

ENERGY TRANSITION IN GERMANY

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ABSTRACT: *Germany's energy transition, known as the Energiewende, is a comprehensive plan to shift the country's energy system away from fossil fuels and nuclear power towards renewable energy sources. This ambitious undertaking aims to achieve a climate-neutral energy system by 2045.*

KEY WORDS: *energy, renewable energy, climate change, sustainable, power.*

1. INTRODUCTION

Renewable energy expansion: Germany has significantly increased its renewable energy capacity, particularly in solar and wind power. The government has set ambitious targets for renewable energy to reach 80% of electricity generation by 2030. [1]

Phasing out nuclear power: Germany has committed to phasing out nuclear power by 2022, with the last nuclear power plants scheduled to be decommissioned in 2022.

Energy efficiency: The Energiewende emphasizes energy efficiency measures to reduce overall energy consumption. This includes improving building insulation, promoting energy-efficient appliances, and encouraging sustainable transportation options.

Grid modernization: Germany is investing in modernizing its electricity grid to accommodate the increasing share of renewable energy sources[2], which often fluctuate depending on weather conditions.

Challenges and progress: While the Energiewende has made significant progress, it has also faced challenges:

Balancing supply and demand: Integrating large amounts of variable renewable energy

into the grid requires sophisticated balancing mechanisms to ensure a stable supply of electricity.

Storage solutions: Developing cost-effective and efficient energy storage solutions is crucial for managing fluctuations in renewable energy generation.

Public acceptance: Some local communities have expressed concerns about the visual impact of renewable energy installations and potential negative effects on the environment. Despite these challenges, Germany's Energiewende has become a global model for energy transition, demonstrating the potential for a successful shift towards a low-carbon economy[9].

2. FACTS OF CLIMATE CHANGE

The Earth is warming rapidly. The average global temperature has increased by about 1.1 degrees Celsius (2 degrees Fahrenheit) since the late 19th century, and the rate of warming is accelerating[6].

Human activities are the main driver of climate change. The burning of fossil fuels like coal[4], oil, and natural gas releases greenhouse gases into the atmosphere, trapping heat and causing the planet to warm.

The consequences of climate change are far-reaching. These include more frequent and intense heatwaves, droughts, floods, wildfires, sea-level rise, and more severe storms[3].

Climate change is already affecting human health. Heat-related illnesses and deaths, as well as respiratory problems from air pollution, are becoming more common[12].

Climate change is also harming ecosystems and biodiversity. Many species are losing their habitats due to rising temperatures and changing precipitation patterns.

The impacts of climate change are being felt disproportionately by vulnerable communities. These include low-income communities, people of color, and indigenous communities.

Limiting global warming will require significant reductions in greenhouse gas emissions. To keep global warming below 1.5 degrees Celsius, we need to reduce our emissions by at least 50% by 2030 and reach net-zero emissions by 2050[5].

