

Agrivoltaics in North Germany

Bremen, Hamburg, Niedersachsen,
Mecklenburg-Vorpommern, and Schleswig-Holstein

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Questions Explored

- What were the datasets used and methods incorporated for energy analysis?
- What kind of energy sources provide power in North Germany?
- Do we observe power loss in PV plants?
- What does the Geospatial analysis tell us about North Germany?
- Does the tax rate influence PV installations in North Germany?
- Can Solar Energy compete against Wind Energy in North Germany?
- Does the current political scenario affect PV and Wind Energy projects in North Germany?
- What conclusions have we drawn from our analysis of North Germany?

Datasets and Methods

Datasets and Methods Used

Datasets

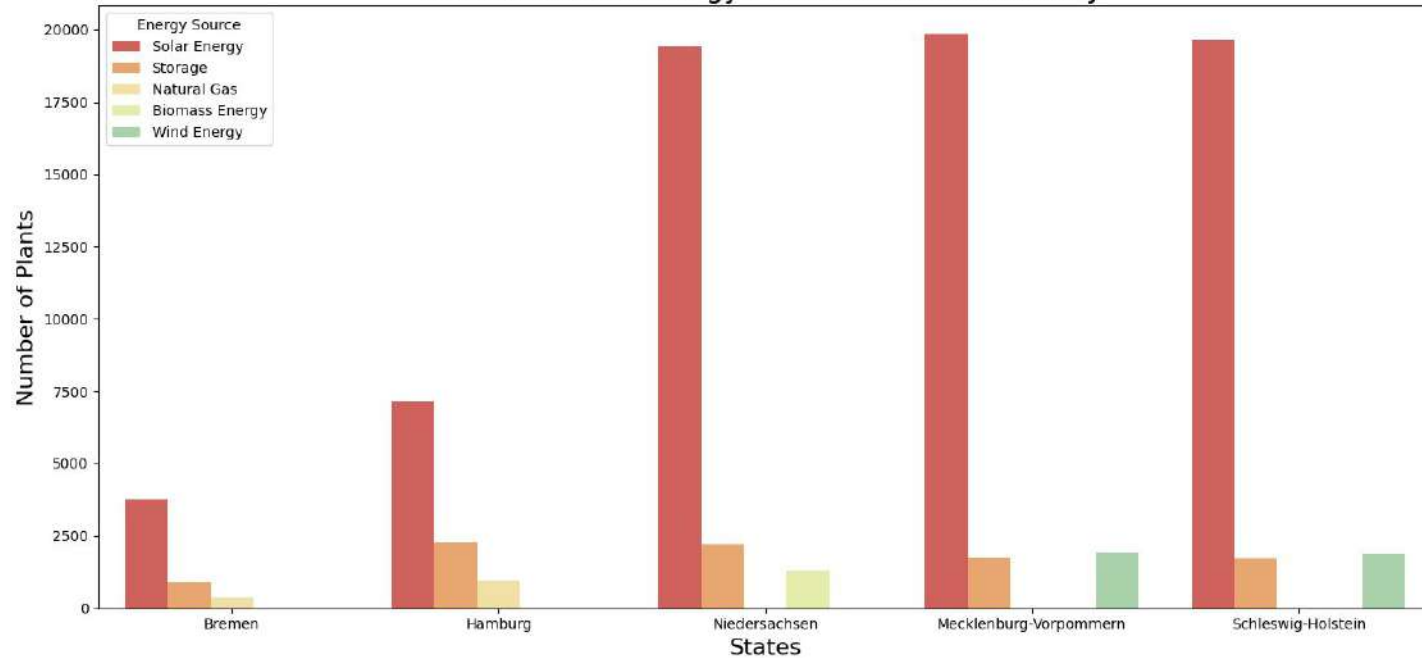
- Marktstammdatenregister
 - filtered based on Wind and PV installations till 16.11.2022
- Tax Rates by Gemeinde
 - <https://www.statistikportal.de/en/node/571>
- Seasonal Sunshine Hours data
 - https://opendata.dwd.de/climate_environment/CDC/observations_global/CLIMAT/monthly/qc/sunshine_duration/

Tools for Analysis

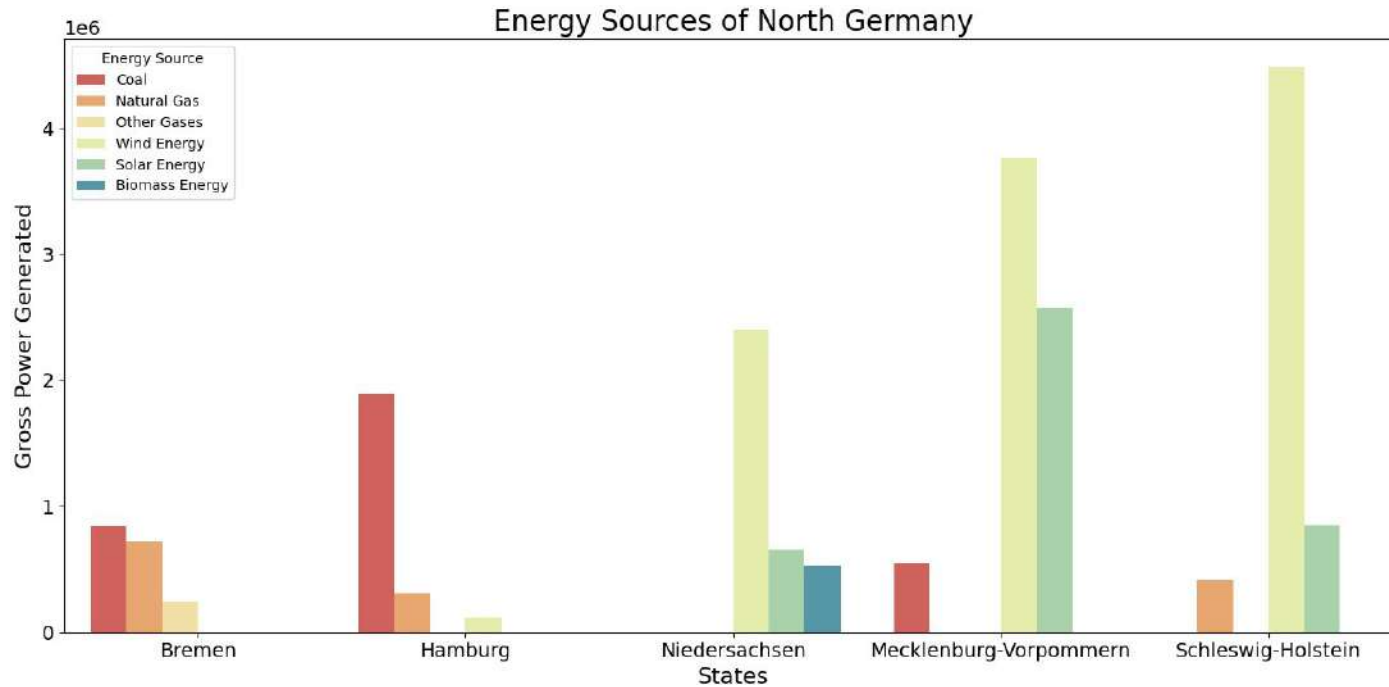
- Geopandas for geospatial representation of energy source installations
- Seaborn to visualize multiple different insights

