Building Towards a Sustainable US Energy Industry,

The Danish Initiative and Carbon Credit System as Basis for a Framework

ESADE Business School

Michael William Madden

Wanxin Cao

Baptist Jacques A Gilson

Table of Content

Abstract

This study establishes a new framework for the transition of the United States energy industry from one dominated by traditional forms of energy to one that incorporates a larger proportion of sustainable energy. This thesis explores the current landscape of the United States energy industry to analyze how the Danish Initiative and the Carbon Credit System can provide the basis. This model targets both the cause – the energy industry as the United States' biggest polluter (McDonnell, 2015) – and the possible solution – this sector has the tools and infrastructure to lead the transition towards sustainability (UCSusa, 2017) – to carbon emission mitigation, in an effort to take the best factors from each approach to determine which characteristics are applicable to the US. Through documentary analyses and data collection from expert interviews and traditional energy industry surveys, the study finds evidence of a resistance to change, the need for government and industry spending, and renewable energy technology imperfections all of which inhibit the transition. The model consists of both a short- and long-term approach. The short-term focuses on the implementation of solar and wind infrastructure and R&D as well as the introduction of the study's new carbon credit trading system. The long-term suggests the continuation of efforts and the addition of other renewables, ultimately to achieve an energy production portfolio comprised of 50% renewable energies by 2050. To conclude, the thesis recognizes potential drawbacks and identifies possible directions for future research.

1. Introduction

This thesis aims to develop a framework that outlines the transition of the United States energy industry from a traditional to a more renewable model. Due to the differences in regional energy networks in the US, this thesis focuses on West Virginia since it is one of the biggest energy producing and polluting states in the United States (Energy Information Administration eia.gov, 2014,2015) and presents a lot of similarities with other large producing and polluting regions in the United States, such as the surrounding Appalachian Region. A small-scale survey (Appendix C) was conducted to provide insight on the views of West Virginia energy companies on the future landscape of the US energy industry. The study explores the United States in general because of its exemplary role on a global scale and the likelihood that other countries will follow if the above-mentioned strategy were to be successfully implemented in the United States.

Throughout this thesis, concepts and ideas will be used and combined such as the Danish Initiative, the Carbon Credit System, and several forms of alternative energies will be outlined. Following these theoretical background, which goes further in an extensive Literature Review, a methodology section is introduced, demonstrating how this research was conducted and how the results were analyzed. The study concludes with the analysis of these results, giving the reader an overview of the history, current situation and final recommendations, based on concepts and research introduced before, for the challenge that the US energy industry faces, becoming more sustainable.

1.1 The Danish Initiative

Denmark, for the sake of its economy, has always had to rely on other countries to import its energy supply. Rüdiger (2014), in his study on Denmark's energy supply pre- and post-oil crisis, explains Denmark's situation before the 1973 Oil Crisis: "Growing consumption was a common feature of the Western countries, but the potential to meet demands differed between countries with their own energy resources and countries that had to import them. Denmark belonged in the latter category" (p. 94). Because the country had no natural resources that could be used for energy, it had to heavily rely on others. During 1973, the Arab Organization of Oil Producing Countries (OAPEC) decided to limit its production of oil in order to drive up prices. In doing so, OAPEC targeted certain countries to economically damage them for various reasons: "OAPEC launched an embargo against the United States and the Netherlands because of the two countries' support of Israel during the war" (Rüdiger, 2014, p. 100). Because many countries depended on oil coming from OAPEC, large economic impacts of the supply cut were endured. OAPEC decided to cut supply to Denmark for political reasons explained by Rüdiger: "Although Denmark wholeheartedly supported Israel, the country was initially not on the embargo list. However, the country was just about to find itself on the list when, at a closed meeting in November 1973…Prime Minister Anker Jørgensen commented that the Arab policy was actually a desire to drive Israel into the sea. His statement was leaked to the press, and the Arab countries immediately threatened to embargo Denmark…The embargo was lifted on March 18^{th}, 1974. The high prices turned out to be long-lasting, however, and had a great impact on Western countries" (Rüdiger, 2014, p. 100-101).

This threat triggered an immediate response by the Danish government. The country had to plan for the worst: not receiving oil at a suitable price and accounting for major ramifications to its economy. When OAPEC made this threat, it highlighted Denmark's reliance on others for energy and, by holding Denmark hostage for six months longer than countries like the United States, they were making an example out of Denmark. In return, the country immediately began implementing policies and measures to devise a solution to this supply insecurity. In doing so, the country devised a new multifaceted design, consisting of renewable forms of energy, ultimately allowing it to become more energy independent. This paper identifies this design as The Danish Initiative.

It is important to assess the percentage of renewable for both the United States and Denmark as to be able to better compare the two countries. According to a recent report on Denmark's Energy and Climate Outlook for 2017, "the renewable share of final energy consumption will reach 40% in 2020" (Rüdiger, 2014, p. 7). Meanwhile for 2016, according to the US EIA, "renewable energy sources provided 15% of US electricity" (EIA, 2016). Taking these into consideration, it is also important to recognize how much each country depends on fossil fuels and how each country responds to spikes in oil prices.

From the oil embargo, the Danish Initiative was produced. This model outlines policies and actions that serve as an exemplary model for other countries and regions to follow in making the transition towards the use of renewable energies rather than fossil fuels. A report by the Danish Energy Agency outlines some of the positive features of the Danish Energy Model. One of which is the reduction of greenhouse gases: "Denmark has reduced the adjusted greenhouse gas emissions by more than 30% since 1990. With current measures in place, the Danish Energy Agency estimates that emissions will be approximately 40% lower by 2020—surpassing Denmark's legally binding EU commitment of 34%" (DEA). Because Denmark, a country that is relatively small when compared with the United States, was able to become more ecofriendly and eliminate its dependence on other countries for energy, then the United States and other countries should be capable to follow a similar process, because of similarities which are discussed further on in this paper.

1.2 The Carbon Credit System

Another important system to consider, besides The Danish Initiative, is the Carbon Credit System. Basically, this system allows countries and companies to buy greenhouse gas emission rights from each other (Rinkesh, 2017). “Carbon credits are developed from land conservation and renewable energy projects which reduce the amount of carbon dioxide (CO_2) – or “greenhouse gas” – released into the air or remove existing CO_2 from the air” (National Indian Carbon Coalition, 2015). Companies will often purchase carbon credits to offset their own CO_2 emissions, and this is something that can apply to other countries as well. Since the current situation in the US is not 100% energy neutral and it is widely understood that it will take time for the US to transition to renewable energy sources, a system like this one offers the possibility to make the transition smoother and see more short-term effects. Moreover, if the US develops a more advanced system for rewarding eco-positive behavior, it will encourage a smoother transition. This “artificial manipulation” of US emissions could push the transition towards a sustainable energy industry faster and provide a positive impact on the overall economy. The current market value of the carbon trading is valued currently well over 100 billion USD and is estimated to grow to $ 1 trillion in the coming decade (GreenChipStocks, 2017). This study explores the system deeper and evaluates how a tailored version of the Carbon Credit System could help the transition of the US energy industry.

Many countries and energy companies are becoming involved in carbon markets to benefit from both an environmental and economic standpoint. Many countries are currently involved in the carbon market: “at a national level legislated emissions trading schemes (ETSs) exist in the European Union, Switzerland, New Zealand, Australia, South Korea, and Kazakhstan. Some subnational schemes are legislated in the US, Canada, and Japan” (Talberg &

Swoboda, 2013). The more countries involved in the carbon market, the more sustainable our planet will remain. Moreover, the United States, the world's biggest carbon emitter, pledged in 2015 to start a carbon market in 2017 to help it cap emissions by about 2030" (Bloomberg, 2017). Although the United States as a nation is not involved in legislated emission trading schemes, some states and companies are involved.

