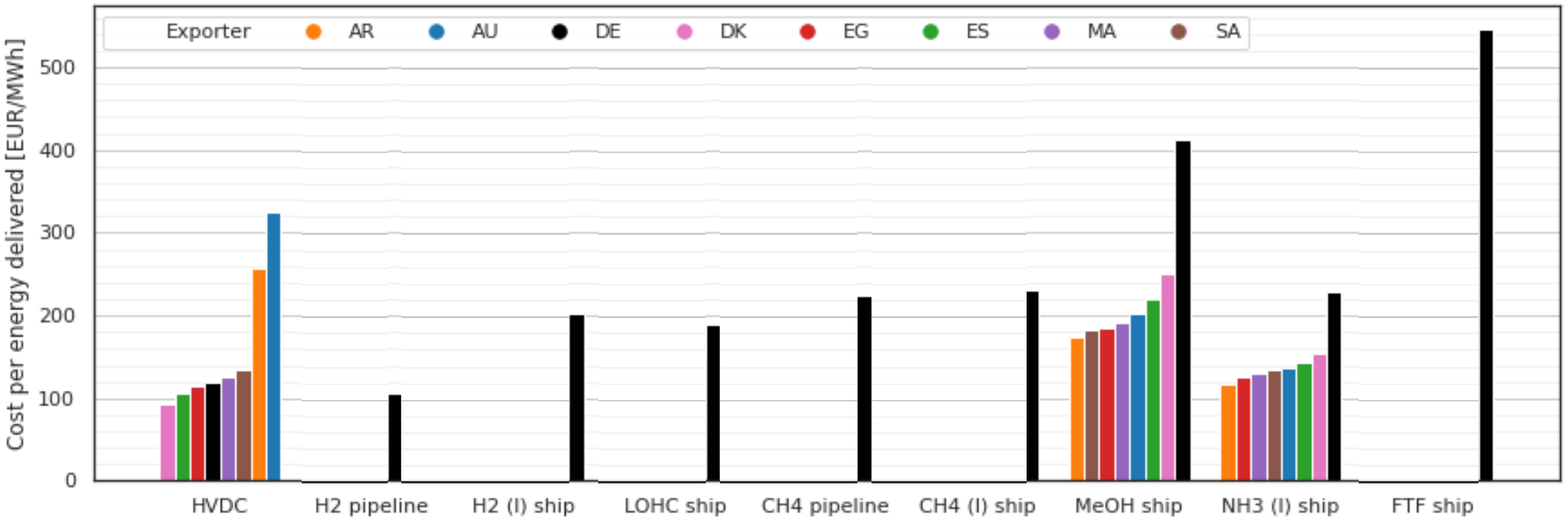

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