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Cost Minimized Hydrogen from Solar and Wind – Production and Supply in the European Catchment Area

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[1] [2] [3] [4] [5] [6]

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Background

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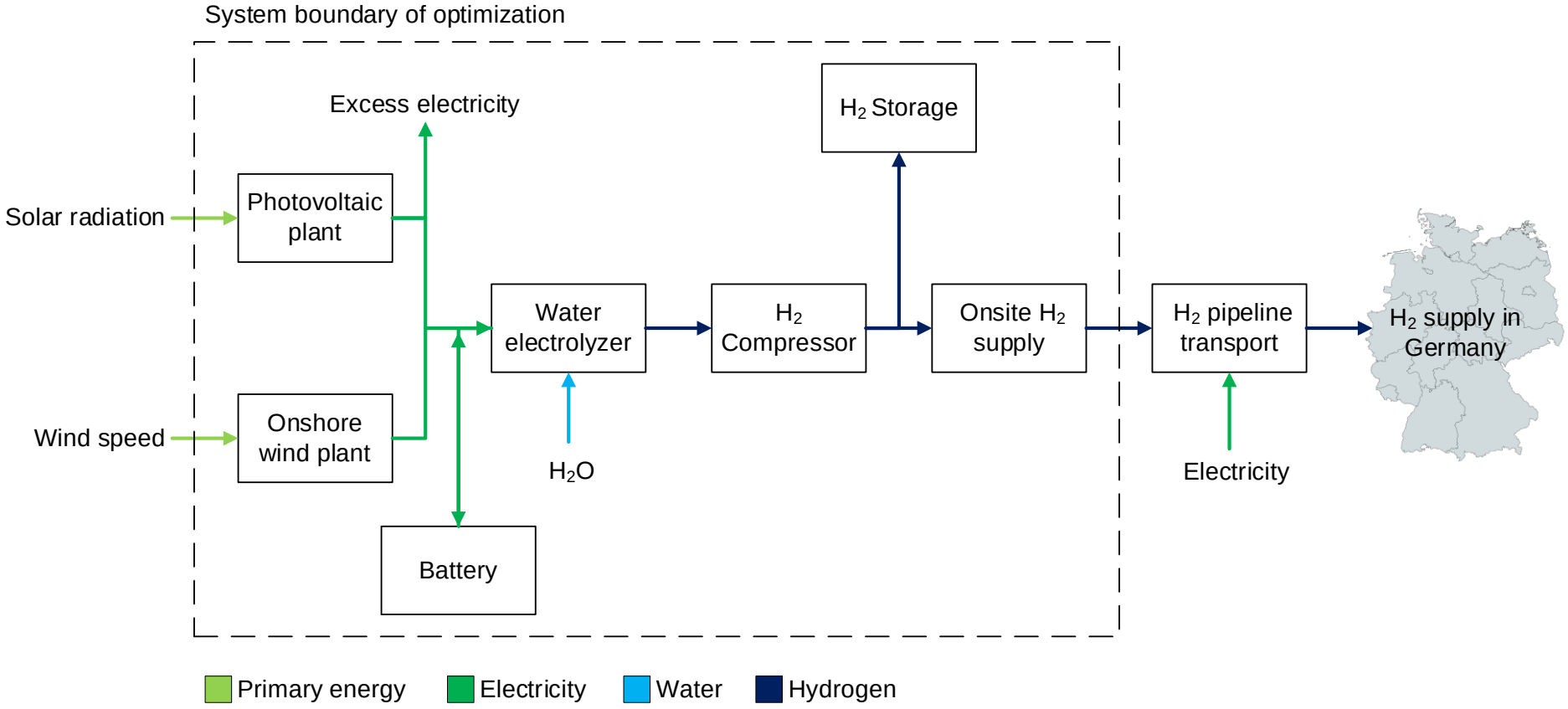
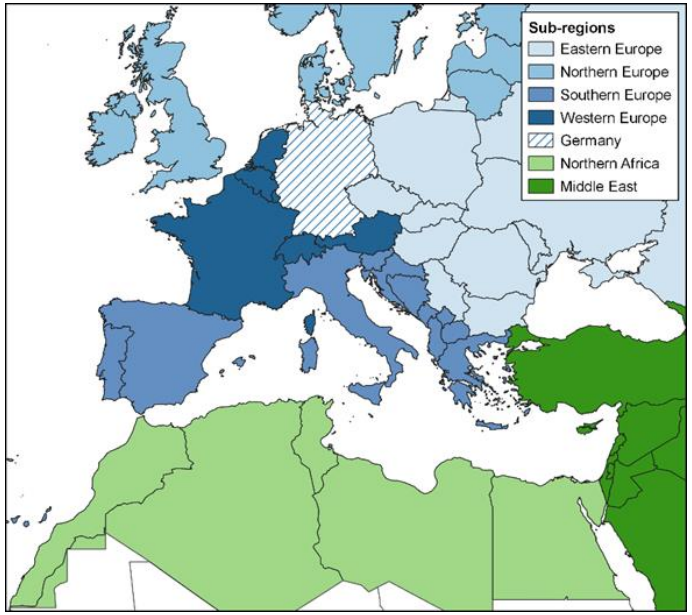
Background

- Which regions obtain the lowest onsite hydrogen supply cost?
- What is the magnitude of the hydrogen supply potential to Germany?
- What is the optimal renewable electricity generation power ratio?
- Do we generate excess electricity?
- How many annual full load hours are achieved by the electrolyzer?
- What size of storage capacities are necessary to overcome dark doldrums?
- Does the implementation of salt cavern storage changes the overall picture?
- What is the space demand for the production of green hydrogen?