However, there are still some flaws in this system. The first problem confronted at the beginning, is how to allocate the carbon credits fairly among participating countries and companies (Gray & Metcalf, 2017). Secondly, it still lacks a monitoring and managing system, resulting in illegal transactions and fewer environmental effects on pollution (Gray & Metcalf, 2017). Last but not least, the motivation for those who pollute more is weak (Wara, 2007). High-polluting companies have large possibilities to choose to keep their current situation as they have enough credits to pollute instead of decreasing pollution, since investments in infrastructure and operations leading to decreased pollution often come at a higher cost than purchasing carbon credits (Wara, 2007). Even though there are still some drawbacks, the essence of the carbon credit trading system could contribute to the US energy industry transition.

1.3 Why the United States as Research Subject?

The United States of America was chosen due to a combination of several considerations and implications that the outcome of this study hopes to provide. An overview of the three biggest reasons can be found below.

First, the current energy landscape in the US is the main reason why the United States is a good research subject. Renewable energy sources currently provide just 15 % of US electricity, which illustrates that there is much room for improvement. On the contrary, about 65% of the United States energy production is still generated using fossil fuels (eia.gov, 2017). Finally, the remaining 20% is generated by nuclear power. The United States is also responsible for 14.36% of global carbon emissions (Friedrich, Ge & Pickens, 2017) and about 18% of the world's energy consumption (eia.gov, 2017).

Secondly, it is important to analyze the United States, its role in the global ecosystem, and the possible influence it has all over the world. The United States economy is the world's largest economy (Riley & Sherman, 2017). This, combined with the notion that many studies have researched and proven, concludes that the United States is in fact the world's leader (Weickgenant, 2017) and implies very heavily that a significant change in the United States will not only have a national impact, but an international one as well. This international influence produces a ripple effect – "The continuing and spreading results of an event or action" (Oxford University Press, 2017) – and leads us to believe that the United States has an exemplary role in regards to the rest of the world. A change in the US is likely to lead to a global change, and that is why this study proposes a viable framework for the US that leads to a sustainable energy industry.

Thirdly, the US is a very interesting research subject as it is the only major economy in the world that has not signed the international climate agreement. Whereas China for example, currently the world's second largest economy next to the US, has signed this and is making great effort into moving towards sustainable energy sources.

Finally, there are important similarities between Denmark and the United States that increases the possibility of creating a sustainable energy framework that is viable in the United States, based on The Danish Initiative. There are many similarities to be found, but this study focuses on those relevant in regards to the energy industry. Researchers per 1000 employees: 11 (Denmark) vs. 10 (US) (Bruenig, 2015); time required to start a business in days: 5,5 (Denmark) vs. 5 (US) (NationMaster, 2017); demographic similarities such as dependents to working-age population: 0.51 (Denmark) vs. 0.49 (US) (NationMaster, 2017); literacy grade of total population: 99% (Denmark) vs. 99% (US) (NationMaster, 2017); life expectancy: 78,6 years (Denmark) vs. 78,4 years (US) (NationMaster, 2017); GDP per capita: $56,210 (Denmark) vs. $49,965 (US) (NationMaster, 2017), all of the previously mentioned similarities show the relationship between the culture and economy of Denmark and the United States. Although above-mentioned similarities are significant, we must point out that there are many differences between the US and Denmark as well, going from cultural and demographical to economical.

Should the US, with both similarities and differences to the country of Denmark, is successful in leading by example and demonstrating its influential role, the impact will be recognized and felt on a global scale, all of which makes the US an ideal and relevant research subject.

1.4 West Virginia as Exemplary Region in The United States

Currently, West Virginia has an insignificant amount of renewable energy. For centuries, the state has relied on coal to drive its economy. The EIA found that “less than 5% of West Virginia’s electricity generation comes from renewable resources” (EIA, 2015). If the state implements more renewables, the impacts would be far greater than just noticeable in West Virginia alone.

The United States must decide on some of the most viable regions to implement renewable energy. In a utopian situation, it would be most logical to have different renewables in different regions of the country and transfer those forms of energy to different locations when needed. Unfortunately, it is not that simple, because to do this efficiently a nationwide-sized infrastructure network is required.

It would be reasonable to pick a state, such as West Virginia which is currently still highly reliant on traditional energy sources, that should start transitioning towards renewable energy. If West Virginia follows a course of action to make this transition, the surrounding areas would also benefit. Other states that border West Virginia would reap some benefits and, hopefully in return, would follow a similar procedure. However, many factors play into the decision of which state or states.

When renewables replace traditional forms of energy, the environmental, social, and economic impacts differ by region. For example, a study on the benefits of renewables in different regions explains that, “a wind turbine in West Virginia displaces twice as much carbon dioxide as the same turbine in California…the sites with the highest energy output do not yield the greatest social benefits in many cases” (Siler-Evans, et al, 2013). Therefore, it is necessary for the United States to make plans for a state and then a region that would have the largest impact and serve as a model for other states and regions.

Thus, it appears as though West Virginia is a viable location to begin making more efforts towards reliance on renewable energy. West Virginia relies heavily on fossil fuels; according to the United States Energy Information Administration (2016), West Virginia is among the top three states in the nation in recoverable coal reserves at producing mines, and the state accounts for more than one-tenth of the nation’s coal production. West Virginia supplies a significant amount of fossil fuels to the rest of the United States and to other countries. In doing so, it is causing large amounts of environmental damage and is a major player upholding the country’s reliance of conventional forms of energy.

But the harmful effects of West Virginia’s production do not remain in that state alone. Instead, the impacts are interconnected throughout the United States and even into other countries: “About three-fourths of West Virginia’s mined coal is shipped out of state, mostly to almost two dozen other states, but also to other countries. The rest is used in state. In addition to the coal that stays in West Virginia, coal arrives from states in the surrounding Appalachian region…Almost all the coal consumed in or shipped from West Virginia goes to the electric power sector” (EIA, 2015). The reliance of West Virginia and the areas that use the coal produced from West Virginia further inhibit the incentive for renewable energy. However, if renewable energy sources were implemented, the benefits would resonate far further than just the borders of West Virginia.

Moreover, although West Virginia does not have land that touches the water, some of the surrounding states do. In return for coal, these states could provide West Virginia with land to implement alternative renewable sources of energy. Moreover, the high mountainous terrain could be further utilized if the overall sentiment of renewable energy were more accepted by West Virginians. We believe this to be one of the greater challenges of West Virginia; because of its long traditional history and economic dependence on coal, West Virginia is engrained with the idea that coal is a positive source of energy and coal is tied to their identity (Carfagno, 2018, Appendix D).

When President Trump visited Charleston, West Virginia to give an election speech, thousands of West Virginians held pro-coal signs that read “Trump Digs Coal.” After he won the election, at the annual meeting of the West Virginia Coal Association a party was held were people “mingled with a lightness that would have been unthinkable just a year before” (Worland, 2017). After years of decline, coal is back and many would think that with it are thousands of jobs in the coal industry. But to many, this is a false sentiment: “it’s a disservice to coal-mining communities to tell them they will have a mighty comeback,” says Ted Boettner, the executive director of the West Virginia Centre on Budget & Policy (Worland, 2017). Other government figures in West Virginia are beginning to look past this false sentiment that coal will bring a lot of jobs and positive economic impacts: Governor Jim Justice, a wealthy man who built his wealth on the coal industry and grew up in West Virginia, "skipped the industry conference…instead he sent his chief of staff to deliver a dose of reality: a budget proposal for a slew of new fees, including a potential tax increase on coal companies" (Worland, 2017). In the past, West Virginians seem to have a strong sentiment towards coal. Now, it seems as though there is a large shift. Further data on justification for West Virginia as exemplary region can be found in Appendix B, where energy production potential for wind and solar energy is given, as well as general energy production data about the US domestic energy industry.