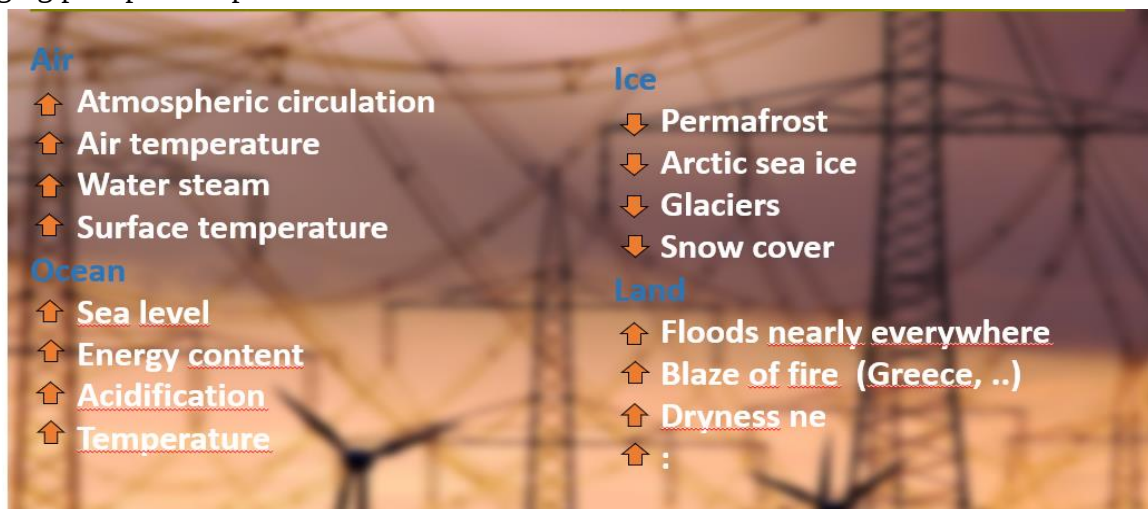


Figure 1. Facts of climate change

3. ROAD TO CLIMATE NEUTRALITY

Fossil carbon is basically replaced [8].
But how do we get there?

A simple but memorable diagram is the following 5-tower model.



Figure 2. Five tower model

These five towers help make the world green.

1. **Energy Efficiency:** This pillar focuses on reducing energy consumption through various strategies like improving building insulation, using energy-efficient appliances, and optimizing industrial processes.
2. **Energy Sufficiency:** This pillar aims to ensure that the energy system can meet the demand for energy without compromising the environment or future generations. It involves strategies like demand-side management and energy storage.
3. **Renewable Energy:** This pillar emphasizes the use of renewable energy sources like solar, wind, hydro, and biomass to generate clean and sustainable energy[7].
4. **Direct Electricity:** This pillar highlights the importance of using electricity directly for various applications, including powering electric vehicles, heating and cooling systems, and industrial processes.
5. **Green Molecules (PtX):** This pillar focuses on producing green hydrogen and other green

molecules through processes like electrolysis, which can be used for transportation, heating, and industrial processes[10].

This five-tower model provides a comprehensive framework for building a sustainable energy system that is efficient, sufficient, clean, and versatile. Conclusion from all this is that a huge amount of electrical power is required and it has to be produced and be transported from the producer to the consumer. The electricity is transported via the electrical grids.

Power to X – what does it mean

We find it as **PtX**, P2X Power to X

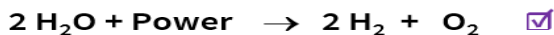
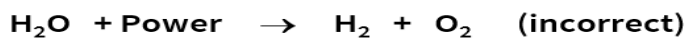
- **Very important** Only green Power is allowed
- **Then we get** Green X

What is X (means Green X!)

- What is X? = $\begin{cases} \text{Gas (Hydrogen, Methan, ...)} \\ \text{Liquid (Kerosene, Diesel, ...)} \\ \text{Plastic (Polymer Materials)} \end{cases}$

