Energy Transition Impacts for Workers: A Comparative Analysis of Differences in Energy Transition Policies in Germany and Appalachia and their Impact on Coal Employment Outcomes

by

Matthew Barnes

B.S Environmental Systems Engineering, The Pennsylvania State University, 2012

SUBMITTED TO THE SYSTEM DESIGN AND MANAGEMENT PROGRAM IN PARTIAL FULFILLMENT OF THE REQUIREMENTS OF THE DEGREE OF

MASTER OF SCIENCE IN ENGINEERING AND MANAGEMENT

AT THE

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

SEPTEMBER 2022

Signature of Author: _____

System Design and Management Program
August 1, 2022

Certified By: _____

Nicholas A. Ashford
Thesis Supervisor
Professor of Technology and Policy
Technology & Law Program

Accepted By: _____

Joan Rubin
Executive Director
System Design and Management Program

(This page intentionally left blank)

Energy Transition Impacts for Workers: A Comparative Analysis of Differences in Energy Transition Policies in Germany and Appalachia and their Impact on Coal Employment Outcomes

by

Matthew Barnes

Submitted to the System Design and Management Program

On August 1, 2022 in Partial Fulfillment of the Requirement for the Degree of

Master of Science in Engineering and Management

Abstract

Energy transitions are occurring across the globe as natural gas and renewable energies increasingly compete with and displace coal-fired electricity, and the need to reduce greenhouse gas emissions to combat climate change becomes more urgent. As energy sources transition, so too does the entire energy system in which they operate. For the coal industry, the energy transition leads to significant structural changes to the communities that are losing coal-based employment. Through a comparative analysis of the energy policies of Germany and the United States using a transdisciplinary framework, this thesis identifies potential policy actions to overcome barriers to a just transition and improve outcomes for workers with durable legislative policy. Extensive literature review including policies, analysis, commentary, and publicly available data, is employed to contextualize the energy transition in Germany and Appalachia. Germany, with a long history of energy transition policies and similarities between its coal regions and that of Appalachia, provides a useful study of policy strategies. This thesis suggests that within the context of the United States, durable legislated policy, not executive action, is paramount to sending the stable policy signals required to encourage further development of policy actions to manage the energy transition.

Thesis Supervisor: Nicholas A. Ashford
Title: Professor of Technology and Policy, Technology & Law Program

Acknowledgements

First, I would like to thank my advisor, Professor Nick Ashford, for his support and guidance throughout the process of writing this thesis. From our very first conversation your interest in the topic and enthusiasm in working with me to create a thesis that was interesting, enjoyable, and meaningful set the tone for how I would approach every step of this process. As the world changed in the midst of writing my thesis, your constant energy, suggestions for articles and sources, and frank discussions helped keep me energized, focused, and able to resist distractions. I enjoyed working with you to write this thesis, and I am grateful for your excitement and willingness to work with me.

To my fellow cohort and classmates, you have all made this entire experience incredible. This really has been an amazing year and I am grateful that I was able to share it with you and your families. It has been a gift to be part of such an invigorating group of people with diverse interests and backgrounds, but most importantly a sense of community and mutual support for each other. I am thankful for every moment that we were able to spend with each other, even if it was just trying to blow of a little steam in between classes, assignments, and thesis work.

To my parents, your love, patience, and encouragement over the past three decades has helped me become the person that I am today. You have always supported me, my interests, my passions, and are the reason that I was able to take on such a demanding academic endeavor.

Most importantly, this thesis is dedicated to my incredible wife, Sarah. There is no way that I would have been able to get though the past year without you. You balanced your career, constant travel, and keeping our lives together so I could focus on academics. Putting our “normal” lives on hold to move to Massachusetts was not a trivial challenge, and I cannot thank you enough for making the sacrifices that you made in order to make this happen. This past year has been an unexpected adventure and I am lucky to have had you here to make the most of it. I love you.

Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction

1.1 Background and Motivation for Research:

Global energy systems are in the midst of a transformation as electricity demand begins to displace oil demand, renewable energy and decentralized generation facilities replace centralized heat-based power systems, digital technology becomes more embedded in management of electricity systems, and energy markets are upended due to the Russian invasion of Ukraine, all within the context of attempting to limit the severity and impacts of climate change (International Energy Agency [IEA], 2020b; Tollefson, 2022). The "Energy System" meets the definition of both a "system" and a "complex system" as defined by Crawley et al. (2016) where a system is defined as "a set of entities and their relationships, whose functionality is greater than the sum of the individual entities" and a complex system is defined as having "many elements or entities that are highly interrelated, interconnected, or interwoven." Systems of all types are becoming more complex as the demands on these systems increases for more performance, safety, resilience, adaptability, and other requirements (Crawley et al., 2016). Energy systems are experiencing the same growth in system requirements and complexity as electricity demand across the globe is growing, while governments around the world are attempting to meet this demand and simultaneously reduce greenhouse gas emissions (IEA, 2022c). As governments create policy to manage these changing demands, shifts in employment are expected as new clean energy industries are established and grow jobs, while fossil fuels such as coal experience job losses (IEA, 2021a). System changes due to decarbonization are also expected in transportation, agriculture, and housing, as well as in manufacturing as a whole, requiring broader structural shifts (Ashford & Renda, 2016).

In a 2009 opinion piece, Paul Krugman questions if whether based on the economic performance outcomes of Germany and the United States during the recession occurring at that time, the United States "might have something to learn" from Germany's strategy to weather the recession

(Krugman, 2009). This thesis conducts a comparative analysis of how the federal energy transition policies of Germany and the United States impact employment outcomes for coal workers and explores if there is in fact something to learn about how to use policy to improve outcomes for coal workers in the two countries while addressing new dynamics of energy sources and supplies.

This thesis focuses on energy transition policy impacts on employment in the coal industry as coal is projected to see a 3% decline in its share of electricity generation in the United States by 2023 (Energy Information Administration [EIA], 2022i), and in Germany coal is in the process of being phased out entirely (Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz [BMUV], 2021). As Thomas Friedman (2022) opines, "The Stone Age, as they say, didn't end because we ran out of stones. And the oil age won't end because we run out of oil. It will end with millions of barrels still in the ground because we've made oil for transportation obsolete". This scenario could be applied for the coal industry as the Coal Age may be ending due to the obsolescence of coal as it is increasingly phased-out due to cheaper natural gas and renewable energy sources (Gruenspecht, 2019). Although natural gas and petroleum production and demand will remain significant for several decades (EIA, 2022a), the lessons learned from the coal phase-out may be useful to improve outcomes for workers in the event of similar phase-outs for oil and natural gas.

1.2 Research Method & Questions:

This thesis was completed utilizing a review of relevant literature, commentary, regulations, legislation, government publications, and publicly available data sets. Sources were investigated based on a general transdisciplinary analysis framework as described by N. Ashford (personal communication, January 18, 2022):

1. What is the background and current state of the system?
2. What is the ideal state of the system?
3. What are the barriers to realizing the ideal state of the system?

4. How can some barriers be addressed?

This thesis applies this transdisciplinary framework to explore how energy transition policies affect employment outcomes for coal workers. Through this analysis, this thesis seeks to answer the following questions:

1. How do the policy approaches of Germany and the United States to manage the energy transition differ?
2. What impact has the energy transition and associated policies had on outcomes for workers?
3. What are the hallmarks of successful energy transition policies for workers?
4. What lessons can be shared to inform better energy transition policies for workers in the United States and Germany?

1.3 Thesis Focus:

While this thesis uses literature and data to demonstrate that there are fundamental changes occurring in the energy systems in Germany and the United States, the author assumes that these changes are in fact occurring, will be far reaching, but the rate and scope of the changes, as well as the exact makeup of future energy systems is not projected or explored. The author accepts that change is occurring and focuses on what impacts will result to coal industry employment based on historical trends, literature, analysis, and commentary.

The author accepts that, as detailed in Intergovernmental Panel on Climate Change (IPCC) reports, climate change is real, is happening, and is caused by human activity. (Intergovernmental Panel on Climate Change [IPCC], 2022) The author also accepts that the decisions that are made about the speed and magnitude of emissions reductions will impact the degree to which the planet experiences warming, and that higher levels of warming will lead to more severe consequences. (IPCC, 2022) With that in mind, the goal of this thesis is not to examine the impacts of climate change or modeling the effect of potential emissions reduction pathways on employment, but to analyze how the outcomes of

current and past policies related to the energy transition have, and will continue to, affect workers, and anticipate what changes in future policies are desirable.

1.4 Personal Motivation:

The challenges that workers of all industries must manage in the face of technologic, economic, and employment transitions cannot be understated. Growing up in a suburb of Cleveland, Ohio with a father who worked in one of the city's dwindling number of large industrial plants, I was acutely aware of the stress that employment uncertainty places on hard-working families and their children. Layoffs, plant closures, and furloughs were threats that felt like they could happen at any time. While my family was fortunate to never face these realities directly, it left a strong impression on me that there are real people behind the numbers and figures for layoffs and unemployment, and these events have a profound impact on not just workers, but their whole families.

By analyzing energy transition policies and their impacts on workers, I hope to highlight the importance and need to approach the challenge of energy transition with a systems thinking mindset as policy has countless interfaces within the energy system and has a real impact on people. I am optimistic that the energy transition will improve the world that we live in; however, I believe that thoughtful management of changes to the system are required in order to realize the best outcomes for workers and the environment.

1.5 Thesis Structure:

Chapter 1 – Introduction

- This chapter introduces the thesis topic and research framework. It also discusses the underlying assumptions that support the basis of the thesis but are not further discussed in later chapters, as well as personal motivations for the research.

Chapter 2 – The Changing Relationships and Dynamics of a Country's Energy Needs and Employment

- This chapter explores how energy demand has been changing and is projected to change in Germany and the United Sates as well as the evolution of the relationship between labor and energy. This chapter also compares the changing nature of work in Germany and the United States, including the impact of the COVID-19 pandemic. This chapter also examines broad impacts of the Russian war in Ukraine on energy markets and compares the likely impacts in Germany and the United States.

Chapter 3 – The Energy Transition in Germany

- This chapter describes the current state of energy generation in Germany, a brief history of coal mining, and the current state of the coal industry including production and employment. The chapter also examines energy transition policies in Germany by providing the historical context of the energy transition, and reviews major energy transition policies and legislation that impact the coal industry. The chapter further examines how Russia's war in Ukraine has impacted the German energy transition.

Chapter 4 – The Energy Transition in the United States and Appalachia

- This chapter describes the history of coal mining in Appalachia, the state of the United States energy industry, the history and current state of the coal industry in Appalachia including production and employment, as well as an analysis of current United States energy policy. The chapter also summarizes several proposed strategies from the literature to manage the energy transition for the Appalachian region.

Chapter 5 – Comparative Analysis of Germany and United States Policies and Outcomes

- This chapter examines the differences in energy transition policies between the United States and Germany, particularly in the context of emissions targets and policies to manage the decline of the coal industry. This chapter also defines a potential ideal state for a successful transition

for Appalachian coal workers, barriers that exist to a just transition, and proposals to overcome barriers to a just transition.

Chapter 6 – Conclusion

- This chapter summarizes the results from the comparative analysis of energy policies in Germany and the United States and policy proposals to realize improved outcomes for workers and the global climate. This chapter also includes a discussion of opportunities for further research.

Chapter 2: The Changing Relationships and Dynamics of a Country's Energy Needs and Employment

2.1 The Dynamics of Energy Needs Today

Global energy systems are changing as the world becomes increasingly electrified in an effort to combat climate change (IEA, 2022b). For Germany and the United States, energy needs are deeply rooted in economic development, national security, and the challenges of climate change (Bundesministerium für Wirtschaft und Klimaschutz [BMWK], 2022b). For a fossil fuel resource-rich country like the United States, which has recently become a net exporter of energy, access to energy is less of a security concern than the climate impacts of continued consumption of fossil fuels (Eule, 2020).

Germany, which is significantly dependent on energy imports such as natural gas from Russia, is exposed to the economic and geopolitical concerns of maintaining a secure energy supply (Stelzenmüller, 2022). For Germany, renewable energies are viewed as a more secure energy source with increased domestic employment benefits, leading to social and political motivation to expedite their transition from fossil fuels and transform the energy system to one based on renewable energy sources (BMWK, 2022h). Conflicts, such as the war in Ukraine, have highlighted the risk of Germany's dependence on energy imports, particularly natural gas from Russia, by exposing the country to the potential damage that sudden cessation of the use or supply, or costs, of Russian natural gas could have on the German and international economies (Stelzenmüller, 2022).

In Germany and the United States, particularly in Appalachian coal country, the identities of communities are interwoven with their relationship to coal mining (Bell & York, 2010; Dahlbeck et al., 2022). Unlike Germany, the United States does not enjoy the same history of federal policies to leave fossil fuel energy technologies behind and focus on developing future energy systems (Benoit, 2022; Hake et al., 2015). Nonetheless, the energy system is transforming both in the United States and in Appalachia, and the coal industry has been on a long decline which is expected to continue into the

future (Bowen et al., 2021), even as politicians from coal producing states, such as West Virginia's Joe Manchin and Kentucky's Mitch McConnell, continue to stymie national efforts to wean the US from coal (Davenport, 2015; Prokop, 2014; Weisman & Friedman, 2021).

2.2 The Changing Nature of Energy Demand

As energy demand increases, the form in which energy is being consumed is changing. For global consumers, electricity is increasingly used to meet household needs with electric cars, electric heat, electric cooking, etc. (IEA, 2021b). Even under strict emissions reduction scenarios, projections show steady growth in global electricity demand from the years 2021 to 2050 (IEA, 2021b). Although there is a global desire to eliminate the use of fossil fuels, renewable energy capacity is not growing fast enough to meet increasing demand, which is creating a demand gap that is filled by increased fossil fuel usage (Tan, 2021).

Similar to global trends, energy use in the United States is expected to increase between the years 2022 and 2050 (EIA, 2022a). Over this same period, natural gas and petroleum use are expected to increase, even with a substantial rise in the use of renewables. In line with IEA (2021) projections, coal use is projected to steadily decline over this period, being replaced with natural gas and renewable energy sources in the form of solar and wind (EIA, 2022a). In all economic growth scenarios, the EIA (2022a) projects that growing energy demand will outpace new renewable energy capacity, which results in the projected increased growth in natural gas and petroleum consumption. To provide for the increased electricity demand, projections by the IEA (2021b) show that coal does not have a significant place in a future energy system that meets climate goals as all scenarios require a prompt decrease in its use. While the EIA (2022a) projects that nuclear power will provide less electricity in 2050, changes in public perception and reactor design could lead to increased acceptance of nuclear power in the United States (Penn, 2022). The growth trends for energy consumption is driven by projections that energy

consumption due to increased economic growth will outpace improvements in energy efficiency (EIA, 2022a).

Electricity consumption and demand in Germany are expected to increase as economic sectors such as heating, transportation, and industrial processes are electrified; however, significant energy efficiency measures are expected to offset the demand increase (Bundesministerium für Wirtschaft und Energie [BMWi], 2017).

2.3 The Changing Relationship of Labor and Energy

As economies evolve to the changing energy landscape and the advancement of sustainability in other sectors of business, the associated skills needed in the workforce are also anticipated to change (International Labour Office, 2019). One study found that globally, only two percent of all jobs would be affected by the energy transition, but among those affected, workers in mining, construction, manufacturing, and transport would be in high demand in the new economy, with only workers in building trades such as electricians being in higher demand (International Labour Office, 2019). While employment in coal is expected to decrease with the decline in coal power, the workers that are displaced could have a place in the renewable energy workforce due to their skills (International Labour Office, 2019).

Although workers displaced by the transition may still be in demand, many workers will need to be reskilled as they transition into a new industry (International Renewable Energy Agency [IRENA] & International Labour Organization, 2021). Investment in retraining is needed as well as strategies to ensure that workers are being trained, or re-trained, with skills that enable them to participate in the renewable energy industry (International Labour Office, 2019). One report comparing a country's environmental performance with policies in place to develop skills for the "green" economy showed that the United States had high environmental performance but lacked in policies to develop skills for the new economy; however, Germany scored highly in both categories (International Labour Office, 2019).

Without a well-designed policy framework, there is a risk that workers will not develop the right skills to meet the demands of the emerging energy economy and other industries that take the place of coal. (IRENA & International Labour Organization, 2021). In both Germany and Appalachia, even if sufficient skills were developed nationwide, workers may be adversely affected if a jobs market does not exist for these workers in their communities (Inclusive Economics, 2021), as jobs in the renewable energy economy may not be located in the communities where jobs were lost (IEA, 2021a). The need for replacement employment does not necessarily preclude rural areas from successful transitions, as the results of one study of coal transitions of communities in Appalachia suggests that distance from urban centers was not a barrier to communities that had successfully transitioned away from a coal-based economy (Lobao et al., 2020).

Research into the employment intensity of energy sources in Europe, or how many workers are required per gigawatt-hour of energy generated from a source, shows that renewable energy sources have a higher employment intensity than fossil fuels (Fragkos & Paroussos, 2018). Renewable energy sources also create more "domestic" jobs than fossil fuels, that is renewable energies create more jobs inside the country that is generating the electricity (Fragkos & Paroussos, 2018). A similar trend appears to hold in the United States for the year 2020 as solar power generation employed 316,675 workers while coal power generation employed 71,403 (U.S. Department of Energy, 2021), even though solar accounted for only about 1.3% of total primary energy consumed whereas coal provided approximately 9.8% that year (EIA, 2022h).[1]

2.4 The Impacts of COVID-19 on Employment

The COVID-19 pandemic had an impact on both Germany and the United States in terms of employment and energy consumption, although each country experienced different magnitudes of impacts. Figure 1 shows the unemployment Rates of Germany and the United States from 2007 – 2022.

[1] Author's own calculations based on data from EIA (2022h).

Germany and the United States had both been experiencing a trend of decreasing unemployment rates from around the year 2008 and experienced an increase in unemployment when the Covid-19 pandemic began. As shown in Figure 1, the United States experienced a much sharper increase in unemployment rates than were experienced in Germany once the pandemic started shortly before April 2020. One reason that Germany did not see as sharp of an increase in unemployment is a long-standing short-term work support program, known as Kurzarbeit, that provided funds for employers to reduce workers hours while supporting their incomes, instead of eliminating positions (Aiyar & Dao, 2021). This strategy resulted in about one-third less of workers becoming unemployed than could have been realized (Aiyar & Dao, 2021). In the United States, policies related to unemployment differed from the German model as job protection was done mostly through work-sharing programs and government policy focused on financially-supporting business and displaced workers with strategies such as unemployment insurance benefits as well as other financial support measures (Edelberg et al., 2022). As of April 2022, the unemployment rates in both countries had returned to near pre-pandemic levels.

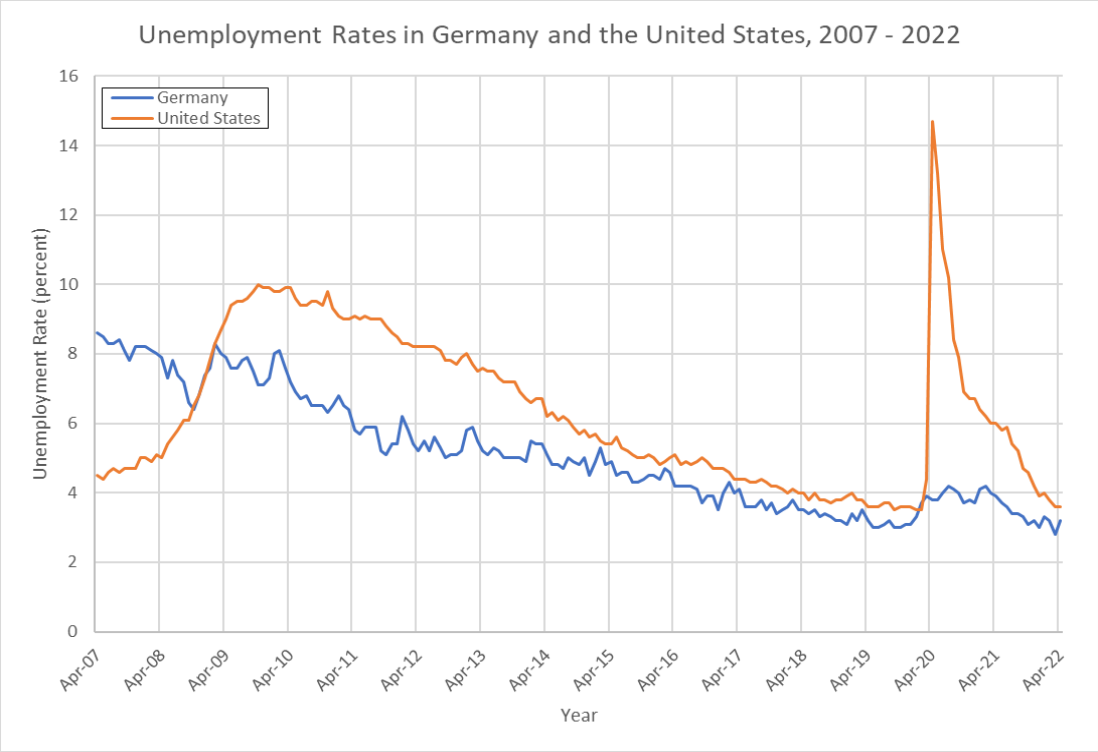

Figure 1: Unemployment Rates in Germany (Statistisches Bundesamt, 2022d) and the United States (U.S. Bureau of Labor Statistics, 2022) from 2007 through 2022[2]

In addition to employment effects of the COVID-19 pandemic, energy use decreased as a result of impacts and measures to contain the pandemic. In 2020, global energy use decreased by four percent; however, in 2021 demand exceeded pre-pandemic levels as it increased by 4.6% (IEA, 2022a). In terms of greenhouse gas emissions, Germany saw a decrease in emissions in 2020 due to the pandemic, but across sectors rebounded in 2021 and counteracting the emissions decreases seen in 2020 (Umweltbundesamt, 2022). In the United States, a similar trend of emissions growth was realized as emissions decreased by 9.5% in 2020, but increased by 6.5% in 2021 from 2020 levels (Davis et al., 2022).

For Germany and the United States, the COVID-19 pandemic had an acute impact on employment, energy demand, and emissions. While the two countries relied on differing policies to

[2] Author's own graph based on data from the U.S. Bureau of Labor Statistics (2022) and Statistisches Bundesamt (2022d).

manage impacts of the COVID-19 pandemic on employment, ultimately the impacts were relatively short-lived as unemployment and emissions returned to near pre-pandemic levels by end of year 2021.

2.5 The Changing Nature of Work

In response to the COVID-19 pandemic, Germany passed the Infection Protection Act which required that employers allow employees to work from home if the job can be done remotely, and concurrently obligated employees to work from home if able (Die Bundesregierung, 2021a). As of April 2022, 24.9% of German employees were still working remotely, even as work from home orders lapsed (Ifo Institute, 2022). Prior to the COVID-19 pandemic, only 13% of employees in Germany occasionally worked from home (Schattenberg, 2021). One research brief concluded that some blend of remote work and office work will be the future of work in Germany (Schattenberg, 2021).

In the United States, a survey conducted in early 2022 showed that about 59% of respondents whose jobs could be done from home were working remotely most to all of the time (Pew Research Center, 2022). Prior to the COVID-19 pandemic, only 23% of employees frequently worked from home (Pew Research Center, 2022). One analysis of work from home trends in the United States concludes that "hybrid" work, an arrangement where employees spend some of their time working in the office and some of their time working from home, is developing into an expected employment arrangement amongst workers (Wigert, 2022).

Before the emergence of the COVID-19 pandemic, the skills needed for workers had been evolving both in Germany and the United States. In the United States, labor needs have been shifting as physical and manual skills are becoming less important compared to analytical, communication, and social skills (Pew Research Center, 2016). This skills shift has been precipitated by the loss of manufacturing jobs and the rise of opportunities in the service and knowledge industries such as healthcare and business services (Pew Research Center, 2016). In Germany, automation through computers and artificial intelligence is seen as a significant threat to jobs (Organisation for Economic Co-

operation and Development [OECD], 2021). Among the German workforce, there is a shortage of science, technology, engineering, and math skills in workers to meet employment needs (OECD, 2021). The coal industry has long been experiencing a loss of employment due to increased automation as mining methods have shifted to less labor-intensive practices such as open pit mining. (Saha & Liu, 2017) Germany and the United States had previously experienced the impact of technological changes on employment as increasing mechanization and automation technologies displaced a significant portion of the mining workforce in both countries (Brauers et al., 2018; Saha & Liu, 2017).