Energy Sources Analysis

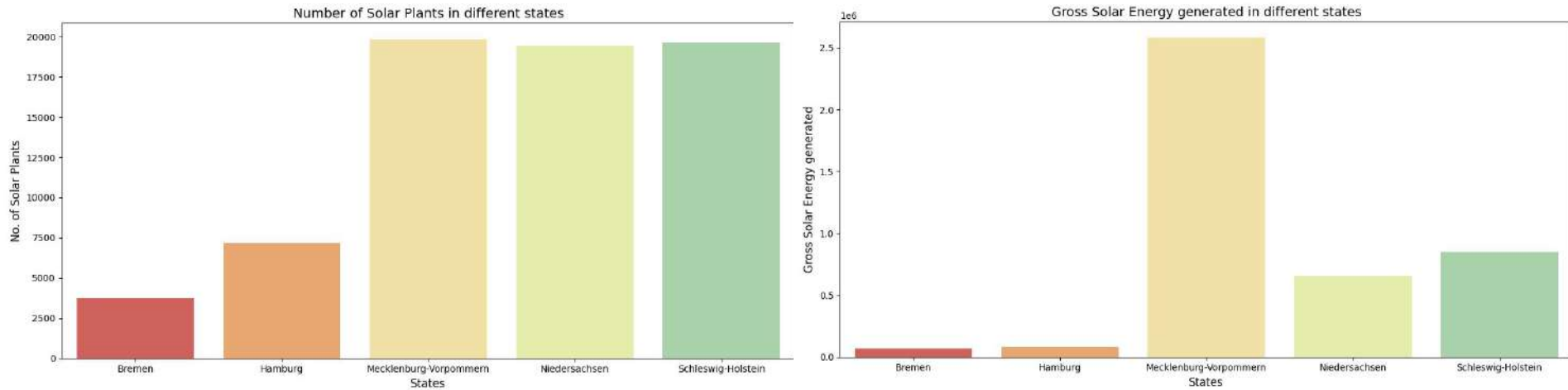
Distribution of Energy Plants in North Germany



- Solar Energy, Storage Energy, Natural Gas, Biomass Energy and Wind Energy are some of the major energy plants in North Germany
- all states have higher number of plant installations for Solar Energy
- research showed us that Solar plants are usually smaller in size (capacity) and more in numbers



- however, Solar Energy is not the most significant contributor of energy for North Germany
- Coal is the major energy source for Bremen and Hamburg
- while Wind Energy plays a major role for energy demands in Mecklenburg-Vorpommern, Niedersachsen, and Schleswig-Holstein



- bigger Northern states have almost 4 times the number of solar panel installations than our smaller states like Bremen and Hamburg
- Mecklenburg-Vorpommern, Niedersachsen, and Schleswig-Holstein have almost similar number of solar plant installations
- however, Mecklenburg-Vorpommern has significantly higher gross Solar Energy generation than the other two states

Power Loss in PV

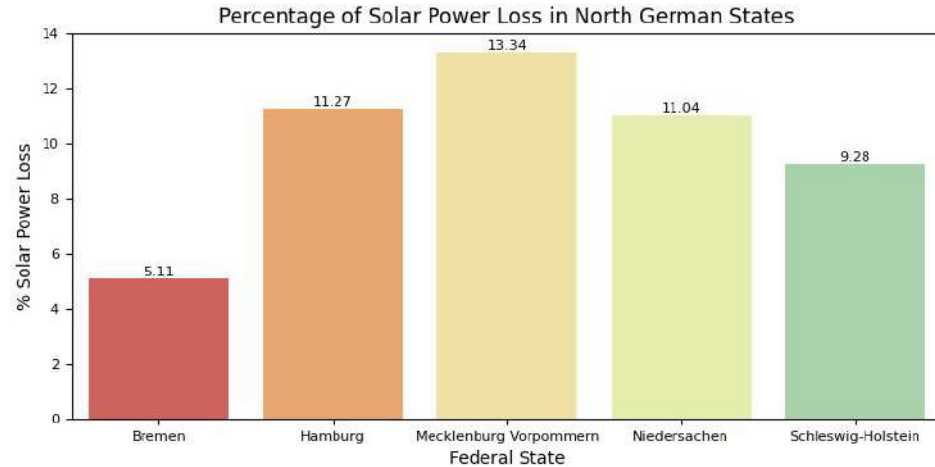
Solar Power Loss in North Germany

- $\% \text{ power loss} = (G - N) / (G) * 100$

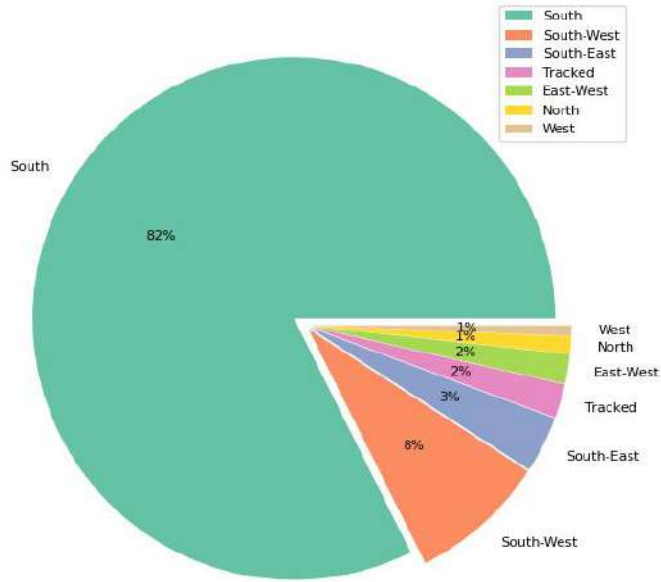
where G - sum of gross solar power

N - sum of net solar power

- Bremen has the lowest percent of solar power loss in North Germany
- while Mecklenburg-Vorpommern has the highest solar power loss

