German Japanese Energy Transition Council

Comparing the Basic Strategies of Japan and Germany Against the Energy Crisis While Aiming to Achieve Their Climate Mitigation Goals

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List of Abbreviations, Units and Symbols

Abbreviations

BEG	Federal Funding for Efficient Buildings
BEW	Federal Funding for Efficient Heating Networks
BMWi	German Federal Ministry for Economic Affairs and Energy
BMWK	Ministry of Economics and Climate Action
CCUS	Carbon Capture, Utilization and Storage
CE	Circular economy
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilization
CCUS	Carbon Capture Utilization and Storage
DAC	Direct air capture
EEG	Energy Efficiency Law
EnEfG	Energy Efficiency Act
Fig.	Figure
FSRU	Floating Storage and Regasification Unit
GEG	Buildings Energy Law
GHG	Greenhouse gas
GJETC	German Japanese Energy Transition Council
GW	Gigawatt
GWP	Global warming potential
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IRA	Inflation Reduction Act
ISO	International Organization for Standardization
KWP	Municipal Heat Planning Act
LCA	Life-cycle assessment
LNG	Liquefied natural gas
LPG	Liquefied Petroleum Gas
NDC	National Determined Contribution
PV	Photovoltaic
R&D	Research and development
RE	Renewable Energy
SES	System Development Strategy
Tab.	Table
WI	Wuppertal Institut für Klima, Umwelt, Energie GmbH
WindSeeG	Offshore Wind Energy Act
ZEB	Zero energy building
ZEH	Zero energy house

Units and Symbols

$	US dollar
%	Per cent
€	Euro
°C	Degrees Celsius
bn	Billion
CO_2	Carbon dioxide
CO_2 eq.	Carbon dioxide equivalents
g	Gram
Gt	Giga tonne
GW	Gigawatt
h	Hour
H_2	Hydrogen
H_2O	Water
kg	Kilogram
kt	Kiloton
kW	Kilowatt
kWh	Kilowatt hour
m	Million
MCM	Methylcyclohexane
MJ	Megajoule
Mt	Metric tonne
MW	Megawatt
Nm^3	Normal cubic metre
p.a.	per annum
PJ	Petajoule
t	Tonne
TWh	Terawatt hour

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1 Executive Summary

This paper compares the climate protection strategies of Japan and Germany in the context of the energy crisis triggered by the Russian invasion of Ukraine. It examines whether, and if so, how previous climate protection goals and strategies have been altered by the energy crisis, particularly with regard to security of supply and the mitigation of price effects.

Japan has set a goal of reducing greenhouse gas emissions in 2030 by 46 % from 2013 levels. It has also made an international pledge to achieve a carbon neutral society by 2050. Germany aims to be greenhouse gas-neutral in less than 25 years – in 2045 at the latest. It also targets for electricity supply in 2030 to be based on 80 % of renewables.

On the way to carbon neutral societies Germany and Japan have many common, but also differentiated challenges to be solved. Both countries have low energy self-sufficiency rates. Therefore, the path to a carbon-neutral society must strengthen the national energy sovereignty. Especially with the experience of the current energy crisis, this means that the national potentials for energy and resource efficiency and renewable energy sources should be exploited as much as feasible with highest priority. Japan places the highest priority on energy conservation and renewables, just like Germany. But by considering short-to mid-term necessity of fossil fuels and challenges of significant improvement of energy efficiency and limited potential of renewable supply, Japan is also planning to continue using fossil fuels directly (with CCUS) or through imports of blue hydrogen or ammonia, and therefore needs a strong “decarbonization of fossil fuels” strategy. In addition, Japan seeks for utilizing nuclear power as a substitute for fossil power generation. Germany (like the EU) is more focused on the accelerated reduction of fossil fuels by renewables and energy conservation. Induced by the energy crisis, In Germany and the EU, the ambition in the targets for energy efficiency and renewables has even been increased, aiming for synergies between energy sovereignty and climate mitigation. However, on the other hand, steps have been taken for the massive expansion of LNG terminals and for diversification activities with regard to fossil energy supply sources, which raise questions of climate-relevant lock-ins and of compatibility with the climate protection goals.

On the surface, the strategies of Japan and Germany appear to be very different, but it could be argued that, in reality, there are more common challenges. Firstly, both countries put priority on energy and resource conservation as well as the supply of renewable energy sources. Secondly, both need to use fossil fuels as a transitional pathway to a carbon neutral society, and thus have to take actions to ensure security of supply. One difference may lie in whether or not there is confidence for building the future energy system completely based on energy conservation and renewable energy, and hence the duration of the use of fossil fuels as a transitional pathway. This different perspective may be due to the geographical and geopolitical conditions in which both countries find themselves. With regard to current policy priorities, there is a clear difference concerning the role of nuclear energy.

Questions remain on the one hand as to whether and how Germany (the EU) can achieve the ambitious climate protection goals primarily based on renewable energies and energy efficiency under changed geostrategic conditions. On the other hand, Japan faces the challenge of how to develop a decarbonization path under the special conditions of an island state that generates minimal risks in the long term and is prepared for the competition on global GreenTech lead markets for renewables and energy efficiency.

2 Japan: Combining Efforts to Reduce and to Decarbonize Fossil Fuels

2.1 Fossil Fuel Situation in Japan

Japan has set a goal of reducing greenhouse gas emissions in 2030 by 46 % from 2013 levels. It has also made an international pledge to achieve a carbon neutral society by 2050. Japan, like other countries, is taking national measures to address climate change.

However, the energy situation has changed drastically since the 2011 Great East Japan Earthquake shut down nuclear power generation, the economic stagnation caused by the spread of coronavirus infection that has continued for the past three years, and the Russian invasion of Ukraine that began in February 2022. In addition, Japan has not made enough progress in creating an environment for electricity deregulation, developing a grid to actively introduce renewable energy, and restarting nuclear power plants.

To begin with, Japan, surrounded by the sea and lacking its own energy resources, relies on imports of fossil resources and fuels from overseas. As a result, Japan is very sensitive to sudden changes and fluctuations in energy supply and demand. As an aside, Japan used to mine coal and other resources domestically. Due to rapid economic growth in the 1970s and the expansion of imports of cheap energy resources from abroad, the domestic supply of energy resources has gradually shrunk and is now almost non-existent. Therefore, it was necessary to import high-density energy resources to Japan with high efficiency, and more than 50 years ago, the world's first project to liquefy and transport natural gas was successfully completed. Since the arrival of a 30,000-ton liquefied natural gas (LNG) carrier from Alaska to Japan in 1969, this marine transportation of energy by LNG has now become a global standard.

Incidentally, Japan's energy self-sufficiency rate is only about 12 %. Figure 1 compares the primary energy self-sufficiency ratios among major nation. In Japan it is very low compared to other developed countries, and it is only about 1/3 of the self-sufficiency rate of Germany (about 35 %).

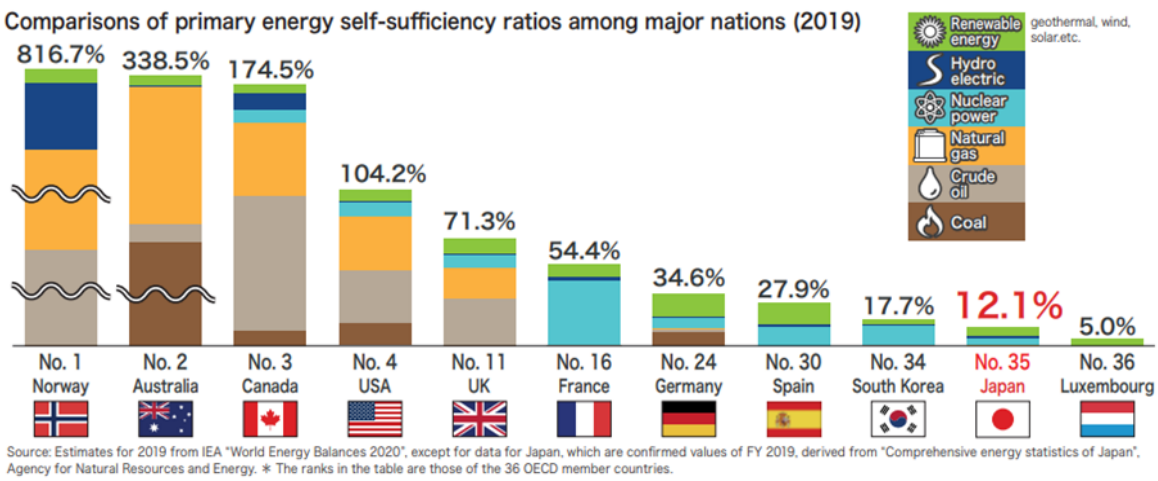


Figure 1: Comparison of primary energy self-sufficiency ratios among major nations

Source: Ministry of Economy, Trade and Industry Japan A, 2022

Therefore, Japan is sensitive to the world's energy situation. In other words, just like other countries and due to the global energy crisis around the world, Japan is experiencing a tight power supply and demand situation and energy prices are increasing. This means that Japan is facing an energy crisis comparable to the oil crisis that occurred in Japan in 1973. The recurrence of such an energy crisis demonstrates the fragility of Japan's energy supply system and the issues of energy security. This is a critical issue because ensuring a stable energy supply is fundamental to people's lives and corporate activities. In this point of view, Japan is promoting thorough energy conservation, structural transformation of the manufacturing industry (fuel conversion and raw material conversion), active introduction of renewable energy, utilization of nuclear power, promotion of introduction of CO_2-free fuels such as hydrogen and ammonia, strengthening of international cooperation to secure resources and energy, and promotion of carbon recycling and CCS introduction. Please add a short remark whether these strategies are accelerated by the current energy crisis.

2.2 Energy Structure in Japan

As described earlier, Japan relies on imports from abroad for most of its primary energy. Figure 2 shows energy flows in Japan. The values on the left side of the figure show the energy supply but it can be seen that oil, coal, and natural gas supply almost all of it.

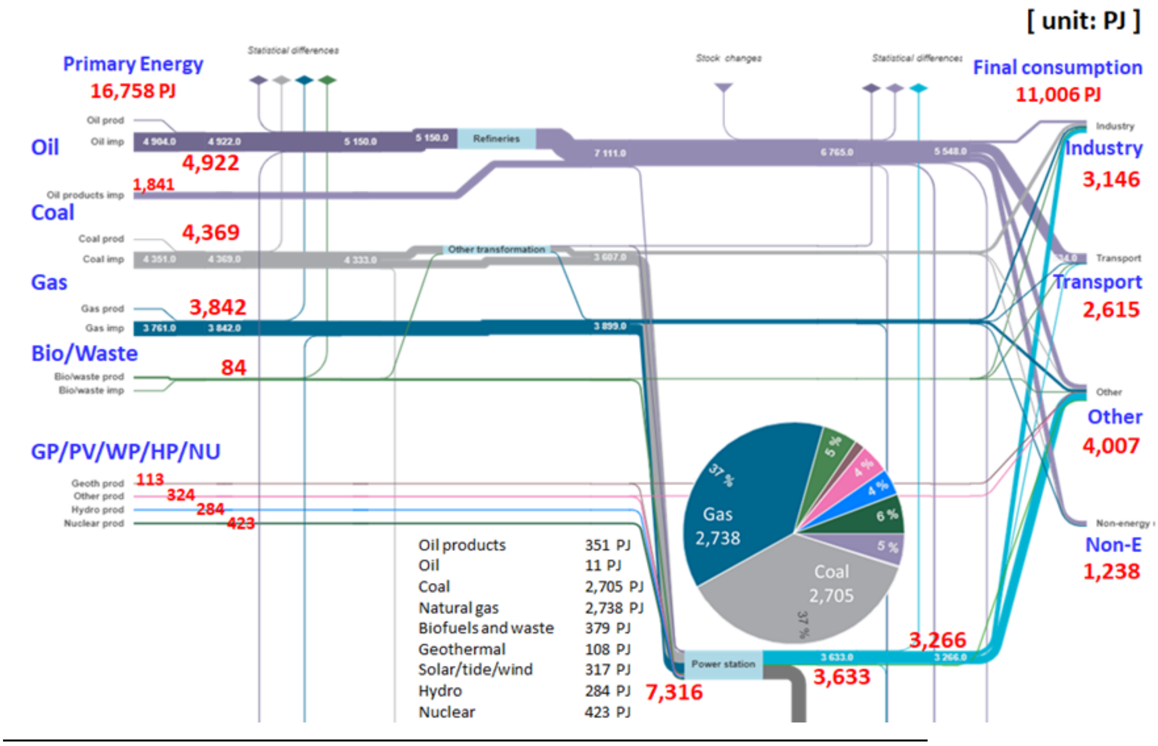


Figure 2: Energy flow in Japan

Source: International Energy Agency, 2020

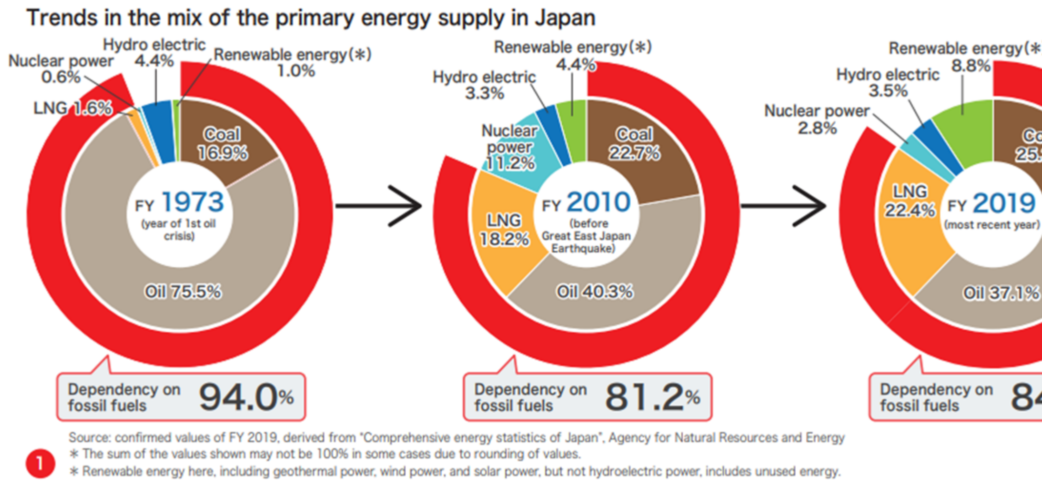


Figure 3: Trends in the Mix of the Primary Energy Supply in Japan

Source: Ministry of Economy, Trade and Industry Japan A (2022)

