The Challenges and Opportunities of Phasing out Nuclear and Fossil Fuel Reliance Simultaneously

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April, 2021

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Abstract

Our climate is changing dramatically and rapidly. The international Paris Agreement sets emission reduction targets for 2050 before the earth suffers from irreversible damages to the environment. A large portion of the world's emissions are produced through energy sources - nuclear energy serves as an extremely contentious issue. On one hand, nuclear power produces large amounts of energy with minimal carbon emissions. Some politicians even attempt to deem it as a 'clean energy source.' On the other hand, there exists no long term solution for nuclear waste and nuclear energy production poses the threat of large scale catastrophes like Chernobyl and Fukushima.

This paper sets out to delve into the challenges of phasing out fossil fuel reliance and nuclear energy simultaneously through a multiple case study analysis. Each case study currently or recently is in the process of decommissioning a nuclear plant. Not every case holds an anti-nuclear energy agenda.

The key findings from the research reveal that largely the shift away from nuclear energy at the same time that reliance on fossil fuels disappears is largely dictated by political will. The question remains as to what the best avenue towards a low carbon society looks like. Germany, the most aggressive anti-nuclear case, chose a path of complete nuclear decommissioning in a short period of time. While this decision led to large job losses in the energy sector and a spike in electricity prices, Germany managed to slowly decrease emissions over the years as well as build up a strong and diverse renewable-based energy system.

Other case studies, namely France, hold a strong pro-nuclear stance. As a result, France has maintained reliable energy, its renewable energy sector has suffered losses and the country still remains largely dependent on oil extraction.

While there is no single answer as to how to treat nuclear energy, nuclear is not a 'sustainable' source. In the short term, nuclear energy may be helpful in reaching emission reduction targets set for 2050, but the entire process of nuclear generation must undergo a bottom-up restructuring to address community needs. Once reduction targets are reached in 2050, all nuclear must be phased out to solidify energy dependence on renewable sources.

Introduction

This paper will highlight the ways in which global governments have dealt with the dual challenge of phasing out nuclear energy reliance while trying to reduce overall emissions and dependency on fossil fuels. Through observing case studies in California, Germany, France, and Sweden, this paper will aim to articulate the challenges and opportunities of phasing out nuclear energy and fossil fuel energy sources simultaneously. Some countries, like France have leaned into a pro nuclear stance in order to maintain a sense of energy dependence from the rest of the world while other countries like Germany have vowed to decommission all nuclear reactors by 2022. (Murray, 2020) The arguments in favor of nuclear often cite concerns about the intermittent nature of renewable energy. Opposition to nuclear energy often comes in the form of large political pressure in order to avoid the potential for large scale disasters like the Three Mile Island incident or the Fukushima disaster.

Important considerations when dealing with the overall role of nuclear in our energy portfolios include global climate agreements. These agreements, namely the Paris Agreement, set strict goals for total greenhouse gas (GHG) emission reductions by 2050. (UNFCCC, 2015) As a potentially dangerous form of energy production, nuclear reactors take long amounts of time and are extremely costly to build. On the other hand, nuclear power provides a steady stream of produced energy, allowing energy prices to remain relatively low when compared to renewables. (World Nuclear Association 'Nuclear Power Today,' 2020) Another important consideration moving forward is how reliance on nuclear energy will shape the emphasis towards renewable energy creation. Ultimately nuclear power is not sustainable to our planet as there are no solutions that exist for long term nuclear waste disposal. (National Research Council, 1999) If the transition towards a low carbon future involves any amount of dependence on nuclear energy, that reliance cannot overshadow the importance of rapidly building up renewable energy systems.

In the route towards a low carbon future, the U.S must forge its own path and learn from worldwide decisions towards nuclear energy. Currently, U.S nuclear policy is plagued by political gridlock - specifically waste allocation policies. The U.S must work to build trust and transparency around nuclear energy policy moving forward as political pressure can be one of the strongest tools against moving forward with nuclear generation. Any path forward towards phasing out both nuclear and fossil fuels needs to place a stronger emphasis on decreasing fossil fuel dependence first. This will create an easier pathway towards meeting the goals set in the Paris Agreement. While the emphasis on fossil fuels will expedite the U.S's ability to reach these goals, nuclear power generation in general needs to undergo drastic changes that will reduce reactor capacity as well as costs.

While divesting the U.S energy portfolio from both nuclear and fossil fuels will be a complicated and time consuming process, the renewable energy sector is ripe with opportunities in job creation and more stable long term energy access. The entire nuclear generation process is due for a drastic restructuring all the way from uranium extraction to waste allocation practices. If the U.S insists on using nuclear energy to wean itself onto renewables, that process must include drastically reducing financial costs as well as finding ways to create transparency with the general public to decrease political costs. It is time for the U.S to forge its way forward to a zero carbon future with strictly sustainable energy sources, it is just a matter of what that path will look like.

Background

The first self-sustaining nuclear chain reaction was achieved in 1942 at the University of Chicago - three years later the U.S became the first country to test an atomic bomb. In 1945, the U.S dropped two atomic bombs - one on Hiroshima and the next on Nagasaki to force Japan to ultimately surrender and end WWII. (U.S D.O.E, 2002) In 1946, Congress passed the Atomic Energy Act, creating the Atomic Energy Commission (AEC) to explore peaceful uses of atomic energy. After several years of testing, President Eisenhower signed the Atomic Energy Act of 1954 giving the civilian nuclear power program more access to nuclear technology. The first large scale nuclear power plant was built in Pennsylvania in 1957. (U.S.NRC, 2020) After years of criticism and backlash for failing to meet rigorous safety standards, the AEC was dissolved in the Energy Reorganization Act of 1974, officially becoming the Nuclear Regulatory Commission (NRC) in 1975. (U.S.NRC, 2020)

In 1977, Jimmy Carter signed the Department of Energy Organization Act, creating the Department of Energy (DOE). The Nuclear Waste Policy Act was enacted in 1983 to fund the development and research of permanent repositories for high level nuclear waste and spent nuclear fuel. (U.S D.O.E, 'NWPA,' 1982) By 1984, nuclear power generated about 14% of all electricity in the U.S. 1986 marks the year of the nuclear disaster at Chernobyl in the midst of the Cold War. In 1987, the NWPA was amended and congress directed funding to research the possibility of using Yucca mountain in Nevada as a permanent storage site for spent nuclear waste. By 1991, 22% of electricity in the U.S was generated by nuclear power. According to the U.S Energy Information Administration, the U.S has decreased its reliance on nuclear energy slightly and it represents the source of 19.7% of electricity generated today. (U.S Energy Information Administration, 2020)

Worldwide, 10.2% of electricity is nuclear, generated from 440 nuclear reactors. Countries with the highest proportion of nuclear energy to electricity are France (71%), Hungary (49%), Slovakia (54%), Ukraine (54%), Belgium (48%), Sweden (34%), Slovenia (37%), Bulgaria (38%), Finland (35%), and Czech Republic (35%). Other notable countries are Switzerland, South Korea, UK, US, Japan, Spain, Romania, and Russia (typically generating between 20%-30% of electricity with nuclear power). (World Nuclear Association 'Nuclear Power Today, 2020) Unlike during the Cold War, there is no longer a 'East and West' division between the use of nuclear power as the nuclear industry has essentially been globalized. (World Nuclear Association 'Nuclear Power Today, 2020)

Originally developed and utilized as a weapon, nuclear power has become a significant source of energy not only for the U.S, but the world. Currently there are 98 operating nuclear power plants in the U.S in 30 different states, with each state operated by different power companies. (World Nuclear Association 'Nuclear Power in the USA,' 2020) Germany currently has only six operating reactors with another 26 in the process of decommissioning. (IAEA 'Germany,' 2020) There are 56 operating nuclear reactors in France with two units in decommissioning. (IAEA 'France,' 2020) Sweden has seven operating nuclear reactors with plans for the newest six to enter long term operation. There are no plans to build new reactors in Sweden as the process of licensing a waste repository is ongoing. (IAEA 'Sweden,' 2020)

By the 1990s, a general consensus had developed that the best option for long-term nuclear waste disposal was 'geological-isolation.'(National Research Council, 1999) The consensus by organizations like Nuclear Energy Agency (NEA), as well as the International NEA, was tapered by the fact that there was still significant work and research to be done in the realm of nuclear waste disposal. Specifically around geological isolation, there were deep concerns around long term environmental and geological changes, how to create long term ‘waste packaging,’ and attempts to predict and direct long term human behavior around these dump sites. (National Research Council, 1999)

The Nuclear Waste Policy Act, written in 1982, promotes the research of and future use of deep geological burial sites for nuclear waste. It gave power to the DOE to operate the production and use of these sites. (U.S E.P.A, 1982) In 1987, the NWPA was amended to name Yucca Mountain in Nevada as the sole repository site up for consideration for the creation of a permanent geological site. (Eureka County, Nevada - Nuclear Waste Office, 2018) Since Yucca Mountain was designated as the site for nuclear waste storage, it has been plagued by political gridlock. Eventually, in 2010, the Obama administration hired a panel of experts to assess potential future decisions regarding the site before production was ultimately shut down. Since then, the site has faced legal and political barriers. As it now sits, Yucca Mountain is home to an empty five mile exploratory tunnel and no nuclear waste. (Eureka County, Nevada - Nuclear Waste Office, 2018) The U.S does not have any coherent future plans for creating a long term geological dump site after over 25 years of indecision and political gridlock.

In 2012, the Blue Ribbon Commission on America’s Nuclear Future issued a report to the secretary of energy urging necessary changes to eliminate gridlock on taking concrete steps towards tackling the mounting pile of nuclear waste. The report proposed several relevant changes to the NWPA that have largely tied the fate of nuclear waste disposal to the Yucca Mountain site through a top down approach without first reaching out to the community. Some of the proposed changes include instituting a new consent-based process of siting new repositories outside of just Yucca Mountain, broadening the reach of funds to increase safety of the jurisdictions through which nuclear waste is transported, establishing a new waste management system separate from the DOE dedicated entirely to nuclear waste disposal, ensuring access of the Nuclear Waste Fund (NWF) to the nuclear waste program, and increasing international engagement and cooperation towards long term waste disposal. (Office of Nuclear Energy, 2012)

Political gridlock - especially gridlock around nuclear power plants and tests sites - proves extremely costly, mostly to taxpayers. According to the Nuclear Energy Institute (NEI), government inaction on finding permanent solutions to nuclear waste disposal has cost taxpayers upwards of $6 billion, with an additional cost of $800 million each year. (Nuclear Energy Institute, 2021) While potential solutions are extremely costly and nuclear waste disposal is extremely difficult to garner public support for, the inaction that has defined nuclear waste policy in the U.S is likely becoming the more expensive option. The top down approach utilized to choose the Yucca Mountain site made it extremely difficult to move forward with substantial legislation. In the future, the government must utilize a bottom-up framework to obtain consent from communities and create a vital level of transparency.

Beyond technical (waste) and political issues with power plant construction and operation, the main threat to nuclear power is financial viability. Energy markets have undergone significant deregulation. In 2019, the NEA Committee for Technical and Economic Studies on Nuclear Energy Development and the Fuel Cycle (NDC) released a study on the impacts of electricity market deregulation on power plants. The study found that competitiveness for nuclear power in the energy market has decreased radically in the past two decades when compared to natural gas sources. Predicting electricity prices in a competitive market in the long run proves difficult, creating another disincentive to embarking on the long process of building new power plants. Increased safety costs to nuclear power plants further make them a riskier investment. Deregulation of the energy market takes away the emphasis of nuclear's low carbon energy potential while placing emphasis on strictly the profitability of power generation. (Nuclear Energy Agency, 2019)

The U.S entered global efforts to help reduce and combat the impacts of climate change in the 1990s. In 1992, then President George Bush signed the UN Framework Convention on Climate Change (UNFCCC). (Center for Climate and Energy Solutions, 2021) In 1997 the Kyoto Protocol was created to mobilize the UNFCCC in getting industrialized countries to meet their individual GHG reduction targets. (UNFCCC, 2012) In 2001, George Bush backed America out of the Protocol over concerns that it would harm the U.S economy, citing disagreements over the emission reduction goals of other countries. Since then, most U.S energy policy has emphasized market based mechanisms like cap and trade to lower emissions but the success of these programs is still largely debated. (Center for Climate and Energy Solutions, 2021) The Paris Agreement was established in 2015 as a legally binding climate change treaty with the goal of limiting global warming below 1.5-2 degrees celsius. This marked the first international binding agreement in the fight against climate change. (UNFCCC, 2015) The Trump administration backed out of the agreement in 2017, but the Biden administration recently reentered the deal that emphasizes emissions reduction. (Cho, 2021)

While there exists no perfect permanent solutions to the very serious issue of nuclear waste disposal, politicians are often attracted to nuclear energy for its efficiency and relative reliability compared to other energy sources. Politicians are also less likely to invest valuable time and energy into researching the vastly more complex and decentralized energy system required in order for our country to run on 100% renewable energy. As with the generation that preceded us, we are more than likely to pass the problem of nuclear waste down to our children, grandchildren and grandchildren's grandchildren. The political fears that motivate legislators into inaction on nuclear waste disposal also appear in the form of promoting nuclear as a source of sustainable energy, pointing out that when power plants close, emissions often rise with electricity prices because “solar and wind are not reliable substitutes to fossil fuels.” (Shellenberger, 2019) Political pressure remains one of the most powerful and historically impactful drivers for nuclear policy regulation.