Hydrogen Supply Cost Estimation



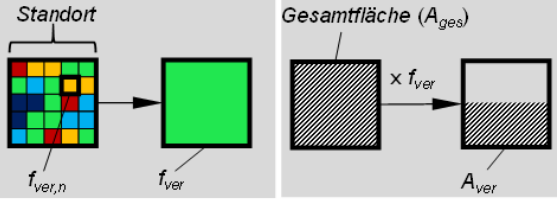
Hydrogen Production Potential



Verfügbare Fläche (A_{ver}) für die Installation von Photovoltaik und Windkraftanlagen

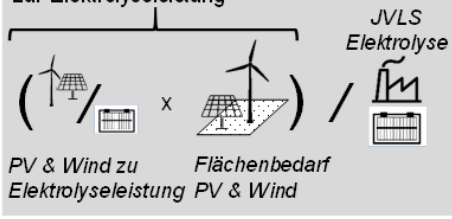
Mittelung der Sub-Flächen-verfügbarkeitsfaktoren ($f_{ver,n}$) der Standort Sub-Flächen

Bestimmung der Fläche (A_{ver}) für die Installation von PV und Windkraftanlagen

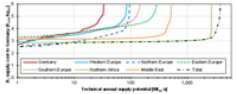


Spezifischer Flächenbedarf (a_{H2}) für die Wasserstoffproduktion

Spezifischer Flächenbedarf ($a_{pv+wind}$) der Stromerzeugungsleistung relativ zur Elektrolyseleistung



Jährliches technisches Wasserstoffproduktionspotential (Q_{H2})



$$Q_{H2} = A_{ver} / a_{H2}$$

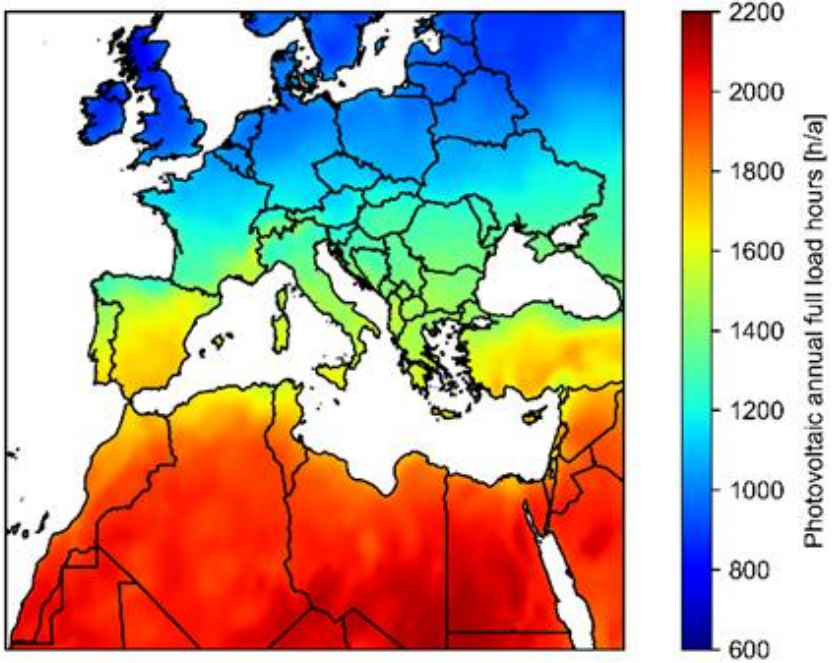
Input Data

	Year	PV [a]	Onshore Wind [a]	Battery [b]	PEMEL [a]	Pressure Tank [c]	Salt Cavern [c]
CAPEX [a] [€$_{2020}$/kW] [b] [€$_{2020}$/kWh] [c] [€$_{2020}$/kg$_{H2}$]	2030	400	1,110	180	860	460	50
	2050	280	1,010	90	510		
Efficiency	2030	-	-	87%	67%	-	-
	2050	-	-		71%	-	-

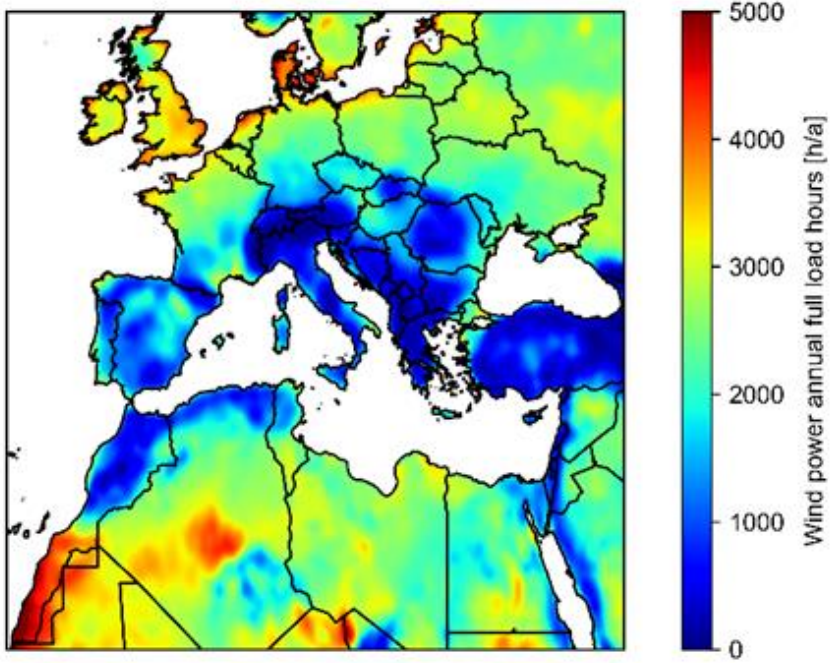
- Climate dataset: ERA5 (hourly resolution)
- Weather year: 2012
- Supply profile: Constant hourly hydrogen supply
- Value of excess electricity: 0 €$_{2020}$/kWh
- Real weighted average cost of capital: 6%