1.5 An Overview of Possible Sustainable Energy Sources for West Virginia

1.5.1 Wind Energy. According to the American Wind Energy Association, "The US generated more wind power than any other country last year, finishing 2015 with 74 gigawatts of installed capacity" (Unger, 2016). In March of 2017, the US set a new renewable energy milestone: "wind and solar accounted for 10 percent of all electricity generation, with wind comprising 8 percent and solar coming in at 2 percent" (EIA). There are certain states that have been increasing their wind and solar production because of how well certain renewables do in certain regions: "Texas generated more wind and solar energy than any other state, nearly all of which came from wind" (EIA). Moreover, according to the American Wind Energy Association, there are "41 US states with operating utility-scale wind energy projects" one of which is West Virginia. During 2015, according to data released by the Global Wind Energy Council (GWEC) and by the US EIA, "over 31 percent of Iowa's in-state electricity generation came from wind last year" (Vaughan & Kelley, (AWEA)). If the United States continues to lead in wind energy production, it can have a competitive advantage and lead the way for other countries. Today, out of all the energy consumed by the United States, “wind power provides 1.9 percent,” but in 2015, “wind power accounted for 4.7 percent of all electricity generated in the US” (IER).

Unfortunately, not every state is viable for wind energy production and “for comparison purposes, and taking into account capacity, the land area covered by wind power station of the same energy output as a nuclear power station would be about 2,000 times as great” (IER). Because of tax credits and other government subsidies, “more than half the states have renewable portfolio standards requiring a certain percentage of their electricity to be generated from qualified renewable energy technologies. These standards have helped develop onshore wind energy as it is the least expensive qualifying renewable technology” (IER). Wind energy is an option for West Virginia, thanks to its mountainous and hilly landscape, which creates large wind drafts in the valleys and can catch large winds on altitude.

1.5.2 Solar Energy. As the world continues to warm up from pollution, the need for alternative clean energy becomes increasingly important. Solar energy is among one of the more popular forms of energy that is gaining popularity in the United States. Even with increasing implementation of solar energy, more should be done and at a rapid rate. Jessika Trancik, a professor of engineering systems at Massachusetts Institute of Technology, believes “there’s no question solar has…huge potential to contribute to meeting climate change goals. But it’s still an open question as to whether it will get there” (Unger, 2016). It is important to recognize the need to transition to cleaner energy. The United States has been making progress: “The US hit 1 million solar installations at the end of February, amounting to roughly 27.2 gigawatts of solar power capacity” (Solar Energy Industries Association (Unger 2016)). It is important to put this number into perspective and realize that “there were 285 gigawatts of coal capacity in the US at the end of 2015" (American Coalition for Clean Coal Electricity (Unger 2016)). The International Energy Agency projects the US could install 305 gigawatts of solar by 2030 and 737 gigawatts by 2050. This would put the US well over the amount of capacity of coal left and would be a remarkable accomplishment. On a year to year basis: "That's more than a 1,000 percent increase over 14 years from today. This would require that the US install an average of roughly 20 gigawatts of new solar capacity each year between now and 2030. By comparison, the US added 7.3 gigawatts of new solar power last year, and that was a record" (Unger 2016). However, the viability and legitimacy of these numbers is also equally important to understand. Cédric Philibert, author of the IEA report, comments "I don't think it's realistic" and the outlook became much rosier, Philibert and other experts said, when Congress extended an important solar tax credit at the end of last year. That extension will result in more than 50 percent net growth in solar installation from 2016 to 2020, according to Greentech Media (GTM) Research (Unger 2016). More should be done in the US to more towards a more sustainable country. A national target for solar does not exist, and the last unsuccessful attempt was in 2009. Instead, individual states are left to set their own targets.

1.5.3 Hydropower. Hydropower is one of the oldest sources to produce mechanical and electrical energy, and has been used for thousands of years by humans (eia.gov, 2017). In essence, energy is generated by taking advantage of gravity and the water cycle (Union of Concerned Scientists, 2017). To understand hydropower, one must first understand the water cycle to comprehend that water is always moving, thus leading to a great opportunity for extracting energy. The water cycle has three steps (eia.gov, 2017):

- Water on the surface of rivers, lakes, and oceans is heated up and evaporated by solar energy.

- Water vapor condenses into clouds and falls as precipitation (rain, snow, etc.).
- Precipitation collects in streams and rivers, which empty into lakes and oceans where it evaporates and the cycle starts again (Appendix H).

To generate electricity from the kinetic energy in moving water, the water moves with sufficient speed and volume to spin a turbine – a propeller like device – which rotates a generator to generate electricity (Appendix H). One gallon of water per second falling one hundred feet can generate one kilowatt of electricity (Union of Concerned Scientists, 2017). This kinetic energy from water is mostly extracted through dams, but the process can also be done without a dam. Seasonal variations and long-term changes in precipitation patterns, such as droughts, have a big impact on hydropower production and are possible drawbacks (eia.gov, 2017). Another drawback is the fact that although the generation of hydropower does not emit air pollution or greenhouse gas emissions, blocking rivers with dams can have negative environmental consequences such as degrading water quality, damaging aquatic habitat, blocking migratory fish passage or displace local communities (Union of Concerned Scientists, 2017).

Hydropower in the United States is the largest renewable energy source together with win energy. In 2016, it accounted for 6.5% of total US utility-scale electricity generation and 44% of total utility-scale electricity generation from all renewable energy (eia.gov, 2017). One important drawback of hydropower is that it is already a very established form of energy. It has been significantly around for decades now, but not claiming an increasing part of energy production (EIA.gov, 2018). This is mainly because of two reasons, firstly there is a limited amount of locations that provide the necessary natural circumstances to install an efficient hydropower plant. Secondly, hydropower infrastructure is naturally very big (dams for example), and hard and expensive to replace, renew or update with the latest technology.

1.5.4 Nuclear Energy. As another alternative choice for coal, nuclear power is quite popular. Nuclear power is not the best choice for the substitution of traditional energies, even though it is feasible and efficient. It uses a nuclear reaction by splitting atoms of certain elements to release energy and provide electricity. The core part of this process lies within the nuclear reactor. There are different types (Appendix I) but there are 7 main components: fuel, moderator, control rods, coolant, pressure tubes, steam generator and containment. In a nuclear reactor, the released energy from the fission of atoms is transferred to heat producing steam to produce electricity. Based on the information from World Nuclear Association, nearly 85% of the world's nuclear electricity comes from the same reactor design that evolved from the design of submarines and large ships.

According to the data from IAEA (International Atomic Energy Agency), in 2012, 10.8% of the world's electricity was produced by nuclear power. The US is the world's largest nuclear electricity producer making up more than 30% of the total nuclear electricity (Appendix I). The US has 99 reactors allocated in 30 states and operated by 30 different energy companies. The remaining two reactors are owned by construction companies.

The reasons why nuclear power is often proposed as an alternative to traditional energy are as followed: (1) There is an increasing electricity need of by the world to substitute traditional energy, such as fossil fuels, and to meet future expectations. (2) Nuclear power reactors can produce electricity at a 91% efficiency rate 24/7 all while emitting zero greenhouse gases. (3) Compared to other renewable energies, modern nuclear plants can generate electricity for four cents per kilowatt hour. (4) The raw material—uranium—is an element that is energy-rich and could generate a huge amount of electricity with just a fingertip. (5) The US has competitive advantages in nuclear power because of its advanced technologies, rich experience, mature market mechanisms (relative to other countries), supportive policies from government, etc. (6) Nuclear helps the US to save around $12 billion in energy costs.

