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Impact of the Nuclear Phase-Out in Germany: Examining the Costs and Benefits of Aggresive Energy Policy in Relation to a Sustainable Future

David M. Olio
Union College - Schenectady, NY

IMPACT OF THE NUCLEAR PHASE-OUT IN GERMANY: EXAMINING THE COSTS AND BENEFITS OF AGGRESSIVE ENERGY POLICY IN RELATION TO A SUSTAINABLE FUTURE

By

David Olio

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ABSTRACT

Olio, David IMPACT OF THE NUCLEAR PHASE-OUT IN GERMANY: EXAMINING THE COSTS AND BENEFITS OF AGGRESSIVE ENERGY POLICY IN RELATION TO A SUSTAINABLE FUTURE

Advisor: James Kenney

The German nuclear phase-out legislation of 2011 will cause substantial changes in the country's energy mix, energy generation and electricity grid demands. The phase-out exists as part of the Energiewende, or energy transition, occurring in Germany where renewable energy has been subsidized to replace the share of nuclear energy, which is decreasing annually and moving towards a complete phase-out in 2022. This paper will analyze the benefits and costs of Germany's decision to phase out nuclear power. First, it will explore the dynamic history of German energy policy and discuss how a history of anti-nuclear sentiments led to the nuclear moratorium. Then, it will present relevant data about the impact of the phase-out on various German sectors, looking at the costs of grid expansion, the rising electricity rates and the improvements needed to make the legislation possible. We will find that the benefits of implementing the nuclear phase-out exceed the monetary costs due to future economic opportunity and an increase in energy independence and sustainability.

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1.1 Introduction

Climate change has developed into a fundamental problem facing today's world. We are witnessing historic events in terms of melting glaciers, record heat and drought waves, unpredictably powerful storms and rising sea levels across the globe that threaten coastal communities. 99% of scientists concur that these are man-made changes driven by heavy industrialization. Extensive greenhouse gas emissions, which are changing the atmospheric composition, provide challenging living conditions for communities at risk. Because of climate change, humans today need to adjust their provincial outlook on life and focus on the long-term survival of our species through raising awareness and sponsoring political figures who recognize and are committed to protecting the fragility of the earth's climate. Unfortunately, a large majority of countries in the world sport shortsighted policies aimed at economic growth and sustainability rather than the long-term health of our earth. Renewable energy is the future of energy, but it is a time dependent energy. At some point, natural, finite resources will become scarce enough to incentivize countries to invest in renewable-based energy mixes. For this reason, countries who proactively work to advance their energy mix beyond a reliance on conventional energy sources will have an advantage over other countries in energy independence and renewable energy technology. Because global citizens are becoming more aware of the fragile state of our earth, large green movements are occurring across the globe. Only some governments respond to the sustainability interests of their citizens.

1.2 Purpose of the Study

Time and time again, Germany has stood out against the throng as an international leader in combatting climate change. It has advanced the expectations of a green economy and provided important international leadership in various climate accords, such as the Paris Agreement or the

Kyoto Protocol. Now, Germany is pushing for more. In their Energiewende, a long-term policy aimed at combatting climate change through an increased reliance on renewable energy production, Germany has promised to phase-out its nuclear power. While the goals of this policy are many, the single focus is to create a sustainable, independent energy supply free of the inherent risks of nuclear energy as well as to reduce the country's carbon footprint. The purpose of this study is to evaluate Germany's decision to phase-out nuclear energy, based on their ability to meet their carbon emission reduction goals, increase energy independence, and protect basic human rights while maintaining the strength of their export based industrial economy. In summation, what will be the overall costs and benefits of the nuclear moratorium in Germany?

1.3 Outline of the Study

Chapter 2 will provide the historical context for the study. Germany's decision to pursue a nuclear phase-out stems from a long political and social history of anti-nuclear sentiments, combined with the nuclear disasters that have plagued our civilization in recent decades. The changes in energy policy from the 1960's forward influenced the decision to move away from nuclear power towards more sustainable and renewable energy sources. This chapter will serve to provide a background against which the nuclear phase-out has occurred. Additionally, this chapter will outline the specifics of the German Energiewende, including the various targets the legislature has set for 2035 and 2050 for their carbon reductions and energy improvements.

Following this, Chapter 3 will outline the anticipated outcomes of the phase-out of nuclear power. This will assess how various sectors of the German economy will be affected by the loss of nuclear power, and how international relations may change. Because nuclear power comprised such a large portion of Germany's energy mix prior to its moratorium in 2011, large

changes must occur to account for its loss and thus, sectors will have to adapt to a different energy mix and different energy costs.

Chapter 4 will present the entities which will play a role in the benefit cost analysis. It will explain the costs associated with the nuclear phase-out and investigate the outcomes the decision on social, political and economic spheres. This chapter will take information from chapter 3 and analyze how exactly it will either benefit or cost Germany, which will be further discussed in the subsequent conclusion.

Chapter 5 will conclude this study with the results of the benefit cost analysis. Chapter 4 will have outlined the costs and benefits but this concluding chapter will determine and explain how the German nuclear phase-out benefits Germany more than it costs them. Ultimately, the social and environmental benefits will diminish the significance of the cost of grid expansion and nuclear moratorium, as the long-term results of the nuclear phase-out will repair the short-term costs of revamping the energy mix through renewable energy generation and increased fossil-fuel use.

2.1 Introduction to the Nuclear History of Germany

This chapter will outline the history and transition of nuclear power in Germany from the perspective of social, political and policy-based events. The decision to phase out nuclear energy did not spontaneously arise, but rather stems from a long history of anti-nuclear sentiments and the country's energy policy transition towards cleaner and more reliable sources. Additionally, this chapter will present relevant policy information in order to catalogue the current basis on which Germany evaluates its energy standards.

Because Germany is part of the European Union, its policy is perpetually shaped by the guidelines and goals of what the EU determines for the countries in its membership; however, Germany has consistently pushed further than the baseline set by the European Union in terms of its standards for energy policy, specifically in terms of renewable and nuclear energy. Germany is unique in recent history, compared to nearby nations, in that it was split into two separate countries from 1949 to 1990, East and West Germany. East Germany stood out as the foremost polluter, as it was the main polluter of coal-burning, the country's major source of fossil fuel. Thus, the unification of the two states in 1990 conjoined a single energy policy. Throughout its varied past, Germany, as shown by its citizenry and political agenda, has established a clear priority to reduce its carbon footprint through increasing renewable energy and the phase out of nuclear energy. This interest permeates the past five decades in Germany, indicative of the fact that the current policy on nuclear energy is a result of more than rudimentary decisions made by the leaders of today. The decision includes the transitions and sentiments of the past, just as much as the present. The movement to phase out nuclear energy stems from Germany's interest in renewable energy growth, improving energy efficiency and moving towards a sustainable future safe from the unpredictable risks nuclear entails.

2.2 Anti-Nuclear Sentiments in Germany

An expansive history of social, political and economic factors has led to the current energy policy in Germany. Nuclear energy entered the German dialogue in the early 1950's, when West Germany was considered progressive in their energy policy for pursuing nuclear energy as a solution to the modernized costs of increasing industrialization nationwide. Following this, the German government began establishing research centers to delve further into nuclear power, looking at enrichment, reprocessing and the development of novel reactors to counter their energy dependence on the U.S., as they were importing 80% of their fossil fuels from America.[1] Nonetheless, there was strong nuclear opposition from the onset of research, growing largely from the citizens. Planning for the Brokdorf Reactor had begun in the 1960's, but the government struggled against public protests in their attempts to complete the project. In 1973, vehement public opposition sparked conflicts with the state and in 1976, when the government began construction, simultaneously closing the area to local citizens, violence broke out and turned the Brokdorf reactor into a national issue. As a result, in 1977, 30,000 people successfully gathered to halt construction. Again, in 1981, 100,000 people protested when the government attempted to resume construction, yet despite their efforts, the reactor was successfully completed in 1986.[2] These protests, according to Glaser, were not direct results of anti-nuclear opposition from the public, but rather a statement against, "the nontransparent and authoritarian style in which the federal government pursued its big-industry projects, exemplified by excessive

[1] Alexander Glaser. 2012. "From brokdorf to fukushima: The long journey to nuclear phase-out." *Bulletin of the Atomic Scientists* 68 (6): 10-21.
[2] Glaser, "From brokdorf."

use of police force."[3] Nonetheless, nuclear energy developed into a contentious issue summarily following its inception.

From there, protests spread across the country, specifically in its southwestern corner, where local citizens, combined with many of the area's wine farmers, fought rigidly against the planned installation of a nuclear power plant. At this time, the political elite in Germany, namely the Christian Democrats and Social Democrats, thought that nuclear energy was the future of clean energy, to the point that it "might one day even eliminate energy bills."[4] German activists found solace in their struggle resonating throughout Europe in an anti-nuclear push from the citizenry.

Protests continued despite the stated goals of the political powers, such as in 1975, when 28,000 protestors halted the construction of a nuclear site in Whyl simply by delaying construction schedules.[5] And, after the accident at Three Mile Island in 1979, 200,000 people protested in the streets of Hannover and Bonn opposing the German's reliance on nuclear energy. Furthermore, the government pursued the construction of the pursuit of a risky high speed reactor, the SRN-300, near the city of Kalkar only to be met with huge demonstrations in 1977. Simultaneously, independent experts were raising questions about the security risks of plutonium enhancement. A prototype speed reactor at Bethe-Tait had recently suffered a meltdown, confirming many theories of the risk and uncertainty surrounding nuclear energy.[6] The government completed the Kalkar project in 1985, but following the introduction of a "Red-

[3] Glaser, "From brokdorf."
[4] David Blackbourn. *The Culture and Politics of Energy in Germany: A Historical Perspective.* Rachel Carson Center. 2013.
[5] Kerstine Appunn. "The History Behind Germany's Nuclear Phase-Out." *Clean Energy Wire.* July 24, 2015. https://www.cleanenergywire.org/factsheets/history-behind-germanys-nuclear-phase-out. (Accessed January 9, 2017.)
[6] Glaser, "From brokdorf."

Green Germany" in 1991, the $4 billion was stopped forever. This contentious moment showed one of the biggest citizen-governmental conflicts in the history of German nuclear power.

At the same time, in 1983, President Ronald Reagan was storing nuclear missiles in Germany, which sparked an outrage from citizens and protests from all parts of society, including environmentalists and peace movements. Thus, by the mid-decade, the German nuclear dialogue was finally focused on the risks of nuclear proliferation and storage.

2.3 Chernobyl Exacerbates Anti-Nuclear Movement

The disaster at Chernobyl, Ukraine in April of 1986 struck fear in all of Europe in pursuing nuclear energy as a realistic option for the future. In Germany, it brought the risks of the nuclear phase into the political sphere, making the topic the primary concern for most parties. This disaster became a defining moment for the Social Democrats, who had previously been adamant about the use of nuclear energy and were now beginning to turn their attention against nuclear power. They developed a platform against nuclear enrichment and made a strong stance in favor of a nuclear phase-out, citing, "We want to achieve a secure and environment-friendly energy supply without nuclear power as soon as possible. We consider the plutonium economy a mistake."[7] Just before the Chernobyl meltdown, the German Green Party had entered politics for the first time in their election to the Bundestag, the German federal parliament, in 1983. Their platform evolved around the promotion of green technology and enforcing a nuclear phase-out. Thus, because of Chernobyl, the Green Party formed a coalition government with the Social Democrats in the election of 1998 and begin directing national energy policy away from nuclear energy. Simultaneously, 1986 marked the year that climate change entered the German political

[7] Glaser, "From brokdorf."

system. Again, the Green party was instrumental in this dialogue, aided by the speed of German science studies in the 1980's and 1990's on the man-made effects of global climate change.[8]

2.4 Germany in response to the Energy Crisis of 1970

Another change in Germany's energy policy, influencing both nuclear and renewable energy, came out of the Energy Crises of the 1970's, which resulted from the Middle East driving up oil prices in two instances: first, because of "Western support for Israel in the Yom Kippur War in 1973," and second, following the Iranian Revolution of 1979.[9] As a result, a world-wide debate about the duration of fossil fuels was sparked, suggesting that the current energy strategy may leave the world without energy in the near future. Thus, many countries, like the United States and Denmark, began experimenting with renewable energies, while Germany was pushed back into its interest with nuclear energy; however, in response to this, activists worked to form the 'Greens,' a nation-wide political party which had influence in the political and social sectors, hoping to remove nuclear energy from the country's energy policy. With their growing influence, "renewables, energy savings, low-impact lifestyles, sustainable development, mobility alternatives, and smart urban design" developed more ground in the political atmosphere of Germany.[10] Thus, the Green Party, a director of green politics, grew simultaneously from anti-nuclear sentiments and doubts arising around the Energy Crisis of 1970.

2.5 Legislation Changes 1990-2016

Significantly, in 1991, the German chancellor Helmut Kohl formed the Ministry for the Environment Nature Conservation and Nuclear Safety which then organized the 1990 Renewable

[8] Paul Hockenos. "The history of the Energiewende – the First Four Decades." *Clean Energy Wire.* June 22, 2015.
[9] Blackbourn, "Culture and Politics."
[10] Blackbourn, "Culture and Politics."

