THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

Geospatial Analysis of European Green Hydrogen Potential to Meet Germany's 2030 Targets

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Introduction

In Germany, the National Hydrogen Strategy (*Nationale Wasserstoffstragie*, NWS) was released in 2020, with a progress checkpoint for research until 2023 to strategize and provide funding for hydrogen and domestic hydrogen derivative projects including fuel cell investment. The policy institutes a structure for a governance model with a hydrogen advisory board and outlines goals encourage progress to Net Zero (*Die Nationale Wasserstoffstrategie*, 2020). For research and development of green hydrogen, the government has allocated 7 billion Euro, with 2 billion Euro additionally set aside for promoting international trade relationships and collaborative projects. The policy works towards decreased reliance on Russian natural gas through increased domestic storage of energy as chemical storage. The RePowerEU policy works towards similar goals for EU hydrogen trade, and the EU published that "since September 2022, Russian gas accounts for only 8% of all pipelined gas imported into the EU, compared to 41% of EU imports from Russian gas in August 2021," (*REPowerEU*, 2022).

As an energy carrier hydrogen may be transformed from other energy sources using a variety of methods. Hydrogen energy, which has been utilized for decades in energy-intensive industries such as steel production and the chemical industry, is most often produced using steam-methane reforming, yielding what is termed ***gray hydrogen***. The utilization of carbon capture and storage technologies to abate harmful emissions in hydrogen production creates ***blue hydrogen***, which falls under the umbrella of ***clean hydrogen*** alongside ***green hydrogen***. Green hydrogen is produced through electrolysis, which transforms water into hydrogen and oxygen through a zero-emissions process using renewable energy. Additional types of hydrogen production include *pink hydrogen*, or hydrogen produced through coupling with nuclear generation, and *turquoise hydrogen*, which is produced through methane pyrolysis yielding solid carbon and hydrogen with the option to use animal waste as a feedstock.

Methodology

This research asks whether domestic technical potential for green hydrogen production matches Germany's goals for installation of new capacity for clean hydrogen production by the year 2030. We seek to predict optimal application for green hydrogen development to meet the policy goals established by the German government. Within the scope of measured renewable energy technical potential from the EU Joint Research Center (JRC) and research from Neuwirth et. al (2022), the research examines the current state of hydrogen technology in Europe and progress within likely end uses for hydrogen deployment. Technical potential for green hydrogen production in and surrounding Germany is calculated to locate sites of investment for hydrogen electrolysis plant development and new hydrogen transport infrastructure.

What are the goals of the German Hydrogen Strategy?

1. Ensure the sufficient availability of hydrogen energy
2. Develop efficient hydrogen infrastructure
3. Establish applications for hydrogen
4. Execute effective (economic, political) frameworks

National Hydrogen Strategy's Goal of Installed Capacity for Clean Hydrogen by 2030	Sector of Deployment for Economic Investment into Hydrogen Energy According to Installation Targets	Calculation of Kilotonnes H2 Supply Needed for Energy Systems at Targets
3.00 GW	Green Hydrogen Ancillary Services	600
2.50 GW	Industrial Projects through IPCEIs on Hydrogen (Important Projects of Common European Interest)	500
2.00 GW	RED II Pipeline	400
1.30 GW	Further Indirect Action for Increased Electrolyzer Capacity	260
1.00 GW	New Subsidy Directive for Offshore Wind Electrolysis	200
0.02 GW	Energy Transition Research	4
10 GW	**Total production of Hydrogen Energy**	**2,105**

Table 1. Deployment of Green Hydrogen Potential by GW of Capacity. The projections by the National Hydrogen Strategy are compared to the amount of hydrogen, in metric kilotons, needed to meet the goal.