2.6 Impact of the Russian war in Ukraine on Global Energy Markets

Russia's war in Ukraine caused turmoil in worldwide energy markets as countries have moved to reduce dependence on Russian fossil fuels (Tollefson, 2022). In Europe, which is highly dependent upon Russia for fossil fuels, especially gas (Tollefson, 2022), leaders of European Union (EU) states are promoting a strategy of seeking new fuel supplies – including increasing the imports of liquified natural gas, expanding renewable energies, energy efficiency, and expanding the connections between natural gas and electricity network infrastructures between states (European Council, 2022; Reed, 2022). Germany's reliance on Russia is particularly high, with Russian gas and coal accounting for half of its supplies and Russian oil accounting for more than a third prior to the start of the war in Ukraine (Tollefson, 2022). Eliminating imports of Russian fossil fuels in Germany will require a combination of measures that could include the increased importation of liquified natural gas from countries such as the United States, Australia, and Qatar (Reed, 2022), gas rationing, energy conservation, improving energy efficiency, and increasing the use of coal power plants (Tollefson, 2022).

As Russia began to reduce natural gas flows into Europe in the first half of 2022, Germany responded by increasing the use of coal power to enable more gas to be diverted to storage in preparation for the coming winter and in anticipation of further reduction of natural gas supplies from Russia (Meredith, 2022). The long-term global impacts of the war in Ukraine on energy systems are

unknown and could delay the transition to renewable energy; however, in Germany it has prompted action to create more aggressive energy transition goals, such as transitioning the power sector to 100% renewables by 2035 (Tollefson, 2022).

The United States does not have the same reliance on Russian fuels as the European Union (Tollefson, 2022). Aside from being able to ban imports of Russian oil, the United States is in a position to provide more liquified natural gas to Europe as an alternative source to Russia (Tollefson, 2022). From January through April of 2022, the United States exported 74% of its liquefied natural gas to Europe (EIA, 2022j). In the short term, as prices of natural gas and liquefied natural gas increase due to the war in Ukraine, the United States may be prompted to keep generating power using coal in the face of high gas prices (Zakaria, 2022).

Germany and the United States are affected very differently by energy markets in the wake of the Russian war in Ukraine. The outcome of the war in Ukraine is far from certain, and the extent of the wars impacts on energy markets are yet to be known (Tollefson, 2022).

2.7 Summary

Projections of future energy demand in Germany and the United States differ, with Germany seeing slight decreases in consumption and the United States expected to experience increases, although the extent is uncertain (BMWi, 2017; EIA, 2022a). What is common between the two countries is that over time the energy sources that meet that demand will change, particularly with a decline in coal power and a rise in renewable energy (BMWi, 2017; EIA, 2022a). These trends occur within the context of a world that is moving to reduce CO2 emissions, which will largely be driven through electrification of many sectors of the economy (IEA, 2021b). Russia's war in Ukraine has created turmoil in world energy markets and the impact on energy systems is yet to be realized (Tollefson, 2022).

In addition to the changing energy needs, the nature of employment and work in Germany and the United States are evolving. Both Germany and the United States have experienced employment

impacts due to the COVID-19 pandemic (Aiyar & Dao, 2021), and prior to the pandemic had been undergoing a shift in labor skill needs in their respective markets (OECD, 2021; Pew Research Center, 2016, p. 201). As each country emerges from the pandemic, they share an anticipated expansion of working from home options as worker expectations evolve (Schattenberg, 2021; Wigert, 2022).

2.8 Expected Outcomes of Analysis for Policy Formulation

Germany and the United States are both key players in international affairs politically and economically, exemplified by their membership in the G7 and OECD. (European Commission, n.d.; OECD, n.d.) At a population of 332.8 million people, (United States Census Bureau, 2022) the US population is significantly larger than Germany's 83.2 million people. (Statistisches Bundesamt, 2022c) Specifically comparing Appalachia with Germany's four coal producing Länder, or states, Appalachia had a population of 25.7 million in 2019 (Appalachian Regional Commission [ARC], n.d.-f), with a working population of 11.2 million. (Pollard & Jacobsen, 2021). German coal producing Länder had a combined population of about 26.7 million in the same year (Statistisches Bundesamt, 2022e), with a working population of about 14.3 million (Statistisches Bundesamt, 2022a). From an economic perspective, in 2020 the U.S. economy was the world's largest with a GDP of 20.95 trillion dollars, while Germany was fourth largest at 3.85 trillion dollars. (World Bank, 2022). Overall populations and actual working populations in Appalachia and German coal producing states in both countries are similar.

The United States and Germany have taken markedly different approaches to the energy transition, where Germany has a long track record of taking policy action to catalyze the transition to renewable energy (Hake et al., 2015) while the United States does not have a history of long lasting climate and energy transition policies (Richels et al., 2022). The Paris Agreement marked a seminal moment for global commitment to address climate change, and although there have been mixed results for delivering on commitments and volatile participation by the United States, the agreement is a global

acknowledgement of the need to transform our energy systems to attempt to prevent the worst impacts of climate change (Denchak, 2021).

This thesis is focused on the impacts of the energy transition on coal employment in the United States and Germany. Coal has played an important historical role as an energy source for each country, and the industry has seen declines in recent years as economic pressures, such as relatively cheap natural gas and expanding renewables, have reduced the market share from the once dominant energy source (EIA, 2021a). The German government has managed this transition through legislation and partnership with communities and the coal industry to manage the phase-out of coal, but for the United States, the transition has been described as "happening haphazardly and without foresight and without thought" (Schonhardt, 2022). Although the Energiewende has been criticized as being slow and expensive (Wacket, 2021) or coming too late, the German experience can provide insight to guide policy recommendations for the United States (Schonhardt, 2022).

The concept of "Energiewende" is engrained in German politics and policy, and although the policies may be criticized, Germany has been a world leader in managing their energy transition (Pflugmann et al., 2019). A thorough review and comparison of the energy transition policies of the United States and Germany and the impact of the energy transition and these policies on coal industry employment is conducted in this thesis to identify potential policy recommendations that may be incorporated into U.S. energy policy to better improve the outcome for workers. While certain contextual elements between the two countries may differ, such as the structure of the political systems, at a high level of abstraction of the systems, both countries are highly economically-developed western democracies with prominent roles in global leadership that are attempting to navigate a transition from fossil fuels to the energy system of the future. Further, within the study area of this thesis, Germany and Appalachia have similar coal-working population sizes and consist of varying levels of industrialization from highly industrialized cities to rural areas. As Germany has a long record of

intentionally managing energy transitions, it is the focus of this thesis to discern if there are specific elements of the German experience that can be applied in the context of the United States and overcome barriers for improved worker outcomes in the energy transition.

Chapter 3: The Energy Transition in Germany

Over the past century, Germany has undergone numerous periods of transition, from the Weimar Republic, the horrific period of Nazi Germany and World War II, post-war division between East and West Germany, re-unification after the fall of the Berlin Wall, and most recently efforts to fundamentally transform the energy system of the country to meet the challenges of climate change, and has emerged as one of the largest economies in the world by GDP (World Bank, 2022). Germany has been long recognized as a leader in the adoption of renewable energy and has been a forerunner in developing policies to facilitate the expansion of renewable energy and to manage the phase-out of fossil fuels (Pflugmann et al., 2019). The energy policy landscape in Germany is complex and consists of numerous acts to cover many aspects of the energy system (Jacobs, 2012). This chapter presents an overview of the history of coal production within Germany, the current state of the coal industry, a legislative overview of the key laws that govern the phase-out of coal and further the goals of Germany's energy transition, as well as the current state of the broader energy system.

3.1 German Energy System Overview:

In the Germany energy system, renewable energy, which includes solar, onshore and offshore wind, biomass, and other renewables, have experienced 12.6% of growth between the years 2015 and 2021[3] (Bundesnetzagentur, 2022). This growth in renewables has resulted in a contraction in power generation from lignite of 5.4%, from hard coal of 4.8%, and from nuclear of 2.8%[4] (Bundesnetzagentur, 2022). Figure 2 and Figure 3 show how Germany's energy mix has changed from 2015 compared to 2021. Policies adopted as part of the Energiewende have driven the expansion of renewables and natural gas as well as the reduction in coal and nuclear (IEA, 2020a). By design, Germany has been

[3] Author's own calculation based on electricity generation data from the SMARD database. (Bundesnetzagentur, 2022)
[4] Author's own calculation based on electricity generation data from the SMARD database. (Bundesnetzagentur, 2022)

phasing out coal and nuclear power, with targets to eliminate coal-fired power by 2030 and cease nuclear energy production by the end of 2022 (BMWK, 2022d).

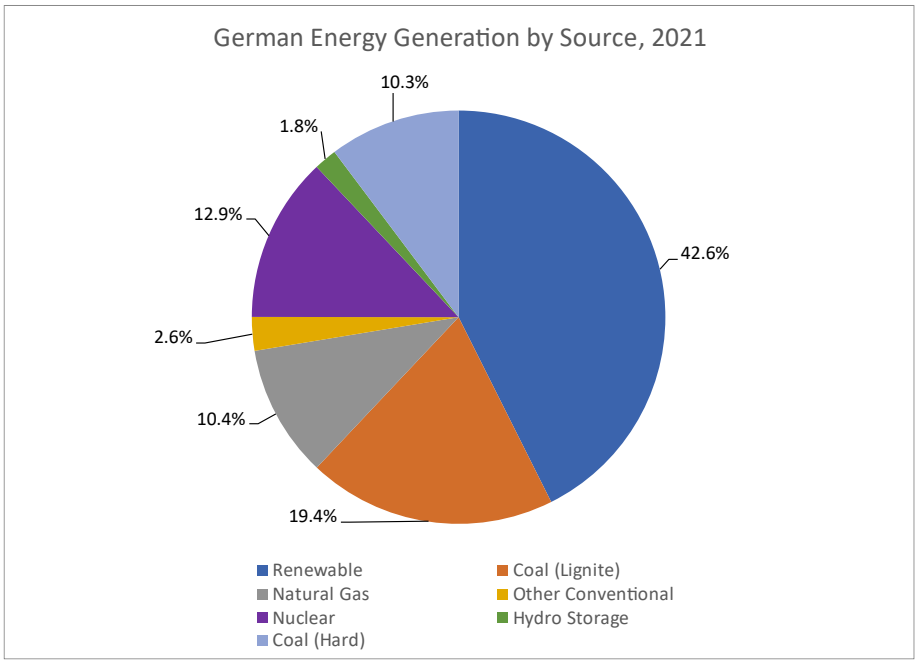

Figure 2 Total German energy generation by source for the year 2021[5] (Bundesnetzagentur, 2022)

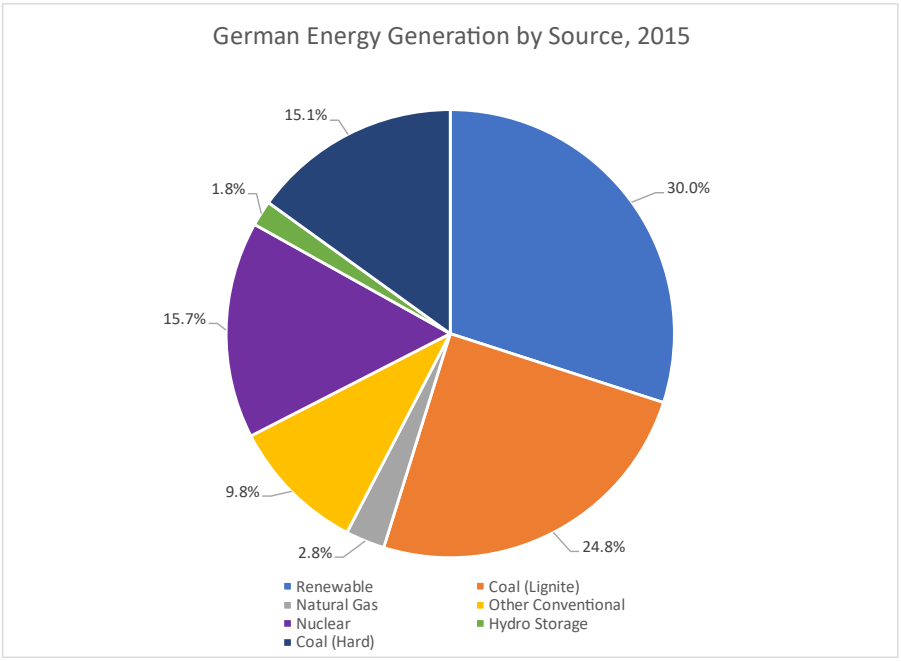

Figure 3 Total German energy generation by source for the year 2015[6] (Bundesnetzagentur, 2022)

[5] Author's own figure based on Bundesnetzagentur (2022) data.
[6] Author's own figure based on Bundesnetzagentur (2022) data.

3.2 History and Overview of the Coal Mining Industry in Germany:

Germany's coal reserves consist of hard coal and lignite, also known as brown coal (Euracoal, 2020). Coal mining has existed in Germany for hundreds of years; however, industrialization in the mid-1800's led to significant growth in coal mining (Deutsche Welle, 2007). Germany's coal resources were divided as a result of the separation of Germany after World War II, with West Germany having access to lignite production and all German hard coal resources (Brauers et al., 2018), while the German Democratic Republic (GDR) only had access to lignite resources (Krümmelbein et al., 2012).

3.2.1 Hard Coal Mining

Hard coal mining peaked around 1957 when the industry employed over 600,00 workers, as shown in Figure 4 (Statistik der Kohlenwirtschaft e.V., 2019a). The introduction of cheap imported hard coal and oil at this time led to a crisis within the industry as German hard coal was rendered uncompetitive; however, due to close relationships between the hard coal industry, steel industry, unions, and politicians as well as the desire for continued access to the European Coal and Steel Community, the hard coal industry received government subsidies to support it (Brauers et al., 2018). Figure 4 illustrates that over the next 60 years following the 1957 peak, the hard coal mining industry experienced a steady decline in employment. In 2007 the German government, federal states, hard coal mining industry, and labor unions agreed on a plan for the end of hard coal subsidies and an associated phase-out of the remaining hard coal mines (BMWK, 2022a). Mining and production of hard coal in Germany ceased in 2018 following the expiration of government subsidies, leaving lignite as the only domestic coal production in the country (Oei et al., 2020).

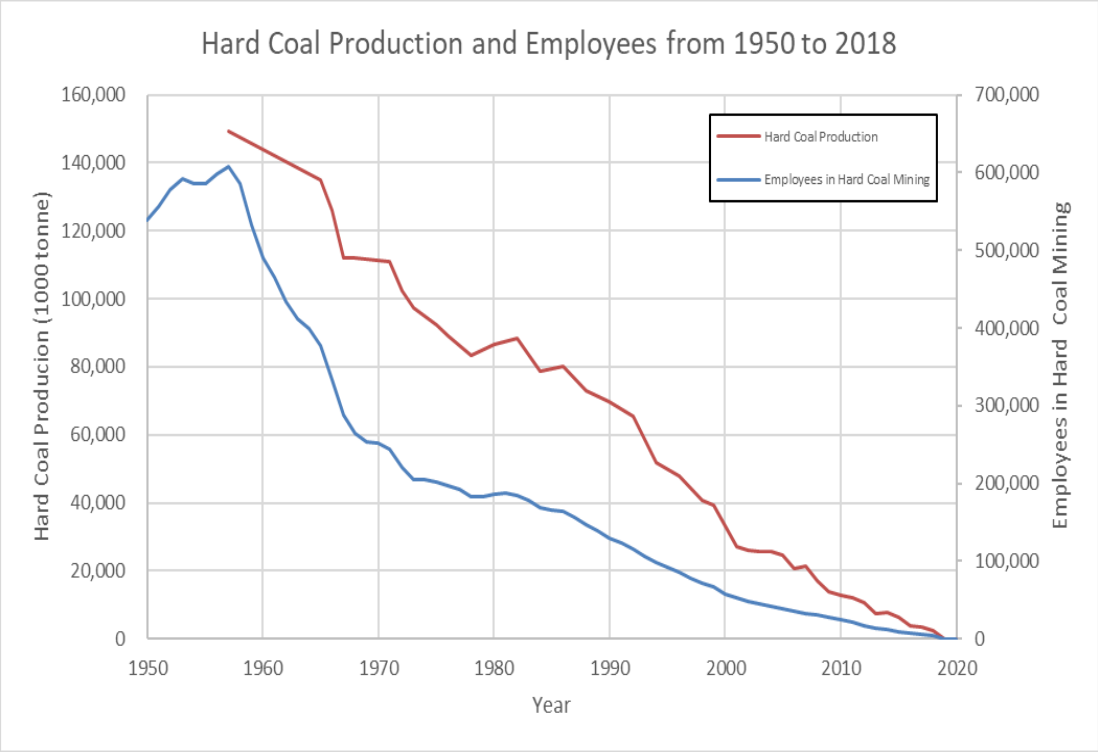

Figure 4 Hard Coal Production (Statistik der Kohlenwirtschaft e.V., 2019b) and Employment (Statistik der Kohlenwirtschaft e.V., 2019a) from the years 1950 to 2018.[7]

3.2.2 Lignite Mining

Lignite mining increased at a relatively steady pace in Germany prior to reunification, largely driven by production growth in the GDR (Brauers et al., 2018). As illustrated in Figure 5, combined employment in lignite mining in West Germany and the GDR peaked in 1985 at 160,348 employees, then saw a sharp decline in production and employment following reunification in 1990. This decline in employment and production was driven by the higher productivity of West German coal workers and the exposure of the former GDR lignite industry to competition with West Germany (Brauers et al., 2018). The lignite production declines that occur within the 2010 to 2020 period as shown in Figure 5 are expected to continue with the passing of Germany's coal phase-out legislation and the lignite industry approaches the 2038 phase-out date (IEA, 2020a).

[7] Author's own figure based on data from Statistik der Kohlenwirtschaft e.V. (2019a, 2019b). The number of employees does not include powerplants or employees involved in any remediation work following mine closure. Production and employee data was extended to "0" after 2018 for illustrative purposes in the chart as hard coal production ceased in 2018.

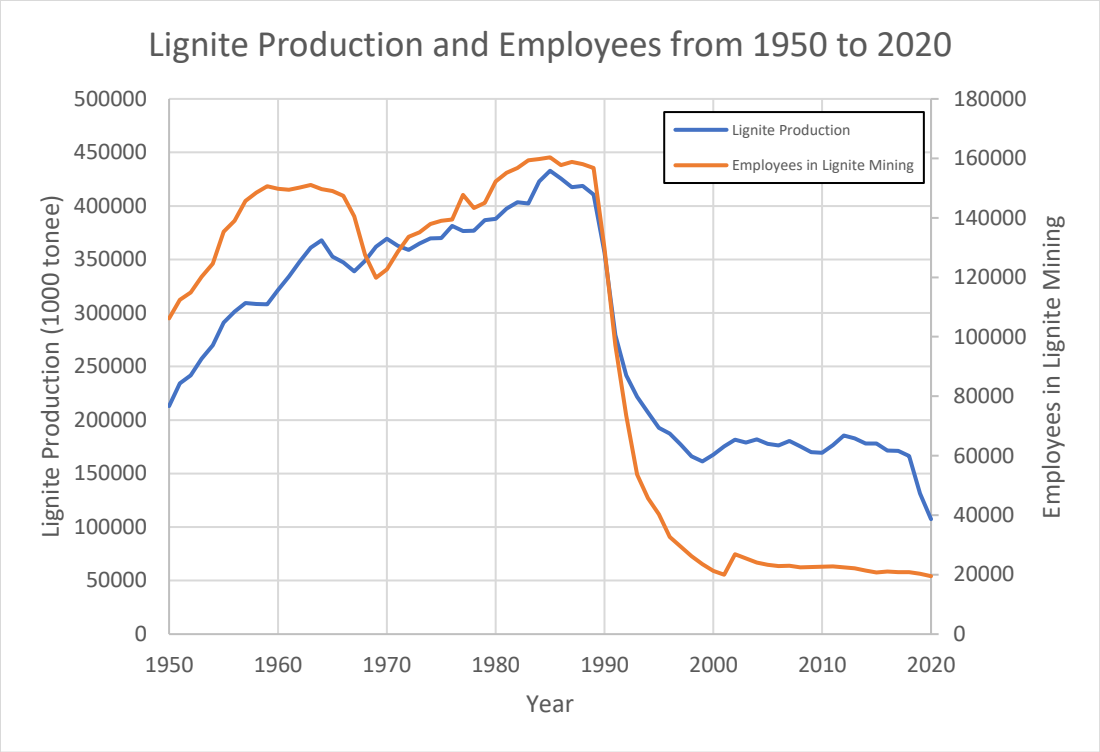

Figure 5 Lignite production (Statistik Der Kohlenwirtschaft e.V., 2021) and number of employees in lignite mining (Statistik Der Kohlenwirtschaft e.V., 2022) from the years 1950 to 2020.[8]

3.3 Current State of the German Coal Industry:

3.3.1 Coal Reserves and Production:

There are three regions in Germany with active lignite mines; the Rheinland, Lausitz, and Mitteldeutschland (BMWK, 2022a). Table 1 lists the 10 operating lignite mines with their associated region and operating company (Statistik Der Kohlenwirtschaft e.V., 2021).

[8] Author's own figure based on data from Statistik der Kohlenwirtschaft e.V. (2021, 2022).

Table 1 Operating Lignite Mines in Germany as of 2020 (Statistik Der Kohlenwirtschaft e.V., 2021)

Operating Lignite Mines in Germany	
Mines	**Companies**
Rheinland Area	
Garzweiler	RWE Power
Hambach	RWE Power
Inden	RWE Power
Lausitz Area	
Jänschwalde	LEAG
Welzow-Süd	LEAG
Nochten	LEAG
Reichwalde	LEAG
Mitteldeutschland Area	
Profen	MIBRAG
Schleenhain	MIBRAG
Amsdorf	ROMONTA

Germany is the largest producer of lignite in the EU in 2020, accounting for 44% of total EU production, or 107.4 million tonnes (Eurostat, 2021). Germany's lignite reserves are estimated to be 35.9 billion tonnes as of end of year 2020, and assuming constant 2020 production levels would amount to 334 years of available lignite reserves (bp, 2021). Germany uses nearly all of its lignite domestically, of which about ninety percent is used for electricity generation and heating applications (BMWK, 2022a). Other uses for lignite include, but are not limited to, the production of montan wax or lignite briquettes which may then be sold domestically or exported (Euracoal, 2020). Lignite mines and coal-fired power plants are often co-located to maximize operational efficiency (BMWK, 2022a).

3.3.2 The Profile of German Mining Employment:

In 2021, the lignite industry, which includes mining and power generation, employed 17,948 workers (Statistik Der Kohlenwirtschaft e.V., 2022). Employment in the lignite industry has been declining steadily since 1990, when mining alone provided 129,727 jobs (Statistik Der Kohlenwirtschaft e.V., 2022). Much of the lignite mining workforce is nearing retirement age, with nearly two-thirds of the workforce anticipated to retire by 2030 (Hermann et al., 2018). As of 2015, more than fifty percent of all lignite employees, including mining and powerplants, were over the age of 50 (Hermann et al., 2018).

On average, in 2021 workers employed in lignite mining earn a yearly salary of €57,603[9] (Statistisches Bundesamt, 2022b). The average annual salary for full-time employees across all sectors in Germany in 2021 was €49,200, meaning that those employed in the lignite mining sector were earning salaries above the national average[10] (Statistisches Bundesamt, n.d.).

