Paths to a Climate-Neutral Future – the Citizens Decide on its Success

BY DIETER OESTERWIND AND PHILIPP RIEGEBAUER

Abstract

Over the next two decades, the German energy system will be completely transformed. There is no one-dimensional path that will lead us to a climate-neutral future. Conflicting goals, obstacles and imponderables lurk along the way. The citizens decide on its success.

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The EU and Germany have set themselves the goal of becoming climate-neutral by 2045/50. For the transition from the fossil to the regenerative age, the German government wants four technological paths to be followed: 1st the large-scale transformation of today's energy industry into a smart ecosystem (sector coupling), 2nd the expansion of renewable energies, 3rd the development of a hydrogen infrastructure, as well as 4th a significant increase in energy efficiency.

However, in focusing on the 2045/50 climate target, we must not lose sight of the fact that there is no one-dimensional path that will lead us to a climate-neutral future. A secure and affordable energy supply are equally important goals. This bundle of goals provides the background for the analysis of the pathways. Let's take a look at them.

Cross-sector electrification

Fossil energies will possibly be replaced by electricity in all consumption sectors. For example, in the transport sector through electromobility and in the heat supply using electricity-based heat pumps. These direct electricity applications are to be supplemented by climate-neutral hydrogen technologies. However, hydrogen is only a climate-neutral form of energy if it is produced with green electricity in an electrolysis process. The green electricity must be generated predominantly in wind and photovoltaic plants. Since the solar and wind supply fluctuates, it must be supplemented by flexibility options such as hydrogen salt cavern storage, decentralized batteries, and flexible loads.

This all makes green electricity the basis of our future energy system for all direct energy applications (light, power, heat). The corresponding processes are summarized under the term Power to X. By coupling the consumption sectors, the fluctuations in supply and demand can be balanced. In the future, sector coupling will regulate all energy flows and therefore play a major role in maintaining security of supply.

The digital ecosystem

While in the "old" fossil-nuclear centralized world 700 power plants had to be integrated into the electricity grid, today there are already almost 2 million photovoltaic systems and around 30,000 intermittent wind energy systems feeding into the grid. In addition to this fluctuation-dependent generation, there are around 200,000 battery storage systems and a rapidly growing number of new consumers such as electromobility, heat pumps and hydrogen applications. Decentralization, small scale and volatility of the physical energy flows increase the complexity of this energy supply concept. Intelligent management of sector coupling must therefore digitally process the entire energy industry infrastructure in real time. Making the complex networked infrastructure fail-safe and prevent external cyberattacks to the critical infrastructure is a daunting task.

Compared to today's energy system, however, sector coupling is not only more complex. There is another important aspect. Our current energy system is largely sectoral. We have fuels for mobility, natural gas for heating, and electricity for light and power. If mineral oil imports are interrupted, we can still heat with natural gas or have heating oil in the cellar tank. The electricity comes from our fossil and nuclear "continuous runners". If only natural gas is in short supply, we are left with the car, etc.. In future we will have a volatile, sometimes unpredictable electricity supply combined with (hydrogen) storage facilities that will have to be sufficient even if an unpredictable prolonged break of sun or wind brings electricity generation largely to halt. Otherwise, the PC stays off, the car remains in the garage and in winter the flat would become an icebox. No power, no action. To ensure that such a scenario remains a fiction, the goals of climate neutrality and security of supply must be reconciled. In the coming decades, this immense challenge will have to be overcome. Let's look at it and start with energy demand.

Energy efficiency first

For Germany the total energy consumption has to be reduced by 50 percent across all consumption sectors (transport, households, industry) by 2045/50 to reach federal climate targets.