Annual Full Load Hours of PV and Wind

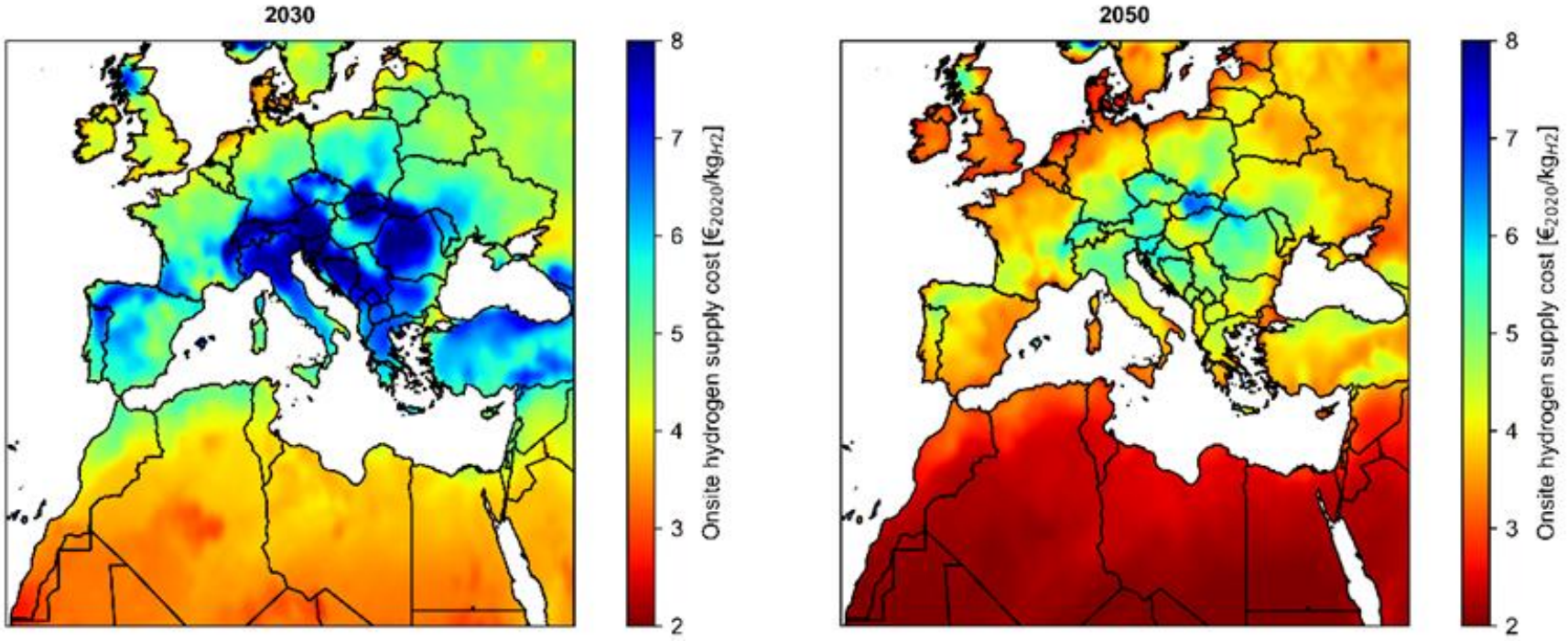
PV



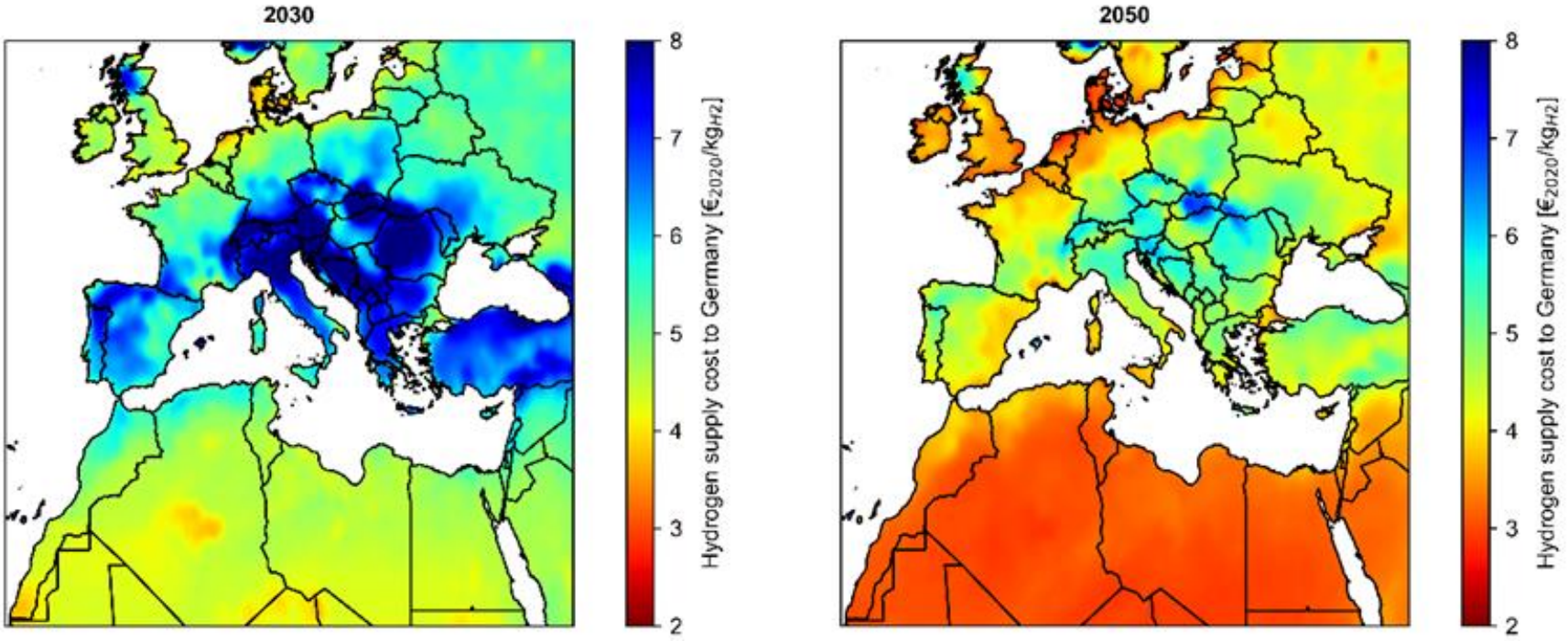
Wind



Onsite Hydrogen Supply Cost

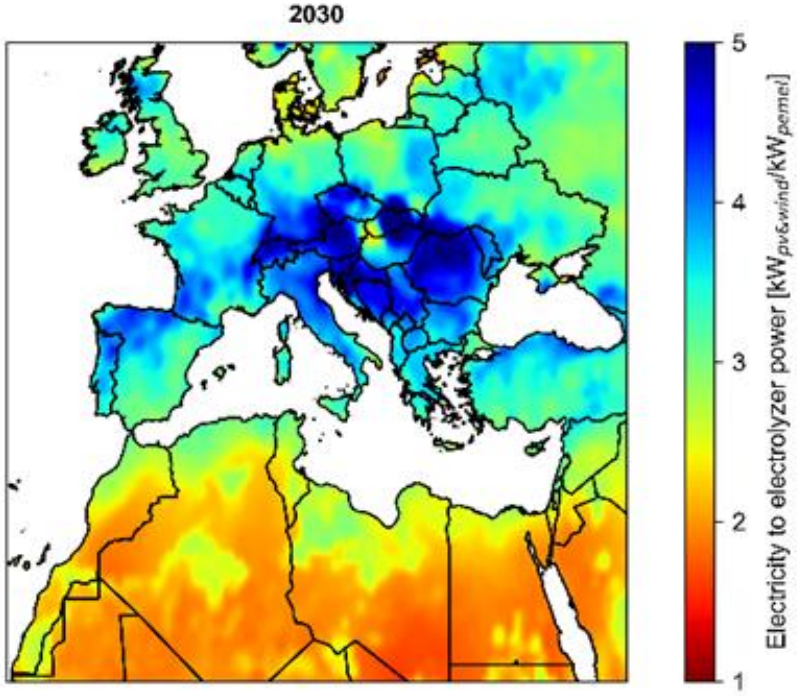


Hydrogen Supply Cost to Germany

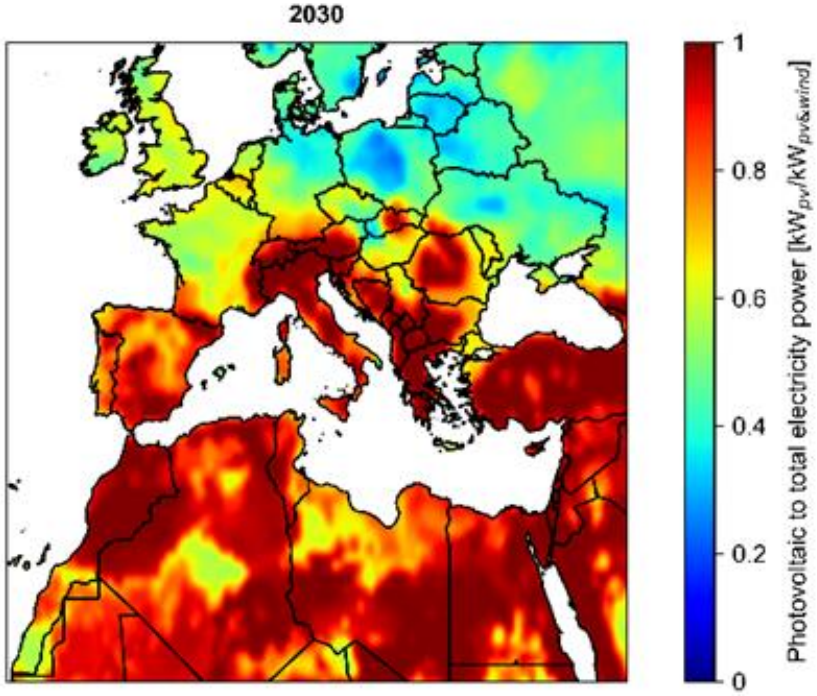


PV & Wind Power Design

PV/Wind to Electrolyzer Power

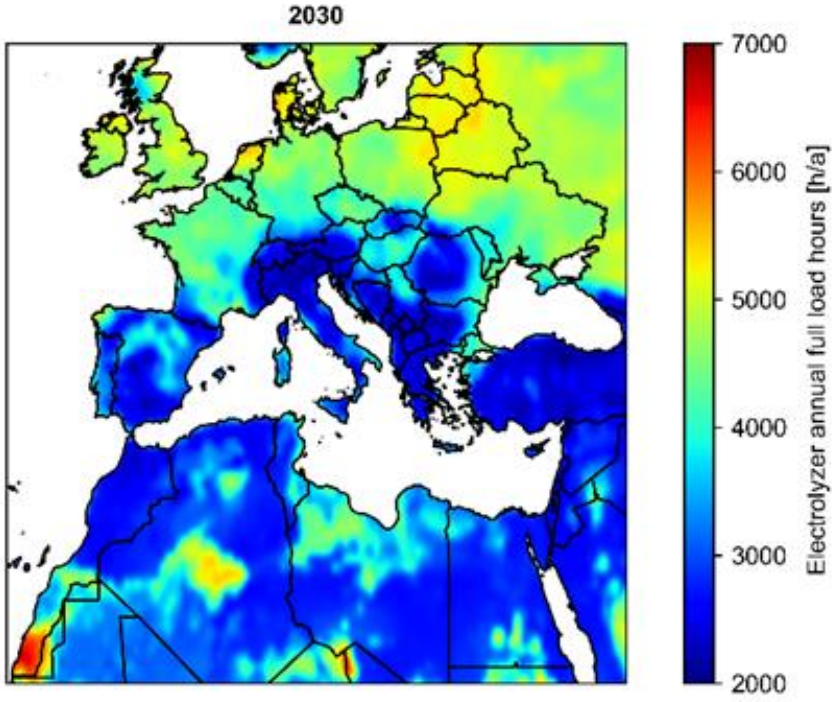


PV Share

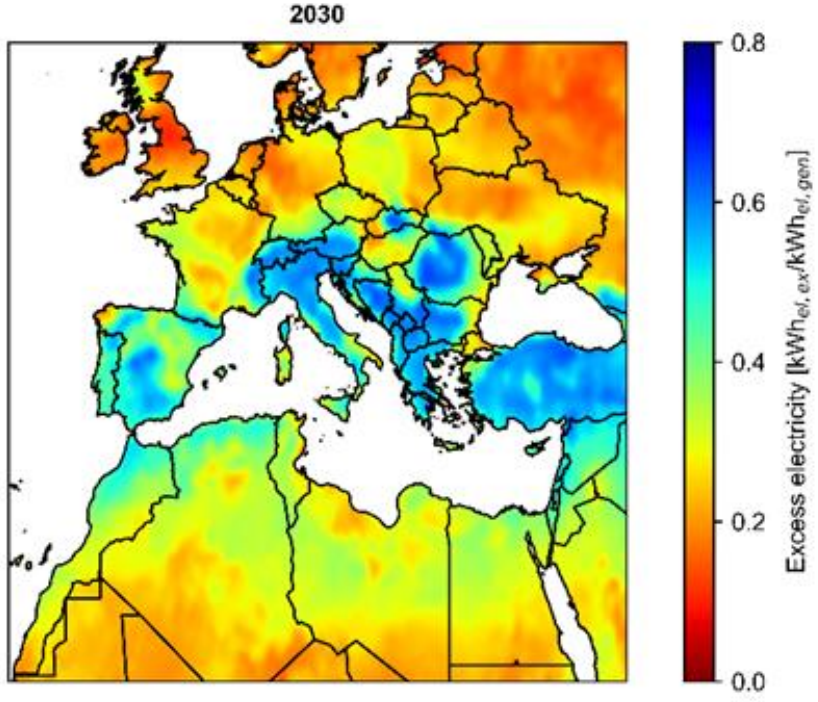


Electrolyzer Design

Electrolyzer Annual Full Load Hours

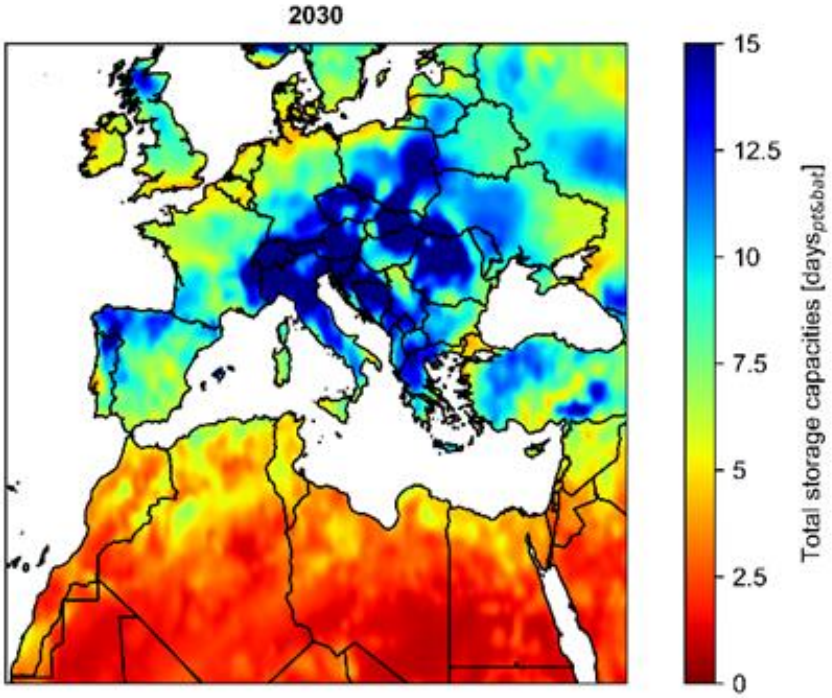


Excess Electricity