There are some factors that impede the feasibility of operating nuclear energy plants in West Virginia. Firstly, there is currently no nuclear plant in West Virginia because it is required to obtain a license from NRC (The Nuclear Regulatory Commission). Due to its capital-intensive characteristics, it would be very costly at the beginning and long-term construction along with a decrease attraction of investors. Secondly, nuclear power is still controversial in society because of its lack of confidence in security. Finally, quite a lot of nuclear power plants are coal-fired. Therefore, these plants still pollute the environment and harm people's lives. Although nuclear energy is a common substitute for oil, coal and gas, this study does not believe it fits in a sustainable transition framework.

1.6 Research Objectives

The main research objective of this paper is to make the United States as a whole more sustainable by focusing on the energy industry—in particular, the states with the largest dependency on traditional energy sources. To do so, this paper offers a framework for transition based on theoretical analysis and research.

Transitioning towards a more sustainable energy industry is a different concept for every country and state, since they each start at a different starting point. Since a state like California cannot be compared with a state like West Virginia in terms of progress that still needs to be made, we introduce the concept of a *"sustainability date"*. This study focuses on developing a framework for states with a high dependency on traditional energy sources (coal in particular) to define the sustainability date or "the date on which 50% or more of energy production in that state is from renewable energy sources." Since certain other states might have already exceeded the point of 50%, the sustainability date is a rather flexible concept, representing the goal that a certain percentage of energy production is coming from renewables by a certain date. Each state and country have a different sustainability date, depending on their starting point and potential progress to be made in the future. Calculating West Virginia's sustainability date is one of the main objectives of this paper, as well as backing this calculation with proficient data and research.

The second main objective of this thesis is to raise the awareness of the issues surrounding climate change and demonstrate just one of the many different and necessary solutions without destroying or losing significant economic value in the process.

2. Literature Review

We conducted a preliminary literature review focusing on four categories: The Evolution of the US energy transition, the Danish Initiative, the Carbon Credits System and Relevant Traditional & Non-Traditional Energy Sources. Multiple literatures describing the evolution of the United States energy transition point out the past failed trials, current situation, and future obstacles hindering the process. The Danish Initiative section discusses the achievement of the Danish energy transition and the reasons why they were successful, while also discussing the difficulties for further transition. Thirdly, the literature review refers to carbon credits and introduces the development and practice of the carbon credit system along with potential drawbacks. Finally, the last subset introduces main renewable energies used to substitute current energies as well as nuclear energy.

2.1 Evolution of US Energy Transition

The transition of an energy industry usually takes a substantial amount of time and the transition of the one in the United States is still in progress. Although the United States made a plan that shifted towards a hydrogen-driven society from 1979 to 2007 (Lattin & Utgikar, 2007), the United States energy industry is still dominated by three major fossil fuels – petroleum, natural gas and coal – which accounted for more than 78% of overall energy production, according to the data from US Energy Information Administration.

The following economic and social factors that hinder the transition include, but are not limited to: environmental concerns, changing patterns of energy end-use, and constraints on petroleum supply (O'Connor & Cleveland, 2014). Moreover, when compared to countries such as Sweden, Netherlands, Italy, Spain and England, the United States' energy intensity is relatively high despite a declining trend decreasing from 90 MJ per $1999 (PPP) to 20 MJ from

1780 to 2010 (O'Connor & Cleveland, 2014). Though the amount of renewable resources in US is abundant, issues of dispatch ability, variability, scalability, energy storage, geographic limitations, and investment costs are critical in determining future progress (Tran & Smith, 2017). The United States government has announced a series of policies to establish a green portfolio for the energy system that eliminates carbon dioxide emission and encourages the usage of renewable energies. However, polices have and continue to change overtime. Changing perceptions about the availability of renewable versus non-renewable energy supplies add to the slow transition. Socially constructed deliberation takes place over the purposes of a new energy policy; moreover, physical constraints in natural resources are also observed and processed into updated perceptions of relative feasibility among policy choices (Shum, 2015). If these problems are resolved, a transition in the US energy industry could have exemplary effects for other countries (Dima & Dima, 2017).

Despite inconsistent and frequently changed policies about different energies, there is an increasing trend in the US energy transition that favors the development of renewable energies; governance of the energy industry evolves from the central government to local governments, even to customers (Tomain, 2016). It is urgent that the US handles the uncertain factors, such as changed policies, to stabilize or accelerate the speed of the energy transition.

2.2 The Danish Initiative

Since the first oil crisis, Denmark has been gradually moving towards renewable energy and the optimization of production, usage, and overall management (Parajuli, 2012) to become the pioneer in energy transition. Denmark first began to change their energy system from traditional to renewable in the 1960s. While doing so, they set two goals: by 2030, 50% of the energy supply should come from renewable energy and by 2050, 100% should be sourced from renewables. Denmark proves that a country can achieve an energy transformation in a relatively short amount of time (Sovacool, 2013). The Danish wind energy model, which integrates wind energy into the national electricity grid portfolio, demonstrates its unique characteristics and is regarded as a success. It offers policymakers an opportunity to imitate such aspects as a strong political commitment, consistent policy mechanisms, and an incremental "hands-on" approach to R&D (Sovacool, Lindboe & Odgaard, 2008). Among all the initiatives contributing to a smooth transition, several studies from different scholars (Mendonça, Lacey & Hvelplund, 2009) (Lund, 2010) (Hvelplund, Østergaard & Meyer, 2017) emphasize the local acceptance and stress the importance of public awareness. The main issues revolve around motivating the public to adopt and contribute to a new energy system. The study from Andreasen & Sovacool in 2014 raises further consequences regarding stakeholder conflicts during the transition. However, according to an evolutionary economics perspective, these conflicts contain not only negative effects but also a chance for positive technical developments. In order to solve this issue, it proposes a new solution: an "innovative democracy system" (Peter Andreasen & Sovacool, 2014). The Danish government plays a significant role in promoting the transition. Some studies emphasize on the importance of coordination between the central government and municipals to raise the balance of centralization and decentralization; they believe that in order to reach the goal of a 100% renewable energy structure, it is necessary to align the national goals with the local governments to form a consensus (Sperling, Hvelplund & Mathiesen, 2011). As Dr. Carfagno told during the expert interview (Appendix D), the people received a stake in the newly built wind turbines. This preserved a "Not in My Backyard" movement of starting up. While some articles doubt the liberalization of the energy market (Meyer, 2004), others illustrate the reality that competitive markets make the transition more smoothly.

However, there still exist some obstacles that slow down the process such as the integration of different energy systems, supply security, flexibility of energy sources, etc. Lessons from energy policies of Denmark could be used for reference in the United States energy transition (Sovacool, 2013).

2.3 Development of Carbon Credit System

Another popular method for shifting non-renewable energies to renewable is to limit carbon emission. This can be artificially achieved by the carbon credit trading system.

Historically, countries also used this system to meet the requirements outlined and regulated by the Kyoto Protocol. The carbon credit system aims to decrease the GHG (Greenhouse Gases) and mitigate the harmful influences of the emissions related to climate change. The carbon credit trading system creates a new purchasing power that did not exist before in two types of markets: compliance and verified market credits. This system is similar to the process in which a bank creates dollar credits in the form of a currency to facilitate commerce between people. Normally, carbon credits will be assigned at a fixed amount to countries based on their previous emission data. Governments use the carbon credit system to allow companies to adopt new perspectives and actions necessary to preserve rainforests, transform energy infrastructure, and promote low-carbon technologies (Mathews, 2008). Carbon credit trading has already been illustrated to be efficient across the gasoline and diesel fuel markets. It can lower the average costs of carbon reductions by up to 98%, depending on forecasts of biofuel suppliers and carbon intensities (Rubin & Leiby, 2013). It helps to create a safe market for new technology in low-carbon energy (Wara, 2007).