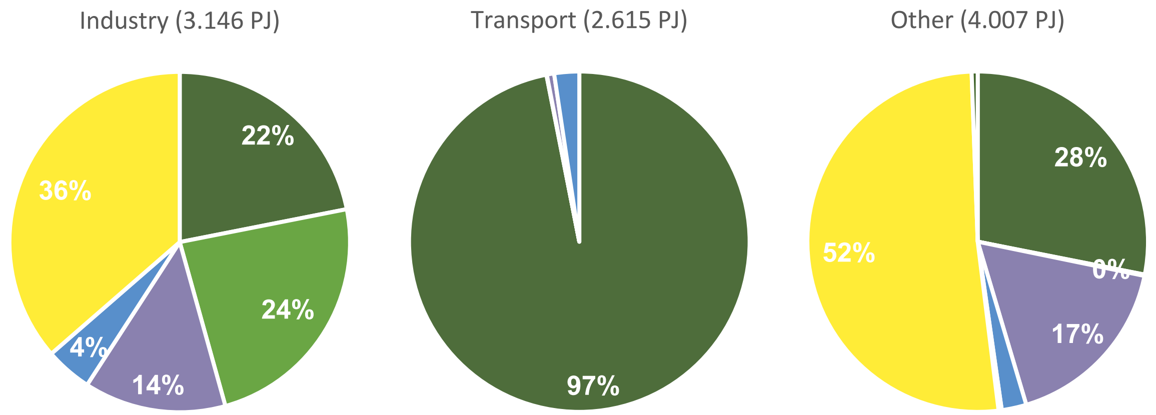
For clarity, the primary energy source is depicted in a pie chart in Figure 3 until the Great East Japan Earthquake in 2011, the country had actively promoted the introduction of nuclear power and renewable energy in order to reduce its dependence on fossil resources and fossil fuels, but since the earthquake, the country's dependence on fossil resources (fuels) has increased again. Primary energy consumption in Japan is approximately 17,000 PJ as shown in Figure 2. Of this primary energy source, oil, coal, and natural gas account for about 85 % and are sources of CO_2 emissions. Of this primary energy, about 7,300 PJ (about 43 %) is consumed for power generation. And fossil fuels account for about 80 % (about 5 % oil, 37 % coal, and 37 % natural gas) of the fuels used for power generation. Renewable energy, including hydropower, accounts for about 12 %. Approximately 7,300 PJ of energy supplied to the power plant is converted into electricity, which is then supplied to the industrial, transportation, and consumer (household and business) sectors as approximately 3,300 PJ of electricity. This means that the power generation conversion efficiency is about 45 % on average. Of the approximately 17,000 PJ of primary energy, approximately 9,700 PJ of energy not used for power generation is consumed in the industrial, transportation, and consumer sectors as raw materials for products, fuel for manufacturing, and heat sources. The amount of energy consumed in the industrial, transportation, and consumer sectors is 3,146 PJ, 2,615 PJ, and 4,007 PJ, respectively. Renewable energy is an essential tool for decarbonization, but the energy structure of Japan shows that renewable electricity alone is not enough to decarbonize the country. In other words, even if all electricity is supplied by renewable energy sources, it represents only 30 % of primary energy as shown in Figure 2. The remaining 70 % are raw materials and fuels derived from oil, natural gas, and coal. This is where CO_2-free raw materials and fuels must be supplied.

There is a limit to the amount of renewable energy that can be introduced in Japan. Japan has few flat lands and limited areas with good wind conditions. Many areas on the Sea of Japan side of the country have large amounts of snowfall, making them unsuitable for solar and wind power generation. In addition, suitable locations for renewable energy are unevenly distributed in regional areas and are distant from densely populated areas (energy-consuming areas). This means that large-scale reinforcement of power transmission and distribution facilities will be necessary.

Policies are underway in Japan for the active introduction of offshore wind power generation. Japan does not have as much suitable shallow water as Europe, and is hit by typhoons and other storms, making it difficult to introduce wind power quickly and in large quantities. Of course, it also takes time to obtain the consent of local fishery associations and residents. Therefore, in the future, the policy must be promoted with a view to importing renewable energy. Therefore, various methods are currently being considered in Japan. Hydrogen, ammonia, methanol, and MCH (Methylcyclohexane) are being considered as energy carriers.

2.3 Energy Usage by Sector and Directions for Decarbonization

The different sectors use energy in very different ways. Figure 4 shows a breakdown of energy consumption in each sector. This figure shows that the transportation sector is dependent on gasoline and other petroleum products. On the other hand, it can be seen that the consumer sector (other section in Figure 4) is the most electrified. The industrial sector is very complex due to the mix of various industries. In this way, there is no general solution for all sectors toward carbon neutrality (decarbonization).



Source	Industry (PJ)	Transport (PJ)	Other (PJ)
Oil products	689 (22 %)	2.534 (97 %)	1.126 (28 %)
Coal	748 (24 %)		5
Natural gas	424 (14 %)	1	688 (17 %)
Bio/waste	140	18	94
Geothermal			5
PV/tide/WP			7
Electricity	1.145 (36 %)	62	2.059 (52 %)
Heat			23
Total	3.146	2.615	4.007

Figure 4: Energy consumption for each sector in Japan based on International Energy Agency, 2020

2.3.1 Transport Sector

The transport sector is heavily dependent on gasoline and other petroleum products, which account for 97 % of the total as shown in Figure 4. In other words, the key to decarbonizing the transport sector is how to replace these petroleum products with CO_2-free fuels. The solution would be to introduce zero-emission vehicles such as electric vehicles and fuel cell vehicles. However, although Japan is also actively introducing electric vehicles, they account for only about 2 % of electricity consumption. Further introduction of electric vehicles would be desirable.

On the other hand, the introduction of electric and fuel cell vehicles, of course, requires the supply of electricity and hydrogen. As an extreme example, if all internal combustion engine vehicles running in Japan were replaced with electric vehicles, how much electricity would be required? The number of automobiles running in Japan is approximately 80 million. Automobile fuel can be broadly divided into three types: gasoline, diesel fuel and LPG (Liquefied Petroleum Gas). The fuel consumption and vehicle mileage for each are compiled by the Japanese Ministry of Internal Affairs and Communications (Ministry of Internal Affairs and Communications, 2022). Although the details of the calculation are omitted, the amount of electricity required for electric vehicles can be calculated from Ministry of Internal Affairs and Communications data to be approximately 100 billion kWh (about 380 PJ). If this amount of electricity were to be supplied by photovoltaic power generation approximately 100 GW of solar panels would be required, assuming that the annual installed utilization rate of photovoltaic power generation in Japan is approximately 12 %. This capacity of photovoltaic power generation is approximately 1.5 times greater than the amount of installed capacity that currently exists in Japan. Similarly, if internal combustion engine vehicles were replaced by fuel cell vehicles, about 5 million tons (55 billion Nm^3) of hydrogen would be required. Please refer to GJETC scenario comparison up to 2050 (Obane et al., 2022). It is impossible to procure such quantities of electricity and hydrogen right now. But this impact must be remembered. The process to realize such a society, and how to obtain electricity and hydrogen cheaply and in large quantities, is anticipated to require an extensive duration for completion and will be very important in the future. Incidentally, the Japanese government has set a goal of 100 % electric vehicles in new passenger car sales by 2035 (Ministry of Economy, Trade and Industry Japan, 2020). With regarding hydrogen, the goal is to introduce up to 3 million tons of hydrogen by 2030, and about 20 million tons by 2050.

Another method is to use synthetic fuels that can be produced from biomass, waste cooking oil, and carbon dioxide. However, if synthetic fuels are produced from CO_2 and used, and if the CO_2 source is fossil fuels, then new strategies will be needed to achieve decarbonization, such as utilizing technology to capture CO_2 from the atmosphere (DAC).

2.3.2 Consumer (Household and Business) Sectors

The consumer sector is the most electrified. Therefore, the fastest way to achieve decarbonization in this sector is to make electricity CO_2-free, i.e., to introduce renewable energy. However, as noted earlier, there is a limit to the amount of renewable energy that can be introduced, so energy imports from overseas will be inevitable in the future. All-electric houses and buildings exist in Japan. However, the recent Russian invasion of Ukraine has resulted in an insufficient procurement of fuel for power generation, causing electricity prices to increase sharply. This makes it difficult to keep warm, especially in all-electric homes, as the utility costs are a financial pressure on the family budget. Even if renewable energy is imported from overseas in the future, we must aim to minimize these price fluctuations and ensure a stable power supply. In addition, since renewable energy is an unstable power source that is affected by weather conditions and other factors, the strategy will need to include the introduction of energy carriers and the operation of nuclear power. Non-electricity energy is mainly oil and gas, most of it consumed for heating purposes. The introduction of CO_2-free fuels is essential to decarbonize oil and gas products. As discussed in the transport sector, synthetic fuels from biomass, waste cooking oil, and carbon dioxide are the most likely candidates.

The spread of energy-complete buildings such as Zero energy buildings (ZEB) and Zero energy houses (ZEH) is also important for decarbonization. In Japan, the Sixth Basic Energy Plan sets a goal of ensuring that new houses and buildings constructed after 2030 have ZEH/ZEB level energy efficiency and conservation performance.

2.3.3 Industrial Sector

The industrial sector is a mixture of various sectors, and different sectors use fossil fuels in different ways. In the field of steelmaking, the blast furnace/converter method is the dominant method in the world, accounting for approximately 70-80 % of crude steel production. However, the blast furnace/converter method consumes a large amount of coal-derived coke, resulting in high CO_2 emissions. In order to reduce coke consumption, the introduction of hydrogen-reduced steelmaking and direct-reduced steelmaking is under consideration.

In the hydrogen reduction steelmaking process, the reduction reaction with hydrogen is an endothermic reaction, which means that a large amount of hydrogen cannot be supplied to maintain the temperature in the furnace. Of course, there is also the issue of how to obtain hydrogen. In the direct reduction method, iron ore is reduced in solid form using natural gas, etc., and then transferred to an electric furnace for further processing. This method does not use coke, thus reducing CO_2 emissions. However, electric furnaces used in post-processing are more difficult to remove impurities than blast furnaces, and low-grade iron ore with high impurities content cannot be used. Another disadvantage of this method is that it is less energy efficient than the blast furnace method because iron ore reduction cannot be performed in a single furnace. In addition, the advantage of steelmaking in areas where natural gas is cheaply available should not be overlooked. Nevertheless, the direct reduction method has already been introduced in the world and is a promising method for the future. The electric furnace method is attracting worldwide attention because it does not require a reduction reaction and can drastically reduce CO_2 emissions. It is said that CO_2 emissions can be reduced to 1/3 compared to the blast furnace method. In the electric furnace method, scrap iron generated in the city or in steel mills is collected and used as a source of iron. Since the sources of steel scrap in the city are dispersed, there is a need to recover steel scrap in a stable and efficient manner. Scrap iron is already component-adjusted. Therefore, it is not suitable as a raw material for products that require processability and strength. The electric furnace method, which does not use fossil fuels, is the most promising method for decarbonization, but as already mentioned, stable availability of steel scrap and electricity supply are important issues. Instead of natural gas used in direct reduction, synthetic fuels produced from CO_2 and ammonia are candidates for reductants, but the technology is not yet mature.

The cement production process emits a large amount of CO_2 during clinker calcination. To express the process more differenciated, limestone and clay are calcined at 1400 °C or higher to produce clinker, and a large amount of CO_2 is emitted during this process. Therefore, CO_2 emissions can be reduced by using CO_2-free raw materials in place of limestone. If CO_2 can be separated and recovered from factory exhaust gases to produce calcium carbonate, it can be used as a raw material to replace limestone, thereby reducing CO_2 emissions. There are also other methods. After cement is produced from clinker, water and aggregate are mixed to produce concrete, but there are other methods of fixing CO_2 in concrete by using new materials that utilize CO_2 in the aggregate. Furthermore, in order to control the strength of concrete, CO_2 is absorbed in the concrete (curing process), and if CO_2 recovered from factory exhaust gas is used for this CO_2, it can contribute to CO_2 reduction. Thus, when CO_2 is used in the cement production process, the process is simpler because, unlike the production of synthetic fuels and chemicals from CO_2, hydrogen is not needed at all. The Japanese government's carbon recycling technology roadmap published in 2019 (revised in 2021) also clearly states this and sets a high priority for its introduction as a Carbon Capture and Utilization (CCU) product. However, the heat source (fuel) used for clinker firing, etc. is a fossil fuel, and decarbonization of the heat source must be considered separately. The same argument can be made in the chemical industry (petrochemicals) as in the steel and cement sectors. Since the sources of CO_2 emissions in this field are electricity, raw materials, and heat source (steam), they should be CO_2-free. Of these, electricity and heat source (steam) are related to fossil fuels.