3.3.3 German Coal Powerplants

German coal powerplants are fueled by hard coal, all of which is imported, and lignite, all of which is produced domestically. While lignite fueled powerplants are concentrated near lignite mines, Germany's hard coal plants are spread across the country. As of January 2022, there were 63 coal-fired power stations operating in Germany (Global Energy Monitor, 2022); however, in mid-2022 Germany announced plans to start more coal fired units in response to energy pressures caused by Russia's invasion of Ukraine (Connolly, 2022).

3.3.4 German Coal-Fired Powerplant Employment:

As of 2008, employment figures for lignite mining and powerplant workers have been combined and are not reported as separate values (Statistik Der Kohlenwirtschaft e.V., 2022). In 2008, there were 5,952 reported workers in lignite fired power plants (Statistik Der Kohlenwirtschaft e.V., 2022). Combined lignite employees, including mining and powerplants, has decreased from 22,482 in 2008 to 17,948 in 2021; however, it is unclear in the data how many of these jobs were in lignite powerplants (Statistik Der Kohlenwirtschaft e.V., 2022). The most recent data calculation for employees in hard coal powerplants shows that they employed 7,830 workers in 2019 (Agora Energiewende und Aurora Energy Research, 2019).

[9] Author's own calculation based on Destatis, 2022b
[10] Author's own calculation based on Destatis, 2022a

3.4 The German Energiewende and Supporting Policies:

The German Energiewende, or energy transition, is a decades-long process that has been occurring in Germany to transition away from fossil fuel energy sources (IEA, 2020a). The Energiewende is not a policy itself, rather it is a collection of policies that are enacted to meet the energy transition goals of Germany (European Commission et al., 2018). The term "Energiewende" is not historically limited to the transition of the German energy system away from fossil fuels; instead, the term is rooted in the anti-nuclear movement of the 1970s, and was first used in a publication by the Oko-Institut in 1980 to describe the movement (Jacobs, 2012). In the German context, the term encompasses the concepts of sustainable and long-lived changes to the status quo for both energy systems and related environmental policies (Paul, 2018). As described by the German BMWK, or Federal Ministry for Economic Affairs and Climate Action, the Energiewende is Germany's "pathway into a future that is secure, environmentally-friendly, and economically successful" (BMWK, 2022b).

Over time, the policy momentum to drive the Energiewende has waxed and waned with different governments in the Bundestag, the German parliament; however, following Helmut Kohl's tenure as Chancellor, there has been a relatively consistent effort made to enact policies that further the Energiewende starting with the Social Democrat and Green Party coalition government in 1998, through Angela Merkel's chancellorship (Jacobs, 2012), and continuing into the coalition government led by Olaf Scholz since 2021 (Jordans, 2022).

3.4.1 Klimaschutzplan 2050

The Klimaschutzplan 2050, or Climate Action Plan 2050, was created to set greenhouse gas emissions targets for Germany based on developing European targets and the 2015 Paris climate agreement (Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit [BMU], 2016). At a high level, the Klimaschutzplan 2050 does not amend the German government's goal of 80% to 95% reduction of CO2 emission from 1990 levels by 2050; however, it recognizes the long-term goal of

reaching net zero emissions in the Paris Agreement (BMU, 2016). In the medium term, the Klimaschutzplan 2050 sets a target emissions reduction goal of at least 55% from 1990 levels by the year 2030 (BMU, 2016). Emissions reductions targets are defined for "Areas of Action" including: Energy Sector, Buildings, Transport, Industry, Agriculture, and Other (BMU, 2016). Within the Klimaschutzplan 2050, it is recognized that renewable electricity will become Germany's primary energy source, electricity from coal needs to be reduced, and employment and economic impacts need to be addressed prior to actions to phase-out coal (BMU, 2016). To meet this goal, the Klimaschutzplan 2050 mandates the formation of the "commission for growth, structural change, and regional development", the goals and outcomes of which are discussed further in this thesis (BMU, 2016). For each of the Areas of Action, the Klimaschutzplan 2050 dictates guiding principles, measures, and targets in order to meet the overall emissions reduction goal for 2050, and as a strategic decision by the government provides the framework for success, while requiring further area specific plans and legislation to detail how each goal will be met (BMU, 2016).

3.4.2 Bundes-Klimaschutzgesetz 2019 and 2021 Amendments

The Bundes-Klimaschutzgesetz 2019, or Federal Climate Change Act 2019, created the first legally binding emissions reduction targets by economic sector to address climate change in Germany (BMUV, 2019). The statutory requirements and compliance responsibilities for each sector in the act were based on the Klimaschutzplan 2050 (BMUV, 2019). The 2019 Act created a more stringent emissions reduction goal than that of the Klimaschutzplan 2050 by requiring that Germany be carbon neutral by 2050, as opposed to the goal to reduce CO2 emissions to 80% to 95% of 1990 levels (Das BMUV, 2019). The 2021 amendment act further accelerates Germany's emissions reduction goals by mandating that Germany reach net-zero greenhouse gas emissions by 2045, and for Germany to be carbon negative by 2050 (Die Bundesregierung, 2021b). The 2021 version of the act also increased the 2030 GHG emissions reduction target to 65% of 1990 levels, includes an 8 billion euro budget to further

emissions reduction effort, and provides a schedule of milestones for setting emissions reduction targets for 2031 to 2045 as well as the associated sectoral reduction goals (Die Bundesregierung, 2021b).

3.4.3 Erneuerbare-Energien-Gesetz

In 2000, Germany passed the Erneuerbare-Energien-Gesetz (EEG), or "Renewable Energy Act", which has been a catalyst for the development of renewable energy in Germany and a significant policy of the Energiewende (BMWK, 2022c). The EEG sets renewable energy expansion targets and creates policy to meet those targets (BMWK, 2022c). One of the defining features of the 2000 version of the EEG was guaranteed grid prioritization over fossil fuels for renewable energies and a cost recovery mechanism, funded by a surcharge to consumers, to ease the economic burden of investing in renewable energies (Oschmann, 2010). Since the first version was passed in 2000, the EEG has undergone a series of amendments, not all of which are described in this thesis as the EEG has been updated frequently. The 2004 amendment introduced a mechanism to exempt railways and companies that consume large amounts of electricity from the surcharge (BMWi, 2020). A significant amendment in 2014 included electricity grid improvements and changes to how renewable energy is marketed and remuneration to renewable plant operators is determined, among other improvements (Lang & Lang, 2015). In 2017, the EEG was amended to use competitive auctions, rather than set pricing, to determine the compensation level for new renewable energy installations (BMWi, 2020).

In April 2022, the Federal Government passed an omnibus legislative package, called the Easter Package, to amend several acts related to energy and climate policy in response to growing urgency to address climate change and Russia's war in Ukraine highlighting the need to end fossil fuel use through increased renewable energies (BMWK, 2022f). As part of this legislation, amendments to the EEG are included that set a 2030 target of 80 percent of electricity consumption to be sources from renewables, eliminate the EEG surcharge for consumers, increase the importance of renewable energy when evaluating against other potential focus areas, increase the planned development rates for wind

(onshore and offshore) and solar, and several other measures to encourage rapid development of renewable energies (BMWK, 2022f). In the 22 years that the EEG has been implemented, its success can be seen in the growth of renewable energy from accounting for roughly six percent of electricity generation in 2000 (BMWi, 2020) to 42.6% in 2021 (Bundesnetzagentur, 2022).

3.4.4 Gesetz zur Reduzierung und zur Beendigung der Kohleverstromung

The Energiewende policy that most directly addresses the German government's plan for coal fired power is the "Gesetz zur Reduzierung und zur Beendigung der Kohleverstromung", translated to "Act to Reduce and End Coal-Fired Power Generation" (Die Bundesregierung, 2022a). This act is also referred to as the Kohleausstiegsgesetz, translated to the "Coal Phase-Out Act" (Die Bundesregierung, 2022a). The act, as passed in 2020, stipulated a phased approach to eliminating coal use by the year 2038, with an early target phase-out date of 2035 (BMUV, 2021). The act commits 4.35 billion euros of compensation to lignite powerplant operators for the shutdown of their facilities (BMUV, 2021). Hard coal powerplant operators are not guaranteed compensation for shutdown, but will receive close-down premiums determined via a bidding process (BMUV, 2021). In 2021, as part of negotiations to form the coalition government consisting of the Social Democratic Party (SPD), Greens, and Free Democratic Party (FDP), the coalition agreed to accelerate the coal phase-out date to 2030, including changing the scheduled 2026 review period that is required by the Coal Phase-Out Act to occur by the end of 2022 (Sozialdemokratische Partei Deutschlands et al., 2021). The coalition agreement acknowledged that even with significant growth of renewable energy, natural gas power plants will be needed as a bridge to meet electricity demand (Sozialdemokratische Partei Deutschlands et al., 2021).

3.4.5 Strukturstärkungsgesetz

In addition to the Kohleausstiegsgesetz, in 2020 Germany also passed the Strukturstärkungsgesetz, or the Structural Development Act (BMWK, 2020). The Strukturstärkungsgesetz is a policy commitment that provides funding and support to workers and communities in regions that

will be impacted by the decommissioning of lignite coal mines and power plants (Die Bundesregierung, 2022b). The act commits 14 billion euros, dispersed over time until 2038, of federal investment to be divided among the different mining areas, with Lausitz receiving 43 percent, Rheinland receiving 37 percent, and Mitteldeutschland receiving 20 percent (Die Bundesregierung, 2022b). Each state is responsible for managing the investment of their allocated funds, but they are required to use the funds in a way that replaces the value lost by mining, such as improved infrastructure, environmental conservation, or telecommunications (Die Bundesregierung, 2022b). An additional 26 billion euros will be invested by the federal government in research programs to aid the lignite mining regions, as well as introduce up to 5,000 jobs at federal facilities that are to be created in the regions (Die Bundesregierung, 2022b).

3.4.6 Die Kommission "Wachstum, Strukturwandel und Beschäftigung"

The two German acts which directly govern the phase-out of coal and the support structure for the affected regions, the Kohleausstiegsgesetz and the Strukturstärkungsgesetz, are the result of negotiations and recommendations made by Die Kommission Wachstum, Strukturwandel und Beschäftigung, or the “Commission on Growth, Structural Change and Employment”, also known as the “Coal Commission” (Oei et al., 2019). The voting members of the Coal Commission included mining and power plant representatives, trade unions, representatives from local governments in coal regions, environmental non-governmental organizations, researchers, and community members from coal regions (Reitzenstein & Popp, 2019). The Coal Commission was tasked with developing policy strategies to manage the phase-out of the coal industry and to mitigate the impact this will bring to coal producing regions (Reitzenstein & Popp, 2019). In addition to the voting members, federal and state legislators

were able to actively participate in committee meetings, but had no voting power (Hermwille & Kiyar, 2022). In its charter, the scope of the Coal Commission was described as (BMWi, 2019):

- Develop a plan for the phased elimination of coal power plants, including all accompanying support measures such as economic and legal policies.
- Develop a plan for the energy industry to contribute to reaching the 2030 emissions goal as mandated by the Climate Action Plan.
- Propose economic, social, climate, and structural policy strategies as well as the potential for new energy markets in the affected regions.
- Produce new opportunities employment that are resilient against future economic changes
- Identify areas for investment from the German government to support the to support the economic, structural, and social changes in the affected regions.

The Coal Commission was ultimately able to propose two recommended plans, both of which were eventually ratified as the Kohleausstiegsgesetz and the Strukturstärkungsgesetz (BMUV, 2021).

3.4.7 Coal Commission Challenges

Although the Coal Commission was successful in developing two strategies that were ratified into law, it was not without its challenges or criticisms. The policy recommendations generated by the Coal Commission were not legally binding themselves and needed to be subsequently adopted as law by the German government (BMWi, 2019). Passing of the Kohleausstiegsgesetz and Strukturstärkungsgesetz laws didn't occur for over a year after the completion of the Coal Commission report (Hermwille & Kiyar, 2022). The Coal Commission's proposal included short term strategies to meet 2020 emissions targets; however, the year delay in passing the relevant laws rendered these recommendations obsolete (Hermwille & Kiyar, 2022).

Even after the Kohleausstiegsgesetz and Strukturstärkungsgesetz laws were passed, implementation faced challenges. For example, the 2021 coalition government agreed to accelerate the

coal phase-out from 2038 to 2030 (Sozialdemokratische Partei Deutschlands et al., 2021), a target date which was again then into question with the 2022 Russian war on Ukraine (Backhaus et al., 2022). Political considerations also influenced the outcomes of the commission, as exemplified by the Christian Democratic Union's (CDU) reluctance to adopt an aggressive phase-out schedule over concerns that it may alienate their voters and push them toward the Alternative für Deutschland (AfD), a far-right populist party that is both popular in the Lausitz coal region and opposed to the phase-out of coal (Hermwille & Kiyar, 2022).

Environmental groups contend that the targets set by the Coal Commission are in line with German targets, but fall short of those needed to comply with the Paris agreement (Agora Energiewende und Aurora Energy Research, 2019). While the assertion that phase-out timetable for coal does not align with the Paris agreement is accurate (Agora Energiewende und Aurora Energy Research, 2019), the charter for the Coal Commission defined success as meeting climate targets were those defined in Germany's Klimaschutzplan 2050, a goal which it was able to meet (Hermwille & Kiyar, 2022).

Other critiques such as concerns about seemingly high payments to power plants operators, energy supply risks, fear of increased electricity prices, and overall expense to the government to fund the recommended policies represent the views from many of the diverse stakeholders that were involved in or impacted by the Coal Commission's recommendations (Agora Energiewende und Aurora Energy Research, 2019). As found by Reitzenstein and Popp (2019), the inherent vagueness that solutions negotiated by multi-stakeholders can result in increased publicly scrutiny over the results. Though the Coal Commission did not produce a perfect outcome for every stakeholder, the lessons

learned through the experience are applicable to transition efforts yet to be undertaken in other coal dependent countries (Hermwille & Kiyar, 2022).

3.5 The Role of Labor Unions and Collective Bargaining in the Coal Phase-Out

Organized labor has played an active role in the German Energiewende, as evidenced by their role in the Coal Commission (Hermwille & Kiyar, 2022). The Industriegewerkschaft Bergbau, Chemie, und Energie (IGBCE, 2021) is the labor union that represents workers in mining and power generation, as well as several other industries. Workers are also represented by the Ver.di union (Deutsche Welle, 2018). Membership in these unions has resulted in the workers being well organized, as exemplified by 2018 demonstration in Bergheim outside of a Coal Commission meeting in which 20,000 workers participated (Deutsche Welle, 2018).

In addition to labor union membership and representation, Germany has a long history of workers councils and codetermination in industry dating back to 1848 (Page, 2018). In the German context, codetermination gives employees the right to influence where they work through legal rights, employer-union agreements, and other agreements between employers and workers (Deutscher Gewerkschaftsbund [DGB], n.d.). Through the Betriebsverfassungsgesetz, or Works Constitution Act, a works council is to be elected at any employer with 5 or more employees and can enter into agreements about working conditions, such as hours and wages, that are legally binding (DGB, n.d.). For the coal industry, The Coal, Iron, and Steel Codetermination Act specifically applies to companies that have more than 1000 employees, and requires that half of the company board is comprised of employee representatives (DGB, n.d.). This representation gives considerable power to workers and requires consent from workers on a wide range of decisions from wages to layoffs (Furnaro et al., 2021).

Labor unions were integrated into Germany's coal commission, with a representative from each the IGBCE, Ver.di, and the DGB unions on the commission (Hermwille & Kiyar, 2022). The labor unions were recognized as being an influential force on the commission (Hermwille & Kiyar, 2022). Their role

within the commission involved balancing the need to ensure that no employees were left behind in the transition with the environmental objectives of the coal phase-out (Hermwille & Kiyar, 2022). As seen in decline of hard coal in Germany, the focus of job preservation by unions can lead to resistance to change and a focus on maintaining the status quo and can prevent economic progress when change is needed (Hospers, 2004). Labor unions have the potential to retard the speed of transitions, as observed during the hard coal transition in the Ruhr area where unions were focused on maintaining the status quo instead of promoting economic diversification in the region (Reitzenstein et al., 2022). The influence of German labor unions on the Coal Commission as described by Hermwille & Kiyar (2022) underscore an argument by Prinz & Pegels (2018) that building cooperative relationships between organized labor in the ”green” and “brown” sectors is necessary for effective energy transitions.

3.6 Impact of Energiewende Policies on Greenhouse Gas Emissions

The effect of Germany’s climate efforts are reflected in the country’s greenhouse gas (GHG) emissions since 1990. From 1990 to 2021, Germany has achieved GHG emissions reductions of about 39% (Umweltbundesamt, 2022b), with the energy industry reducing emissions by about 43.9% over the same period[11] (Umweltbundesamt, 2022a). Germany had met its 2020 goals to reduce GHG emissions by 40%, but an increase in emissions, largely by the energy industry as shown in Figure 6, will cause Germany to miss that target in 2021 (Umweltbundesamt, 2022a). The impact of the COVID-19 pandemic in 2020 on economic activity enabled Germany to meet its 2020 climate target; however, resumption of economic activity, high natural gas prices, adverse environmental conditions for wind and solar production, and low temperatures drove GHG emissions higher in 2021 (Agora Energiewende, 2022). With a target year of 2045 to have net zero carbon emissions, Germany’s decarbonization efforts need to be accelerated to meet its emissions reduction goals (Agora Energiewende, 2022).

[11] Author’s own calculations based on data from Umweltbundesamt (2022a).

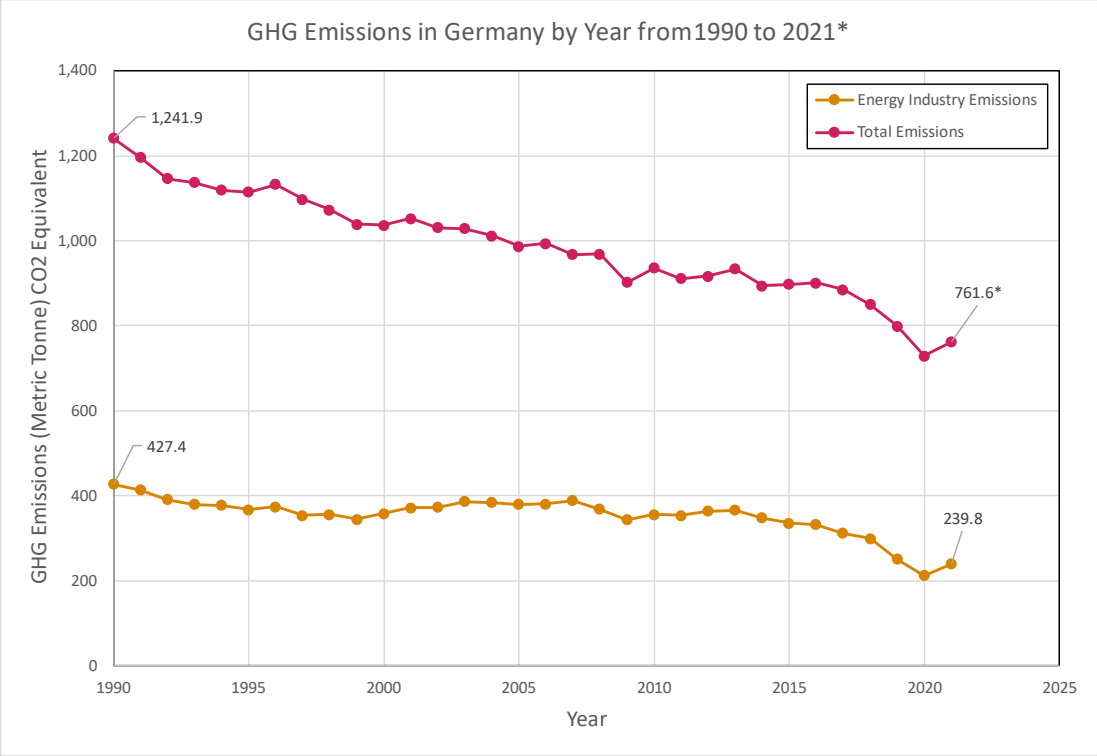

Figure 6 GHG Emissions in Germany by year from 1990 to 2021[12] (Umweltbundesamt, 2022a)

3.7 Challenge to the Energiewende: The War in Ukraine

The status quo of global energy markets was challenged when Russia invaded Ukraine on February 24, 2022 (Welt, 2022).

Europe is heavily dependent on Russian fossil fuels, with Russian imports accounting for 41.1% of natural gas, 36.5% of oil, and 19.3% of combined lignite, hard coal, and coke imports in the year 2020. (Eurostat, 2022) While import volumes from Russia vary from country to country, Germany is notably reliant upon Russian energy imports (Wintour, 2022).

Since the fall of the Soviet Union, Germany has used economic ties with Russia, particularly in the form of energy imports, as a foreign policy strategy to develop a mutually-beneficial relationship that keeps Russian ties with the EU and in turn help maintain peace (David-Wilp & Kleine-Brockhoff, 2022). The impacts of this strategy can be seen in Germany's fossil fuel imports in 2020, where 58.9% of

[12] Author's own figure based on Umweltbundesamt (2022a) data. Total emissions are calculated as CO2 equivalent without land use, land use change and forestry.

natural gas, 35.2% of oil, and 21.5% of hard coal were imported from Russia alone (Eurostat, 2022). This trade relationship has taken many forms, but two high profile natural gas pipeline projects, Nord Stream 1 and, most recently, Nord Stream 2 highlighted concerns about Germany's increasing dependence on Russian energy and the associated geopolitical risks (Belkin et al., 2022). Debate about the Nord Stream 2 project ranged from legality within the EU regulatory framework and concerns about alignment with EU climate goals, to fears of Russian supply restrictions on countries and routing gas away from Ukrainian pipelines to reduce Ukrainian income from pipeline transit fees (Russell, 2021). These concerns about the impacts of the Nord Stream 2 project were never realized as in response to Russia's mobilization of troops to the border of Ukraine, the United States President Joe Biden announced sanctions against Nord Stream 2 AG, the company responsible for the pipeline, and its corporate officers (Lefebvre, 2022), and Germany's Chancellor Olaf Scholz announced that certification for the Nord Stream 2 pipeline had been suspended, thus stopping the project from advancing (Marsh & Chambers, 2022). As of late June 2022, the pipeline remained out of operation and Germany was considering seizing a portion of the pipeline to reuse as part of an LNG terminal (Evans, 2022).

There are several potential courses of action that could suddenly restrict or cutoff the flow of Russian energy into Germany and the broader European Union. One route is the restriction or cessation of the exports of natural gas to the EU by the Kremlin (Cooban, 2022a). Another route is by the EU imposing sanctions on Russian coal, oil, and natural gas, preventing their export from Russia into EU member states (Cooban, 2022b). As of 14 July 2022, the EU has imposed six sanctions packages against Russia (Council of the EU, 2022b). The fifth sanctions package bans solid fossil fuels, including coal, from being imported into the EU if they are sourced from or exported by Russia, taking effect in August of 2022 (Council of the EU, 2022a). The sixth sanctions package bans Russian crude oil and certain refined products from being imported into the EU, with certain exceptions (Council of the EU, 2022b). As described in Germany's energy response strategy, the country recognized and prepared for the

possibility of either, or both, of these eventualities occurring, and is working to secure its energy supply ahead of further supply restrictions (BMWK, 2022d). The pressure to secure energy supplies increased when Russia shut down the Nord Stream 1 pipeline for annual maintenance without redirecting flows through alternate pipelines to Germany, stoking concerns that Russia may keep the Nord Stream 1 pipeline out of service (Eddy, 2022).

Germany's energy transition plans rely on the use of natural gas as a bridge fuel for the country, allowing for the decommissioning of coal-fired plants, and ultimately being replaced itself by renewable energies (Oei et al., 2019). Russia's war in Ukraine challenges this strategy as Germany looks to continue along its path to decarbonization without the bridge of Russian natural gas (BMWK, 2022d). Germany's path forward now has two goals: Decrease the use of fossil fuels while decreasing reliance on Russian energy imports (BMWK, 2022d).

