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An Examination of Germany's Transition to a Low-Carbon Future

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ABSTRACT

Germany's image as the leader in green energy and the creator of "*Energiewende*" (energy transition) is under siege. According to a recent study, the self-committed goal to reduce carbon emissions by 40 percent by 2020 will likely be missed. This potential shortcoming does not come as a surprise to Germany and has been an intensively discussed issue for many years. Does this mean the end of Germany's energy transition? This paper analyses the energy-supply aspect and provides a German perspective to the issue. It offers an insight into the remaining challenges and a historical explanation as to why this glitch might even foster the process.

INTRODUCTION: 'ENERGIEWENDE'

Introduced in 2000 by the coalition of Social Democrats and Greens (1998–2005), *Energiewende* became the blueprint for Germany's ambitious energy policy goals towards "an environmentally sound, reliable and affordable energy supply."[1] *Energiewende* was first used in a

publication of the German Institute of Applied Ecology in the 1980s. It described how growth could be decoupled from energy consumption[2] and offered an alternative to "Limits of Growth," published in 1972 by the Club of Rome. With its energy policy statement in September 2010[3] and the resolutions on accelerating the energy transition in summer 2011, it entered first national and then international policy discourses. The goals are based on a paper published by the government in 2007. Priority measures include the expansion of renewable energy, decentralised power generation, intensified development of electricity grids, and higher energy efficiency.

Table 1.

	2020	2030	2040	2050
Nuclear Power	*exit*			
Increase in share of **renewables in gross final energy consumption**	18%	30%	45%	60%
Increase in share of **renewable energy in gross electricity consumption**	35%	50%	65%	80
Reduction of **greenhouse gas emissions** (compared to 1990)	–40%	–55%	–70%	–80–95%
Reduction of **primary energy consumption**	–20%			–50%
Reduction of **electricity consumption** (compared to 2008)	–10%			–25%
Reduction of **heating demand in buildings**	–20%			–80%
Increasing **energy productivity** to 2.1 percent per year in terms of final energy consumption				

Source: German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety.[4]

These policies, however, seem unrealistic, especially considering that Germany, one of the world's economic powerhouses, generates only 30 percent of its energy with internal resources.[5] Germany is highly dependent on imported raw materials to run its export-oriented

industry. In 2016, the country imported 98 percent of its mineral oil, 92 percent of its gas and 93 percent of its hard coal to produce its total energy,[6] a historic fact due to the tension between energy-intense industries on the one hand and low natural resources on the other. In 1961, the first nuclear power plant was established, and this technology seemed to offer a solution for issues concerning both national security and reliable energy for a flourishing industry.[7] However, following the incident involving the nuclear reactor in Fukushima in Japan, the future of this technology was officially buried.

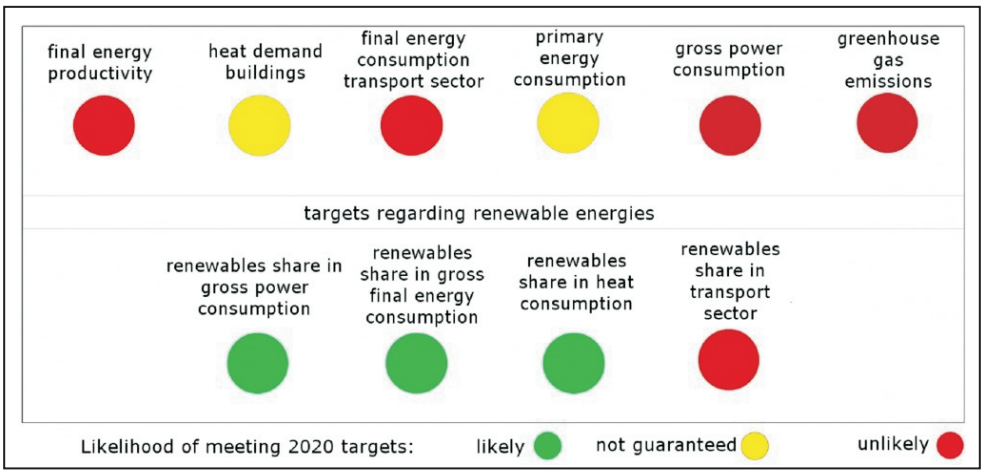
Today, the global trend seems to point in the reverse direction. According to the Global Coal Exit List, over 400 companies worldwide are planning to expand their coal activities. More than 1,600 new coal plants and units are planned or under development in 62 countries.[8] If built, these new plants would increase the world's installed coal capacity by over 42 percent.[9] The same trend is observed in nuclear energy. About 440 nuclear power reactors are currently operating in 30 countries, and 50 new power reactors are under construction in 13 countries, notably in China, India, UAE and Russia.[10] Most reactors currently planned are in the Asian region, with fast-growing economies and rapidly rising electricity demand. In all, over 160 power reactors are on order or planned, and over 300 more have been proposed.[11]

While the rest of the world might be ramping up conventional sources of energy, Germany strives for the opposite. There are three aspects to be conceded, which offer both critics and supporters of the energy transition a viable argument:

1. Against many critical voices, Germany has exceeded its planned capacities in renewable energy.
2. Several targets such as energy productivity, consumption and share of renewables in the transport sector have not been met.

3. The central goal of a 40-percent reduction in GHG emissions until 2020 will not likely be met due to the current gap between quota and target.[12]

Figure 1: Overall Assessment by Expert Commission on Meeting 2020 Targets



Source: Monitoring Report 2016/cleanenergywire.[13]

In a 2014 survey, Indian experts described *Energiewende* as "extraordinary, [...] setting benchmarks worldwide" but also acknowledged that "Germany is implementing its transition at an unusually quick pace."[14] The German public, on the other hand, sees *Energiewende* as an unavoidable and necessary step. The current progress is perceived as unsatisfactory, with plenty of room for improvement: 88 percent of the German public supports the energy transition and is critical of the foreseeable failure to meet the 2020 emission goals. Most supporters of all parties represented in the German Parliament back this project. Even among the 77 percent of people who are sceptical about climate change, *Energiewende* and its 2050 goals[15] are not questioned. Around 63 percent of the whole population advocates for an exit from lignite, the largest contributor of GHG emissions in Germany.[16] A study initiated by the German Industry Federation (BDI) has concluded that the 2050 goals might be realistic if political engagement is intensified.[17]

In 2011, the German Advisory Council on the Environment (SRU) ran eight scenarios and came to the conclusion that a transition to 100 percent renewable energy by 2050 is possible.[18]

In this context, the following questions must be answered:

A) How can the establishment and strong public support of *Energiewende* be explained and why is a roll-back unlikely to happen?

B) What is the status quo, the dependencies and developments in the European and global context?

I. From Bottom-up to Brussels-down

A. Environmental Awareness

Germany's decision to leave the nuclear age behind and progress into a carbon-neutral future at the same time was, and still is, hard to understand for observers from abroad. While historically, the shift from one dominating power source to another—coal to fossil fuels—was initiated and driven by economic and rational reasons, *Energiewende* and the transition to renewables was born out of an emotional and moral civil movement against a rational and empiric global mainstream.

The roots of German environmental awareness go back to 1713, with the creation of the first comprehensive treatise on sustainable forestry.[19] Later in the mid-19th century, when side effects of the industrial revolution surfaced and the effects of industrialisation on societal changes and pollution materialised, nature became a central theme in philosophy, art and science. Consequently, several foundations, institutions and policies were established over time.[20] The 1960s and 1970s were dominated by the global environmental discourse. The first global oil crisis in 1973 made the dependence on

fossil fuels as well as the absence of road traffic obvious for every citizen: when private transportation was temporarily banned to save fuel, it led to empty streets and clean air but also to a restriction in personal freedom. Growing environmental awareness, together with the anti-nuclear movement, shaped national and European policies. It carried the progressive-left Green Party first into a state Parliament (1979/80)[21] and later into federal Parliament (1983).[22] Environmental policies became both an issue and an asset. Chancellor Helmut Kohl declared in 1982, "...Environmental protection is, in addition to the prevention of armed conflicts, the most important task of mankind in the coming years."[23] Later, his traditional and centre-right party, CDU, passed the Feed-in Act, 1991, which was the first feed-in tariff for renewables worldwide.[24]

The nuclear accidents of Three Mile Island (1979) and Chernobyl (1986) had considerable influence on public opinion in Germany. The latter resulted in radioactive fallout over Germany and affected people's daily lives.[25] The subsequent discourse was fuelled by fear and a rising opposition against a technology which had always been praised by experts and lobbyists as "clean and safe". Germany's geopolitical position at the forefront of Cold War, with nuclear missiles from both superpowers based in East and West Germany, did not help in developing a positive attitude towards nuclear technology. The rising amount and unresolved long-term storage of nuclear waste raised doubts about economic feasibility and questions regarding the ethical responsibility of the current generation.