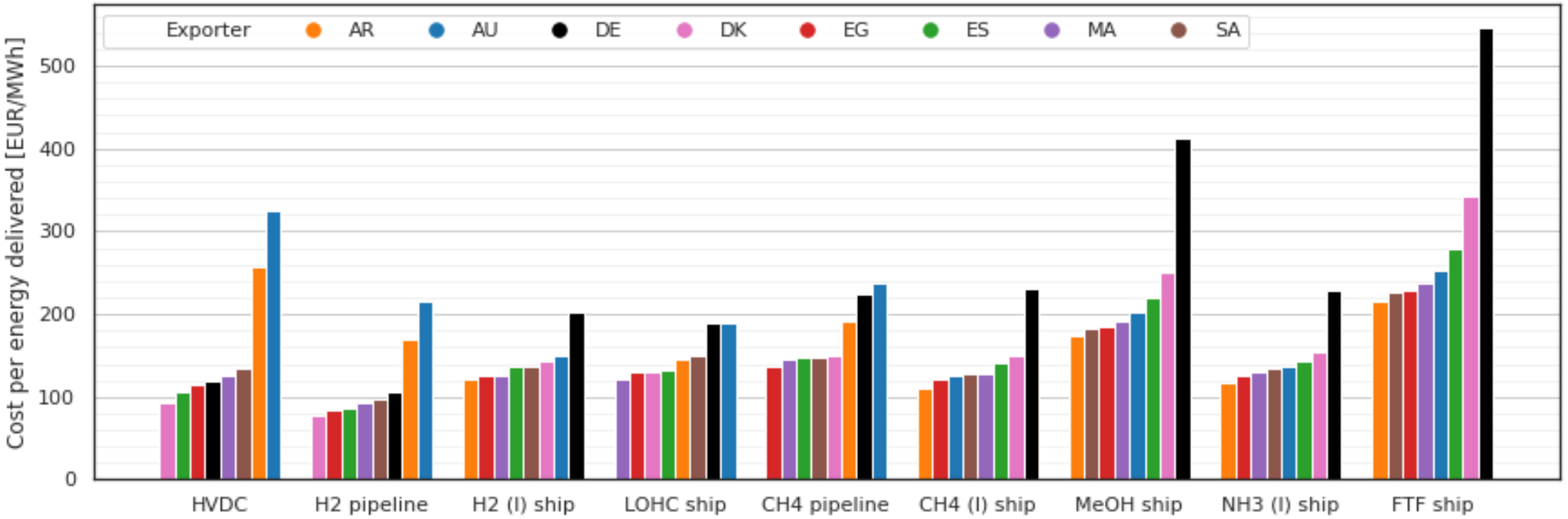
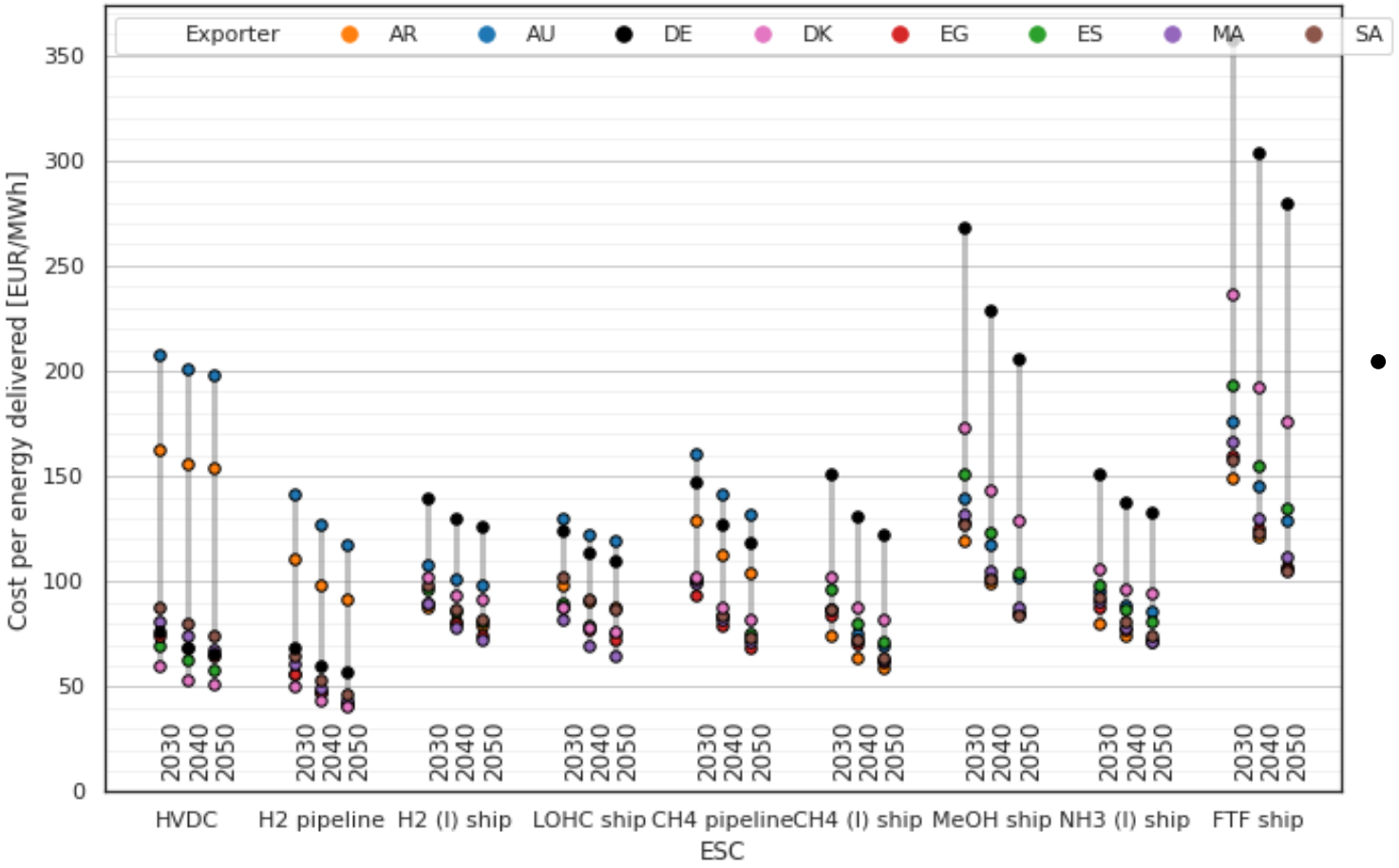