In the face of the uncertainty created by the war, the German Federal Minister for Economic Affairs and Climate Action, Robert Habeck, has stated that accelerating the energy transition and renewable energy development is critical to energy security (BMWK, 2022d). To achieve this, Germany's path forward in responding to the war in Ukraine has been described as the following (BMWK, 2022d):

1. Speed up renewable energy development
2. Speed up development of hydrogen infrastructure
3. Source non-Russian fuel supplies
4. Maintain a strategic reserve of coal-fired power plants

The EU and Germany are planning to reduce, and eventually eliminate, imports of Russian gas by 2030, with a 2022 goal in the EU of cutting Russian gas imports by two-thirds via imports of liquefied natural gas from Qatar, the United States, Egypt, and West Africa (BMWK, 2022e). This commitment is underscored by energy agreements between Germany and Qatar, including LNG shipments, as well as agreements between German and Dutch utilities to construct an LNG terminal in Schleswig-Holstein

(BMWK, 2022d). Germany still views these LNG imports as a temporary bridge, as renewable energy is recognized as the best strategy for improving Germany's energy security (BMWK, 2022e). The importance of renewable energy in Germany's strategy for energy security is underscored by Christian Lindner, the German Finance Minister, describing renewable energy as "the energy of freedom" (Reuters, 2022).

Another potential strategy to decreasing reliance on Russian gas is to prolong the use of coal power (Meredith, 2022). Germany's efforts in 2022 enabled it to decrease imports of Russian coal to only 8 percent of the German supply by May of the year (BMWK, 2022g). In response to decreased gas volumes from Russia, the German government enacted an emergency policy to restart coal power plants and divert more natural gas to storage in preparation for winter (Connolly, 2022). The prospect of prolonging the use of coal poses a challenge to the Energiewende goals of Germany and the accelerated 2030 coal phase-out target date (Connolly, 2022). Within the coal industry, the potential to prolong the use of coal is not necessarily viewed as a positive outcome. As a spokesperson for the Jänschwalde Power Plant described in an interview with the German news agency Deutsche Welle, the phase-out of coal within Germany is well governed, and the coal industry isn't celebrating their potential need to operate past the agreed-upon phase-out deadlines (DW News, 2022).

In interviews with the Rheinische Post leading up to May 2022 elections, political candidates in North Rhein Westphalia (NRW) expressed their views on the potential impact of the Russian war in Ukraine on potential extension of coal phase-out deadlines (Backhaus et al., 2022). The CDU candidate stated that the 2030 phase-out date was realistic, but was unwilling to commit to the date due to the uncertainty in energy supplies (Backhaus et al., 2022). Conversely, the Green party candidate believes that lignite mining should cease before 2030 (Backhaus et al., 2022). While the candidates from each political party had different views on the exact dates of the coal phase-out, all candidates interviewed

which represented the CDU, SPD, Greens, FDP, and Left party all acknowledged that the coal phase-out will still occur and that the future of energy in Germany was in renewables (Backhaus et al., 2022).

There are many stakeholders involved in the German coal industry and there remains uncertainty about the impacts of the Russian war in Ukraine on German energy (Tollefson, 2022), but it is evident through key stakeholder sentiment in NRW that the coal phase-out is expected to occur around the 2030 target date (Backhaus et al., 2022). The decision to restart coal-fired powerplants and sentiment expressed by national and state politicians do not indicate a full reversal of the coal phase-out plan, as renewable energy is still viewed as the strategic focus for the future of a secure and reliable German energy system (Backhaus et al., 2022; Connolly, 2022).

3.8 Summary:

Germany's Energiewende policies set clear deadlines and incentives to transform the energy system away from coal and carbon intensive power and embrace other energy sources. (BMWK, 2022b) Germany's Energiewende policies are largely codified in legislation covering not only promotion of renewable energy (BMWK, 2022c), but specific emissions reduction targets (Die Bundesregierung, 2021b), mandated phase-out of coal, and support to manage the structural transition that is occurring in German coal regions (Agora Energiewende und Aurora Energy Research, 2019). Germany's approach to the coal phase-out is deliberate and, while it has received criticism (Agora Energiewende und Aurora Energy Research, 2019), is an example of managing a major transition through cooperation of a wide set of stakeholders with divergent interests (Schonhardt, 2022). Russia's war in Ukraine introduces uncertainty in the near-term as Germany's energy security is challenged (Tollefson, 2022), and it is yet to be seen if this will spur rapid development of renewable energies (BMWK, 2022h) or slow the progress of the Energiewende (Connolly, 2022).

Chapter 4: The Energy Transition in the United States and Appalachia

4.1 History of the Coal Mining Industry in Appalachia

The Appalachian coal region extends from Alabama through Pennsylvania and includes Eastern Kentucky, Maryland, Ohio, Tennessee, Virginia, and West Virginia (EIA, 2021d). The natural resources of the Appalachian region have played a historically significant economic role from the earliest days of frontier exploration by fur traders, to the timber industry, and ultimately the mining of coal (Zipper et al., 2021). The Appalachian coal fields are divided into three regions (Ruppert et al., 2014):

- Southern Appalachian Basin – Alabama, Tennessee
- Central Appalachian Basin – Tennessee, West Virginia, Eastern Kentucky, Virginia
- Northern Appalachian Basin – West Virginia, Maryland, Ohio, Pennsylvania

The ranks of Appalachian coal resources consist of anthracite, bituminous, and sub-bituminous coals (Ruppert et al., 2014). In the United States, anthracite mines are only found in the Northeastern Pennsylvania region (EIA, 2021e).

Coal from Appalachia fueled, literally and figuratively, industrial development in America from salt, iron, and glass manufacturing, to transportation and electrification (Zipper et al., 2021). Coal was used as a fuel source for heat and power in applications like blast furnaces or steam power, as well as for the production of coke for use in the steel-making process (Zipper et al., 2021). Appalachian coal production enjoyed a long period of market dominance; however, by the 1990's the demand began to shift as economic competition from other fuels for electricity generation such as natural gas grew and mines in the western U.S. provided a larger share of coal for electricity production (Zipper et al., 2021).

4.2 State of the U.S. Energy Industry

The energy industry in the United States has been in a state of transformation since the nation's founding. Wood dominated energy consumption until the late 1800s when it was overtaken by coal, and then coal was subsequently outpaced by the growth of petroleum and natural gas (EIA, 2011). Today,

the US energy mix is again in flux with the rise of natural gas and renewables further challenging the place of coal in the U.S. energy mix (EIA, 2022d). Figure 7 illustrates the changing trends of energy consumption in the U.S. from 1949 – 2021 for energy use across all use sectors (EIA, 2022h). Coal consumption peaked in 2005 and has been steadily declining since 2008, reaching an inflection point in 2019 when renewable energy accounted for more primary energy consumption than coal.

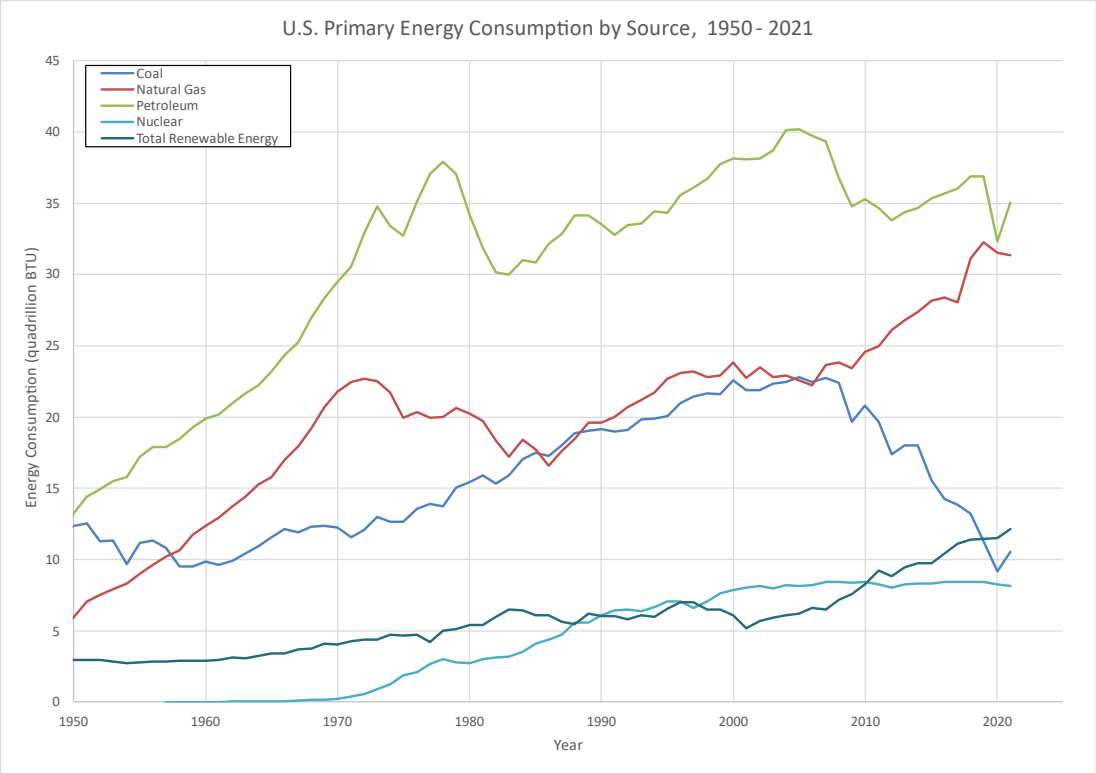

Figure 7 U.S. Primary Energy Consumption by Source, 1949 – 2021[13] (EIA, 2022h)

Figure 8 illustrates how the electricity generation sector, including electric utilities and independent power producers, has experienced a similar decline of coal power and a corresponding increase in the share of generation from natural gas and renewables. In electricity generation, from 2017 natural gas has displaced coal as the largest provider of energy. Figure 7 and Figure 8 both illustrate the change that has been occurring in the U.S. energy mix as coal has experienced a significant and steady decline from its once prominent fuel position.

[13] Author's own figure based on EIA (2022h) data.

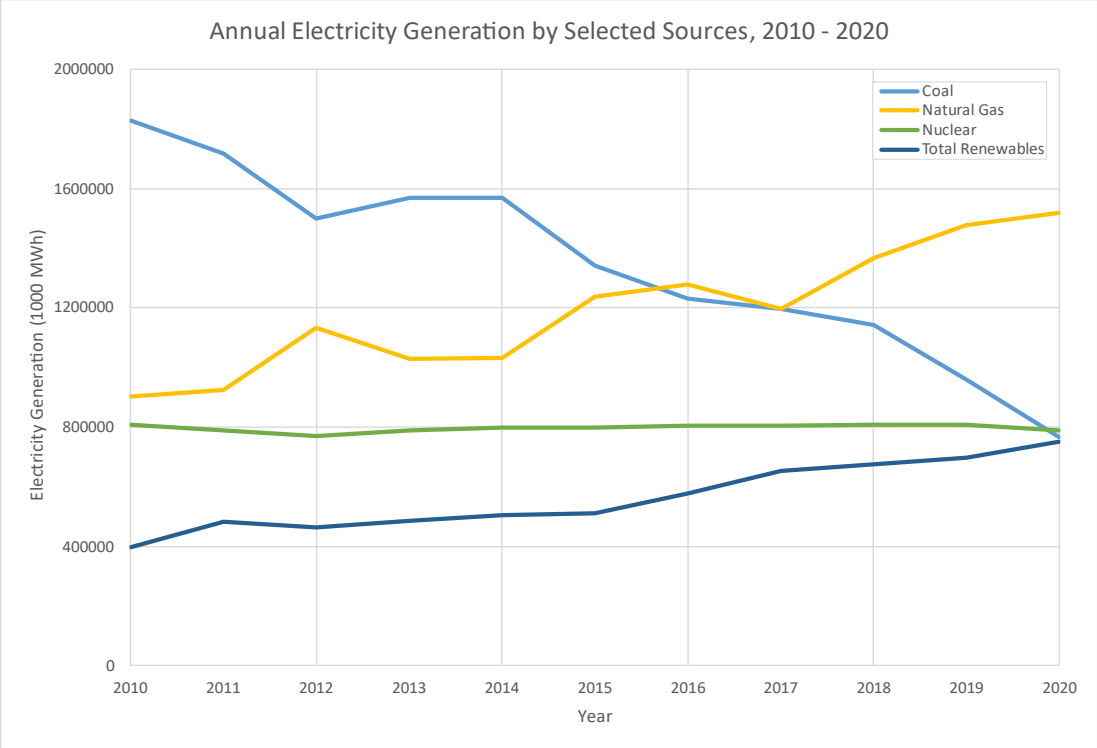

Figure 8 Annual Electricity Generation by Selected Sources, 2010 – 2020[14] (EIA, 2022f, 2022g)

Figure 9 shows projections for energy sources in the U.S. energy industry from 2022 to 2050. Over this period, renewable energies are expected to see the largest growth, with natural gas having modest gains between 2035 and 2050. While coal has been experiencing a steep decline since the late 2000's (EIA, 2022h), the rate of decline is projected to slow and level out near 2050. From Figure 9 there are two key takeaways that impact the future of coal mining and power generation in the United States. First, coal power is not projected to be eliminated as a fuel source by 2050. Second, the coal industry is not projected to experience growth and return to the prominence that it once enjoyed.

[14] Author's own figure based own calculation from EIA (2022f, 2022g) data of electricity generation by utilities and independent producers. Calculations and figures do not include energy contributions from "hydroelectric pumped storage", "Other Gas" and "Other" sources.

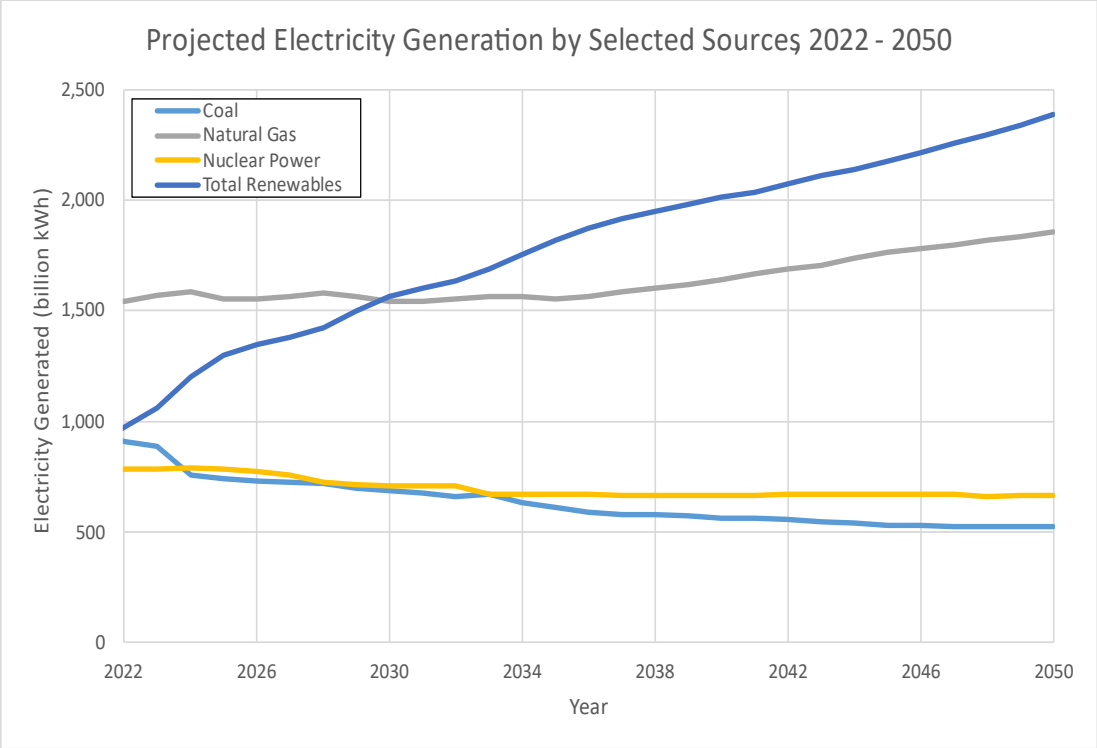

Figure 9 Projected Electricity Supply by Selected Sources, 2022 – 2050[15] (EIA, 2022e)

4.3 The State of the Coal Industry

4.3.1 Coal Power Generation

The decline in coal-fired power as described in Section 4.2 has led to a decline in employment in power generation, as shown in Figure 10. Figure 10 illustrates how employment has changed by state in Appalachia, with an overall decreasing trend. While extended data is not available, between 2016 and 2019 Appalachian power plants lost 5,019 jobs, a decrease of about 18% over the course of four years[16] (BW Research Partnership, 2020). Most of these losses were realized in Ohio, where 4,708 jobs were lost[17] (BW Research Partnership, 2020). In the case of Ohio, coal plants have been closing because they are no longer economically competitive (Associated Press, 2021; Flitter, 2017).

[15] Author's own figure based on EIA (2022e) data.
[16] Author's own calculation based on BW Research Partnership (2020) data.
[17] Author's own calculation based on BW Research Partnership (2020) data

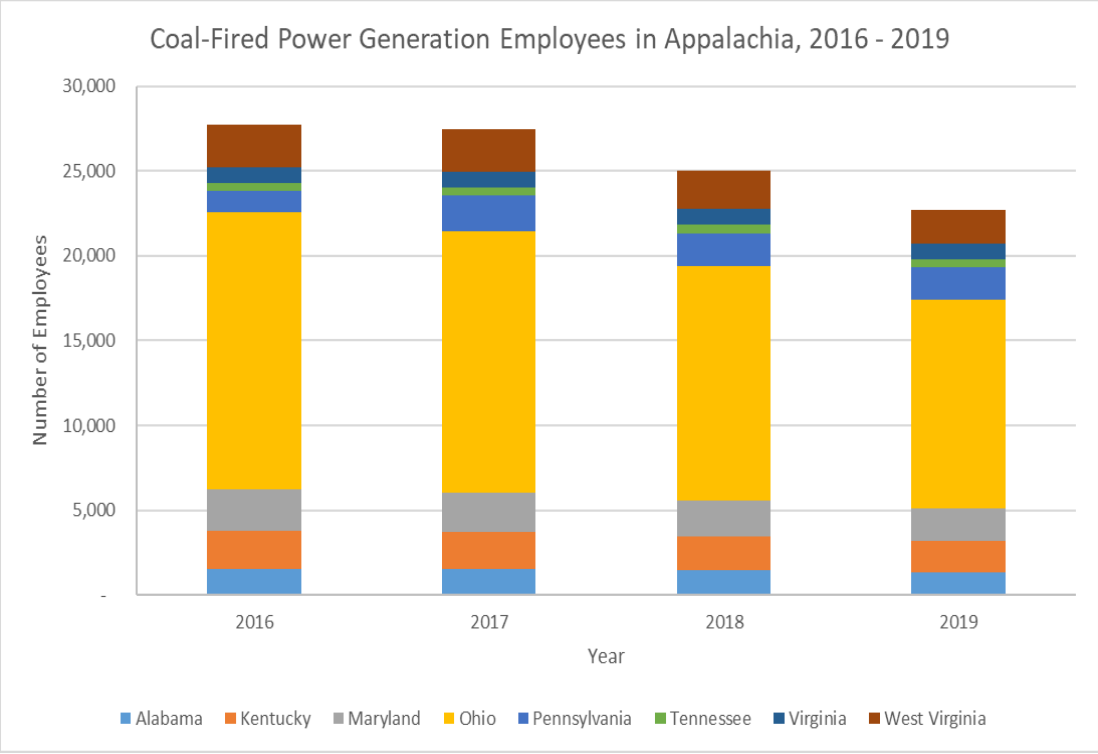

Figure 10 Coal-Fired Power Generation Employees in Appalachia by state for the years 2016 - 2019[18] (BW Research Partnership, 2020)

4.3.2 Coal Mining

As discussed in Section 4.2, after nearly a half-century of steady growth, the coal power industry has been in decline since around 2008. Coal production has seen a similar trend of steady growth and a sharp decline. Figure 11 illustrates the historic production of coal and shows the sharp decline in coal production, with 2020 production levels at about 54% less than the historic peak production in 2008.[19]

[18] Author's own figure based on BW Research Partnership (2020) data.
[19] Author's own calculation based on (2021b) data.

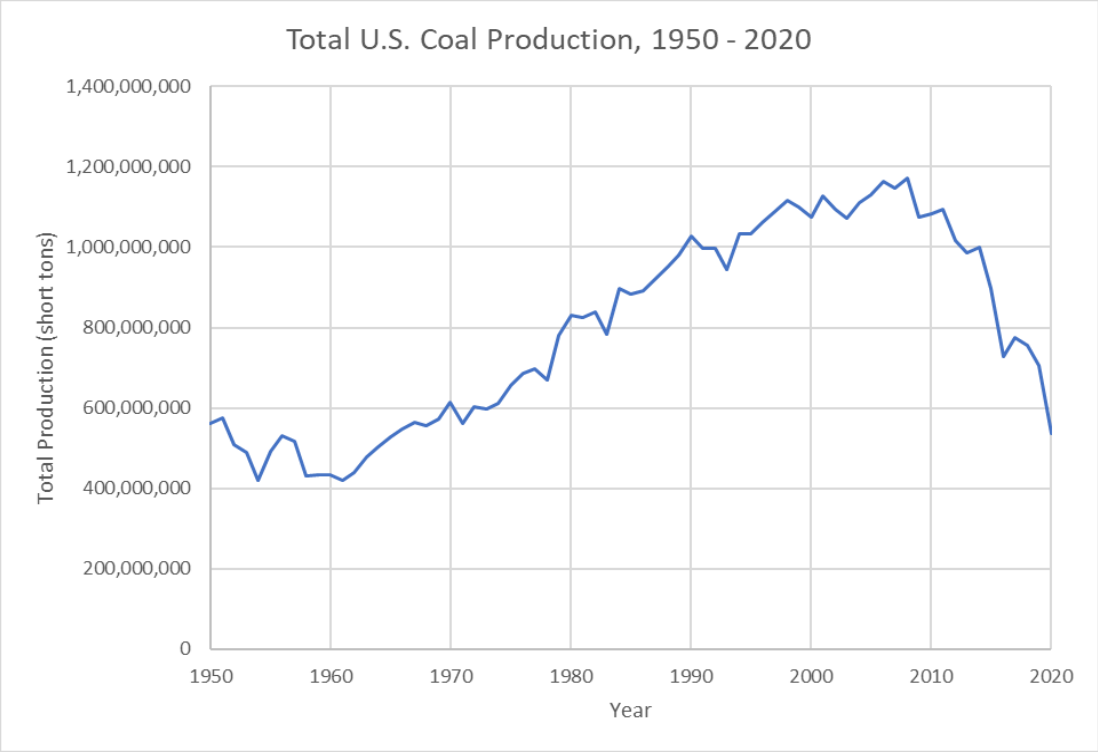

Figure 11 Total U.S. Coal Production, 1950 – 2020[20] (EIA, 2021b)

Coal mining in the United States is separated in to three mining regions: Appalachia, Interior, and Western (EIA, 2021e). For much of the 20th century, Appalachia was the largest producer of coal in the United States; however, around the year 2000 the Western region overtook Appalachia as the most productive region (Lobao et al., 2020). Figure 12 shows how all three coal mining regions have experienced production declines since the 2008 peak, but at a roughly 67% decline from 2008 production levels the Appalachia region has been impacted the hardest by production declines.[21]

[20] Author's own figure based on EIA (2021b) data.
[21] Author's own calculation based on EIA (2022c) data.