From 1998 to 2005, the Greens did not get into the national driver's seat but in the shotgun position beside Chancellor Gerhard Schroeder to form a centre-left coalition in the federal government.[26] In those years, Germany established one of the most effective programmes in history to drive development and installation of clean energy, to compensate for a

progressive nuclear exit in the short run and a fossil-fuel exit in the long run. Thus, *Energiewende* was born. Together with the German nuclear-power industry, a consensus about a consequent phase-out was negotiated. Although surveys of public opinion towards nuclear energy were inconclusive, the support for policies leading to a low-carbon future grew over time.[27] Renewable energy sources promised to tackle both the effects on climate change and the historic dependence on resources.

Before Angela Merkel became Chancellor in 2005, she served as Minister for Environment (1994–98). Under her leadership, the liberal-conservative coalition published in 2010 the *Energy Concept*.[28] While the goals of the previous government were reiterated and substantiated, the former consensus on nuclear exit was redesigned. The life span of all nuclear power plants was extended by an average of 12 years. Indeed, public support for nuclear energy had gradually recovered. Most voters condoned nuclear power as long as there were sufficient security precautions and regulations.[29] However, while the nuclear accident in Russia was portrayed as a result of sloppy safety management and outdated Soviet Union technology, the nuclear accident in Japan—a country with reputable high technological standards—served as proof of the intrinsic unreliability of the technology itself. Following the incident, not only public opinion turned completely against nuclear technology, it even triggered dramatic loss of support among the elites.[30] Angela Merkel's government promptly ordered the shutdown of all 17 nuclear power plants for "security assessments."[31] Subsequently, the government decided to completely phase out nuclear energy by 2022, beginning with the immediate and final shutdown of the oldest plants. Although the industry warned against nationwide blackouts and negative effects on economic growth, none of these predictions came to pass.

Since *Energiewende* became the long-term energy and climate strategy, there has been no decrease in environmental awareness.

Studies conducted by the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety between 2004[32] and 2014[33] acknowledged only a "generational shift." While the environmental consciousness from the 1960s was strongly anchored in an individual value system, the awareness of the current generation is characterised by a "post-modern" value mix; pragmatism, flexibility, adaptability and resilience (to crises) are important features. The interdependencies between ecological symptoms and social challenges on a global level become more obvious and give environmental awareness a holistic perspective with long-term goals, as opposed to the specific and narrow perspective that came with the short-term solutions of the '60s.

The latest study in 2016 observes a continuously rising self-reflective awareness about the shortcomings of environmental strategies. The current commitments by industry and government are considered insufficient.[34]

B. Base Year

The peaceful revolution in East Germany, which had led to the German Reunification in 1990, was another grassroots movement. It played a key role for the climate discourse, not only in Germany but also in Europe and the world.

Both sides—East and West—faced the need for environmental protection in light of the high-grade pollution caused by 40 years of socialism,[35] which - like any other ideology - ranked the principles of a dogmatic and abstract theory higher than concrete political solutions in practise. The government of the unified Germany was forced to mitigate environmental standards at the European policy level for a limited time. Before, the (West) German industry was one of the most pressing lobbies for an upward harmonisation of environmental standards in the European Community (EC) to secure its competitiveness in the

European market. The environmental disaster in East Germany—the former German Democratic Republic (GDR)—required a delay in West Germany's push to promote progressive environmental standards at a supranational level. The same regulations became a burden that could not be implemented without shutting down the complete industry and power production in the East, which primarily ran on lignite power. Subsequently, Germany successfully lobbied for a transition period of six years with derogations in several areas.[36] In the years after the reunion, the Maastricht Treaty, 1992 turned the EC into the more integrating European Union (EU). The majority vote was introduced also to enforce higher environmental standards more easily, compared to the unanimous agreements required before. This was an initiative of Germany, Netherlands and Denmark. In the 1992 negotiations for the Kyoto Protocol, Germany and a few other countries insisted on 1990 being the base year for commitments to reduce national GHG emissions.

What was the reason?

"The base year of 1990 was very advantageous to European countries. In the UK, you had already experienced the 'dash for gas' from coal - then in Germany they merged Eastern Germany where tremendous restructuring occurred."[37]

Indeed, the 1990 base was both necessary and helpful for Germany. West German economy, which was already sliding into recession, experienced a boom by the sudden demand caused by East Germans desperate for consumer goods. In the East—within only a few years—a significant number of GHG emitters had been shut down or upgraded due to European emission regulations. This helped rapidly reduce national gross GHG emissions in a relatively short time after 1990.

However, without the reunion, Germany—as two separate entities—would have neither achieved substantial reduction in GHG

emissions nor experienced the hike in production accompanied by a rise in GHG emissions.

C. Legal Framework

Phasing out nuclear energy and reducing GHG emissions required a viable alternative. It became necessary to resolve tensions between affordability, security and reliability, to provide a roadmap flanked by concrete limitations and stimulations. Energiewende's legal backbone is the Renewable Energy Sources Act (Erneuerbare Energien Gesetz, EEG) initiated in 2000.[38] It guarantees long-term security for investments to overcome teething troubles, attract enough investment in renewables to stimulate mass production to achieve economies of scales, and reach a minimum share in gross power consumption of 80 percent in 2050, without further financial assistance at a later state.[39]

The Renewables Energy Act (EEG)

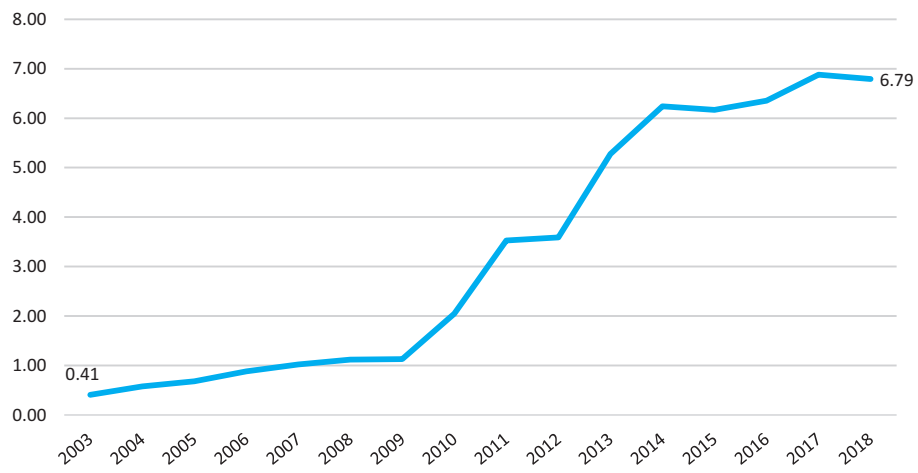
The aim of the Renewable Energy Sources Act (EEG) is to promote the expansion of wind power, photovoltaics and biomass, and to make renewable energies competitive in the long term.

This is how the EEG works:

The operators of plants for regenerative power generation receive a fixed rate of remuneration per kilowatt-hour, for a period of 20 years. The amount of the feed-in tariff depends on the type of power generation, location and the size of the installation. Remunerations are graduated by a declining rate, i.e. the later a system goes online, the lower the feed-in tariff guaranteed for 20 years. In addition, the EEG regulates the feed-in priority of electricity from renewable energy sources, i.e. the operators are entitled to the immediate and preferential connection of their installations to the grid as well as the

acceptance of their electricity by the grid operators. As the electricity price is lower than the fixed remuneration rates for renewable energies, a difference arises, the so-called EEG surcharge. The end user pays this surcharge with the electricity bill. Energy-intensive companies are partially exempt from the EEG surcharge.

Figure 2: EEG Surcharge, in Euro Cents (2003–18)



Source: German Federal Centre for Political Education (2013)[40]/German Federal Network Agency, 2018.[41]

Although EEG is perhaps Energiewende's most powerful tool, it is only one of many others to guarantee a systematic approach, stimulate investment in renewables, and provide a reliable, clean and secure power supply. The Energy Concept, initially published in 2010, is a consistently developing "compass of *Energiewende*."[42] It includes additional decisions of the Parliament and European specifications, and covers all aspects from energy production to transport and consumption. It also defines the strategy to achieve these goals. German energy governance consists of acts handling over 25 aspects, accompanied by several ordinances. This integrated policy framework covers all sectors of economy and regulates everything including funding, energy security, grid development, saving and efficiency,

mobility, mining, water, and emission standards.[43] The transition system operators (TSO), together with the Federal Network Agency and public participation,[44] develop a grid plan for electricity aligned with the current developments. It is updated every two years.[45]

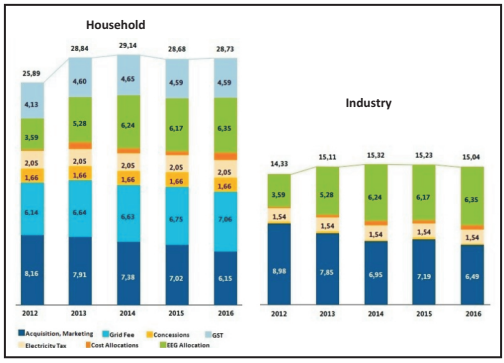
European legislation provides the supranational framework for reaching the climate goals. It sets the floor for national standards by directives and guidelines that all member states agree on, to guarantee a consistent legal sphere in the EU. The European 2050 Energy Strategy[46] is based on the German Energy Concept and the lessons learned from it.