Methods

To answer the question of what the challenges of simultaneously phasing out nuclear and fossil fuel energy are, I will conduct a multiple case study analysis. The four case studies included in this analysis all recently or are currently in the process of shutting down two unit power plants. Each case study - California, Germany, France, and Sweden - serves roughly the same geographic size, but each varies in population size.

The criteria used in evaluating and comparing these case studies will take into account the notable differences in population and seek to compare each study based on five different criteria: 1. Energy Portfolio 2. Energy Costs 3. Net Energy Jobs 4. Emissions 5. Transition Plan.

The first section will evaluate the overall energy portfolio of a region before and after power plant closures. This will allow a comparison and analysis of what resources became more heavily burdened in the aftermath of nuclear power generation whether that be on fossil fuels, renewable energy, or other sources. The main aim of this specific criteria serves to evaluate the multiple avenues away from reliance on nuclear energy and the resources required by different countries in that transition.

The energy cost section will delve into energy prices pre and post power plant closures. Opponents of denuclearization often cite increased energy costs as a reason for keeping power plants in operation. This section will evaluate the validity of this claim in different countries. It will also provide insight into the true price of the implementation of renewable and alternative energy sources and the preconditions to either keeping energy prices low or suffering from price increases.

The net energy jobs section will explore energy jobs pre and post plant closures. Proponents of renewable energy emphasize the long run creation of energy jobs while opponents fear the short term and immediate loss of jobs through plant closures. This section will evaluate the overall net increase or decrease in energy jobs over time to obtain a clearer picture of how long it takes energy jobs to rebound after power plant closures and the conditions that best facilitate energy job growth.

The emissions section will observe overall emissions before and after power plant closures. Power plants do not compose a prominent percentage of global GHG emissions and are highly effective energy sources. Proponents of power plants emphasize that transitioning away from nuclear power will actually harm emission reduction goals by demanding an increase on fossil fuel reliance in the short term if renewable energy sources cannot fill the energy gap left in the absence of nuclear power. This section will evaluate how true these assertions are - if true in some case studies but not others, the research will delve into what factors facilitate the most seamless transition away from nuclear power.

Finally, the transition plan section will evaluate each case study's government transition plan away from nuclear power (if such exists). Factors in this section will include the length of time under which goals are set, major world events that influence decision making, and overall governmental structures that govern each case study. This section will evaluate the reality of nuclear transition goals and their feasibility in a given time period - this section will also rely on the politics of the given country and delve into opposing sides of the argument.

The data used in this research will come from a mix of primary and secondary sources. For the quantitative aspects of the case studies - including energy portfolio, energy costs, jobs, and emissions - my research will come from government websites and documents tracking the country data. The qualitative aspects of my research - mainly the politics and planning of transition plans - will come from a wider range of sources including newspaper articles, peer reviewed sources, and in some cases specific pieces of legislation. This will help me to combine the quantitative data with actual government action to evaluate whether or not the two line up. Further, the combination of this qualitative and quantitative data will allow me to provide policy recommendations about the best way to move forward with nuclear energy as we head into an increasingly low carbon future.

This analysis will allow me to answer key questions: What role will nuclear energy play in the world's future? What does energy portfolio diversification look like, and how effective of a role can renewables play in meeting energy demands? How do decision makers view the role and function of nuclear energy? Where should we go from here?

Literature Review

Introduction

Heated debate accompanies the role that nuclear energy will play in a carbon neutral future for a wide range of reasons spanning from cost efficiency to environmental implications. Some argue that nuclear energy provides the only logical path forward in producing the amount of energy we need while lowering carbon emissions. Others argue that nuclear energy poses a threat to human life as we know it through increasing stockpiles of radioactive waste and its potential for large scale disasters. Finally, others simply make the argument that nuclear energy is *not* in fact the most cost effective tool we have in reimagining what energy will look like in the future.

The Case for Nuclear

In an article published in the Santa Maria Times, Representative Jordan Cunningham utilizes fear tactics to argue for diversification of policy and investment in energy sources for California. Cunningham represents the 35th district of the California State Assembly. This article serves as an example of a state representative attempting to use his platform to shift the conversation on nuclear energy in the state. He repeatedly cites a ‘mad max’ type future for California if the current trajectory of energy policy goes unaltered. (Cunningham, 2020) His argument aims mainly at challenging the decision to shut down the Diablo Canyon power plant by 2025, inciting the fear of rolling blackouts and the notion of short sighted political motivations.

In a New York Times article, Michael Shellenberger argues against the decision to close the Diablo Canyon power plant. Shellenberger is the founder of an environmental research and policy organization called Environmental Progress, and according to his organization, the plan to close Diablo Canyon would only require an investment that would cover ⅕ of the carbon free energy the nuclear site currently produces. Further, Shellenberger makes the argument that to make up for lost energy production, PG&E will be forced to actually rely more heavily on fossil fuels to continue to provide adequate service. Finally, he cites the concept that the only countries that have been able to transition to low carbon power production relied heavily on nuclear during the transition. (Shellenberger, 2020)

The World Nuclear Association is an advocate for the expansion of nuclear energy production and creates documents aimed at thoroughly explaining and promoting nuclear power activities throughout the world. The association is critical of production tax credits (PTCs) that prove unhelpful to the production of nuclear power plants in the US, also arguing that the only people footing the bill for this political incompetence are the ratepayers. The World Nuclear Association asserts that the recent closures of power plants across the US due to environmental restrictions has placed a strain on energy production efforts and argues that there is no way for the US to meet increasing energy demands with clean energy outside of nuclear power. The association also complains that the clean power plan heavily favors 'other' renewables like wind and solar, but not nuclear. They argue that aspects of the plan limit the economic viability of plants across the US - the closures of which would lead to a decrease in energy diversification, decreased production, and price volatility. (World Nuclear Association 'Nuclear Power in the USA,' 2020)

Some countries, like France, have doubled down on nuclear power reliance. Emmanuel Macron is a huge proponent of nuclear power for France's future, quoted in 2020 saying "our energy and ecological future depends on nuclear power; our economic and industrial future depends on nuclear power; and France's strategic future depends on nuclear power.” (World Nuclear News ‘Macron,’ 2020) France is the world’s largest exporter of electricity, largely due to the low cost of production thanks to nuclear power. Macron believes that nuclear energy production facilitates Frances’ autonomy and keeps energy costs low. On September 3, 2020, France committed 500 million Euro ($606 million USD) to the nuclear sector to combat challenges faced by the pandemic. (World Nuclear News ‘Macron,’ 2020)

The Case Against Nuclear

A California Globe article delves into what it would mean if AB2898 - California Renewables Portfolio Standard Program - passed into law. The bill aims to redefine nuclear energy as a renewable energy source. The article quotes experts on both sides of the bill - proponents of AB2898 argue mainly that California cannot transition to a carbon neutral future without the assistance of nuclear energy. Opponents of the bill cite the plethora of renewable energy options now available in California, claiming it is not only safer but a cheaper energy alternative. (Symon, 2020) Proponents of nuclear energy often use an economic frame to compare nuclear with individual renewables, easily skewing the way that people can comprehend what a future may look like with a diversified renewable energy portfolio.

Germany has a long history of anti-nuclear sentiment dating back to the 1970s. Numerous rallies and protests raged against nuclear power in the 1970s, partly in response to international accidents like the Three Mile Island incident in the U.S in 1979. These anti nuclear movements were partly responsible for creating the Green Party in Germany in 1980. Protests continued well throughout the 80s after the Chernobyl disaster and into the 90s against nuclear waste storage facilities. (Appunn, 2014) After some back and forth political disagreements, in 2011 Germany decided to phase out nuclear power completely. In 2015, an opinion poll showed that 81% of the German population favored the nuclear phase out, especially young people. (Appunn, 2014)

Nuclear Waste

An article written by Helen Gordon takes us deep into the world's only long term nuclear waste disposal site, explaining the dangers and realities of different levels of nuclear waste, how long waste remains dangerous to humans, and the biology behind radiation poisoning. The author highlights the dangers and burdens being placed on new generations as no current nuclear waste storage facility could possibly safely store the waste for the duration needed to protect human life. This article touches on arguments and critiques of how governments enact policy to create long term waste repositories, mainly citing their inability to convince local residents of the validity and safety of their plans. The director of nuclear waste and material regulation at STUK (the Finnish Radiation and Nuclear Safety Authority) is quoted directly in his critique of the continued development of interim storage units. He also addresses concerns about the longevity of the spent fuel pods, arguing that the first 1,000 (out of 100,000) years are the most dangerous, but also the easiest to calculate and predict. The senior vice president of development of the Onkalo site describes how the years of trust and transparency built around nuclear reactor sites in Finland made this repository feasible. (Gordon, 2017)

Decommissioning Process

A report by Southern California Edison (SCE), the owner of the San Onofre Nuclear Generating Station (SONGS), aims to create transparency with the public about what 'decommissioning' means in terms of shutting down the plant. SCE executives worked closely with the California Coastal Commission on the unanimous decision to shut down the plant, focussing on generating jobs and ensuring the safety of the surrounding communities in the process. SCE aims to work with the public and remain transparent about daily radiation levels and operations on the site as they wait for the federal government to make a long term nuclear waste repository available. SCE claims the dismantlement of the plant will create around 800 jobs in the approximately ten years it will take to finish - and they promise to take those jobs only from the San Diego region. (Southern California Edison, 2019) This document is an important step in gaining public support for the decommissioning of this plant and facing barriers (like public opinion) in the transition away from nuclear power.

SB1090, written and enacted in 2018, was created in response to a request for funds from PG&E to decommission the Diablo Canyon power plant. The bill specifies an employee retention program and also mandates no increase in emissions during the decommissioning process. (Bill Text - SB-1090 Diablo Canyon Nuclear Powerplant., 2018) This document serves as an example of a utility company responding to the economic incentives created by the federal government to deregulate nuclear power plants. The main focus of the bill aims at minimizing impact to local communities in terms of electricity production, decreasing GHG emissions while producing enough electricity, and keeping power plant workers employed on site. This bill mainly comes in response to the failures of the San Onofre site closure where employee retention was not emphasized, electricity production fell through the cracks, and the local communities were not properly prepared or informed.

Is Nuclear Energy "Renewable"?

Defining the word 'renewable' has proven to be a contentious and divisive issue in regards to where nuclear energy stands for the future of energy production. The Natural Resources Defense Council (NRDC) defines renewable energy as energy that "comes from natural sources or processes that are constantly replenished." (Shinn, 2018) The debate comes in when the terms 'renewable energy' and 'clean energy' become interchangeable. The Department of Energy likes to make the argument that nuclear energy is both clean and sustainable for three reasons: nuclear energy protects air quality, nuclear energy's land footprint is small, and nuclear energy produces minimal waste. (Office of Nuclear Energy, 2020) The debate boils down to framing and terminology - the DOE would like you to focus on the facts that nuclear is efficient and clean and does not produce GHGs - unfortunately this does not make nuclear energy renewable and the framing minimizes the harm that nuclear waste causes to our environment.

AB2898, introduced by Jordan Cunningham (Representative of 35th District in California State Assembly) in the 2019-2020 cycle aimed to redefine nuclear energy as 'renewable.' While this bill failed to pass, the language used in the bill is emblematic of familiar reframing tactics. Most of the bill ties energy production to their economic outcomes. If passed, it would have required energy companies to supply information about energy sources as a percentage of annual sales. (Cunningham, 2020) While a law similar to this already exists, Rep. Jordan Cunningham utilizes a purely economic lens throughout the rest of the bill, as opposed to coming up with creative energy solutions that when put together can be even more economically efficient than nuclear. Pitting each individual energy source against another creates a sense that nuclear energy is the only answer, and that is exactly what this bill aims to do.