Energy Law, instituting one of the world's first subsidies employing feed-in tariffs (FIT) for the stimulation of renewable energy development.[11] The tariffs incentivized investment in renewable energy and jumpstarted a change in the energy market of Germany. Following this, Kohl and the right-wing government was voted out of office in 1998 and replaced by a coalition of Social Democrats and Greens, coining the phrase, "Red-Green Germany." They promised to make the expansion of renewable energy their primary platform in order to combat the growing threats of climate change. At the same time, the administration passed the Renewable Energy Act (EEG), including feed-in-tariffs for a number of renewable energies that could not have competed with the market energy because of "high investment costs."[12] This policy expanded the tariffs created by the 1990 Renewable Energy Law. The energy market was simultaneously opened for smaller energy investments into the grid by some of the EU directives in the 1990's, which aimed for the "liberalization of domestic energy markets," since many countries, and Germany in particular, were subject to the monopolization of energy markets by large companies unwilling to share the market with smaller investors.[13] As a result of these directives, the monopolistic quality of the German energy market dissipated, such that there are over 1000 investors and participants in the energy market in Germany today.[14]

Each year, however, the EEG faces considerable pressure for changes and adaptation to its structure, subsidies and target goals for the energy mix, and, as a result, the national German energy dialogue is dynamic and fluid. Thus, in 2000 the government replaced the FIT legislation with the Renewable Energy Law of 2000, which guaranteed the feed-in prices paid by gird

[11] Blackbourn, "Culture and Politics."
[12] Blackbourn, "Culture and Politics."
[13] Blackbourn, "Culture and Politics."
[14] Blackbourn, "Culture and Politics."

operators to producers of renewable energy for a set period of 15-20 years, rather than an unlimited span of time. This was supposed to encourage development of renewable energy technology but not suffocate the German consumer with energy taxes.[15] Furthermore, the purpose of the Renewable Energy Law was to double the share of renewable energy in the country's total energy consumption while simultaneously increasing the amount of renewable technology involved in energy production.[16]

Around the same time, the German Bundestag, the highest portion of their parliament, amended the Act on the Peaceful Utilization of Atomic Energy and the Protection Against Its Hazards (the Atomic Energy Act) of 1959 after having reached an agreement with the major utilities on the future restriction of existing nuclear power plants. This amendment comprehensively stood for all the past anti-nuclear sentiments permeating throughout the German political dialogue over the past decades, in that it set a timeline for the phase out of all nuclear energy. The amendment stipulated that the life of individual reactors and the commercial production of nuclear energy would be extended for 32 years due to safety concerns and the risk inherent in developing and managing atomic energy. (These 32 years were an estimation of remaining energy output, and the logical timeline for their calculations led to the 2022 expiration date.)[17] Furthermore, the amendment specified that no further licenses would be granted for the construction of new nuclear plants, but the ones currently in use would be maintained and evaluated consistently for safety measures. And, reprocessing nuclear waste would no longer be

[15] Miranda A. Schreurs. 2012. "The politics of phase-out." *Bulletin of the Atomic Scientists* 68 (6): 30-41.
[16] Craig Morris, Arne Jungjohann, and Ebook Library. 2016. "Energy democracy: Germany's Energiewende to Renewables." Switzerland: Palgrave Macmillan.
[17] Morris, "Energy Democracy."

allowed, forcing the local plant operator to store the toxic waste in a responsible and legal way.[18] With this legislation, Germany solidified its stance on moving away from nuclear energy as a fuel source, making it a keystone event in the history of Germany's nuclear phase out. At this time, 35% of Germany's power came from nuclear energy production, meaning that massive improvements in renewable energy, and likely coal, were needed to substitute in the energy mix. Though many domestic critics argued this policy was short sighted, nuclear phase-outs were common throughout the European Union. Denmark, Austria and Italy had confirmed similar legislation years, and in some cases, decades, previously, while Belgium had recently devised a plan to phase-out nuclear energy by 2025.[19]

Germany continued to display energy policy supporting the nuclear phase out and growth of the renewable sector from here on. In the EEG Amendment of 2004, Germany committed to increase the country's share of renewable energy for electricity to 12.5% by 2010 and to 20%, at least, by 2020.[20] These targets were relatively meaningless, as the German's had well exceeded that, making the mix 17% renewable by 2010, which ultimately led the goal of 2020 to be increased to 35%.

Yet again, Germany's energy policy was amended in 2009, when it was expanded from its 22 sections in 2004 to 66 sections. The amendment included the change to 35% renewable energy by 2020 in addition to the inclusion of avoided costs in determining the surcharge for renewable energy. This meant that the FIT now became the difference between the amount that

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[18] Axel Vorwek. "The 2002 Amendment to the German Atomic Energy Act Concerning the Phase Out of Nuclear Power." Nuclear Legislation Division. https://www.oecd-nea.org/law/nlb/nlb-69/nlb69-vorwerk.pdf. (Accessed January 25, 2017.)
[19] Morris, "Energy Democracy."
[20] M. Corre Mendonça, J. "Feed-In Tariffs Support renewable energy in Germany." *World Future Council* (2008): http://www.e-parl.net/eparliament/pdf/080603%20FIT%20toolkit.pdf. (Accessed November 10, 2017.)

grid operators paid to the producers of renewable energy and the revenue the companies made, such that the ratepayers covered the difference.[21] By this same time, four nuclear power plants (Biblis A and B, Neckarwestheim and Brunsbuttel) had been shut down to compensate for the 2002 agreement.

Nonetheless, the 2009 elections gave power back to the conservative parties, the Christian Democratic Union and the Federal Democratic Party (FDP), who developed a coalition under Angela Merkel. Their agenda included extending the lives of nuclear power plants past the preconceived schedule of 2002, using nuclear as a bridge technology during its own phase-out.[22] This majority amended the Atomic Energy Law in a controversial method which surpassed the upper house (Bundesrat) and passed in the lower house (Bundestag) to extend nuclear energy into 2036. Even so, 49% of the population was against the phase-out and 29% supported limiting the lifetimes of nuclear plants, showing that the majority of the population was in favor of ruling out nuclear. The extension deal gave plants constructed before 1980 an 8-year life span and those built after 1980 a 14-year life span. In opposition, 120,000 German citizens formed a human chain between the Brunsbuttel and Krummel reactors to dually commemorate the anniversary of the Chernobyl disaster and express their anti-nuclear beliefs.

Though the conservatively run coalition had expanded the projected lifetime of nuclear power, their focus was still on revamping energy policy to reduce Germany's carbon footprint and increase the share of renewable energy. Thus, in 2010, the government introduced the Energy Concept, part of Germany's Energiewende, or "energy revolution", which set a target goal of cutting national green-house gas emissions by at least 40% from 1990 levels by 2020,

[21] Morris, "Energy Democracy."
[22] Schreuers, "Politics."

and 80% by 2050.[23] This radical decision lead to widespread debate over its feasibility, with many business owners both questioning how much this transition will cost the country and fearing a mass exodus of domestic, energy intensive industries who want to avoid potentially rising electricity prices. Hans-Erner Sinn, president of the Ifo Institute for Economic Research at the University of Munich chimed in, "It is wrong to shut down the atomic power plants, because this is a cheap source of energy, and wind and solar power are by no means able to provide a replacement. They are much more expensive, and the energy that comes out is of inferior quality."[24]

2.6 Aftermath of Fukushima

On March 11, 2011, the Tohoku earthquake initiated a tsunami that struck the Fukushima I Nuclear Power Plant in Fukushima, Japan, causing three nuclear meltdowns and untold radioactive exposure throughout the surrounding area. The Christian Democratic Union, who had previously placed their faith in the technological efficiency and reliability of German nuclear power plants, reconsidered their previous position. The fact that this scale of a disaster had happened in what they consider to be a technologically sound country reinforced the prior national belief in ousting nuclear energy.[25] Only months after the disaster, on June 11, Angela Merkel closed 8 of the 17 nuclear power plants active in Germany and set the phase out for 2022, therefore repealing the 2002 amendment to the Atomic Energy Law. She defended her aggressive decision in saying,

> You can only accept the residual risk of nuclear power if you are convinced that it will not occur as far as it is humanly possible to determine…And this is exactly the point—

[23] Talbot, David. "The Great Germany Energy Experiment." *MIT Technology Review*. June 18, 2012. https://www.technologyreview.com/s/428145/the-great-german-energy-experiment/. (Accessed January 19, 2017.)
[24] Talbot, "The Great."
[25] Schreuers, "Politics."

> it's not about whether Germany can have such a disastrous earthquake, such a catastrophic tsunami as Japan. Everyone knows it won't happen the same. No, after Fukushima we're talking about something else. We're talking about the reliability of risk assessments and the reliability of probability analyses…Fukushima changed my stance on nuclear power.[26]

Thus, the German parliament returned to their previous goals for the nuclear phase-out, believing that it gave enough time for utilities, the economy and the renewable sector to compensate for the loss of nuclear power, both in terms of energy and the economy. While some view Merkel's decision, supported unilaterally by her political party, as unfounded and reckless, it follows from decades of anti-nuclear sentiments in Germany, stemming from political and citizen desires.

2.7 The Energiewende

Germany's nuclear phase-out is encompassed in their revolutionary energy policies, the Energiewende, otherwise known as the energy transition. Ideally, the Energiewende stems from the sum of decades of renewable energy promotion and anti-nuclear sentiments throughout the German citizenry and political sphere, starting in the 1960's as detailed above; however, it specifically refers to legislation that began through the Feed-in Tariff Law of 1990, which accelerated the development of renewable energy and jumpstarted energy policy directed at moving away from conventional power sources such as coal and nuclear power generation. Similarly, the Renewable Energy Laws of 2000 and 2014 provided further incentives for Germany to revolutionize its energy production in that the subsidies for solar PV and wind development were increased to encourage investment in green energy. The Energiewende comprises all of this, including the nuclear phase-out, to push Germany forward towards an unparalleled, aggressive energy mix.

[26] Morris, "Energy Democracy."

According to the Agora Energiewende FAQ, there are four main objectives of the energy transition: combatting climate change, avoiding nuclear risks, improving energy security, inciting competitiveness and growth.[27]

		Status quo	2020	2025	2030	2035	2040	2050
Greenhouse gas emissions	Reduction of CO_2 emissions in all sectors compared to 1990 levels	-26.4% (2014)*	-40%		-55%		-70%	-80 – 95%
Nuclear phase-out	Gradual shut down of all nuclear power plants by 2022	11 units shut down (2015)	Gradual shut down of remaining 8 reactors					
Renewable energies	Share in final energy consumption	12.4% (2013)	18%		30%		45%	min. 60%
	Share in gross electricity consumption	27.3% (2014)*		40 – 45%		55 – 60%		min. 80%
Energy efficiency	Reduction of primary energy consumption compared to 2008 levels	-9.1% (2014)*	-20%					-50%
	Reduction of gross electricity consumption compared to 2008 levels	-4.8% (2014)*	-10%					-25%

Figure 1: German Energiewende Targets

As represented in Figure 1, Germany has set hugely ambitious targets for their energy production through time-based intervals. Though they are part of the European Union and therefore involved in various sustainable energy goals, their domestic policy vastly exceeds that of the EU. First, the policy aims at reducing CO_2 emissions by 80-95% by 2050. They aim to achieve this through their past subsidization of renewable energy and efforts to curb energy efficiency, which are aimed at a 25% reduction by 2050. Additionally, the transition encompasses the nuclear phase out, set for 2022, initially established in 2002 and then reestablished in 2011 by Angela Merkel and the coalition government of the Christian Democrats and the Green Party. Encouraging the growth of renewable energy is expected to account for the loss of nuclear power, as the Energiewende sets an increase to 60% of the share in final energy consumption by

[27] Agora Energiewende (2015). *Understanding the Energiewende: FAQ on the ongoing transition of the German power system* (PDF). Berlin, Germany: Agora Energiewende. (Accessed February 12, 2017.)

renewable energies by 2050, with an 80% share of the gross electricity consumption stemming from renewable energies. Furthermore, Germany has set out to increase their energy efficiency to help reduce the pressure of the nuclear phase out on the energy mix. They plan to reduce primary energy consumption (compare to 2008 levels) by 50%, and to reduce gross electricity consumption by 25%.[28]

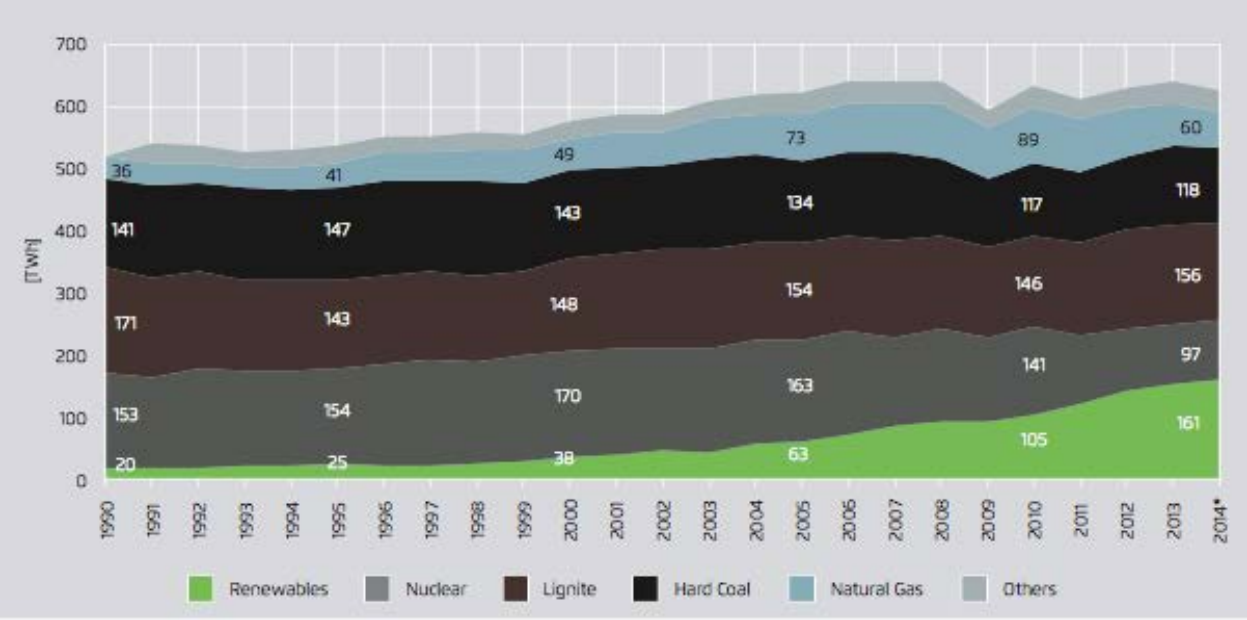

Figure 2. Gross Electricity Generation in Germany 1990-2014

In recent years, Germany's policies have led to substantial changes in their energy mix. For instance, 2014 was the first year that Germany produced more electricity through renewable energy than fossil-fueled power plants.[29] Figure 2 contains the transition of energy generation in Germany throughout the past two decades. Since 1990, renewable energy has increased from 3.6% of the total electricity production to 25.8% in 2014, and also accounts for 27.3% of the national electricity consumption. Nuclear energy, due to Angela Merkel's closing of 8 nuclear power plants, has declined from 27.7% in 1990 to 15.5%. Lignite coal has remained relatively

[28] Agora, "Understanding."
[29] IBID.

constant over the past 20 years, comprising 24.1% of the energy mix in 2014, parallel to hard coal, which made up 18.9% of the mix.[30]

2.8 Conclusion

The nature of any country's policies, no matter the focus, is evolutionary. Constantly changing variables require the need for adaptation from governments and from citizens to address the needs of a nation. Germany's nuclear history is the archetype of change and adaptation, as decades of citizen protests and governmental decisions led to the ultimate phasing out of nuclear energy and the rapid, unseen development of clean, sustainable energy. Now, the Energiewende will guide German policy through the future, while keeping the decisions of the past in mind.