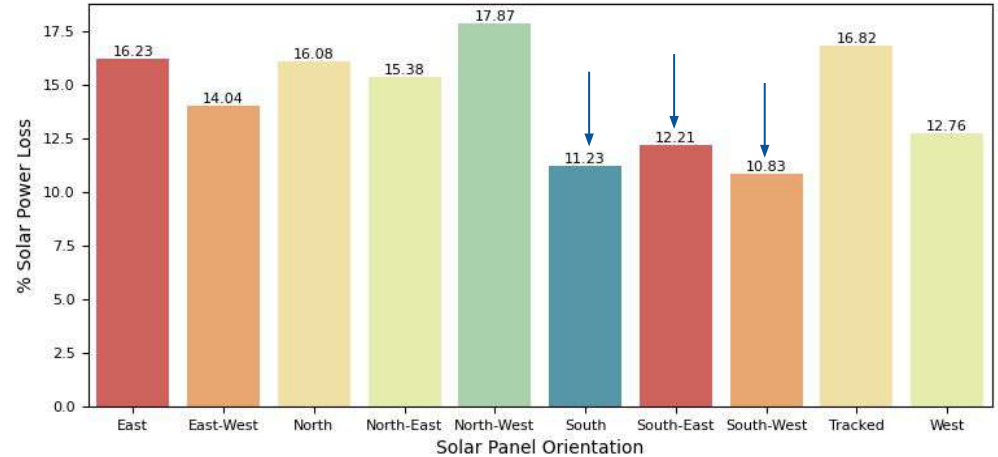


Solar Panel Orientation



82% of the installed solar modules in north germany are south facing

Solar Power Loss due to Solar Panel Orientation

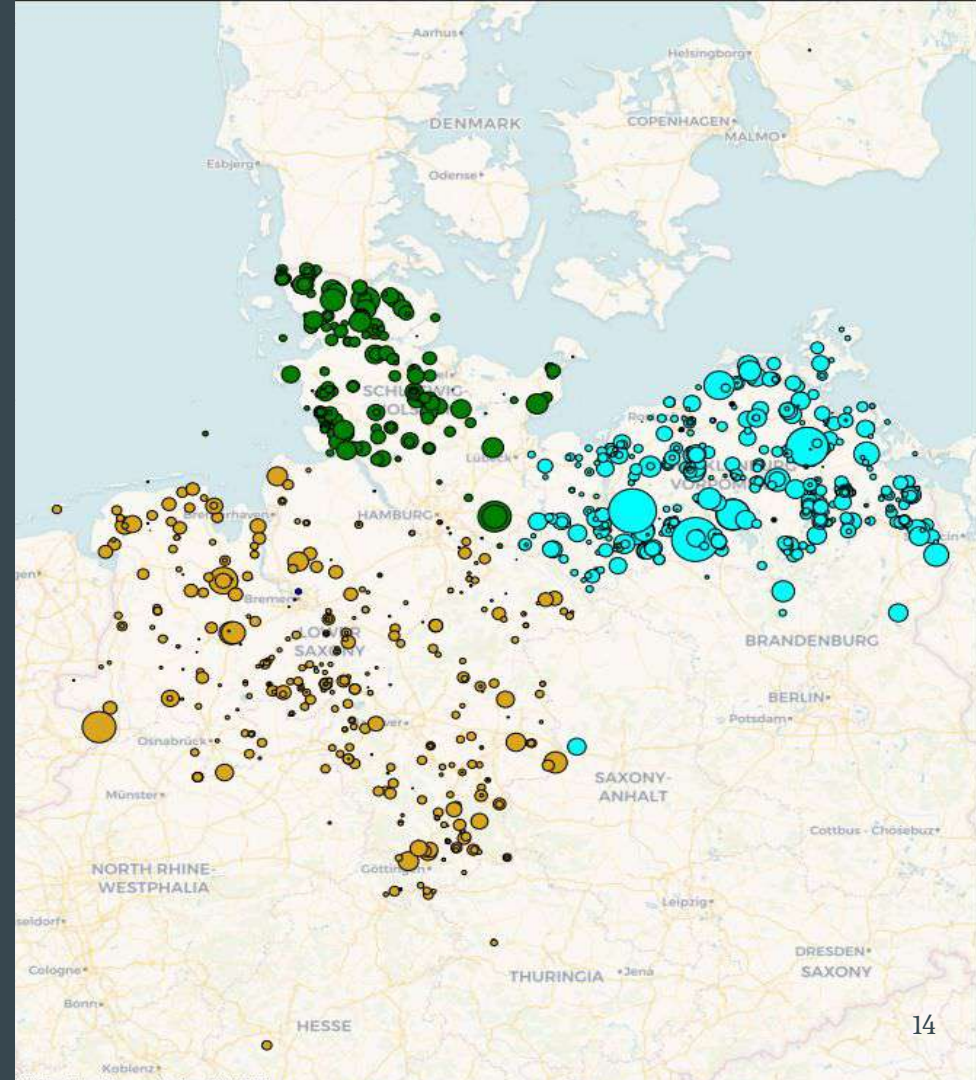


South facing panel orientations result in minimum loss of solar energy

Geospatial Analysis

Freeland Solar Installations

- in Mecklenburg-Vorpommern we see bigger PV plant installations by gross generated power
- in line with the fact that it receives the most sunshine of all northern states
- relatively smaller plants in Lower Saxony
- a higher concentration along the coastal regions of Schleswig holstein (is seen to have a higher solar GHI than rest of the state)

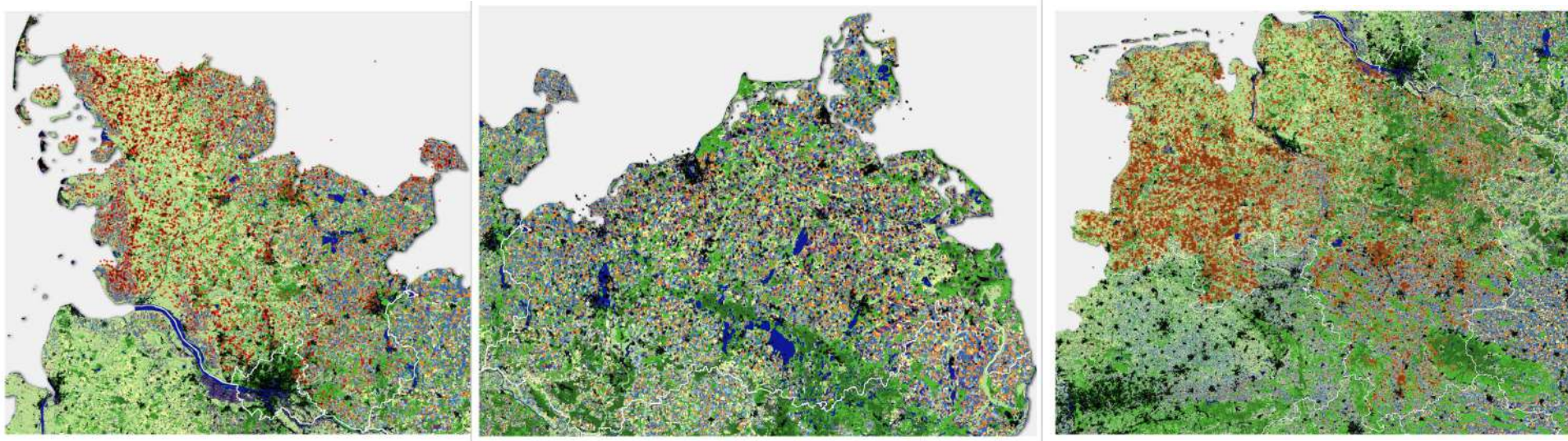


Night View of Northern States

- lit up areas in the map indicate densely populated cities and built up areas
- plant installations are concentrated away from cities and residential regions
- there is more free land to be utilized

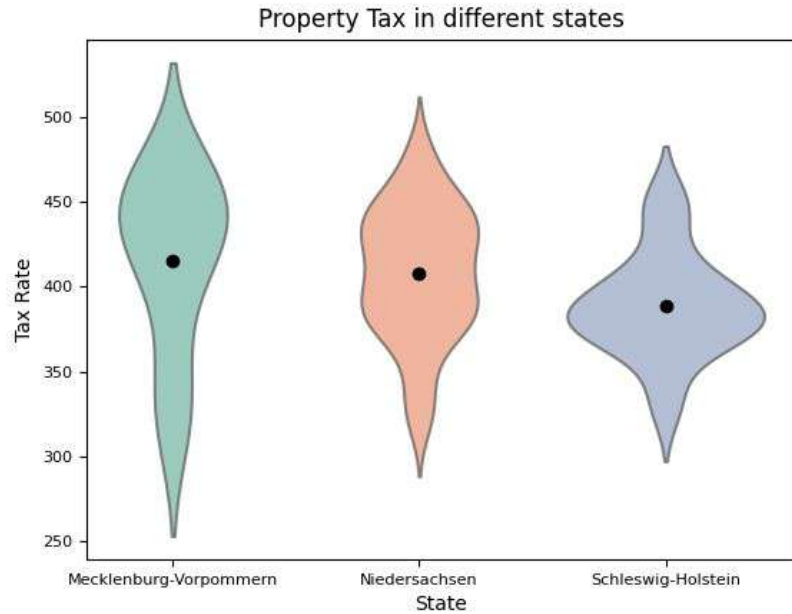


PV vs Agricultural Landscape



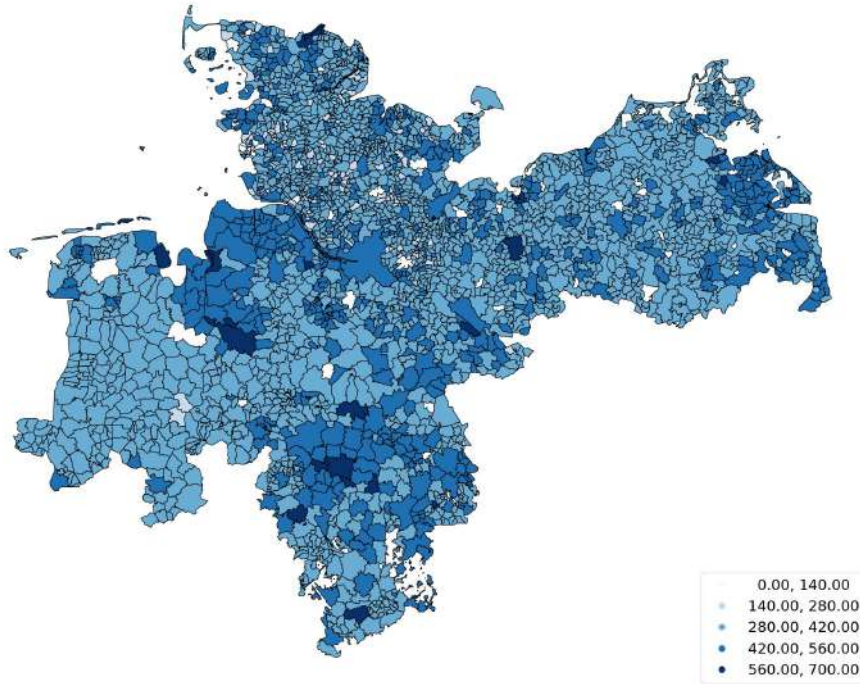
- most of the grassland areas in Niedersachsen and Schleswig-Holstein don't have any PV installations
- Mecklenburg-Vorpommern has more built-up areas, so the concentration of freeland PV installation is low