Environmental Justice

The nuclear energy industry is notorious for contributing to and exacerbating the impacts of environmental racism. Nuclear energy production has a long history of only offering the most dangerous jobs at power plants to people of color (after allowing white people to fill the administrative positions), mining uranium close to communities of color, not distributing the wealth to the communities that bear the brunt of the burden of uranium extraction, locating reactors more often in poor communities and even more often in communities of color, pushing for indigenous communities to be considered as repository sites for nuclear waste, and more. (Jantz, 2018)

The NRC has done an inadequate job of addressing environmental racism within the sector of nuclear energy, opting to pursue procedural changes over substantive ones. (Jantz, 2018) The environmental justice angle when considering the future role of nuclear energy is crucial because history has shown that communities of color share an unequal burden of the negative impacts of extraction, production, and storage of nuclear materials - if we want to consider a legitimate future with nuclear energy playing a role, we must not repeat the abhorrent trends in our past. Especially when the dangers and impacts of nuclear energy production can be so hard to demonstrate, it is important to acknowledge the negative health and environmental impacts and the very real people suffering the consequences.

Challenges of Net Zero Emissions Without Nuclear

In a study conducted by the National Institute for Environmental Studies, researchers laid out two potential plans into a low carbon future: one including the use of nuclear power and one without it. The findings indicated that in a future with nuclear energy, we would need to increase the world's dependence on nuclear power to 31% of energy production. This pathway (set on a 45 year timeline) would cost about $55 trillion. (Kainuma et al.) By contrast, the plan excluding the use of nuclear energy would cost an estimated $58 trillion. The study found that the main concerns with transitioning away from nuclear largely involved meeting the short run energy demand. The study highlights several ways to reduce energy demand, including "dematerialization, structural changes in the industrial sector, and the development of low-carbon cities." (Kainuma et al., 2013) The study also indicated that the biggest obstacle towards a future without nuclear energy is the need for significant investment in low carbon technologies.

The German government has faced backlash for its decision to phase out nuclear energy in 2011. Immediately following several power plant closures, Germany was forced to lean on lignite, coal, and gas to fill in the gaps left by nuclear. On top of that, since renewable energy like wind and solar is intermittent, there was an increased reliance on energy imports from Denmark, France, and the Czech Republic when energy was not available. (Ritchie & Roser 'GHG Emissions,' 2020) In making the decision to close power plants after the Fukushima disaster, the German government did not rely on using cost-benefit analysis. Instead they utilized command and control policies to avert potential future disasters without having to put a price tag on the lives of German citizens. A Berkeley study utilized cost-benefit analysis to examine Germany's decision (that 81% of the population still supports). The study estimated that the benefit of avoiding potential future accidents came to $200 million while the costs due to increased energy production costs, pollution, and increased mortality rates added up to $12 billion per year. (Jarvis et al., 2019)

Regulatory Changes - International Reactions to Disaster

The nuclear energy industry has undergone a slew of policy changes and increased regulations in the wake of events like 9/11 and Fukushima. For example, immediately following 9/11, the U.S Nuclear Regulatory Commission (USNRC) "issued Orders to nuclear power reactors, decommissioning reactors, gaseous diffusion plants, the uranium conversion facility, fuel fabrication facilities, and panoramic irradiator license requiring them to implement enhanced security measures designed to protect against an increased threat." (U.S.NRC 'NRC 9/11,' 2020)

The industry now carries a heavier load of safety measures and expenditures that caused the production of nuclear energy to grow in costs over recent years. In 2017, one of world's largest providers of nuclear technology, Westinghouse, filed for bankruptcy. Westinghouse cited increased safety regulations as taking a toll on their finances, particularly post-9/11 policies like the requirement for an AP1000 power plant to be able to withstand an aircraft collision. (Pearce, 2017)

Fukushima also created drastic global repercussions on nuclear power production. Immediately following the incident, Japan shut down all 48 of its nuclear power plants for safety checks and today only five are back online. On top of this, the cost of the disaster was placed at $180 billion and the plant operator - TEPCO - has no way of paying. (Pearce, 2017) Germany had one of the strongest reactions to Fukushima other than Japan, and did a complete 180 on its energy policy, immediately shutting down eight of its 17 power plants in 2011 with plans to shut down the remaining nine by 2022. (Appunn, 2021)

Not everyone has been as deterred as Germany from nuclear power after the Fukushima disaster. Following the incident, France imposed increased regulations in 2015 as well as a goal to reduce energy reliance on nuclear to 50% by 2025, but later pushed that date back to 2035, citing challenges meeting energy demands. Finally, in late 2020, France recommitted to its nuclear energy dependence and began heavily investing in the nuclear energy sector in order to maintain its international energy ‘independence.’ (World Nuclear News ‘Macron,’ 2020)

Data Findings/ Analysis

In each case study, governments responded differently to impending global pressures to reduce emissions as well as to domestic concerns over the safety of nuclear energy production. These two pressures created a scenario prompting countries to both phase out reliance on nuclear energy (a large power source in many countries), and simultaneously eliminate usage of heavy emitting fossil fuels. This double blow places an even greater emphasis on the need for renewable sources of energy production.

California chose a comparatively slower nuclear phase out when contrasted to a more extreme example we will see in Germany. This slower transition allowed for a steady increase in energy jobs as well as a slow decrease in emissions, contrary to fears of increased fossil fuel reliance replacing the gaps left by nuclear decommissioning. The slow transition still facilitated a relative increase in energy prices for Californians as renewable energy infrastructure remains in the process upscaling.

Out of all the case studies, Germany took the most extreme command-and-control route when it came to decommissioning nuclear power. This was largely in response to the Fukushima disaster in 2011. Germany's decision showed extremely successful outcomes in shifting its energy reliance to renewable energy sources, now serving as over 44% of its total energy production. The main issues with Germany's drastic steps include steady increases in energy costs to the German population as well as heavy job and revenue losses in the energy industry.

Similar to other nuclear-reliant countries, France responded to the Fukushima disaster with plans to phase out nuclear energy. After the election of Emmanuel Macron in 2017, France firmly rededicated itself towards reliance on nuclear energy. France remains on target for emission reductions but its renewable energy sector is the weakest of all the case studies.

Renewable energy jobs suffered steady losses over the years and overall energy comes mostly from oil and nuclear. Energy costs rose slightly over the past 15 years but Macron stands firm that nuclear holds the key to France's independence.

Sweden still remains semi-reliant on nuclear energy, but it has the most diverse energy portfolio of all the case studies with a growing renewable energy industry. Hydropower is huge in Sweden (largely thanks to its coastal location), and energy jobs grow steadily over the years - mostly in renewable energy positions. Even with a decreased reliance on nuclear power, Sweden managed to lower emissions and keep energy prices from skyrocketing.

The data collected in this report covers four separate case studies of recent and proposed decommissioned power plants in the U.S, Germany, France, and Sweden. Each case study has data according to five different criteria: 1. Energy Portfolio 2. Energy Costs 3. Net Energy Jobs 4. Emissions 5. Transition Plan

In terms of renewable technologies, the strongest energy portfolios will be diverse. One of the main concerns over renewable energy surrounds the tendency for intermittent coverage (for example solar energy). A diverse portfolio helps to fill these gaps without relying on dirty fuels. Transitioning to a renewable based energy system can be expensive, so each case study will be evaluated on electricity price trends. Energy jobs comprise a hugely important criteria because ending reliance on fossil fuels means removing a plethora of jobs from local and global economies. While not all nuclear power plant jobs can translate into the clean energy sector, some countries handle this transition more smoothly than others.

The last two criteria - emissions and transition plan - both relate to the goals set by the Paris Agreement for carbon neutrality by the year 2050. Some countries favor nuclear for its low carbon energy production and aim to utilize its power to reach these international goals. The combination of these two criteria will shed light onto the efficacy of certain trajectories and plans as to achieving longer term emission reduction goals, and what these strategies might spell out for their futures.

	California	**Germany**	**France**	**Sweden**
Main Energy Source	Natural Gas (34.23% total)	Lignite (16.3% total)	Nuclear (36.79% total)	Nuclear (26.65% total)
Main Renewable Source	Solar (12.28% total)	Onshore Wind (18.7% total)	Hydropower (5.39% total)	Hydropower (26.14% total)
Energy Costs (USD)	$0.163/kWh (USD)	$0.39/kWh (USD)	$0.22/kWh (USD)	$0.22/kWh (USD)
Total Emissions (2000)	468.2 MMTC02	899.78 MMTC02	416.27 MMTC02	54.69 MMTC02
Total Emissions (2018)	425.3 MMTC02 (9.2% ↓)	755.36 MMTC02 (16.05% ↓)	331.73 MMTC02 (20.31% ↓)	41.77 MMTC02 (23.62% ↓)
Emissions Per Capita (2000)	13.6 MTC02	11.05 MTC02	7.05 MTC02	6.16 MTC02
Emissions Per Capita (2018)	10.7 MTC02 (21.3% ↓)	9.09 MTC02 (17.7% ↓)	5.10 MTC02 (27.7% ↓)	4.19 MTC02 (32% ↓)

Appunn, K., Haas, Y., & Wettengel, J. (2015, June 17). *Germany's energy consumption and power mix in charts*. Clean Energy Wire. https://www.cleanenergywire.org/factsheets/germanys-energy-consumption-and-power-mix-charts
California Air Resources Board. (2011). *California Greenhouse Gas Emissions Inventory: 2000—2009*. 32.
California Air Resources Board. (2018). *GHG Emission Inventory Graphs | California Air Resources Board*. https://ww2.arb.ca.gov/ghg-inventory-graphs
California ISO. (2021). *California ISO*. http://www.caiso.com/Pages/default.aspx
Eurostat. (2020). *Electricity prices for household consumers—Bi-annual data (from 2007 onwards)*. https://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_price_statistics
Huyge, L. (2020). *The energy sector in Sweden*. 14.
International Energy Agency. (2021). *France—Countries & Regions*. IEA. https://www.iea.org/countries/france
Swedish Energy Agency. (n.d.). *Priser på naturgas för hushållskunder 2007–*. Statistiska Centralbyrån. Retrieved February 12, 2021, from http://www.scb.se/hitta-statistik/statistik-efter-amne/energi/prisutvecklingen-inom-energiomradet/energipriser-pa-naturgas-och-el/pong/tabell-och-diagram/genomsnittspriser-per-halvar-2007/priser-pa-naturgas-for-hushallskunder-2007/
Vinnova. (2017). *The Energy Industry in Sweden continues to grow*. https://publector.org/publication/The-Energy-Industry-in-Sweden-continues-to-grow

U.S - California

Diablo Canyon power plant is the last operating nuclear power plant in California. In February 2018, PG&E announced it would not seek a California Public Utilities Commission (CPUC) hearing on the Diablo plant and would be withdrawing its federal license renewal application, setting an official decommission date for 2025. The two unit power plant is planned for shutdown in 2024 and 2025. (PG&E, 2018)

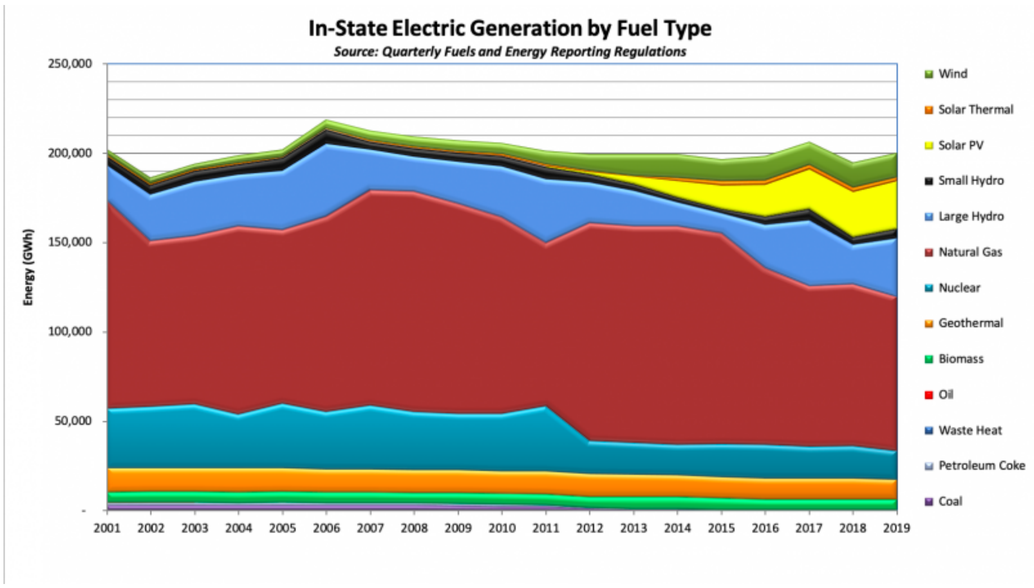
PG&E has stated its commitment to the surrounding community by holding public meetings and workshops to make a living document through the Diablo Canyon Decommissioning Engagement Panel (DCDEP). DCDEP uses these panels to observe potential economic opportunities and the potential for job creation throughout the decommissioning process while limiting the amount of demolition and harm to marine life. (World Nuclear News 'Diablo Canyon Panel,'2019)