Nevertheless, there are some important drawbacks to the carbon trading system with regards to the correct allocation and management of credits (Gray & Metcalf, 2017). Because credits are distributed based on past emissions, the system is somewhat flawed. To begin, companies might be motivated to keep their current emissions low enough to keep credits for more emission in the future. Furthermore, the current carbon credit system is politically oriented because it mitigates the influence of environmental goals and green economic growth. In other words, the system is still sufficient. According to Wara's study in 2007, the global carbon market is a very insufficient subsidy. Wara also believes developing countries are the key factor for an effective system. Some argue as well that the system of carbon credits holds developing countries back in terms of their own industrial development, because their emissions get bought by developed countries (Winterhalder, 2018, Appendix D), thus having a negative overall influence on the economy.

Although there are some negative aspects about carbon trading, some essential and effective parts could be extracted and emphasized to help motivate the US energy transition.

2.4 Relevant Traditional & Non-Traditional Energy Sources

Transitioning to a completely renewable society takes a long time and needs a step-by-step progress, which means the process will be divided into several stages. Each stage will have different focuses and goals. Because renewable energies have some limits and require the lengthy building of infrastructures, it is necessary to produce an energy mix scheme as well as a back-up plan for any possible sudden problems. After examining current energy transitions all over the world, such as Germany, China, South Korea, Switzerland, etc., it is clear that each have used nuclear energy as an interim choice and a backup source when renewable energies do not work as well. Wind and solar energies are the most popular types for renewable choices because they are stable, abundant, less expensive, and consist of more mature technology (Kannan & Turton, 2016; Chung & Kim, 2018; Guidolin & Guseo, 2016).

2.4.1 Nuclear Energy. Nuclear energy is one of the most important global energy supplies that meets more than 12% of global electricity needs (IEA, 2015). It is regarded as a possible solution for sustainability given the worldwide increasing demand for energy, its production capacity, mature technology, and low carbon emission for operation (Grandin, Jagers & Kullander, 2010). Through de-carbonization, it helps to improve the disturbances of climate changes and stops the globe from warming at 2℃ above pre-industrial levels to ensure the stability of the Earth (Fawcett et al., 2015). Nuclear energy is usually used at the beginning of a transition as a mitigation tool to make the transition smoother and more sustainable in the short-term (Gralla, Abson, Møller, Lang & von Wehrden, 2017). However, there is a serious downside of nuclear energy because of safety issues and the radioactive wastes it creates. Even though current technology usually guarantees that power plants are safe by having internal mechanisms to stop radioactive release from escaping from the infrastructure (Högberg, 2013), several accidents still occurred in the past decades including the famous Chernobyl accident (1986) and Fukushima Daiichi accident (2011) which resulted in thousands of deaths and a destroying impact on the environment. Another disadvantage stems from the waste that is produced. The waste is highly radioactive and cannot be easily or safely stored and will remain radioactive on this planet for up to one hundred thousand years (Horvath & Rachlew, 2015).

With the exception of recent years, nuclear power plant constructions have been stagnant for many years in the United States. However, due to an increasing demand of energy and new and improved technology, several large reactors have been constructed in the country. Compared to large reactors, small modular reactors have advantages in cost efficiency, safety, and economic value. Therefore, these reactors have been adopted and are expected to be broadly advocated for in the future (Vegel & Quinn, 2017). In the short-term, nuclear energy has the potential to play a critical role in the transition to a low-carbon society. In the long-term, it also has the potential to smooth the transition to a renewable dominated energy society as the United States continues to build more nuclear power plants.

2.4.2 Wind Energy. Wind energy has been illustrated among several European countries such as Denmark, Germany, Netherlands, etc. to be successful in the efficiency of electricity transformation, safety, and ease degree of integration to current energy structures (Sovacool, Lindboe & Odgaard, 2008). Its technology is mature enough so that the cost will be lower than other alternatives in R&D (Hvelplund, Østergaard & Meyer, 2017). According to the statistics from Global Wind Energy Council, it was not until 2015 that there were more than 430 gigawatts of wind energy being produced all over the world and 60% of this is coming from Europe, led by Germany, Spain, and Denmark. Other major investors consist of China, the United States, India, and Japan. In 2020, experts predict that 12% of the world's energy supply and 20% of Europe's energy consumption will come from wind. Compared to traditional energies, wind energy is the most economically viable and rapidly developing renewable energy with the well-known advantages of zero carbon emission during operation, zero loss of resources, increasing local employment, wide application possibilities (from industries to households or from agriculture to high-tech), improvement of power grids, easy and less expensive construction and etc. which enabled it to become the most popular substitute energy for traditional energies (Köktürk & Tokuç, 2017).

However, there are several limits leading to why wind energy could not be the only source for energy supply for a country. First, it is unstable since wind is not always constant and the intensity is hard to predict; therefore, choosing the right location becomes very important ("Advantages and Disadvantages of Wind Energy - Clean Energy Ideas", 2018). Secondly, the original installation cost is very expensive as its return on investment period is long ("Advantages and Disadvantages of Wind Energy - Clean Energy Ideas", 2018). Thirdly, it threatens the life of wild animals, especially birds and bats which may negatively influence the eco-balance in the local. Next, as is a problem with almost all renewable energy sources, their energy cannot or hardly efficiently be stored. Last but not the least, it creates noise and visual pollution that affects the life quality of people living around the turbines ("Advantages and Disadvantages of Wind Energy - Clean Energy Ideas", 2018).

In previous studies and practices, wind energy in general is a practical and viable choice for energy transition. Currently in the United States, the energy generated by wind counts for 8% of the overall capacity which is more than any other renewable energy (EIA, 2018). Wind energy would be a feasible solution for the United States energy transition.

2.4.3 Solar Energy. Solar energy is also broadly recognized as one of the most feasible alternatives for traditional energies to achieve the goal of a low-carbon society (Saikku et al., 2017). The energy generated by solar can be acquired in a range of methods from large-scale operators to small decentralized actors. The main two technologies of solar electricity are respectively solar photovoltaic (PV) and solar water heaters (SWHs); PV is the more popular of the two (Urban, Wang & Geall, 2018). PV has less geographical restrictions, a larger potential of energy generation, more stable and mature technology in constructing solar power station, and can collect energy more easily (Unger, 2016).

However, there are some constraints that limit the expansion of solar energy. Firstly, only large players can enter the market because of the high initial cost of introducing a solar system. The second limitation is due to the dependence the system has on the weather, inhibiting the possibility of operating every day of the year. To add to the list, the storage expenditure is very expensive as well. Once it is produced, it has to be used immediately or stored in large batteries with capacities that are currently in development to become more sufficient. Lastly, the transportation and construction of solar energy emits greenhouse gases that offset the part it saves (“Advantages & Disadvantages of Solar Energy (2018) | GreenMatch”, 2018).

Solar is one of the most popular renewable energies in the United States, and even though there is no national plan of the United States, several states make some progress in achieving their goals on solar energy (Unger, 2016). Policy changes, such as increasing tariffs on the importing solar panels, hinder the development of solar energy in United States. However, as an important alternative, the United States will develop more solar plants in the future.

Climate change and sustainability problems point out serious issues for all countries. The United States, a large leading country, needs to adopt changes and devise plans to contribute to the solution. On the one hand, it is an urgent issue for the US and other countries to promote the energy transition and take responsibility for serious climate changes; on the other hand, the US lacks a complete overall framework to guide the country’s energy transition. Although some states have implemented policies or stated future goals to become more sustainable, no region of the country has collectively designed a framework to guide this transition. This is particularly important because many of the states that neighbor one another import and export energy across their borders; therefore, the more states in a particular region that follow similar plans for sustainability, the more efficient and on-page those regions will be and the smoother the transition will be for the country as a whole. Finally, there is no study that combines both the Danish Initiative and the Carbon Credit Trading System to orchestrate a change. Based on this, this paper creates a customized framework designed for a specific area of the United States that produces a majority of non-renewable energy to ultimately guide the country towards a renewable energy industry.