II. The German Reality: Developments and Challenges

A. Flow of Funds

The reality of *Energiewende* is by far more complicated than the historic retrospect might offer. Both the legal framework and the figures are enormous. A total amount of €520 billion (2000–25) is funded solely by a premium on every kWh consumed.[47] Grid operators must refund the producers of renewable energy with a fixed price and allocate these costs to the end consumer. The higher the difference between market prices and the guaranteed feed-in tariff, the higher the EEG allocation. Today, a regular household in Germany has an annual power bill of €1,100, of which only €185 is for electricity.[48] In addition to costs for administration, tax, royalties and fees, the EEG surcharge currently has a share of around 24 percent. The industry sector profits from a liberalised electricity market (competition) and is excluded from several allocations. Moreover, energy-intensive industries can apply for an exemption from the EEG surcharge (marked in green, below). In 2017, around 2,092 energy-intensive companies opted in.[49] The following comparison shows the end price for households and industry.

Figure 3: Average Electricity Prices and the Components, in Cent Per kWh (2016)

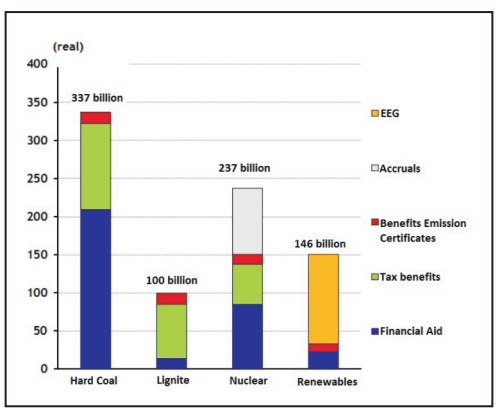


Source: German Federal Ministry for Economic Affairs and Energy, 2017.[50]

However, the EEG allocation is expected to level out from 2020. The latest tenders for offshore wind already exclude any such a stimulating tool due to lower investment costs and higher efficiency.[51]

The electricity price does not accurately reflect the total costs. While the extra charge for renewables becomes obvious in the electricity bill, expenditures for other energy sources covered by the government (financial aid, tax benefits and other favourable frameworks) are not included and, therefore, invisible. To get a clearer picture on government facilitation, the following calculation identifies the hidden expenditures for all energy sources covered by the tax payer.

Figure 4: Government Facilitation in Billion Euro, by Technology (1970–2016)



Source: Forum Ökologisch-Soziale Marktwirtschaft e.V., 2016.[52]

Energiewende seems to be an expensive adventure only at first glance: a net profit of €50 billion until 2030 and €100–500 billion until 2050 is expected as government facilitations for conventional energy is reduced to zero,[53] savings of social and health costs caused by conventional sources of power not included.

It is important to take a closer look at the supply side. So far, more than one-third of renewable energy production has been from private sources: a process of decentralisation of energy, accompanied by democratisation and a spread of income.

Figure 5: Ownership of Renewable Energy Production in Germany (2016)

private households	**31.5%**	**other energy suppliers**	**4.3%**
development companies	**14.4%**	**international energy suppliers**	**3.1%**
funds/banks	**13.4%**	**regional energy suppliers**	**2.9%**
industry / trade	**13.4%**	**other**	**0.9%**
farmers	**10.5%**	**contracting companies**	**0.1%**
"Big 4"*	**5.4%**		

Source: Trend Research, 2017.[54]

* EnBW, E.ON, RWE, Vattenfall

Renewables—sweetened with special government credits—became a lucrative, secure and affordable investment for every citizen. As more (renewable) energy became available, the wholesale price for electricity (supply) and renewables (advanced technology, economy of scales) dropped. The additional supply of renewables entering this field of competition every year is a key element of an industry-friendly development. But the decentralisation has hurt the "Big 4" energy companies running base-load power plants on fossil and nuclear fuels. In 2015, E.ON and RWE wrote off their conventional power plants by a total of €11 billion (80 percent in the case of E.ON). Not even one of their power plants earns its capital costs.[55] The "Big 4" were simply not prepared for this rapid development.

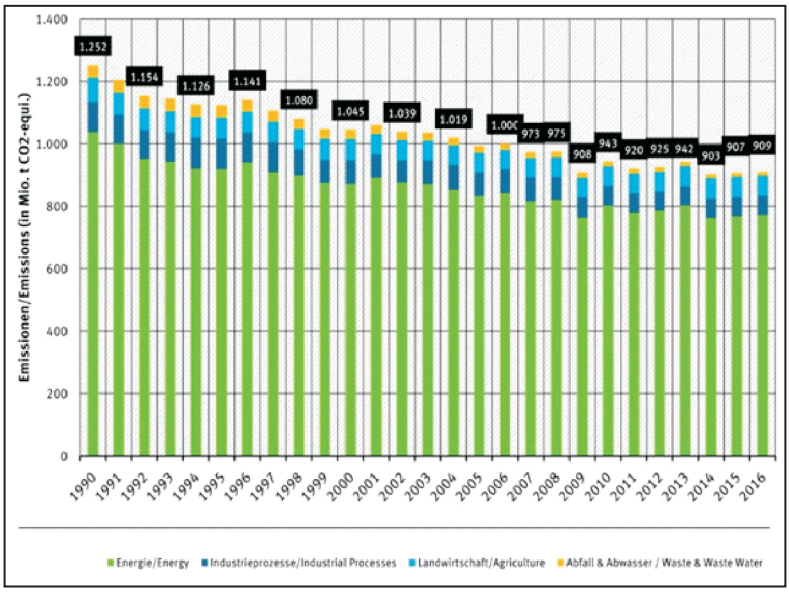
However, several of these fossil-fuelled power plants were not liquidated. They deferred their availability for periods of extreme weather condition (cold reserve). Suitable reserve power plants, capable of providing the reserve service in a timely and targeted manner, are still required. In February this year, the EU agreed that Germany tenders a capacity reserve of 2 GW for the period between 2019 and 2025. This standby reserve is only to be used for covering a potential capacity deficit. To reduce the necessity for this on-demand supply in the future, electricity suppliers who are unable to meet their delivery obligations will have to pay a proportion of the total cost of the reserve commensurate to their contribution. The minimum price for suppliers who are unable to cover their obligations will be €20,000 per MWh. In 2017, the average wholesale price on the day-ahead market was €34 per MWh. As a result, suppliers will have a strong incentive to hedge their delivery obligations through forward transactions or agreements with their customers at an early stage.[56]

B. Emissions and Growth

Current figures reveal the inconsistent and unpleasant reality of Germany's green future. The focus on the energy sector and the transition to renewables made sense, as 85 percent of GHG emissions are generated here. However, while Germany has achieved several of its goals, some issues have come to light.

a) Since 2009, there has been a certain stagnation in GHG emissions, with a slight increase in the second year in a row (2014–16).[57] This is primarily caused by the growing transport sector.[58]

Figure 6: Greenhouse Gas Emissions in Germany, by Sector (1990–2016)



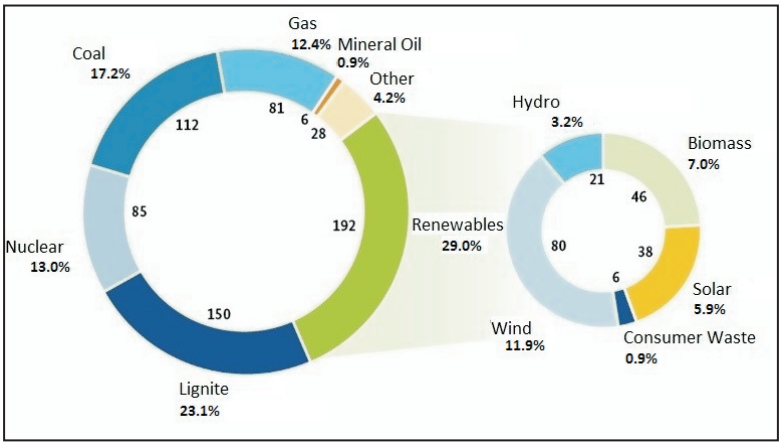
Source: German Federal Environment Agency.[59]

b) The growth in renewables is so high that on sunny and windy days, the energy production can cover more than two-thirds and temporarily even up to 95 percent.[60] However, Germany is not yet able to distribute the renewable energy generated in the windy north to the economic powerhouses in the south.

c) Germany is ranked only 30th in the world in Yale University's Environmental Performance Index (EPI).[61] Compared to other countries, it is still one of the highest emitters of GHG in Europe, responsible for 20.8 percent of GHG emissions of the EU.[62]

d) The most powerful, yet one of the most energy-consuming economies in Europe, Germany still obtains approximately 54 percent of its power requirements from fossil fuels. The main polluter in the energy sector are lignite power plants, which still supply over 23 percent of the total energy produced.