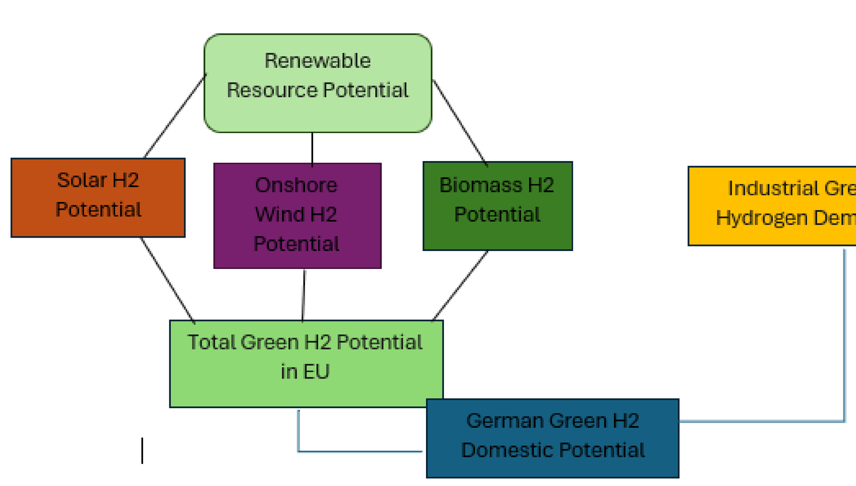


Figure 3. The schematic illustrates transformation of intake datasets, sourced from ENSRESO (Ruiz 2019) and Neuwirth et. al (2022). The goal of the project is to match up future demand and supply within the reference point of the Installation Targets for Capacity of Clean Hydrogen in Germany in 2030.

Conversion of ENSPRESO to kt H2:

$$H_{2,production} = RE_{capacity,TWh} \cdot \frac{10^9\ kWh}{1\ TWh} \cdot \frac{1\ kg\ H_2}{33.3\ kWh} \cdot \frac{0.80\ output}{1\ input}$$

Total kt H2 calculation:

$$H_{2,total\ production}(ktonnes) = \frac{H_{2\ (solar,kg)} + H_{2\ (wind,kg)} + H_{2\ (biomass,kg)}}{1000^2}$$

Industrial Projected Hydrogen Demand:

$$H_{2,\ industrial\ demand,kt} = Potenial\ for\ H2\ demand_{TWh} \cdot \frac{10^9\ kWh}{1\ TWh} \cdot \frac{1\ kg\ H_2}{33.3\ kWh} \cdot \frac{10^9\ t}{1000\ kg} \cdot \frac{1\ kt}{1000\ t}$$

Data sourced from Neuwirth. et. al (2022) estimates potential for hydrogen demand from industries within the sectors of:

- Basic chemicals
- Steel
- Non-ferrous metals
- Glass
- Pulp and paper
- Mineral processing
- Refineries
- Metal processing

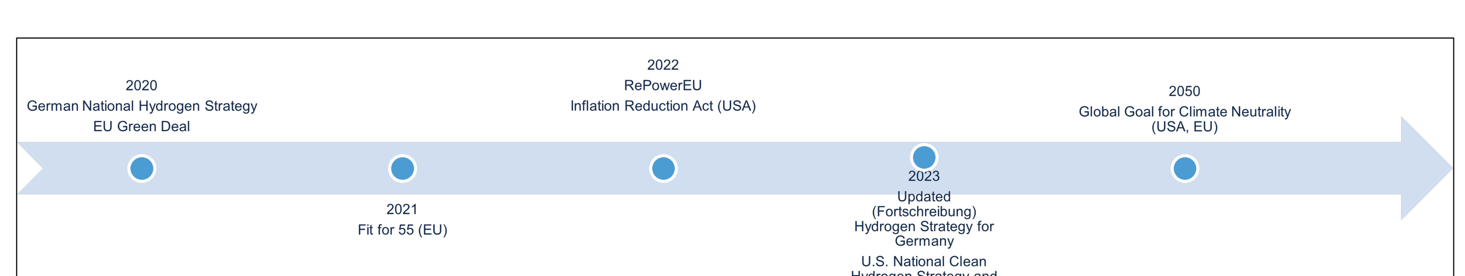


Figure 2. Global trends towards decarbonization have begun to include emphasis on hydrogen energy as a trategy to prevent climate change. This timeline visualizes some of the policy action taken to promote hydrogen energy globally.