Power to X – how does it work?
it follows the principal equations

a) with $X = H_2$ – the simplest procedure

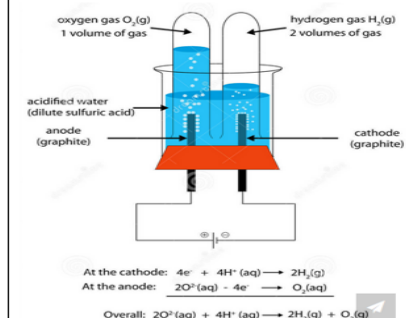


➤ this procedure we call **Electrolysis**

➤ in this case is **X = Gas = Hydrogen**

➤ We assume that the Power is green in all cases

Electrolysis, Electrolyzer



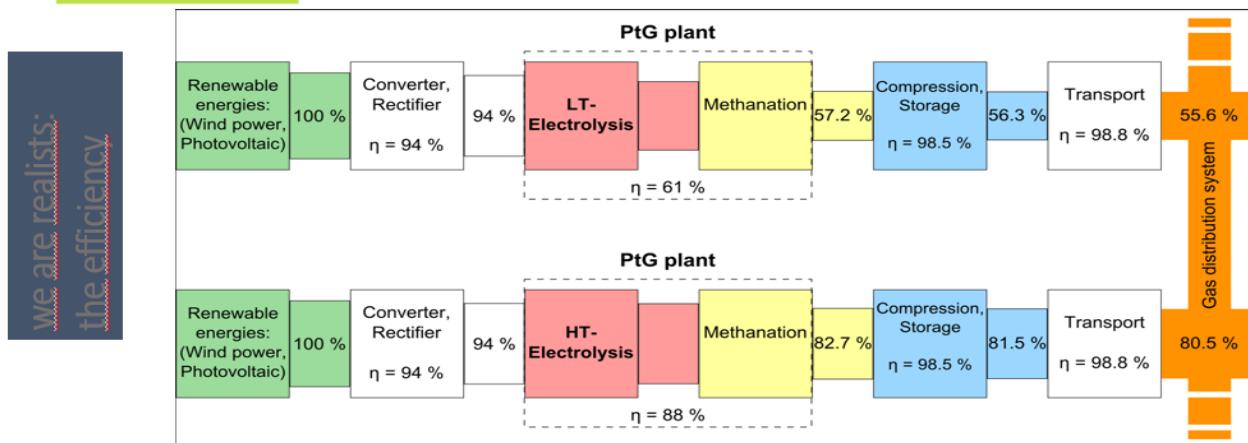
1 of 3 each 2 MW
in Werlte Germany
since year 2013

ME 100/35. Per day:
- 5.4 MWh Energy
= 4 MWh H_2 +
1 MWh Heating
- so $\eta = 0.95$
- $P_{el} = 225 \text{ kW}$



Figure 3. Electrolyzers in Werlte, Germany

Power to X – how does it work?



The extra-high voltage grid of the future is the European interconnected grid [11]. And Romania is part of this grid.

Today and in the future, the extra-high-voltage grid in Germany is in the hands of the four transmission system operators (TSOs): Tennet; 50Hertz; Amprion; TransnetBW.



The TSOs bear the responsibility for the control area = ensure, among other things, that the grid frequency is 50 Hertz. To this end, the TSOs are (already) setting the timetable (feed-in schedule) for the power

plants for (every) tomorrow. This means that for every 1/4th of an hour of the following day, it is predicted what consumption there will be and which feed-ins are necessary for this.

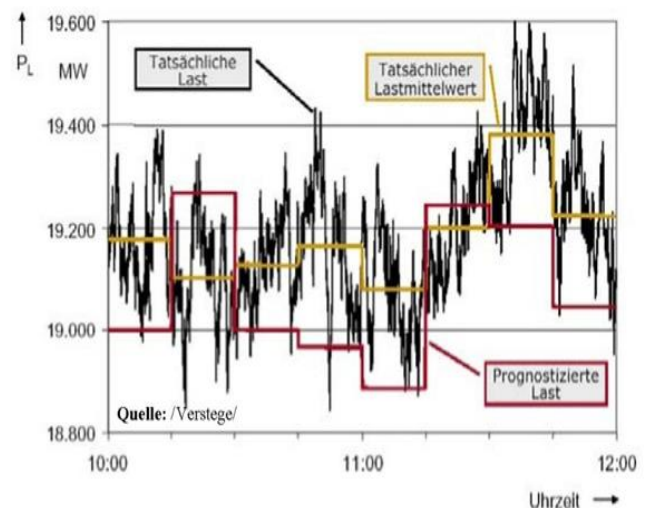


Figure 4. Predicted and actual load curve of one day, of two hours from one day

In figure 5 is presented the fluctuations in the grid frequency of different countries. At the top of each image is 50,2 Hz, at the bottom it is 49,8 Hz. Time slot is 48 h.