[30] IBID.

3.1 Introduction to the Impact of the Nuclear Phase-Out

This chapter will present specific information on the impact of Germany's implementation of the nuclear phase-out. It will focus on the anticipated costs, both to individuals and the country primarily focusing on the cost of electricity and the necessary spending that will need to occur to compensate for the loss of nuclear power in the energy mix. One of the main components of the phase-out is replacing the nuclear contribution of power to continue Germany's industrial based economy. Thus, the impact on European power grids and carbon production are major pieces of a successful phase-out. Additionally, it will provide perspective on the accelerated policy of Germany in an investigation of Europe's response to Germany's approach towards a more sustainable energy supply free from the risks inherent in nuclear energy. This will entail a description of the surrounding countries energy policy to act as comparable energy transitions.

3.2 Impact of the Nuclear Phase-Out on Electricity Prices and Sources

Ultimately, the German government asserts that the nuclear phase-out aims to curb the increase of electricity prices for both industry and households. Additionally, they anticipate the phase-out, as part of the Energiewende, will decrease CO_2 emissions while simultaneously replacing the energy once provided by nuclear plants in Germany with other conventional sources of power, mainly solar and wind power. B. Knopf et. al conducted a study in which they assessed the various costs and expected outcomes of a German energy mix absent of nuclear power generation. Figure 3 shows the projected timeline of closing nuclear plants and the waning electricity generation which follows. It indicates a gradual decrease in reliance on nuclear while renewables have time to develop and replace the energy production from nuclear plants.

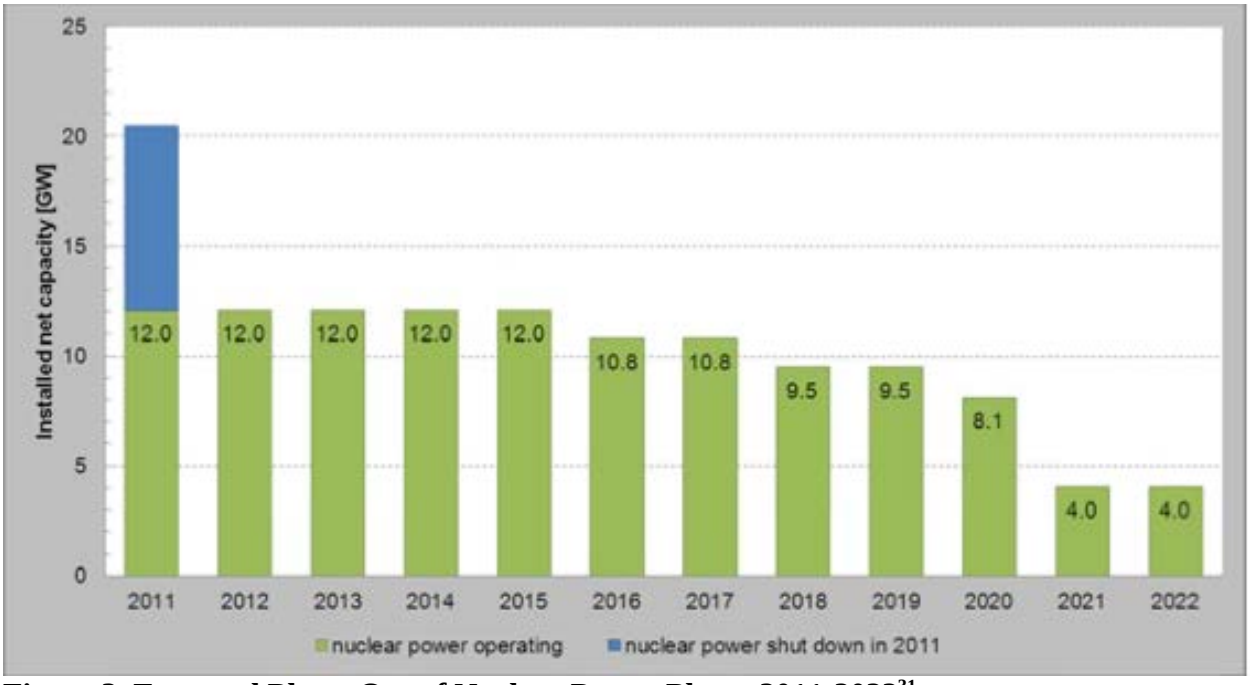

Figure 3. Expected Phase-Out of Nuclear Power Plants 2011-2022[31]

Following Angela Merkel's decision to phase-out nuclear power and immediately close eight reactors in the summer of 2011, German policy has had to replace a large source of electricity generation quickly. Withdrawing from nuclear entirely, at this point, would require replacing 21 GW in net electricity generation by the estimated 2022.[32] With the 2011 'moratorium' of nuclear power plants, 10 GW of electricity generation were lost immediately, which was temporarily accounted for by employing overcapacity generation and reducing the typical amount of electricity exports to neighboring European countries.[33] In 2015, a number of fossil-fueled power plants were constructed with a general capacity of 11 GW, but at the same time, Germany

[31] Knopf et a., 2012 Knopf, B., Pahle, M., Kondziellab, M., Joas, F., Ottmar Edenhofer, O., Bruckner, T., 2012. Germany's Nuclear Phase-out: Impacts on Electricity Prices, CO_2 Emissions and on Europe, *Potsdam Institute for Climate Impact Research (PIK).* Report, Potsdam, Germany. https://www.mcc-berlin.net/fileadmin/data/pdf/Publikationen/Knopf_Pahle_Joas_Edenhofer_Germanys_nuclear_phase-out_2012.pdf (Accessed February 20, 2017).

[32] Knopf et. al, "Germany's."

[33] Knopf et. al, "Germany's."

is closing 14 GW of old coal-fueled power plants, and plan to close an additional 13 GW of plants by the completion of the phase-out in the next 5 years. Thus, up to 27 GW of electricity generation will be needed to replace the dwindling nuclear power sources.[34] Knopf et al., in the following tables, uses the anticipate renewable energy expansion, increased energy efficiency and increased imports of net energy to supply the 27 GW of energy needed by 2022.

Germany is a liberalized electricity market, which means that the market prices are based on an average value of all the power plants and energy generators in the market, otherwise known as their merit order. In this type of market, the marginal plant, which is the plant with the most expensive energy production costs, determines the market price. Because nuclear energy is cheap to produce (once it has been built through expensive investments), it precedes lignite, hard coal and gas power plants in the merit order. Therefore, since it is the cheapest energy available, the spot market price will increase following its phase-out as the average price of energy production will rise due to the simultaneous increase in more expensive energy production, namely fossil-fueled electricity generation; however, the increase in renewable energy as part of Germany's energy mix will gradually offset the rising average induced by the loss of nuclear power generation. Because renewable energy is supplied to the grid at a negative cost in order to ensure that grid operators purchase energy from renewable energy producers, it largely reduces the cost of the spot market price.

[34] Knopf et. al, "Germany's."

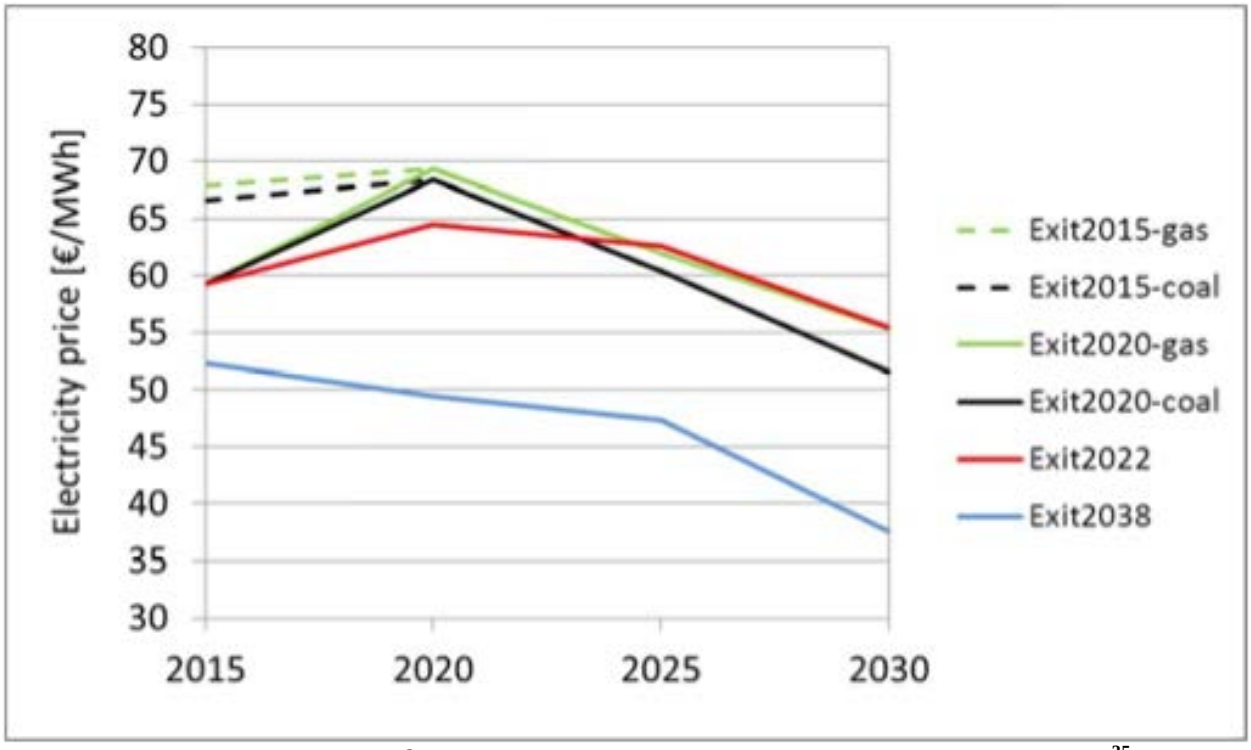

Figure 4. Estimated Impact of Nuclear Phase-Out on Wholesale Electricity Prices[35]

Figure 4 represents the anticipated changes in electricity prices throughout the nuclear phase out and the increased share of renewables in Germany's energy mix. on the basis of assumed fuel and CO_2 prices, electricity production costs for gas and coal plants are roughly equal, and therefore will have a similar impact on the market price. Knopf et al. employed three scenarios for changes in electricity prices, but given that Germany has adopted the 2022 nuclear phase-out, that is the only relevant data. Wholesale electricity prices are expected to rise to 65 ct/KWh by 2020 and steadily decline following the completion of the phase-out. In entirety, this will lead to a 6.45 ct/KWH increase by 2022.[36]

Germany's wholesale electricity market creates different price scenarios for industry and household consumers. Because the Feed-In Tariff is not applied to large industries to increase

[35] Knopf et. al, "Germany's."
[36] Knopf et. al, "Germany's."

their competitiveness with other countries, the surcharge given to end-use consumers on account of subsidizing renewable energy results in a higher electricity cost for individuals and small, non-exempt industry.