Results

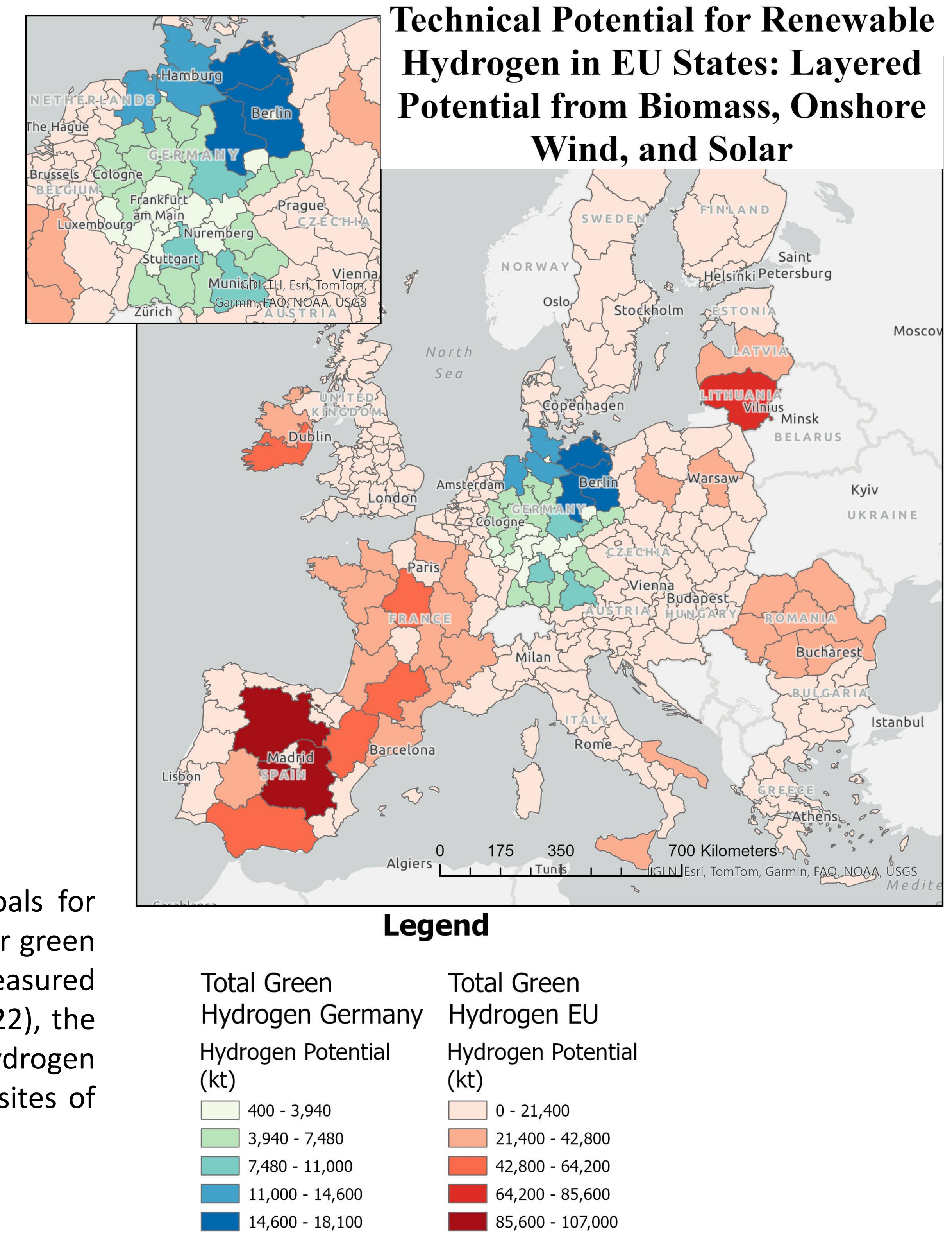
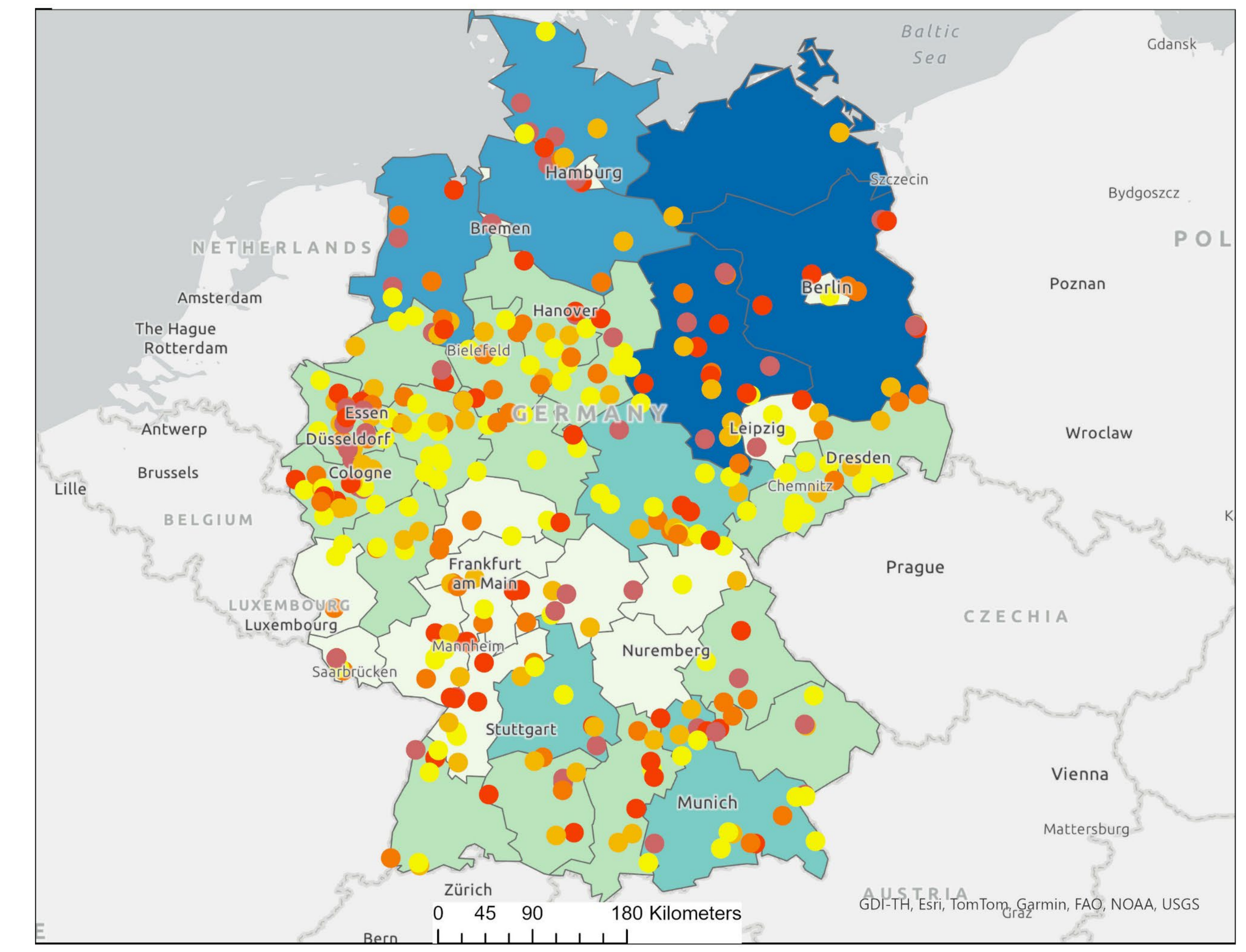