Energy Portfolio:

Over the years California has gradually shifted its reliance away from non-renewable sources of energy, but still has much further to go. In 2014, renewable energy sources comprised 20.29% of the overall California power mix, with the largest renewable source being wind power at 8.08%. (California Energy Commission, 2014) Just 5 years later as of 2019, renewable energy sources comprised 31.70% of the overall California power mix, with the largest renewable source being solar power at 12.28% and wind power now at 10.17%. (California Energy Commission, 2019) During this time period, California slightly increased its reliance on nuclear energy. In 2014, nuclear energy comprised 8.49% of the overall California power mix while in 2019 it comprised 8.98%. (California Energy Commission, 2014) (California Energy Commission, 2019)

Starting in 2012, California's energy portfolio finally made bigger strides away from nuclear energy. In 2011, nuclear energy consisted of 18% of in state electricity production. In 2012, that number was down to 9%. In 2019 that number was down to 8%. (California Energy Commission, 2012) (California Energy Commission, 2019)

California Fuel Generation by Energy Source:



California Energy Commission. (2021). *Electric Generation Capacity and Energy*. California Energy Commission; California Energy Commission. https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/electric-generation-capacity-and-energy

California Energy Mix 2019:

Fuel Type	California In-State Generation (GWh)	Percent of California In-State Generation	Northwest Imports (GWh)	Southwest Imports (GWh)	Total Imports (GWh)	Percent of Imports	Total California Energy Mix (GWh)	Total California Power Mix
Coal	248	0.12%	219	7,765	7,985	10.34%	8,233	2.96%
Natural Gas	86,136	42.97%	62	8,859	8,921	11.55%	95,057	34.23%
Oil	36	0.02%	0	0	0	0.00%	36	0.01%
Other (Waste Heat / Petroleum Coke)	411	0.20%	0	11	11	0.01%	422	0.15%
Nuclear	16,163	8.06%	39	8,743	8,782	11.37%	24,945	8.98%
Large Hydro	33,145	16.53%	6,387	1,071	7,458	9.66%	40,603	14.62%
Unspecified	0	0.00%	6,609	13,767	20,376	26.38%	20,376	7.34%
Non-Renewables and Unspecified Totals	136,139	67.91%	13,315	40,218	53,533	69.32%	189,672	68.30%
Biomass	5,851	2.92%	903	33	936	1.21%	6,787	2.44%
Geothermal	10,943	5.46%	99	2,218	2,318	3.00%	13,260	4.77%
Small Hydro	5,349	2.67%	292	4	296	0.38%	5,646	2.03%
Solar	28,513	14.22%	282	5,295	5,577	7.22%	34,090	12.28%
Wind	13,680	6.82%	9,038	5,531	14,569	18.87%	28,249	10.17%
Renewables Totals	64,336	32.09%	10,615	13,081	23,696	30.68%	88,032	31.70%
System Totals	200,475	100.00%	23,930	53,299	77,229	100.00%	277,704	100.00%

California Energy Commission. (2021). *2019 Total System Electric Generation*. California Energy Commission; California Energy Commission. https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/2019-total-system-electric-generation

Energy Costs:

In 2018, total energy expenditures in California totaled $138,992.4 million. (EIA, 2018) Costs to consumers have only risen over the years. From 1990-2018, the average annual increase in price to the industrial sector was 3.8% - the average annual increase in the commercial sector was 2.8%. (One Energy, 2020)

<u>Average California Electricity Prices 1999-2018</u>:

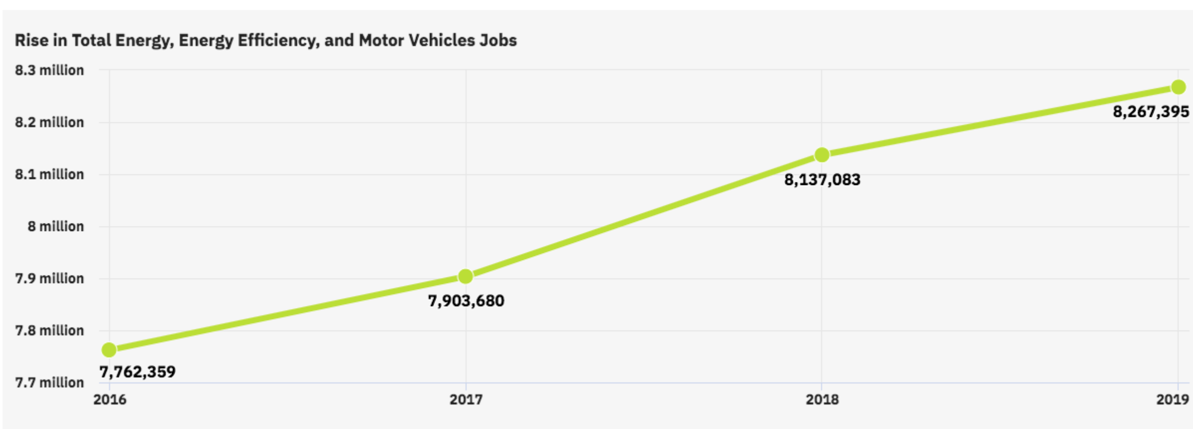
ELECTRICITY RATE SUMMARY ($/kWh)					
	1999 AVERAGE RATE	2018 AVERAGE RATE	AVERAGE ANNUAL INCREASE	TOTAL INCREASE	PREDICTED 2038 RATE
INDUSTRIAL	$0.063	$0.132	3.8%	110.5%	$0.278
COMMERCIAL	$0.094	$0.163	2.8%	73.1%	$0.283

One Energy. (2020). *1.6.5 Historical Electricity Rates | One Energy*. https://oneenergy.com/future-customers/customer-toolkit/historical-electricity-rates/

Energy Jobs:

Energy jobs in California have been constantly on the rise, increasing the number of total energy sector jobs from 7.7 million in 2016 to 8.2 million in 2019. (USEER, 2020) Of the 120,300 jobs added to the California energy industry in the past year, 51,5000 of those jobs went towards non-renewable energy positions. (USEER, 2020)

<u>California Renewable Energy Jobs 2016-2019</u>:



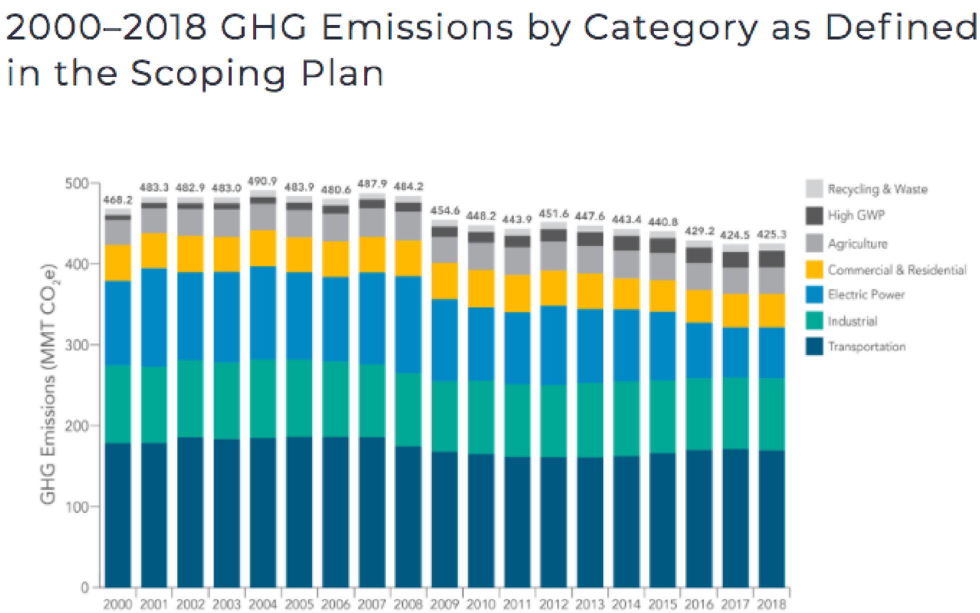
USEER. (2020). *2020 U.S. Energy and Employment Report (USEER)*. 2020 U.S. Energy and Employment Report (USEER). https://www.usenergyjobs.org

Emissions:

Since 2000, California has incrementally decreased its GHG emissions each year, mainly making reductions in the electricity production sector. In 2000, California emissions totalled

468.2 million metric tons of carbon dioxide (MMT C02). In 2018, emissions decreased to 425.3 MMT C02. (California Air Resources Board, 2018)

California Emissions by Sector 2000-2018:



California Air Resources Board. (2018). *GHG Emission Inventory Graphs | California Air Resources Board*. https://ww2.arb.ca.gov/ghg-inventory-graphs

Transition Plan:

The role of nuclear energy is still hotly debated in California, even as Diablo Canyon is set to close in 2024 and 2025. (PG&E, 2018) This decision by PG&E did not come without opposition. The main debate in California centers around whether or not nuclear should be considered a renewable source of energy. Nuclear power provides a vast amount of energy without any of the 'nasty emissions' that we hear all about.

So much of the debate and rhetoric about climate change centers around GHG emissions. Technically, nuclear energy is not a carbon emitting source of energy - this does not mean nuclear energy production does not carry its own set of risks in production and waste management. Following the Fukushima disaster in 2011, fears over ensuring the safety of power plants skyrocketed, especially considering the fact that Diablo Canyon lays on major fault lines. (Sweeney, 2016)

Following the Fukushima disaster, the U.S (among many other countries) Nuclear Regulatory Commission created requirements for new equipment, safety regulations, and updated emergency preparedness procedures. (U.S.NRC, 2020) These new regulations equate to dollar signs in the eyes of potential future investors in nuclear technology, serving as another deterrent. With PG&E already partnering with environmental groups like Friends of the Earth to heavily invest in solar and wind technologies following the Diablo Canyon closures, nuclear energy in California appears to be running its final laps.

This does not stop organizations like the World Nuclear Association from arguing on behalf of nuclear, citing increased emissions and prices to consumers in the wake of power plant closures. (World Nuclear Association 'Nuclear Power in the USA,' 2020) The question remains one of thinking long into the future or emphasizing the impacts here and now. Investing in renewables will be beneficial in the long term, but it is a time-intensive and costly investment that will require willpower and the performative success of renewable energy to achieve.

<u>Germany</u>

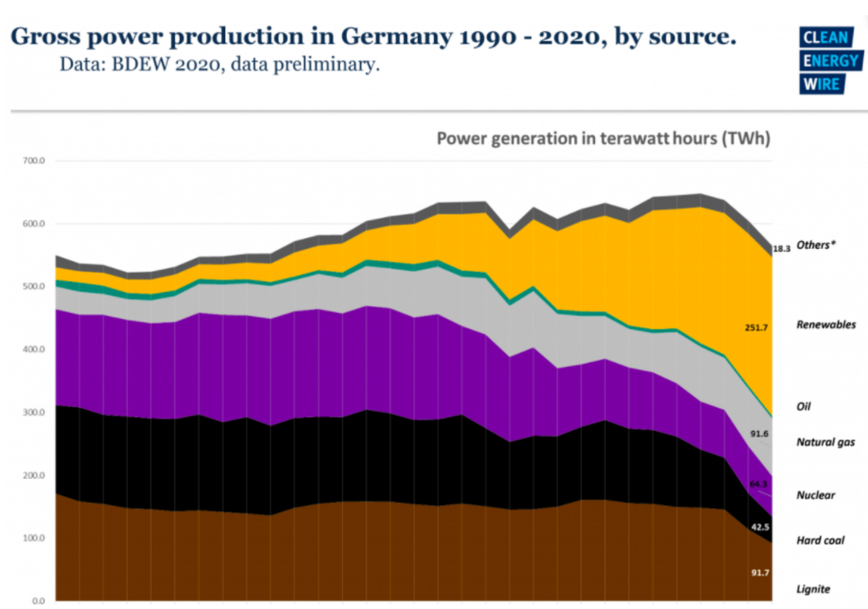
In 2010, Germany granted eight year license extensions to power plants built before 1980 and 14 year extensions to power plants built after 1980. These extensions came with the caveat of a tax of $175 (€145) per gram of uranium or plutonium for six years. The extensions also included payment of €14 million between 2011-2016 followed by a €0.9 c/kWh tax for every year after 2016. All of these funds were intended to be diverted towards renewable energy projects. (World Nuclear News, 'German Reactor Shut Down,' 2018)

In 2011, after the Fukushima disaster, the German government decided to commence with a nuclear phase out plan that would decommission all nuclear plants by 2022. (World Nuclear News 'German Reactor Shut Down,' 2018) Gundremmingen B (built in 1984), just 74 miles northwest of Munich, officially shut down on December 31, 2017. Gundremmingen C, the last remaining reactor at the site is still in operation with plans to shut down in 2021. (Staudenmaier, 2017)

Energy Portfolio:

Germany has made an extremely concerted effort to shift its energy production to renewable energy over the past 20 years. In the past 10 years, Germany has managed a marked reduction in its reliance on nuclear, coal, and now lignite.