As mentioned before, the use of renewable energy is essential for the decarbonization of electricity. However, the amount of renewable energy introduced in Japan is limited, and the development of transmission and distribution networks for renewable energy has lagged. Therefore, the use of non-renewable energy sources and CO_2-free fuels to supply electricity is also being considered. Of course, this is not limited to the chemical industry. These are solid fuels using biomass and waste plastics, liquid fuels using energy carriers such as hydrogen, ammonia, MCH, and methanol, and gaseous fuels using biogas and synthetic methane. However, CO_2 is generated during fuel production and combustion of energy carriers (during power generation). Therefore, it is necessary to introduce the concept of carbon recycling by, for example, recovering the CO_2 and producing the fuel again. There are three ways to decarbonize heat: (1) effective utilization of unused heat (waste heat), (2) CO_2-free heat sources, and (3) use of electric heat conversion. Even though waste heat is generated as a by-product in almost all technical processes, it is often lost without being utilized. Waste heat is readily available, but the balance between waste heat sources and consumers is very important. In particular, it is necessary to investigate the temperature range, heat content, waste heat flow, timing of heat supply and heat demand, type of heat medium, and local conditions. Effective use of unused heat (waste heat) can significantly reduce fossil fuel consumption and CO_2 emissions. However, as long as fossil fuels are used as heat sources, CO_2 emissions cannot be reduced to zero. Therefore, replacing natural gas, light oil, and heavy oil used as heat sources with CCU fuels is expected to significantly reduce CO_2 emissions from heat sources. However, to decarbonize, the CO_2 emitted after combustion (steam production) of the CCU fuel must be recovered. This would not be the case if the CO_2 recovered by DAC is used to produce fuel. Alternatively, CO_2 could be captured by Carbon Capture and Storage (CCS). As for the electrification of heat using electrothermal conversion technology, it is seen only in small-scale applications. If it is to be made large scale, there are still major issues to be solved, such as securing large scale electricity from renewable energy sources.

2.4 Policy Trends in Japan

The Japanese government announced the 6th Basic Energy Plan in 2021 (Ministry of Economy, Trade and Industry Japan A, 2021). It sets targets for domestic energy supply and demand necessary to achieve Japan's GHG emissions reduction target for 2030. Figure 5 shows the target power source composition for Japan in 2030 (right side in Figure 5). According to this, the expected electricity supply in 2030 is 934 billion kWh, and renewable energy sources are expected to account for 36-38 % (336~353 billion kWh) of this amount. In addition, the goal is to generate 1 % of the total amount of electricity generated by hydrogen and ammonia as energy carriers (approximately 9 billion kWh).

Targets for hydrogen and ammonia are described in the Green Growth Strategy (Ministry of Economy, Trade and Industry Japan B, 2021) released by the Japanese government in 2021, which includes targets for their introduction. Hydrogen is targeted to be introduced up to 3 million tons per year in 2030 and about 20 million tons per year in 2050. Ammonia demand in Japan is expected to be 3 million tons per year in 2030 and 30 million tons per year in 2050. For synthetic methane, similarly, targets have been set in the Green Growth Strategy. According to the strategy, the goal is to inject 1 % of synthetic methane into existing infrastructure by 2030 and 90 % by 2050. The supply of synthetic methane in 2050 would thus be equivalent to approximately 25 million tons. To achieve these goals, public-private councils (Ministry of Economy, Trade and Industry Japan, 2023; Ministry of Economy, Trade and Industry Japan B, 2022; Ministry of Economy, Trade and Industry Japan C, 2022; Ministry of Economy, Trade and Industry Japan D, 2022) have been established to create incentives for businesses formulating a supply chain as soon as possible, and active discussions are still taking place.

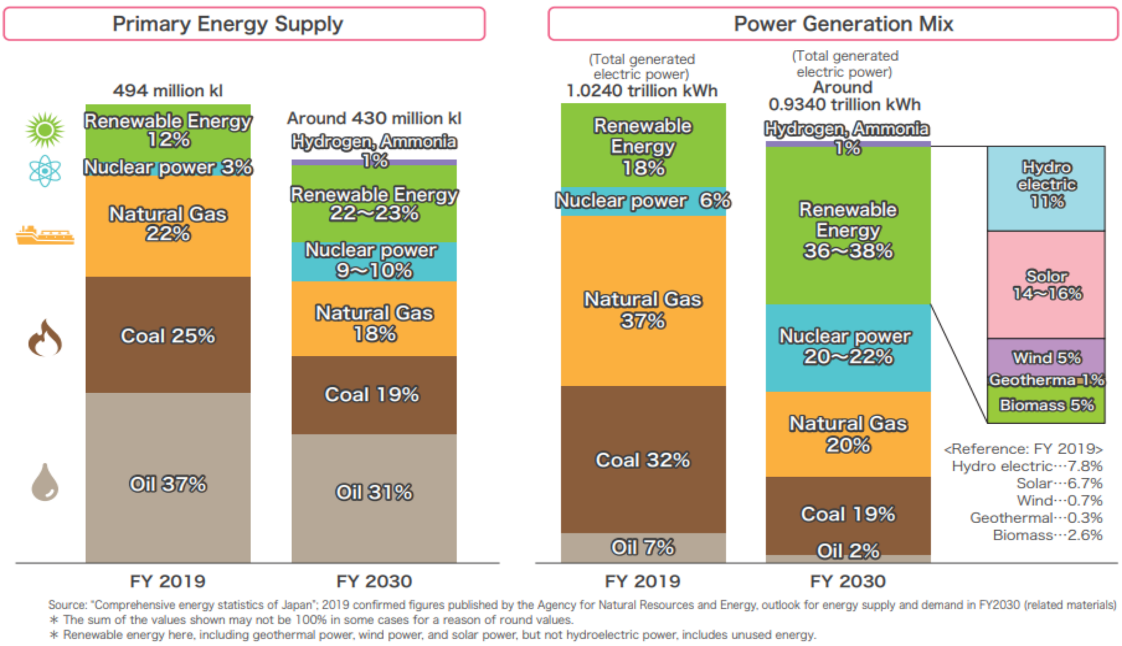


Figure 5: Primary energy supply and Structure of power sources in 2030 in Japan

Source: Ministry of Economy, Trade and Industry Japan A (2022)

The roadmap for carbon recycling technology was established in June 2019. Subsequently, it was revised in July 2021 due to rapid progress in R&D aimed at international collaboration and the positioning of carbon recycling as a key technology for achieving carbon neutrality in the "Green

Growth Strategy Accompanying Carbon Neutrality in 2050" in 2021. Figure 6 shows the carbon recycling technology roadmap.

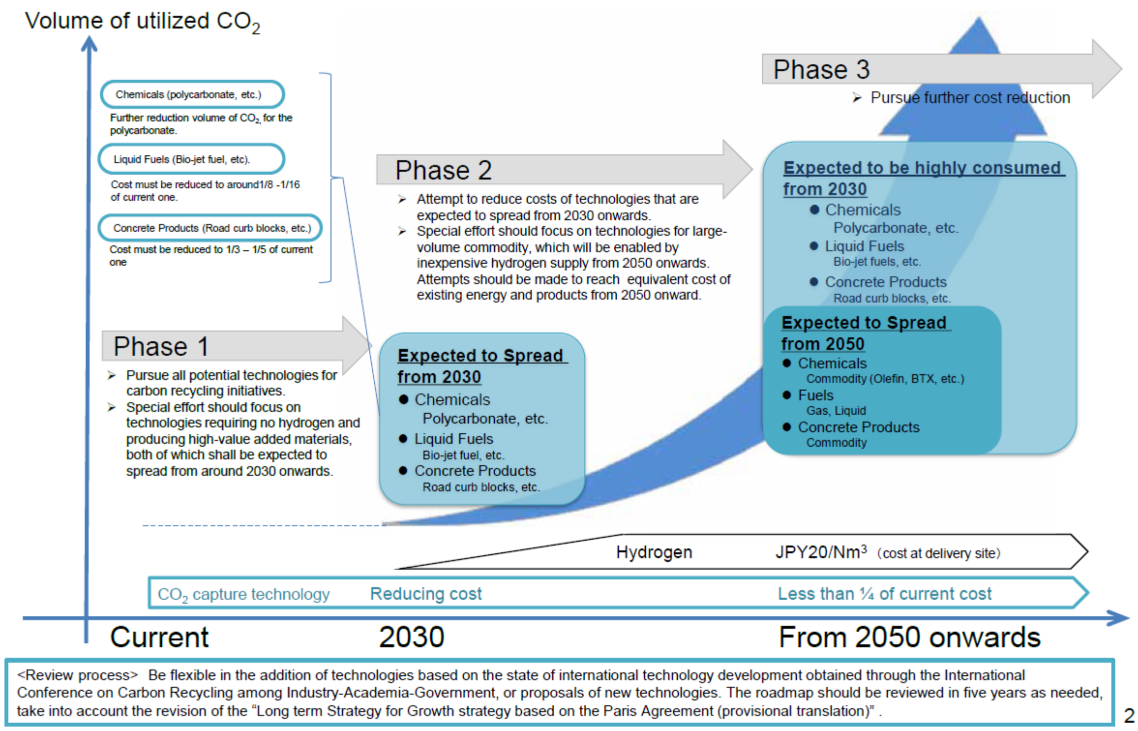


Figure 6: Roadmap for Carbon Recycling Technologies

Source: Ministry of Economy, Trade and Industry Japan (2019)

While the effort toward decarbonization was accelerating, Russia invaded Ukraine. In the long term, improving energy self-sufficiency through energy conservation and renewable energy will be central to countermeasures in terms of both energy security and climate change, and Japan also has a policy to pursue it. However, it will take a long time to realize because it will involve structural changes, thus it will not be sufficient in terms of time horizon of the crises we are facing now. Under such circumstances, the most immediate option that Japan can actually take is to restart existing nuclear power plants. Restarting one nuclear power plant (approximately 1 GW) can reduce annual LNG imports by approximately 1 million tons. Against this background, in August 2022, Prime Minister Kishida announced a policy to accelerate the restart of existing nuclear power plants. He also indicated a policy of extending the operational life up to 60 years, and even considering the construction (replacement) of a new reactor. These nuclear policies represent the significant change in Japan since Russia's invasion of Ukraine.

The decarbonization strategy responding to Russia's invasion of Ukraine was published in December 2022, "Basic Strategy for Realizing Green Transformation (GX)"

a. Foremost effort for energy efficiency improvement
b. Making the renewable energies as a mainstream of power supply
c. Utilize nuclear energy
d. Other key areas

- Promote hydrogen and ammonia

- Reform gas and power market
- Strengthen resource diplomacy
- Battery industry
- Resource cycling
- Green transformation of the transport sector
- Digital investment
- Housing and building
- Social infrastructure
- Carbon recycling/CCS
- Food, agriculture, fishery, and forestry

3 Germany: Accelerated Replacement of Fossil Fuels While Diversifying Their Supply

In January 2022, shortly before the Russian invasion into the Ukraine (24.2.2022), the German Federal Ministry for Economic Affairs and Climate Action (BMWK C 2022) published "Germany`s Current Climate Action Status". According to this publication, the goals of the current government can be summarized as follows:

1 | Germany should be greenhouse gas-neutral in less than 25 years – in 2045 at the latest.
2 | Electricity supply in 2030 should be based on 80 % renewables.
3 | Emissions reductions must more than double in the coming years and then nearly triple by 2030
4 | The Climate Change Act, following the Federal Constitutional Court's landmark ruling on climate protection in March 2021, requires that greenhouse gas emissions must fall by 65 % from 1990 by 2030. All sectors must contribute to this reduction by binding targets
5 | The European Union has set itself the goal of greenhouse gas neutrality by 2050 and has raised the 2030 target to a 55 per cent reduction in greenhouse gas emissions from the 1990 figure. Both targets have been made binding under international law by the European Union in the context of the Paris Agreement.

In this paper we take this political action status as a starting point to discuss the question whether and how Germany might have changed its basic strategies due to the impact of the energy crisis.

3.1 Medium Term Compensation for the Ban on Russian Fossil Fuels

Russia's war of aggression against the Ukraine has been perceived by the German Government and the public as a fundamental turning point ("Zeitenwende") (Bundesregierung A, 2022) of geopolitics and as a dramatic break with rule-based foreign policies. This turning point came also as a challenge and surprise for many experts concerning current energy policies, import strategies, and long-term decarbonization strategies. The German Government decided on huge immediate relief programs for households and companies, which are not part of this paper (Bundesregierung B, 2022). Here we focus on the policies and measures to compensate for the ban on Russian gas, oil and coal (based, i.e., on Ariadne, 2022). There is no comparable industrialized country, where the historical, self-responsible and risky decisions on import dependencies (especially for gas) were as seriously challenging as for Germany. However, as a member state of the EU, Germany can rely on other member states to find solutions. The key question for the German Government, which was raised by the ban, was *whether, and if yes, how ambitious climate mitigation policies can be combined with protecting energy sovereignty and security of supply.* Following the events of February 2022, the Ministry of Economics and Climate Action (BMWK) is prioritizing the reduction and substitution of fossil fuels over their decarbonization. Highest priority is given to the question how much, how quick and with what socioeconomic implications the forced "reduction of fossil fuels" (e.g. by energy efficiency, renewable energies, diversification of supply) is possible, getting rid of the import dependencies.

Japan and Germany have taken different approaches to the energy crisis, with Japan focusing on decarbonizing fossil fuels and Germany prioritizing the reduction and substitution of fossil fuels.

This paper does not look into the specific challenges of “decarbonization of energy intensive industries”[1], where the wording “decarbonization of fossil fuels” can have a special meaning without referring to the energy crisis. Transforming the production processes in industries like steelmaking, aluminum, cement and chemicals (fertilizers), “decarbonization” includes a wide range of time horizons and technologies such as e.g. hydrogen, CCS, Carbon Capture Utilization and Storage (CCUS), low carbon products and Circular Economy (CE) strategies.