Tax Rate Influence on PV



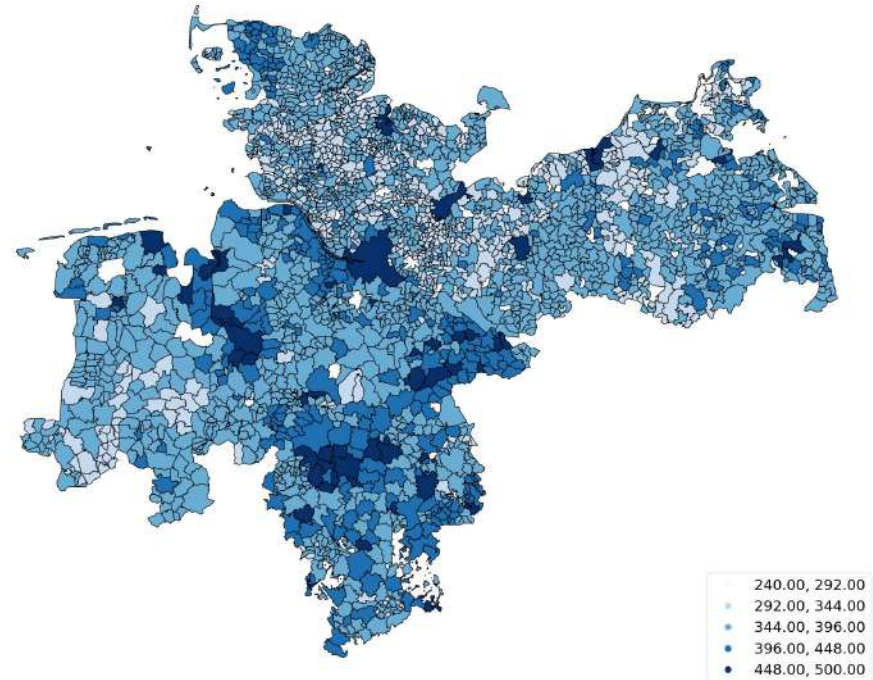
- mean property tax (Trade Tax) doesn't vary much by different states
- however, a higher variation is seen in Mecklenburg-Vorpommern
- some areas are incentivized with lower trade tax rates

North Germany Grundsteuer B distribution



Grundsteuer B

North Germany Gewerbesteuer distribution

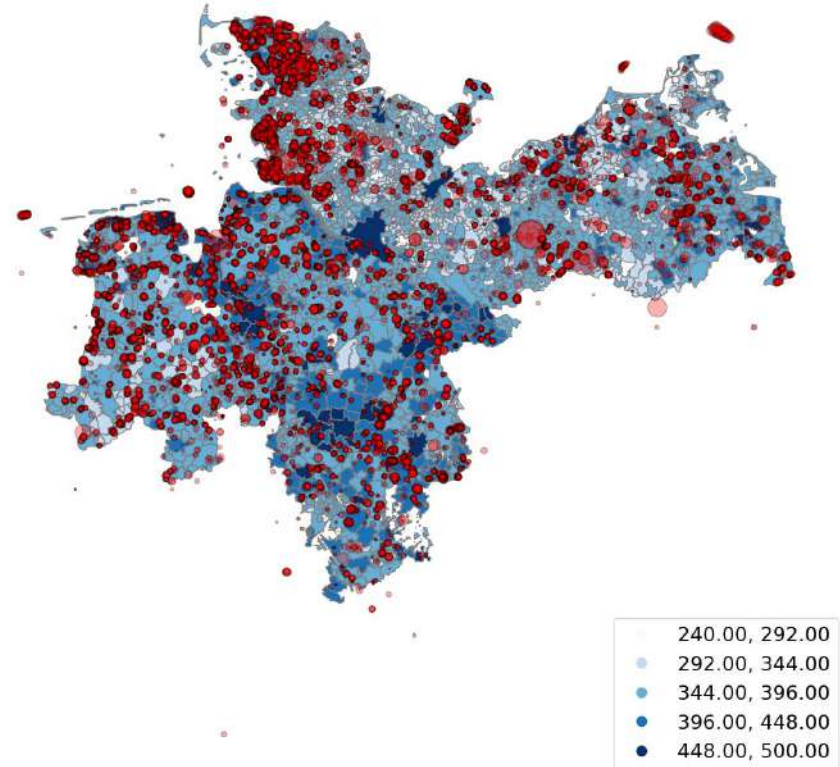


Gewerbesteuer

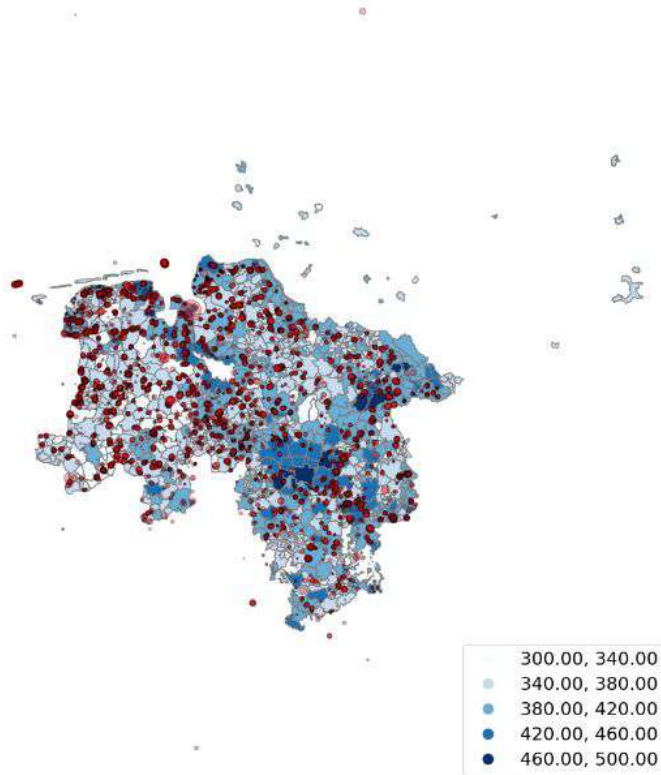
Distribution of Grundsteuer B and Gewerbesteuer for Gemeinde's in North Germany

Distribution of Freifläche Installations across North Germany

Distribution of Freifläche Solar and Wind installations by Gewerbesteuer in North Germany