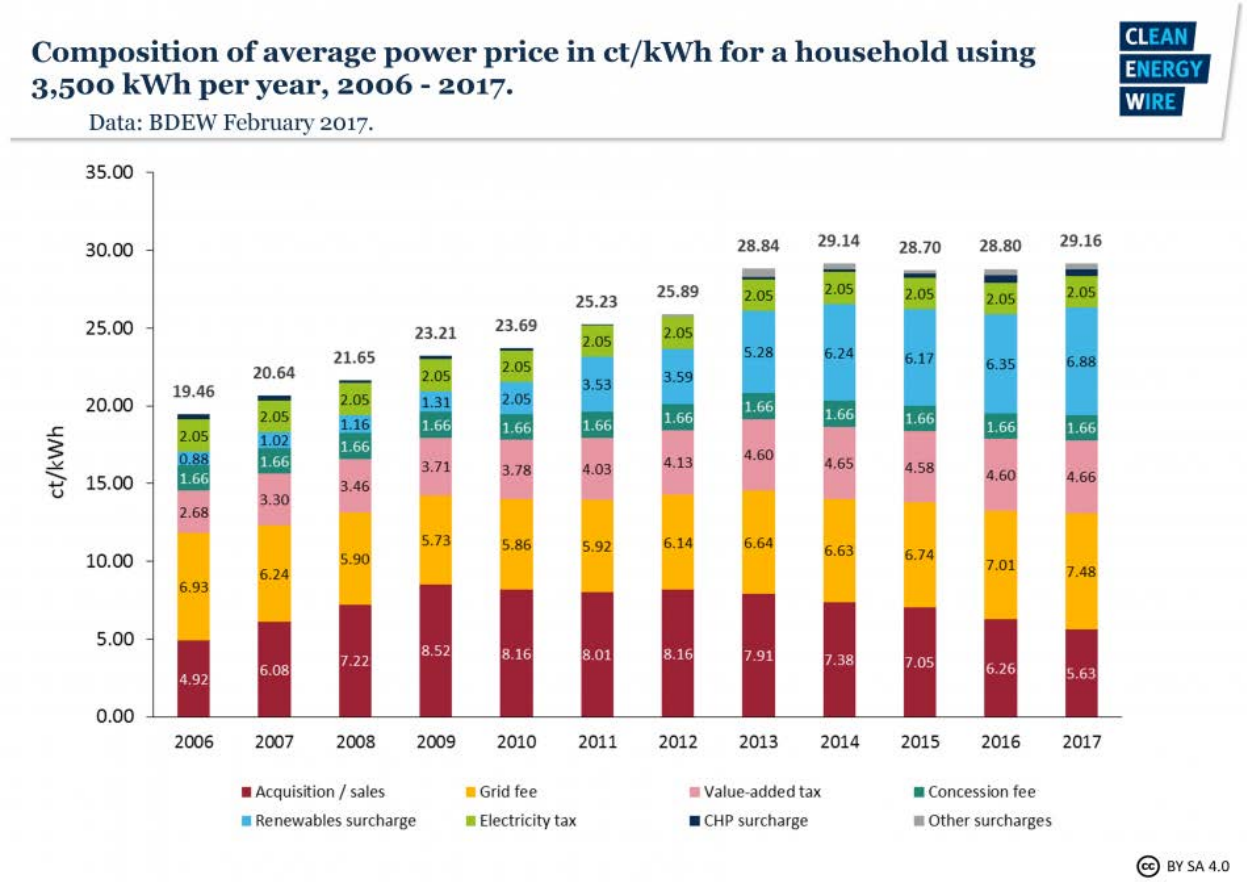

Figure 5. Household Power Price by Composition for Households Using 3,500 KWh per year[37]

As represented by Figure 5, electricity prices have been steadily rising for the average family of three in Germany, exceeding the average price in 1998 by 68%. And, in the same window of time, the surcharge has risen 10%.[38] Consumer electricity costs are broken down in the following ways: 19.3% (cost of power for supplier) 23.6% (Renewable energy surcharge) 16% (sales tax)

[37] Thalman, Ellen and Benjamin Wehrmann. *What German Households pay for power*. The Clean Energy Wire. February 16, 2017. https://www.cleanenergywire.org/factsheets/what-german-households-pay-power. Accessed February 21, 2017.
[38] Thalman, 2017.

7% (electricity tax) 5.7% (Concession levy) 0.1% (Levy for offshore liabilities) 1.5% (Surcharge for combined heat and power plants) 1.3% (levy for industry rebate on grid fees). For this reason, the nuclear phase-out, if accomplished by 2022, will continue to accelerate the cost of electricity for the consumer. As more nuclear plants are closed, the increased dependence on renewable energy will continue to increase the percentage of the surcharge.

3.3 Impact on the Transmission Grids

A change in energy generation will influence change in the transmission of electricity throughout Germany. Presently, long distance transmission lines transport electricity across Germany and even across international boundaries, totaling 35,000 km in length.[39] The four main service companies in Germany, TenneT, 50Hertz Transmission, Amprion and TransnetBW, are responsible for operating these grids, in terms of maintaining and upgrading infrastructure, extending and updating power cables and providing electricity generators with grid access.

Nuclear reactors in Germany were located largely in the southern parts of the country, nearby the industrial regions that require the highest demand for electricity production. Thus, in the nuclear phase-out, one of the main implications is the transfer of energy production from the southern region towards the northern region where most of the renewable energy will be installed to compensate for the diminishing nuclear power generation. By the complete phase-out in 2022, electricity will have to be transmitted to the southern parts of the country to meet the demand of the industrial sectors. With excess electricity coming from Northern Germany because of the increase in renewable energy production, largely from wind, and with fluctuating

[39] Electricity Grids of the Future. Federal Ministry for Economic Affairs and Energy. Bundesnetzagentur.

energy contributions, there will be abnormal congestion in the North-South transmission axis.[40] This congestion results from a change in the flow of energy caused by RES technology. Kenneth Brunnix asserts that the 883-85 line in Southern Germany will be most congested in this scenario (refer to Figure 6).[41] As a result, the limited transmission capacity of the grid is the most limiting factor, such that the North-South axis will have to be expanded in order to overcome shortfalls in the current construction of the German grid, and, as of 2017, limits the consumptive proportion of renewable energy produced in the northern sectors.

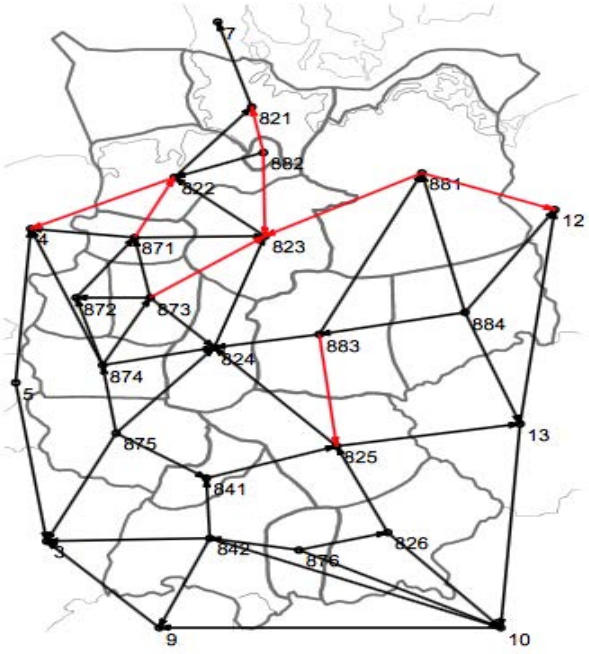

Figure 6. Outline of German Transmission Lines. [42]

[40] Kenneth Brunnix, Darin Madzharov, Erik Delarue, and William D'haeseleer. 2013. Impact of the german nuclear phase-out on europe's electricity generation - A comprehensive study. *Energy Policy* 60 : 251.
[41] Brunnix, "Impact."
[42] IBID.

Additionally, Germany is changing from a net exporter of energy prior to the nuclear phase-out to a net importer of electricity, which will therefore change the flow of energy in the grid causing further congestion issues and need for adaptation.

3.3.1 Legislative Process Governing Grid Expansion

Because German energy policy changes annually, so must the plan for expanding the grid. The Germans have constructed a concrete series of steps and legislation to help accelerate the expansion of the grid to accommodate the changes necessitated by the phase-out. Four acts govern grid infrastructure. First, The Energy Industry Act (EnWG) focuses on maintaining annual grid expansion with transparency towards the public and coordination between utilities. Second, The Grid Expansion Acceleration Act (NABEG) pursues rapid expansion, as the name implies, to parallel the rapid production of renewable technology entering the electricity market. It helps to resolve border issues, between both state and national lines, streamlining the process and the federal approval of projects for new or updated lines. Third, the Federal Requirement Plan Act (BBPIG) works to identify priority projects for transmission line expansion based off state legislation like the Grid Development Plan and the Offshore Grid Development Plan. Finally, the Power Grid Expansion Act, approved at least every three years, provides projects that independent state in Germany must pursue on their own.[43] The coordination of these laws helps Germany to identify the necessary grid expansions and pursue them at the speed necessary to match the decrease in nuclear power generation.

[43] Press Release. Offshore grid expansion on track: more expansion, low liability surcharge. BMWI. http://www.bmwi.de/Redaktion/EN/Pressemitteilungen/2015/20151019-offshore-netzausbau-auf-kurs-mehr-ausbau-geringe-haftungsumlage.html. (Accessed February 22, 2017.)

Similarly, the Federal Network Agency (German: Bundesnetzagentur or BNetzA) outlines the steps involved in grid expansion. They follow the same, methodical outline each time. First, a scenario framework is drawn, which describes the needed developments in the energy landscape, such as grid expansion or maintenance, which is drafted by the grid operators and then approved by the BNetzA. Following this, a network development plan and environmental assessment outlines the expansion requirements for the following year while evaluating the potential environmental impact. This allows utilities to build transmission lines with the smallest impact on citizens and natural ecosystems. Upon completion, the Federal Network Agency in charge of the electricity sector develops a federal requirements plan containing a list of the necessary projects with start and end goals for construction. Fourth, federal sector planning assesses which bodies of government must be involved based off the various borders that will be crossed to help expedite the approval of various projects. Finally comes the planning approval that determines the best route for the transmission lines to be built.[44] This generic set of guidelines enables Germany to rapidly develop new plans for grid expansion.

3.3.2 Status of German Grids

The current state of the German grid system includes a total of 35,000 km of transmission lines, but with the rapid increase of new energy inputs, this will have to increase annually and therefore requires large governmental oversight as discussed above. Additionally, 77,000 km of distribution lines (high voltage: 60V to 220V) transport power from the high voltage grid to transformer substations around population centers and industrialized regions. The medium

[44] Federal Network Agency. How it works: Grid expansion in five steps. https://www.netzausbau.de/EN/5steps/en.html (Accessed February 22, 2017).

voltage grid (6 kV to 60 kV) distributes electricity to large facilities like hospitals and factories, with an approximate length of 479,000 km. Lastly, the low voltage grid (30 V to 400 V) is composed of 1,123,000 km and services private households, small companies, commercial enterprises and end users.[45]

Much of Germany's renewable energy expansion will come from offshore wind, since the options for onshore are decreasing annually. Currently, Germany has only 500 MW of wind power installed offshore in depths of up to 40 meters; however, they plan to increase that to 10,000 MW up to 160 km off shore and of depths up to 70 meters.[46] Beyond this, Germany needs an estimated 3,800 km (2,361 miles) of new transmission lines by 2022 to connect the four main grid operators, with an estimated cost of 20 billion euros, yet as of 2012 they had installed only 200 km of transmission lines to connect offshore wind energy.[47] Other sources believe the spending may exceed that drastically. "Various economic think tanks predict that the country will spend somewhere between $125 billion and $250 billion on infrastructure expansion and subsidies in the next eight years—between 3.5 and 7 percent of Germany's 2011 GDP."[48]

3.4 Impact on Carbon Emissions

Because nuclear, at its height in Germany, comprised almost a quarter of the country's energy production and a fifth of its energy consumption, its exit will leave wide holes in the energy mix that need to be replaced in order to maintain the same levels of industrial prowess and living conditions. Germany operates within the EU Emissions Trading System (ETS), meaning that

[45] Electricity Grids of the Future. Federal Ministry for Economic Affairs and Energy. Bundesnetzagentur.
[46] Talbot, "The Great."
[47] Spiegel Staff. "German Power Grid Expansion to Cost Billions." *Spiegel Online.* May 30, 2012. http://www.spiegel.de/international/germany/germany-needs-miles-of-new-power-lines-to-make-energy-transition-a-835979.html. (Accessed February 21, 2017.)
[48] Talbot, "The Great."

companies can trade and purchase emission permits if they expect to increase their carbon emissions. The basic principle of the ETS, established in 2005, sets a limit on emissions and offers allowances to large emitters that can then trade or sell those depending on their current emissions. Companies can then either purchase more allowances from other companies if it is going to surpass its original allowance or decide to invest in technology that will reduce emissions.[49] Ideally, the ETS was constructed to help curb Europe's carbon footprint, but conversely, it lead to the construction of coal powered plants across Europe. In fact, Europe's eight biggest utilities invested over 20 billion euros in new fossil-fueled facilities from 2003-2005.[50] This influenced the German utilities as well, when the four major utilities quadrupled in size as their CO_2 allowance rose to 50 billion euros and they built 9 new coal power generation plants in 2009 alone.[51] Both Angela Merkel and the Environmental Minister Sigmar Gabriel understood the importance of coal in the energy transition, stating that new fossil-fueled power plants are paramount to an efficient phase-out of nuclear energy.[52] Because of the ETS, overall emissions should be unaffected by the phase-out because there is a firm EU cap on total emissions.

Currently, Germany has increased reliance on lignite coal, the dirtiest form of carbon available, as it is cheap and mined domestically. The Energy Minister in 2012 opened up another new coal electricity generator, arguing, "If one builds a new state-of-the-art lignite power plant to replace several older and much less efficient plants, then I feel this should also be

[49] Morris, "Energy Democracy."
[50] Morris, "Energy Democracy."
[51] Morris, "Energy Democracy."
[52] Morris, "Energy Democracy."

acknowledged as a contribution to our climate protection efforts."[53] Between 2011 and 2015, 10.7 GW of coal based power production were added to Germany's energy mix.[54] Figure 7 details the current energy mix in Germany, showing the strongest ties to fossil fuel and renewable energy generation.