- In transport, this is to be achieved with more efficient and climate-neutral drive technologies e.g. battery-electric drives, fuel cells and plug-in hybrids. To ensure that the owners of electric cars are not left behind, the charging infrastructure and the distribution networks in the residential streets must be expanded quickly across the board and a time-variable electricity tariff must be introduced to set incentive to balance the loads and to avoid peak loads. The hydrogen infrastructure for

refueling trucks, trains, vans and buses is also still missing.
- The energy demand in the building is mainly used for heat generation in residential buildings. In Germany, the housing stock of single-family and multi-family houses was mainly built after the 1950s. In order to achieve a 50 percent increase in thermal efficiency by 2045/50, these houses must be modernized at an annual rate of 2 percent. For the existing large and small apartment buildings, which house half of all flats in Germany, there is a lack of alternatives suitable for the masses. Thus, the installation of electric heat pumps unfortunately still fails far too often due to the technical and economic conditions on site. Moreover, there is a lack of well-trained skilled workers to professionally renovate 20 million buildings in Germany. And as long as education policy does not pay more attention to the skilled trades, this will not change much.
- Let's move on to industry. With a share of 78 percent of the total industrial energy demand, process heat generation plays a significant role in CO_2 reduction. This means coal and natural gas must be replaced with electricity, hydrogen, synthetic gas and biocoal. Industry will be the largest consumer of hydrogen in the future.

The look into the "engine room" of the energy transition has revealed immense challenges to achieve the targeted energy efficiency goals. Let us now return from the "engine room" to the surface and be optimistic and confident that we can halve the final energy demand from today's approx. 3300 TWh (terawatt hours) to the order of 1600 TWh by 2045/50. Because this goal should be achieved at all costs. Every kilowatt hour that is not saved must be generated from renewable sources and every kilowatt hour that is saved increases the security of supply.

Quadruple the green power supply

Let us turn to the supply side. Depending on the study and scenario, the expansion potential of renewable electricity generation in Germany is between 700 and 1100 TWh. This wide range results from different assessments regarding economic viability, social acceptance, technological progress and nature conservation requirements (26 percent of all wind turbines are already located in protected areas). In order to generate 1000 TWh in 2050, renewable electricity generation must be increased by a factor of 4 from 243 TWh in 2019 to 471 GW. To this end, the German government reformed the Renewable Energy Sources Act (EEG) in December 2020. Among other things, it provides for higher expansion paths for photovoltaic and wind power plants. If these measures give new impetus to wind expansion - in recent years wind expansion has often been blocked by citizens' protests - 1000 TWh of green electricity from wind and photovoltaic plants will probably be available in 2045/50. But this appearance is deceptive. As 750 TWh will be needed for direct use the remaining 250 TWh green electricity does not match with 400 TWh of hydrogen needed for transport, energy use in industry and to bridge dark slack periods. But that is not enough. If we look beyond the energetic use of hydrogen to the use for the production of chemical raw materials in the basic chemical processes, according to calculations in the 2019 "Roadmap Chemie 2050" study by the German Chemical Industry Association - an additional electricity demand of 628 TWh to produce the green hydrogen is demanded. Since this additional demand cannot be met in Germany, the consequence is that in the future we will have to import considerable quantities of hydrogen and possibly other synthetic products.

Hydrogen imports as a beacon of hope

Regions with high solar radiation, long hours of sunshine and favorable wind conditions are ideal for import. Regions with these favorable conditions are North Africa, the Middle East, Patagonia, Canada, Iceland, Ireland and Norway. The technical know-how to build a worldwide hydrogen infrastructure for a worldwide market volume of up to 6000 TWh in 2050 is available. However, according to the analyses of the scientists of the Fraunhofer Institute for Systems Research (Policy Brief 03/2020), many questions still need to be clarified if Germany wants to get a piece of this pie. Are the potential regions politically stable enough to guarantee a reliable supply? Is there a sufficient supply of water for electrolysis without jeopardizing the water supply in the country of origin? This is why overarching governance structures that respect environmental and social standards and a fair balance of interests etc. along the entire supply chain are part of the content of energy partnerships, as envisaged in the EU Commission's hydrogen strategy and the German government's national hydrogen strategy.

Keeping an eye on the costs

Let's move on to the question "How much does it all cost".