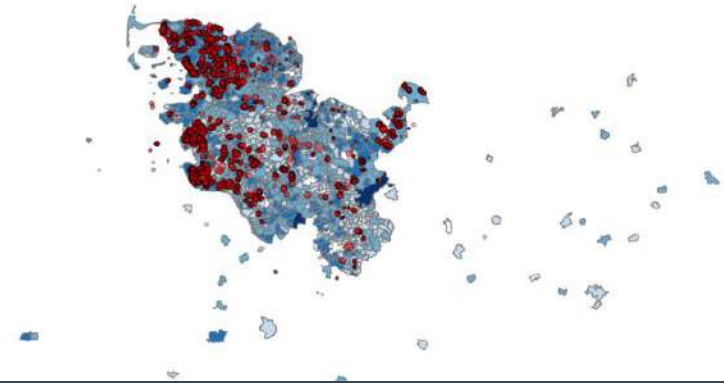


Distribution of Freifläche installations by Gewerbesteuer in Niedersachsen



Freifläche installations in Niedersachsen by Gewerbesteuer

Distribution of Freifläche installations by Gewerbesteuer in Schleswig-Holstein

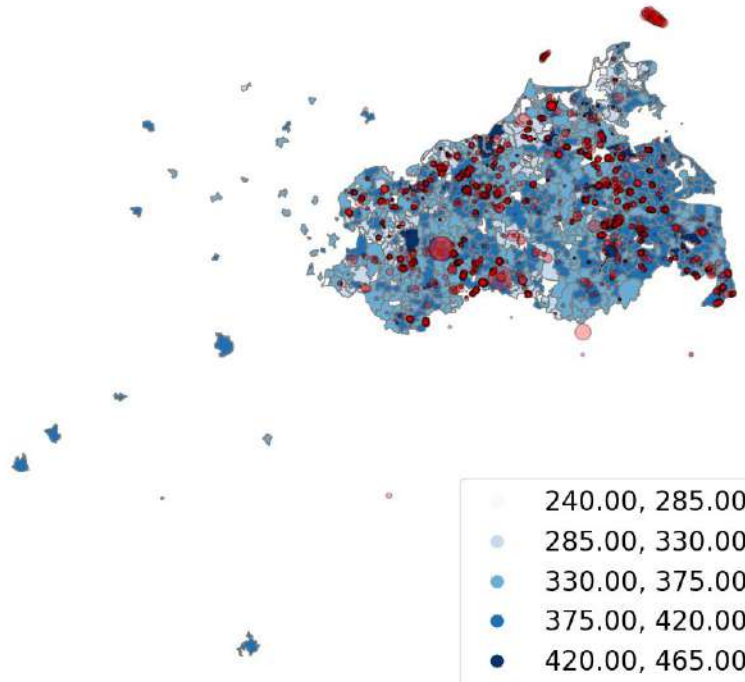


Freifläche installations in Schleswig-Holstein by Gewerbesteuer

- almost similar trend of installations in Niedersachsen and Schleswig-Holstein
- extremely strong concentration of installations along the coastal regions (majority wind)
- moderately strong distribution of installation throughout the states in lower taxed regions
- lack of concentrated installations in higher taxed municipalities

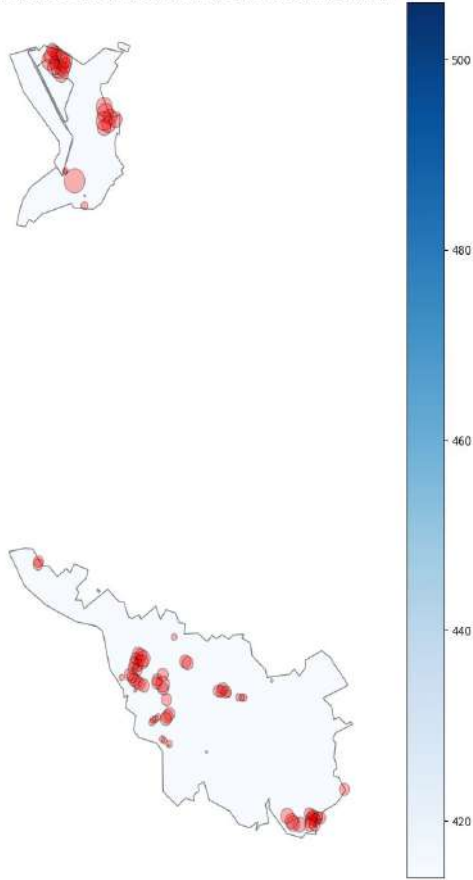
Distribution of Freifläche installations by Gewerbesteuer in Mecklenburg-Vorpommern

Freifläche installations in Mecklenburg-Vorpommern by Gewerbesteuer



- follows general trend of avoiding higher taxed municipalities
- observed lack of installations in lower taxed regions
- majority installations are wind (approx. 75% of all installations)

Distribution of Freifläche installations by Gewerbesteuer in Bremen



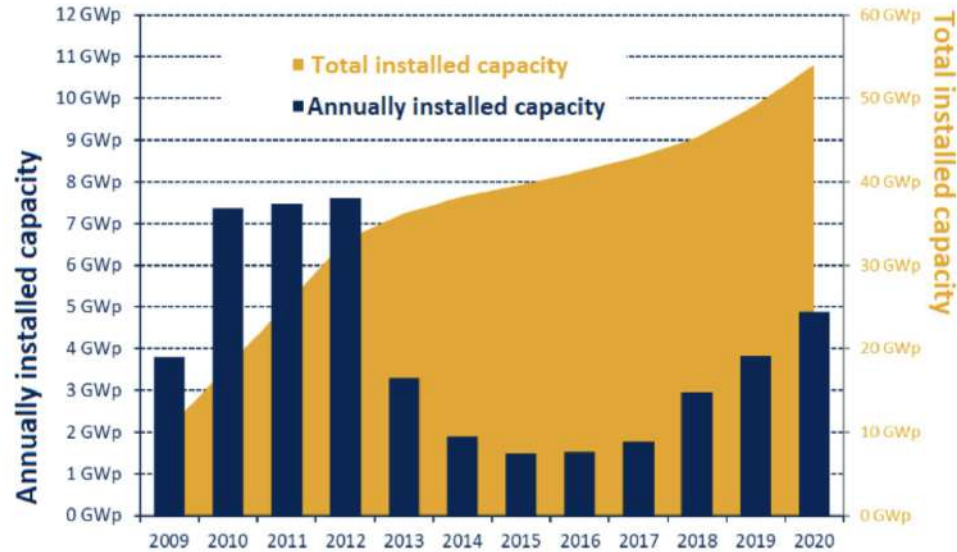
Distribution of Freifläche installations by Gewerbesteuer in Hamburg



Freifläche installations in Bremen and Hamburg by Gewerbesteuer

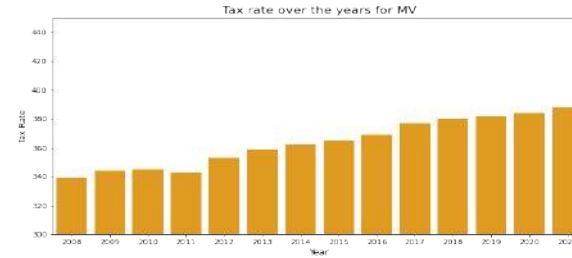
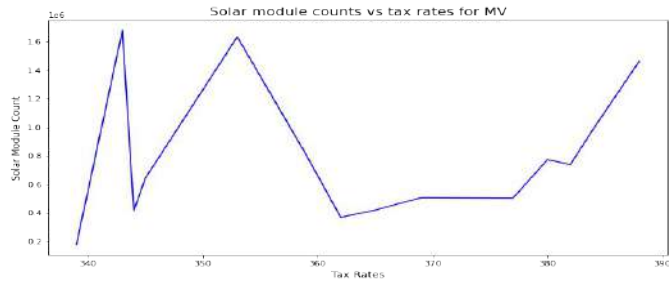
- city states of Bremen and Hamburg show very little variation in tax rates
- above 95% of all installations in both states are wind

Growth of installed solar-PV capacity in Germany

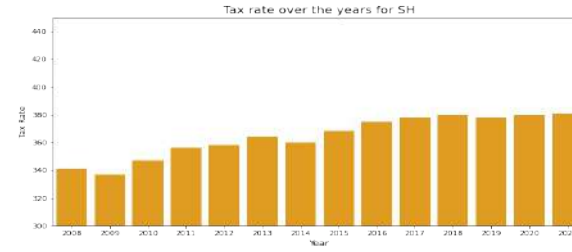
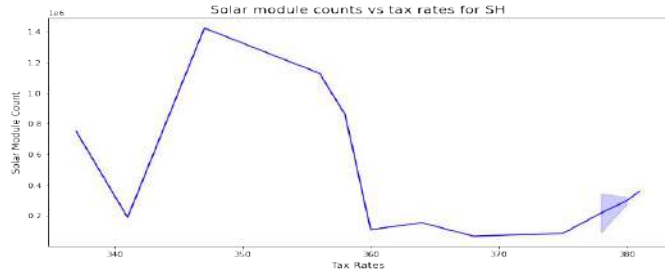