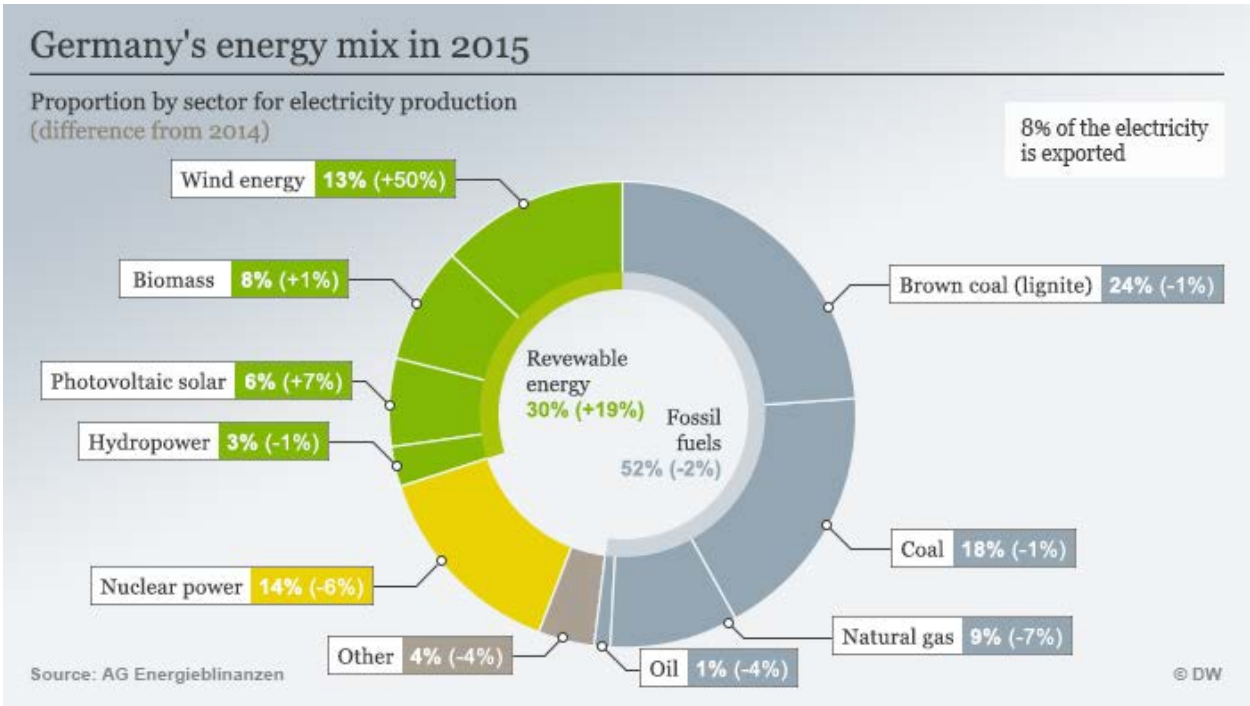

Figure 7. Germany's Energy Mix in 2015 Compared to 2014.[55]

3.5 Influence and Impact of Surrounding Nations

The decision to phase-out nuclear energy may be unique to the Germans, but several other European countries are pursuing comparable energy transitions towards cleaner, more sustainable energy. The European Union as a whole is pushing towards the decarbonization of

[53] Robert Wilson. "Why Germany's Nuclear Phase Out is Leading to More Coal Burning." *The Energy Collective.* January 20, 2014. http://www.theenergycollective.com/robertwilson190/328841/why-germanys-nuclear-phase-out-leading-more-coal-burning. (Accessed January 19, 2016.)
[54] Wilson, "Why Germany's."
[55] Kerstine Appunn. "Germany's energy consumption and power mix in charts." The Clean Energy Wire. Dec 23, 2016. https://www.cleanenergywire.org/factsheets/germanys-energy-consumption-and-power-mix-charts (Accessed February 4, 2017).

their economy by 2050 as part of the Energy and Climate package, which also set interim targets for 2020 and 2030.[56] The European Council manages the goals of the EU membership countries and decided on these goals back in October 2014, including a 40% reduction in greenhouse gas emissions in comparison to 1990 levels, a 27% share of renewable energy by 2030 and a 27% improvement in energy efficiency by 2030 for all member nations.[57] These nations together, named the Energy Union, are working towards a comprehensive European strategy aimed at improving energy security, sustainability and competitiveness together. Each has signed the Paris agreement. Thus, the Germans are part of a larger European strategy that embraces, and sometimes exceeds, the ambitious targets incentivizing a cleaner energy system.

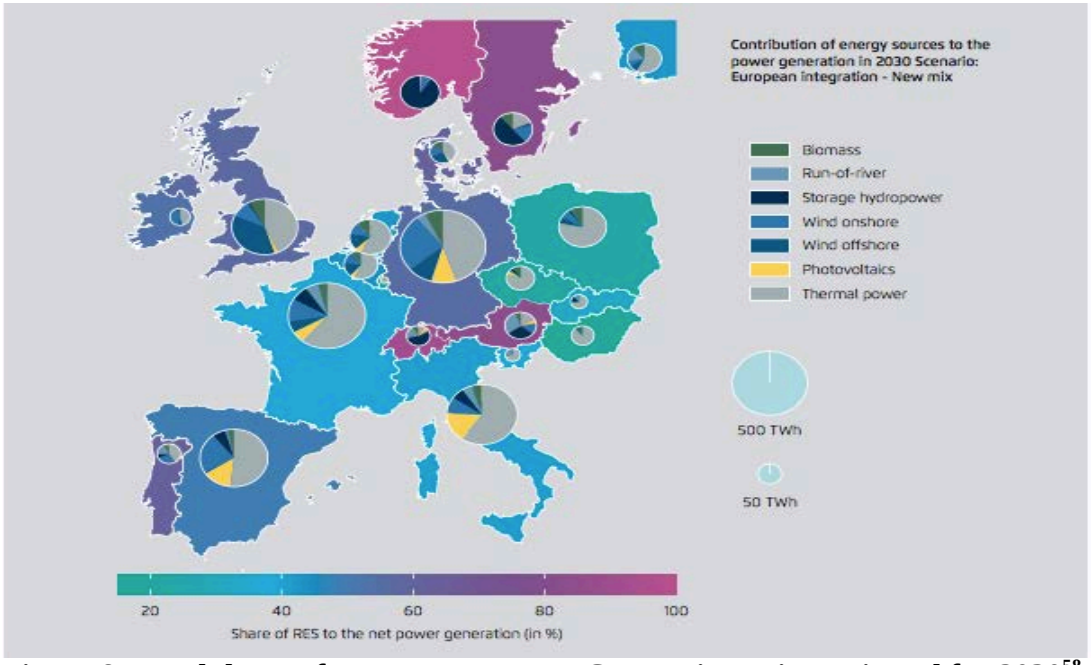

Figure 8. Breakdown of European Energy Generation Mix Projected for 2030[58]

As indicated by Figure 8, Germany is in the middle of a conglomeration of states who are focused on radically increasing the share of renewable energy in their energy mix. In fact,

[56] Agora, "Understanding."
[57] Agora, "Understanding."
[58] Agora, "Understanding."

Germany's Energiewende falls near the middle in terms of their renewable energy goals. Since 2013, renewables make up 70% of installed energy generation capacity in Europe, indicating a continental trend of transitioning towards sustainable energy reliance.

Given that these states have similar goals, they face similar challenges. As a result, the Energy Union Framework Strategy was created in 2015 to help link the countries in a cooperative front. In 2016, better interconnection and regional cooperation was accomplished as part of the infrastructure challenge.[59]

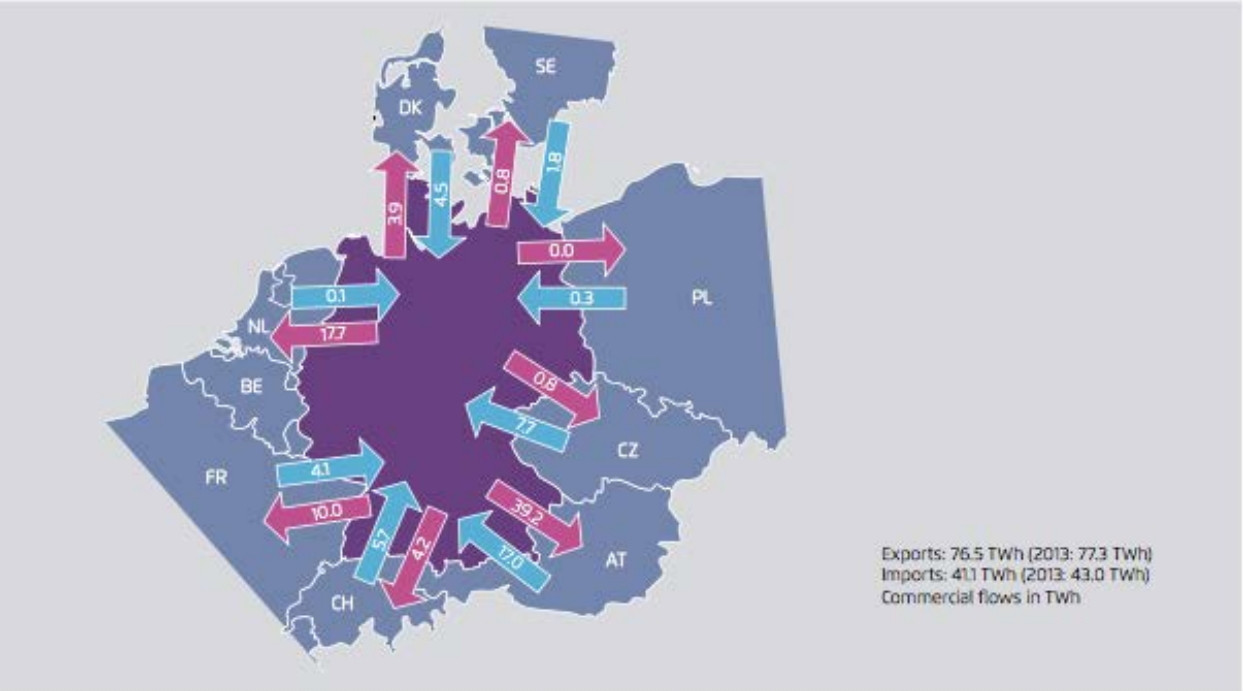

Figure 9. German Energy Exchange in 2014[60]

Even so, bottlenecks (problems with energy transmission) still exist due to outdated or missing infrastructure, such as in south-western Europe and northern and eastern Europe (between Germany, Poland and Czech Republic).[61] In total, the European Commission expects that to

[59] European Commission. Second Report on the State of the Energy Union. Brussels, 1.2.2017. COM (2017).
[60] Agora, "Understanding."
[61] European Commission, "Second Report."

reach the 2030 energy goals, the Energy Union will have to spend EUR 379 billion annually on infrastructure improvements.[62] Because of the cost and nature of the European grid, improving interconnectivity is one of the main challenges to the European energy transition. Germany itself, having the largest annual electricity demand and generation, is connected with ten separate countries and has a transfer capacity of 20 GW (see Figure 9). In 2014, the Germans imported 41.1 TWh and exported 76.5 TWh, showing the reliance of each country on others for energy.[63] For this reason, the energy transitions of neighboring countries could not be more relevant to the impact of the German nuclear phase-out on energy production and interconnectivity.

3.5.1 Poland

Poland, situated to the east of Germany, is the biggest coal producer in all of Europe, supplying 85% of their electricity needs in 2015 through 75 million tons of extracted coal, of which 51% is hard coal and 35% is lignite.[64] In the past two years, they have built five new coal fired power plants, and have tried to opt out of the EU ETS by claiming that their forests can account for their increased carbon emissions. On May 5, 2016, Poland announced the Law on Renewable Energy Sources, stipulating that they would pursue the same share of renewable energy in their mix rather than increase it, as many of the neighboring countries have done. In fact, the RES Law intends to reduce the already minimal influence of wind energy on their electricity production, as it stipulates that less than 1% of Polish land will be made available for future turbine construction.[65] This is not necessarily a negative approach, as Poland was second in the world to Germany in installed wind capacity in 2015, with 4,592 MW providing 10,231

[62] European Commission, “Second Report.”
[63] Agora, “Understanding.”
[64] Craig Morris and Martin Pehnt. “The German Energiewende Book.” *An initiative of the Heinrich Boll Foundation*. E-Book: https://book.energytransition.org
[65] Morris, “German.”

GWh and almost 30% of their electricity. So, while Poland has developed substantial RES based energy production in recent years, their government has clearly stated that coal is the future of their energy production because of the energy independence it provides and are not concerned with the EU commissions standards or rising CO_2 production.

3.5.2 Denmark

Denmark historically has surpassed all countries in renewable energy production but has recently stagnated in expanding further. By 2030, they hope to have a 35% renewable energy share and to completely phase-out fossil fuels by 2050.[66] Denmark began their energy transition before any country in the world with legislation aimed at curbing CO_2 emissions in 1989. Currently, Danish citizens pay substantial taxes for electricity, but their money is reinvested in future wind projects, such as the Horns Rev III. This off shore wind farm is expected to be finished by 2017 and will sustain 400,000 homes and produce 400 MW, added on top of the 370 MW already produced by the Horns Rev I and II.[67] In 2014, 39% of the net consumed energy came from wind based energy and, like Germany, the citizens have a large share of this production, as over 40,000 citizens either individually or partially own some of the 5200 wind farms. The Danes have vastly exceeded their own targets in addition to the Energy Union expectations and therefore are moving towards the latter parts of their energy transition.