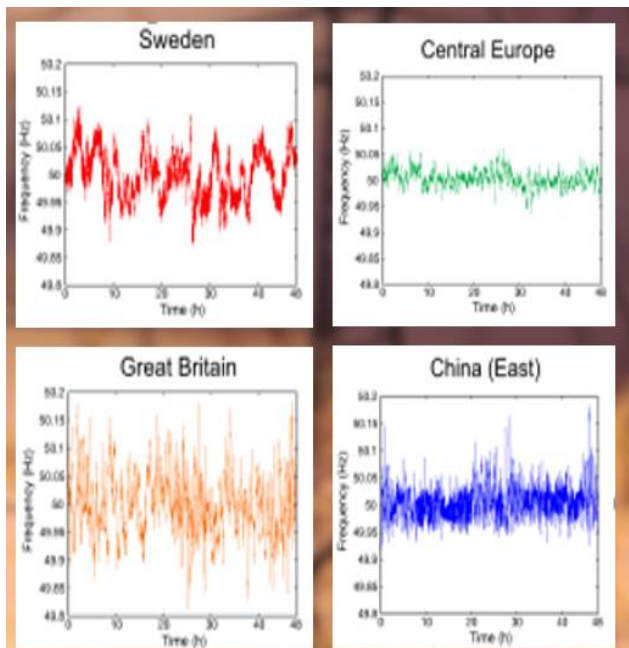


Figure 5. Fluctuations in the grid frequency of different countries

Result:

The TSOs know the German extra-high-voltage grid very well. The TSOs forecast precisely when and where and how much electrical energy is required and control the feed-in. With the requirements of the Federal Government, Parliament, the EU, the TSOs plan is to expand the grid until 2037 to climate neutrality in 2045/2050. That is why TSOs play the most important role in grid expansion[14].

Energy consumption in Germany

Primary energy consumption in Germany is shown in figure 6.