Figure 7: Gross Power Production in Germany (2016) in TWh and Total Share (Percentage)

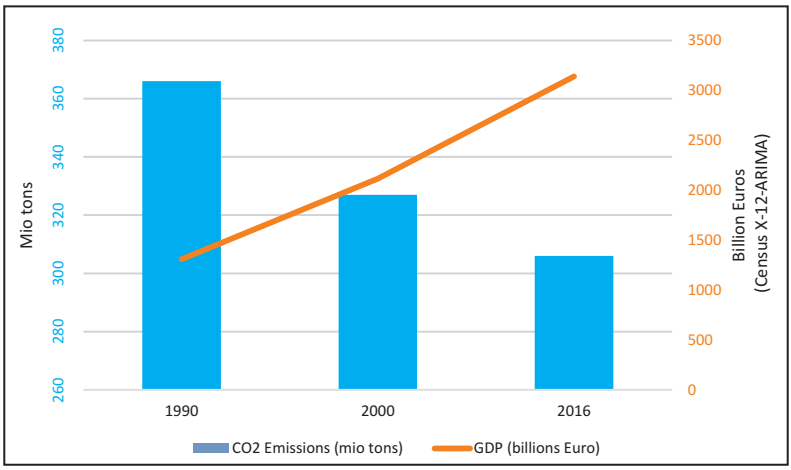


Source: German Federal Ministry for Economic Affairs and Energy, March 2017.[63]

In 2014, a McKinsey report said Germany might not be able to meet the 2020 targets due to the significant coal-based energy sector.[64] While the latest report from the German government expects to miss its reduction goals in 2020 by 5.3 percent,[65] a study from AGORA *Energiewende*, a German NGO that attracted international awareness in September 2017,[66] predicts a gap of 9–10 percent or 120 million tonnes of CO_2 in 2020. Indeed, if no additional climate programme is implemented by the first half of 2018, the envisioned figures seem impossible to meet.

To contextualise these statistical figures, it must be taken into account that during this period of 26 years, Germany's GDP grew by an additional 139 percent.

Figure 8: CO_2 Emissions of the Energy Sector/GDP (1990/2000/2016)



Source: Statistsches Bundesamt, 2017[67] / German Federal Environment Agency, 2016.[68]

Although these figures reflect the aspiration of decoupling growth from the emissions caused by the energy sector, the 2020 emission goals seem unreachable. In the climate discourse, economic growth has often diminished the gains in savings. As a result, the GHG gross emissions worldwide are still on the rise.

C. The Coal Burden

The main reason for the high GHG emissions in Germany is coal. This source of energy still provides over 40 percent of Germany's electric power and causes—as per a study by an NGO (2016)—87 percent of GHG emissions in the energy sector (including for heat-generation purposes[69] and 78 percent for electricity only), 28 percent related to hard coal, 50 percent to lignite.[70]

In 2016, 66 power plants[71] accounted for around 78 percent of the total hard-coal consumption, the steel industry for around 20 percent. While currently only 10 percent of hard coal is from national sources, the reliance on imports will rise to 100 percent after 2018.[72] In 2007, both

industry and government agreed to close the remaining hard-coal mines.[73] Due to deep located mineral deposits, hard coal has never been an economical source of power as the mines generate further—infinite—maintenance costs.[74] This is different from lignite, which is harvested in open mines and is therefore highly cost effective. However, lignite is under public pressure as it emits the most GHG of all fossil fuels.

Figure 9: CO_2 Emissions by Source in Germany Related to Power Generation (g/kWh)

Gas	391
Hard Coal	863
Lignite	1,151

Source: German Federal Environment Agency, 2017.[75]

Like in other countries, Germany's policy-makers must handle the trilemma of maintaining economic growth of energy-intense industries, low national resources, and energy security. Because of *Energiewende*, there is now the additional dilemma that the country still relies on coal while self-determined ambitious environmental targets have to be fulfilled. In Germany, less than 20,000 people are employed in the lignite sector[76] and all the 45 lignite power plants[77] are in only three out of 16 states.[78] Thus, the social costs for a shutdown would be relatively low. Gas, currently the only alternative source of power, is expensive and the lignite energy lobby remains influential.[79] Therefore, the remaining lignite power plants might be operated as long as politically and legally possible due to the low operating costs and the price effects caused by the power surplus. Running on lignite is profitable for business and is neither a social matter nor–officially– a security matter.

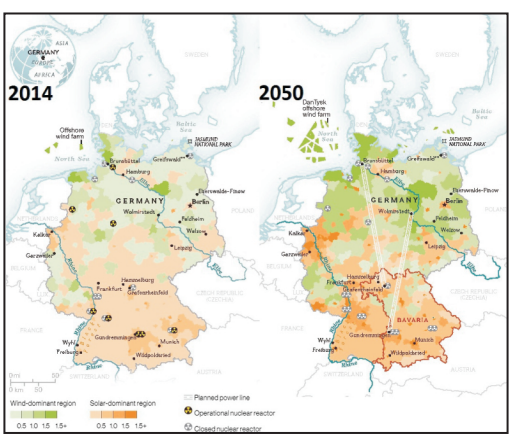
Nevertheless, a political decision has shifted the responsibility from national to supranational policy level and paved the way for a lignite exit indirectly and effectively.[80] Germany has voted—together with other coal-intensive countries such as Czech Republic and Poland—against European regulations, which raise limiting values for particulate matter,

mercury and nitrogen oxide (effective 2021). However, the German government failed to meet the deadline for recourse to the courts.[81] As a consequence, more than 100 coal and lignite power plants in Europe—representing a third—have to be either closed or upgraded.[82] Practically, this means that Germany has passively agreed to either shut off or retrofit all its remaining power plants within the next three years. According to a study by Energy Brainpool, shutting down the oldest and least efficient coal and lignite power plants would not jeopardise national energy security.[83] However, every intervention on the supply side requires significant adjustments of the power transmission grids.

D. Grid Flexibility: Merging Gas and Power

The power grid is the weakest link in the chain and requires continuous investments. In the latest grid plan, the Federal Network Agency scheduled around 3,050 km of optimisation and reinforcement measures in the existing grid and around 2,750 km of new routes added until 2024.[84] The expected costs are about €15 billion for the connection to offshore wind parks and €18 billion for grid enforcement on land. However, these figures do not include the additional costs for underground cables on land.[85]

Figure 10: Solar and Wind Energy in Germany: Installed capacity by Postal Code Area, Megawatts/Square Mile



Source: National Geographic/Fraunhofer IWES; US Energy Information Administration, German federal Ministry for the Environment; Eurostat.[86]

Once developed and shaped by a centralised power generation in a concise number of major power plants, the power sources today multiply while the development of the grid lacks in quality as well as quantity.[87] In the coming years, major investments are essential. To handle the volatile flow of supply and demand, the adjustment costs of the grid grew from €715 million (2016) to €1 billion (2017).[88]

So far, the grid seems to have kept up with the challenges. Although the strains on the grid are rising both in terms of numbers of suppliers and consumers, the incidents as well as duration of current interruption are continuously decreasing:

Figure 11: Tabular List of Supply Interruptions, 2006–16 (Nationwide)

	General Data		Low Voltage		Mid Voltage		
Year							
	Grid operators / Grids	end consumers (in mio.)	current interruptions (in thousand)	SAIDIEnWG* (minutes)	current interruptions (in thousand)	ASIDIEnWG** (minutes)	SAIDIEnWG-total*** (minutes)
2016	860 / 868	50,3	148,3	2,10	24,3	10,70	12,80
2015	850 / 860	49,9	150,9	2,25	26,7	10,45	12,70
2014	874 / 884	49,6	147,8	2,19	26,0	10,09	12,28
2013	868 / 878	49,5	151,4	2,47	27,8	12,85	15,32
2012	866 / 883	49,3	159,0	2,57	32,0	13,35	15,91
2011	864 / 928	48,9	172,0	2,63	34,7	12,68	15,31
2010	890 / 963	49,0	169,2	2,80	37,1	12,10	14,90
2009	821 / 842	48,4	163,9	2,63	35,1	12,00	14,63
2008	814 / 835	48,4	171,5	2,57	36,6	14,32	16,89
2007	825	48,5	196,3	2,75	39,5	16,50	19,25
2006	781	48,5	193,6	2,86	34,4	18,67	21,53