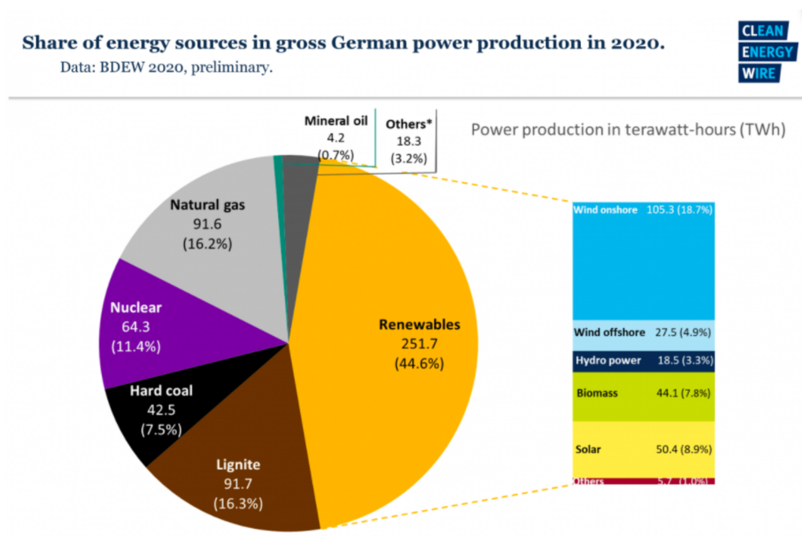
<u>*Germany Energy Production by Source 1990-2020*</u>:



Appunn, K., Haas, Y., & Wettengel, J. (2015, June 17). *Germany's energy consumption and power mix in charts*. Clean Energy Wire. https://www.cleanenergywire.org/factsheets/germanys-energy-consumption-and-power-mix-charts

As of 2020, renewable energy makes up 44.6% of all power production in Germany. The main source of renewable energy comes from onshore wind, providing 18.7% of all energy produced in the country. Other non-renewable sources include lignite (16.3%), natural gas (16.2%), nuclear (11.4%), and coal (7.5%). (Appunn et al., 2015)

Germany Energy Mix 2020:

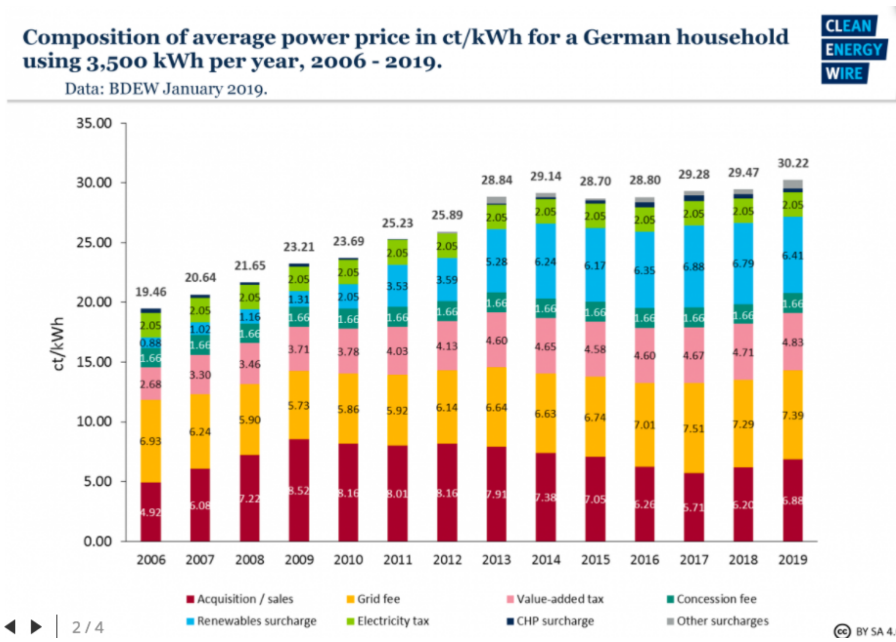


Appunn, K., Haas, Y., & Wettengel, J. (2015, June 17). *Germany's energy consumption and power mix in charts*. Clean Energy Wire. https://www.cleanenergywire.org/factsheets/germanys-energy-consumption-and-power-mix-charts

Energy Costs:

Average household power prices have risen somewhat substantially in Germany since 2006. The average household consuming 3,500 kilowatt-hours (kWh) per year in 2006 would pay about 19.46 ct/kWH for energy. The same household in 2020 is paying 30.22 ct/kWh. The main increases in price have to do with renewable surcharges and increased grid fees. (Thalman and Wehrmann, 2015)

Average Electricity Prices for Average German Households 2006-2019:



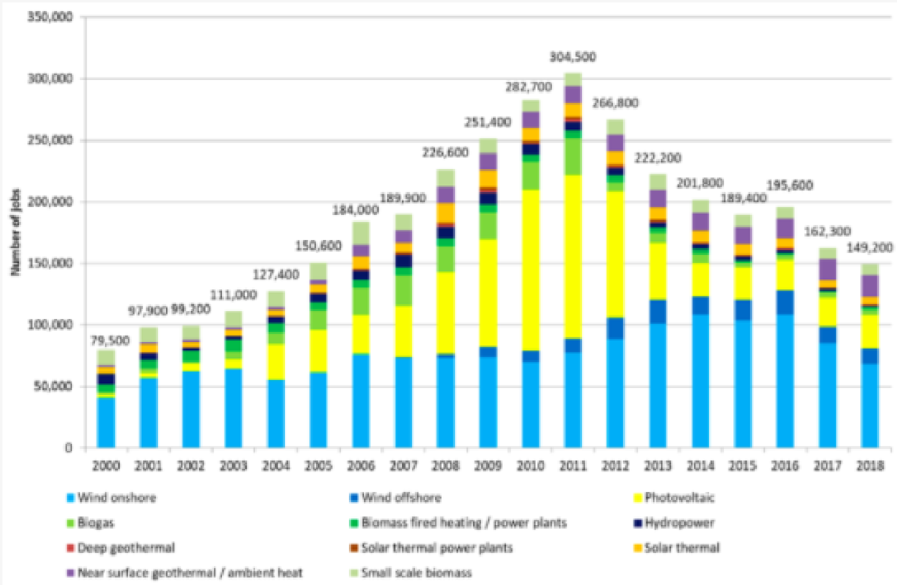
Thalman, E., & Wehrmann, B. (2015, January 23). *What German households pay for power*. Clean Energy Wire. https://www.cleanenergywire.org/factsheets/what-german-households-pay-power

Energy Jobs:

Investments in renewable energy created a large amount of jobs in the renewable sector. The number of jobs peaked in 2011 with heavy investment in photovoltaic technology, but the number of photovoltaic related jobs has greatly decreased in recent years. Currently the number one renewable energy job provider in Germany relates to wind power.

New Employment From Renewable German Energy Sources 2000-2018:

Figure 8. Employment in Germany triggered by investments in RES-technologies in the period 2000–2018 (see **supplementary material**).

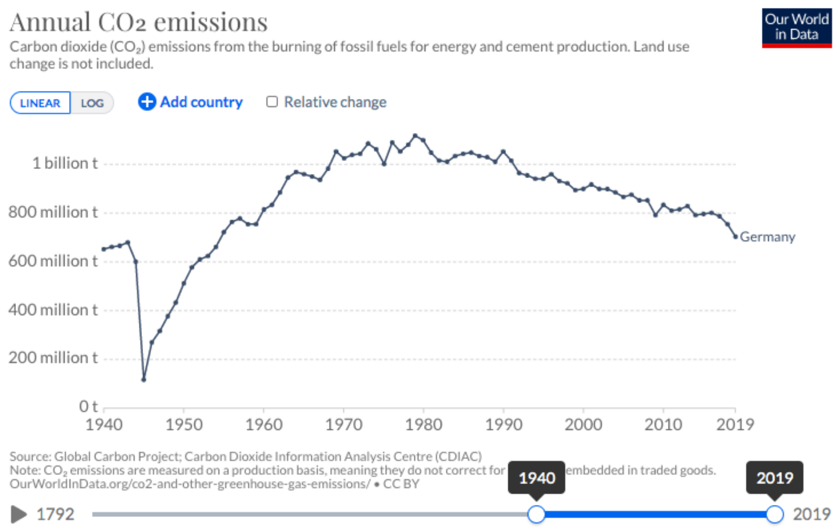


O'Sullivan, M., & Edler, D. (2020). Gross Employment Effects in the Renewable Energy Industry in Germany—An Input–Output Analysis from 2000 to 2018. *Sustainability*, *12*(15), 6163. https://doi.org/10.3390/su12156163

Emissions:

After WWII Germany slowly rebuilt its energy industry and along with it, its C02 emissions. Emissions peaked in Germany in 1979. Since then, Germany has come close to halving all of its emissions, with one of the largest drops between 2015 and 2020.

Annual German C02 Emissions 1940-2019:



Ritchie, H., & Roser, M. (2020). CO_2 and Greenhouse Gas Emissions. *Our World in Data*. https://ourworldindata.org/co2/country/germany

Transition Plan:

Following the Fukushima disaster, the German government made the decision to shut down all power plants by 2022 - without conducting a 'cost-benefit' analysis. (Toulouse School of Economics, 2020) Cost-benefit analyses make fighting for a more sustainable future extremely difficult, as moneyed interests will always appear to outweigh a slight decrease in emissions. Even though emissions were not a factor in the decision, Chancellor Angela Merkel and the German government felt they would have strong public support for their decision, particularly as a highly protested issue in the country. (Toulouse School of Economics, 2020)

The plans to close all nuclear power plants were initially introduced in 1998 and then cancelled in 2009 by Chancellor Angela Merkel. Following Fukushima, however, Merkel stated that the risk of another similar incident occurring was "just too enormous to be controlled by humans." (Murray, 2020) Despite backlash and concerns over increased emissions in the wake of power plant closures, a 2015 poll showed that 81% of Germans were still in favor of the decision to phase out nuclear. (Appunn, 2021)

The sudden and immediate phase out from nuclear left Germany heavily reliant on coal for energy, particularly lignite (brown coal). Coal is widely accepted as a harmful and counterproductive energy resource in terms of reaching low emission goals. Recently, a $4.8 billion plan was introduced to pay out energy providers over the next 15 years to shut down coal plants. (Sengupta and Eddy, 2020)

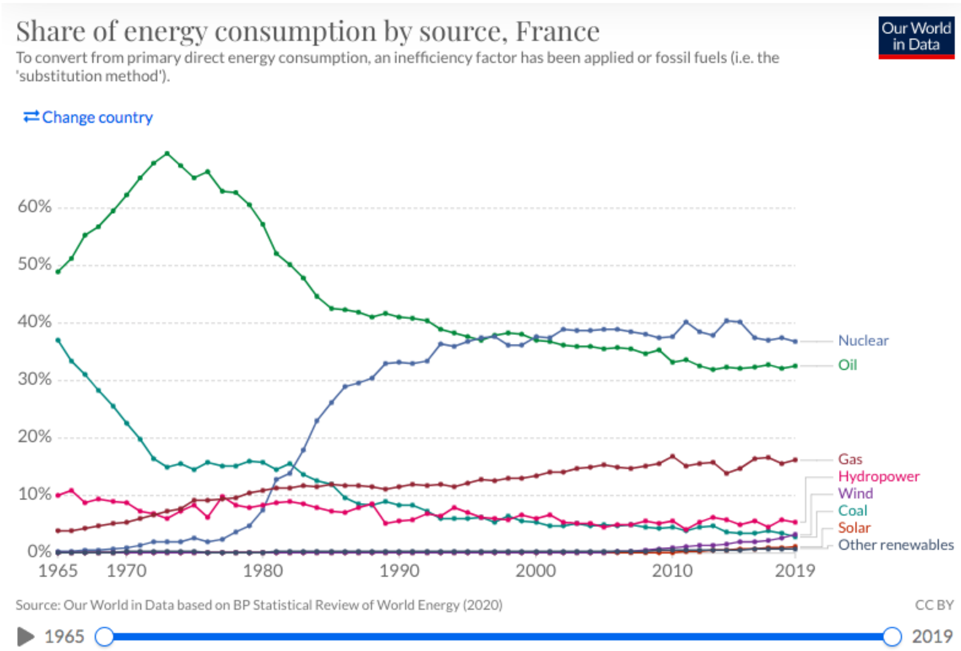
France

The plan to close the Fessenheim two unit power plant was set in motion by France's former President Francois Hollande. As the oldest power plant in France, the reactors have been in operation since 1977 and 1978. It came as part of a plan to reduce France's reliance on nuclear energy output to 50% by 2025. (World Nuclear News 'France Completes Closure of Fessenheim,' 2020) Reactor one was shut down in February 2020 and reactor two was shut down shortly after on June 29. It was predicted that upwards of 2000 jobs would be lost in the process of the long debated closure of the Fessenheim plant. (BBC News, 2020)