In Germany, recent research endeavors and projects within the "scenario community" (BMWK A 2023) have emerged, focusing on modifying previous scenario analyses to address potential challenges arising from the altered international energy agenda subsequent to February 2022. Thus the BMWK is moderating a scenario based dialogue on a “System Development Strategy” (“Systementwicklungsstrategie/SES”):

> “Against this background, there is a great need for coordination between the planning processes for infrastructure and the strategies for the various sectors and energy sources. The SES sets a framework that provides orientation for follow-up processes, such as the network development plans for electricity and gas or hydrogen, as well as the sector- and energy-source-specific strategies and programs. In this way, it ensures the coherence of the various strategies and programs in terms of an inexpensive, consumer-friendly, efficient, environmentally friendly and climate-neutral overall system. The SES is created by the BMWK in a participatory process involving representatives from the energy sector, industry, civil society and politics.” (ibid; own translation)

We will come back to some of these initiatives at the end of this paper.

Figure 7 shows Germany's import dependency on oil, natural gas, and hard coal before the war, as well as the share that was imported from Russia.

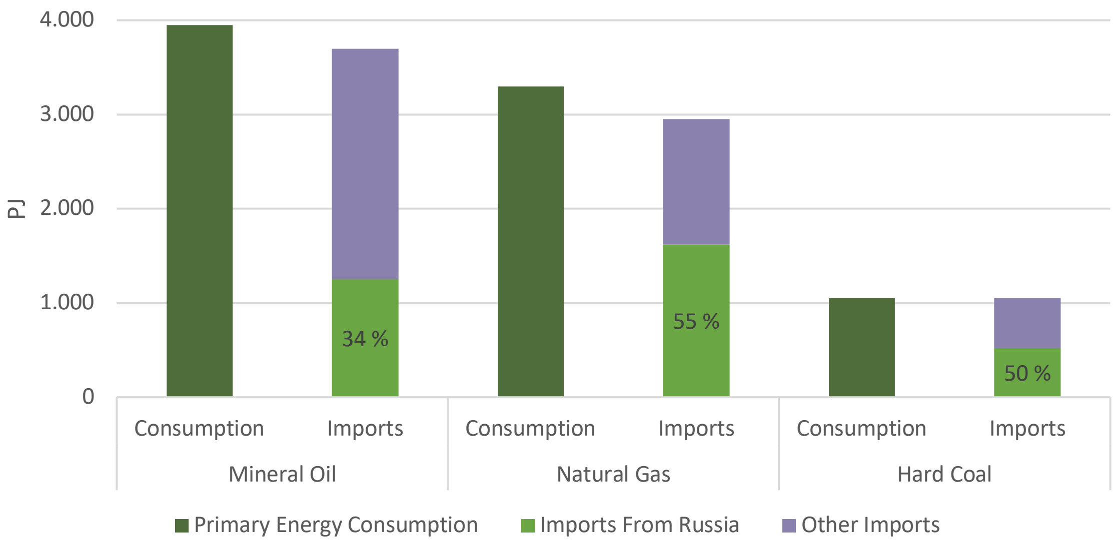


Figure 7: Fossil Fuel Import Dependency of Germany Before 2/2022

Source: Ariadne, 2022, 4

[1] The GJETC conducted special papers on steelmaking and chemicals, see https://gjetc.org/studies/

Figure 8 illustrates the distribution of natural gas demand across key sectors up to 2020, including private households, the commercial sector, electricity and heat production, industry, and other sectors.

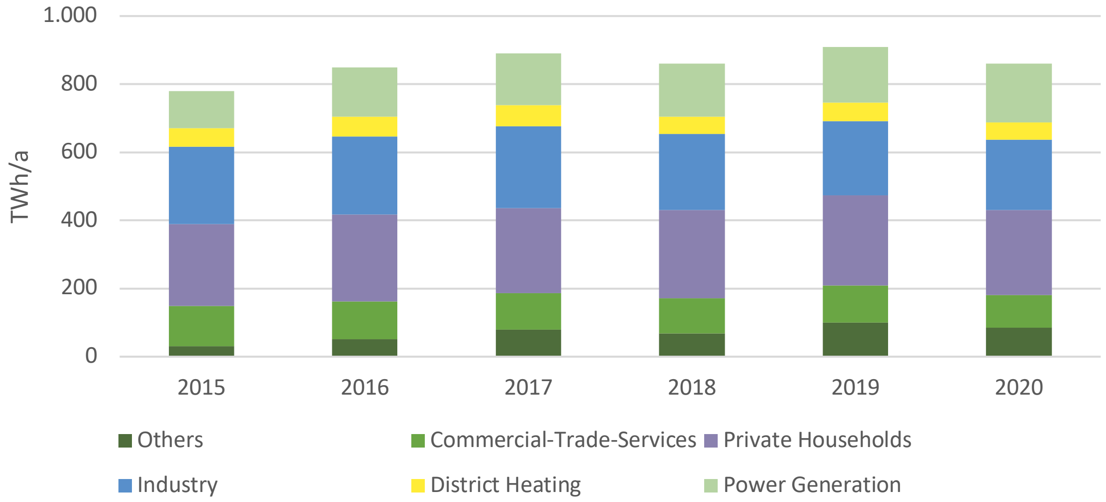


Figure 8: Sectoral Demand for Natural Gas in Germany

Source: Ariadne, 2022, 5

3.2 Stronger Energy Efficiency and Savings

Regarding natural gas conservation potential, Figure 9 displays the potential for mobilizing short-term energy conservation in various sectors, as indicated by different studies:

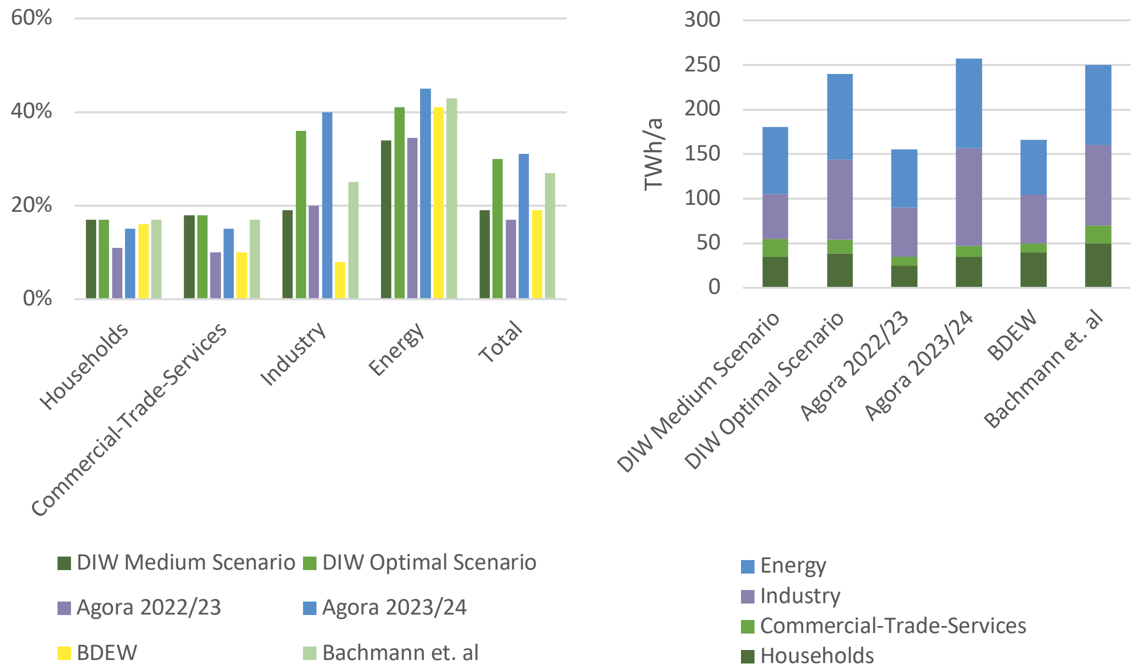


Figure 9: Short Run (2022/2023) Gas Potential According to Different Studies (left in % and right in absolute figures)

Source: Ariadne, 2022, 8

So, what has been accomplished in the short run? Several studies, including those by Agora (2022), UBA (2023) and BMWK (C 2022), summarize some key impacts as of the end of 2022:

- Emergency measures to ensure security of supply have generally been successful (BMWK C 2022), despite the cessation of all fossil fuel imports from Russia. During the winter period, gas consumption in Germany was reduced by around 19 % compared to the period 2018-21 exceeding the 15 % target set by the European Council (i.e., the governments of the EU Member States). However, the German energy grid regulator (Bundesnetzagentur) suggests that gas savings should have been even higher (25 %) to characterize the status quo as “stable”.
- CO_2 emissions in 2022 decreased by 1,9 %, which translates to 15 Mt less than in 2021. This reduction was mainly due to decreases in the industry and household sectors, while emissions in the energy and the transportation sectors increased.
- Primary energy consumption declined by 4.7 % in 2022 compared to 2021, thanks to energy efficiency, energy savings, production declines, and low heating consumption due to mild weather. Fossil gas consumption fell compared to 2021, while oil and coal consumption increased by three and five percent, respectively.
- Renewable energy sources produced more electricity in 2022 than ever before, generating 256 TWh, a 9 % increase compared to 2021. Wind power remains the largest supplier of renewable electricity with 128 TWh, but the addition of 2.4 GW was still far too low. Solar power production increased by 23 % compared to 2021 due to a good year for sunshine and the addition of 7.2 GW.
- Two more coal-fired power plants, activated from reserve (2 GW), were on the market than at the end of 2021. As a result, lignite and hard coal-fired power plants supplied 18 TWh more, while generation from gas-fired power plants fell by 15 TWh.
- Surveys conducted among citizens on the most significant topics in Germany reflect the multiple crises of 2022. Climate and environmental protection were among the top two issues in the monthly polls during the year. A large part of the population sees the expansion of renewable energies as the best response to the Russian invasion. The acceptance of renewable energies is increasing again at a high level.
- Energy savings, increased gas imports, and the first three Floating Storage and Regasification Unit (FSRU) LNG terminals in German ports have brought gas prices down again (see below).

Figure 10 illustrates how the energy crisis initially caused a severe energy price crisis, which brought some companies and vulnerable households close to the brink of existence. Meanwhile, the gas price has nearly returned to its pre-war level, and Ariadne (2022) does not anticipate a similar future price hike as in 2022.

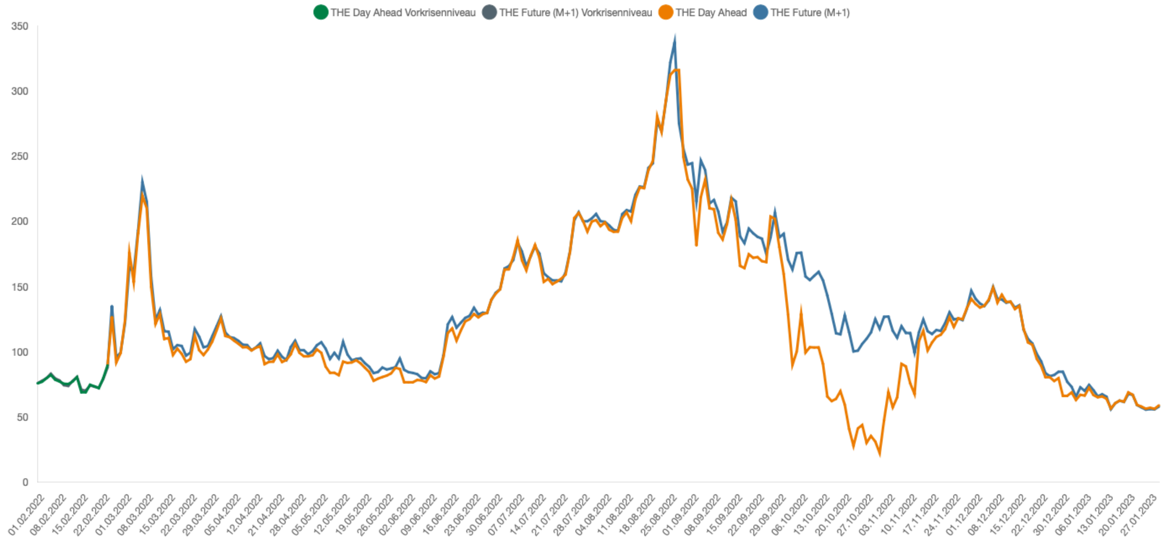


Figure 10: Wholesale Gas Prices 2/2022 to 1/2023

(Source: Bundesnetzagentur (2023)

What are the mid- and long-term prospects? As of February 2023, there are no fully adapted and updated scenarios compared to the representative studies, which have been compared by the GJETC (2022). Therefore, we refer to recent studies that focus on the gas market and renewable electricity prospects up to 2035.

Figure 11 summarizes the final result of the Ariadne study (2022). It shows how a mixture of energy efficiency and conservation measures in all sectors and additional LNG imports can substitute for the energy supply gap caused by the cessation of gas imports from Russia in 2022. Within its dossier, Ariadne (2022) examined the mid-term perspectives (up to 2030) of the gas supply and demand. It concluded that with support from additional LNG imports, about 600 TWh of gas supply from saved sources can be secured for Germany. This would mean a reduction of about 30 to 50 % compared to the pre-war level of gas demand, which would also contribute significantly to achieving Germany's climate mitigation targets. However, it raises questions about how this energy efficiency and conservation effort can be reached and stabilized and what this would mean for the need to build up a comprehensive new LNG-infrastructure (see below).