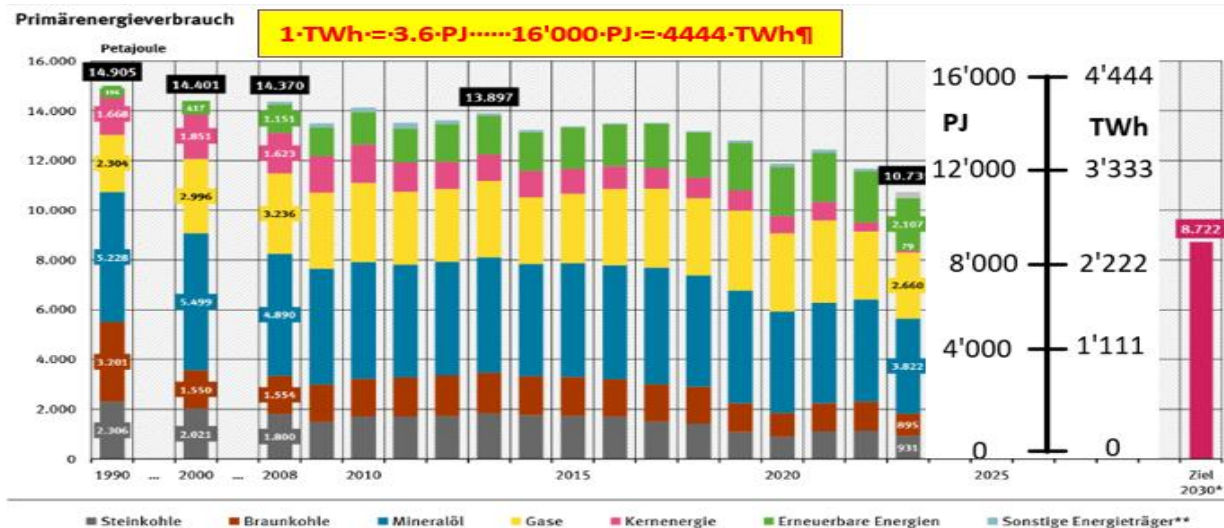


Figure 6. Primary energy consumption in Germany

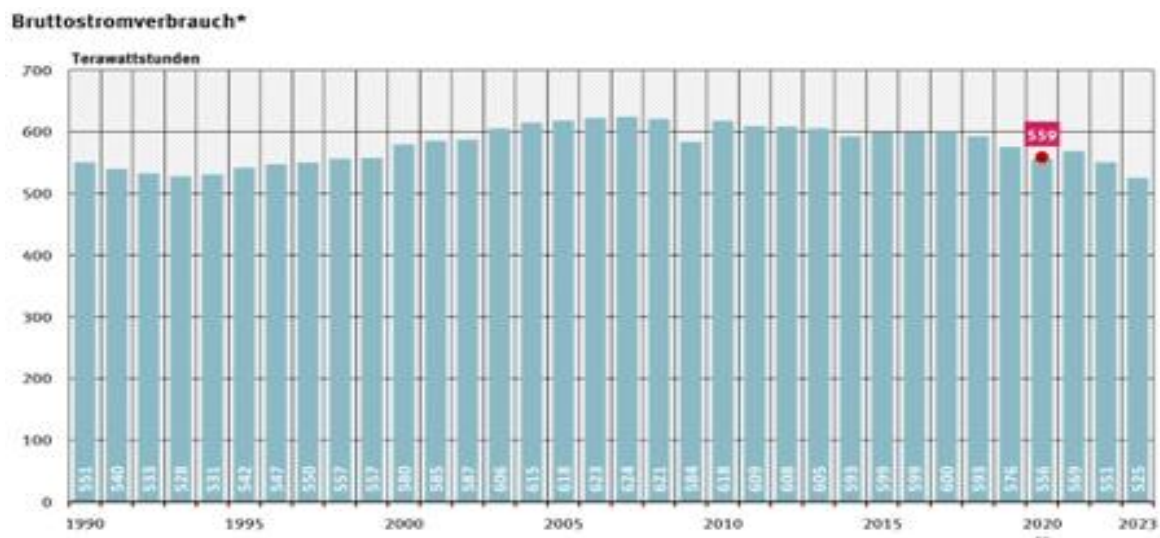


Figure 7. Gross electricity consumption in Germany

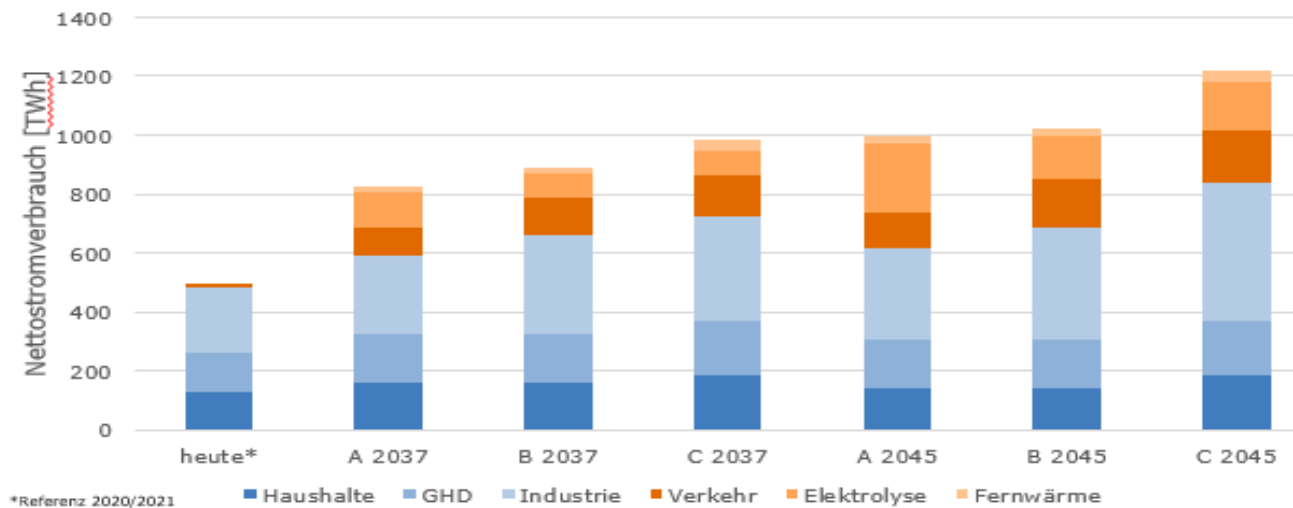


Figure 8. Estimated consumption of electrical energy in TWh

CONCLUSION

Greenhouse gas neutrality have to be achieved by 2045. The Bundesnetzagentur (Federal Network Agency) (BNetzA) has given the TSOs the goal of showing three paths A, B and C for climate neutrality: scenarios.[13] Extrapolation periods are 2037 and 2045. Overall, all scenarios assume a significant increase in electricity consumption. The main drivers are the increasing penetration of e-mobility, an increasing number of heat pumps and power-to-heat systems, a strong ramp-up of electrolysis and the decarbonisation of industry.

The scenario framework applies to forecasts to the years 2037/2045:

- Installed capacities of renewable energies;
- Installed capacities of conventional power plants;
- Efficiency gains & Sector coupling;
- Electric cars, battery storage, P2X;
- Electricity consumption;
- Flexibility options;
- Fuel prices;
- Transmission capacities to neighbouring countries;
- Fixings for regionalization.

The path to energy transition is a complex and multifaceted one, involving a range of technological, economic, and societal changes. Here are some key elements of this path:

a). Renewable Energy Expansion:

- **Massive investment:** Increased investment in renewable energy sources like solar, wind, hydro, and geothermal power.

- **Technological advancements:**

Continued development and deployment of advanced renewable energy technologies to improve efficiency and reduce costs.

- **Grid modernization:** Upgrading the electricity grid to accommodate the integration of variable renewable energy sources.

b). Energy Efficiency:

- **Improved building standards:**

Implementing stricter building codes to reduce energy consumption in buildings.

- **Energy-efficient appliances:**