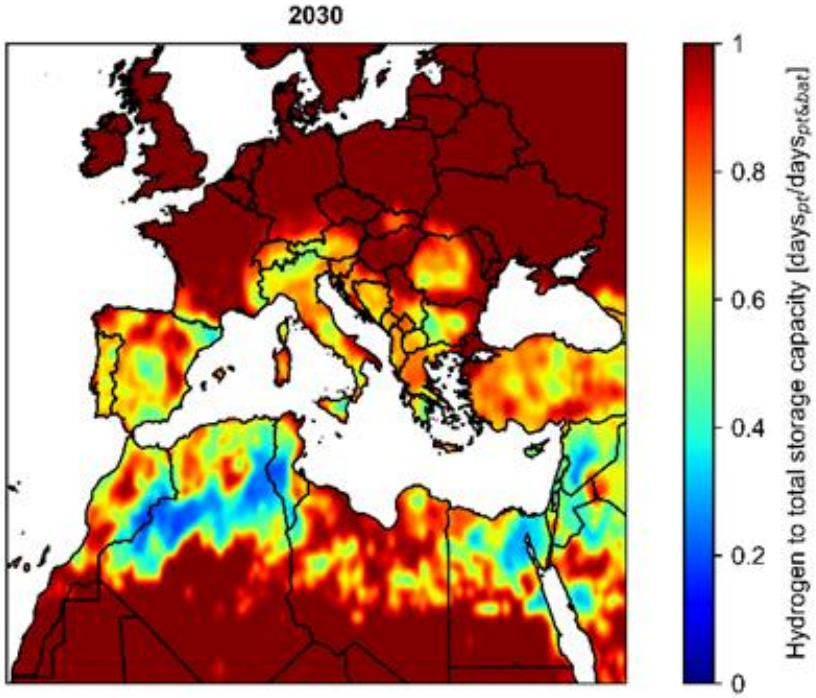


Storage Design

Total Storage Capacities

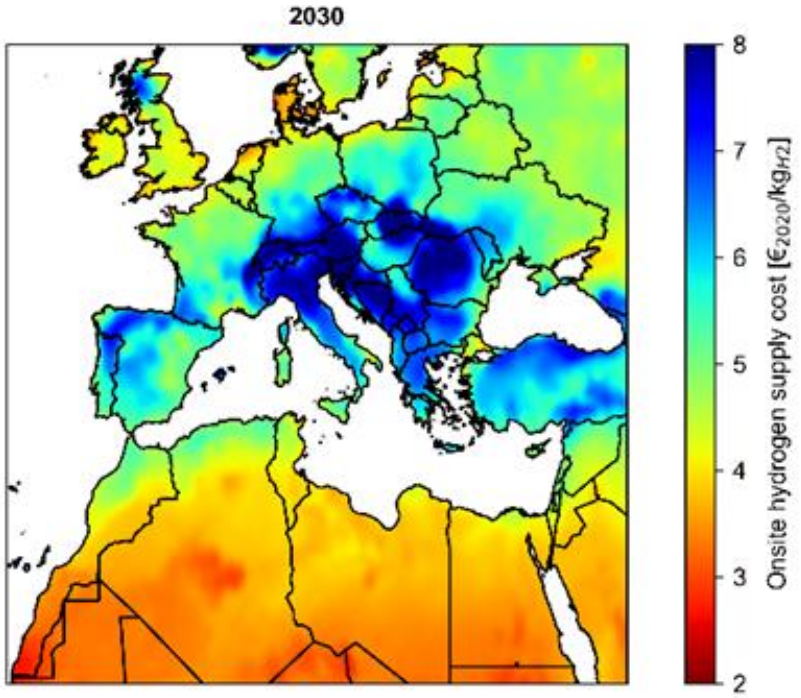


Hydrogen to Battery Storage Ratio

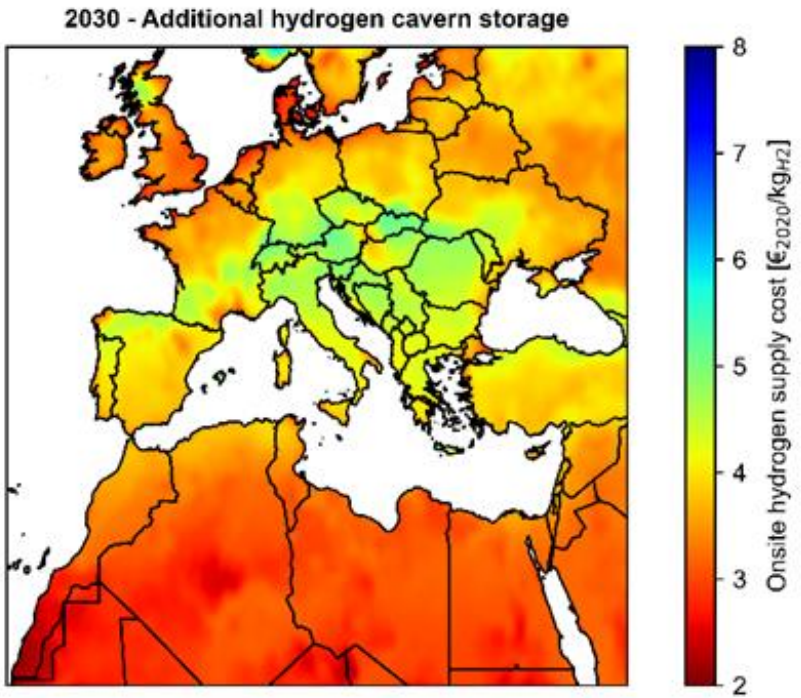


Salt Cavern Implementation – Onsite Hydrogen Supply Cost

Without Salt Cavern

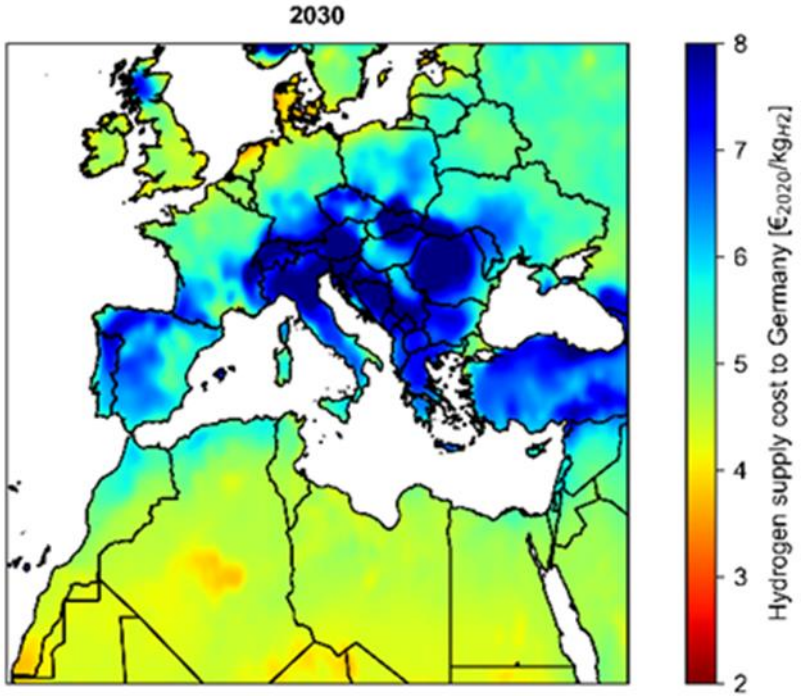


With Salt Cavern

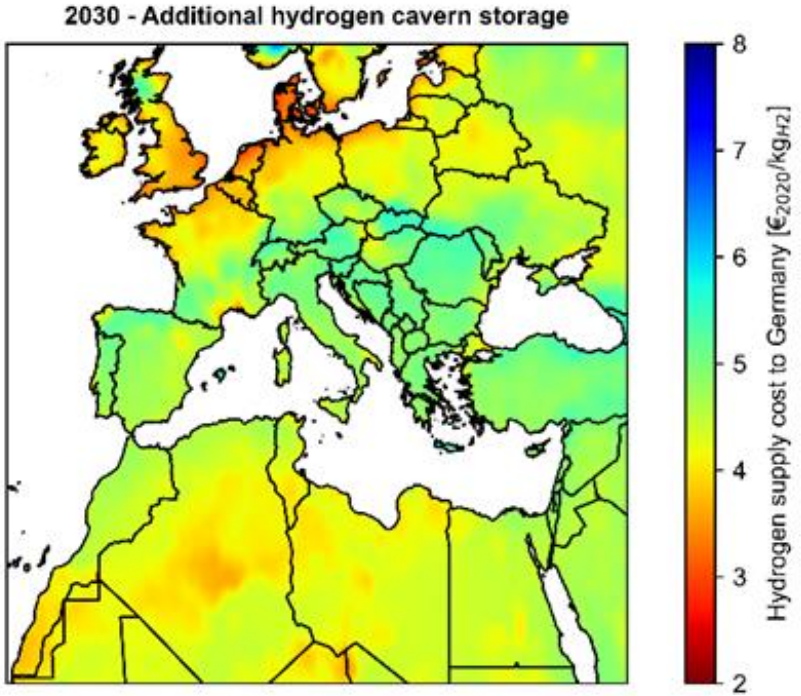


Salt Cavern Implementation – Hydrogen Supply Cost to Germany

Without Salt Cavern

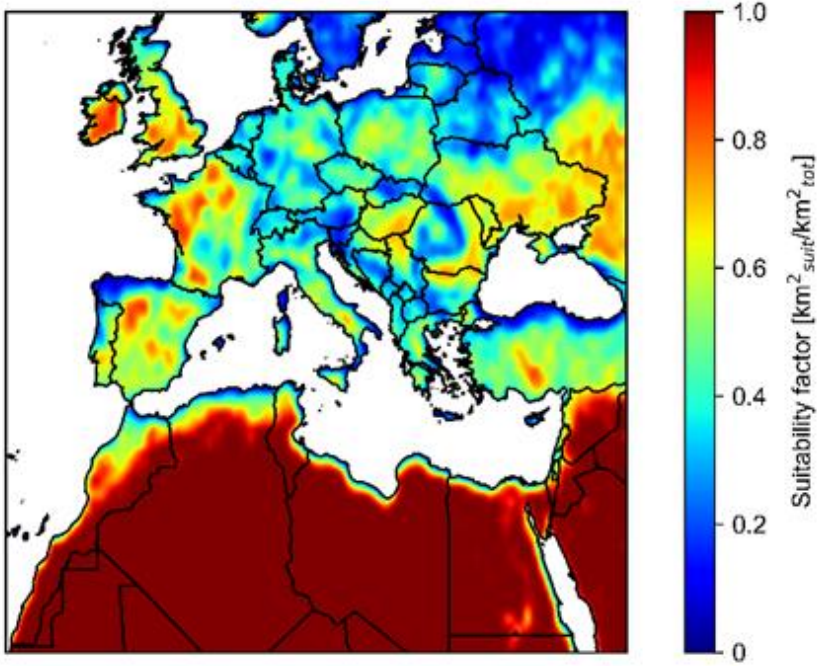


With Salt Cavern