3.5.3 France

France does not share Germany's desire to reduce their reliance on nuclear energy. Currently, nuclear composes 75% of their energy production, and their 2025 goal aims to reduce that only by 25%.[68] They intend to reduce energy consumption by 50% by 2050 from 2012 levels, but

[66] IBID.
[67] IBID.
[68] IBID.

have yet to reinforce the support schemes in place to help that transition (tax credits and eco-loans for efficiency). France's energy plan, the Planification Pluriannuelle de L'énergie (PPE), has raised alarms because of its avoiding concrete plans for nuclear power. It has conglomerated all of the power sectors into a "single trajectory" in order to achieve all 2030 objectives.[69] The PPE determined that no steps towards changing the nuclear path will be made before 2018, excepting the closing of the oldest plant in the country at Fessenheim. Therefore, the PPE leaves a lot of ambiguity in terms of their plans to reduce the share of nuclear in the energy mix. Given that reaching 50% nuclear energy by 2025 would require shutting down 25 reactors, France would have to close 5 a year if they were to begin a small phase-out by 2020.[70] This schedule does not account for how they will replace nuclear energy or by what means, which indicates that their energy transition may falter behind neighboring countries.

3.5.4 Czech Republic

Like France, the Czech Republic relies heavily on nuclear energy, as it makes up 32% of their electricity generation.[71] Unlike other countries, however, they do not intend to reduce their nuclear reliance, but rather increase the role of nuclear energy in their electricity production. The State Energy Policy of 2015 plans to further the development of nuclear energy by building new plants over the next decade, estimating to spend 20-32 billion crowns in the process and to improve their energy security. While nuclear is very much the future, the Renewables Support Act of 2005 helped to establish a movement towards increased development of RES technology by jumpstarting investment in wind, biomass and solar energy. Then, the National Action Plan

[69] IBID.
[70] IBID.
[71] IEA. Czech Republic Energy System Overview. https://www.iea.org/media/countries/CzechRepublic.pdf(Accessed March 1, 2017.)

for Renewable Energy set a goal for a share of 10% of renewables in energy consumption by 2020, but in 2016, that target was changed to 15.9%.[72] While this legislation recognizes the need for renewables in a modern energy mix, the Czech Republic clearly favors nuclear power.

3.5.5 Spain

Spain, like Denmark, started before many countries in pursuit of a renewable-based energy mix, implementing both FIT and FIP (Feed-in Premium) schemes, even before Germany, to accelerate investment in and development of RES technology. In 2009, Spain passed the Renewable Energy directive which mandated renewable energy targets for the next decades. Despite this legislation, the government had to delay measures to build new energy plants in 2012 because of high consumer electricity prices and an increasing tariff deficit resulting from failing FIT policy.[73] 10% of citizens in Spain could not afford their electricity bills at this time. In 2014, Spain only had a 16% share of renewable energy out of their cumulative energy mix and face an uphill battle to meet 2030 Energy Union targets.

3.5.6 Austria

Austria, though focused on a renewable energy structure, has a perplexing energy system. Greenhouse gas emissions increased from 1990 to 2012 meaning that they failed to meet the Kyoto protocol target and that they had to buy certificates to account for 71.55 million tons of excess CO_2 through the EU ETS.[74] Despite this failure, Austria has among the strongest renewable portfolios in Europe. More than 20 years ago, they embarked on a hydropower transition, leading them to become the 4th largest producer of hydroelectricity in the world. As a result, in 2014, 33% of Austria's total energy consumption came from RES sources, and 71% of

[72] Craig Morris, "German Energiewende."
[73] IBID.
[74] IBID.

their electricity is provided by renewables, mainly hydropower and biomass.[75] Even so, the potential for expansion in hydropower of biomass has decreased exponentially, which was the motivation behind the Ökostromgesetz in 2011. The Ökostromgesetz is the Austrian version of the Energiewende, in that its purpose is to accelerate the growth of solar and wind power. Because of this legislation, Austria will likely reach 80% renewable electricity production by 2020 and 100% by 2030.[76] Though this will increase energy dependence for electricity production, Austria still imports 64% of its energy at a cost of EUR 11.4 billion annually and will need to continue to increase renewable energy to further its energy independence.[77]

3.5.7 United Kingdom

Out of all the nations surrounding Germany, the United Kingdom falls short in renewable energy development. This is due to the domination of utilities in the energy discussion, as they make it impossible for smaller companies to enter the grid through renewable production. Each political party is tied to one of the six major utility companies, so small contributors find it impossible to pay the hugely expensive fees for a grid license or grid access.[78] Germany and Denmark have both benefitted tremendously through the liberalization of the grid, which is one of the reasons they greatly surpass the UK in renewable energy production. Furthermore, the United Kingdom does not subsidize renewable energy and has no merit order in place, making it even more difficult for small producers to contribute energy to the grid. Currently, they are submitting applications for shale gas, coal bed methane and underground coal gasification in an effort to decarbonize their energy mix despite strong citizen opposition to natural gas.[79] The United

[75] IBID.
[76] IBID.
[77] IBID.
[78] IBID.
[79] IBID.

Kingdom may still meet the 202 targets set by the Energy Commission, as its energy share increased to 13.9% in 2013.

3.6 Conclusion

This chapter provided an overview of the various impacts that the German nuclear phase-out will have on various sectors and countries. The information above explores the impact on electricity prices, transmission grids and neighboring countries. The countries examined, excluding the United Kingdom, all directly import or export energy to Germany and thus are involved in the phase-out of nuclear energy and the larger Energiewende in Germany. Their own energy transitions indicate that Germany's energy transition is part of a larger movement in Europe and is not unique to energy policy. Chapter 4 will contain further analysis of the impacts of the phase-out in a benefit-cost manner.

4.1 Introduction to the Benefits and Costs of the Nuclear Phase-Out

This chapter will analyze the various costs and benefits associated with Germany's nuclear phase out. Benefit-cost analyses can include specific numerical comparisons with a given scenario, but because of the nature of the nuclear phase-out in Germany, this chapter will focus on a diverse set of conditions for determining the economic, social and political costs of a drastic energy policy decision. Furthermore, since Germany has set specific targets in mind for carbon emissions reductions, increased energy efficiency and renewable power generation, this analysis will attribute the specific time constraints of a nuclear phase-out by 2022 and the Energiewende goals for 2035 and 2050, respectively. These time constraints will allow for a more concrete estimate of the longevity of certain costs and certain benefits.

The concepts explored have been explained and referenced to earlier in this thesis to provide pertinent background information and a description of their current standing. Thus, the analysis will explore the relative costs and benefits of the nuclear phase-out on citizen support, economic opportunity, government popularity, energy trade between Germany and neighboring countries, risk reduction, economic cost to the state and their ability to meet their set climate goals. In conclusion, the analysis will show that the nuclear phase-out benefits Germany more than it costs them.

4.2 Citizen Approval

As discussed earlier, the social pressure to phase out nuclear energy was one of the main components influencing Chancellor Merkel's decision in 2011 to commit to the transition away from nuclear power generation. Citizen movements in the 1970's and 1980's made nuclear a non-issue and incited the growing opposition to uranium based power. This far-left opinion eventually won a voice in the national dialogue through the Green Party's election to the

Bundestag in 1998 and has pressured the direction of energy policy ever since. Now, the citizen approval of the nuclear phase-out continues, as the German people show a clear desire for sustainable, clean, risk-free energy, despite the costs that follow.

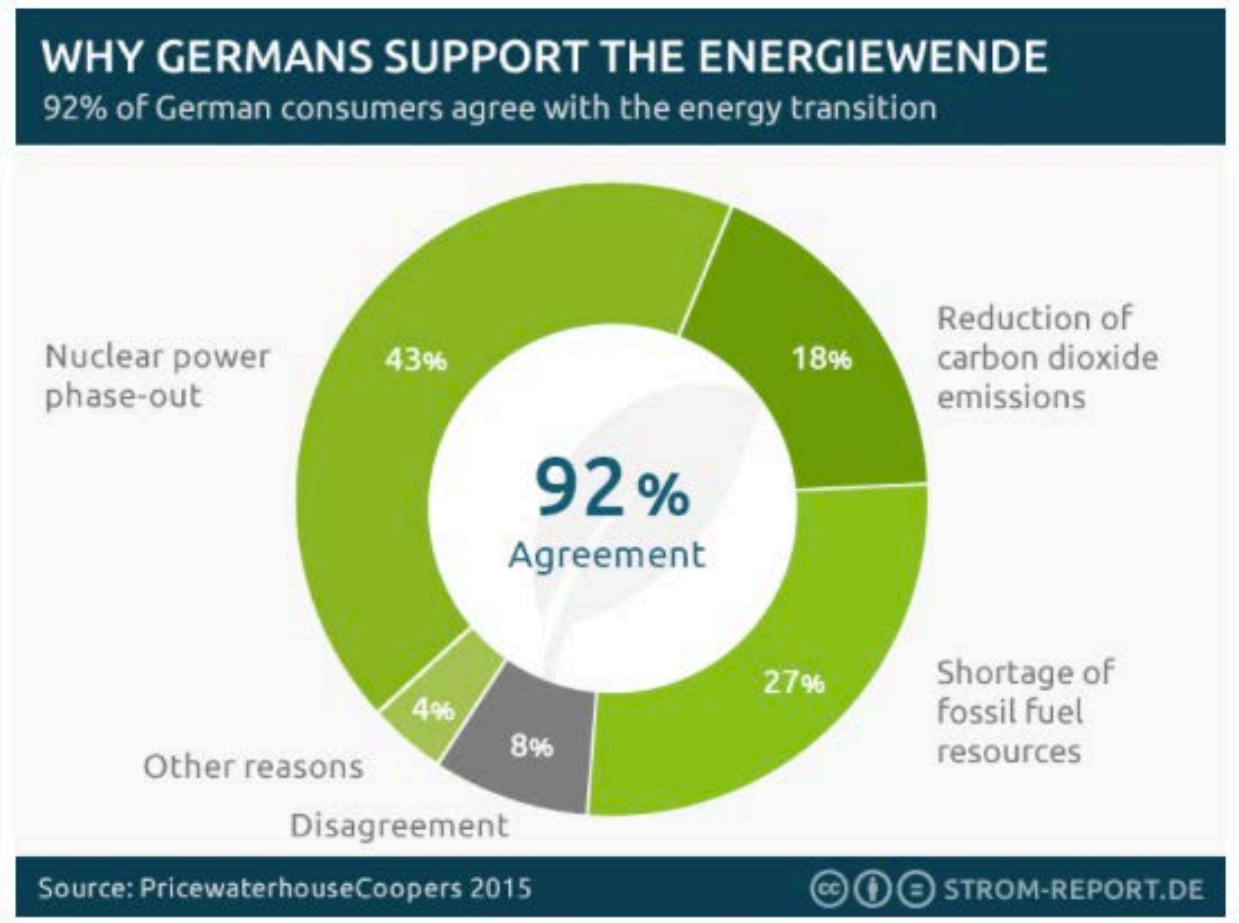

Figure 10. Why German's Support the Energiewende.[80]

Figure 1 depicts the current perception of the nuclear phase-out from the perspective of the citizens. The fact that 92% of the population agrees with the policies of the Energiewende speaks for the public's support for the energy transition and therefore the nuclear phase-out. Whether it

[80] Soren Amelang and Julian Wettengel. "Polls Reveal citizens' support for Energiewende." The Clean Energy Wire. January 23, 2017. https://www.cleanenergywire.org/factsheets/polls-reveal-citizens-support-energiewende(Accessed March 1, 2017).

is because they want to rid of nuclear power, reduce carbon emissions or fear the realities of fossil fuel shortage, they all feel that the Energiewende is the method to accomplish their goals.

More importantly and more specifically, German's generally agree with the nuclear-phase out aspect of the Energiewende. A study by the Renewable Energy Hamburg Cluster asked a group of citizens, "Do you believe the decision to exit nuclear power and to move to renewable energies was the right decision from today's perspective?"[81] In entirety, 74% answered yes and conversely, 24% answered no, with the Northern part of the country offering more support for the nuclear phase-out. This is a vital statistic for two reasons. First, consumers bear the burden of the EEG surcharge above all other parties in the German society, and therefore are paying for the transition away from nuclear energy with higher electricity bills. Thus, the survey shows that citizens do not feel deterred by the cost of a phase-out but rather are willing to make sacrifices in order to achieve it. This is supported by a survey conducted by Stiebel Eltron titled, "Trendmonitor," which revealed that 88% of consumers agreed with the statement, "I am generally in favor of the principles behind the Energiewende, but the costs for private consumers are too high."[82] Second, the difference between the Northern and Southern support, (80% in the North and 72% in the South) shows that the Northern parts of the country think they will benefit from the phase out more so than those residents in the south. This likely stems from the opportunity for economic involvement, since the majority of the additions of renewable energy will be coming from the Northern part of the country. Interestingly, support for the Energiewende has been waning over the past few years, dropping from 66% believing its introduction was very good in 2012 to only 57% in 2015, but that does not include those who

[81] Amelang, "Polls Reveal."
[82] Amelang, "Polls Reveal."

feel 'moderate,' which still supports that the majority of citizens approve.[83] Nonetheless, the citizens who advocated for the phase-out of nuclear energy remain satisfied and committed to the project through today.

4.3 Economic Opportunity

One of the subtle advantages of the implementation of the nuclear phase-out, in combination with the Energiewende, is the liberalization of the energy market, allowing small investors and energy producers to participate collectively in the development of renewable energy. Most countries have a centralized market, where utilities and large corporations have the exclusive rights to power production and grid access. But in Germany, citizens have the freedom to choose their power provider or to become prosumers (simultaneous producers and consumers).[84] And, in other countries, governments will employ quota systems that require power producers to produce a certain amount of green energy at the threat of a fine. In Germany, this is not the case, as both utilities and citizens are part of the energy transition following the nuclear phase-out. One in sixty Germans is an energy producer.