Encouraging the use of energy-efficient appliances and equipment.

- **Behavioral changes:** Promoting

energy-saving practices among individuals and businesses.

c). Energy Storage:

- **Development of storage technologies:**

Investing in research and development of advanced energy storage solutions like batteries, hydrogen, and pumped hydro storage.

Grid-scale storage: Deploying large-scale energy storage systems to balance supply and demand.

d). Electrification of Transportation:

- **Electric vehicles:** Promoting the adoption of electric vehicles and charging infrastructure.

• **Electrification of heating and cooling:** Shifting towards electric heating and cooling systems, especially with the integration of renewable energy sources.

e). Carbon Capture, Utilization, and Storage (CCUS):

- **Developing CCUS technologies:**

Investing in technologies to capture and store carbon dioxide emissions from industrial processes and power plants.

- **Utilizing captured carbon:** Exploring ways to use captured carbon for various applications, such as enhanced oil recovery or producing carbon-neutral fuels.

f). Policy and Regulatory Framework:

- **Strong policy support:** Implementing supportive policies and regulations to incentivize renewable energy adoption, energy efficiency, and low-carbon technologies.

- **Carbon pricing:** Implementing carbon pricing mechanisms to encourage emissions reductions.

- **International cooperation:** Fostering international collaboration to share best practices and accelerate the energy transition.

g). Public Awareness and Education:

- **Raising awareness:** Educating the public about climate change, the benefits of renewable energy, and the importance of energy conservation.

- **Empowering individuals:** Providing information and tools to enable individuals to make informed choices about energy consumption.

By pursuing these key elements, we can accelerate the energy transition and create a more sustainable and resilient energy future.

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