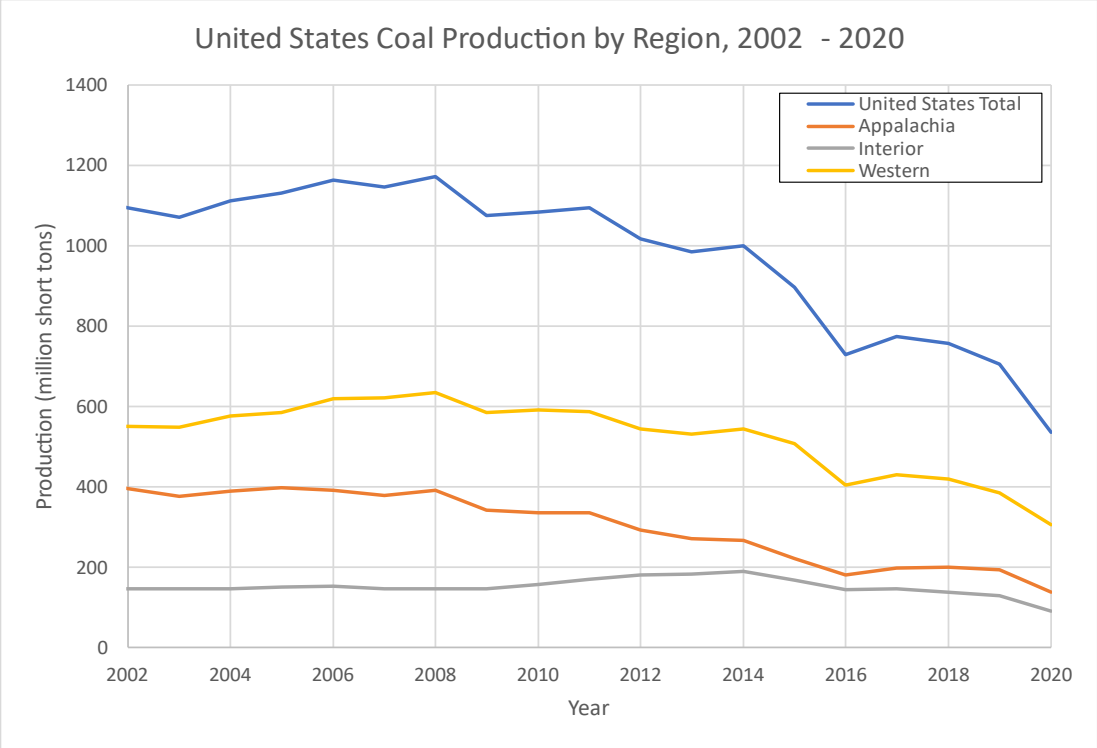

Figure 12 Total Coal Production by Region, 2001 – 2020[22] (EIA, 2022c)

Figure 13 presents the production in each of the Appalachian coal regions from 2001 to 2020. Each region has seen a decline in production; however, the Central region experienced a larger production drop than the other regions, producing roughly 82% less coal in 2020 than in 2001.[23] Total production from the Appalachian region declined by roughly 67%, with the production declines Central region accounting for about 82% of the overall decline.[24]

[22] Author's own figure based on EIA (2022c) data.
[23] Author's own calculation based on EIA (2022c) data.
[24] Author's own calculation based on EIA (2022c) data.

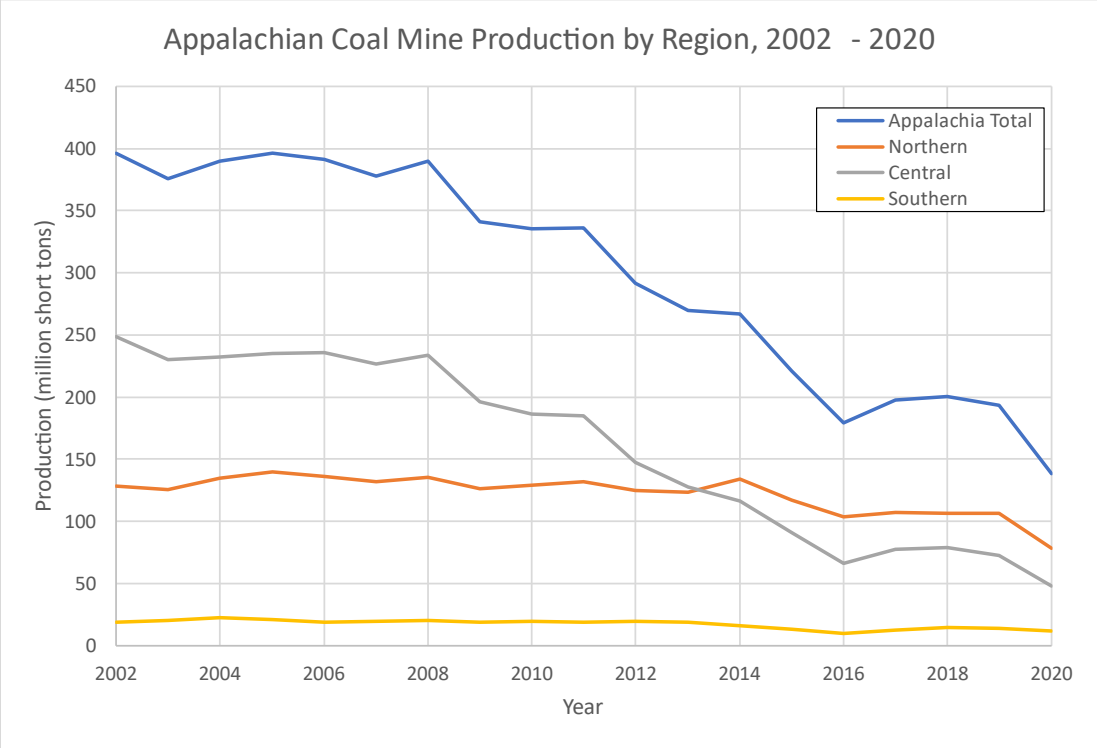

Figure 13 Appalachian Coal Mine Production by Region, 2001 – 2020[25] (EIA, 2022c)

4.3.3 Coal Mining Employment

Mining employment has also been impacted by the overall decline of the coal industry. Figure 14 illustrates coal mining employment trends in the three mining regions of the United States from 2002 to 2020. US mining employment peaked in 2011 and steadily declined through to 2020. The overall employment trend, as shown in Figure 14, is strongly affected by employment in Appalachia. Of the 49,452 jobs that were lost in US coal mines between 2011 and 2020, the Appalachia region accounted for roughly 73% of the losses.[26] Figure 15 shows that within Appalachia, the central region accounted for 25,701 of the 36,269 jobs that were lost in Appalachia, or about 70% of regional job losses.[27] Over the 2011 to 2020 period the Central Appalachia region lost more jobs than all other regions combined, including the northern and southern Appalachia regions.[28]

[25] Author's own figure based on EIA (2022c) data.
[26] Author's own calculation based on EIA (2022b) data.
[27] Author's own calculation based on EIA (2022b) data.
[28] Author's own calculation based on EIA (2022b) data.

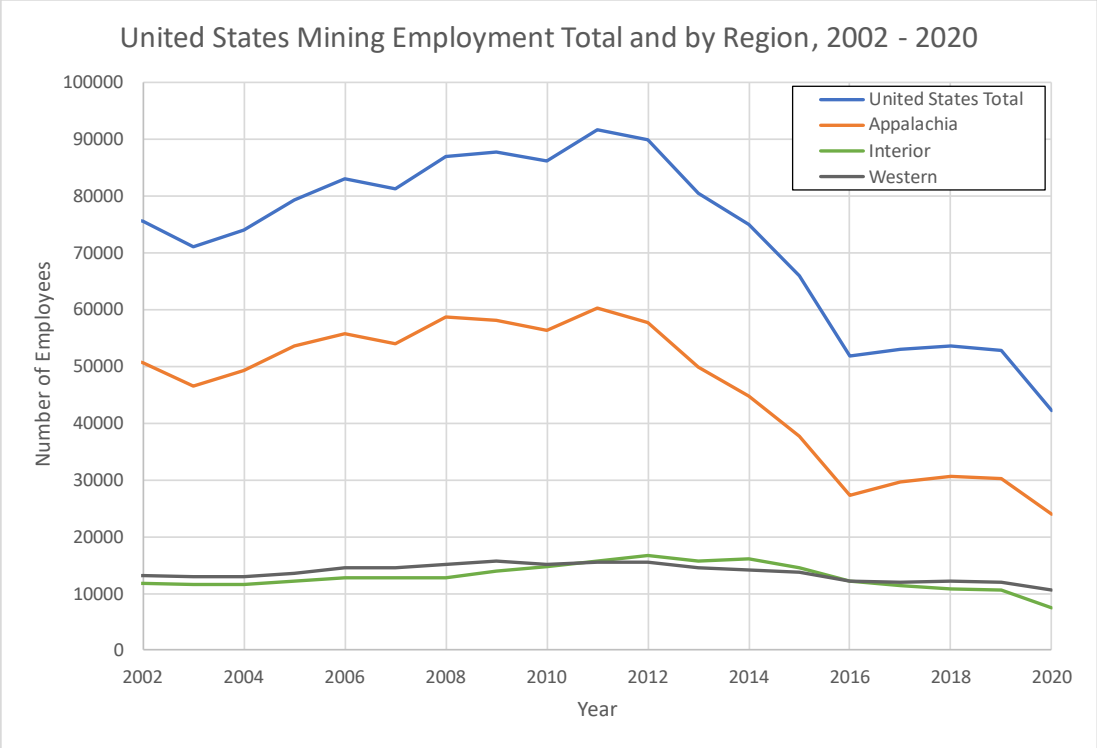

Figure 14 U.S. Mining Employment Total and by Region, 2001 – 2020[29] (EIA, 2022b)

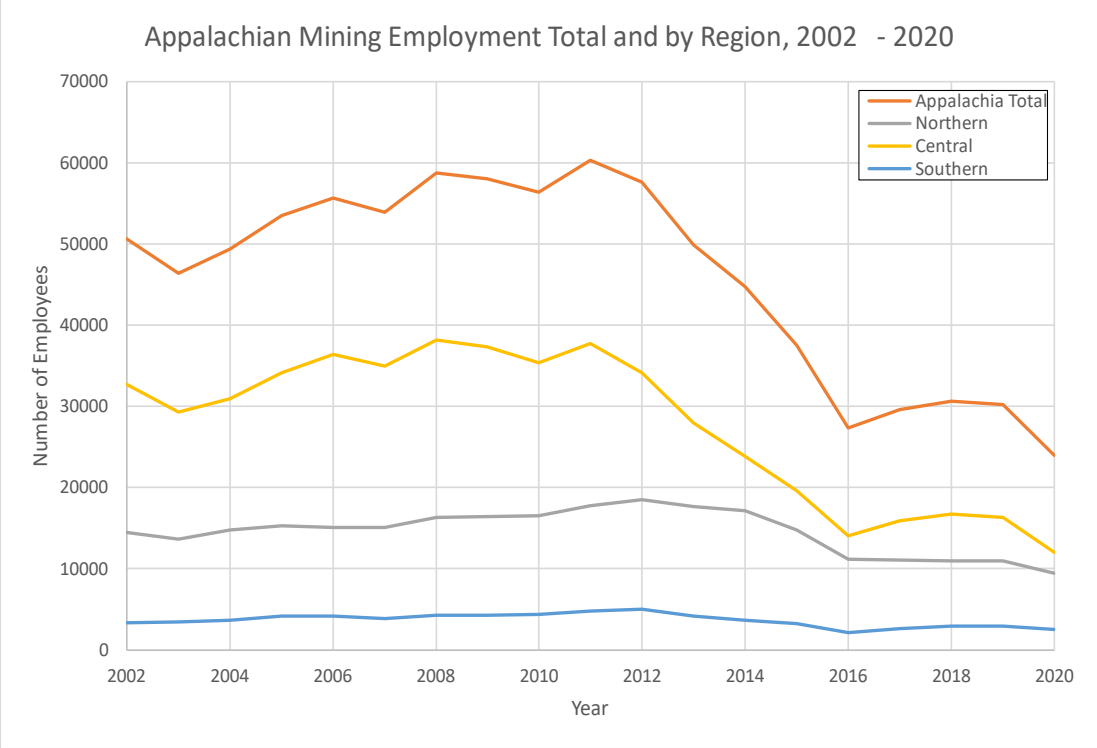

Figure 15 Appalachian Mining Employment Total and by Region, 2001 – 2020[30] (EIA, 2022b)

[29] Author's own figure based on EIA (2022b) data.
[30] Author's own figure based on EIA (2022b) data.

An analysis of employment statistics by Bowen et al. (2021) suggests that the losses in Appalachian mining employment seen in Figure 15 between the years 2011 and 2016 depressed employment growth in coal mining counties in Appalachia. While the United States and non-mining counties in Appalachia saw private sector employment gains over this time, private sector employment was relatively stagnant, and even fell between the years 2015 and 2016 (Bowen et al., 2021). This observed behavior, according to Bowen et al. (2021), could be due to "spillover" that the loss of mining employment had on restraining broader economic growth in coal mining counties.

4.4 Current State of the United States Energy Policy

In general, most policy in the United States is generated from two of the three "powers" of the government: The executive branch and the legislative branch. In general, the legislative branch governs administrative agencies whose activities are directed by the executive branch (Ashford & Caldart, 2008). The legislative branch creates and grants powers to administrative agencies through statutory mandates and has the ability to influence agencies through formal and informal mechanisms (Ashford & Caldart, 2008). Once created, administrative agencies exist under the purview of the executive branch (Ashford & Caldart, 2008). The executive branch is therefore able to exert significant influence over the direction agencies, largely through the appointment and dismissal of agency leaders, as well as the budget process (Ashford & Caldart, 2008). The legislative branch can create policy through their primary function of passing laws to directly create rules or to guide the actions of administrative agencies (Ashford & Caldart, 2008).

It is not the function judicial branch of government to create policy; however, they play a significant role on the creation and implementation of policy by reviewing policy created by agencies and the congress, as well as providing interpretations when hearing legal challenges to agency rules (Ashford & Caldart, 2008). For example, in June 2022 the Supreme Court decision in EPA v. West Virginia, which relied on a constructed doctrine called the "major decisions doctrine", stripped the EPA

of the ability to implement a national climate plan similar to the Clean Power Plan (Hill, 2022). The impacts of this decision are discussed in Section 4.4.8.

Other policies, such as Executive Orders, are created by a President's administration and tend to produce a short-lived policy and lack long term direction as they are easily overturned by the next administration (Thrush, 2021). This is exemplified by 14 of the 30 executive orders enacted by U.S. President Joe Biden in his first 48 hours as President that were focused on repealing the executive actions of former president Donald Trump (Thrush, 2021). The legislative branch, consisting of congress, creates policy through lawmaking. Legislation passed by the Congress is not easily repealed, leading to more robust and resilient policy measures (Thrush, 2021).

In this section, energy and environmental policy that affects the energy transition, primarily related to coal, will be discussed. The underlying legal framework in which these policies are drafted is not further discussed, except in instances where changes to that framework have recently occurred or are being challenged.

4.4.1 The Clean Power Plan

The Clean Power Plan (CPP), which was enacted by the EPA under the Obama administration in 2015, set emissions standards for powerplants and mandated state specific goals to reduce CO2 emissions (US Environmental Protection Agency [EPA], 2017a). The goal of the CPP was to reduce CO2 emissions from power generation to 32 percent of 2015 levels by 2030 (EPA, 2017a). In addition to the performance standards, requirements for state plans, and accountability measures, the CPP introduced a CO2 emissions trading scheme (EPA, 2017a). The emissions trading scheme was to enable power plants to meet their emissions targets through acquiring emissions credits from other operators, and to incentive operators to reduce emissions more than mandated for early adoption and to reduce emissions quickly to take advantage of the emissions trading market (EPA, 2017a). The estimated benefits of the CPP included accelerating emissions reductions, improving health outcomes for

communities, encouraging investment in development of renewable energy and the associated employment gains, and preventing the costs associated with climate change (EPA, 2017a). Ultimately, full implementation of the CPP was not realized as it was repealed by the EPA in 2019 under the Trump administration (EPA, 2017b).

4.4.2 Affordable Clean Energy Rule

In 2019 the EPA under the Trump administration issued the Affordable Clean Energy Rule (ACE) which repealed the CPP and promulgated emissions guidelines for coal fired power plants (EPA, 2019). The guidelines for the ACE were focused on heat rate improvement to increase the fuel efficiency of coal-fired power plants as the best system of emissions reduction for reducing CO2 emissions (EPA, 2019). Ultimately, the ACE was vacated in 2021 by the D.C. Circuit Court of Appeals, and the EPA issued a memorandum that states did not need to develop plans to meet Clean Air Act requirements under ACE (EPA, 2021).

4.4.3 Mercury and Air Toxics Standards

The Mercury and Air Toxics Standards (MATS) were introduced in 2011 by the EPA under the Obama administration with the goal of decreasing emissions of heavy metals and acid gases from coal and oil power plants (EPA, 2011). MATS regulated the emissions of mercury, arsenic, chromium, nickel, hydrochloric acid, and hydrofluoric acid (EPA, 2011). The EPA estimates that MATS implementation, along with technology development in power generation, resulted in an 86 percent reduction in mercury emissions, 96 percent reduction in acid gasses, and 81 percent reduction of emissions of other metals from 2010 levels (EPA, 2022). One study found that market shocks, defined as natural gas prices, renewable energy, and demand for electricity, explained the coal powerplant profit declines and closures with MATS having only a small effect on these outcomes (Linn & McCormack, 2019). Another study found that regulations had little effect on coal consumption in the United States, and that consumption declines were largely due to the availability of cheap natural gas, with the MATS ruling

accounting for a .6 percent decrease in 2014 coal production (Coglianese et al., 2020). While MATS is not explicitly climate legislation, it is a recent example of successful air emissions regulations on the power sector.

4.4.4 Executive Order 14008

On January 27, 2021 President Biden issued an executive order to take action to address climate change (Exec. Order No. 14008, 2021). The executive order establishes targets for the United States to achieve net zero emissions by 2050 and for electricity generation to be carbon pollution-free by 2035 (Exec. Order No. 14008, 2021). The executive order also establishes multiple working groups/task forces, of particular interest the Interagency Working Group on Coal and Power Plant Communities and Economic Revitalization to coordinate federal assistance to communities dependent on fossil fuel extraction and power generation and to identify projects to improve environmental pollution and public health impacts from fossil fuel extraction and use (Exec. Order No. 14008, 2021). There is a distinct focus on the creation of "well-paying union jobs" as an integral component to achieving climate goals and revitalizing and strengthening communities and demonstrates a clear commitment by the Biden administration to coordinate climate aspirations with economic resilience (Exec. Order No. 14008, 2021).

4.4.5 The Paris Agreement to the United Nations Framework Convention on Climate Change

The Paris Climate Agreement is a legally binding international treaty to reduce greenhouse gas emissions in efforts to limit global temperature rise to 2 degrees Celsius, with a stretch goal of limiting the increase to 1.5 degrees Celsius (Paris Agreement to the United Nations Framework Convention on Climate Change [Paris Agreement], 2022). Each country that has signed on to the Paris Agreement sets Nationally Determined Contributions (NDC), which are the voluntary emissions reductions targets and strategies that the country commits to meet and update on a five-year interval (Paris Agreement, 2022). The Paris Agreement also has an optional provision for countries to develop "long-term strategies" for

their climate goals and provide a longer-term framework for the NDCs (Paris Agreement, 2022). The United States joined the Paris Agreement in 2016; however, the Trump administration withdrew from the agreement in 2019 (Denchak, 2021).

In 2021, President Biden rejoined the Paris Agreement and the United States submitted an NDC to reduce net economy-wide GHG emissions to 50-52% below 2005 levels by 2030 (United States Department of State, 2021). The United States also created the optional Long-Term Strategy which, although it does not contain specific commitments outside of the NDC, is intended to inform domestic initiatives as well as promote international aspirations to achieve more ambitious goals (United States Department of State & United States Executive Office of the President, 2021).

4.4.6 Infrastructure Investment and Jobs Act & Build Back Better Act

The Infrastructure Investment and Jobs Act is a bipartisan bill that was passed by congress in 2021 to invest in improving the nation's infrastructure, create union jobs, and address climate change (The White House, n.d.). The act contains several elements that can contribute to economic improvement in coal regions such as expansion of high-speed internet access, $21 billion dollars for environmental remediation including abandoned mine reclamation, and funding for transportation infrastructure improvements (The White House, n.d.). The act provides significant support to infrastructure in the Appalachian region with $1 billion of funding to the ARC, $1.2 billion for the Appalachian Development Highway System, as well as prioritizing rural areas for energy projects (The White House, 2022). Further investments in climate change mitigation and clean energy development of $555 billion were included in the Build Back Better Framework, another spending package that was proposed in addition to the Infrastructure Investment and Jobs Act (Zandi & Yaros, 2021); however, after passing in the House of Representatives, the bill was stalled in the Senate and failed after West Virginia Senator Joe Manchin pulled his support for the bill (Kapur & Sarlin, 2022). On July 27th, 2022, Senator Joe Manchin reached a deal with Senator Chuck Schumer to support a bill known as the

"Inflation Reduction Act", a bill which includes significant climate change management provisions, but as of the writing of this thesis has not passed through the steps to become law (Zhou, 2022).

4.4.7 The Appalachian Regional Commission

Created as a result of the Appalachian Regional Development Act which was passed by congress and signed into law in 1965, the ARC was established to improve the economy of the Appalachian region through investment in development projects (ARC, n.d.-b). ARC is led by a presidentially appointed co-chair, 13 governors from the Appalachian states, and includes local participation via local development districts (ARC, n.d.-d). One of priorities for ARC is to invest in and support businesses in Appalachia, promote economic diversification, and increase the resilience of the economies of Appalachian communities to endure through economic transitions, recessions, or other economic challenges (ARC, n.d.-e). One study found that over its history ARC has had a positive effect on reducing extreme poverty and improving incomes in Appalachia (Ziliak, 2010). The ARC is an important instrument to addressing structural improvements in Appalachia, as exemplified by the $1 billion of funding that it received through the Infrastructure Investment and Jobs Act (The White House, 2022).

4.4.8 West Virginia v. EPA and the Major Questions Doctrine

On June 30, 2022, the United States Supreme Court ruled against the EPA's power to regulate power plant emissions of carbon dioxide under a provision of the Clean Air Act, a ruling which, although based on a case which had no standing regulation as the CPP was never enacted, restricts the ability of the Biden administration to advance an agenda to address climate change (Liptak, 2022). The decision of the Court was based on a concept known as the "Major Questions Doctrine", which purports that an administrative agency must show that legislators clearly mandated the agency to take an action with significant political or economic impacts (Liptak, 2022). While this ruling hampered the ability of the EPA to directly regulate carbon dioxide emissions from power plants, there are other legislative mechanisms in place to reduce carbon dioxide emissions within other sections of the Clean Air Act and other

legislation such as the Toxic Substances Control Act (Irfan & Dhanesha, 2022). The ruling by the Supreme Court and application of the Major Questions Doctrine could have far reaching impacts on the ability of administrative agencies create regulation and effectively function (Irfan & Dhanesha, 2022).

4.4.9 Strategies to Manage the Energy Transition

It has been evident since the 1960s and passing of the Appalachian Regional Development Act that Appalachia needs support to overcome significant economic challenges, a fact that has not changed today (ARC, n.d.-a). As the energy transition continues to progress, decarbonization will result in more impacts to fossil fuel dependent workers and communities (Richardson & Anderson, 2021). Identifying strategies to support this transition has been a subject of multiple studies (for example see Renda and Ashford (2016)) and government initiatives. Studies by Lobao et al. (2020) and Richardson and Anderson (2021) provide policy and investment suggestions for the coal sector, while the ARC is actively investing in improving the economic outcomes of the Appalachia. Table 2 summarizes these proposed policy frameworks and strategies and actual implemented investment strategies to aid in successfully navigating the transition.

Table 2 Comparison of proposed energy transition strategies for workers and communities from Lobao et al. (2020) and Union of Concerned Scientists (2021) to actual agency strategy from the ARC (n.d.-c).

Lobao et al., (2020)	Richardson and Anderson (2021)	ARC (n.d.-c)
Buyout Coal Miners	Five Year Wage Replacement	Invest in local community businesses and projects
Training and Education	Educational Benefits for workers and families	Invest in education for students, worker training
State and/or federal subsidies for lost income tax revenue	Job Placement and Training	Invest in healthcare access and substance abuse treatment
Relocation assistance	Relocation Assistance	Invest in infrastructure (transportation, telecommunication, energy)
Diversify local economies	Educational Benefits for recently displaced workers (2015 – 2019)	Invest in regional culture and tourism
Short term financial support to local businesses	Mental Health and counseling	Invest in leadership development and entrepreneurship
Invest in environmental remediation		
Utilize “higher-level” agencies to coordinate the transition with local groups.		