Source: BSW Solar, BNetzA, as of Feb'21

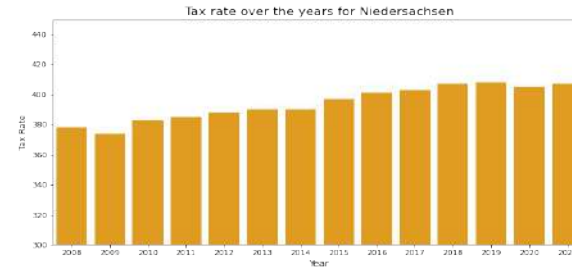
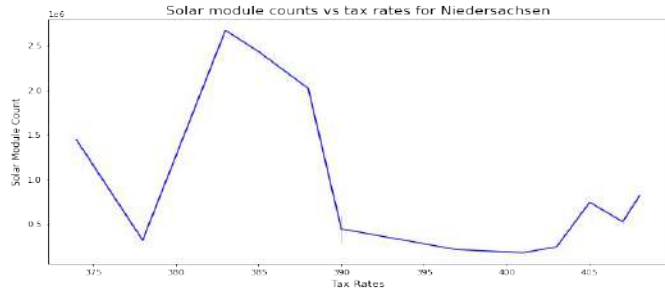
- EU had put in place trade limitations with China against cheap solar panels
- solar expansion fell by 80 percent between 2013 and 2015, because of low adopters as a result of high prices
- EU Commission abandoned trade limitations on Chinese solar panels in 2018 - marking the increase in installation of solar panels
- cost of a solar unit is a better indicator for installation numbers than tax rate



Mecklenburg-Vorpommern



Schleswig-Holstein



Niedersachsen

Solar Module growth vs. Trade Tax Rates in the North German states (excluding Bremen and Hamburg)

OBSERVATIONS & FUTURE PROSPECTS

1. **Cost of unit vs. trade taxes**

- a. our observations lead to the conclusion that the cost of unit is a leading driver to growth in volume of PV systems
- b. trade taxes are however a good marker to where PV installations are made

2. **EEG Impact on taxation :**

- a. starting Jan 01, 2023, tax relief on both income and sales tax is to be applied to smaller PV units
- b. this applies to systems of upto 30 kWh (single family or non-residential buildings) and 15 kWh (apartment or mixed-use buildings)
- c. sales tax relief for small businesses upto sales of € 22,000
- d. Section 1a EEG 2023: A target date for the end of the promotion of renewable energy sources is now enshrined in the act. After coal phase out, development of renewable energy sources will be market/demand driven

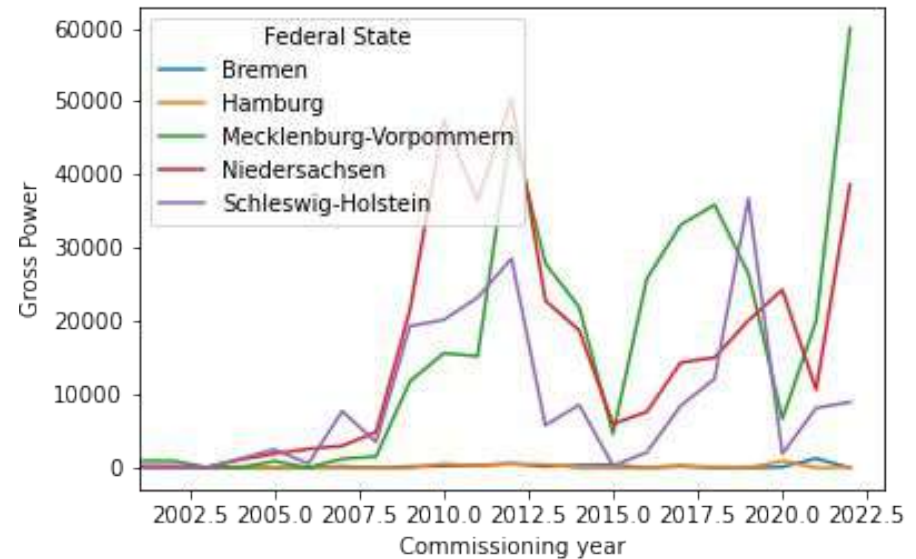
3. **Possible impacts of Grundsteuer C:**

- a. seen as a penalty tax, Grundsteuer C is designed to make speculation on unused land more expensive
- b. as per the Bundesfinanzministerium, introduction of GrStB C is a financial incentive to create housing on building ready land
- c. from regulations, new buildings will need rooftop Solar installations starting Jan 01, 2024
- d. this provides an opportunity for increasing rooftop PV installations

PV vs Wind Power Analysis

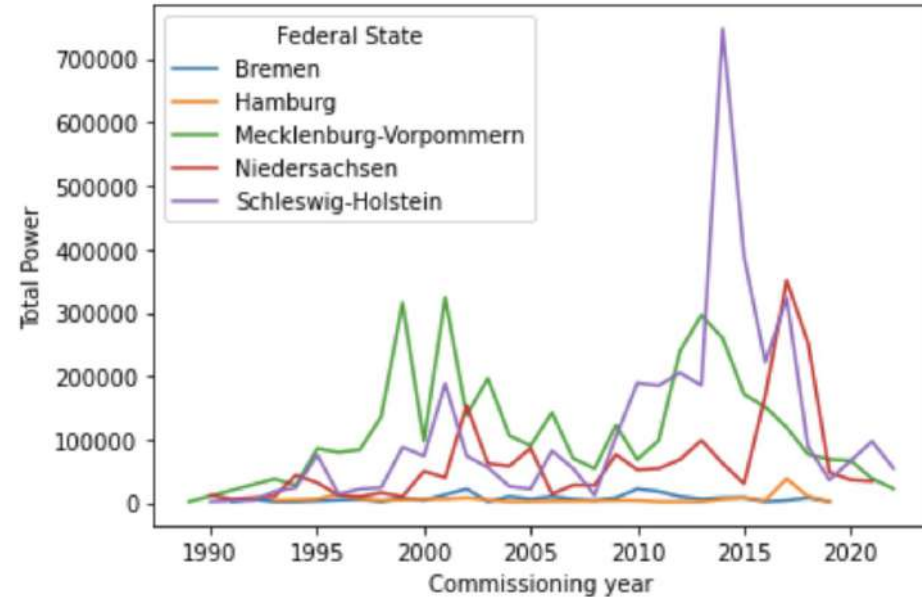
Solar Plant gross power output over the years

- Trade limitations with china caused a dip in commissioned solar modules in from 2014



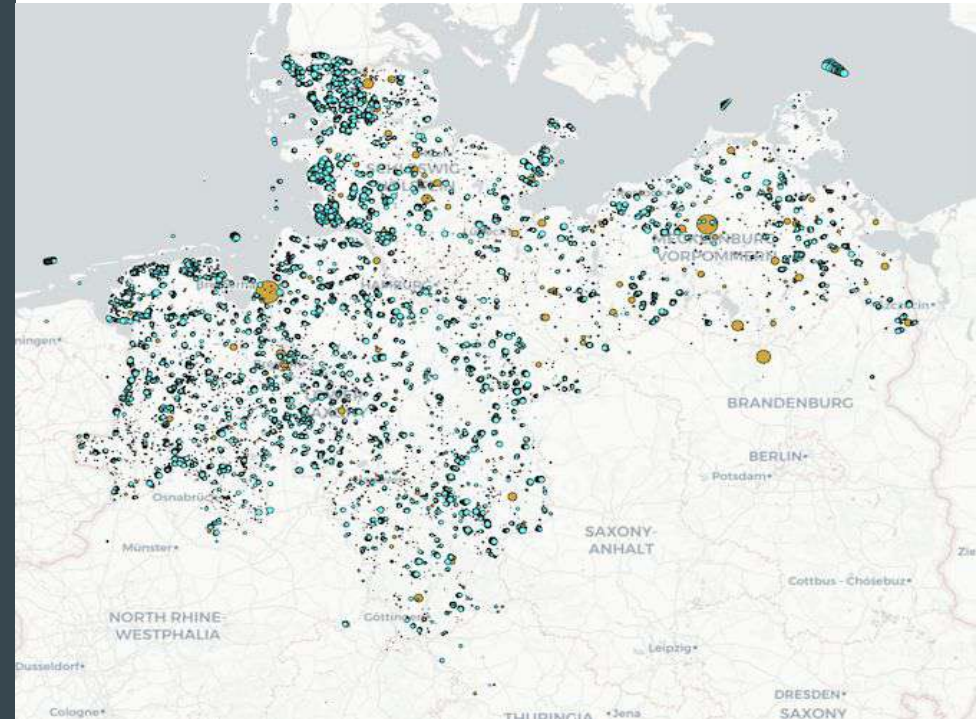
Wind Plant gross power output over the years