Figure 4. Data for biomass, onshore wind, and solar technical potential to produce hydrogen evaluated regionally. Data is subdivided within Germany, which has an overall lower

Technical Potential for Renewable Hydrogen in Germany Compared to Domestic Industrial Hydrogen Demand in 2030



Legend

Industrial Projected Hydrogen Demand Hydrogen Potential (kt)
- 0 - 1
- 2 - 3
- 4 - 9
- 10 - 22
- 23 - 867

Total Green Hydrogen Germany Hydrogen Potential (kt)
- 400 - 3,940
- 3,940 - 7,480
- 7,480 - 11,000
- 11,000 - 14,600
- 14,600 - 18,100

Figure 5. Total Green Hydrogen Potential in Germany and Industrial Projected Hydrogen Demand (Neuwirth et. al 2022). By examining where darker blue regions (higher onshore green hydrogen potential) match to darker red circles (higher demand on the industry side), it is possible to predict areas more suited to generate hydrogen in vicinity of industrial areas.

Conclusion

- Distributed energy systems and hydrogen hubs are viable for German energy-intensive industry. The amount of hydrogen technical potential to meet supply needs according to Germany's National Hydrogen Strategy is sufficient according to the results of this paper. Given appropriate scale-up of green hydrogen technologies, this industry has a fair chance to succeed in the German economy.
- Germany will most likely import electricity from other EU countries to scale up the transition towards natural gas and hydrogen power, which would affect geopolitical relationships and increase dependence on western European nations, as well as countries such as Canada, Norway, Egypt, Namibia, Kazakhstan.
- Challenges to growth of hydrogen include high cost, need for infrastructure development, and regulatory hurdles.

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