Energy Portfolio:

In 2000, France's domestic energy portfolio mainly relied on Nuclear (37.57%), Oil (37.11%), and Gas (13.55%). Renewables consisted of only 6.28% of French energy - the main renewable source was hydropower. As of 2019, France has increased its reliance on renewable energy to 10.45%, mainly resulting from investments in wind power. French reliance on nuclear has remained relatively constant, oil fell to 32.54%, gas reliance increased to 16.16%, and coal reliance fell to 2.79%. (Ritchie and Roser 'France,' 2020)

French Energy Consumption by Source 1965-2019:

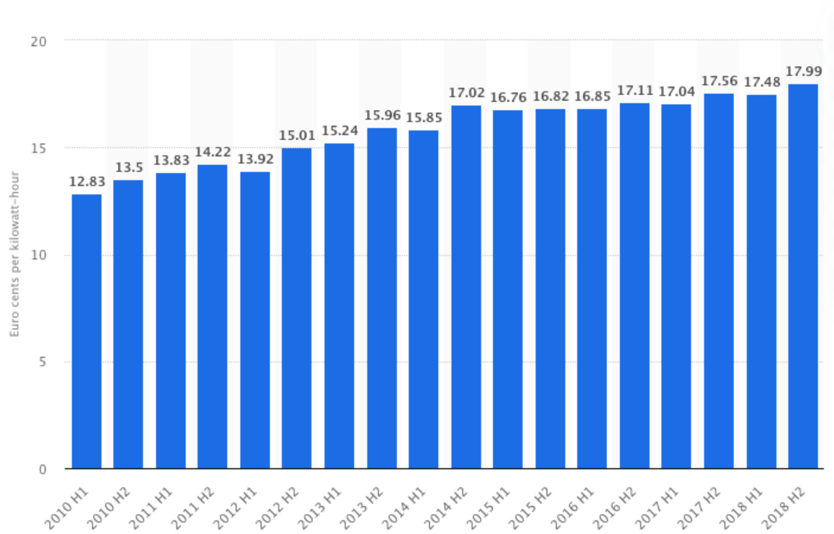


Ritchie, H., & Roser, M. (2020). Energy. *Our World in Data*. https://ourworldindata.org/energy/country/france

Energy Costs:

Electricity prices for the average French household have been on a steady rise over the past ten years. In 2010, the average price (Euro cents per kWh) was 12.83 compared to the average price of 17.99 in 2018. (Eurostat, 2020)

Average Electricity Prices per kW/h 2010-2018:



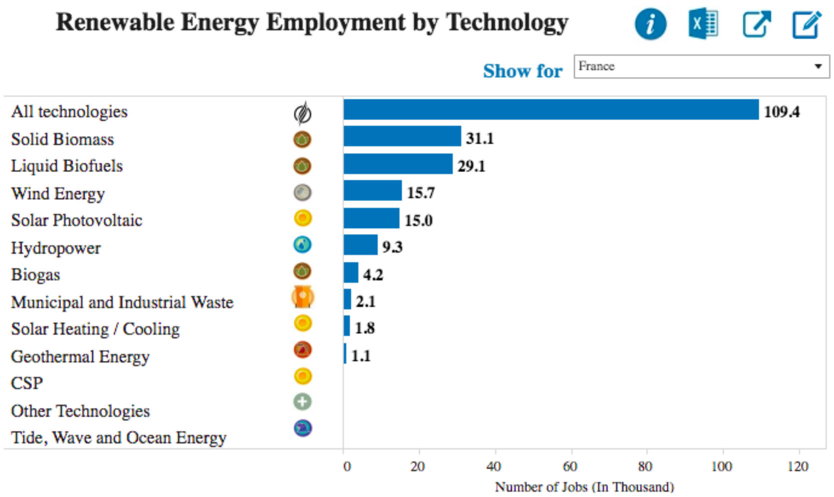
Eurostat. (2020). *Electricity prices for household consumers—Bi-annual data (from 2007 onwards)*. https://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_price_statistics

Energy Jobs:

Reports from the International Renewable Energy Agency (IRENA) depict an overall decline in renewable energy jobs over the past five years. In 2015, IRENA reported 170,000 direct and indirect renewable energy jobs in France with the top two renewable employment sectors being solid biomass (48,000 jobs) and liquid biofuels (35,000 jobs). (Lopez, 2017)

Current reports from IRENA show a decline in the total number of renewable energy related jobs, now totalling 109,424, with similar decreases in solid biomass (31,000) and liquid biofuels (29,100). (IRENA, 2021)

Total Renewable Energy Jobs in France (in thousands):

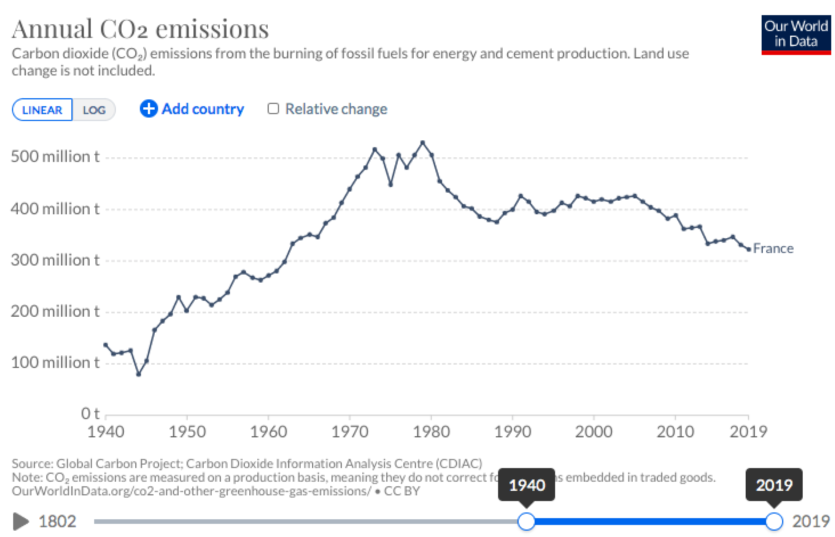


IRENA. (2021). *Renewable Energy Employment by Country*. /Statistics/View-Data-by-Topic/Benefits/Renewable-Energy-Employment-by-Country. /Statistics/View-Data-by-Topic/Benefits/Renewable-Energy-Employment-by-Country

Emissions:

France experienced a similar trajectory to Germany after WWII, but on a much smaller scale due to population size:

Annual French C02 Emissions 1940-2019:



Ritchie, H., & Roser, M. (2020). Energy. *Our World in Data*. https://ourworldindata.org/energy/country/france

Transition Plan:

France continues to place a heavy reliance on nuclear power for energy production, particularly for electricity. In 2014, the French government passed the Energy Transition for Green Growth bill, setting a goal to reduce the share of nuclear energy to 50% of electricity production by 2025. (Gouvernement, 2014) In December, 2017, France postponed this target and President Emmanuel Macron stated that nuclear is "the most carbon-free way to produce electricity with renewables." (World Nuclear Association 'Nuclear Power in France,' 2021)

Macron remains adamant about the pivotal role of nuclear in the future of French energy production. Nuclear is the reason that France is the world's largest exporter of electricity, as exporting renewables is much more costly. (World Nuclear News 'Macron,' 2020) While other countries were scared off from nuclear in the wake of Fukushima, France hardly faltered and now appears to view nuclear power as the source of their independence in the world. France's recent commitment to become carbon neutral by 2050 has actually placed mounting pressure on the role of nuclear in achieving that goal, as divesting from nuclear now would be both costly and unproductive towards the goal of 'reducing emissions.' (Temple, 2019)

<u>Sweden</u>

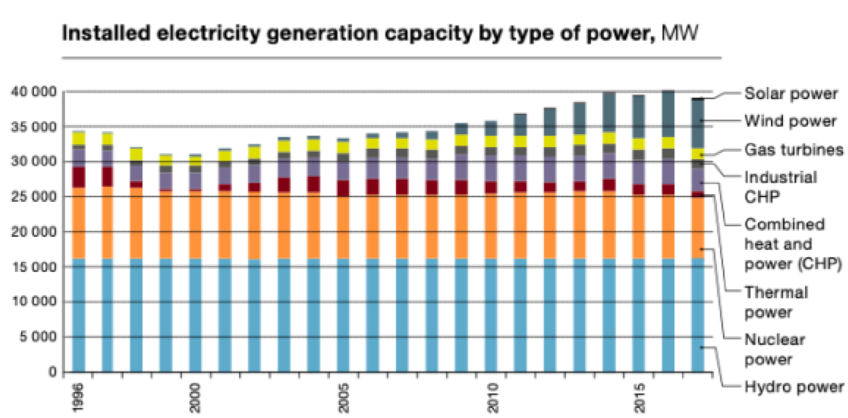
The major shareholder of Oskarshamn power plant, a German utility company called Eon, decided to shut down units one and two of the plant in 2015. Unit one, operating since 1972, is a 473 MWe boiling water reactor. Unit two has been in operation since 1974 and is a slightly larger boiling water reactor at 638 MWe. The closure came about partly as a result of increasing Swedish taxation on nuclear power. (World Nuclear News 'Oskarshamn 1,' 2017)

Unit one was permanently shut down on June 19th, 2017. (IAEA 'Oskarshamn 1 Reactor Details,' 2021) Unit two was permanently shut down on December 22nd, 2016. (IAEA 'Oskarshamn 2 Reactor Details,' 2021) There are four phases to the decommissioning process - first all fuel must be removed and stored in fuel pods for a minimum of a year. Second, the unit itself must undergo a phase of 'care and maintenance.' Third is the dismantling stage. Finally the site must be cleared for radioactivity before it can be repurposed. (Nuclear Engineering International, 2017)

Energy Portfolio:

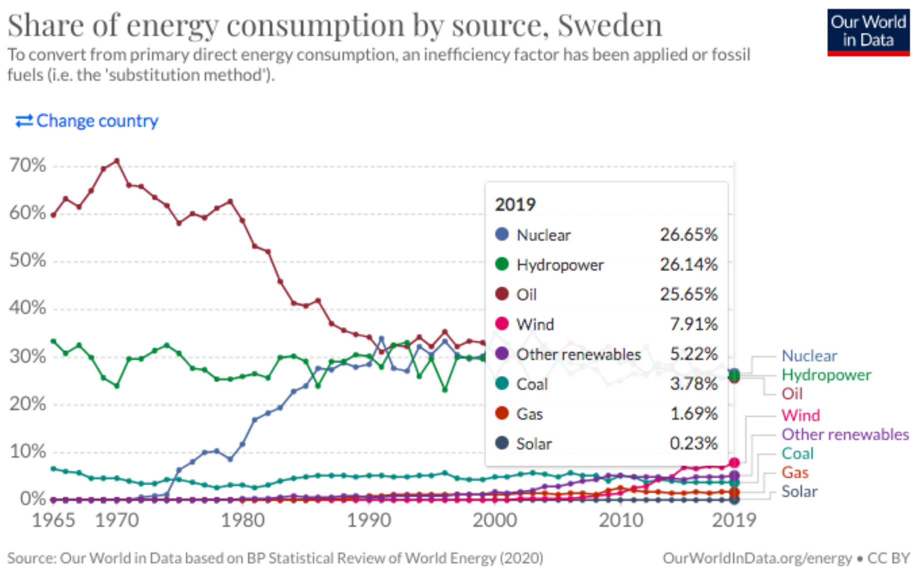
Sweden has drastically increased its reliance on renewable energy since 1990. In 1990, about 33% of Swedish energy was renewable. In 2018, that number was 54.6%. (Swedish Institute, 2015) Energy reliance in Sweden mainly falls on nuclear, thermal, and hydro power. The top two sources of renewable energy are hydropower (largely used for electricity) and bioenergy (largely used for heating). (Swedish Institute, 2015) In terms of in-country energy consumption, Sweden still relies very heavily on nuclear and oil. (Ritchie and Roser 'Sweden,' 2020)

Sweden Energy Mix 1996-2017:



Huyge, L. (2020). *The energy sector in Sweden*. 14.