The three strategies described in Table 2 vary in their details; however, there are common themes. Investment in education and training is universal. The Union of Concerned Scientists and Lobao et al, both identified the need to provide wage compensation to workers that are being displaced from their jobs.

The ARC is already investing in several of the proposed policies and strategies by Lobao et al. and the Union of Concerned Scientists. Training and education, economic diversification, support to local businesses, coordination of efforts with local groups, and healthcare are included in ARC's investment priorities. Policies such as worker buyouts, wage replacement, relocation assistance, and environmental remediation are outside of the ARC's scope. While the United States has not enacted legislation to directly support workers impacted by the energy transition, Lobao et al. (2020) and Richardson and Anderson (2021) provide potential policy measures to improve outcomes for workers.

4.5 Summary

The data presented in this chapter supports the observation that an energy transition in the United States is underway, although there are differing perspectives on what the endpoint of this transition will be (Gelles & Friedman, 2022). The energy mix in the United States is shifting, and coal is not projected to return to prominence in the U.S. energy mix (Richardson & Anderson, 2021). While the job losses associated with this transition and decline of coal are felt in all fossil fuel-dependent communities, the Appalachia region, and central Appalachia in particular, has seen significant job losses (EIA, 2022b). These losses have occurred in a region that has long struggled to achieve the same economic and socioeconomic success as the rest of the country (ARC, n.d.-a).

The United States has had mixed results creating lasting climate change goals (Denchak, 2021) and a legislated policy system to manage the energy transition(Leber, 2021). The executive branch has largely had to rely on executive action to create climate policy when legislative strategies have largely

been unsuccessful (Leber, 2021). The result of this is exemplified in participation in the Paris Agreement where the United States joined the agreement, withdrew, and then re-joined in a reflection of the political and policy ambitions of the standing administration (Mai, 2021). There has been recent success in developing policies to address the structural and employment changes that the energy transition will bring, with an effort to invest in communities that will be hardest impacted by this transition and supporting union employment, such as the passing of the Infrastructure Investment and Jobs Act (The White House, n.d.).

The energy transition in the United States is happening, but without a clear policy framework and strategy it will be a hard transition for communities and workers (Schonhardt, 2022). Further chapters will explore the differences in energy transition policies between Germany and the United States, outcomes for workers, and potential paths forward to improve the employment outcomes of the energy transition.

Chapter 5: Comparative Analysis of Germany and United States Policies and Outcomes

5.1 Overview of Policies to Manage the Energy Transition

In the specific context of managing coal's future, Germany has numerous superior policies to manage the transition away from coal and its impact on workers. Germany has enacted federal legislative policies to promote the development and installation of renewable energy capacity with the EEG (BMWK, 2022c), phase-out lignite mining and power production with the Kohleausstiegsgesetz (Die Bundesregierung, 2022a), and manage the structural changes that the lignite phase-out will cause in affected regions with the Strukturstärkungsgesetz (Die Bundesregierung, 2022b). The Kohleausstiegsgesetz and Strukturstärkungsgesetz were both sourced from proposals by a federally-mandated joint industry, NGO, researcher, and community committee with the Die Kommission Wachstum, Strukturwandel und Beschäftigung (Agora Energiewende und Aurora Energy Research, 2019). Germany has formalized their emissions reduction goals and sectoral targets into federally-legislated policy via the Bundes-Klimaschutzgesetz, originally passed in 2019 and amended with accelerated emissions reduction targets in 2021 (Die Bundesregierung, 2021b).

The United States does not have a similar federal policy framework that comprehensively addresses emissions, employment, and energy source aspects of the energy transition. As of 2022, emissions reduction targets for the United States have been set by executive order (Exec. Order No. 14008, 2021), and as such these targets are not federally-legislated policy. In contrast to the Klimaschutzplan 2050 and the Bundes-Klimaschutzgesetz, the United States has not clearly articulated sector specific emissions reduction targets either in federally-legislated policy or through executive order (Exec. Order No. 14008, 2021). The Long-Term Strategy developed by the United States as the optional long-term framework for meeting the Paris Climate Agreement NDCs describes potential pathways and strategies to reach net-zero carbon emissions by 2050; however, it does not contain

comprehensive sector specific targets that contribute to the overall emissions reduction goal, nor are the strategies within the document legislatively binding (United States Department of State & United States Executive Office of the President, 2021). The Infrastructure Investment and Jobs Act provides tens of billions of dollars of funding to support the Appalachian region including funding the ARC, developing highways and transportation infrastructure, improving telecommunications infrastructure, and environmental remediation; however, unlike the Strukturstärkungsgesetz, the Infrastructure Investment and Jobs Act was not created in the context of a planned phase-out of the coal industry in the region and is focused on built infrastructure, not structural transition (Sprunt, 2021; White House, 2022). Overall, the United States lacks comprehensive federal policies to manage the energy transition, leading to mixed messaging and uncertainty about the energy transition in communities (Graff et al., 2018). The outcome of the 2022 United States midterm elections will no doubt affect the likelihood of further development of specific energy transition policies (Pletka, 2022; Wood Mackenzie, 2022).

Comparatively, Germany has a more holistic policy framework, bolstered by federal legislation, which attempts to comprehensively address all aspects of the energy transition, particularly the fate of coal workers. The United States has little in the way of policy beyond Executive Order 14008, NDCs for the Paris Agreement, and the Infrastructure Investment and Jobs Act. Without federally-legislated policy to manage the energy transition in the United States, the changes that these orders bring about has been described as “fragile” (Fouhy, 2021).

5.2 Policies to Set Energy Transition Targets

Germany has several policies that clearly articulate their climate targets and how they will be reached. The Bundes-Klimaschutzgesetz 2019 & 2021 create legally binding emissions reduction targets at a national level as well as sector specific targets (BMUV, 2019). The value of having these targets clearly articulated is evident in the charter for the Coal Commission as they provided clear goals for the Coal Commission to design policy recommendations to meet (BMWi, 2019). Although the Coal

Commission was given the targets of the Klimaschutzplan 2050, which were not yet part of legislation as the Bundes-Klimaschutzgesetz had not yet been passed, having defined targets in the charter helped bolster the recommendations against criticism that the Commission's proposals were not ambitious enough, as this is ultimately a concern rooted in the targets themselves, not the outcome of the Commission (Hermwille & Kiyar, 2022).

In the United States, Executive Order 14008 is the only federal policy that articulates a GHG emissions target. The United States' 2030 NDC for the Paris climate agreement is not backed by legislated domestic policy. Similarly, the goal articulated in the NDC of 100 percent carbon-pollution free electricity by 2035 also has no legislated domestic policy to support it.

The lack of federal legislative support for the United States climate goals can make them susceptible to change, as exemplified in Chapter 4 by the ability for executive orders and agency rulings to be overturned. Having legally-binding emissions reduction targets can help guide further actions by legislators, industry, and citizens to accept and prepare for the loss of coal mining and power generation from the energy transition.

5.3 Policies to Manage the Decline of the Coal Industry

In the long term, as discussed in Chapters 2, 3, and 4, the coal industries in Germany and the United States have, and will continue to, experience significant declines; however, the approaches to manage the decline differ significantly.

In Germany, the fate of the coal industry is clear: By policy design, lignite mining and coal power production, including the associated jobs, will be eliminated by 2038 at the latest (BMUV, 2021). All 17,948 positions in lignite mining and power production in 2021 will be lost (Statistik Der Kohlenwirtschaft e.V., 2022). Although official numbers of hard coal power plant employees are not available, one estimate based on employment intensity (jobs/MW) for hard coal powerplants calculated

that in 2019 this sector employed 7,830 workers, all of which will be eliminated (Agora Energiewende und Aurora Energy Research, 2019).

For the workers in the lignite industry, the Kohleausstiegsgesetz provides early retirement benefits to workers aged 58 and older for a maximum of five years (Raitbaur, 2021). For workers younger than 58, there is no provision for retraining or prioritization for job placement, even though these measures were recommended by the coal commission (Raitbaur, 2021). Although measures for younger workers were not included in either coal phase-out related acts, German workers have access to health care, retirement, a public job training program, and union-supported job training programs (Pike, 2021). Aside from a national re-training program, American workers lack the institutionalized social support structure to which German workers have access (Pike, 2021). While studies have proposed potential policy measures to support United States coal workers, federal legislation has not been passed to implement them (Lobao et al., 2020; Richardson & Anderson, 2021).

Coal mining employment in Appalachia is not likely to recover; (Gruenspecht, 2019) however, unlike Germany, the United States does not have policy measures in place to intentionally manage this transition for workers (Pike, 2021). Workers that lose their jobs also face a loss of benefits such as health insurance, and although the United States has a public job training program, it lacks in quality those in Germany (Pike, 2021).

5.4 Policy Analysis Summary

Germany's reputation as a leader in the energy transition is bolstered by its extensive federal policy framework to support all aspects of the transition. The effect of this policy is that Germany's emissions reduction ambitions are explicit, the coal phase-out is planned and accepted by affected stakeholders, there is a clear deadline for when coal mining and power generation will cease, and policies are in place to support communities and workers involved in this structural change. As for the policies themselves, Germany has been successful at creating federal legislation to drive the

Energiewende forward, and in the case of the acts pertaining to coal, policy has been constructed in a way that makes overturning the legislation difficult and improbable.

The policy structure in the United States is lagging behind Germany and is primarily dependent on executive orders and actions by the executive branch of government. Recent attempts by Congress to pass legislation to support the United States' climate goals with the Build Back Better Act failed to garner enough support to pass the Senate. While legislation has passed with funding to support structural investments in Appalachia, the United States otherwise has no policies that directly address and manage the shrinking, and potential elimination, of the coal industry as part of the energy transition. The outcome of the United States 2022 midterm elections could possibly change this and enable development of legislated climate policy; however, election results may make the passing of climate-related legislation improbable.

Chapter 6: Policy Proposals and Conclusion

6.1 Defining a Successful Transition for Appalachian Workers

The vision of success for workers affected by the energy transition is articulated in the concept of a "Just Transition." The International Labor Organization (2022) defines the just transition as "greening the economy in a way that is as fair and inclusive as possible to everyone concerned, creating decent work opportunities and leaving no one behind." The just transition concept originated from labor unions, and over time has evolved from focusing on supporting jobs that were lost due to environmental regulations to intentionally planning for the energy transition and developing a system that supports jobs and communities while taking action on climate change (Smith, 2017). The goal of a just transition is present in the Paris Climate Agreement in the opening section which states: "Taking into account the imperatives of a just transition of the workforce and the creation of decent work and quality jobs in accordance with nationally defined development priorities…" (Paris Agreement, 2022).

There is not a single set of policies that, if enacted, will achieve a just transition; instead, policies need to be crafted that are appropriate to the context of each specific country as levels of development, industries, and economies differ across the world (International Labour Organization, 2015). Lessons learned from Germany's coal-phase-out underscore the importance of tailoring actions to specific regions as the needs of the Ruhr mining region, an urban region, differ from the rural Lusatia region (Reitzenstein et al., 2022). For coal workers and communities in the United States and Germany, achieving a just transition can result in increased availability of jobs, higher incomes, enhanced inclusivity, better job quality, and less pollution (International Labour Organization, 2015).

6.2 Policy Barriers to a Just Transition

To achieve the just transition, the International Labour Organization (2015) identifies a set of guidelines for governments to follow when creating policies to achieve a just transition. The first

guideline for governments in creating policy for a just transition is (International Labour Organization, 2015):

"***Provide stable policy signals*** based on social dialogue and a regulatory framework to enable sustainable enterprise development and decent work for all, social inclusion and the eradication of poverty in the transition to sustainable economies;" [*emphasis added*]

The comparative analysis between energy transition policies of Germany and the United States shows that Germany has met this first condition for just transition policies with through federal legislation mandating Germany's emission reduction targets, the coal phase-out, and corresponding structural support, but the United States has not. Further, the timelines included in the coal phase-out act sent clear signals to German coal companies on when coal would be phased out (Raitbaur, 2021). With defined climate reduction goals via the Klimaschutzplan 2050, the Coal Commission had clearly defined targets that served as a basis for their proposal on the phase-out of coal as these targets were explicitly defined in the commission's charter (BMWi, 2019). At the time that the coal commission was chartered these targets had been adopted by the government but had not yet been enshrined in law until the passing of the Bundes-Klimaschutzgesetz in 2019; however, within the German context there were consistent signals for the phase-out of coal and adherence to the emissions reduction targets, even if they were not yet legislation.

The emissions targets of the United States are currently only established by executive order; however, legislation is a more durable policy measure as it is not as easily overturned as executive orders following a presidential administration change (EIA, 2021c). In addition to the domestic targets set via executive order, the United States' wavering commitment with the Paris Agreement (i.e., joining the agreement, withdrawing from the agreement, then joining again) highlight a need for a credible strategy that is not easily reversed (Hultman & Gross, 2021). The emissions target established by Executive Order 14008 will stand as long as the current presidential administration is in office, but

without incorporating this goal into legislation it is vulnerable to being overturned by the next administration. Unexpected Democratic gains for the current administration in the 2022 United States midterm elections could set into motion changes that might be difficult to abandon, even with unfavorable outcome of the Presidential elections in 2024; however, Republican control of the Senate and House of Representatives could limit the ability of the Biden administration to advance climate legislation as the Republican energy and climate plans favor increased fossil fuel development (Newburger, 2022).

6.3 Policy Features to Overcome Just Transition Barriers in Appalachia

According to one analysis, the global energy transition that is underway will be characterized by governments playing a significantly active role in the energy transition policy, strategy, and energy markets (Bordoff & O'Sullivan, 2022). The reliance of governments on market forces to manage energy markets has made energy cheaper and more available; however, in order to meet the needs of the energy transition to deliver energy security as well as an aggressive timeline to eliminate carbon emissions government involvement is needed (Bordoff & O'Sullivan, 2022). Bordoff & O'Sullivan (2022) cite three reasons why government involvement is needed over private markets:

- Building infrastructure to ensure energy security is not incentivized,
- decarbonization is needed quickly and may require short term investments in fossil fuels that need to be retired before they can provide a return on investment,
- externalities associated with fossil fuels are not internalized in the cost of fuel so private markets do not realize the full cost of pollution.

Bordoff & O'Sullivan (2022) further argue that the success of the energy transition relies upon careful government intervention to manage the energy transition and correct for structural failures of the markets.

A commentary by Richels et al. (2022) concurs with Bordoff & O'Sullivan (2022) on the need for policy in the United States strategy to manage climate change and by default the energy transition. They go further to describe the need for "durability" of the climate strategy which they outline as: Setting ambitious and feasible goals, using legislation instead of executive orders, understanding among lawmaker's constituents' on the specific benefits of legislation, a mechanism for frequent progress review and adjustment of policy, and understanding that there will be winners and losers among constituents and some may be alienated as policies are deemed too aggressive or not aggressive enough based on one's personal values (Richels et al., 2022). As LNG exports increase, it is conceivable that the accompanying increase in profits could be used to counteract opposition to the energy transition and the phase-out of the coal industry (N. Ashford, personal communication, July 18, 2020).

Against the framework described by Richels et al. (2022), Germany's Energiewende policies contain many hallmarks of "durability". For example, the Bundes-Klimaschutzgesetz passed in 2019 is legislation that set emissions reduction targets based on the warming limits set in Paris Climate Agreement, an internationally recognized treaty. By linking the Bundes-Klimaschutzgesetz targets to the Paris Climate agreement, and setting gradually decreasing emissions limits across defined sectors, the government lends credibility to not only the emissions reduction targets, but the overall goal to achieve net zero emissions. Within the act, there is a mechanism for progress review (KSG § 12, para. 4), regular adjustment of reduction targets (§ 4, para. 1) as well as provisions to allow further emissions reductions to be required, but not made more less stringent (§ 3, para. 4). The act also contains measures for annual reporting (§ 5, para. 1) and other mechanisms for review and adjustment of emissions targets and managing non-compliance (§8, para. 1). A challenge to the law led to a ruling by German courts that the targets in the 2019 version of the act were insufficient because the act lacked emissions reduction targets after 2030 (Bundesverfassungsgericht, 2021). Following this ruling the act was updated in 2021 with stricter climate targets (Die Bundesregierung, 2021b). These features align with by Richels et al.

(2022) definition of durability, which is exemplified by the ability of the act to be updated and improved when facing a legal challenge.

In Germany and the United States, the Paris Agreement's goal of limiting warming to 2 degrees Celsius while attempting to keep the warming increase below 1.5 degrees Celsius has become the basis of climate policy (Rodgers et al., 2022). In particular, keeping warming below 1.5 degrees requires emissions to be drastically reduced immediately or the target will be missed (Intergovernmental Panel on Climate Change, 2022). The targets in the Paris Agreement, particularly the 2 degree warming limit, have been criticized as not being aggressive enough to avert the worst damage of climate change as climate science and understanding of the impact of emissions on warming becomes clearer (Maizland, 2021; Mulvaney, 2021; Plumer & Popovich, 2021). While the Paris Agreement serves as an international baseline agreement for global warming, any emissions limits set in legislation should be based on the latest climate science to prevent the risks associated with high levels of global warming and be revisited to ensure that emissions reduction targets are sufficient to protect against the impacts of climate change (Rodgers et al., 2022). In fact, even the optimistic effects of meeting a 1.5 degree Celsius global warming level have been criticized as being insufficient to protect the fundamental right to a healthy climate (Rodgers et al., 2022). Other metrics, such as the "Earth's Energy Imbalance", or how much energy is leaving the atmosphere into space vs. what is retained (von Schuckmann et al., 2020), can be used to set science based targets for atmospheric CO2 concentrations and track progress toward climate protection goals (Rodgers et al., 2022). Ultimately, science-based targets can improve climate outcomes, and enable courts to hear and decide climate cases to protect the fundamental rights of citizens (Rodgers et al., 2022).

6.4 Policy Proposals and Conclusion

This United States needs science-based mandatory emissions targets that are established by durable legislation. The current emissions targets of the United States fall short for improving the

employment outcome for coal industry workers in several ways when compared to Germany energy transition policies. Going forward, legislated solutions for managing the energy transition for workers will be important, as the result of West Virginia v. EPA and the invocation of the Major Questions Doctrine has limited the ability of agencies to regulate the process.

The emissions targets of the United States, established by executive order, lack many of the elements of durable climate and energy transition policy as defined by Richels et al. (2022). While the targets may be appropriately ambitious as they stand now (Gross, 2021), they lack legislative durability to ensure the targets are long lasting and can evolve with the understanding of climate science or the realities of emissions reduction progress in the United States and internationally. Germany's Bundes-Klimaschutzgesetz serves as a reasonable template for emissions reduction legislation that is durable, effective, and is designed to evolve and respond to the dynamics of the challenges of climate change. The United States must craft legislation that fits within its national political context, and the German Bundes-Klimaschutzgesetz provides a relevant contemporary example to build upon.

Second, even without a policy that manages the reduction and elimination of the coal industry, legislated policy to support workers through structural change that is occurring in Appalachian coal regions will improve employment outcomes for the region. This requires further action than just committing funds for regional investment. A similar process to the development of Germany's Strukturstärkungsgesetz, where a commission of industry, locals, researchers, and other stakeholders are brought together to develop policy proposals to manage the structural changes in coal regions could prove a successful model in developing robust policy to support Appalachian coal workers. A study of the phase-out of hard coal in Germany supports the approach of involving local stakeholders in developing the solutions for structural changes as this is critical to creating strategies that work for the region (Oei et al., 2020). Further, commissions need a well-defined scope that is focused on a particular

set of objectives (Agora Energiewende und Aurora Energy Research, 2019), and commissions should not be taxed with trying to accomplish too much to be appropriately thorough (Reitzenstein & Popp, 2019).

Finally, timing is a critical aspect of any measures that are passed to manage the energy transition and support coal workers. Germany's decades long phase-out of hard coal mining, although criticized for its cost and long history of subsidies, was successful for workers as no workers were displaced due to the slow nature of the decline (Oei et al., 2020). This is not to suggest that a just transition for coal workers requires decades of industrial subsidies, as Oei et al. (2020) conclude that a just transition in the hard coal phase-out in Germany could have been achieved in a faster and less expensive manner. Further, the longer the United States delays making significant GHG emission reductions, the faster reductions will need to be made in the future, which risks significant negative economic disruption (Harvey et al., 2021). The sooner that the United States develops legislated emissions targets and structural support for transitions in coal regions, the better the outcome is likely to be for workers and the climate.

This thesis argues that to achieve a just transition for coal workers in Appalachia in the energy transition, durable federally-legislated policy to set emissions reduction targets and to manage the structural transition of the Appalachian region are two critical elements. These are not the only policies needed to secure a just transition for workers as federal, state, and local policies are all elements of a complete policy system. The policy proposals represent only a portion of what is needed to fully address the energy transition, coal industry employment, and maintaining a healthy climate for future generations.

6.5 Opportunities for Further Research

The policy recommendations in this thesis are based on the comparison of policy frameworks between the United States and Germany and published data regarding employment, production, and consumption figures related to coal. Further opportunities exist to examine the impacts of policies at a

sub-country level and focus on specific regions and communities, the opportunities for the development of new industries, and the potential economic and employment impacts for those communities. Potential phase-out pathways for Appalachia could also be explored, including evaluating the opportunities to repurposing coal plants to contribute to a renewable energy infrastructure. This thesis primarily analyzed federal policies, thus creating opportunities for further analysis of state and local policies related to the energy transition and employment outcomes for coal workers. Finally, a full systems analysis of local community economies could be completed to identify opportunities for diversification and development of policies based in full understanding of the socio-economic and socio-technical systems that exist in coal communities.

References

Agora Energiewende. (2022). *Die Energiewende in Deutschland: Stand der Dinge 2021. Rückblick auf die wesentlichen Entwicklungen sowie Ausblick auf 2022.* (p. 72). Agora Energiewende. https://www.agora-energiewende.de/veroeffentlichungen/die-energiewende-in-deutschland-stand-der-dinge-2021/#:~:text=Die%20Treibhausgasemissionen%20steigen%202021%20auf,ab%202022%20j%C3%A4hrlich%2037%20Mio.

Agora Energiewende und Aurora Energy Research. (2019). *The German Coal Commission. A Roadmap for a Just Transition from Coal to Renewables*. 56. https://static.agora-energiewende.de/fileadmin/Projekte/2019/Kohlekommission_Ergebnisse/168_Kohlekommission_EN.pdf

Aiyar, S., & Dao, M. C. (2021). *The Effectiveness of Job-Retention Schemes: COVID-19 Evidence From the German States.* IMF Working Paper No. 2021/242. https://www.imf.org/en/Publications/WP/Issues/2021/10/01/The-Effectiveness-of-Job-Retention-Schemes-COVID-19-Evidence-From-the-German-States-474182

Appalachian Regional Commission. (n.d.-a). *About the Appalachian Region*. Appalachian Regional Commission. Retrieved July 13, 2022, from https://www.arc.gov/about-the-appalachian-region/

Appalachian Regional Commission. (n.d.-b). *ARC's History and Work in Appalachia*. Appalachian Regional Commission. Retrieved May 25, 2022, from https://www.arc.gov/arcs-history-and-work-in-appalachia/

Appalachian Regional Commission. (n.d.-c). *ARC's Investment Priorities for Appalachia*. Appalachian Regional Commission. Retrieved July 13, 2022, from https://www.arc.gov/investment-priorities/

Appalachian Regional Commission. (n.d.-d). *ARC's Structure and Leadership*. Appalachian Regional Commission. Retrieved May 25, 2022, from https://www.arc.gov/arcs-structure-and-leadership/

Appalachian Regional Commission. (n.d.-e). *Building Appalachian Businesses*. Appalachian Regional Commission. Retrieved May 25, 2022, from https://www.arc.gov/investment-priority/building-appalachian-businesses/

Appalachian Regional Commission. (n.d.-f). *Population and Age in Appalachia*. Appalachian Regional Commission. Retrieved June 5, 2022, from https://www.arc.gov/appalachias-population/

Ashford, N. A., & Caldart, C. C. (2008). *Environmental Law, Policy, and Economics: Reclaiming the Environmental Agenda* (1st ed., Vol. 1, pp. xxxv–xxxv). MIT Press.