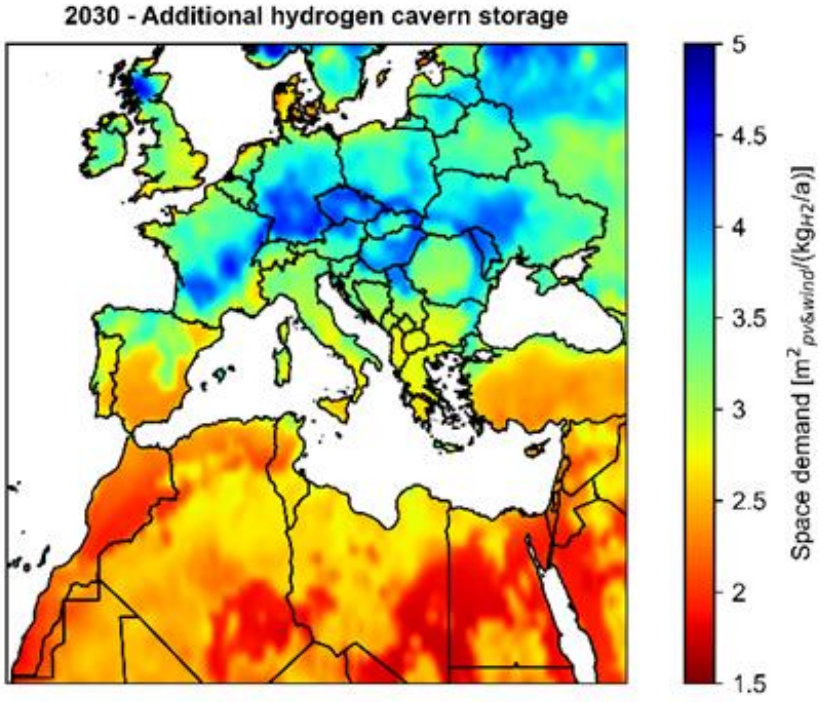


Land Suitability and Space Demand

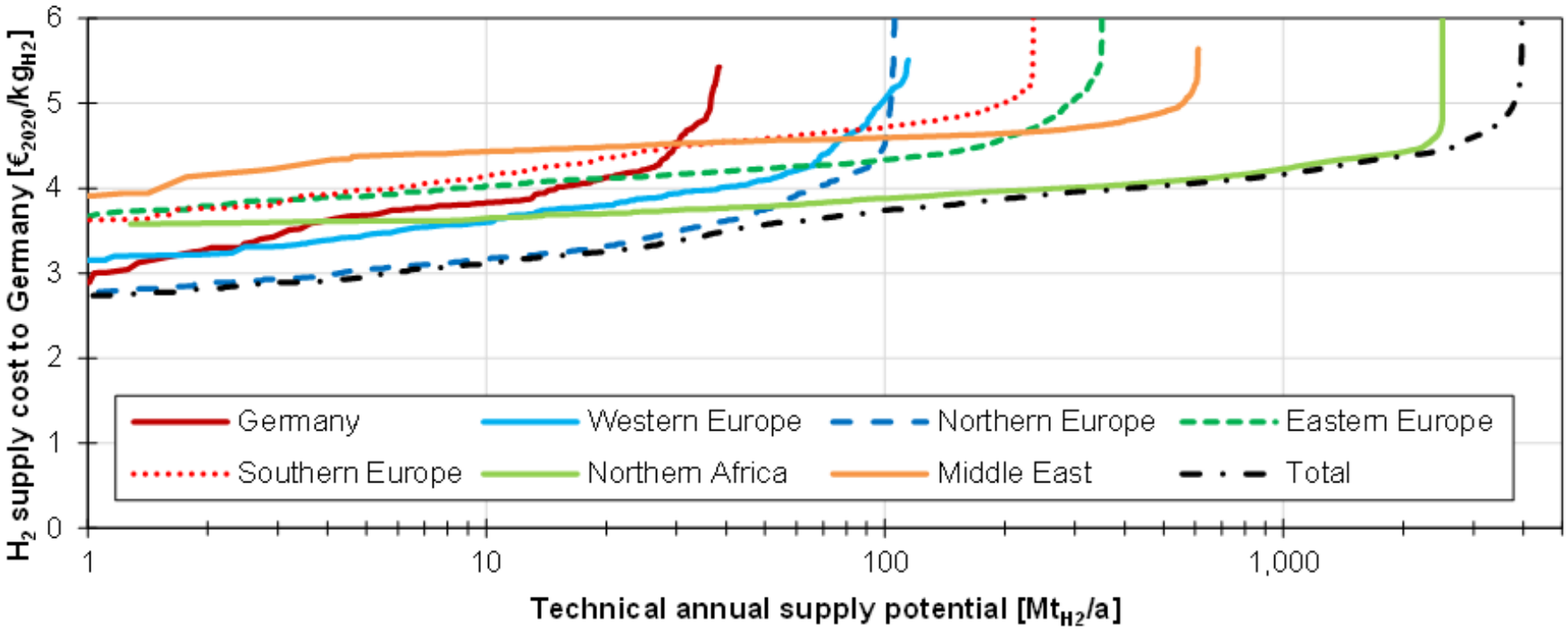
Suitability Factor



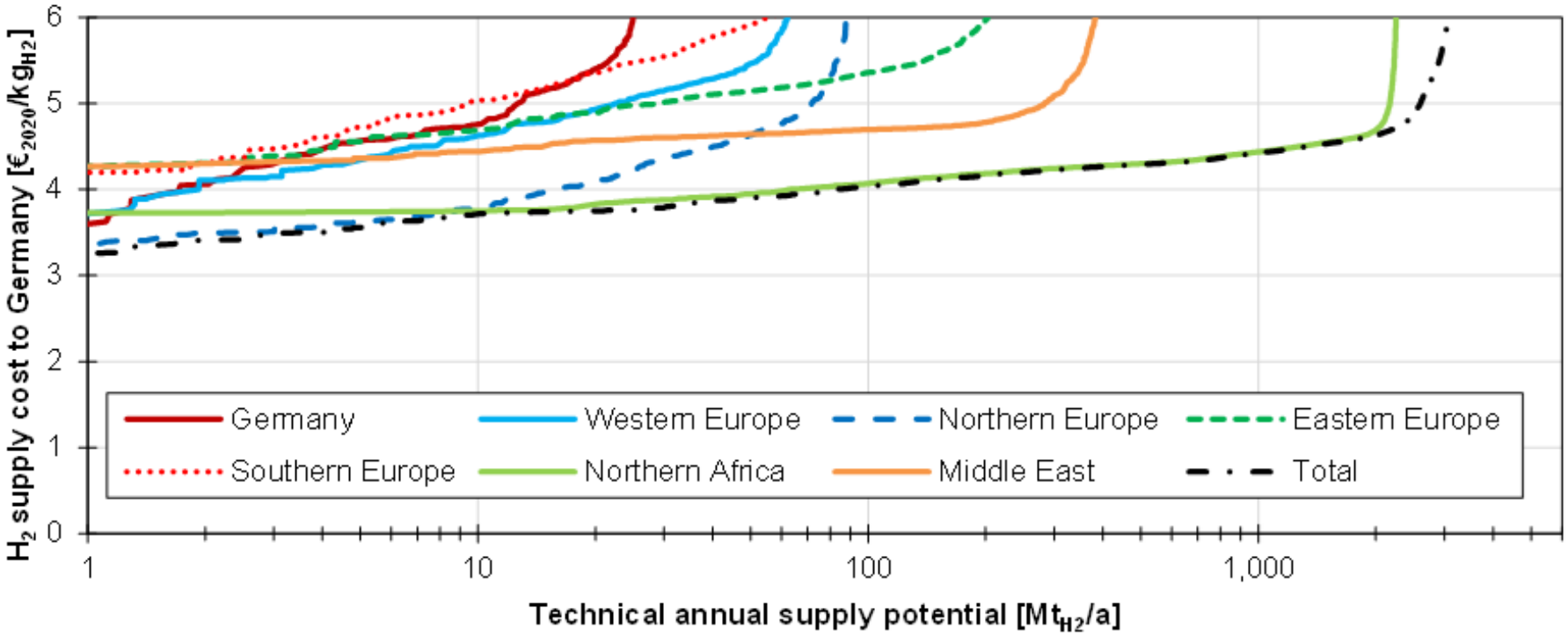
Space Demand



Supply Potential with Salt Cavern Use (2030)



Supply Potential without Salt Cavern Use (2030)



Conclusion

- Which regions obtain the lowest onsite hydrogen supply cost?
  - Western Sahara, Central Algeria and Coastal Location at the North Sea with 3 €$_{2020}$/kg$_{H2}$ (2030) and 2 €$_{2020}$/kg (2050)

- What is the magnitude of the hydrogen supply potential to Germany?