For example, another study by E3G, together with the Wuppertal Institute, showed that a comprehensive program of energy efficiency, paired with green electrification and district heat in the building sector, could save up to 250 TWh/yr of gas by 2030 and avoid the need to build two land-based LNG terminals that are planned for 2026 and 2028 to replace FSRUs (Koch et al. 2022).

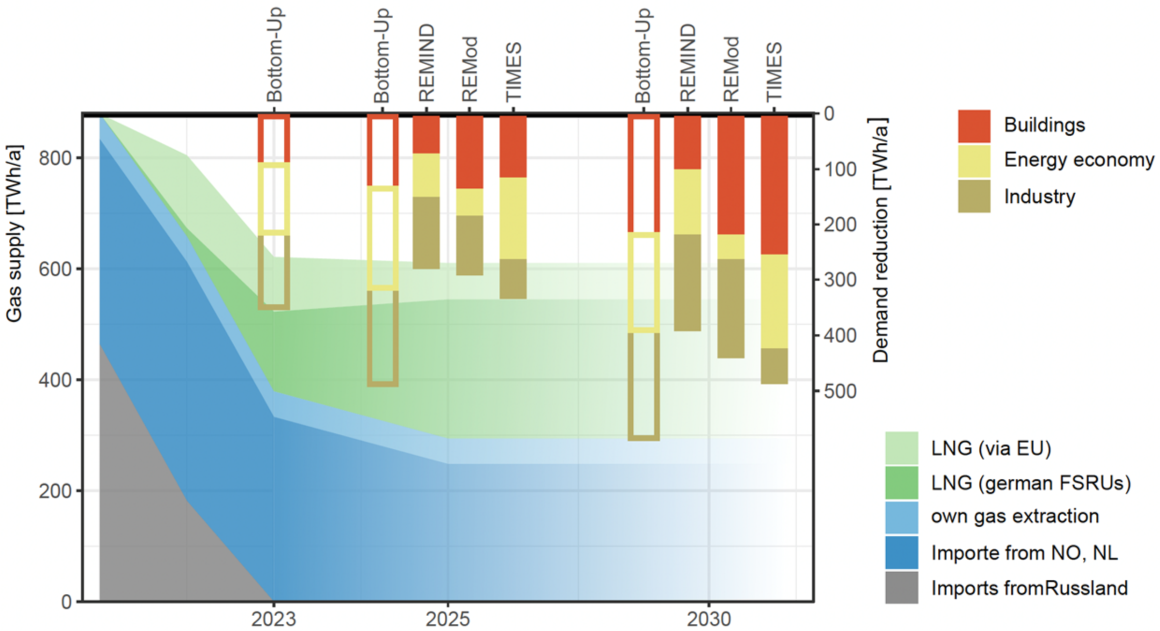


Figure 11: Sectoral and overall gas savings in a scenario energy sovereignty compared with the supply gap after the export stop of Russian gas

Source: Ariadne, 2022, 2

In sum, the Ariadne study identified energy savings potentials in the building, energy industry, and industry sectors to be "[…] in principle sufficient to reduce the gas consumption up to the year 2025 to a level, which enables a high level of energy sovereignty and especially independence of Russian gas imports. For this, a clear trend change in the energy industry and in buildings is necessary, which could not realize demand reductions up to now" (Ariadne 2022, 3, own translation). The deficits of the existing energy efficiency and savings governance have been perceived as one of the weakest points of the German climate mitigation and energy transition policies (BMWK D 2022). Up to now, there is no binding target on energy efficiency, and it is unclear which institution bears the steering and coordination responsibilities for the implementation of cross-cutting saving policy packages to harvest the "low hanging fruits" of energy efficiency. With this background and due to pressure from the EU, an Energy Efficiency Law ("Energieeffizienzgesetz"/EEG) with mandatory targets and a comprehensive revision of the Buildings Energy Law ("Gebäudeenergie-Gesetz"/GEG) are under development, which might bring some progress in the near term. The government has implemented further plans with detailed measures (see below). The Ariadne Study noted that the extension of the life of the three remaining nuclear power plants up to April 2023 "[leads] to additional electricity exports and reduces the GHG-emissions, but contributes only marginally to gas savings in Germany" (Ariadne 2022, 2). Although the Ariadne Study focuses on the gas supply topic and does not discuss the implications of an ambitious reduction of the gas demand (30 to 50 % by 2030) for the existing gas infrastructure, the profitability of the gas grid, and the transition to a hydrogen economy, there is growing concern about the future of the gas grid within the community of many Municipal utilities in Germany (about 850). Municipal utilities are worried about whether gas grids "remain a business case" (ZfK 2023, February, 2). In the future, it appears clear that the fixed cost of the grid must be distributed to less gas supply, which would mean raising transmission fees. The question of blending natural gas with hydrogen or developing a special hydrogen grid is also being debated within municipal utilities (cf. ibid). Transformative planning has become an imperative for local and regional heat planning, and the task is accelerated by the energy/gas crisis.

3.3 Accelerated Deployment of Renewable Power

It is remarkable how the German government reacted to the energy supply and price crisis after 2/2022 by deciding on a very comprehensive package of measures to speed up the market introduction of Photovoltaic (PV) and wind. This move also implemented the government's plans from the coalition treaty of November 2021.

The German government has decided on dozens of specific measures to speed up the implementation of wind power (offshore/onshore) and of PV. Among others, the following key decisions are expected to help to boost the market deployment (BMWK B 2023):

- The newly introduced principle that "Renewable Energy (RE) is in the overriding public interest and serves public safety". This means that renewables will have priority over other interests when making weighing decisions. It is expected to increase the speed of planning and approval processes.
- In the case of PV-roof systems with fixed remuneration, the remuneration will be increased from up to 6.24 cents/kWh to up to 13.4 cents/kWh.
- Introduction of the 2 % area target for all federal states: states are obliged to make sufficient areas available for the expansion of wind energy on land.
- Wind and solar projects from citizen energy companies up to a size of 18 MW (wind) and 6 MW (PV-FF) no longer have to participate in tenders from 2023.
- The expansion targets for offshore wind energy have been significantly increased to at least 30 GW by 2030, at least 40 GW by 2035 and at least 70 GW by 2045 and are legally anchored in the Offshore Wind Energy Act (WindSeeG).

Despite the progress made in the deployment of renewable power, there are still challenges to overcome. The integration of renewable power into the grid and the need for energy storage solutions are major issues that require attention. Additionally, the future of coal-fired power plants needs to be addressed, as the government has set a goal to phase out coal by 2038 at the latest. This will require a significant increase in renewable power deployment and energy efficiency measures. The technical feasibility of transforming the power sector to 80 % renewables by 2030 and achieving a completely carbon-neutral electricity system by 2035 has been analyzed in a recent study by Agora Energiewende (2022), which was published in June 2022. The study evaluates the specific challenges associated with this transition, in accordance with the coalition treaty and the EEG 2023, and builds on the recent carbon-neutral scenarios for 2045. While the study could not address the specific additional challenges posed by the ban on fossil fuel imports from Russia, it is certain that the German government remains committed to the expansion plans for wind and PV, and considers energy sovereignty as a key factor in decarbonizing the economy.

The expansion of wind and solar PV must be given a much higher priority, combined with a paradigm shift in the development of power and hydrogen grids, and flexibility resources, if renewable energy is to cover 80 % of electricity consumption in Germany by 2030. Faster planning and approval procedures must also be established to facilitate this transition. The phase-out of coal and the establishment of a climate-neutral power system by 2035 will depend on the combination of 80 % renewable electricity and gas-fired power plants that increasingly run on renewable hydrogen. One of the biggest challenges to achieving a switch to green electricity in industry, buildings, and transport is the need for a coordinated strategy for electrolyzers, electric vehicles, heat pumps, and, in some cases, electrode boilers, which must be implemented from the outset. Additionally, this strategy must be supported by a reform of grid charges, the intelligent operation of distribution grids, and a comprehensive smart meter rollout. Figure 12 illustrates how the demand for green electricity is expected to accelerate due to the electrification of the transport sector (through battery electric vehicles wherever feasible) and the building sector, by promoting the market introduction of heat pumps.

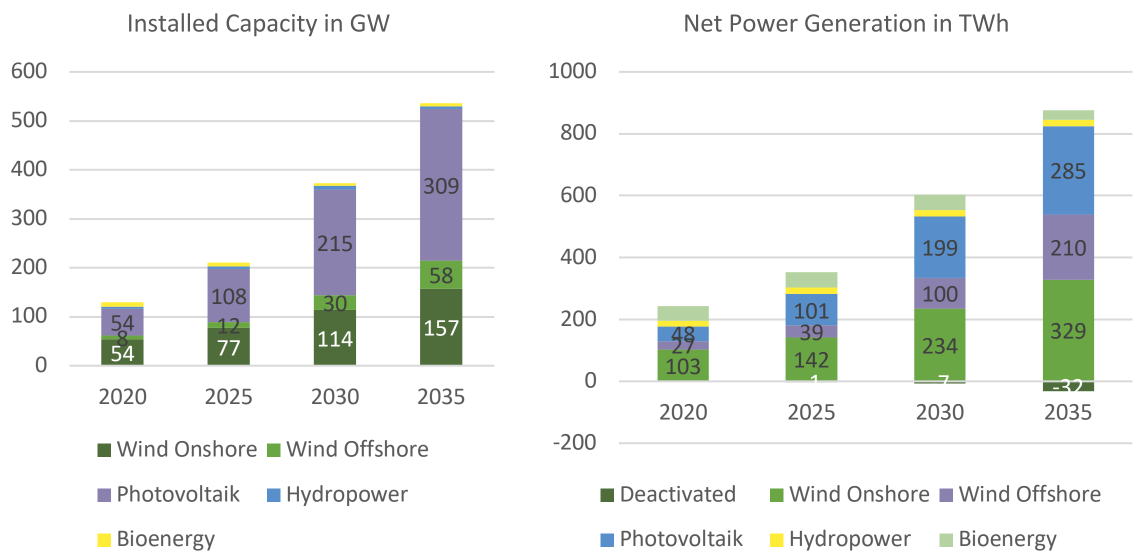
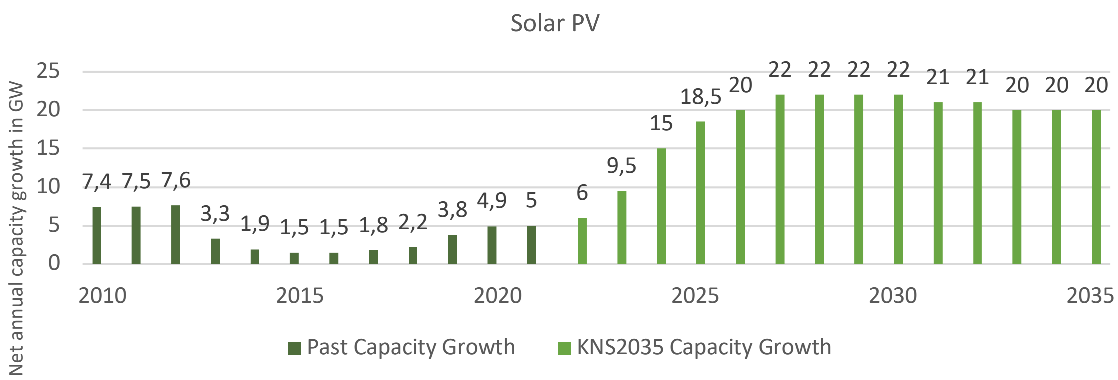


Figure 12: Installed capacity and net electricity production from renewable energy sources in the Agora-Study

Source: Agora Energiewende 2023, 23

Figure 13 illustrates compared to the past the unprecedented speed required for the yearly capacity increase of PV and wind up to 2035. Therefore, the question arises as to what extent this rapid increase could be facilitated by a targeted Energy/Electricity Savings Strategy and by initiating a supporting sufficiency policy to anticipate and, if possible, avoid rebound effects.



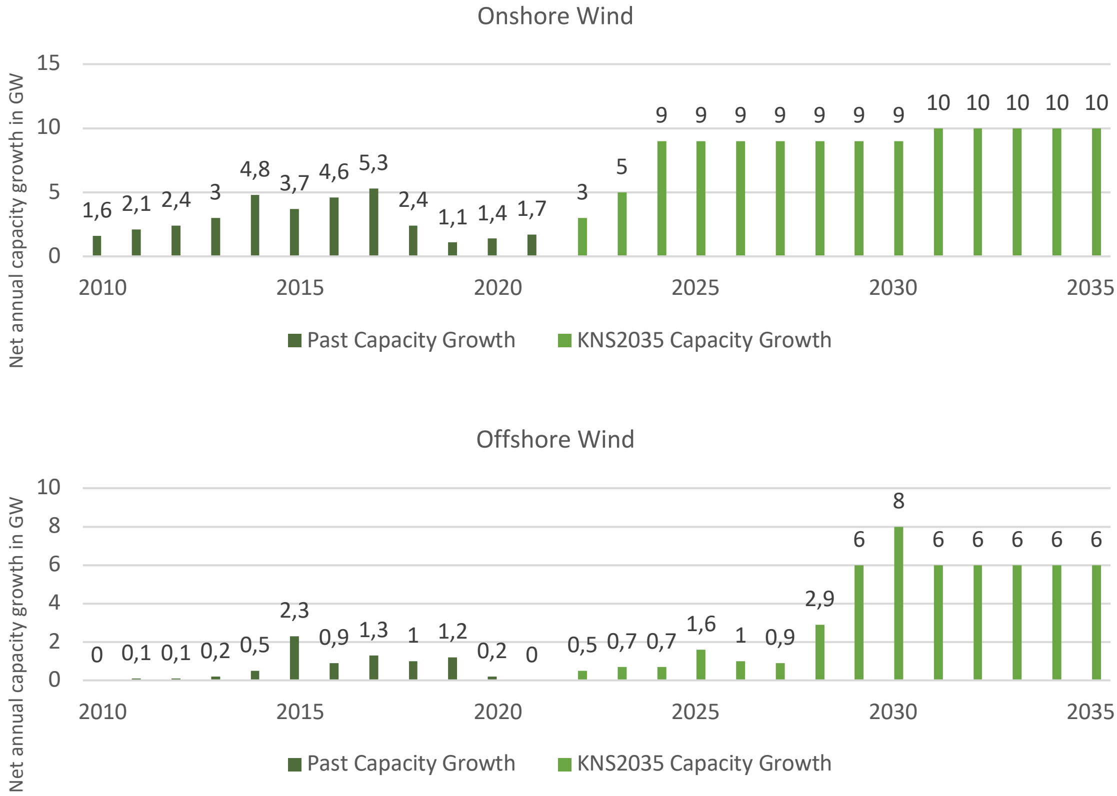


Figure 13: The necessary speeding up of capacity increase for wind and PV to meet EEG 2023 targets according to results of the Agora 2022 study

Source: Agora Energiewende 2023, 24

It is noteworthy that the Expert Council on Climate (2022) has identified electricity conservation as a special recommendation to the government (see below), but there is no public information available yet on whether the government is acting on these recommendations.