3. Methodology

The aim of this thesis is to conclude with a framework to help transition the United States towards a more sustainable energy industry; to accomplish this goal, the research is divided in three main parts. This paper has been built up in the following order to ensure a logical flow of information for the reader.

3.1 Theoretical Analysis & Case Studies

The thesis starts off with the theoretical analysis of main concepts and case studies around these topics. These concepts include the Danish Initiative, the Carbon Credit System, and the history of the energy transition in the US. This theoretical analysis is required to set the stage around sustainable theories and concepts on which the paper builds further upon and is divided between the Introduction and the Literature Review. A reference to which literature was consulted for this Literature Review can be found in the Literature Tree in Appendix A.

3.2 Research

Besides the theoretical research and analysis, we also include new research, consisting of data collected through both interviews with energy companies in and around West Virginia (Appendix C), as well as with industry experts (Appendix D). Surprisingly, we experienced a fairly high response rate for the interviews with traditional energy companies in the region. They do wish to remain anonymous and unpublished. This data collection is analyzed in section 4, where survey results and findings can be found.

Secondly, the expert interviews included were conducted with two experts in the field of sustainable energy. The first is Dr. Kerrie Carfagno, an American professor at the University of Virginia with extensive experience in renewable energy research. Each year she leads a trip to Denmark for her undergraduate students, making her the ideal source of information to compare the United States energy industry and the Danish Initiative. The other expert that we interviewed is Dr. Francisco Lozano Winterhalder who teaches Social Sciences at ESADE Business School. Besides being our tutor, Dr. Winterhalder is also an expert in the field of renewable energy and sustainability.

3.3 Analysis + Framework

Based on the above-mentioned research and analysis, this study provides a transitional framework for the US energy industry. The simplified framework can be seen in visual form in section 5.1, and consists of two main parts: a short-term and a long-term approach. We recognize that there is need for a different approach on short- and long-term, since both feasibility and objectives in these periods will be different. After developing a guidance system for both periods, the study also notes possible drawbacks and obstacles.

For the short-term approach, the study analyzes the current production and consumption of West Virginia to provide data on how much energy actually needs to be replaced by sustainable alternatives. After this quantity was been determined, we included sustainable options such as solar, wind, and nuclear energy with explanations as to what extent each one could provide solutions for the short-term. Moreover, we take into account investment price, implementation time, and possible energy production. An important role for the short-term is also assigned to the government, since research shows that they have the power to make a large impact in little time. Because of this, the paper proposes several actions the government could take and introduces a new “credit” system – based on the original carbon credit system – to regulate emissions better and support the transition towards a sustainable energy industry. Following this analysis, we make a calculation to predict the time in which a certain percentage of the energy portfolio will consist of renewable energies that keep the country on track to becoming sustainable together with some short-term predictions.

For the long-term, the study begins by forecasting the required production for the period following the short-term. To do this, we analyze the amount of energy that could feasibly be offset by solar and wind energy by taking into account their current efficiency as well as possible efficiency increases in the future. As defined in section 1.6, this will lead us to a sustainability date, where the dependence on renewable energy sources will achieve 50% of the total energy portfolio. Both an aspirational and (predicted) actual sustainability date will be introduced and supported by data.

The last part of the analysis focuses on possible drawbacks and obstacles these two frameworks might encounter. The study looks closer at the importance of politics and the government, technological barriers and opportunities, and the need for an optimal transition rate, the rate at which the United States makes the transition with the least damaging effects to the economy.

4. Research Findings & Results

The thesis interviews two professors who have done lots of research in sustainability and related topics. As stated earlier, we also distributed surveys to energy companies in and around West Virginia with questions regarding their attitudes towards a renewable energy transition, current investment in renewables, possible incentives they would accept to change and etc. In the end, we received fourteen responses, each of which wished that their names remained confidential. Some of these companies together contribute to the production of more than half the energy supply in the state of West Virginia. In this section, the findings and results are described. Although the respondents wish to remain anonymous, the quality of the answers does provide meaningful insights.

4.1 Expert Interviews

The expert interviews were conducted related to three dimensions of the overall framework – the Danish Model, Carbon Credit System, and opinions on the US energy transition. Detailed information of the interviews can be found in Appendix D.

Both of the professors believe that the Danish model could be regarded as a successful example for rest of the world. Specifically, Dr. Carfagno believes the Danish model "is a good example of how other companies and countries can alter their energy use. They did it in a slow and logical way, which is key." Dr. Winterhalder, on the other hand, pointed out the extraordinary outcomes the Danish made: more than 50% of current energy production is from wind although the country only aimed at reaching 100% by 2050. In summary, both interviews pointed to factors that motivated the Danish transition. These are as follows: 1) social pressure pushes that help to guarantee the issue of people buy-in; 2) economic and strategic independence helps to accelerate the whole country to transit; 3) the transition urgently began due to the oil embargo; 4) concentrated and consistent strategies guided the transition to help guarantee the long-term action follows through. However, the experts also believe that there are still some drawbacks of this model. Such drawbacks include but are not limited to the stagnant capacity of wind turbines that require further technology improvement on productivity and efficiency and the high prices caused by high costs and unstable political influences. When providing solutions, it would be practical to follow the practices that proved to be useful and try to avoid bottlenecks Denmark faces now.

Regarding the carbon credit system, both Dr. Carfagno and Dr. Winterhalder hold conservative ideas. Each of them recognize that the original credit system has some flaws such as trade between developed countries and developing countries that limit their original function of decreasing carbon emission. With regards to this system, Dr. Winterhalder points out: “This was, apparently, one important way to motivate rich and poor countries for acting against climate change, but in fact, it is an important reason to delay the economic growth of poor countries and to allow exceeding in terms of emissions, for the rich countries.” To some point, simply integrating the original carbon credit system into the transition framework is not a feasible nor efficient method. Adjustments or redesign of the original carbon credit system could be used as a motivation tool to push the transition forward.

For the US energy transition, the two professors, Carfagno and Winterhalder, noted multiple similarities regarding the trend of countries going renewable. First of all, each believes that the trend is globally spread and that the US transition is in the midst of occurring. The two agree that it is difficult to predict just how long it will take for the transition to be significant. Moreover, the two recognize that the order of actions is also important because a different series of actions in different orders will yield different results. However, they each exhibit concern of the current government led by President Donald Trump and his policy decisions. After all, policies have been seen to revert on energy issues that they promoted the traditional energies. Finally, their other concern deals with the large private players in the market that may be difficult to convince to change due to their large concentration of power.

To summarize, both agree that providing solutions for the US energy transition by means of a combination of the Danish model and a redesigned carbon credit system is a feasible option when considering solely the United States and its unique characteristics.

4.2 Survey

4.2.1 Survey Findings. According to the surveys collected from 14 energy companies in and around West Virginia, there are several findings that help to clearly identify the factors from the traditional energy side that may accelerate or hinder the transition. The findings also help to summarize the problems and determine solutions. Detailed information about these responses can be found in Appendix E and Appendix F.