Because Germany operates with a feed-in tariff system, they have the opportunity for more renewable energy generation because profits are spread out across all investors. So, while electricity prices are rising for consumers, they have the opportunity to offset those costs by investing in energy production themselves, therefore helping the Energiwende and decreasing the individual cost of the loss of nuclear power. Smaller communities are the archetype of this type of investment. In Freiburg, a town of 220,000 people, one third of the investments costs of their four turbines are supplied by citizens, and the other two-thirds comes from bank loans.[85] Local

[83] Amelang, "Polls Reveal."
[84] Morris, "German Energiewende."
[85] Morris, "German Energiewende."

banks also benefit from the phase-out. Since so many people are investing in individual turbines or solar farms, the bank can offer low interest rates because of high equity rates, allowing small producers easy access to join in on renewable energy projects. Similarly, the Island of Pellworm has developed a hybrid power plant that fuses solar, wind and biomass energy and has reduced energy imports to the island by 90% for the 1,200 residents.[86] This isolated instance exemplifies the potential for individuals who want to invest in energy, as they can reduce domestic dependence on energy imports and make a profit at the same time.

These community projects, known as energy cooperatives, raised 1.67 billion euros in investments from over 130,000 citizens in 2015 alone.[87] The majority of these (90%) are solar energy, and investments in these projects cost as little as 500 euros, even dropping to 100 euros for small solar arrays.[88] The economic opportunity for a citizen in this rapidly changing energy dynamic is not only cheap but also financially rewarding.

4.4 Political Reputation

Angela Merkel's decision to shut down eight existing nuclear reactors following the Fukushima disaster was a sharp political U-turn. Back in 2011, prior to the Fukushima incident, Merkel had strongly opposed a phase-out of nuclear power, stating, "I am against shutting down our nuclear power plants only to have atomic power imported into Germany from other countries. That won't happen on my watch."[89] In fact, the very platform of her party, the Christian Democratic Union, as part of the governmental coalition with the Christian Social Union and the Free

[86] Morris, "German Energiewende."
[87] Morris, "German Energiewende."
[88] IBID.
[89] Daniel Johnson. "Why Germany Said No to Nuclear Power." The Telegraph. May 30, 2011. http://www.telegraph.co.uk/news/worldnews/europe/germany/8546608/Why-Germany-said-no-to-nuclear-power.html(Accessed March 1, 2017).

Democratic Party, has been built off a nuclear-positive energy policy. So, many viewed her decision as radical and illogical given her prior commitments; however, Merkel simply employed realpolitik, a "system of politics based on practical rather than moral or ideological considerations."[90] For years, the Green Party had been gaining political momentum due to the large environmentalism movement in Germany, while the CDU continued to push outdated nuclear focused energy policy concerned with extending the lives of reactors. Thus, Merkel gambled in her decision to phase-out nuclear energy, as it uprooted the basis of her party's energy policy. The country, despite largely agreeing with her decision, does not favor the method in which she decided. 70% of citizens feel that her decision was a campaign strategy, given that it preceded an important parliamentary election in the state of Baden-Wurttemberg, where 60,000 protestors had gathered to rally against her pro-nuclear stance in 2011.[91] Other members of the parliament called her decision a "political panic reaction."[92] So, while her decision was popular in terms of what it accomplished, it damaged both her own and her coalitions political reputation.

In the long run, that is a small blemish compared to the energy transition that Germany is undergoing. They have the opportunity to direct international energy policy if the nuclear phase-out, as part of the Energiewende, is a success. By 2022, Germany will sever all reliance of energy security on nuclear energy, having supplanted that production with renewable energies, smarter grids and better energy efficiency. Thus, the benefit-cost of the nuclear phase-out varies with the relative success of the Energiewende, which can only be measured decades down the

[90] Johnson, "Why Germany."
[91] Spiegel Staff. "Merkel Gambles Credibility with Nuclear U-Turn." Spiegel Online. March 21, 2011. http://www.spiegel.de/international/germany/out-of-control-merkel-gambles-credibility-with-nuclear-u-turn-a-752163.html (Accessed March 1, 2017).
[92] Spiegel Staff, "Merkel gambles."

roads. At this moment in time, as supported by the similar energy transitions of nearby countries, Germany is transitioning into one of the world leaders in energy independence and reliance on sustainable energy.

Additionally, the distributive effects of political loss and gain are centralized to only a few individuals. For instance, in 2010, when the conservative coalition passed the tenth amendment to the Atomic Energy Law increasing the lifespan of the nuclear reactors and reversing the decision of the 2002 Atomic Energy Law under Chancellor Schroder, Environmental Minister Norbet Rottgen nearly lost his position. But, when this decision was reversed, the public revered him for his role in determining environmentally focused policy.[93] These small changes are not significant in the overall analysis of the nuclear phase-out, which impacts millions of people and hundreds of large companies. Therefore, while Merkel's popularity may have been shortly injured by her political flip-flopping, long-term success and international leadership will rectify the cost of her political inconsistency.

4.5 Energy Trade

One of the major concerns experts rose about the feasibility of the nuclear phase-out was the impact it would have on Germany's energy trade with neighboring countries. As stated in Chapter 3, Germany shares its grid with much of Europe and trades electricity with ten other countries. Therefore, the reduction of power production induced by the absence of nuclear power production would have rippling effects across Europe as well as on Germany's balance between importing and exporting electricity. Throughout its history, Germany has been a net exporter of energy because their domestic energy supply vastly exceeds their energy demand. Even in 2011, following the shutdown of eight nuclear reactors, Germany closed the year with a

[93] Spiegel Staff, "Merkel gambles."

net production of 100,000 MW but only had an 80,000 MW demand. At the beginning of the year, they were exporting 90,000 MWh per day and at the end of the year that had dropped to a net import of 50,000 MWh per day.[94]

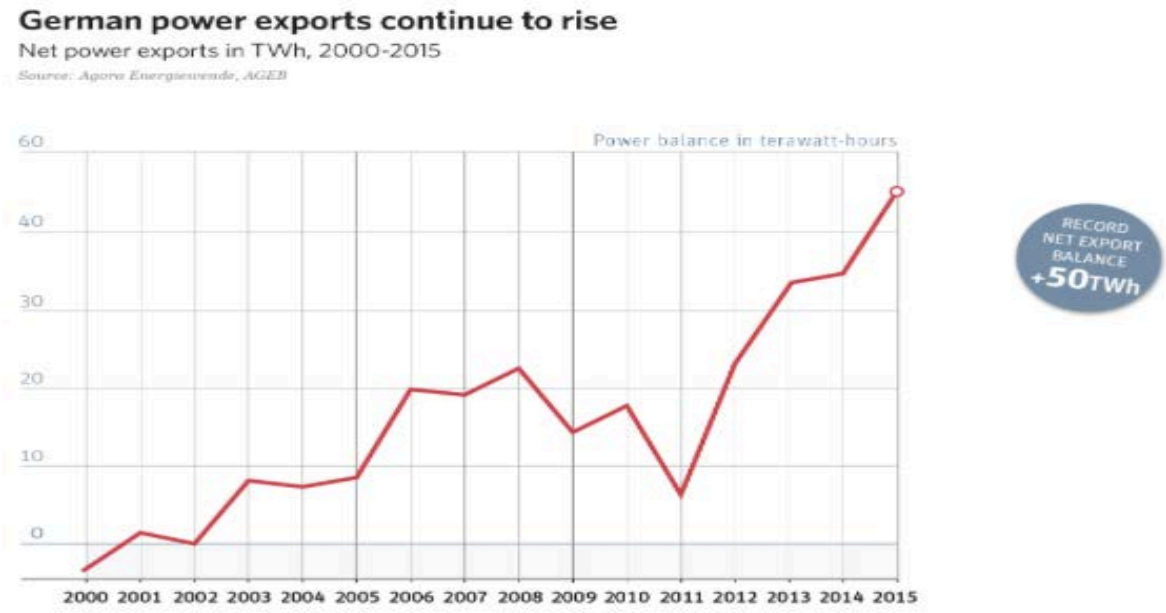

Figure 11. German Power Exports 2000-2015[95]

Clearly, German energy security and independence is not hindered by the nuclear phase-out. Figure 2 shows the current trend of exports, starting from 2000 and going through 2015. Excepting the drop in 2011, where less energy was exported as excess energy production was used to compensate for the closure of eight nuclear reactors, Germany has easily replaced the share of nuclear energy and is exporting energy at even higher rates than before. This results from the rise in renewables combined with the rise in coal use, but has proven that the phase-out did not disrupt the energy capacity of Germany. In fact, the phase-out has increased Germany's ability to export energy, therefore benefitting their economy and energy security in the long-term.

[94] Morris, "German Energiewende."
[95] Morris, "German Energiewende."

4.6 Economic Cost to the Individual and Society

The benefit-cost analysis relies partially on the economic impact of the nuclear phase-out on citizen living standards, industrial companies and the overall gross domestic product. While the benefits of energy independence and reliance on renewable energy outweigh the economic costs, it is worthwhile to discuss the expected financial burden incurred by Germany from the loss of nuclear power, and the distributive effects that cost will have. The shutdown of reactors itself cost 500 million euros, and while the energy industry pursued compensation, federal courts denied them because the amendment to the Atomic Energy Law was considered legal.[96] 3 out of the 4 companies in charge of operating German nuclear power plants, (E.ON, RWE and Vattenfall,) appealed for compensation because they argued that, "their fundamental rights to property and occupational liberty [had] been violated."[97]Nonetheless, this argument failed in court as the law asserts that those rights can be suspended if they are intended to protect the average citizen. And, even though they wanted compensation, each company had already profited from their investments. The average time it takes to gain profit for a nuclear reactor was 19 years, and each company had at least 27 years of investment.[98] So, even though the reactors were costly to close, industry contributors did not necessarily lose profit and the distributive effects of the cost are not damaging to the utilities. Furthermore, as conventional sources of energy are unpredictable and are expected to rise in the long-term, such as oil and fossil fuel sources, renewable energy is becoming cheaper and cheaper as technology improves. Germany

[96] Spiegel Staff, "Merkel gambles."
[97] Rossnagel, Alexander, and Anja Hentschel. 2012. "The legalities of a nuclear shutdown." *Bulletin of the Atomic Scientists* 68 (6): 55-66.
[98] Rossnagel, "The legalities."

will save more money long term by investing in larger shares of renewable energy and providing their advanced renewable technology to other countries.

There are wide arrays of the anticipated costs of the nuclear phase-out. For consistency, this paper will use a general estimate. The German Institute for Economic Research (DIW) estimated that the cost would be 200 billion euros from 2012-2022, the duration of the phase-out, which translates to 10 euros per household if distributed equally.[99] Though large industry will likely bear a larger burden of the cost because of the opportunity cost of continuing to provide nuclear energy to the grid, they have an equal opportunity to pursue further investments in renewable technologies or fossil-fueled power plants, giving them the ability to rectify their lost nuclear profit. For this reason, the majority of the distributive effect falls on the individual consumer.

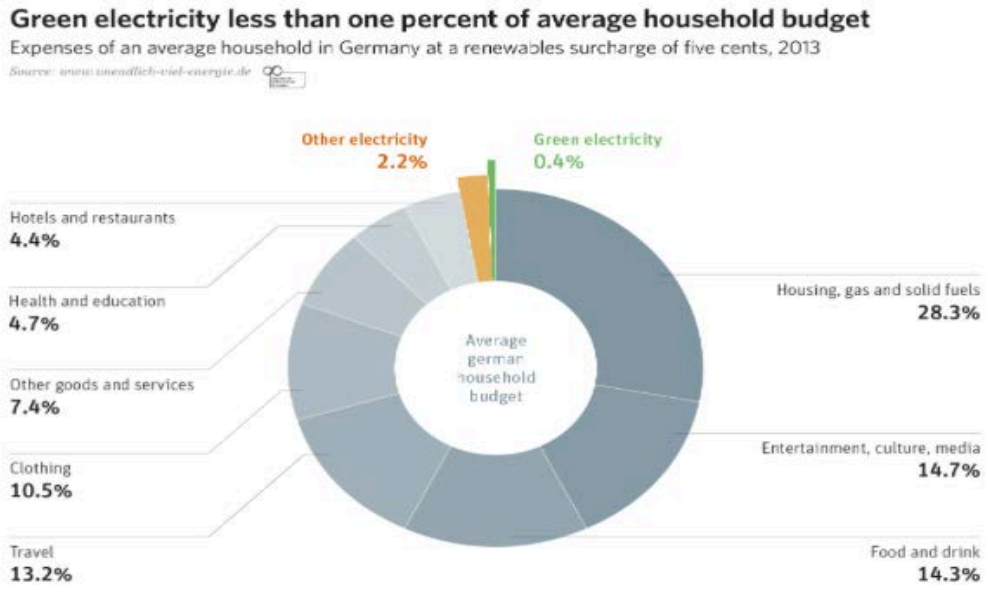

Figure 12. Breakdown of Household Consumer Expenses 2013[100]

[99] Morris, "German Energiewende."
[100] Morris, "German Energiewende."

As referenced in Chapter 3, household consumer electricity prices have been steadily rising since the introduction of the EEG surcharge in the Renewable Energy Law of 2001. As more renewables enter the grid, the surcharge increases to provide those producers with the promised feed-in tariff; however, the German government is slowly phasing out the feed-in tariff system as renewables are becoming mainstream and no longer need subsidization for support. And, as shown by Figure 3, the EEG surcharge only accounts for 0.4% of an average German income annually. Although the EEG surcharge is expensive and drives the German electricity bill higher than neighboring countries, it is a cost that consumers are willing to handle because of the long-term benefits that accompany it.