The Agora study found no fundamental objections to a high share of fluctuating PV and wind supply (see Figure 14) if dispatchable generation is used in combination with flexibility resources such as electricity and heat storage and demand-side management.

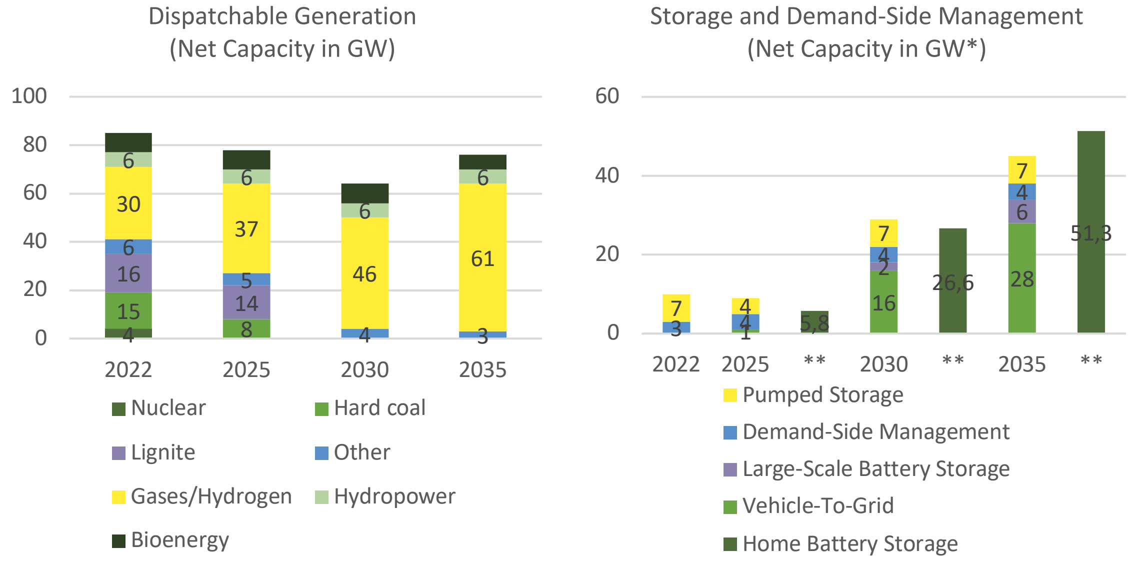


Figure 14: Dispatchable generation, Storage and Demand-Side Management

* Average storage capacity: battery storage = 1 hour, pumped storage = 8 hours / Demand-side management (DSM) = short-term loas shifting potential in industry / Vehicle-to-frid: battery-electric vehicles that can also feed into the power grid from their battery.

** Home battery storage systems are partially operated for self-consumption

Source: Agora Energiewende 2023, 38

As previously mentioned, the Agora study was conducted and published before the ban on Russian gas imports. Nevertheless, it is interesting to note how the study perceives the usage and conservation of gas. Agora confirms the energy conservation analyses of the Ariadne Study, demonstrating that it is feasible to reduce gas demand from 861 TWh to about 620 TWh by 2030 through energy efficiency alone. All sectors must contribute to these energy savings, but a key question remains unanswered: how can the existing energy efficiency potentials be realized in practice? Past monitoring studies have criticized the existing energy efficiency policy package for being insufficient to fully realize all cost-effective potentials. In addition, Agora highlights the important role of controllable gas power plants if they are constructed from the start to be "H_2-ready":

> "In 2035, 89 percent of renewable electricity is directly generated by renewables and 7 percent is generated in hydrogen power plants […]. To back-up this dependence on variable renewables, dispatchable gas-fired power plants are used in the 2030s to cover the residual load. Generation from these plants trends downward, from 107 TWh in 2030 to 86 TWh in 2035. In the climate-neutral electricity system of 2035, the installed capacity of gas-fired power plants doubles from 30 GW (2022) to 61 GW. Fossil gas is increasingly replaced by hydrogen, so that the share of fossil gas in electricity generation is only two percent in 2035. In 2030, electricity generation from hydrogen amounts to about 13 TWh. This will require 4 to 6 GW of hydrogen-capable power plants. In 2035, gas-fired power plants will generate 86 TWh of electricity. […] For the successful implementation of the energy transition, three ramp-up paths in the hydrogen sector are crucial and must be initiated immediately: hydrogen production; hydrogen-capable power plants; and hydrogen infrastructure. Starting now, new power plants must be 100 percent H_2-ready. To ensure that the production and consumption of the rapidly increasing amounts of hydrogen can be coordinated in terms of location and time, new hydrogen transport and storage infrastructure will be necessary. The options of using the hydrogen derivative ammonia in power plants must also be examined in order to counter shortages in hydrogen supply, as ammonia is particularly easy to import." (Althoff et al. 2022, 7)

In conclusion, the decarbonization of the German energy sector is a complex and multifaceted challenge that requires ambitious and coordinated efforts across all sectors. The initiatives outlined in this chapter represent important steps towards achieving Germany's climate goals, but further action and transformative planning will be necessary to ensure a successful energy transition. In the next section, we will examine sector-specific initiatives that aim to decarbonize other industries beyond the power sector, such as transportation and buildings. These sectors are essential for achieving the climate targets set by the German government, and there are already a variety of efforts underway to reduce their carbon footprint.

3.4 Other Sector-Specific Decarbonization Initiatives

In the context of the Expert Council on Climate's Biennial Appraisal in November 2022, it was noted that current emission reduction rates are insufficient to achieve climate protection goals by 2030 (ERK 2022). The Council recommends addressing changes in consumer behavior and rapid restructuring of capital stock to meet climate goals. This chapter highlights that sufficiency policies could be a valid and effective third pillar in combination with efficiency and renewables in decarbonization strategies. The aim of sufficiency policies is to enable and empower people to change their daily routines and practices towards more sufficient choices through adequate public and non-motorized transport infrastructures, energy-saving building technologies, and appliances. Sufficiency policies should be perceived as contributing to a better quality of life, especially for vulnerable households who suffer most from climate change but cause much less emissions (Chancel 2022). The Intergovernmental Panel on Climate Change (IPCC 2018) special report concerning a 1.5°C increase in global warming presents a noteworthy insight into the substantial impact of behavioral alterations and demand-side management as strategies for diminishing greenhouse gas emissions:

> "Political and financial stakeholders may find climate actions more cost- effective and socially acceptable if multiple factors affecting behavior are considered, including aligning these actions with people's core values […]. Behavior- and lifestyle- related measures and demand-side management have already led to emission reductions around the world and can enable significant future reductions […]. Social innovation through bottom-up initiatives can result in greater participation in the governance of systems transitions and increase support for technologies, practices and policies that are part of the global response to limit warming to 1.5°C." (IPCC 2018, 317).

Finally, the German Climate Protection Act has defined binding sectoral CO_2 reduction targets up to 2030, and it is crucial to create and implement action plans to meet these targets (Bundesregierung 2021).

3.4.1 The Transport Sector

The challenge of meeting emission targets in the car-oriented German mobility system has led to unresolved fundamental controversies about suitable countermeasures within the current Coalition of the SPD, Grüne and FDP parties. Traditionally, the German Ministry of Transportation is led by ministers from political parties that prioritize private car mobility, which is also true for the current FDP minister who advocates for the expansion of Autobahnen as a new planning priority, arguing that it lies in the overriding public interest. This planning principle would give the green light to an expansion plan for new and larger Autobahnen according to the current Federal Transport Route Plan ("Bundesverkehrswegeplan"). This "car mobility first" concept is fiercely opposed as outdated by the Green Party, NGOs, most transportation experts, and is not compatible with the binding targets of the Climate Law. "Germany does not need more motorways, trunk roads or airports per se [...]. This is in contradiction to the desired climate neutrality" (Bauchmüller, 2022)[2].

This dispute is not yet resolved (as of February 2023), and it presents an opportunity for Germany to learn from Japan, especially when it comes to public transportation and a rapid train system like the Shinkansen. However, transforming the transportation system to a decarbonized and more equitable system of "Sustainable Mobility for all" (Hennicke et al., 2021) is a highly complex undertaking in Germany. Therefore, this topical paper will not expand further on the topic of transportation. With the background of this paper analyzing the impact of the energy crisis, this seems justified for Germany, as the energy price and supply crisis only partly affected the transport sector. From April 2022 (all-time high 2,27 €/l), to October 2022 (1,78€/l) and January 2023 (2,03 €/l), the German gasoline price fluctuated, and the state offered a fuel discount, moderating the impact of the energy price crisis. However, it should be noted that decarbonizing the automobile sector in Germany is entirely guided by the concept of e-mobility wherever possible. Thus, the additional green electricity needed to decarbonize the transportation sector depends on the future role that individual automobility should and can play, as there are many interlinkages within the context of sector coupling. In general, two contradictory approaches are competing: It is anticipated by some that there may be an increase in the quantity of automobiles (48.5 million in 2022), the average weight (trend to SUVs), and the increasing average horsepower (for new cars between 200-250 in 2022) (Furman 2022) in the future, if the fleet is powered with green electricity. The German Environment Agency argues that by enabling more sustainable transportation modes (e.g., public transportation, bicycle, sharing), the fleet can be halved and must be downsized to be in line with climate mitigation and resource protection targets. Compelling evidence and reasoning have been presented to support the assertion that, not only concerning climate mitigation but also area conflicts (protecting the countryside and raising the quality of life in cities), the guiding principle of "Sustainable Mobility for all" could gain more public acceptance than an "all electric car" strategy (Hennicke et al. 2021).

Overall, the transport sector in Germany faces complex challenges in its transformation to sustainable mobility, and finding suitable solutions will require cooperation and innovation from various stakeholders.

3.4.2 The Building Sector

According to the monitoring report on the development of CO_2 emissions in the building sector, "[F]inal energy consumption in the building sector increased by 4.2 percent in 2019 compared to the previous year. It has fallen by an average of 1 percent per year since 2008. The savings target for 2020 (minus 20 percent) will therefore not be achieved" (BMWi 2021, 7). As of 2021, this discrepancy remains unaddressed; however, the Expert Council on Climate Issues (Expertenrat für Klimafragen) expresses an increased degree of optimism regarding the potential transition towards a CO2 reduction strategy within the building sector. An emergency program became necessary

[2] own translation of Dirk Messners quote in Bauchmüller, M. 2022

because the emissions from the building sector in 2021 exceeded the permitted annual emissions by two million tons of CO_2 equivalents (115 Mt CO_2 eq. instead of 113 Mt CO_2 eq.).

Figures 15 and 16 illustrate the implications of aligning the building sector with a comprehensive decarbonization approach, extending through to the year 2045. Both figures have been sourced from the work of Prognos, Öko-Institut, and Wuppertal Institut (2021), which modelled a comprehensive decarbonization strategy by 2045. The message is straightforward and has not changed since the energy crisis: gas and oil have to be substituted by 2040 at the latest through energy efficiency, reducing the heat demand, and supplying a growing share of heat by heat pumps with green electricity and green district heat. Although policies and measures addressing the rapid transformation of the heat market as a response to the energy supply and energy price crisis are not yet as comprehensive as in the energy sector, important steps have been decided that might speed up the transformation process.