Ashford, N. A., & Renda, A. (2016). *Aligning Policies for Low-Carbon Systemic Innovation in Europe* [Technical Report]. Center for European Policy Studies. https://www.ceps.eu/ceps-publications/aligning-policies-low-carbon-systemic-innovation-europe/

Associated Press. (2021, June 10). *Coal plants in Maryland, Pennsylvania and Ohio to shut down*. AP NEWS. https://apnews.com/article/government-and-politics-maryland-pennsylvania-ohio-environment-and-nature-1358a422f958c7a68f597dc7c7142ddc

Backhaus, V. A., Vallata, S., Wibbeke, M., & Pasvantis, C. (2022, May 10). Landtagswahl im Erkelenzer Land: Uneinigkeit beim Kohleausstieg. *RP ONLINE*. https://rp-online.de/nrw/staedte/erkelenz/landtagswahl-im-kreis-heinsberg-uneinigkeit-beim-kohleausstieg_aid-69212019

Belkin, P., Ratner, M., & Welt, C. (2022). *Russia's Nord Stream 2 Natural Gas Pipeline to Germany Halted* (CRS Report No. IF11138). U.S. Congressional Research Service . https://crsreports.congress.gov/product/pdf/IF/IF11138

Bell, S. E., & York, R. (2010). Community Economic Identity: The Coal Industry and Ideology Construction in West Virginia. *Rural Sociology*, *75*(1), 111–143. https://doi.org/10.1111/j.1549-0831.2009.00004.x

Benoit, B. (2022, April 14). *Long-term U.S. strategic energy policy needed*. Grant Thornton. https://www.grantthornton.com/insights/articles/energy/2022/long-term-us-strategic-energy-policy-needed

Bordoff, J., & O'Sullivan, M. L. (2022, June 8). The New Energy Order. *Foreign Policy*. https://www.foreignaffairs.com/articles/energy/2022-06-07/markets-new-energy-order

Bowen, E., Chistiadi, Deskins, J., & Lego, B. (2021). *An Overview of Coal and the Economy in Appalachia*. Appalachian Regional Commission. https://www.arc.gov/report/an-overview-of-coal-and-the-economy-in-appalachia/

bp. (2021). *Bp Statistical Review of World Energy 2021*. https://www-bp-com.libproxy.mit.edu/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2021-full-report.pdf

Brauers, H., Herpich, P., & Oei, P.-Y. (2018). The Transformation of the German Coal Sector from 1950 to 2017: An Historical Overview. In C. von Hirschhausen, C. Gerbaulet, C. Kemfert, C. Lorenz, & P.-Y. Oei (Eds.), *Energiewende "Made in Germany": Low Carbon Electricity Sector Reform in the European Context* (pp. 45–78). Springer International Publishing. https://doi.org/10.1007/978-3-319-95126-3_3

Bundes-Klimaschutzgesetz [KSG] [Federal Climate Change Act], December 12, 2019, Bundesgesetzblatt, Teil I [BGBl. I] at 2513, last amended by Gesetz [G], August 18, 2021, [BGBl. I S] at 3905 (Ger.), http://www.gesetze-im-internet.de/ksg/BJNR251310019.html

Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit. (2016). *Climate Action Plan 2050 – Principles and goals of the German government's climate policy* (p. 92). https://www.bmuv.de/fileadmin/Daten_BMU/Pools/Broschueren/klimaschutzplan_2050_en_bf.pdf

Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz. (2019a, October 9). *Federal Climate Change Act—BMUV-Laws*. https://www.bmuv.de/GE838-1

Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz. (2019b, October 9). *Minister Schulze: Climate action becomes law!* [Press Release] https://www.bmuv.de/PM8743-1

Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz. (2021, August 18). *Frequently Asked Questions on Germany's coal phase-out*. Bundesministerium Für Umwelt, Naturschutz, Nukleare Sicherheit Und Verbraucherschutz. https://www.bmuv.de/en/topics/climate-

adaptation/climate-protection/national-climate-policy/translate-to-english-fragen-und-antworten-zum-kohleausstieg-in-deutschland

Bundesministerium für Wirtschaft und Energie. (2017). *Electricity 2030, Long-term trends—Tasks for the coming years*. https://www.bmwk.de/Redaktion/EN/Publikationen/electricity-2030-concluding-paper.pdf?__blob=publicationFile&v=7

Bundesministerium für Wirtschaft und Energie. (2019). *Commission on Growth, Structural Change and Employment—Final Report*. https://www.bmwk.de/Redaktion/EN/Publikationen/commission-on-growth-structural-change-and-employment.pdf?__blob=publicationFile&v=3

Bundesministerium für Wirtschaft und Energie. (2020). *Renewable energy sources in figures* (p. 88). https://www.bmwk.de/Redaktion/EN/Publikationen/Energie/renewable-energy-sources-in-figures.pdf?__blob=publicationFile&v=3

Bundesministerium für Wirtschaft und Klimaschutz. (2020, September 24). *Strukturstärkungsgesetz Kohleregionen*. https://www.bmwk.de/Redaktion/DE/Textsammlungen/Wirtschaft/strukturstaerkungsgesetz-kohleregionen.html

Bundesministerium für Wirtschaft und Klimaschutz. (2022a). *Coal*. https://www.bmwi.de/Redaktion/EN/Artikel/Energy/coal.html

Bundesministerium für Wirtschaft und Klimaschutz. (2022b). *Our energy transition for an energy supply that is secure, clean, and affordable*. https://www.bmwk.de/Redaktion/EN/Dossier/energy-transition.html

Bundesministerium für Wirtschaft und Klimaschutz. (2022c). *Renewable Energy*. https://www.bmwi.de/Redaktion/EN/Dossier/renewable-energy.html

Bundesministerium für Wirtschaft und Klimaschutz. (2022d, April 1). *A question of security*. https://www.bmwi-energiewende.de/EWD/Redaktion/EN/Newsletter/2022/03/Meldung/topthema.html

Bundesministerium für Wirtschaft und Klimaschutz. (2022e, April 1). *How can we get away from gas?* https://www.bmwi-energiewende.de/EWD/Redaktion/EN/Newsletter/2022/03/Meldung/direkt-finds-get-away-from-gas.html

Bundesministerium für Wirtschaft und Klimaschutz. (2022f). *Overview of the Easter Package*. BMWK. https://www.bmwk.de/Redaktion/EN/Downloads/Energy/0406_ueberblickspapier_osterpaket_en.pdf?__blob=publicationFile&v=5

Bundesministerium für Wirtschaft und Klimaschutz. (2022g). *Second energy security progress report*. https://www.bmwk.de/Redaktion/EN/Downloads/Energy/0501_zweiter-fortschrittsbericht_energiesicherheit_EN.pdf?__blob=publicationFile&v=2

Bundesministerium für Wirtschaft und Klimaschutz. (2022h, May 11). *An accelerated energy transition for greater energy security*. Energiewende Direkt. https://www.bmwi-energiewende.de/EWD/Redaktion/EN/Newsletter/2022/04/Meldung/news.html

Bundesnetzagentur. (2022). *Electricity Generation—Actual Generation*. Bundesnetzagentur. https://www.smard.de/en/downloadcenter/download-market-data#!?downloadAttributes=%7B%22selectedCategory%22:1,%22selectedSubCategory%22:1,%22selectedRegion%22:%22DE%22,%22from%22:1420066800000,%22to%22:1483311599999,%22selectedFileType%22:%22XLS%22%7D

Bundesverfassungsgericht. (2021). *Constitutional complaints against the Federal Climate Change Act partially successful* (Press Release No. 31/2021). [Press Release] https://www.bundesverfassungsgericht.de/SharedDocs/Pressemitteilungen/EN/2021/bvg21-031.html

BW Research Partnership. (2020). *2016-2019 Energy, Energy Efficiency, and Motor Vehicles Sector and Subsector Employment. Washington, D.C.* www.USEnergyJobs.org/research

Coglianese, J., Gerarden, T. D., & Stock, J. H. (2020). The Effects of Fuel Prices, Environmental Regulations, and Other Factors on U.S. Coal Production, 2008-2016. *The Energy Journal*, *41*(1). https://doi.org/10.5547/01956574.41.1.jcog

Connolly, K. (2022, July 8). Germany to reactivate coal power plants as Russia curbs gas flow. *The Guardian*. https://www.theguardian.com/world/2022/jul/08/germany-reactivate-coal-power-plants-russia-curbs-gas-flow

Cooban, A. (2022a, April 27). *Europe braces for gas crisis as Russia halts some supplies*. CNN. https://www.cnn.com/2022/04/27/energy/russia-europe-gas-supply/index.html

Cooban, A. (2022b, May 5). *Europe is planning to ditch Russia's oil. Will it go after its gas?* CNN. https://www.cnn.com/2022/05/05/energy/europe-russia-gas-sanctions/index.html

Council of the EU. (2022a, April 11). *EU adopts fifth round of sanctions against Russia over its military aggression against Ukraine* [Press Release]. https://www.consilium.europa.eu/en/press/press-releases/2022/04/08/eu-adopts-fifth-round-of-sanctions-against-russia-over-its-military-aggression-against-ukraine/

Council of the EU. (2022b, June 3). *Russia's aggression against Ukraine: EU adopts sixth package of sanctions* [Press Release]. https://www.consilium.europa.eu/en/press/press-releases/2022/06/03/russia-s-aggression-against-ukraine-eu-adopts-sixth-package-of-sanctions/

Crawley, E., Cameron, B., & Selva, D. (2016). *System Architecture: Strategy and Product Development for Complex Systems*. Pearson Higher Education, Inc.

Dahlbeck, E., Gärtner, S., Best, B., Kurwan, J., Wehnert, T., & Beutel, J. (2022). *Analysis of the historical structural change in the German hard coal mining Ruhr area* (p. 94). Umweltbundesamt. https://www.energiewende-global.com/fileadmin/user_upload/giz-website/Media_Library/Just_Transition/Analysis_of_the_historical__structural_change_in_the_German_hard_coal_mining_Ruhr_area.pdf

Davenport, C. (2015, March 20). McConnell Urges States to Help Thwart Obama's 'War on Coal.' *The New York Times*. https://www.nytimes.com/2015/03/20/us/politics/mitch-mcconnell-urges-states-to-help-thwart-obamas-war-on-coal.html

David-Wilp, S., & Kleine-Brockhoff, T. (2022, March 16). A New Germany. *Foreign Affairs* https://www.foreignaffairs.com/articles/germany/2022-03-01/new-germany

Davis, S. J., Liu, Z., Deng, Z., Zhu, B., Ke, P., Sun, T., Guo, R., Hong, C., Zheng, B., Wang, Y., Boucher, O., Gentine, P., & Ciais, P. (2022). Emissions rebound from the COVID-19 pandemic. *Nature Climate Change*, *12*(5), 412–414. https://doi.org/10.1038/s41558-022-01332-6

Denchak, M. (2021, February 19). *Paris Climate Agreement: Everything You Need to Know*. NRDC. https://www.nrdc.org/stories/paris-climate-agreement-everything-you-need-know

Deutsche Welle. (2007, January 31). *The Rise and Fall of Germany's Coal Mining Industry.* https://www.dw.com/en/the-rise-and-fall-of-germanys-coal-mining-industry/a-2331545

Deutsche Welle. (2018, October 24). *Thousands protest German coal phaseout.* https://www.dw.com/en/thousands-protest-german-coal-phaseout/a-46019342

Deutscher Gewerkschaftsbund. (n.d.). *German Codetermination*. Codetermination, Vocational Training, Minimum Wage. Retrieved May 21, 2022, from https://en.dgb.de/fields-of-work/german-codetermination

Die Bundesregierung. (2021a, April 21). *Infection Protection Act in the German Bundestag: Nationwide emergency brake passed*. https://www.bundesregierung.de/breg-en/news/nationwide-emergency-brake-1889136

Die Bundesregierung. (2021b, June 25). *Climate Change Act 2021: Intergenerational contract for the climate*. Retrieved May 18, 2022. https://www.bundesregierung.de/breg-de/themen/klimaschutz/climate-change-act-2021-1936846

Die Bundesregierung. (2022a). *Bundesregierung beschließt Kohleausstiegsgesetz*. Retrieved May 16, 2022. https://www.bundesregierung.de/breg-en/news/kohleausstiegsgesetz-1717014

Die Bundesregierung. (2022b). *Bundesregierung unterstützt Strukturwandel*. Retrieved May 16, 2022. https://www.bundesregierung.de/breg-en/news/kohleregionen-foerderung-1665150

Deutsche Welle. (2022, March 15). *Germany reconsiders coal phase out due to Russia's invasion of Ukraine* [Video]. Youtube. https://www.youtube.com/watch?v=JFzktV9dKQo

Eddy, M. (2022, July 19). Germany Is on Edge Waiting for Russia to Restart the Gas on Nord Stream 1. *The New York Times*. https://www.nytimes.com/2022/07/19/business/nordstream-shutdown.html

Edelberg, W., Sheiner, L., & Wessel, D. (Eds.). (2022). *Recession Remedies. Lessons Learned from the U.S. Economic Policy Response to Covid-19*. The Brookings Institution. https://www.brookings.edu/wp-content/uploads/2022/04/RR-Complete-Volume.pdf

Eule, S. (2020, October 28). *U.S. Energy Security Achieved its Best Level in 2019*. Global Energy Institute. https://www.globalenergyinstitute.org/us-energy-security-achieved-its-best-level-2019-0

Euracoal. (2020, February 16). *Germany*. Retrieved April 22, 2022. https://euracoal.eu/info/country-profiles/germany/

European Commission. (n.d.). *G7*. Retrieved June 26, 2022. https://ec.europa.eu/info/food-farming-fisheries/farming/international-cooperation/international-organisations/g7_en

European Commission, Directorate-General for Research and Innovation, Velte, D., Kuittinen, H. (2018). *Mission-oriented R&I policies: In-depth case studies : Energiewende (Germany) : Case Study Report.* Publications Office. https://data.europa.eu/doi/10.2777/835267

European Council. (2022). *Impact of Russia's invasion of Ukraine on the markets: EU response*. https://www.consilium.europa.eu/en/policies/eu-response-ukraine-invasion/impact-of-russia-s-invasion-of-ukraine-on-the-markets-eu-response/

Eurostat (2021). *Production of lignite in the EU - statistics*. Retrieved April 22, 2022. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Production_of_lignite_in_the_EU_-_statistics

Eurostat. (2022, March 4). *EU energy mix and import dependency*. Retrieved May 12, 2022. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=EU_energy_mix_and_import_dependency

Evans, B. (2022, June 24). *Germany considers seizing parts of a Russian gas pipeline to use in an LNG terminal as Europe reels from an energy crisis, report says*. Markets Insider. https://markets.businessinsider.com/news/commodities/europe-energy-crisis-germany-russia-gas-pipeline-nord-stream-2-2022-6

Everett, B. (2022, July 14). *Manchin's offer to Dems: Take a health care deal or try again later*. POLITICO. https://www.politico.com/news/2022/07/14/manchin-rejects-climate-tax-elements-of-party-line-dem-bill-00046018

Exec. Order No. 14,008, 86 FR 7619 (February 1, 2021)

Flitter, E. (2017, March 20). *Two Ohio coal-fired plants to close, deepening industry decline.* Reuters. https://www.reuters.com/article/us-usa-coal-closures-idUSKBN16R2D4

Fouhy, B. (2021, January 29). *"Fragile change": Biden signs executive orders but many lack force.* NBC News. https://www.nbcnews.com/politics/white-house/fragile-change-biden-inks-executive-orders-many-lack-force-n1256165

Fragkos, P., & Paroussos, L. (2018). Employment creation in EU related to renewables expansion. *Applied Energy*, *230*, 935–945. https://doi.org/10.1016/j.apenergy.2018.09.032

Friedman, T. L. (2022, May 17). Why Do We Swallow What Big Oil and the Green Movement Tell Us? *The New York Times*. https://www.nytimes.com/2022/05/17/opinion/russian-oil-green-energy.html

Furnaro, A., Herpich, P., Brauers, H., Oei, P.-Y., Kemfert, C., & Look, W. (2021). *German Just Transition: A Review of Public Policies to Assist German Coal Communities in Transition*. Resources for the Future. https://www.rff.org/publications/reports/german-just-transition-a-review-of-public-policies-to-assist-german-coal-communities-in-transition/

Gelles, D., & Friedman, L. (2022, March 19). There's a Messaging Battle Right Now Over America's Energy Future. *The New York Times*. https://www.nytimes.com/2022/03/19/climate/energy-transition-climate-change.html

Global Energy Monitor. (2022). *Summary Tables: Coal Plants by Region (Power Stations)*. https://globalenergymonitor.org/projects/global-coal-plant-tracker/summary-tables/

Graff, M., Carley, S., & Konisky, D. (2018). Stakeholder perceptions of the United States energy transition: Local-level dynamics and community responses to national politics and policy. *Energy Research & Social Science*, *43*. https://doi.org/10.1016/j.erss.2018.05.017

Gross, S. (2021, May 10). *Barriers to achieving US climate goals are more political than technical.* The Brookings Institution. https://www.brookings.edu/blog/planetpolicy/2021/05/10/barriers-to-achieving-us-climate-goals-are-more-political-than-technical/

Gruenspecht, H. (2019). *The U.S. Coal Sector. Recent and continuing challenges* (Paper 6). The Brookings Institution. https://www.brookings.edu/wp-content/uploads/2019/01/H.Gruenspecht_U.S.-Coal-Sector_Final_Jan_20191.pdf

Hake, J.-F., Fischer, W., Venghaus, S., & Weckenbrock, C. (2015). The German Energiewende – History and status quo. *Energy*, *92*, 532–546. https://doi.org/10.1016/j.energy.2015.04.027

Harvey, H., Aggarwal, S., Mahajan, M., & Deng, M. (2021). *The Costs of Delay*. Energy Innovation Policy & Technology LLC. https://energyinnovation.org/wp-content/uploads/2021/01/Cost_of_Delay.pdf

Hermann, H., Schumacher, K., & Förster, H. (2018). *Beschäftigungsentwicklung in der Braunkohleindustrie: Status quo und Projektion*. Umweltbundesamt. https://www.umweltbundesamt.de/publikationen/beschaeftigungsentwicklung-in-der

Hermwille, L., & Kiyar, D. (2022). Late and Expensive. In M. Jakob & J. C. Steckel (Eds.), *The Political Economy of Coal: Obstacles to Clean Energy Transitions* (1st ed.). Routledge. https://doi.org/10.4324/9781003044543

Hill, A. C. (2022, July 19). What Does the Supreme Court's Decision in West Virginia v. EPA Mean for U.S. Action on Climate? *Council on Foreign Relations*. https://www.cfr.org/blog/what-does-supreme-courts-decision-west-virginia-v-epa-mean-us-action-climate

Hospers, G.-J. (2004). Restructuring Europe's Rustbelt. *Intereconomics*, *39*(3), 147–156. https://doi.org/10.1007/BF02933582

Hultman, N., & Gross, S. (2021). *How the United States can return to credible climate leadership*. The Brookings Institution. https://www.brookings.edu/research/us-action-is-the-lynchpin-for-successful-international-climate-policy-in-2021/

Ifo Institute. (2022, May 9). *In Germany, Number of People Working from Home Barely Lower despite End of Remote-Working Obligation*. https://www.ifo.de/en/node/69501

Inclusive Economics. (2021). *High-Road Workforce Guide for City Climate Action*. https://www.usdn.org/uploads/cms/documents/workforce-guide_4.12.21_form.pdf

Industriegewerkschaft Bergbau, Chemie, und Energie. (2021). *Branchen*. Retrieved May 21, 2022. https://igbce.de/igbce/ueber-uns/branchen

Intergovernmental Panel on Climate Change. (2022). *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press. https://www.ipcc.ch/report/sixth-assessment-report-working-group-ii/

Intergovernmental Panel on Climate Change. (2022). *The evidence is clear: The time for action is now. We can halve emissions by 2030* [Press Release]. https://www.ipcc.ch/2022/04/04/ipcc-ar6-wgiii-pressrelease/

International Energy Agency. (2020a). *Germany 2020—Energy Policy Review* (p. 229). https://www.iea.org/reports/germany-2020

International Energy Agency. (2020b). *Power Systems in Transition*. IEA. Paris https://doi.org/10.1787/4ad57c0e-en

International Energy Agency. (2021a). *The importance of focusing on jobs and fairness in clean energy transitions*. IEA. https://www.iea.org/commentaries/the-importance-of-focusing-on-jobs-and-fairness-in-clean-energy-transitions

International Energy Agency. (2021b). *World Energy Outlook 2021* (p. 386). IEA. www.iea.org/weo

International Energy Agency. (2022a). *COVID-19. Exploring the impacts of the Covid-19 pandemic on global energy markets, energy resilience, and climate change.* IEA. https://www.iea.org/topics/covid-19

International Energy Agency. (2022b). *Electricity*. IEA. https://www.iea.org/reports/electricity-market-report-january-2022

International Energy Agency. (2022c). *Electricity Market Report—Jan 2022* (p. 118). IEA. https://www.iea.org/reports/electricity-market-report-january-2022

International Labour Office. (2019). *Skills for a greener future: A global view based on 32 country studies*. International Labour Organization. https://www.ilo.org/skills/pubs/WCMS_732214/lang--en/index.htm

International Labour Organization. (2015). *Guidelines for a just transition towards environmentally sustainable economies and scoieties for all*. https://www.ilo.org/wcmsp5/groups/public/---ed_emp/---emp_ent/documents/publication/wcms_432859.pdf

International Labour Organization. (2022). *Frequently Asked Questions on just transition*. http://www.ilo.org/global/topics/green-jobs/WCMS_824102/lang--en/index.htm

International Renewable Energy Agency & International Labour Organization. (2021). *Renewable Energy and Jobs—Annual Review 2021*. https://www.irena.org/publications/2021/Oct/Renewable-Energy-and-Jobs-Annual-Review-2021

Irfan, U., & Dhanesha, N. (2022, June 30). *The Supreme Court's EPA ruling isn't the only legal attack on the environment*. Vox. https://www.vox.com/23181832/supreme-court-epa-west-virginia-climate-regulation

Jacobs, D. (2012). The German Energiewende – History, Targets, Policies and Challenges. *Renewable Energy Law and Policy Review*, *3*(4), 223–233. http://www.jstor.org/stable/24324660

Jordans, F. (2022, July 7). *German lawmakers back plan to expand renewable energy*. AP News. https://apnews.com/article/russia-ukraine-germany-moscow-berlin-54f68326b9516d43dbbe2cde82c64dda

Kapur, S., & Sarlin, B. (2022, February 3). *Manchin says Build Back Better is "dead." Here's what he might resurrect.* NBC News. https://www.nbcnews.com/politics/congress/manchin-says-build-back-better-dead-here-s-what-he-n1288492

Krugman, P. (2009, November 13). Free to Lose. *The New York Times*. https://www.nytimes.com/2009/11/13/opinion/13krugman.html

Krümmelbein, J., Bens, O., Raab, T., & Anne Naeth, M. (2012). A history of lignite coal mining and reclamation practices in Lusatia, eastern Germany. *Canadian Journal of Soil Science*, *92*(1), 53–66. https://doi.org/10.4141/cjss2010-063

Lang, M., & Lang, A. (2015). The 2014 German Renewable Energy Sources Act revision – from feed-in tariffs to direct marketing to competitive bidding. *Journal of Energy & Natural Resources Law*, *33*(2), 131–146. https://doi.org/10.1080/02646811.2015.1022439

Leber, R. (2021, October 27). *Biden's Plan B for the climate crisis, explained*. Vox. https://www.vox.com/22738414/democrats-manchin-climate-reconciliation-plan-b

Lefebvre, B. (2022, February 23). *White House imposes sanctions on Nord Stream 2 pipeline company and CEO*. POLITICO. https://www.politico.com/news/2022/02/23/white-house-sanctions-nord-stream-2-pipeline-00010968

Linn, J., & McCormack, K. (2019). The roles of energy markets and environmental regulation in reducing coal-fired plant profits and electricity sector emissions. *The RAND Journal of Economics*, *50*(4), 733–767. https://doi.org/10.1111/1756-2171.12294