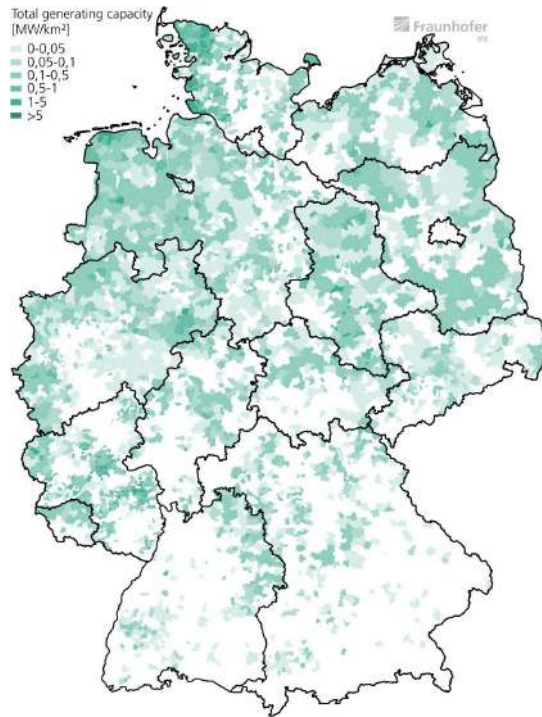
- 2014 saw the record installation of more than **1,700 wind turbines** in Germany
- 8 Nuclear plants were closed in 2011 as a consequence of nuclear risks, needed renewables to compensate
- Solar took a hit in 2014 (trade limitations), lead to more push towards Wind energy



Wind Plants vs Solar Plants installments in North Germany

- Schleswig-Holstein's coastal area has a really high concentration of wind farms
- the proportion of solar farms to that of wind mills is very low in Northern states





Durchschnittliche Sonnenstunden pro Jahr nach Landkreis

Sonnenstunden pro Jahr

1483,47 1822,02

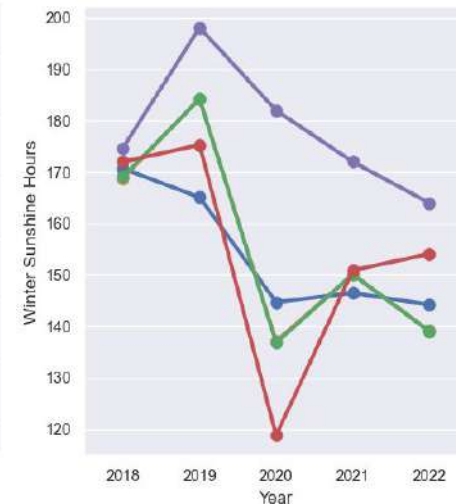
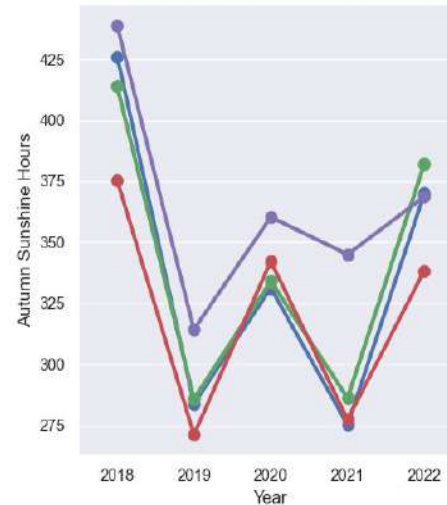
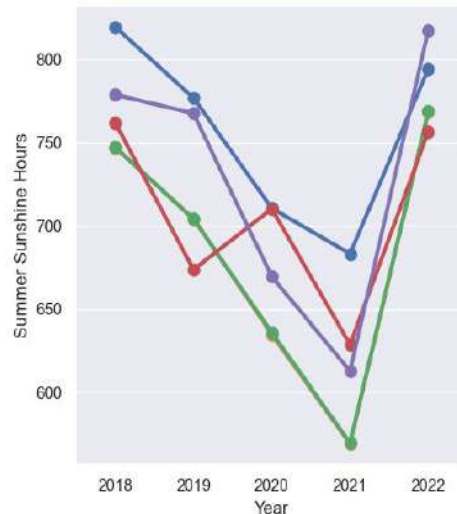
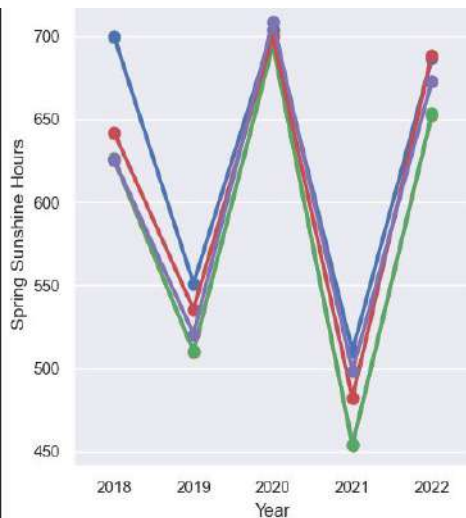
Grafik: /u/waterg • Quelle: DWD • Erstellt mit Datenwrapper

Great wind
potential in
North Germany

Low solar
potential in
North Germany

Federal States

- Mecklenburg-Vorpommern
- Niedersachsen
- Hamburg/Bremen
- Schleswig-Holstein
- Deutschland



Average sunshine received (in hours) per season for the last 5 years in North Germany compared to the national average

Hybrid Power Plants - A New Era!

- Hybrid power plants are a solution to the volatility of renewables
- reduced costs, land requirements and risks because of shared infrastructure for solar and wind farms
- a 15.9-MW wind farm in Einöllen has been retrofitted and had its capacity boosted by 3 MW for photovoltaics
- lots of wind farms in North Germany are in grassland areas - possibility of installing PV alongside?



Image: DEW21

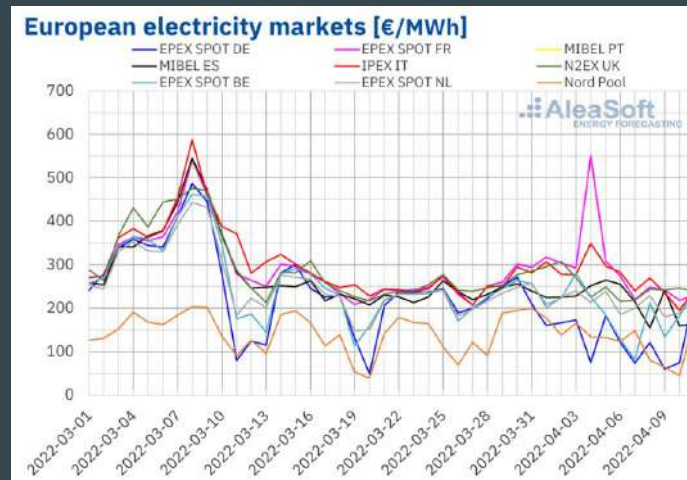
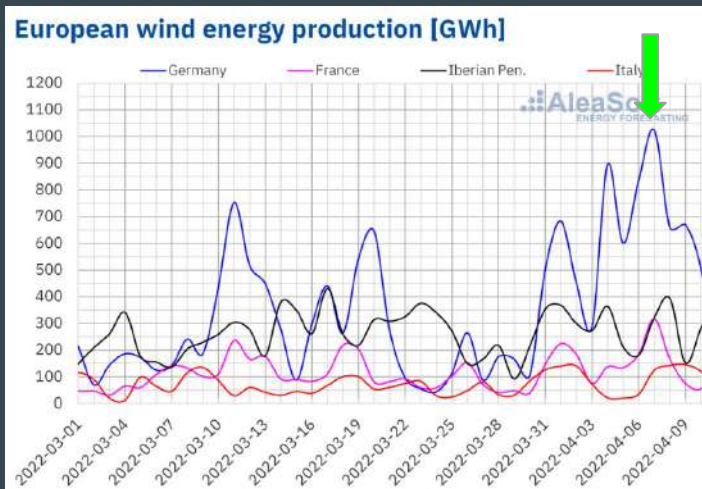
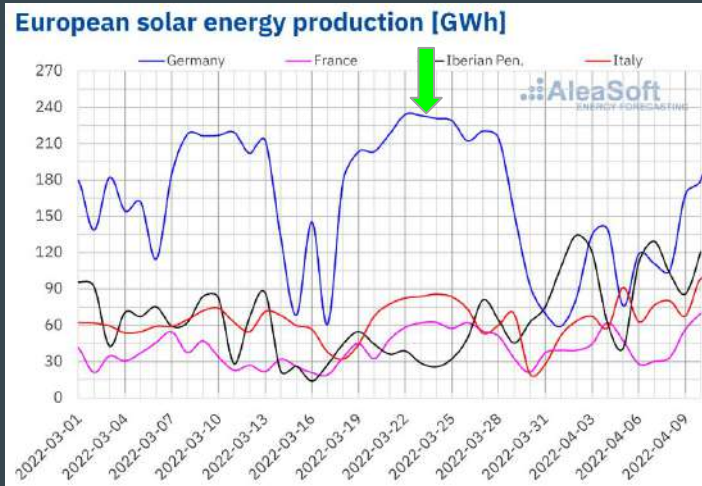
Effect of Agrivoltaics on crop yield