* System Average Interruption Duration Index: average supply interruption per connected consumer within a calendar year
** Average System Interruption Duration Index: average supply interruption per connected consumer unit within a calendar year
*** SAIDIEnWG-total: sum of both

Source: German Federal Network Agency, 2017.[89]

The conventional approach in securing national power on the supply side is a distinction between base load, medium load and peak load. The reason for this practice was a centralised power generation by plants, which cannot be regulated due to technical and/or economic reasons. A nuclear or coal power plant can only be turned on or off. However, with the rising supply of renewables, flexible power plants—most likely gas—are required to cover the "residual base." Residual base describes

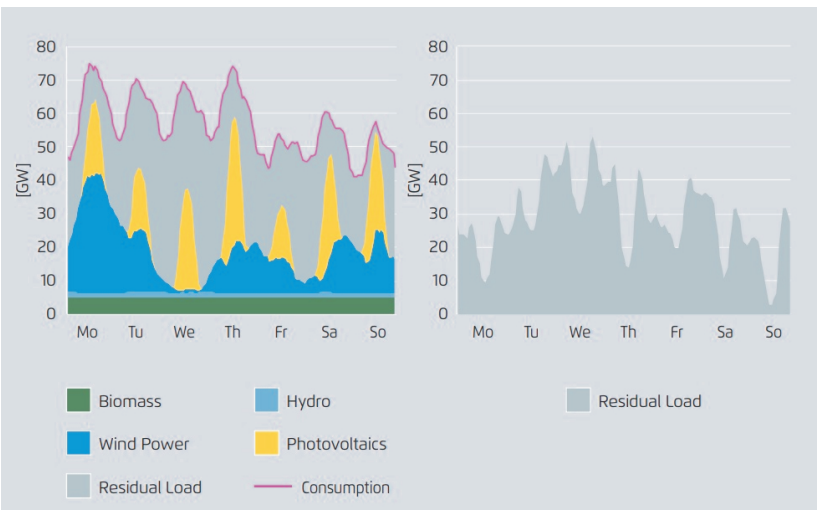
the positive or negative gap between total demand and renewables (flexibles) added by current base-load plants (nuclear, fossil fuel). With a rising share of renewables (volatile supply) and diminishing amount of conventional base-load power, residual base becomes the crucial figure to be monitored and covered by:

a) residual-base power plants (demand higher than the supply; residual base is positive)

b) storage technologies (supply higher than demand; residual base is negative)

Flexibility in quantity and quality becomes the main attribute of "residual base."

Figure 12: Gross Electricity Generation and Residual Load in Germany (Sample Week in April 2022 with 50 Percent Renewables)



Source: Agora Energiewende.[90]

In 2011, a study predicted a systemic conflict in Germany and the end of classic base-load power plants from 2020.[91] Four years later, another study declared the base-load principle as outdated and

insufficient for tackling the challenges of intermittence of renewables.[92] In a scenario of 100-percent renewable supply, affordable and reliable storage technologies become essential. Such flexibility can be achieved by:

a) thermal gas power plants, which can be quickly booted;

b) smart meter technologies, which regulate supply and demand by necessity and availability;[93]

c) storage technologies, e.g. thermal energy storage (TES) or power-to-X (PtX).[94]

The latter seems to be the most attractive as there is the necessary infrastructure (gas-transmission grid) with a tremendous capacity already in place. While the storage capacity of electricity is currently 0.6 hours, the gas transmission grid can offer a buffer of 2,000 hours or three months.[95] There are several options in PtX:[96]

1. Power-to-Heat (PtH) uses surplus electricity for the heating market; simple heating elements are fed into district-heating systems.

2. Power-to-Valuables (PtV) uses surplus electricity in industry for the targeted production of chemical products, compressed air, melting of metals, surface finishing processes etc.

3. Power-to-Mobility (PtM) uses excess electricity to charge electric vehicles. The car becomes a power storage and feeds energy back into the power grid. Alternatively, hydrogen and methane generated from power-to-gas processes can be used for CNG and LNG mobility.

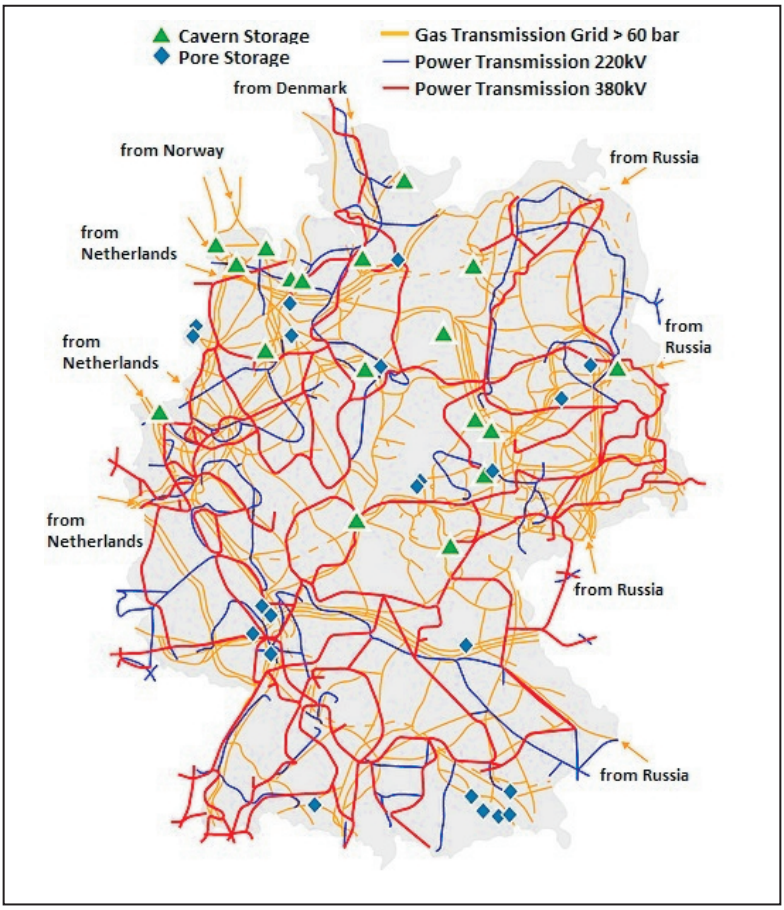
4. Power-to-Liquid (PtL) uses surplus electricity through electrolysis/hydrogen production to usable basic chemicals (e.g. methanol). With this method, fuels can be obtained from synthetic hydrocarbons (dimethyl ester, kerosene etc.).

5. Power-to-Gas (PtG) uses surplus electricity through electrolysis (splitting water into hydrogen and oxygen). The optional subsequent

methanation (production of renewable natural gas by the addition of carbon atoms) serves as a central coupling element between electricity and gas infrastructure.

Following the PtG approach, the existing gas and power grid becomes an asset and serves the diverse requirements of supply and demand. It only requires the necessary installations at both ends of each grid to transform one form of energy to the other. The effects of synergy are expected to be tremendous.

Figure 13: Gas and Power Transmission Grid in Germany (Includes Points of Gas Entry)



Source: Solares bauen GmbH. [97]

The crucial element for this approach is coupling and aligning both gas- and power-transmission grids. Currently, 38 PtG projects for testing and feasibility studies are planned or in operation.[98] Between 2019 and 2027, PtGs producing additional 1,500 MW, with estimated costs of €1.1 billion, are to be installed.[99] Operators will receive carbon-emission certificates for every tonne of GHG avoided. This incentive tool helps reach break-even in the initial phase, as the certificates can be traded on the emissions market.[100]

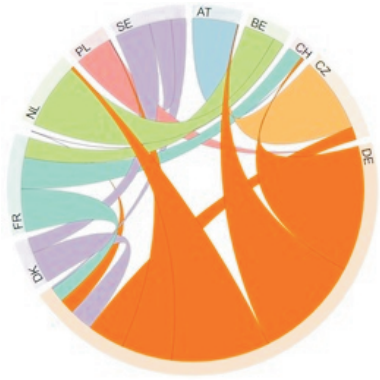
The national divergence and the volatility of the supply and demand of power in the European market is both a challenge and a blessing for the energy transition. It influences the requirements of the gas- and power-grid development. Besides the storage effect, the PtX technology may lead to the end of the dependence on gas imports, and highlights its geopolitical aspect.