Liptak, A. (2022, June 30). Supreme Court Strips Federal Government of Crucial Tool to Control Pollution. *The New York Times*. https://www.nytimes.com/live/2022/06/30/us/supreme-court-epa

Lobao, L., Partridge, M., Hean, O., Kelly, P., & Sung-hun, C. (2020). *Energy transitions in coal regions: Is a just transition in US Appalachia possible? Final Report*. The Ohio State University. https://aede.osu.edu/sites/aede/files/publication_files/Energy%20transitions%20in%20coal%20regions-Is%20a%20just%20transition%20in%20US%20Appalachia%20possible.pdf

Mai, H. J. (2021, February 19). *U.S. Officially Rejoins Paris Agreement On Climate Change.* NPR. https://www.npr.org/2021/02/19/969387323/u-s-officially-rejoins-paris-agreement-on-climate-change

Maizland, L. (2021, November 17). *Global Climate Agreements: Successes and Failures*. Council on Foreign Relations. https://www.cfr.org/backgrounder/paris-global-climate-change-agreements

Marsh, S., & Chambers, M. (2022, February 22). *Germany freezes Nord Stream 2 gas project as Ukraine crisis deepens.* Reuters. https://www.reuters.com/business/energy/germanys-scholz-halts-nord-stream-2-certification-2022-02-22/

Meredith, S. (2022, June 20). *'The situation is serious': Germany plans to fire up coal plants as Russia throttles gas supplies*. CNBC. https://www.cnbc.com/2022/06/20/ukraine-war-germany-turns-to-coal-as-russia-throttles-gas-supplies.html

Mulvaney, K. (2021, October 26). The world is still falling short of meeting its climate goals. *National Geographic*. https://www.nationalgeographic.com/environment/article/the-world-is-still-falling-short-of-meeting-its-climate-goals

Newburger, E. (2022, June 3). *House Republicans unveil energy and climate plan that would boost fossil fuels, hydropower*. CNBC. https://www.cnbc.com/2022/06/03/house-republicans-energy-and-climate-plan-pushes-fossil-fuels-hydro.html

Oei, P.-Y., Brauers, H., & Herpich, P. (2020). Lessons from Germany's hard coal mining phase-out: Policies and transition from 1950 to 2018. *Climate Policy*, *20*(8), 963–979. https://doi.org/10.1080/14693062.2019.1688636

Oei, P.-Y., Brauers, H., Herpich, P., von Hirschhausen, C., Prahl, A., Wehnert, T., Bierwirth, A., Fischedick, M., Kurwan, J., Mersmann, F., Peters, A., Samadi, S., Umpfenbach, K., Lechtenböhmer, S., Nebel, A., Wagner, O., Lorenz, C., Teichmann, I., & Kemfert, C. (2019). *Phasing out coal in the German energy sector—Interdependencies, challenges and potential solutions*. German Institute for Economic Research, Wuppertal Institute, Ecologic Institute. https://www.ecologic.eu/sites/default/files/publication/2019/3537-kohlereader_englisch-final.pdf

Organisation for Economic Co-operation and Development. (n.d.). *About the OECD*. Retrieved June 26, 2022, from https://www.oecd.org/about/

Organisation for Economic Co-operation and Development. (2021). *Continuing Education and Training in Germany*. OECD Publishing, Paris. https://doi.org/10.1787/1f552468-en

Oschmann, V. (2010). A Success Story – The German Renewable Energy Act Turns Ten. *Renewable Energy Law and Policy Review*, *1*(1), 45–59. http://www.jstor.org/stable/24324586

Page, R. (2018). *Co-determination in Germany—A Beginner's Guide, Arbeitspapier, No. 313,*. Hans-Böckler-Stiftung. https://www.econstor.eu/bitstream/10419/209552/1/hbs-ap-313.pdf

Paul, F. C. (2018). Deep entanglements: History, space and (energy) struggle in the German Energiewende. *Geoforum*, *91*, 1–9. https://doi.org/10.1016/j.geoforum.2018.02.017

Paris Agreement to the United Nations Framework Convention on Climate Change, December 12, 2015, T.I.A.S. No 16-1104

Penn, I. (2022, July 5). Nuclear Power Gets New Push in U.S., Winning Converts. *The New York Times*. https://www.nytimes.com/2022/07/05/business/energy-environment/nuclear-energy-politics.html

Pew Research Center. (2016). *The State of American Jobs: How the shifting economic landscape is reshaping work and society and affecting the way people think about the skills and training they need to get ahead.* https://www.pewresearch.org/social-trends/2016/10/06/the-state-of-american-jobs/

Pew Research Center. (2022). *COVID-19 Pandemic Continues To Reshape Work in America*. https://www.pewresearch.org/social-trends/2022/02/16/covid-19-pandemic-continues-to-reshape-work-in-america/

Pflugmann, F., Ritzenhofen, I., Stockhausen, F., & Vahlenkamp, T. (2019). *Germany's energy transition: A country at a crossroads*. McKinsey & Company. https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/germanys-energy-transition-at-a-crossroads

Pike, L. (2021, March 31). *What should coal communities do when power plants shut down? Ask Germany.* Vox. https://www.vox.com/energy-and-environment/22349104/coal-climate-change-biden-infrastructure-plan-germany-just-transition

Pletka, D. (2022, June 2). The Republicans Could Win the U.S. Midterms. Here's What that Means for the World. *Foreign Policy*. https://foreignpolicy-com.libproxy.mit.edu/2022/06/02/gop-congress-midterms-foreign-policy-ukraine-taiwan/

Plumer, B., & Popovich, N. (2021, October 25). Yes, There Has Been Progress on Climate. No, It's Not Nearly Enough. *The New York Times*. https://www.nytimes.com/interactive/2021/10/25/climate/world-climate-pledges-cop26.html

Pollard, K., & Jacobsen, L. A. (2021). *The Appalachian Region: A Data Overview from the 2015-2019 American Community Survey Chartbook* (p. 181). Appalachian Regional Commission. https://www.arc.gov/report/the-appalachian-region-a-data-overview-from-the-2015-2019-american-community-survey/

Prinz, L., & Pegels, A. (2018). The role of labour power in sustainability transitions: Insights from comparative political economy on Germany's electricity transition. *Energy Research & Social Science*, *41*, 210–219. https://doi.org/10.1016/j.erss.2018.04.010

Prokop, A. (2014, June 6). *6 Democrats opposing action on climate change*. Vox. https://www.vox.com/2014/6/6/5780008/6-democrats-standing-in-the-way-of-action-on-climate-change

Stelzenmüller, C. (2022). *Putin's war and European energy security: A German perspective on decoupling from Russian fossil fuels*. The Brookings Institution. https://www.brookings.edu/testimonies/putins-war-and-european-energy-security-a-german-perspective-on-decoupling-from-russian-fossil-fuels/

Raitbaur, L. (2021). The New German Coal Laws: A Difficult Balancing Act. *Climate Law*, *11*(2), 176–194. https://doi.org/10.1163/18786561-11020003

Reed, S. (2022, June 29). Liquefied Natural Gas Comes to Europe's Rescue. But for How Long? *The New York Times*. https://www.nytimes.com/2022/06/29/business/liquefied-natural-gas-europe.html

Reitzenstein, A., & Popp, R. (2019). *The German Coal commissions—A Role Model for Transformative Change?* E3G. https://www.jstor.org/stable/resrep21748

Reitzenstein, A., Popp, R., Oei, P.-Y., Brauers, H., Stognief, N., Kemfert, C., Kurwan, J., & Wehnert, T. (2022). *Structural change in coal regions as a process of economic and social-ecological transition – Lessons learnt from structural change processes in Germany*. Umweltbundesamt. https://www.umweltbundesamt.de/publikationen/structural-change-in-coal-regions-as-a-process-of

Reuters. (2022, February 28). *Germany aims to get 100% of energy from renewable sources by 2035.* Reuters. https://www.reuters.com/business/sustainable-business/germany-aims-get-100-energy-renewable-sources-by-2035-2022-02-28/

Richardson, J., & Anderson, L. (2021). *Supporting the Nation's Coal Workers and Communities in a Changing Energy Landscape* (p. 12). Union of Concerned Scientists. https://www.ucsusa.org/resources/support-coal-workers

Richels, R., Santer, B., Jacoby, H., & Yohe, G. (2022, June 6). *A durable U.S. climate strategy … or a house of cards?* Yale Climate Connections. http://yaleclimateconnections.org/2022/06/a-durable-u-s-climate-strategy-or-a-house-of-cards/

Rodgers, A., Sancken, L., & Marlow, J. (2022). The Injustice of 1.5˚C–2˚C: The Need for a Scientifically Based Standard of Fundamental Rights Protection in Constitutional Climate Change Cases [Unpublished Manuscript]. *Virginia Environmental Law Journal*, *40*(2).

Ruppert, L. F., Trippi, M. H., & Slucher, E. r. (2014). Correlation chart of Pennsylvanian rocks in Alabama, Tennessee, Kentucky, Virginia, West Virginia, Ohio, Maryland, and Pennsylvania showing approximate position of coal beds, coal zones, and key stratigraphic units. In L. F. Ruppert & R. T. Ryder, *Coal and petroleum resources in the Appalachian basin; Distribution, geologic framework, and geochemical character*. U.S. Geological Survey. https://pubs.usgs.gov/pp/1708/d2/pdf/pp1708_d2.pdf

Russell, M. (2021). *The Nord Stream 2 pipeline* (Briefing PE 690.705; p. 12). European Parliamentary Research Service. https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/690705/EPRS_BRI(2021)690705_EN.pdf

Saha, D., & Liu, S. (2017, January 25). *Increased automation guarantees a bleak outlook for Trump's promises to coal miners*. The Brookings Institution. https://www.brookings.edu/blog/the-avenue/2017/01/25/automation-guarantees-a-bleak-outlook-for-trumps-promises-to-coal-miners/

Schattenberg, M. (2021). *Work from home has come to stay*. Deutsche Bank Research. https://www.dbresearch.com/PROD/RPS_EN-PROD/PROD0000000000515973/Work_from_home_has_come_to_stay.PDF?undefined&realload=m4myDWD1q0UjdG/qOMuZ~rf8fGsHbZexqPM/0QYo3WttoPJ7oN~p072vJwWg/OQa

Schonhardt, S. (2022, January 4). *Germany Lays a Path to Quitting Coal, But the U.S. May Not Follow*. Scientific American. https://www.scientificamerican.com/article/germany-lays-a-path-to-quitting-coal-but-the-u-s-may-not-follow/

Smith, S. (2017). *Just Transition. A Report for the OECD*. Just Transition Center. https://www.oecd.org/environment/cc/g20-climate/collapsecontents/Just-Transition-Centre-report-just-transition.pdf

Sozialdemokratische Partei Deutschlands, Bündnis 90/Die Grünen, & Freie Demokratische Partei. (2021). *Mehr Fortschritt Wagen—Budnist fur Freiheit, Gerechtigkeit und Nachhaltigkeit*. https://www.spd.de/fileadmin/Dokumente/Koalitionsvertrag/Koalitionsvertrag_2021-2025.pdf

Sprunt, B. (2021, November 15). *Here's what's included in the bipartisan infrastructure law.* NPR. https://www.npr.org/2021/06/24/1009923468/heres-whats-included-in-the-infrastructure-deal-that-biden-struck-with-senators

Statistik der Kohlenwirtschaft e.V. (2019a). Steinkohle: *Belegschaft (Arbeiter/Angestellte) von 1945 bis 2018* [Data set]. https://kohlenstatistik.de/downloads/steinkohle/

Statistik der Kohlenwirtschaft e.V. (2019b). Steinkohle: *Förderung von 1952 bis 2018* [Data set]. https://kohlenstatistik.de/downloads/steinkohle/

Statistik Der Kohlenwirtschaft e.V. (2021). Braunkohle: *Braunkohlenförderung* [Data set]. https://kohlenstatistik.de/downloads/braunkohle/

Statistik Der Kohlenwirtschaft e.V. (2022). Braunkohle: *Beschäftigte nach Revieren* [Data set]. https://kohlenstatistik.de/downloads/braunkohle/

Statistisches Bundesamt. (n.d.). *Earnings and earnings differences*. Statistisches Bundesamt. Retrieved April 22, 2022, from https://www.destatis.de/EN/Themes/Labour/Earnings/Earnings-Earnings-Differences/current-economic-activity.html

Statistisches Bundesamt. (2022a). *13211-0007: Registered unemployed, unemployment as a percentage of the civilian labour force, registered vacancies: Länder, years* [Data set]. https://www-genesis.destatis.de/genesis/online

Statistisches Bundesamt. (2022b, April 23). *62321-0001: Bruttoverdienste, Wochenarbeitszeit: Deutschland, Quartale, Wirtschaftszweige, Leistungsgruppen, Geschlecht* [Data set]. https://www-genesis-destatis-de.libproxy.mit.edu/genesis/online

Statistisches Bundesamt. (2022c, June 20). *Germany's population grew slightly in 2021*. Statistisches Bundesamt. Retrieved June 26, 2022. https://www.destatis.de/EN/Press/2022/06/PE22_251_12411.html

Statistisches Bundesamt. (2022d). *13231-0003: Unemployment rate: Germany, months, sex, age groups, original and adjusted data* [Data set]. Statistisches Bundesamt. https://www-genesis.destatis.de/genesis/online

Statistisches Bundesamt. (2022e). *12411-0010: Bevölkerung: Bundesländer, Stichtag* [Data set]. Statistisches Bundesamt. https://www-genesis.destatis.de/genesis/online

Tan, W. (2021, November 4). *What "transition"? Renewable energy is growing, but overall energy demand is growing faster.* CNBC. https://www.cnbc.com/2021/11/04/gap-between-renewable-energy-and-power-demand-oil-gas-coal.html

The White House. (n.d.). *President Biden's Bipartisan Infrastructure Law*. Retrieved May 24, 2022. https://www.whitehouse.gov/bipartisan-infrastructure-law/

The White House. (2022). *Bipartisan Infrastructure Law Rural Playbook: A roadmap for delivering opportunity and investments in rural America*. https://www.whitehouse.gov/wp-content/uploads/2022/04/BIL-Rural-Playbook-.pdf

Thrush, G. (2021, January 23). The Lure of Executive Orders: Easy to Implement, but Just as Easy to Cancel. *The New York Times*. https://www.nytimes.com/2021/01/22/us/politics/biden-executive-orders-trump.html

Tollefson, J. (2022). What the war in Ukraine means for energy, climate and food. *Nature*, *604*(7905), 232–233. https://doi.org/10.1038/d41586-022-00969-9

Umweltbundesamt. (2022, March 17). *Greenhouse gas emissions rose by 4.5 percent in 2021* [Press Release]. https://www.umweltbundesamt.de/en/press/pressinformation/greenhouse-gas-emissions-rose-45-percent-in-2021

Umweltbundesamt. (2022a). *Emission of greenhouse gases covered by the UN Framework Convention on Climate* [Data Set]. Retrieved May 20,2022. https://www.umweltbundesamt.de/en/data/environmental-indicators/indicator-greenhouse-gas-emissions#at-a-glance

Umweltbundesamt. (2022b, March 15). *Indicator: Greenhouse gas emissions*. Umweltbundesamt. Retrieved May 20, 2022. https://www.umweltbundesamt.de/en/data/environmental-indicators/indicator-greenhouse-gas-emissions

U.S. Energy Information Administration. (2011). *History of energy consumption in the United States, 1775–2009*. https://www.eia.gov/todayinenergy/detail.php?id=10

U.S. Energy Information Administration. (2021a, July 14). *In 2020, U.S. coal production fell to its lowest level since 1965*. https://www.eia.gov/todayinenergy/detail.php?id=48696

U.S. Energy Information Administration. (2021b). *Annual Coal Report 2020: Table ES1. Coal Production, 1949-2020*. Energy Information Administration. https://www.eia.gov/coal/annual/

U.S. Energy Information Administration. (2021c, October 4). *Annual Coal Reports—U.S. Energy Information Administration (EIA)*. Coal. https://www.eia.gov/coal/annual/index.php

U.S. Energy Information Administration. (2021d, October 9). *Where our coal comes from—U.S. Energy Information Administration (EIA)*. https://www.eia.gov/energyexplained/coal/where-our-coal-comes-from.php

U.S. Energy Information Administration. (2021e, October 19). *Coal explained—U.S. Energy Information Administration (EIA)*. https://www.eia.gov/energyexplained/coal/

U.S. Energy Information Administration. (2022a). *Annual Energy Outlook 2022 with projections to 2050. Narrative.* https://www.eia.gov/outlooks/aeo/pdf/AEO2022_Narrative.pdf

U.S. Energy Information Administration. (2022b). *Coal Data Browser: Aggregate coal mine average employees*. https://www.eia.gov/coal/data/browser/

U.S. Energy Information Administration. (2022c). *Coal Data Browser: Aggregate coal mine production for total*. https://www.eia.gov/coal/data/browser/

U.S. Energy Information Administration. (2022d, January 11). *Coal will account for 85% of U.S. electric generating capacity retirements in 2022*. https://www.eia.gov/todayinenergy/detail.php?id=50838

U.S. Energy Information Administration. (2022e). *Annual Energy Outlook 2022: Table 8. Electricity Supply, Disposition, Prices, and Emissions*. https://www.eia.gov/outlooks/aeo/tables_ref.php

U.S. Energy Information Administration. (2022f). *Electric Power Annual 2020: Table 3.2.A. Net Generation by Energy Source: Electric Utilities, 2010—2020*. https://www.eia.gov/electricity/annual/pdf/epa.pdf

U.S. Energy Information Administration. (2022g). *Electric Power Annual 2020: Table 3.3.A. Net Generation by Energy Source: Independent Power Producers, 2010—2020*. https://www.eia.gov/electricity/annual/pdf/epa.pdf

U.S. Energy Information Administration. (2022h). *April 2022 Monthly Energy Review: Table 1.3 Primary Energy Consumption by Source*. https://www.eia.gov/totalenergy/data/monthly/

U.S. Energy Information Administration. (2022i, June 7). *Coal*. Short-Term Energy Outlook - U.S. Energy Information Administration (EIA). https://www.eia.gov/outlooks/steo/report/coal.php

U.S. Energy Information Administration. (2022j, June 7). *U.S. liquefied natural gas exports to Europe increased during the first 4 months of 2022*. Today in Energy. https://www.eia.gov/todayinenergy/detail.php?id=52659

United States Census Bureau. (2022). *U.S. and Population Clock*. U.S. Department of Commerce. Retrieved July 1, 2022. https://www.census.gov/popclock/

United States Department of State. (2021). *The United States' Nationally Determined Contribution: Reducing Greenhouse Gases in the United States: A 2030 Emissions Target*. https://unfccc.int/NDCREG

United States Department of State & United States Executive Office of the President. (2021). *The Long-Term Strategy of the United States, Pathways to Net-Zero Greenhouse Gas Emissions by 2050* (p. 65). https://www.whitehouse.gov/wp-content/uploads/2021/10/US-Long-Term-Strategy.pdf

U.S. Bureau of Labor Statistics. (2022). *LNS14000000: (Seas) Unemployment Rate* [Data set]. United States Department of Labor. https://data.bls.gov/cgi-bin/surveymost?bls

U.S. Department of Energy. (2021). *United States Energy & Employment Report 2021* (DOE/SP-0001) [Data set]. Retrieved June 5, 2022. energy.gov/USEER

U.S. Environmental Protection Agency. (2011). *Fact Sheet: Mercury and Air Toxics Standards for Power Plants* [Fact sheet]. https://www.epa.gov/sites/default/files/2015-11/documents/20111221matssummaryfs.pdf

U.S. Environmental Protection Agency. (2017a, January 19). *FACT SHEET: Overview of the Clean Power Plan* [Fact Sheet]. https://19january2017snapshot.epa.gov/cleanpowerplan/fact-sheet-overview-clean-power-plan

U.S. Environmental Protection Agency. (2017b, October 4). *Electric Utility Generating Units: Repealing the Clean Power Plan*. https://www.epa.gov/stationary-sources-air-pollution/electric-utility-generating-units-repealing-clean-power-plan

U.S. Environmental Protection Agency. (2019). *Fact Sheet: The Affordable Clean Energy Rule*. 2.

U.S. Environmental Protection Agency. (2021, February 12). *Status of Affordable Clean Energy Rule and Clean Power Plan*. https://www.epa.gov/sites/default/files/2021-02/documents/ace_letter_021121.doc_signed.pdf

U.S. Environmental Protection Agency. (2022, February 1). *EPA Reaffirms Scientific, Economic, and Legal Underpinnings of Limits on Toxic Emissions* [Press Release]. https://www.epa.gov/newsreleases/epa-reaffirms-scientific-economic-and-legal-underpinnings-limits-toxic-emissions

von Schuckmann, K., Cheng, L., Palmer, M. D., Hansen, J., Tassone, C., Aich, V., Adusumilli, S., Beltrami, H., Boyer, T., Cuesta-Valero, F. J., Desbruyères, D., Domingues, C., García-García, A., Gentine, P., Gilson, J., Gorfer, M., Haimberger, L., Ishii, M., Johnson, G. C., … Wijffels, S. E. (2020). Heat stored in the Earth system: Where does the energy go? *Earth System Science Data*, *12*(3), 2013–2041. https://doi.org/10.5194/essd-12-2013-2020

Wacket, M. (2021, March 30). *Germany's energy drive criticised over expense, risks.* Reuters. https://www.reuters.com/article/germany-energy-audit-idUSL8N2LS2RC

Weisman, J., & Friedman, L. (2021, December 20). Behind Manchin's Opposition, a Long History of Fighting Climate Measures. *The New York Times*. https://www.nytimes.com/2021/12/20/us/politics/manchin-climate-change-coal.html

Welt, C. (2022). *Russia's Invasion of Ukraine: Overview of U.S. Sanctions and Other Responses* (CRS Report No. IN11869;). U.S. Congressional Research Service. https://crsreports.congress.gov/product/pdf/IN/IN11869

Wigert, B. (2022, March 15). *The Future of Hybrid Work: 5 Key Questions Answered With Data*. Gallup. https://www.gallup.com/workplace/390632/future-hybrid-work-key-questions-answered-data.aspx

Wintour, P. (2022, June 2). 'We were all wrong': How Germany got hooked on Russian energy. *The Guardian*. https://www.theguardian.com/world/2022/jun/02/germany-dependence-russian-energy-gas-oil-nord-stream

Wood Mackenzie. (2022, July 7). *What A Republican Mid-Term Victory Could Mean For US Energy And Climate Policy*. Forbes. https://www.forbes.com/sites/woodmackenzie/2022/07/07/what-a-republican-mid-term-victory-could-mean-for-us-energy-and-climate-policy/

World Bank. (2022). *GDP (current US$)*. Retrieved July 14,2022. https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?most_recent_value_desc=true

Zakaria, R. (2022, April 25). *Russia-Ukraine crisis: Short-term risks for electric power, but accelerating energy transition*. IHS Markit. https://ihsmarkit.com/research-analysis/russiaukraine-crisis-shortterm-risks-for-electric-power.html

Zandi, M., & Yaros, B. (2021). *Macroeconomic Consequences of the Infrastructure Investment and Jobs Act & Build Back Better Framework*. Moody's Analytics. https://www.moodysanalytics.com/-/media/article/2021/macroeconomic-consequences-of-the-infrastructure-investment-and-jobs-act-and-build-back-better-framework.pdf

Zhou, L. (2022, July 27). *How Democrats plan to overhaul taxes, climate spending, and health care before the midterms*. Vox. https://www.vox.com/23281547/build-back-better-joe-manchin-inflation-reduction-act

Ziliak, J. (2010). *The Appalachian Regional Development Act and Economic Change* (DP2010-14) University of Kentucky Center for Poverty Research. https://uknowledge.uky.edu/ukcpr_papers/51/

Zipper, C. E., Adams, M. B., & Skousen, J. (2021). The Appalachian Coalfield in Historical Context. In C. E. Zipper & J. Skousen (Eds.), *Appalachia's Coal-Mined Landscapes* (pp. 1–26). Springer International Publishing. https://doi.org/10.1007/978-3-030-57780-3_1