Sweden Energy Consumption 1965-2019:

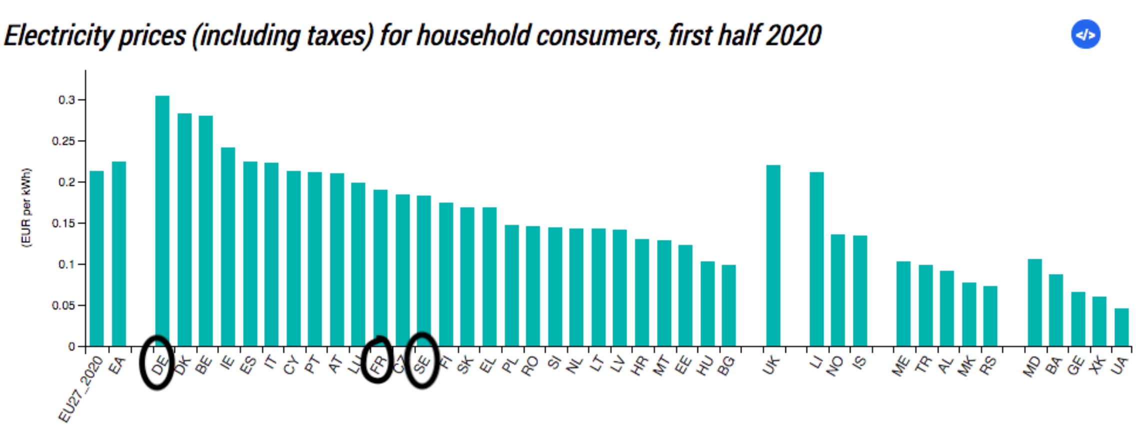


Ritchie, H., & Roser, M. (2020). Energy. *Our World in Data*. https://ourworldindata.org/energy/country/sweden

Energy Costs:

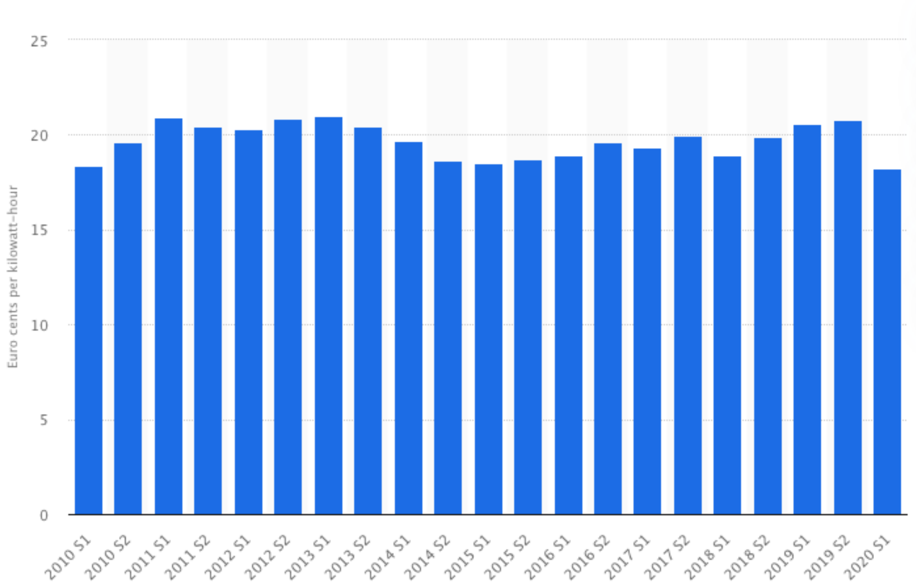
Sweden's energy prices have slightly increased over time, but at a much slower rate than most of its European counterparts. In 2007, the average price of electricity for a Swedish household consuming an average of 35,000 kWh per year was 86 öre/kWh. In 2020, that same household pays about 125 öre/kWh. (Swedish Energy Agency, 2020)

Electricity Prices 2020 - Germany, France, Sweden:



Eurostat. (2020). *Eurostat—Data Explorer*. Retrieved April 5, 2021, from http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_pc_204&lang=en

Swedish Energy Prices Per kW/h 2010-2020:

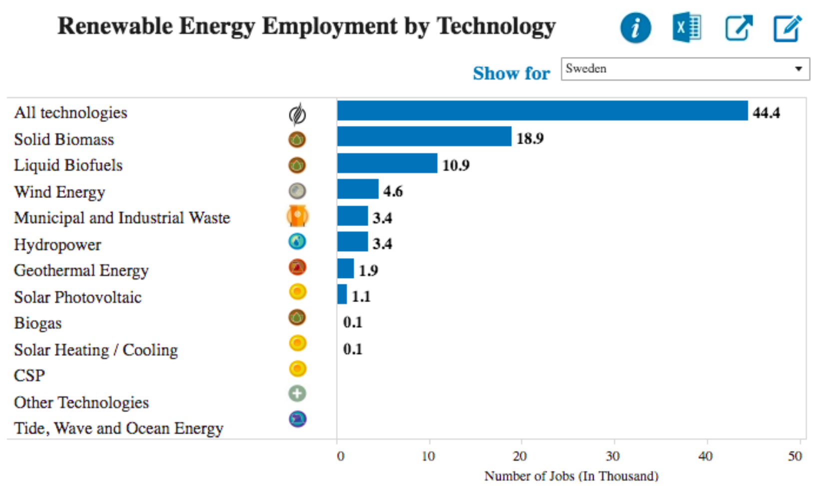


Eurostat. (2020). Electricity prices for household consumers—Bi-annual data (from 2007 onwards). https://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_price_statistics

Energy Jobs:

A European Employment Observatory report in 2009 stated the entire renewable energy industry employed 14,402 individuals. A majority of these jobs came from electricity production and biofuels (6,277) and geothermal (2,628). (Anxo, 2009) An IRENA report from 2021 depicts a massive increase in all renewable energy related jobs, now reporting 44,391 jobs, 18,900 of which are in solid biomass, 10,900 in biofuels, and 4,600 in wind energy. (IRENA, 2021)

<u>Total Renewable Energy Jobs in Sweden (in thousands)</u>:

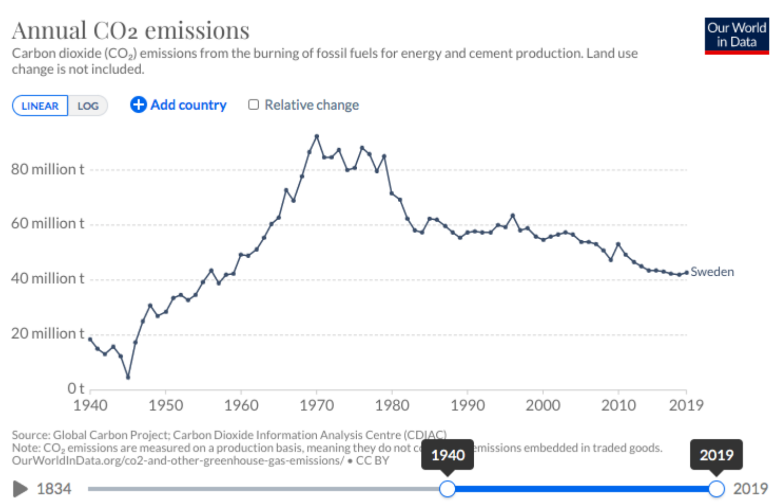


IRENA. (2021). *Renewable Energy Employment by Country*. /Statistics/View-Data-by-Topic/Benefits/Renewable-Energy-Employment-by-Country. /Statistics/View-Data-by-Topic/Benefits/Renewable-Energy-Employment-by-Country

Emissions:

While Sweden drastically increased reliance on hydropower, its other sources of in-country renewable energy consumption remain far behind. This makes it difficult to shift away its current consumption of oil energy. Emission reduction goals have stalled as a result.

<u>Annual Swedish C02 Emissions 1940-2019</u>:



Ritchie, H., & Roser, M. (2020). Energy. *Our World in Data*. https://ourworldindata.org/energy/country/sweden

Transition Plan:

Well before the disaster at Fukushima, the 1979 Three Mile Island incident in the U.S spurred a plethora of safety upgrades and changes to nuclear policy. (U.S.NRC, 2020) In 1980, Sweden voted to stop the expansion of nuclear energy in the country with the last nuclear reactor completed in 1985. Initially there were plans to shut down all nuclear plants by 2010, but impending pressures to reduce emissions in the face of the climate crisis have made nuclear more appealing in Sweden as a low carbon emitting source of energy production. (Duxbury, 2021)

The Swedish reaction to nuclear power generation continued into the 90's with the implementation of a tax on nuclear energy production. The tax was then raised in 2015, making nuclear energy production unattractive by limiting the profits of energy companies investing in nuclear power. In 2016 this tax was repealed and set to phase out by 2019. (Dellinger and Schratzenstaller, 2017)

Today the main debate in Sweden exists between the Social Democrats and the Moderate Party/Far-right Democrats. Social Democrats argue that clean energy means 'renewable' - or more specifically, hydro, solar, and wind. The right defines clean as 'fossil-free' and criticizes the left for not taking strong enough steps to meet energy projection goals. (Duxbury, 2021)

Analysis:

<u>California</u>

California has a relatively strong energy portfolio, but still relies heavily on natural gas as an energy source. The transition towards renewable energy has stalled in comparison to countries like Germany that took drastic steps to decommission nuclear power, forcing them to radically increase the renewable sector. The slower pace in California led to some opposition to decommissioning nuclear power, but that debate looks to be just about over as PG&E announced its partnership with Friends of the Earth.

The slow pace of decommissioning also led to increased energy costs as California weans itself off the largely carbon free and powerful energy source of nuclear power. This plays into the rhetoric that phasing out nuclear energy will lead to increased energy prices. The benefit to this phase out period, however, is that California has maintained a steady increase in jobs in the energy sector - this would not have been possible if California took the more extreme route that Germany did.

Another positive aspect of California's transition away from nuclear energy comes from avoiding the fear that shifting reliance from nuclear will increase emissions. Although slowly, California has reduced its emissions year after year without facing any drastic increases. This does not silence the argument that these reductions might happen more quickly with the aid of nuclear energy production, but they do help to dispel the argument that renewable energy cannot fill in the necessary energy gaps.

Germany

Out of all the case studies, Germany took the most radical route towards phasing out nuclear energy. The fear stirred by the Fukushima disaster prompted the country to take immediate action to phase out power plants. The result on Germany's overall energy portfolio was surprisingly impactful at shifting reliance and investments towards strictly renewable sources. While the renewable energy sector began to boom, other energy sectors took a little bit longer to limit their roles. Notably, coal and lignite (brown coal) both have made drastic decreases in the overall energy portfolio, largely thanks to subsidies from the German government. Throughout this process, Germany also managed to maintain steady decreases in carbon emissions, not being forced to increase reliance on any non-renewable sources.

The main issue with Germany's drastic step towards phasing out nuclear power was a lack of planning for job loss. Germany's four biggest utilities companies suffered large losses in jobs, revenue, and salaries, with employment nearly cut in half between 1991 and 2015. (Hockenos, 2015) Another issue with the German transition away from nuclear is the steady increase in energy prices over the years. The main price increases come from grid fees - this is a long term problem as renewable grids do not necessarily mix with grids that benefit nuclear technology.

France

The Fessenheim case study in France is the one study where the country seemed to entirely reverse course after its closure. Partly due to the election of Emmanuel Macron in 2017, France has stood firm on its pro nuclear stance. Compared to other case studies, France experienced much less progress in renewable energy technologies. While reliance on oil fell from the 70's to the late 90's, it has largely remained stagnant since then. The two main energy providers in France are oil and nuclear. While electricity prices remain steadily on the rise, they are nothing compared to average prices in Germany. This can largely be attributed to nuclear power.

Jobs in the renewable energy sector fell quite drastically in France in the past five years by about 35%. France remains on target for C02 emissions as well, particularly because nuclear energy does not comprise a large source of emissions. Macron firmly believes nuclear is the future of energy for France and views the country's reliance on it as the source of its independence. With a large portion of the world moving away from nuclear and focusing on more expensive forms of renewable energy, it is likely that at the bare minimum Macron will be right in the short term.

Sweden

Sweden's coastal location makes it a prime setting for the generation of hydro power, and that has largely been beneficial to their renewable energy portfolio. The entire energy portfolio represents one of the most balanced and diverse of all the case studies, and has allowed Sweden to keep a leash on energy prices, even beating out France. Sweden has also been the most successful at creating new renewable energy jobs over the years, with a majority of the job creation coming from the energy efficiency sector. (Vinnova, 2017)

Even without a huge reliance on nuclear power, Sweden has kept energy emissions on par, if not lower than France on a per capita level. One of the main attractive features of nuclear energy comes from mass energy production without increasing carbon emissions, but Sweden proves that a diverse portfolio can keep a cap on rising emission rates.