  - around 20 Mt$_{H2}$/a for 4 €$_{2020}$/kg$_{H2}$ (domestic, 2030, salt cavern use) or more than 100 Mt$_{H2}$/a for 3.5 €$_{2020}$/kg$_{H2}$ (Northern Africa, 2030, salt cavern use)

- What is the optimal renewable electricity generation power ratio?
  - Photovoltaic and wind power between 2 to 4 times higher than electrolyzer power

- Do we generate excess electricity?
  - Excess electricity lays between 10 to 30% for the best locations and can be lowered significantly if salt cavern are used

Conclusion

- How many annual full load hours are achieved by the electrolyzer?
  - Annual full load hours vary between 2,000 (PV dominated) to 6,000 FLH/a (Wind dominated)
- What size of storage capacities are necessary to overcome dark doldrums?
  - Around 5 to 10 days self sufficient capacity (increases in the case of salt cavern use)
- Does the implementation of salt cavern storage changes the overall picture?
  - Lowers the onsite cost significantly, especially for locations that have a high solar radiation but still a high seasonality
- What is the space demand for the production of green hydrogen?
  - Between 2 to 4 $m^2/(kg_{H2}/a)$

Paper Download

Associated paper can be downloaded until 15th of July 2022 for free under:

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References

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[3] https://images.app.goo.gl/emZiwi4GPQbrGvHu6

[4] https://images.app.goo.gl/wpf5beDJPAXoCJxF6

[5] https://images.app.goo.gl/bD24v1L26ANsmx4n8

[6] https://images.app.goo.gl/58YNgjNLviaWJ1rZA

[7] https://ccnull.de/foto/mehrere-flaschen-champagner-auf-eis/1010492