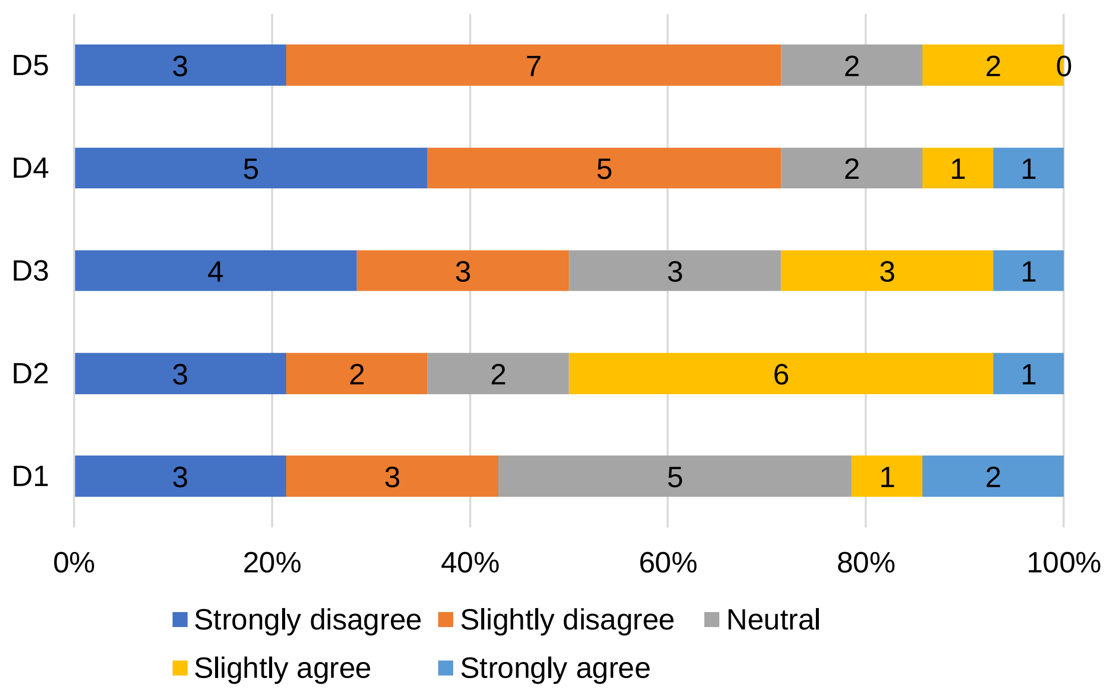


Figure 1. Company's attitude towards sustainability & energy transition. Data is collected by surveys sent out to 14 energy companies. D1-D5 refer to following aspects; D1: My company values sustainability as important or significant; D2: My company thinks there is a shift towards sustainable energy in the coming years; D3: My company is proactively preparing for this shift to remain competitive in the energy industry as shifts towards sustainable energy; D4: My company is remarkably investing in R&D for sustainable energy production methods; D5: Concern about climate change and helping the environment is high on my company's corporate agenda.

As seen in Figure 1, the majorities of the fourteen companies are not favorable of an energy transition and pay less attention to the issue of sustainability as demonstrated by the distribution in left three categories (Strongly disagree, slightly disagree and Neutral). More than 78% of companies do not value the importance of sustainability, half of them deny the fact that there is a shift towards sustainable energy in the coming future, and less than 30% have made proactive preparations for the future shift. It is evident that the companies either do not believe in an energy transformation or remain reluctant to change in the near future. Furthermore, less than 15% of the companies have invested heavily in R&D to develop renewable energies and more than 85% show little interests on climate change. In the end, it is important to recognize and remember that these are the companies partially responsible for climate change.

Based on Figure 2, it could be easily found that around 65% of companies believe their primary resources for energy production by 2050 will stay same instead of switching to renewable energies while another 5 of these 14 companies believe they may change the structure. However, only 2 of the 5 are willing to invest more than 30% (one is 30% and the other is 80%) of their sales to develop renewable energies. The remaining 3 companies, on the other hand, are only willing to invest less than 10% of their sales. With regards to renewable energy investment, these companies mainly focus on wind because of the lower degree of geographic and technological limits.

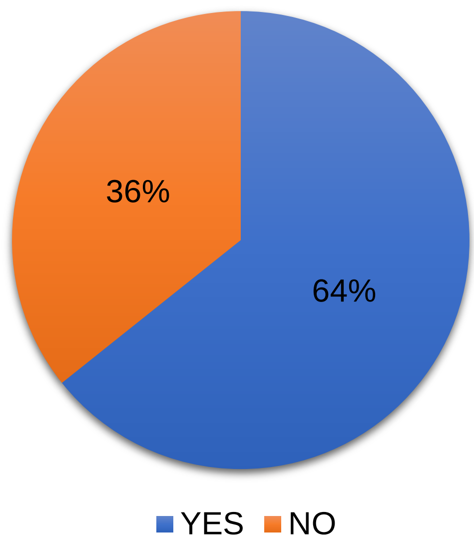
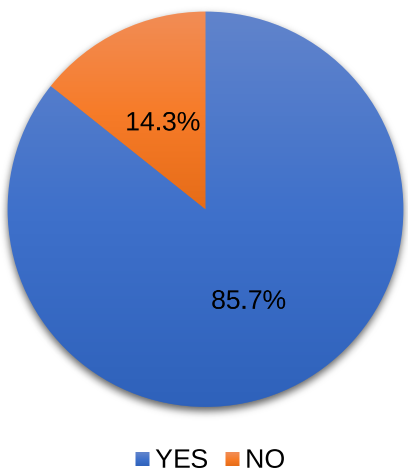


Figure 2. Company's perception about their own company structure in the future. Data is collected by surveys sent out to 14 energy companies.

According to the answers to Question 5 of the survey (Appendix C), companies will make a trade-off between the time required for a return on investment and the risks associated with the investment when making decisions which renewable energy to invest in. These companies are aiming to invest the optimal amount of capital in order to have the highest yield. In order to influence their choices, subsidies such as tax incentives would also influence their choices. The majority of the companies, however, listed technological development as one of the major deciding factors. The more mature the technology for developing or constructing the infrastructures and the more efficiently the renewables can harness energy, the more likely it is that these traditional energy companies adopt renewables. Therefore, it is evident that these companies are not confident in the current state of development of these technologies.

Taking a look at Figure 3, it is obvious that there are only two companies that will not put off their energy transition as long as possible. The majority of the companies believe fossil fuels will be the first to be affected by the increasing amount of renewable energy production. In general, all of them hold pessimistic attitudes on the US energy transition. In fact, only 2 of them believe that the US could move from 15% of renewable production to 50% in less than 50 years while 3 believe it is impossible to achieve this. Through conducting these surveys, it was found that companies hope the government would pay more attention to and invest more on improving the production efficiency of traditional technology and on the development on renewables.



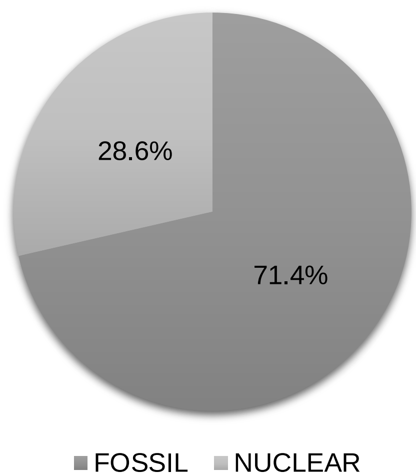
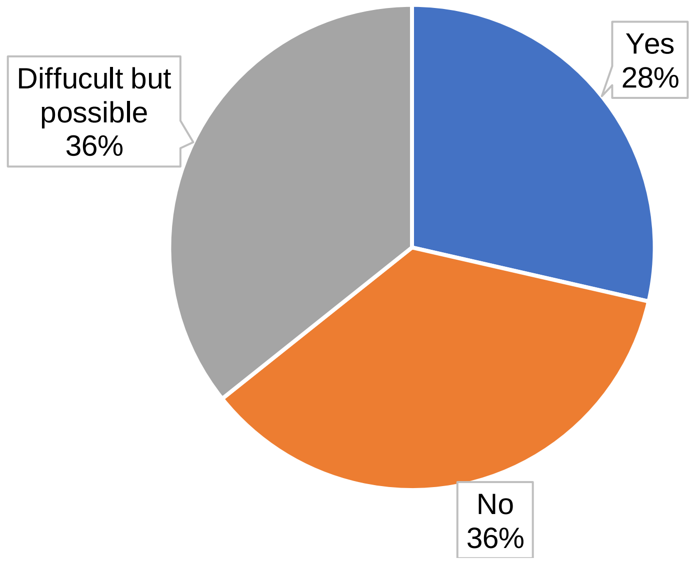


Figure 3. Willingness to put off the energy transition & perception of which energy will be influenced first. Data is collected by surveys sent out to 14 energy companies.