- DE has lower cost import options for each ESC.
- Good candidates are DK (proximity) and AR (good RES)

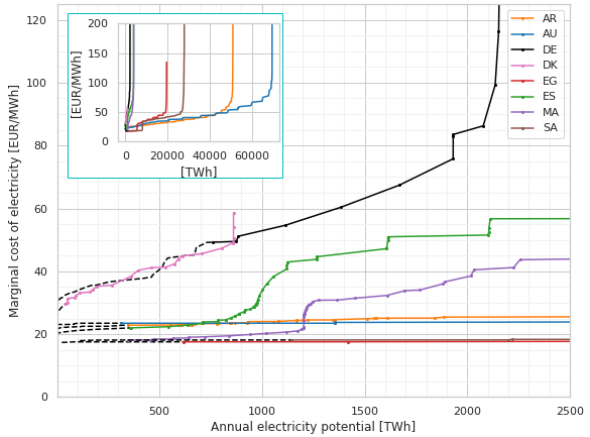
GIS analysis | RES availability | ESC modelling | System optimisation | Results analysis



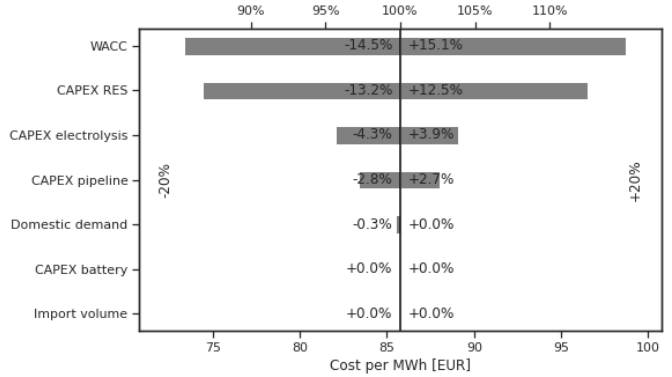
- Anticipated technological development:
  Cost reduction