III. The European Context

A. Common Market

When discussing dependencies, the European context is a crucial aspect. There are two levels of the challenge to handle the indifferent power supply (and demand): national and international. The successive final shutdown of Germany's remaining seven nuclear power plants until 2022,[101] providing 13 percent of Germany's electricity, will result in a gap of the power supply, which needs to be closed. In this context, Europe's liberalised power market balances supply and demand in the continent. Germany can provide temporary power surplus to the rest of Europe, and in turn, power deficits in Germany can be eliminated by its neighbours' supply. The necessary legal frame was established in 1996 when the European energy market was liberalised. From 2007 onwards, every household and industrial consumer was entitled to choose its energy supplier.[102] More and more power was crossing the borders.

Figure 14: Energy Flows: Import/Export, by Country in TWh (2017)



	Import		Export	
A	0.108	D	15.4	A
CH	0.348	D	18.1	CH
CZ	1.8	D	5.3	CZ
DK	3.4	D	4.6	DK
F	6.2	D	2.2	F
L	0	D	2.2	L
NL	0.422	D	14.2	NL
PL	0.1	D	7.4	PL
SE	2.1	D	0.254	SE
TOTAL	14.478		69.654	

Source: Fraunhofer ISE, 2018.[103]

Germany usually consumes only 64 to 78 gigawatts of electricity daily. Conventional power plants, together with renewables, reach between 80 and 90 gigawatts on windy and sunny days.[104] In other words, Germany can shut off 20 of its oldest lignite power plants only by reducing its energy exports. In case of a power shortage, several gas power plants—mostly on standby[105]—ensure the necessary energy supply.[106] As explained in the preceding section, the principle of (national) base load is outdated and not useful, since renewables have been playing a major role. Today, the market price for electricity decides the flows of electricity. A combination of strong winds and high national demand lead to rise in prices in Europe. Base-load power plants start to export their comparably expensive electricity and become an unreliable factor as they create a national gap on the supply side. Therefore, border-crossing analyses instead of base-load calculations became the main tool to ensure national power supply. While investments into the grid are required at the national level, cross-border interconnectors to 12 neighbouring countries are the main focus and cause for disputes at the international level. Even though Europe's energy-consuming industry profits from Germany's exports and the general power surplus,

national—often state-owned—power producers suffer from a lower wholesale price level and higher volatility, as they mostly operate expensive, centralised base-load power plants.

Without a common (energy) market and all countries in Europe sharing their power surplus, Germany's ambitious green-energy transition would not have been possible, simply because the industry's energy demand could not have been guaranteed and costs would have been substantially higher. France was once the main advocate for a common, not liberalised energy market in the late '80s.[107] The massive energy surplus generated by its nuclear power capacities sold on a common energy market promised additional revenues. Back then, this policy was strongly opposed by the German power industry, which saw its national monopoly position being threatened.

B. Diverging Interests

In Europe, national interests still dominate the European disputes, which is clear from the latest discourse applauding a coal exit. While French President Emmanuel Macron and more than 20 other leaders of countries, states and organisations demanded a phase-out deadline of coal-generated energy and formed the Power Past Coal Alliance,[108] Angela Merkel once again refused to fix any date at the COP 23 in Bonn.[109] A lower rate of coal-power share corresponds to such a declaration. For instance, France derives only three percent of its electricity from coal and 75 percent from nuclear energy.[110] The following table explains how national interests are influenced by the dependence on coal:

Figure 15: Europe: Energy from Coal in Percentage (Declared Exit Year)

Poland	81%	Italy (2025)*	15%
Czech Republic	54%	UK (2025)*	15%
Greece	46%	Slovakia	12%
Bulgaria	45%	Finlandx(2030)*	11%
Slovenia	30%	Portugal (2020)	10%
Germany	40%	Austria (2025)*	3%
Romania	27%	France (2023)*	3%
Denmark*	27%	Sweden (2030)	1%
Ireland	26%`	Netherland (2030)*	23%
Spain	20%	Hungary	20%
Croatia	18%	Belgium*, Estonia, Lithuania, Latvia, Switzerland*, Luxemburg*, Norway	0%

*[*Countries that had signed the Power Past Coal Alliance by 16 November 2017]*

Source: Frankfurter Allgemeine Zeitung[111]*/Powering Past Coal Alliance.*[112]

Germany accepts gas as a source of energy (during transition, to cover residual load). Instead, countries of the former Warsaw Pact (today, most of them are members of the EU) such as Poland, identify gas as a threat to national security because the majority share has to be imported from Russia. Gas-powered generation causes a rising dependence due to a lack of sufficient gas fields and a decrease in domestic production in the EU. Theoretically, Germany and France are not dependent on gas imports. Due to either their current spare capacity in renewables and other fossil or nuclear-fuel powered plants, both countries can even increase their electricity exports without importing gas.[113] Germany has the highest gas-storage capacities in Europe[114] to buffer volatilities and temporary reliance on imports. However, the country's dependence on gas imports—foremost from Russia (>35 percent)[115]—is expected to increase with the phase-out of nuclear[116] and might be another reason why Germany still sticks to lignite: Russia's dependence is not as mutual as it might be expected.

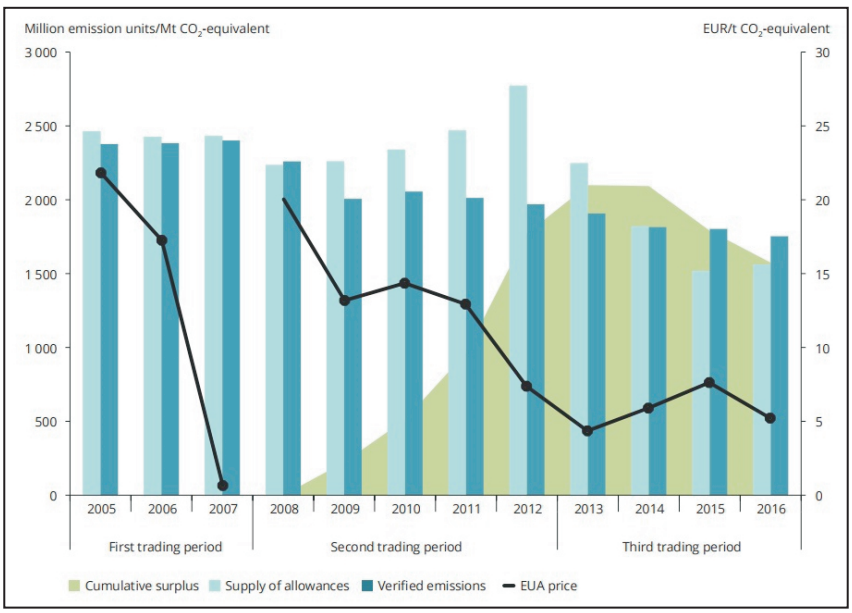
While oil exports represent 50 percent of Russian annual GDP, gas exports add up to "only" five percent.[117] The North Stream Pipeline, built from Russia through the Baltic Sea and delivering gas directly to Germany, is seen by many in the EU as a major threat. The Ukrainian–Russian gas conflict ("Gas War")—which led, in winter 2008–09, to a 90 percent reduction of gas supplies transported via the Ukraine—was a showcase of EU's reliance on the countries between Russia and Germany.[118] Based on their history, it stands to reason that the relationship between Russia and Germany can be more pragmatic and rational than between Russia and its former vassal states. Even though highly controversial,[119] it might be in Germany's economic interest that former Chancellor Gerhard Schroeder calls President Putin a "friend".[120] Schroeder, lately nominated to the Rosneft board,[121] is also chairman of the shareholders' committee of Nord Stream AG, a Gazprom-led consortium established for the construction of the controversial pipeline, which started its operation in 2011. The planned second pipeline (North Stream 2) doubles the capacities as well as the dependency of Europe, which currently consumes 30 percent of piped gas from Russia.[122] Germany's dependence might rise to 50 percent by 2025.[123] Nevertheless, both projects run contrary to Europe's strategy of energy independence. Ending the dependence on Russian piped gas by compensating with LPG imports from the US or Africa, instead, seems highly unrealistic.[124]

C. Emission Certificates

Once introduced as a flagship of the European climate policy, the EU Emissions Trading System (EU ETS) has been developed as a market tool rather than a legal regulatory instrument to influence emitters' behaviour—a market tool that works on the simple principle of demand and supply. The more greenhouse gases (GHG) an emitter produces, the more certificates—European Allowances (EUA)—are required, or more

money has to be spent on reduction technologies to save certificates. This is in theory. In practice, however, a heavy surplus of free EUA emitted in the beginning (2005)[125] ruined the price as well as the goal: carbon-gas emitters, foremost energy-dependent industries, got a free ride. Others sold their certificates. High supply and low demand resulted in low prices (marked as a black line in table below):

Figure 16: Emissions, Allowances, Surplus and Prices in the EU ETS (2005–16)