- soil in North German plains is mostly poor in quality
- research shows that Agrivoltaics can increase crop yield on such lands
- extreme weather conditions reduce agricultural productivity in some lands - giving scope for using such lands for agrivoltaics
- land with higher agricultural productivity should be reserved for agricultural production



Political Factors

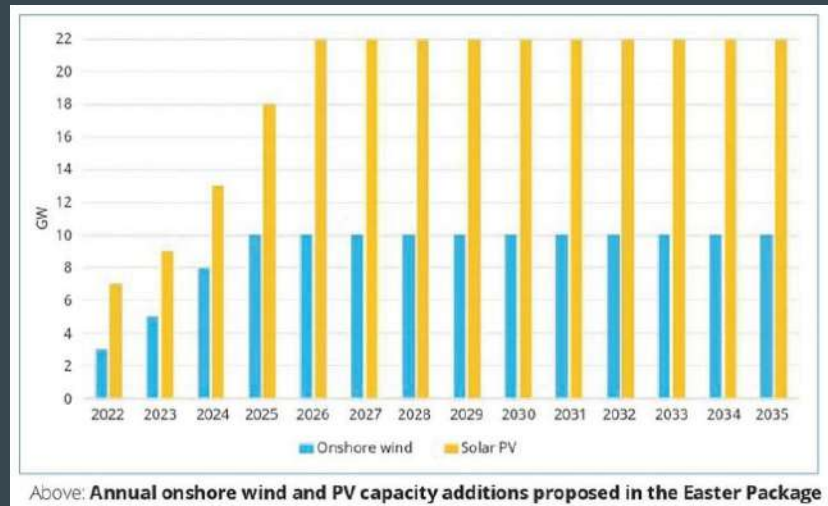
Recent energy trends



In the first week of April, German market witnessed the largest price drop at nearly 51 points

Key points from the “Easter Package”

- German government wants to significantly accelerate the energy transition
- improved funding for solar roofs
- additional areas for offshore wind farms
- faster approval procedures for new and higher onshore wind turbines
- accelerated construction of new power lines
- increased financial participation of municipalities in wind farms



Energy Dependence of South Germany on North Germany

- Bavaria - one of the largest producer of renewable energy, has fallen behind on deployment of wind turbines
- with the loss of coal, and the new situation on the gas market, future is uncertain
- due to major focus on solar plant installations, it depends on North Germany for its energy demands



Made for minds.



Germany's north-south divide flares up over energy

Analysts suggest both politicians have a point.

"It is correct that Bavaria, which is by far the largest of the German states, has fallen well behind on deployment of wind turbines," said Mathias Koch, policy advisor on the German energy transition at E3G, an independent climate change think tank in Berlin. "That being said, taking all sources of renewable energy together, Bavaria is by some metric even leading among German states, thanks to its high capacity of photovoltaics, biomass, and solar heat."

Is Solar the best renewable alternative for North Germany?

- despite being leading in total renewable energy, **Bavaria to struggle in winter** due to lack of diversification
- issues with solar (doesn't work at night, low sunshine hours in winters)
- **one wind turbine** generates the same amount of electricity per kWh as about **48704 solar panels**
- takes **23,822,339 kWh less energy to produce** and maintain one wind turbine than the equivalent number of solar modules (high EROI)
- North Germany's access to Baltic sea and North sea paves way for offshore opportunities
- PV's are a great **opportunity to have an extra earning potential** for agriculture and citizens alike
- however, wind is a more reliable source to realistically ensure the energy security of a state

Mecklenburg-Vorpommern: An Interesting Case

- Mecklenburg-Vorpommern receives the **most amount of sunshine** per year among the Northern states
- however, like other Northern states it **focuses on wind farms!**
- the coalition of SPD-CDU gives more priority to wind energy as per their election program
- instead of Agrivoltaics, they prefer to install more PV panels over built-up areas, as their program states “*without taking valuable agricultural land away from food production and animal husbandry*”

SUMMARY

Energy Source and Geospatial analysis

- number of solar plant installations are higher than any other energy source in all states
- Coal energy is the most significant contributor for Bremen and Hamburg
- Wind Energy is the leading source of energy for Niedersachsen, Mecklenburg-Vorpommern, and Schleswig-Holstein
- Bremen and Hamburg have lesser number of solar plants due to more built up areas
- Mecklenburg-Vorpommern has some of the biggest solar plants amongst the northern states
- Schleswig-Holstein and Niedersachsen have a lot of unutilized grassland areas for PV

SUMMARY

Tax Analysis

- general observation is more installations in areas/municipalities with lower Grundsteuer B except for the city states of Bremen and Hamburg
- irrespective of tax rate, high build up of wind installations are observed in Niedersachsen and Schleswig-Holstein for:
 - coastal areas
 - highly populated urban regions
- amongst the larger states, Mecklenburg-Vorpommern shows an exception since much of the low taxed areas are unutilized
- with many municipalities to enforce the higher Grundsteuer C in 2025 (to alleviate the housing crisis), putting more focus on rooftop PV installations rather than agrivoltaics

SUMMARY

Political Factors

- recent energy trends have shown that the push on renewables in Germany provides a much needed relief in the uncertain and politically influenced energy market
- political agenda leans more towards Wind Energy in Mecklenburg-Vorpommern despite the state's high potential for solar energy production
- future planned installation of PV in North Germany are on built-up areas to avoid conflicts with farmers
- the EEG subsidy for installation of PV on disadvantaged areas have not been adopted by North states
- EEG 2021 influences:
 - reduce the imbalance in generating capacity tilted towards the North
 - get rid of the so called “grid congestion zones” in north due to high onshore wind generating capacity (only until north-south corridor is completed)
 - 500-850 MW per year will be tendered in so called “innovation auctions” (applicable for agricultural areas)

SUMMARY

Agrivoltaics

- Agrivoltaics has a huge potential - current research is already proof of this
- crop yield seems to be higher in Agrivoltaics when compared to freeland PV installation
- another option is hybrid energy production plants, where wind and solar can both be used thereby reducing cost and increasing land utilization
- North Germany is a peculiar case since it cannot use all the renewable energy it's producing
- record amounts of clean energy in the north (primarily through wind), clearly not all of it is being utilized (power grid overload).
- negative wholesale electricity prices, times when consumers are effectively being paid to use excess power.
- a push for more renewables does not make sense for North Germany until it figures out a way to distribute power to other states

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Thank You