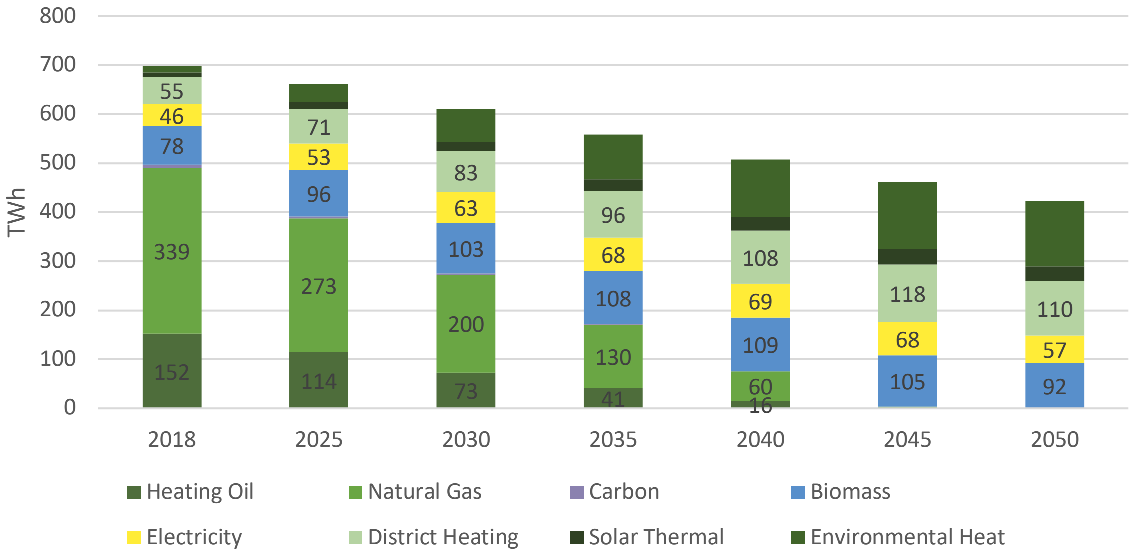


Figure 15: The building sector: Final energy demand and supply for heat in a 2045 net zero scenario

Source: Prognos/Öko-Institut/Wuppertal Institut 2021

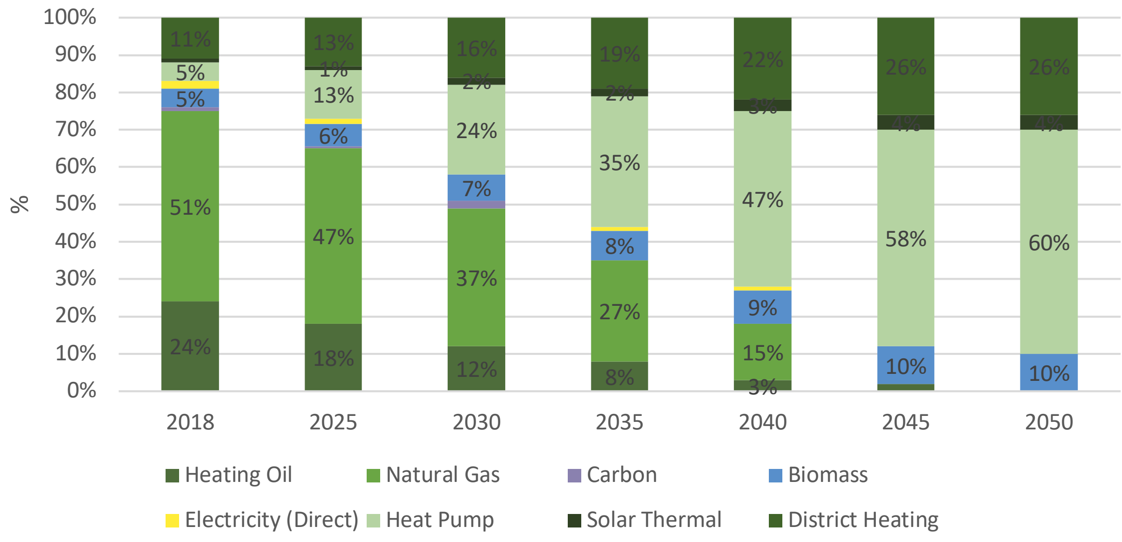


Figure 16: Heating structure of the living space

Source: Prognos/Öko-Institut/Wuppertal Institut 2021

Below are some key measures that the government has decided to speed up the energy transition in the heat sector. It is apparent that these are important announcements to reduce CO_2 emissions in the heat sector. But compared to the power sector, there is neither a comparable ambitious target setting up to now, nor a clear Action Plan on how these measures can work together to get the building sector back on the CO_2-reduction path (cf. forthcoming GJETC Building Study 2023)

1 | 1st Amendment of the Building Energy Act (GEG)

Among other things, the GEG amendment is intended to stipulate by law that from January 1, 2024, every newly installed heating system should be operated with 65 % renewable energy if possible. According to the coalition agreement, the new building standard is to be adjusted to the EH40 standard from 2025 (BMWSB, 2022).

2 | Federal Funding for Efficient Buildings (BEG)

The guiding principle for the realignment of the BEG is to ensure that the building stock will be climate-neutral by 2045. The current renovation dynamics should be maintained. The government plans to spend 12 to 14 billion Euros per year on financial support for building energy renovation and green heating systems until 2026.

3 | Guideline for the Funding of Pilot Projects for Serial Refurbishment and Accompanying Measures

Serial renovation is an innovative method for building renovation that has been funded since May 7, 2021: With prefabricated roof and facade elements, including the associated system technology, buildings are to be renovated quickly and with high quality in terms of energy efficiency.

4 | Initiative Public Buildings

A new measure to increase the refurbishment rate for all public buildings is intended to achieve a higher ambition level of

5 | Redevelopment of Municipal Facilities in the Areas of Sport, Youth and Culture

With a federal program "Renovation of municipal facilities in the areas of sport, youth and culture", municipal facilities in the areas of sport, youth and culture are to be promoted with high quality in terms of their energetic effects and adaptation to climate change.

6 | **Zukunft Bau - Model Project for Innovation in the Building Sector**

The Zukunft Bau funding program supports model projects that test promising research and development solutions in practice.

7 | **Federal Funding for Efficient Heating Networks (BEW)**

The BEW provides incentives for the conversion of predominantly fossil heating networks to renewable energies and waste heat, as well as the construction of new heating networks with at least 75 % feed-in from renewable heat and waste heat.

8 | **Municipal Heat Planning Act**

A federal regulation is planned to introduce municipal heating planning (KWP) in a timely and effective manner with a view to climate targets. The exact design of the federal regulation on the KWP is currently still open.

9 | **Heat Pump Development Program and Qualification Offensive**

Heat pumps are a key technology in the heating sector due to their high degree of efficiency and potential greenhouse gas neutrality. However, there is a widespread shortage of skilled workers, which must be countered with a comprehensive training concept.

10 | **Optimization of Existing Heating Systems**

Various regulatory implementation options beyond funding are currently being developed and discussed. The aim is to promptly initiate an optimization of existing heating systems.

11 | **Energy Efficiency Act (EnEfG)**

The Energy Efficiency Act creates a cross-sectoral legal framework for increasing energy efficiency is created for the first time, laying down the ambition level of the Climate Protection Act for energy efficiency.

Despite these efforts, conflicting developments have occurred, as demonstrated by the fact that in 2022, while the heat pump market grew strongly with just under 230,000 heat pumps sold, an estimated 600,000 gas boilers and 50,000 oil boilers were also sold. With normal lifetimes of 20 to 30 years, many of these boilers would still be in operation in 2045. To address this issue, the government, the heating system industry, and the installation business have recently agreed to work together to achieve 500,000 heat pump installations in 2025. Further increasing numbers will be needed in the years thereafter to achieve the target of 6 million heat pumps in 2030.

In summary, the building sector's decarbonization is a highly complex undertaking that requires comprehensive efforts and cooperation between different stakeholders. The government has taken several measures and enacted policies to speed up the energy transition in space and water heating, such as the 1st amendment of the Building Energy Act, federal funding for efficient buildings, funding for pilot projects for serial refurbishment, and municipal heat planning act. However, more ambitious targets and a clear action plan are still needed to bring the building sector in line with a decarbonization strategy up to 2045.

3.5 How Much Additional LNG Terminals and Capacity is Needed?

Until February 2022, various climate protection scenarios assessed how to achieve the 2045 decarbonization target in Germany. However, the global energy and supply crisis triggered by the

Russian aggression against Ukraine presented a new challenge to the continuity of the previous scenarios. These scenarios included natural gas as a “bridge” to decarbonization, along with the expansion of renewable energies and increased energy efficiency. To safeguard national energy sovereignty and supply security the German government temporarily put 2 GW coal-fired power plants back into operation, extended the service life of the last three nuclear power plants, and purchased expensive natural gas to fill gas storage for the winter of 2022/23.

However, the government's most important short-term supply-side decision was to compensate for the loss of Russian pipeline gas volumes by stepping up entry into the international LNG market and building its own LNG terminals. As of December 2022, 11 import terminals are planned in Germany, 7-8 of them being floating FSRU terminals and three large terminals on land. The FRSU terminals are expected to be operational by the end of 2023, while the land terminals are expected to be launched in 2025-2027. The following list provides an overview of the planned LNG terminals' locations and capacities.

Table 1: Overview on the planned LNG-Terminals in Germany, status dec. 2022

FSRU- Terminals (dez. 2022 – dez- 2023)

Name	Operator	Capacity
FSRU Wilhelmshaven 1	Uniper	7 bcm
FSRU Wilhelmshaven 2	TES / Eon	5 bcm
FSRU Wilhelmshaven 3	NOW	Unclear
FSRU Strade	Hanseatic Energy Hub	5 bcm
FSRU Brunsbuettel	RWE	5 bcm
FSRU Lubmin 1	German ReGas	5 bcm
FSRU Lubmin 2	German ReGas	7 bcm
FSRU Lubmin Investments	RWE / Stena Power	5 bcm
Land Terminals (2025-2027)		
Land terminal Wilhelmshaven	Tree Energy Soluctinos (TES)	16-20 bcm
Land terminal Strade	Hanseatic Energy Hub	13 bcm
Land terminal Brunsbuettel	Gasunie	8 bcm

Source: Energy Comment, 2023

The planned capacity of all the LNG terminals in Germany adds up to at least 73-76 bcm, which is significantly higher than the 46 bcm imported from Russia before the war. Before the onset of the conflict, approximately 97% of Germany's natural gas imports originated from Russia, Norway, and the Netherlands. However, the Netherlands has now become a net importer of natural gas.

A current discourse persists regarding the adequacy and reliability of the natural gas supply chain to Germany. Methane emissions from the gas sector contribute significantly to climate change. Energy Comment (2023) recommends that German gas importers and their suppliers should reduce their methane emissions by using certified suppliers and transparent documentation of their supply chains. According to Energy Comment, Norway has the most sustainable supply chain to Germany, followed by certified gas from the USA and then Qatar. There are four key questions surrounding Germany's decision to import LNG: 1) How will the international LNG markets and geopolitical supply conditions be impacted by the energy crisis? 2) Where will the additional LNG imports come from, and what is the climate impact of these supplies? 3) Could new LNG terminals become stranded assets? 4) What are the technical and economic considerations for converting LNG terminals to use liquid hydrogen or green ammonia?

The USA is expected to supply a large share of European and German LNG imports. Figure 17 demonstrate that natural gas from the USA is likely to substitute for Russian imports under both low and high gas demand projections.

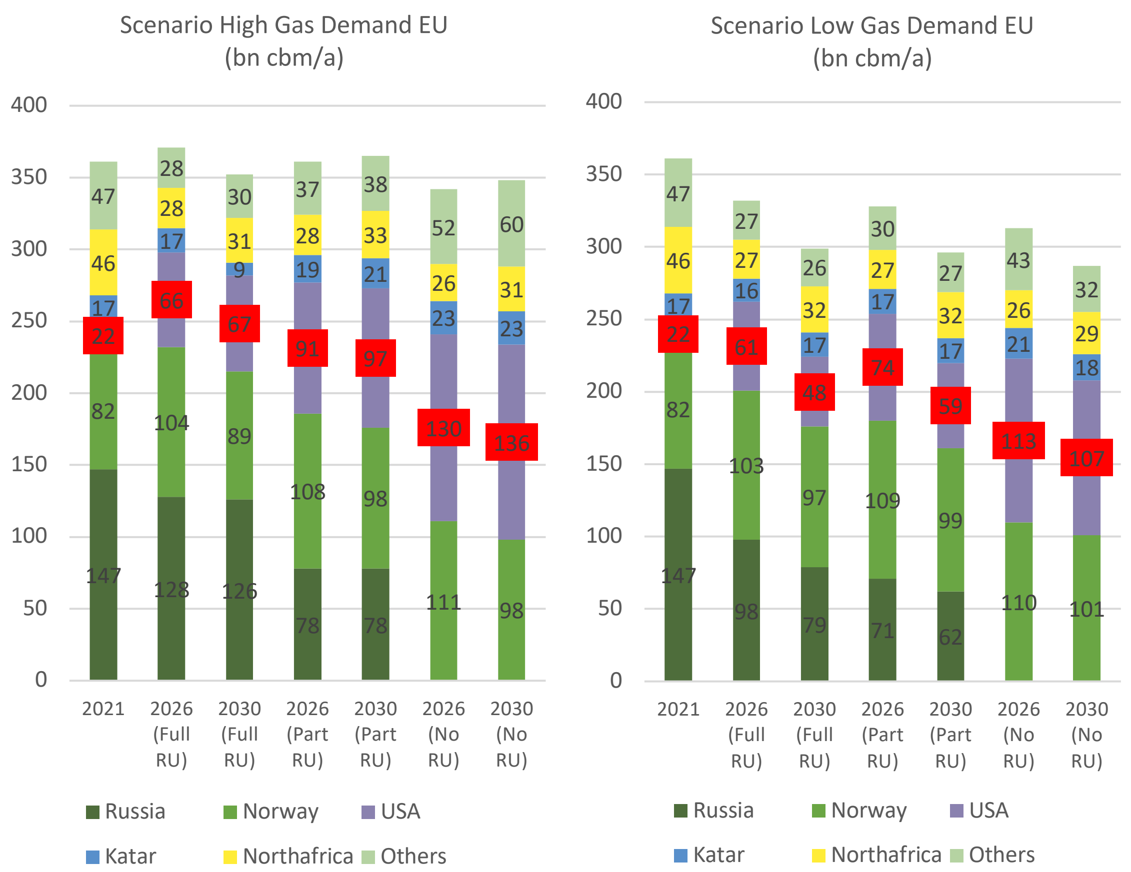


Figure 17: Gas impot scenarios of the EU: Predicting the USA as major supplier by 2030

Source: Cam et al. 2022, 5

A recent study of the New Climate Institute (2022) questions the necessity of planned LNG terminals in Germany, as gas consumption will need to be further reduced to achieve climate neutrality. The study suggests that if all gas savings potentials were used, a FSRU capacity of around 30 billion cubic meters would be sufficient in 2025 (cf. Figure 11 of Ariadne 2022). The risk of stranded assets and fossil fuel lock-ins from overcapacity of LNG terminals could be reduced by planning for conversion to climate-neutral energy carriers from the beginning.