Source: European Environment Agency/Point Carbon, 2012; EEA, 2017; EEX, 2017; ICE, 2017.[126]

With a current price tag of €5 per million tonne of CO_2, this instrument is playing in the same league as the latest calculations published by the US Environmental Protection Agency (EPA) under the current Trump administration, which elaborated a price of US$1 and US$6 for a carbon certificate representing one metric tonne from 2020 on.[127] The EPA under the Obama administration had set a price of about US$50 per metric tonne, [128] which was even more ambitious than the OECD recommendations of US$30 necessary to influence the emitters' behaviour and investment strategies.[129]

In 2008, all European economies, particularly the PIIG[130] countries, were affected by the Global Finance Crisis. They had to cut public spending tremendously and suffered from low foreign direct investment (FDI). The weakness of the European economies and the relatively stable Euro was a gift for the biggest and strongest economy. Germany quickly recovered after two years, profiting from the effects of the worldwide recession.[131] Low fossil fuel and emission certificate prices kept production costs low and profit margins high. While once the value of Deutsche Mark rose with the demand for German products, the exchange rate of the single-currency Euro (introduced 2001) was not rising. German products were kept affordable for the export market outside Europe as the central banks cut interest rates and increased money supply to stabilise financial markets. Conditions were perfect for an export economy with full order books. Although the monetary instruments worked (so far) to stabilise the currency, the market for carbon emissions faced a crisis as the lower demand for certificates further decreased their value.

Moreover, EU ETS has had a negative effect on climate, because it is cheaper to buy and even more profitable to trade certificates instead of reducing carbon emissions. Even though every reform since the introduction of EU ETS has failed to reduce the existing number of certificates in sufficient quantities (backloading), the latest reform proposed by the European Commission seems to approach this issue more effectively—beginning only in 2020—but including an opt-out for "vulnerable industries."[132]

IV. Global Perspective: Power Shifts

A. General Trust and the Moral Aspect

To tackle climate change successfully, it is necessary to consider the causes that have led to the present reality. Developed countries and their

representatives today are trying to convince developing countries to adapt their strategies and reduce GHG emissions. However, reducing GHG emission might prevent economic development – the main goal of these emerging markets. At first glance, the highest emitters of GHG gross emissions worldwide seem to be obvious. A second look shows another picture:

Figure 17: Global GHG Emissions, Total, Per Country in Billion Tonnes CO_2 Equiv. (1990/2016)

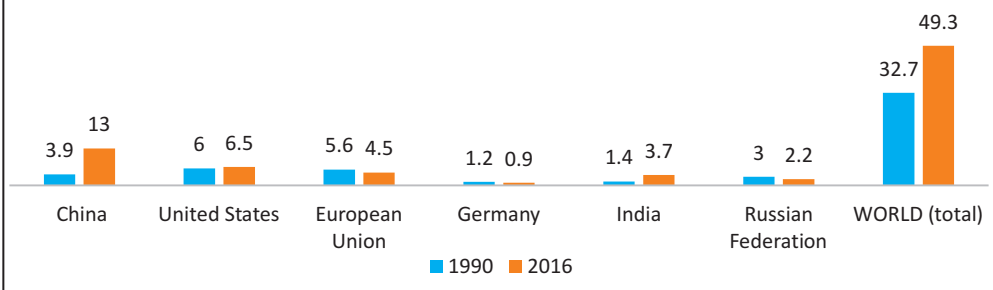
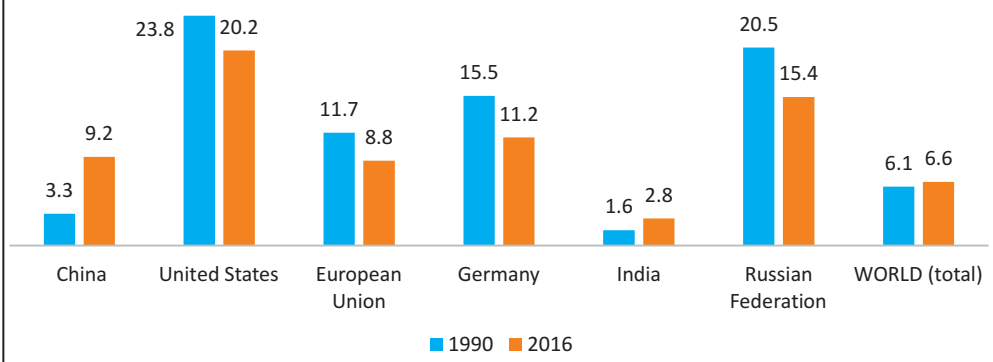


Figure 18: Global GHG Emissions per Capita, Per Country in Metric Tons (1990 / 2016)



Source: PBL Netherlands Environmental Assessment Agency.[133]

This leads to resistance from developing countries in the climate-change dialogue with industrialised countries. It becomes a moral and thereby an emotional issue for both sides. Since developed countries have already economically profited from over a century of

industrialisation and polluting the world, the developing countries are opposed to adapt to higher environmental standards that lead to substantial economic disadvantages.

The effects of climate change (e.g. droughts, rising sea-levels and storms) will further increase. A much higher flood risk than in previous calculations has already been predicted.[134] It is to be expected that every flood and storm will generate and shape the environmental awareness in developing countries. This will create tremendous pressure on politicians and industries to adjust policies, practices and business models, but also on governments of industrialized countries to increase aid and assistance. In such a high emotional discourse, rational arguments go unheard and smart transitions are hard to achieve, especially if the connection between pollution and health, or even survival, becomes an issue in political discourses. Air pollution, for example, is already today the fourth most reason for death.[135]

> *"Pollution is the largest environmental cause of disease and premature death in the world today. Diseases caused by pollution were responsible for an estimated 9 million premature deaths in 2015 – 16 percent of all deaths worldwide – three times more deaths than from AIDS, tuberculosis, and malaria combined and 15 times more than from all wars and other forms of violence. In the most severely affected countries, pollution-related disease is responsible for more than one death in four."*
>
> —The Lancet Commissions, 2017[136]

In the most severely affected countries, pollution-related diseases are responsible for more than one in four deaths. Pollution disproportionately kills the poor and the vulnerable. These effects are most obvious in low- and middle-income countries, where 92 percent of pollution-related deaths occur. Children, in particular, are most affected by pollution.[137]

Interests—and the power to push them through—shape politics. Historically, there are several shareholders, each with different risk awareness and focus within the discourse. While industry, generating income and jobs, is politically highly influential, the German example proves that this pyramid of power can be turned upside down if people are aware of the consequences caused by their behaviour. The matter becomes essential and—especially in a democracy—empowers the masses while the influence of the elites diminishes. The Edelman Trust Barometer describes such a tendency: a loss of trust in the elites in nearly all countries.[138] In the 2017 report, India was the global leader of trust, but in this year's report, India belongs to the six countries with the highest losses.[139] In other words, the detrimental effects of climate change can politicise much of the population, which would then hold the elites (government, and industry, among others) accountable and push for immediate actions. This pressure might bleed through to the developed world, which is expected to share the burden. As witnessed in Germany's nuclear exit, these movements can hardly be rationally explained or forecasted, politically eased or moderated. Instead, more radical and costly steps become necessary or are enforced.

B. It's the Economy, Stupid

Price Drops

Reducing pollution and the effects of climate change is in the interest of all stakeholders. Besides ethical issues, pollution is costly for an economy. GDP in low-and middle-income countries decreases annually by up to two percent. Additional healthcare comprises up to seven percent of total healthcare costs in middle-income countries. Welfare losses caused by pollution sum up to US$46 trillion or 6.2 percent of global economic output,[140] numbers that tend to grow as more diseases can be linked to pollution over time.

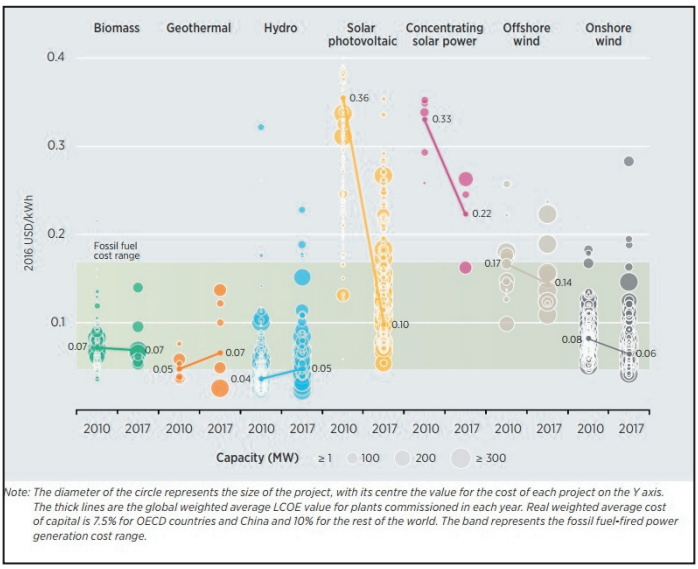
Looking at the energy demand due to economic growth of developing countries, the business opportunities for renewables seem to be significant:

"Powering China and India presents a $4 trillion opportunity. These countries account for 28 percent and 15 percent of all investment in power generation to 2040. Asia Pacific sees almost as much investment as the rest of the world combined, at $4.8 trillion. Of this, just under a third goes to wind, a third to solar, 18 percent to nuclear and 10 percent to coal and gas."[141]

Referring to the major coal-sector development plans mentioned at the beginning of this paper, current figures show the opposite. World coal production dropped by 6.2 percent, or 231 million tonnes of oil equivalent (MTOE), the largest decline on record. China's production fell by 7.9 percent or 140 MTOE, and US production fell by 19 percent or 85 MTOE to 364.8 MTOE.[142] According to these figures editor Chandra Bhushan's prediction of the beginning of "the end of coal" might be accurate.[143] Even if it were not, the recent price cuts for renewable energy installation must be acknowledged in future scenarios.