Extended insights from models

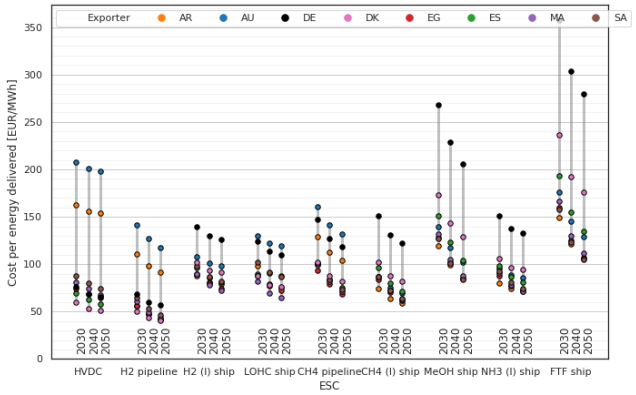
Cost dynamics



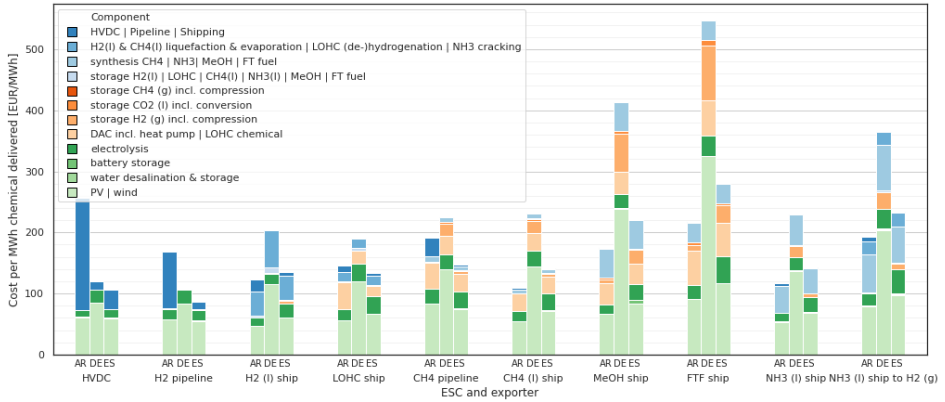
Sensitivities



Technology scale-up



Cost compositions



Comparison today's fossil alternatives

	Cheapest renewable alternatives (2050, 5% WACC)	Fossil market prices (2020)
Ammonia (EUR/t)	368	130-290
Methanol (EUR/t)	465	150-400
Methane (EUR/MWh)	58.5	31.50
FT fuels (EUR/kL)	1476	584

- (favourable) costs > market prices
- Comparable orders of magnitude
- Policy / voluntary actions necessary
- Comparability issue: Costs != prices

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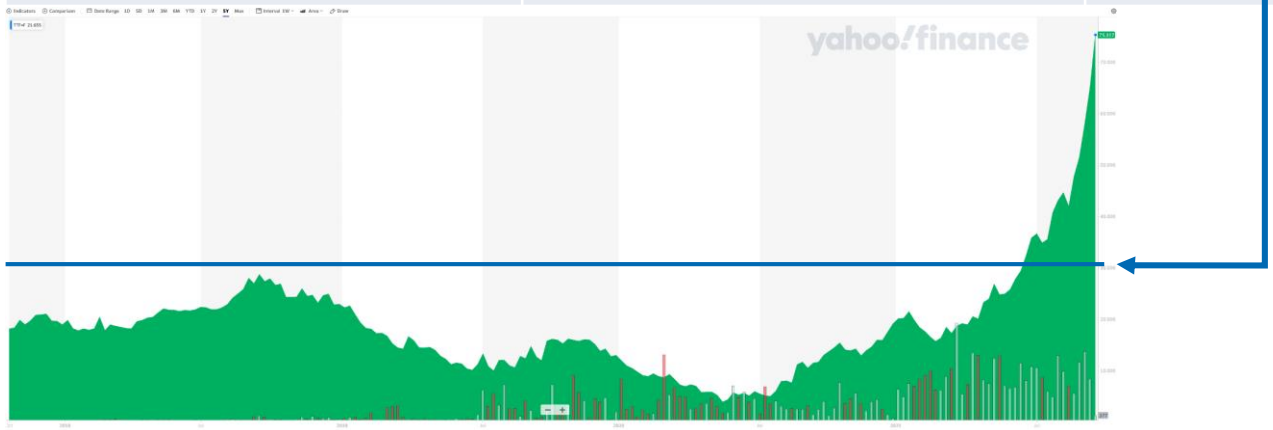

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2021:
Ongoing natural gas price pandemonium
> 70 EUR/MWh spot market prices

Dutch TTF Natural Gas Calendar © 2021 Verizon Media, via finance.yahoo.com .

Conclusion

- We need chemical energy carriers
- Import is an attractive option for Germany
- H2 imports by pipeline are cheapest option
- RES-based chemicals not cost-competitive with today's market prices

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