Besides individual and industrial costs, the German economy remains strong. Unemployment has reached its lowest levels since 1990, partially due to the growth of renewables following the phase-out of nuclear power and the growing influence of the Energiewende. Over 350,000 people are employed by the renewable sector through technician, installer and architect positions, which will continue to increase as offshore wind projects expand and solar PV continues to grow.[101] Even better, these are all domestic jobs that cannot be outsourced and require local citizens to maintain their own power sources. Thus, though costs of grid expansion, grid updates, closing nuclear plants and renewable projects may be large, they are easily offset by the prospects of a sustainable energy system.

4.7 Ability to Meet Climate Goals

The nuclear phase out inevitably results in an increased reliance on fossil-fueled electricity generation. While renewables are growing at alarming rates and will continue to expand through 2050, fossil fuels have had to account for the decreased power generation on account of the

[101] Morris, "German Energiewende."

absence of nuclear power generation, which accounted for 15.8% of Germany's total energy consumption back in 2014. So, will these increases in coal powered energy production disrupt their ability to meet their climate targets set by the Energiewende? Likely not.

In 2012 and 2013, the media widely supported that idea that CO_2 emissions were rising steadily due to the decrease in nuclear power generation. From 2000 to 2014, the share of nuclear power had been steadily declining due to the decommissioning of old plants as part of the 2002 Atomic Energy Law. Simultaneously, Germany was constructing new coal fired power plants to account for the decreasing amount of nuclear energy and to combat the volatile nature of renewable energy sources. Because their output fluctuated, energy security would have been sacrificed to begin relying on RES technology to replace nuclear. This accounts for the increase in CO_2 emissions from 2012-2013, but the extent was overplayed by the media.[102]

Currently, Germany is on track to reach its 2020 goals of a 40% reduction in carbon emissions compared to 1990 levels. From 2013-2014 alone, they were able to reduce their emissions by 5.5%, largely due to increased energy efficiency in buildings.[103] Thus, there is no cost for replacing nuclear with a mix of fossil-fueled and renewable based power. The benefits of increasing renewable energy production vastly outweigh the costs of small increases in carbon based electricity production. And, these small increases in carbon emissions can be attributed to both the dropping price of coal worldwide and the EU ETS system. The price of CO_2 allowances has dropped from 15-17 euros/ton of CO_2 in 2011 to 5-7 euros/ton CO_2 in 2014, so that the increased interest in coal arises more from international markets than from the needs created by a

[102] Conrad Kunze and Paul Lehmann. "The myth of the dark side of the Energiewende." The Energy Post. February 17, 2015. http://energypost.eu/energiewende-dark-side/(Accessed March 1, 2017).
[103] Morris, "German Energiewende."

nuclear phase-out.[104] In conclusion, because the nuclear phase-out is a piece of the Energiewende, it accompanies energy targets and even helps to accelerate the accomplishment of these goals, as its phase-out has led to greater developments in the renewable energy sector.

4.8 Reality of Risk Reduction

As stated earlier in this thesis, risk reduction is one of the main reasons that both supported and influenced Germany's decision to phase-out nuclear power. Angela Merkel declared that the disaster at Fukushima forced the federal government to, "reassess the risks associated with using atomic energy," suggesting that their previous policy did not efficiently protect the German people.[105] So, she instructed two committees to determine the modern risks of their nuclear facilities, namely the Reactor Safety Committee and the Ethics Committee, who submitted their recommendations to the federal government in 2011. The Ethics Committee was intended to address ethical questions about the future of nuclear power, and was "supposed to provide input on the governments risk assessment of nuclear power generation."[106] The Reactor Safety Committee determined that the eight reactors Merkel would eventually close exhibited serious weaknesses, such as their inability to withstand a plane crash. The Ethics Committee backed their findings and considered a nuclear phase-out within a decade feasible, in terms of an economic and energy outlook.[107] The Ethics Committee then worked to outline a plan that the federal government would eventually adopt, containing the immediate shutdown of the oldest nuclear reactors and the plan to expand grids while building new power plants.

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[104] Kunze, "The Myth."
[105] Rossnagel, "The legalities."
[106] Mathias Lang and Annette Lang. "Ethics Commission Report-German Energy Turnaround Decision." German Energy Blog. May 30, 2011. http://www.germanenergyblog.de/?p=6371 (Accessed March 1, 2017).
[107] Lang, "Ethics Commission."

While the government considered risk the main objective of the nuclear phase-out, the question remains, has it actually reduced risk? The constitutional law of Germany, *Das Grundgesetz*, requires strict regulation of the risk that industrial technology brings to society. It stipulates that the federal government needs to ensure the citizens have a "basic right to human life and physical integrity."[108] For this reason, the legislature has a nearly impossible job in mitigating nuclear risk, as they are also responsible for protecting the security of Germany's energy supply, energy prices and greenhouse gas emissions. Domestically, the benefits largely exceed the cost of risk reduction, as Germany is harnessing their own ability to protect the lives and well-being of their citizens while increasing energy security and improving the sustainability of their energy production, all of which are important to the public.

The problem lies internationally. While Germany trades its energy with its neighbors, it does not have any control over their domestic energy supply.

Figure 13. Nuclear Power Plants in Europe, 2016[109]

[108] Rossnagel, "The legalities."
[109] "Nuclear Power Plants in Europe." November 2016. *The European Nuclear Society.* https://www.euronuclear.org/1-information/maps.htm (Accessed March 2, 2017).

As Figure 4 depicts, Germany is surrounded by nuclear power risks. France continues to rely on nuclear as a principal component of its energy mix and other countries show no signs of decreasing their reliance. And, as mentioned in Chapter 3, many are pursuing energy transitions towards sustainable energy, but not at the price of phasing-out nuclear power. In this context, Chancellor Merkel's argument about decreasing the risks of nuclear power loses strength, as their eradication of nuclear power does not eliminate the risks of nuclear power from relatively local, international plants. The cost could prove deadly if Europe experiences a nuclear disaster close to the scale of Fukushima.

4.9 Conclusion

This chapter evaluates the basic benefits and costs of the entities discussed in chapter 3 to provide the context for analysis in the conclusion. Undeniably, the nuclear phase-out's impact pervades all parts of the German society and economy, which makes the complete evaluation of its benefits and costs difficult to enumerate. These conditions depend on the timing of the nuclear phase-out and the reactions of Germany's international neighbors.

5.1 Conclusion - Comparison of Costs and Benefits

This paper extends the argument that the benefits of Germany's decision to phase-out nuclear power largely outweigh the costs and therefore make the Energiewende a successful energy policy in terms of its impact on the economy, environment, and energy mix. German people highly value a sustainable culture, which they believe should be reflected in their energy mix, even as a heavily industrialized nation.

The phase-out, in unison with the Renewable Energy Law, has drastically increased the share of renewable energy in their energy mix, and the citizens' approval rating has responded. While the cost to both the individuals and the industrial sector are large, their commitment to combatting climate change balances that cost. Since 92% of the population supports the Energiewende, and 43% of that agree because of the phase-out of nuclear power, the policy therefore offers huge benefits to the satisfaction of the people. The support that the country shows for the phase-out of nuclear power is a principal benefit of the policy because years of social activism spurned the policy, and therefore it is vital that the citizens continue to support the phase-out. Energy independence is another principle benefit of the nuclear phase-out. Energy security has remained strong and even improved, shown by the growth in energy exports despite the continued decrease in nuclear energy production. In 2015, Germany exported 50 TWh of energy to foreign countries, the most they ever have in their history. This disproves the argument that the German nuclear phase-out would hurt the energy security of other countries reliant on Germany for energy imports, as they have the greatest supply of energy available to them to purchase that they have ever had.

The principle cost of the nuclear phase-out, estimated by the German Institute for Economic Research caps off at 200 billion euros between 2012 and 2022, equaling 20 billion

euros annually. These costs surmount from grid expansion, renewable installation and the cost of subsidizing renewable energy. While this is a large sum, it will not damage the German economy, as 20 billion euros annually will barely hurt Germany's gross domestic product. This is one of the most significant concepts, as the cost of updating the grid while replacing the loss of nuclear power generation were the main criticisms of the policy at its inception. Furthermore, these costs will eventually be repaid by their ability to export excess energy production to neighboring countries as well as their ability to sell advanced renewable technologies to countries just beginning to implement renewable energy in their energy mix.

Similarly, the opportunity for citizens to profit from the subsidization of renewable energy has not only rewarded their commitment to the policy but also encouraged further investments in renewable technologies. This is yet another benefit of the phase-out, as the Energiewende has liberalized the energy sector to invite individual producers to contribute energy to the grid, especially through renewable energy generation. Again, this is a benefit that offsets the cost of higher electricity prices for the public. While not all will invest their money into renewable energy projects, those who do will have the opportunity to make large profits continuously, as their investment will pay off repeatedly through electricity production sold to the grid.

Conversely, while the economic cost does not demean the benefits that accrue from the investments, Angela Merkel's personal reputation suffered because of her inconsistent political decisions. She and her party, the Christian Democratic Union, have lost credibility both domestically and internationally because of their flip-flopping. Nonetheless, the distributive costs of political injury diminish the actual cost of Merkel's decision. Only she and a few other politicians will struggle because of the decision to phase-out nuclear power, while the rest of the

country will benefit. Germany's international prowess as an industry giant and leader in sustainable energy has only grown, so most people gain, looking from a utilitarian perspective.

Finally, while Germany remains at risk because of the locality of international nuclear power plants, they have done their best to mitigate domestic risk and protect the basic human rights of their citizens. Given that they can only control their domestic risk mitigation, the Germans cannot fault themselves for this; however, the reality of the risk remains and the cost of the nuclear moratorium is too great to consider the minimal reduction of risk worth 20 billion euros annually. Thus, in entirety, the German's have accepted short-term costs, such as expensive grid improvements and costly nuclear power plant moratoriums, for long-term benefits like energy independence, renewable technology expansion and a commitment to the satisfaction of its citizens. Although they have not mitigated the risk of nuclear power plant disasters entirely, they have mitigated their domestic risk and therefore have accomplished a piece of their goal.

5.2 Overview of the Nuclear Phase-Out

Germany is well on its way to an energy independent, sustainable economy because of the Energiewende and nuclear phase-out. Critics of these policies thought that the aggressive timeline for a complete moratorium of nuclear power would challenge Germany's ability to produce enough energy, remain an energy exporter and retain their industrial economy. This paper has served to evaluate the history of the nuclear phase-out and determine that there are more benefits than costs in the energy transition.

Germany's energy transformation is a product of their undulating past policy of nuclear energy. Beginning in the early 1960's, they moved from a country heavy reliant on nuclear energy production to a country largely opposed to nuclear energy, evidenced by the collective

efforts of the citizens to publicly advocate for cleaner, more sustainable energy free of the risks inherent in uranium based energy generation. The growth of the Green party and the willingness of other political parties to change their policy lead to Feed-in Tariff legislation, aimed at subsidizing renewable energy technological development, and the Renewable Energy Laws that further promoted the growth of the renewable sector. Encompassing all of this, the Energiewende included the nuclear phase-out in Germany's energy policy plans, forcing the continued development of renewable energy and an increased reliance on coal and fossil-fueled power to account for the loss in the energy mix.

Though the economic impact of the phase-out is significant, it is entirely feasible. The Germans immediately closed eight reactors in 2011 following Angel Merkel's decision to pursue the phase-out legislation, yet did not increase its energy imports or damage the livelihood of any citizens. While the electricity prices have increased due to the EEG surcharge, they are expected to curb around 2030 and then continually decrease, providing long-term energy security and independence for the price of short-term increased prices. And, though Germany will have to invest large sums of money in grid infrastructure, much of which will come from utility companies, they are part of the larger energy transition in Europe as part of the Energy Union. Because of the interconnectivity of electricity grids throughout Europe, Germany's investments will be supported by equal investments from other countries pursuing energy transitions as well, even if they are not reducing the composition of nuclear power in their energy mix.

The phase-out creates energy independence and sustainability. These are immeasurable benefits in comparison to the costly nature of infrastructure expansion, electricity prices and the nuclear moratorium. While this study lacks the precise economic calculations of the expected

economic impact, it asserts that the social and environmental benefits would outweigh any cost to the country.

5.3 Limitations and Assumptions

Though this study works to assess the benefits versus the costs of the German nuclear phase-out, it has severe limitations. The comparisons of prices do not include electricity prices over the next decade, the exact costs of grid expansion and the timeline by which renewables will be able to replace entirely the share of power nuclear once held in the energy mix. Other studies have worked to create these values, but at this point in time, there are too many variables to accurately determine exact numerical calculations. Similar studies in econometrics have attempted to determine more accurate calculations of grid expansion or total costs, but have had to make large assumptions to account for the consistently changing values involved, like energy prices and expected development. For this reason, the comparison of the social and political benefits to the economic benefits and costs are of the utmost sensitivity. They rely on a general study from the DIW and do not account for variables such as undulating renewable energy output, failures or delays in grid expansion nor the inestimable public opinion in the next ten years.

Additionally, this study assumes that Germany will continue to expand their renewable energy production at the current rates such that it will replace the share of nuclear energy by 2022 and will grow without Feed-in Tariff subsidization. If renewables begin to slow or diminish, the costs of the phase-out could multiply and consumers could end up paying the highest electricity bills in the world. Secondly, it assumes that the grid expansion, both in Germany and across international borders, will keep pace with renewable energy expansion and will be able to distribute electricity from the Northern areas of the country to the Southern

industrial sector. Complications can occur because of fluctuating energy production and bottlenecks.

Future studies on the nuclear phase-out in Germany should revisit the topic in 2022 to evaluate the completion of the policy and the state of the economy and energy mix. This topic is extremely time sensitive and will maintain relevance through Germany's entire energy transition. Studies should also investigate the ripple effect of a successful nuclear phase-out, as other countries will likely follow Germany if they prove that this energy transition is not only feasible but ultimately beneficial.

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