Recently, the International Renewable Energy Agency (IRENA) published a report that showed a sharp drop in electricity costs for solar power between 2010 and 2017.[144] Last year, all types of renewable energies entered the cost range of fossil-fuel fired power generation. In other words, renewables became the real competitor of conventional power generation.

Figure 19: Global Levelised Cost of Electricity from Utility-Scale Renewable Power Generation Technologies (2010–17)



Source: IRENA Renewable Cost Database, 2018.[145]

A further drop in costs for renewables is to be expected, with all the additional positive economic effects on areas such as health, jobs and development.[146] Bloomberg New Energy Finance predicts that the once-costly solar power is becoming so cheap that it will push coal and natural-gas plants out of business, latest by 2040.[147] The analysts estimate another 66 percent cost drop of electricity from solar photovoltaic (PV) by 2040. A dollar in 2040 will buy 2.3 times more solar energy than it does today. Costs for onshore wind will drop by 47 percent and costs for offshore wind by 71 percent by 2040. Higher efficiency and an ongoing general development of these technologies drive this reduction.[148] Global clean energy investment totalled US$333.5 billion last year and represents a three-percent rise compared to 2016.[149] The effects are obvious: installation prices for solar PV dropped by 25 percent per megawatt compared to 2016. While China broke another record in clean-energy installation (+25 percent), India's investment, adding up to US$11 billion, dropped (–20 percent) in 2017.[150]

Industry Push

To understand the German insistence on higher environmental standards, first at the national then at the European and third—together with other European countries—at the global level, it must be acknowledged that the force behind pushing environmental policies has always been an environmentally aware public influencing both politics and industry. In the beginning of *Energiewende*, critical voices from many politicians, industrialists and business owners were loud and grew over time. Later, the same industry was pushing politicians to achieve a level-playing field for all players in the common market,[151] the only way to neutralise cost advantages after the national legislative had set strict national environmental standards. Today, for the same reasons, a joint force of civil society and western industries are pushing for higher environmental standards on a global level.

This push is reinforced by a new industry sector that had entered the political arena and had identified global business opportunities. The green-tech sector is increasingly becoming a driving factor for political decisions in favour of environmental-friendly regulations. Even the "conventional" industry is more sensitive about environmental issues than ever before as efficient technologies offer added value in every sector. During the last decades, Germany, as an export-oriented economy, has progressively been profiting from new, leading green technologies and policies pushing for higher standards. Employment has increased and has helped to keep the unemployment rate the lowest in Germany for the last 25 years.[152]

In 2013, a study by Roland Berger Consultants measured the global market for green technology of €2.5 trillion and predicted a size of €5.4 trillion by 2025 implying an annual growth rate of 6.5 percent. The percentage of green tech companies in Germany's GDP would rise from 13 percent (2012) to 20 percent (2025). This trend seems to be

confirmed by the stats of the Borderstep Institute. Between 2006 and 2013, around 170,000 companies were founded in the fields of renewable energies, energy efficiency, circular economy and climate protection. The young companies created 1.1 million new jobs. In total, around 14 percent of all start-ups in Germany make their contribution to an environment and climate-friendly economy with their products and services. Two-thirds of young companies specialise in green services, while another one-third offer environmentally friendly and resource-efficient products. Meanwhile, the high-tech share of green foundations is about 15 percent. In 2013, around 16,700 new green-economy companies were launched.[153] The trend continues. The Green Economy Foundation Monitor 2015[154] focused on the development of green foundations in Germany and compared it to the development in Europe. After trade, the cross-sector Green Economy became the largest start-up field in Germany. In 2014 alone, 21,500 new green-economy companies were founded. About 17.3 percent of all start-ups in 2014 were founded in the fields of renewable energy, energy efficiency, emission reduction, circular economy and other areas of the green economy. In Europe, Germany plays a leading role in long-term start-up share of more than 10 percent in the areas of energy transition and emission avoidance. The focus of green-economy foundations in Germany is renewable energies; in Finland, it is energy efficiency; and in Sweden, it is emission prevention. And the future shines bright for a clean, green industry.

V. Summary and Outlook

The long history of Germany's environmental awareness will not lead future climate policies astray. While at present, Germany is failing to meet the 2020 goals, *Energiewende* is likely to succeed in the long run. Almost 20 years after the initiation of the energy transition project, the broad support of society is stronger than ever before. And it is expected to grow. *Energiewende*, once evolved from emotions and morals, has already turned out to be an economic success story with strong rational

arguments. The monetary benefits of a green economy are obvious: lower public-health costs, cheaper energy costs, a relieved labour market, and future-proof technologies. Already today, *Energiewende* has helped Germany become one of the main profiteers in this sector. The push for green policies is generated not only by public awareness but also by pure business interests—a potential trillion-euro demand of a globalised market—becoming increasingly aware about the benefits of clean(er) technology.

Germany is not the only country pushing for a low carbon economy to fight climate change. But it was one of the first that consequently changed its policies and pushed renewables to break even. Germany has initiated nothing less than a paradigm change in Europe and has become a global trendsetter. However, the toughest decisions and consequences still lie ahead and require continuous public support. As a bottom-up movement, future German governments are expected to get that mandate. The coalition agreement[155] of the new government headed by Angela Merkel mentions explicitly—besides "efficiency first" to reduce the energy demand by 50 percent until 2050—the following targets (to list the most relevant):

1. higher goals for the share of renewables (65 percent) at an earlier stage (2030)
2. better synchronisation between renewables and transmission grids by upgrades and intelligent interfaces (digitalisation)
3. stronger alignment of energy research and development with *Energiewende* to
    a. alleviate access to economic development schemes for start-ups
    b. promote low carbon industry processes and a carbon circular economy
    c. accelerate the transition towards a market launch for PtG and PtL

4. advanced coupling of all sectors to generate and use "green" hydrogen
5. elaborate an action plan for an incremental reduction and final exit of coal power (until end of this year) covering social, structural, legal, and economic aspects.

From an outsider's perspective it may seem impossible that the challenging project *Energiewende* can be sustained until successful completion. However, though the 2020 goals will quite obviously not be achieved, for Germany it is only a matter of "when" coal power plants will be turned off to reach the goals, not "if." The German public as well as the European regulation will enforce the exit by higher emission standards and by increasing renewables. Since renewable energy is becoming the cheapest source and storage issues will likely be solved within the next decade, renewables make sense not only from a moral point of view but from an economic one as well.

Despite these positive aspects, *Energiewende* was neither cheap nor easy to frame. The challenges caused by volatile and unpredictable renewables make it necessary to incrementally move from a base-load towards a residual-load power management. The liberalised power market provides opportunities to share national surplus and supply national demands, but also requires an ongoing update of the grid and cross-border interconnectors at the national borders. So far, Germany's agencies and grid operators were able to handle the challenge and offered one of the most secure energy supplies worldwide. Germany's significant power surplus causes not only dropping wholesale power prices but also political tensions as it reduces profits for all European power producers and enforces adjustments of the neighbours' grids at the same time.

Economic growth, a gift for a society's welfare, is still a burden for the environment. Germany tries to decouple both and even though it seems

to be prepared, it must still prove that its willingness can turn into action.

Environmental awareness, as well as knowledge and belief in anthropogenic global warning (AGW), will grow as negative effects of climate change become more obvious. The concurrence of extreme weather events, too, will increase exponentially. As people's life and health is increasingly affected, industrial production—one foundation for economic wealth and prosperity—will be influenced by public opinion. It will become necessary to decouple production from the negative effects on environment, be it by market regulation or by consumer behaviour. Decision-makers, both in politics and industry, should be prepared for such a development, which has its own logic, strength and dynamic.

ENDNOTES

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