Policy Recommendations

Phasing out fossil fuels and nuclear energy simultaneously represents a difficult and daunting task, but an essential step towards achieving a carbon neutral future envisioned by the Paris Agreement. While the agreement focusses on emissions reductions, nuclear energy remains a viable energy source for its low carbon production. It is also irresponsible to overlook the potential for large scale nuclear disasters as well as the mounting issue of long term nuclear waste disposal - we cannot keep burying waste forever. While nuclear energy by no means epitomizes the safest or 'greenest' option, the serious consequences associated with taking nuclear energy off of the table in terms of energy production, energy jobs, electricity prices, and emission reduction goals need to be considered. While these challenges are surmountable, there are potential safer avenues for utilizing nuclear power in the short term.

Total Phase-Out Starting 2050

First, the long term goal is to completely end any reliance on nuclear energy. There is precedent for utilizing nuclear energy to properly meet emission reduction targets stipulated by the Paris Agreement by 2050, but any nuclear power generation must begin decommissioning once that goal is reached. From this point, there are two viable paths forward: complete nuclear decommissioning or adapted small scale nuclear systems.

The first potential path - total decommissioning - will need to involve comprehensive transition plans to avoid some of the pitfalls that Germany experienced after initiating a strong anti-nuclear stance in the wake of the Fukushima disaster. The decision in Germany came largely in response to mounting political pressure and lacked an adequate transition plan. The main issues with this strategy involved soaring energy prices, loss of jobs and money in the energy sector, and a short term increased reliance on coal and lignite. The German government caught up to some of these pitfalls - specifically subsidizing the renewable energy sector to allow for a more drastic shift away from coal and lignite reliance and expanding renewable energy rapidly to nearly 50% of all energy production.

Learning from the German decommissioning model, the United States can prepare a transition plan to avoid or mitigate some of the potential negative consequences. Issuing a pure command-and-control measure to decommission all power plants will not come without its issues and the federal government needs to prepare to step in and subsidize the transition. Mainly, subsidies towards the renewable energy sector to promote and create jobs in areas where they are lost - nuclear power plants notoriously employ and prop up the communities they serve.

Planning for Community Impacts

Local communities around power plants largely depend on the high paying jobs and increased tax revenue to continue flowing. When plants enter decommissioning, surrounding areas are often left to suffer the economic consequences. Moving forward, Diablo Canyon represents an example of what a more just transition can look like. SB1090, a California law, provides the surrounding area with $400 million in 'mitigation funds.' The funds are intended to provide power plant workers with new jobs in decommissioning and incentivize them to stay in the area. $85 million of these funds are designated to provide financial relief for schools in the wake of decreased local tax revenue. (Healy, 2019)

Community Engagement

In the decommissioning of Diablo Canyon, PG&E made several concerted efforts to engage with and take input from the community in the form of public hearings and surveys, largely thanks to strong on the ground coalition building with Friends of the Earth. (Roland-Holst et al., 2019) The transparency demonstrated by PG&E needs to be replicated in future decommissioning plans. No two areas have the exact same needs in the wake of losing a power plant, but universal concerns exist from a loss of tax revenue to fund essential services as well as a loss of jobs. In the case of Diablo Canyon, most predictions do not find that Diablo Canyon's economy will face a downturn even though the power plant was one of the backbones of the economy. Most studies simply predict a slower rate of economic growth. (Healy, 2019)

Universal Healthcare

On top of constant transparency and dialogue between the utility providers and the communities they serve, other important safety nets must be established to protect the actual plant workers. Providing universal health care represents a step in the right direction to help not just power plant workers, but all workers displaced through a more concentrated push towards renewable energy. While some workers will transition to renewable energy with relative ease, not all current energy jobs can easily transfer to the clean energy sector. It is essential that these workers not be left in the dust with healthcare tied to their jobs. Stripping these workers of their livelihoods is more than enough hardship to place on the workforce. The federal government must shoulder the burden alongside their workers and provide access to basic human services like affordable healthcare.

Housing Affordability

In a joint economic impact assessment on the Diablo plant closure between UC Berkeley and the CPUC, several concerns were raised about the housing affordability crisis in California and more specifically in San Luis Obispo. Power plants provide some of the highest paying jobs in the area. The report concludes that San Luis Obispo is a middle-income county with upper-middle income housing prices. (Roland-Holst et al., 2019) While the report eventually concluded that the Diablo Canyon closure would not have an impact on the housing affordability crisis, it will be important to provide protections for communities around decommissioning power plants to remain viable places to live instead of decimating the population and further stressing tax revenue. SB1090 partly aims to keep workers in the area, but further than temporary government intervention, California needs to tackle its housing crisis head on with lasting legislation to ensure access to affordable housing for all. This will not only save local and state governments money, it will actually take off the imminent pressures of transitioning to a renewable energy based economy.

Emphasis on Subsidizing Renewable Technologies

Subsidies towards adjusting the renewable energy industry will not only create jobs, but it will decrease the amount of time required for utilities to lean on fossil fuels to make up for intermittent renewable energy production. Germany faced a longer transition period with increased coal reliance until government subsidies propped up the renewable energy sector to a point where it became economically and strategically viable to decrease coal dependence. We need to heavily invest in renewable energy now to mitigate that gap - no matter what, moving away from nuclear energy will force burdens on other sources of fuel, but the more quickly we prioritize renewable energy development, the smaller that window will be. A goal of renewable energy investment is to create diverse energy portfolios to fill in the gaps of intermittent energy sources normally filled by nuclear or fossil fuels.

Scale Up Existing Technology

Renewable energy subsidies are ripe with opportunity and no two incentives will necessarily look the same. Priorities include subsidizing research on expanding existing renewable energy sources and building up a more complex energy portfolio. While the potential for new ‘world saving’ technology can be a luring concept, it will be best not to rely on the Elon

Musks of the world to save us all. Instead of wasting time and resources on technology that does not exist, we need to prioritize subsidies towards scaling up existing technologies to overtake our reliance on fossil fuel sources. This needs to be done on a regional level. For example, hydropower, heavily utilized in Sweden, would do little to help renewable energy production in Arizona. The two most important goals in subsiding existing renewable energy are making regional decisions, and not relying too heavily on any single source. This will allow for energy production that will minimize the intermittent nature of renewables.

Decrease Individual Reactor Capacities

While ultimately both fossil fuels and nuclear energy need to be phased out, in the short term the U.S needs to place a greater emphasis on fossil fuel reduction in order to reach emission reduction targets. If policymakers decide that nuclear remains the best option in reaching these goals by 2050, the nuclear sector must undergo drastic changes. First, current operation of nuclear power plants is so big and built on such long time frames that they are rarely economically viable for utility companies anymore even as they can be broad and reliable sources of energy. The most viable argument for the continued use of nuclear is as a backup for renewable and intermittent sources of energy like solar and wind.

Currently, nuclear power makes up about 19% of the U.S energy portfolio. In order to reduce incentives to build up nuclear energy capacity too heavily, a cap needs to be put in place on nuclear production at around 15%. This number will then gradually decrease as emission reduction targets are met. The biggest adjustment to the nuclear sector will be adjusting the scale of plant production. This will cut down on major costs as well as decrease the likelihood of large scale nuclear disasters.

A hard cap must be placed on the size of power plants to no more than one unit per plant. In order to solidify and meet the goals of reducing nuclear capacity, the government needs to mandate and fund research into the best practices of a smaller scale and smaller overall power plant. This will create jobs and help to expedite emission reduction goals by supplementing the gaps left by renewable energy. Mandated smaller plants will also make the goal of decommissioning all nuclear power sources starting in 2050 much more feasible. Currently, power plant investments are long term. Relying on nuclear energy so far into the future decreases an emphasis on scaling up renewable energy - the smaller we build nuclear reactors, the less and less we will frame them as the 'end all be all' to clean energy production.

Strong Oversight

In terms of decommissioning, there needs to be stronger state and federal oversight into the overall process. Before a new plant can even be built, utilities must present comprehensive plans that detail every step of the nuclear process - this includes uranium extraction, waste disposal plans, and job retention programs for decommissioning. Historically these processes have been characterized by a top-down approach. Moving forward it is ESSENTIAL that these processes utilize a bottom-up approach that consults communities first. The main issue with the Yucca Mountain disposal site was that the U.S government decided it was a good idea and *then* went to the community only to face years of political gridlock.

Bottom-Up Approach

Communities will be required to apply for a nuclear plant to be sited in their areas instead of utilities paying their way in. This will reduce incentives for utilities and government officials to undergo the political battle of putting nuclear power in a community where it is not wanted. Ideally under this program there will be next to zero incentive to fight public interest as it only creates political gridlock - this is not something that we have time for. While it may be more difficult to create plans for nuclear power through this system, it will at the very least place a greater emphasis on the need to expand renewable energy coverage and limit nuclear energy production to prioritize community interests.

In terms of the waste allocation process, a bottom up approach represents an essential tool. Currently, gaining access to the Nuclear Waste Fund is a difficult and arduous process. The U.S needs to make reforms to the outdated Nuclear Waste Policy Act in order to make money from the NWF more readily available for communities to apply for. Communities will apply for NWF grants in order to conduct research on the viability of nuclear waste disposal. If research supports the creation of small scale waste repositories, further funds will be granted to finance the operation. Private companies in both Texas and New Mexico are already attempting to gain access to these funds. (Sforza, 2019)

To summarize, the two options moving forward are complete nuclear decommissioning and a supplemental nuclear reliance system that emphasizes a prioritization of phasing out fossil fuel usage before nuclear. The first option will require comprehensive planning and subsidization of the renewable energy industry to limit energy price hikes, job loss, and the time period of emission spikes. The second option will require an entirely new way of looking at nuclear energy generation using a bottom up approach to minimize political opposition. It will also require the creation of small scale and short timelines for nuclear power plants. Both plans involve a complete phase out of nuclear energy, while the second plan utilizes nuclear strictly in the short term to meet renewable energy and emission reduction goals.

Conclusion

In order to properly approach and address the difficulties of phasing out nuclear energy and fossil fuel reliance simultaneously, a case study analysis proved the most effective tool in observing different pathways towards a low carbon future. Each case study - California, Germany, France, and Sweden - either decommissioned or was in the process of decommissioning two unit nuclear reactors. Each study's stance towards nuclear differed, with Germany and France representing the extremes of the spectrum. Today, the issue of whether or not to utilize nuclear energy in the transition towards meeting the emission reduction goals stipulated in the Paris Agreement remains hotly contested. Nuclear energy is a strong, consistent, low carbon emitting power source but faces mounting political and public pressure through its potentials for large scale meltdowns and the long term issue of waste disposal.

Through this research, it became clear that the world needs to wean its dependence off of nuclear energy and focus on energy production that is purely sustainable to the earth. The longer we rely on nuclear power, the more waste we produce, the larger the likelihood of a nuclear incident, and the more time we waste not upscaling renewable energy technology. This being said, the low carbon producing factor along with the strength of nuclear power in providing reliable energy begs the question of what this phase out needs to look like. If we want to continue the use of nuclear energy to aid in the transition to zero carbon production, the role of nuclear power needs to undergo reevaluation. This will look like smaller reactors that operate on shorter time scales, implementation of bottom-up processes to remove nuclear power production from a great deal of political gridlock, and the requirement of comprehensive decommissioning plans upfront. Not every country will undergo an identical process - especially as public pressure on politicians can play a big role as observed in Germany - but if the world can operate on 100%

sustainable energy sources, that is a much more appealing option than the unsustainable nature of nuclear generation.

While the research agrees that nuclear may be a necessary power source in meeting emission reduction goals, ultimately this means nothing without the proper prioritization of developing renewable energy sources. There are several limitations to this research, mainly my lack of access to energy experts and government officials in the time of COVID-19. Ideally, anyone attempting to further this research would have a plethora of conversations with energy experts on both sides of the equation. There are experts and environmental groups both calling for an end to all nuclear power generation as well as similar groups lobbying the government to reform the NWPA in order to pursue more sustainable and environmental justice pathways towards small scale nuclear energy.

The research suggests that there needs to be a compromise between the extreme decommissioning tactics of Germany and the pro-nuclear stance of France. Purely looking at goals set by the Paris Agreement (we are roughly 50% through the timeline set from emission reduction levels from 1990-2050), Germany is at about 33% of its reduction goals and France is only at about 19%. (Ritchie and Roser 'GHG Emissions,' 2020) Though Germany faced setbacks from the quick decision to shut down all power plants, they made strong increases in renewable energy reliance. France, on the other hand, is plagued by its reliance on oil and gas energy production and has not attacked emission reductions nearly as ambitiously. (Ritchie and Roser 'GHG Emissions,' 2020) While nuclear may be a necessary tool in reaching emission goals, without a strong emphasis on renewable energy production, nuclear energy merely represents another non-sustainable energy source to rely on.

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