According to studies by scientists from the Jülich Research Centre, two trillion euros are calculated for the conversion of the entire energy system over the next 30 years. This includes the investments, fixed and variable operating costs, costs for energy imports in the form of hydrogen, minus the saved import costs for mineral oil, natural gas and coal. The additional investments alone in 2050 compared to today, after deducting saved energy costs for fossil energies, will amount to 128 billion euros. In relation to the gross value added of around 3.1 trillion euros (today) and a 1.2 percent increase per year (real) this accounts for 2,8 percent in 2050. The financial investment in the climate-neutral energy system will bring employment and distribution effects that are already becoming visible.

A cautious businessman might ask whether the energy turnaround cannot be obtained more cheaply. Yes, it can! But with limitations! The 2 trillion euros are a sum that results from the assumption that 95 percent of our energy system is converted to climate-neutral sources. If we abandon the 95 percent and settle for 80

percent, the total sum shrinks to 655 billion euros. The reason for this difference is the marginal abatement costs for the last tons of CO_2 to be reduced. The technological path to the 80 per cent target is less electricity-based, but natural gas would continue to be used for the most part in buildings and correspondingly fewer wind and photovoltaic plants would have to be built.

Natural gas as a flexibility option

According to the ideas of the EU Commission and the German government, green electricity and hydrogen are the beacons of hope that will lead us to a climate-neutral world. Natural gas is no longer mentioned. Within the framework of the Green Deal, all coal-fired power plants are to be replaced by renewable energy in the medium term. But whether this will succeed is completely open.

In the north, the German government - against political pressure from the USA, Eastern European countries and the European Parliament - is vehemently defending the completion of the Nord Stream 2 pipeline. Why this political commitment? In Germany, nuclear and coal-fired power plants will be consistently shut down by the energy companies by 2038 according to a legally prescribed phased plan. However, if the capacity of wind and photovoltaic plants, including the high-voltage lines, is not increased to coincide with the shutdowns, there is a risk that part of the peak load forecast of up to 170 GW in 2050 will have to be covered by natural gas power plants.

To this end, it is possible to replace natural gas in the power plant turbines with hydrogen. In order to burn natural gas with lower emissions, more than 10 percent hydrogen could be added after retrofitting the distribution networks. Finally, there is the possibility of converting natural gas into "blue hydrogen" in steam reformers and splitting off the resulting carbon dioxide and storing it underground. Carbon Capture and Storage was already successfully tested ten years ago. However, its realization failed due to citizens' protests in the Brandenburg communities where the CO_2 was planned to be stored in salt caverns sealed off from the atmosphere. Local resistance prevailed with the slogan "We don't want to become Germany's CO_2 toilet".

Wrap-up

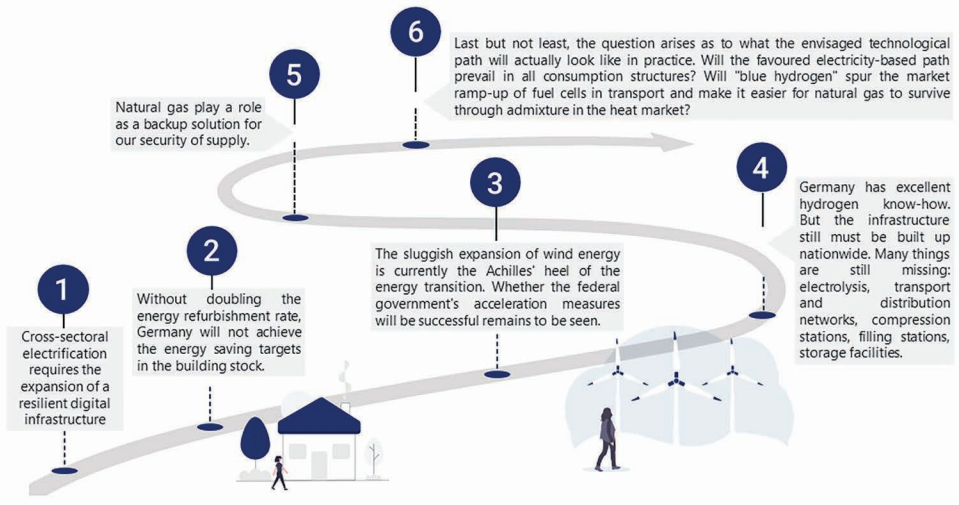
Decisions for the future must be made today. Only if we succeed in dissolving the obstacles and uncertainties in the near future can the path to a climate-neutral future be created. And perhaps there are even innovations that we haven't even thought of yet. The figure briefly summarizes the discussed uncertainties of the energy transition:

It depends on the citizen

It is important to note that new technologies change the world, and, with the world, we change ourselves. This brings us to the crystallization point of the energy transition. There is no question that climate change has picked up speed and we are trying to fight it with new technologies.

But what about us, the people? Have we sufficiently internalized that humans can only survive in the long term in harmony with nature? Evolution has taught us that Homo sapiens could only remain adaptable and ensure its survival in the face of drastic climatic changes or other existential threats by trying out new techniques and sharing new behavioral and value concepts. It is normal for an "old world" to perish and a "new world" to emerge. So today, after 300 years, the fossil age is coming to an end. Whereas in prehistoric times it was the tribal leaders and later the kings and churches that dictated the way of life for the subjects, today it is the free will of the citizens that determines the destiny. This puts us in the middle of the social field of tension of the energy transition. In this field of tension, politics can only stimulate the goals (e.g. Climate Energy Law, decision of Federal Constitutional Court from 2021); whether they are achieved, politics cannot guarantee. Ultimately, it remains dependent on a basic social consensus. A basic consensus that recognizes that human-induced climate change shows the limits of its actions. This humble insight is not a restriction of freedom, but can become a source of inspiration. The containment of the imponderables associated with the energy transition will depend on whether citizens are willing to adapt their way of life, their expectations, norms and values to the political goals. This also means that the major parties must have more courage to discuss the impositions and new visions of the future with the affluent society. All this will be necessary if the climate crisis is not to become a crisis for humanity. (IPCC, Sixth Assessment Report, 2021) For this, we especially need new positive and hopeful images of the future for which it is worth fighting, arguing, and working.

After years of being used as "sewers", lively fish are swimming in the rivers again. The sulphur fumes from power plants are a thing of the past. The air in the cities



has become cleaner thanks to car catalytic converters. International efforts have drastically reduced the hole in the ozone layer. This positive list can be continued. There is always much to be done. The structures of a new global energy system are already visible on the horizon. The "fossil world" still dominates, but in recent years global investment spending on solar and wind plants has been higher than spending on fossil power plants. More and more green funds are investing in climate protection projects. To produce goods, the specific energy input is continuously reduced. And there is also a mosaic of many new visions of the future: we are transforming the previously car-oriented city of cars into a colorful city with lots of greenery, small shops, crafts, and affordable housing. Autonomous mobility will become more convenient and environmentally friendly. In the future, we will have farmers who are committed to animal welfare and organic farming. Consumers who don't follow every fashionable trend, but focus on durable quality.

All over the world, ideas are already becoming visible. Nothing changes overnight. It takes time for a local idea to become a big movement. At the next UN World Climate Conference in Glasgow this autumn, perhaps the awareness will prevail that the global community expects more than mere tongue-in-cheek statements, but concrete, verifiable action. But this presupposes an awareness that accepts that all material goods, which are firmly anchored in the center of our lives, cannot be had without the consumption of raw materials and energy. They are our existential basis of life. We have an open society with its great creative potential that can show its strength here. A society that succeeds in embracing the imponderables of the energy transition will be able to be proud of its climate-neutral, reliable and affordable energy system at the end of 2050.

How do we want to live in the future? For a liberal democratic society, this is an exciting, emotional and perhaps even vital question. Discussing this is overdue. This is the challenging task of the new government resulting from the 2021 election in Germany.

Note

The orders of magnitude used are based on the most recent study by Forschungszentrum Jülich, "Wege für die Energiewende", Jülich 2020, www.fz-juelich.de/zb.. Other relevant studies come to similar conclusions.