In summary, the integrated decision of the German government to combine ambitious climate mitigation with security of supply raises important questions regarding the quality of LNG supplies, the risk of stranded assets, and the feasibility of terminal conversion to climate-neutral energy carriers.

3.6 New Industrial Policy Initiatives to Mitigate the Energy Crisis and Climate Change

Chapter 3.6 discusses the influence of international climate policy developments, particularly the Inflation Reduction Act (IRA) of the US, on European and German decarbonization strategies. While the IRA is estimated to reduce domestic GHG gas emissions, concerns have been raised in Europe over its "Buy American" features, which may contravene international trade rules and discriminate against foreign producers. This has led to calls for a strong European response, possibly including EU subsidies, which could create trade tensions and a subsidy race. However, the IRA also signals a possible paradigm shift towards transformative supply policies and massive reduction of CO_2 emissions in the basic industry with state aid.

3.6.1 The Inflation Reduction Act and the EU

The decarbonization strategies of Germany and Europe are strongly influenced by international climate policy developments, particularly those from the United States, and most recently by the decision on the Inflation Reduction Act (IRA 2022). While the IRA is welcomed for putting the United States on track to achieving its 2030 Nationally Determined Contributions (NDCs) and reducing domestic greenhouse gas (GHG) emissions by an estimated 40 % by 2030 (from 2005 levels), there is growing concern in Europe regarding certain "local content requirements" (e.g., for electric vehicles and clean energy technologies) and subsidies that may contravene international trade rules and discriminate against foreign producers by favoring US companies (E3G 2022, 2ff). It has been argued that the IRA's nationalist "Buy American" and trade-restricting features had to be accepted as an inevitable compromise due to the weak majority of the Democrats, complicated bargaining within the party, and necessary alliances with labor unions. Nonetheless, French President Macron and German Chancellor Scholz are calling for a strong European response, which could include the EU ramping up its subsidies. President Macron has repeatedly called for a ‘Buy European Act’, citing a possible EUR 8 billion loss in green investment due to the IRA (ibid, 8).

The conflict may lead to a subsidy race between wealthy regions like the EU and US, creating a massive barrier against fair global competition with highly negative effects on countries of the Global South, which lack the resources to subsidize clean industries. The E3G study points out that these possible trade tensions between the US and EU underscore "the need for a green overhaul of rules in the international trade regime" (ibid, 14). The G7 suggestion of a Climate Club (G7 Germany, 2022) might be a suitable forum to settle these trade conflicts. The impact of the IRA and accompanying bills in the US goes beyond trade and competition. It also signals a possible paradigm shift of economic policies. The Chips and Science Act (The White House 2022), a new US legislation to expand the US semiconductor sector against Chinese dependence with $280 billion, was reported under the heading "Why industrial policy is back." In the EU, investment funding in the NextGeneration EU Recovery Plan and the conceptual ideas behind the European Green Deal are leading in a comparable direction. Recently, German Minister Habeck used the term "Transformative supply policies." This means targeted and massive reduction of CO_2 emissions in sectors of the basic industry with state aid to enable investments in sustainable decarbonization technologies that are not yet profitable on the market.

3.6.2 The EU "Green Deal Industrial Plan"

On May 18th, 2022, the European Commission published its immediate response to reducing dependence on Russian fossil fuels through the REPowerEU plan (EUC 2022). This plan builds on the Fit for 55 package of proposals and completes actions on energy security of supply and storage. The plan proposes a set of actions that include saving energy, diversifying supplies, quickly substituting fossil fuels by accelerating Europe's clean energy transition, and smartly combining investments and reforms. In this context, the activities can be summarized under a comparable heading like the German reaction: accelerated replacement of imported fossil fuels and diversifying the supply. For example, the energy efficiency target by 2030 was proposed to be increased by 4 %, and the renewable target by 5 %, both increases compared to Fit for 55.

On February 1st, 2023, the European Commission released its "Green Deal Industrial Plan" (cf. EC A 2023) "[…] to enhance the competitiveness of Europe's net-zero industry and support the fast transition to climate neutrality. The Plan aims to provide a more supportive environment for the scaling up of the EU's manufacturing capacity for the net-zero technologies and products required to meet Europe's ambitious climate targets." (EC B 2023). This initiative is a response to the Inflation Reduction Plan (IRA) of the USA, but it is formulated politely. The Commission lists batteries, wind power plants, heat pumps, solar, electrolyzers, and CCS among the technologies that will be targeted. However, the precise product scope remains to be defined, taking technology neutrality as a starting point, and building on an assessment of strategic importance and identified needs of manufacturing investment in different types of net-zero products. Thus, many highly debated topics between EU member states are excluded up to now by this footnote. For example, Nuclear Europe immediately welcomed the "principle of technology neutrality" and pointed out the EU Sustainable Finance Taxonomy, which includes nuclear and natural gas up to now. Nine EU countries wrote a letter to the European Commission demanding technology neutrality, which, in this case, means equal incentives to be set for both renewable and low-carbon hydrogen, proposed to be produced by nuclear. Certain nations have expressed concern over the lack of a systematic emphasis on energy efficiency within the discussed context as a significant risk to the overall success of the plan or the possible detrimental effects of national subsidies schemes on the cohesion of the EU. Specifically, France and Germany were mentioned, which might benefit from relaxed EU state rules on subsidies at the expense of poorer member states with limited resources to subsidize their industries. To enable these member states to support net-zero technology investments, the European Commission proposed a new European Sovereignty Fund as part of the Green Deal Industrial Plan.

3.7 Summarizing the German/EU Crisis Response

The main developments and paradigm of the German/EU response to date can be summarized as follows:

- The basic medium-term strategy of Germany and the EU against the energy crisis is to accelerate climate mitigation actions such as energy efficiency, renewable electricity, electrification of end uses, and green hydrogen, both domestically and in supply chains for imports.
- The strategy aims to achieve strong synergies between energy security and climate mitigation.
- The German government expects power generation to be nearly 100 % supplied by renewable energies in Germany by 2035.
- As a consequence of this strategy, natural gas demand may decrease by up to 50 % by 2030, and coal phase-out may be accelerated ideally to 2030.
- However, there is no strategy yet for energy efficiency and sufficiency policies to maintain the level of energy savings achieved in the winter of 2022/23, such as with 20 % of gas savings.
- Supply of natural gas, oil, and coal has started to diversify since the summer of 2022, replacing almost all imports from Russia by now.
- The LNG import infrastructure has been considerably expanded. However, the capacities planned for installation during the next five years are higher than the historic level of imports from Russia, which is not consistent with the strategy to reduce gas consumption, and may lead to significant import capacity reserves or stranded investments.
- The budget committee of the German Bundestag has requested the government to estimate future gas demand to avoid unnecessary costs to taxpayers.
- The EU and the German strategies against the energy crisis are focused on maximizing synergies between energy security and climate mitigation, but debates among member states about using nuclear energy or questioning the ambition level of decarbonization of the building stock and transportation sector are ongoing.
- In Germany, the debate on speed, necessary public financial support, transformative governance, and needed workforce for decarbonizing buildings and transportation is intensifying.
- Successful implementation processes towards net-zero require courageous target setting by governments, transparent decisions according to the guideline of a "just transition," positive narratives of the common transformation goals, and public participation at all political levels to explain the necessity of climate mitigation strategies and gain public support and the majority of voters.

In 2023, political debates and decisions will be crucial in setting the course for a pathway that achieves synergies between energy security and climate mitigation. The EU often plays a leading role in driving dialog and political processes on these synergies, but debates among Member States and within Germany continue.

4 Comparison of German-Japanese Crisis Management Paradigms

On the way to carbon neutral societies, Germany and Japan face common and differentiated challenges, such as:

- Both countries have low energy self-sufficiency rates, and the path to a carbon-neutral society should prioritize exploiting national potentials for energy and resource efficiency, and renewables to strengthen national energy sovereignty.
- Germany, connected to its neighbors by land, can import and exchange a wide variety of energy, while Japan has to rely on commodity imports by ship which gives less flexibility in term of transaction amount and no power trade is possible with neighborhood countries.
- Both countries are confronted with future challenges of rising shares of imported hydrogen and derived synfuels, the need to diversify H_2-suppliers, and to decarbonize hydrogen as quickly as possible.
- There are also differences between the two countries in terms of their current policies for achieving carbon neutrality. Germany focuses on the reduction of fossil fuels by renewables and energy conservation, while Japan seeks for a variety of other zero-carbon fuels, like nuclear or ammonia, and sees a need for direct or indirect use of significant amounts of fossil fuels, which puts a higher priority on CCUS. However, policies and programs that overlap in terms of the decarbonization strategy can be identified in both Japan and Germany (as well as in the EU).

Table 2 summarizes similarities and differences between Germany and Japan regarding their strategies against the energy crisis. Japan places the highest priority on energy conservation and renewables, just like Germany. But by considering the short-to mid-term necessity of fossil fuels and challenges of significant improvement of energy efficiency and limited potential of renewable supply, Japan is also planning to continue using fossil fuels directly (with CCUS) or through imports of blue hydrogen or ammonia, and therefore needs a strong “decarbonization of fossil fuels” strategy. In addition, Japan seeks for utilizing nuclear power as a substitute for fossil power generation. Germany (like the EU) is more focused on the accelerated reduction of fossil fuels by renewables and energy conservation. Induced by the energy crisis, In Germany and the EU, the ambition in the targets for energy efficiency and renewables has even been increased, aiming for synergies between energy sovereignty and climate mitigation. However, on the other hand, steps have been taken for the massive expansion of LNG terminals and for diversification activities with regard to fossil energy supply sources, which raise questions of climate-relevant lock-ins and of compatibility with the climate protection goals.

On the surface, the strategies of Japan and Germany appear to be very different, but it could be argued that, in reality, there are more common challenges. Firstly, both countries put priority on energy and resource conservation as well as the supply of renewable energy sources. Secondly, both need to use fossil fuels as a transitional pathway to a carbon neutral society, and thus have to take actions to ensure security of supply. One difference may lie in whether or not there is confidence for building the future energy system completely based on energy conservation and renewable energy, and hence the duration of the use of fossil fuels as a transitional pathway. This different perspective may be due to the geographical and geopolitical conditions in which both countries find themselves. With regard to current policy priorities, there is a clear difference concerning the role of nuclear energy.

Questions remain on whether and how Germany (the EU) can achieve ambitious climate protection goals primarily based on renewable energies and energy efficiency under changed geostrategic conditions. Japan faces the challenge of developing a decarbonization path under the special conditions of an island state that generates minimal risks in the long term and is prepared for competition on global GreenTech lead markets for renewables and energy efficiency (BMUV 2021).

Similarities	Differences

• High energy prices
• Mid-century net-zero targets
• Finding ways forward to reach net-zero targets specially beyond 2030
• Promote energy and resource conservation
• Promote renewable energies
• Limited domestic resources compared to demand. (import dependence)
  ○ Feedstock, synthetic fuels, renewable resources (energy carriers*) * hydrogen, ammonia, etc.
• Focus on recycling
	• Physical connections to other countries
	  ○ Germany: Power grid, pipelines
	  ○ Japan: No connections. Transport by ship.
	• Dependence on Russian gas (before crisis)
	• Energy mix and scenario by sector
	  ○ Germany: Strong emphasize on Res
	  ○ Japan: Various zero-carbon energies including decarbonized fossil fuel and nuclear power

Table 2: Similarities and differences between Germany and Japan

5 Recommendations

Heading for the highly ambitious goal of carbon neutral societies, Germany and Japan need to work together, learn from each other, and understand each other's strengths and weaknesses. Based on the similarities and differences between Germany and Japan and comparing the strategies against the energy crisis, there are research questions which should be addressed jointly:

1 | Which national technical and cost-effective potentials for energy and resource conservation and renewables exist under sustainable framework conditions and resource restrictions, and how fast can they be implemented by specific policy priorities?

2 | How far do changes in social practices of using energy but also growth/rebound effects have an impact on the amount and the quality of energy consumption and what role can sufficiency policies play?

3 | What are the pros and cons of options to replace fossil fuels in both countries, and what import strategies especially for green hydrogen and derived fuels can ensure economic and environmental performance?

4 | If there is a need for short-term investments in fossil fuel infrastructure, can it be constructed convertible into infrastructure for hydrogen and derived fuels? To which extent will there be a need for decarbonization of fossil fuels in the medium term, to achieve long-term climate goals?

5 | According to several studies (UNEP 2020; Pauliuk 2021; Acatech 2021), ambitious climate mitigation targets can be reached easier by integrating Circular Economy strategies. How can this policy integration be adopted in both countries?

6 | How can the structural economic change and the developments of technologies, systems, infrastructure, etc. for carbon neutrality be accelerated and how can it be managed as a just transition and accepted by the broad public?

7 | Can the gap between government climate mitigation targets and their achievement in reality be closed by legally binding targets and stronger governance, and what specific actions and management tools are needed up to 2030 and beyond?

While analyzing and comparing these national options and actions for both countries, the global frame conditions, technology markets, and trade agreements should be considered. For example, renewable energies and batteries are being developed around the world, and their costs are falling rapidly. Energy carriers such as hydrogen and synthetic fuels are closely related to renewable energies, so it is important to approach national potentials and relations to import/export countries and regions proactively by an ecological industrial policy.

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