Regarding the question of the incentives on motivating companies to transition, the majority of them mention subsidies from the government because they likely believe this is an attractive way to stimulate a shift. Support from the government may relieve the financial concern from these companies; as seen in some of the responses, the initial investment for the transition is a large amount and the return on investment requires a long time since they believe the market is not fully developed or ready. Moreover, many of their customers' preferences take a long time to change. Besides the concern of large investment, some companies are worried that employers will lose their jobs and the overall value of the company will decrease.



.

Figure 4. Possibility of overcoming cultural hurdles. Data is collected by surveys sent out to 14 energy companies.

As illustrated in Figure 4, nearly one third of these companies hold totally pessimistic attitude on the transition and believe it is impossible to overcome the culture embedding in the traditional energy business they have operated their traditional business for generations. Luckily, five of the companies hold quite optimistic attitudes on this matter. As for the remaining companies, a neutral but slightly pessimistic attitude is held as they think it is not impossible but it would be very difficult and costly to handle the transition.

To conclude, all the companies hold more or less pessimistic attitudes of changing their current business to a more sustainable production. They lack substantial capital for the initial investment and are reluctant to take risks on the sacrifice of current revenues. Furthermore, it is widely admitted that subsidies from government would have positive impacts on promoting the energy transition.

4.2.2 Issues Generated from Survey Findings. Below we have summarized the main issues expressed by the companies surveyed.

(1) Most companies have a lack of motivation to be highly and proactively involved in the transition. The current stage in West Virginia proves that companies prefer to keep business as usual instead of taking “unnecessary” risks to invest for the future. Reasons for this could be: the historical pride instilled in the average West Virginia coal mining family, who’s family has a long tradition of miners that have built strong connections both financially and mentally with coal; the market for renewables does not seem prosperous because customers are not ready for the shift; internal resistance from employees who are afraid to lose their jobs and etc. Since internal factors and external contexts are not favorable, a solution needs to be created either externally or internally to motivate companies to shift by offering benefits such as subsidies.

(2) There exists a lack of expertise on the technology of renewable energies and their production. Many traditional companies are currently devoting most or all of their time and resources to further explore the capabilities of traditional methods and practices. Therefore, these employees have little to no knowledge of renewables. This is also an added investment cost from their point of view. It is necessary to provide guidelines for traditional energy companies on how to get access to the related technology, information, and technical support from governments or research institutes. Within these guidelines, traditional companies should be informed on such things as how to invest and take advantage of subsidies, how to produce, and how to balance the new product portfolio. By doing so, companies would likely feel a decrease in the amount of risk involved in the process and

more confident to make a change.

(3) Many companies surveyed were not certain of the success in the energy transition (from 15% energy production from renewable to more than 50%). All the companies surveyed were not optimistic with the overall sustainable energy transition. For this, possible explanations may include: general policies made by the government; a lack of proper guidelines or timelines announced to the public; a lack of influential actions taken by government; and shifting and diversions of government policies. In order for significant impacts to occur, both the companies and the government need to believe in the success of this shift and its irreversible trend; otherwise, slow and minimal progress will occur. There should be solutions addressed to handle this problem such as providing a general timeline for the long-term transition.

(4) Cultural factors also hinder the speed and process of the transition. Cultural factors mainly refer to the historical bundles among the employees, mining culture and influence, and the impact on the business and company culture. In order to have a smooth transition, the culture encompassed by the traditional industry need to contain a synergy with those in the renewable energy industry.

In conclusion, all of these issues should be given proper attention as soon as possible in order to start making an impactful transition. Moreover, all of the solutions provided by this thesis are based on or partly accounted to the principle of addressing these issues. Once all of these issues are handled, the energy transition will be closer to success.

5. Analysis

5.1 Flowchart

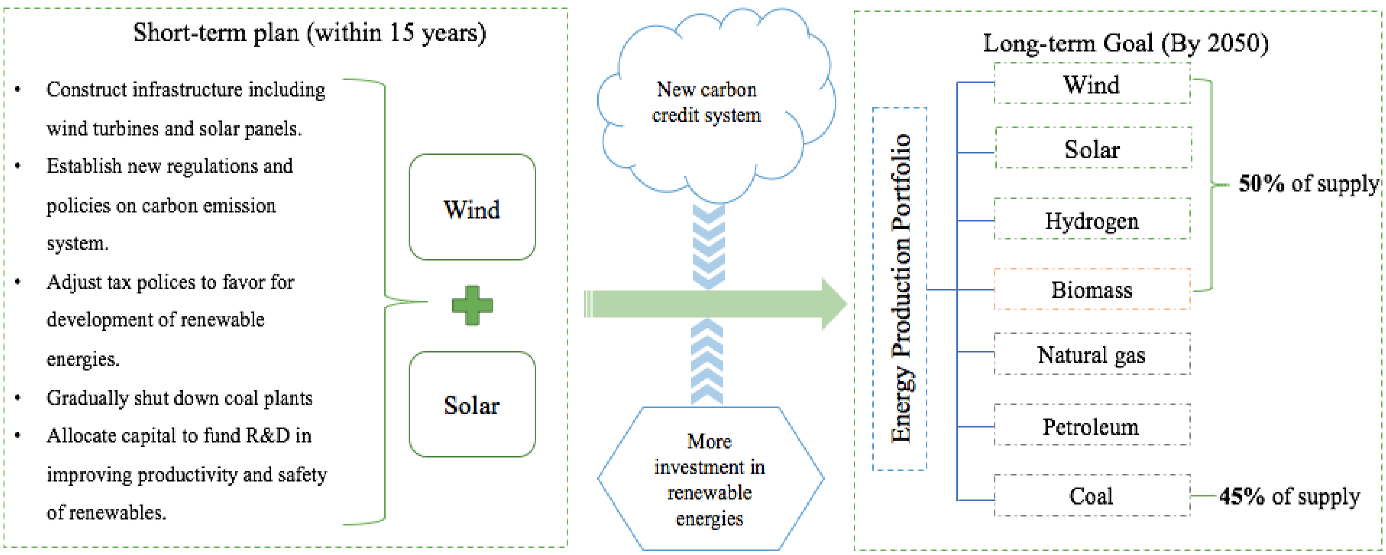


Figure 5. Transition plan for West Virginia. The flowchart is created according to the solutions described in the chapter 5.2 and 5.3.

5.2 Short-term Approach

5.2.1 West Virginia Data. West Virginia is located in the region of Appalachian Mountain, which has rich fossil energy sources as well as large potential for renewable energy sources. The state has a population of around 1.8 million and a GDP of $73.4 billion, ranking No.41 in the United States. Coal, crude oil and natural gas account for more than 95% of its total energy production and contribute increasingly to its GDP. Mining, petroleum-fueling, energy-intensive chemical and coal industries are important parts of its economy. Besides consumption within the state, West Virginia is also a net supplier for other states, largely depending on its significant coal production, and provides almost 5% of the nation's total energy.

The energy production in West Virginia had a total amount of 4,110 trillion Btu (British thermal unit) in 2015, ranking No.4 in the US. The coal production in particular ranked No.2 with an amount of 79,757 thousand short tons, according to data from the US Energy Information Administration. We refer to Figure 6, where is shown that traditional resources are the dominant energies generating electricity in West Virginia and make up more than 95% of the total energy production. This reflects the tough beginning for an energy transition, since renewable energies only contribute 4.4%, indicating that the development of renewable energies is very limited. Although, there is an increasing trend in generating more electricity from wind.

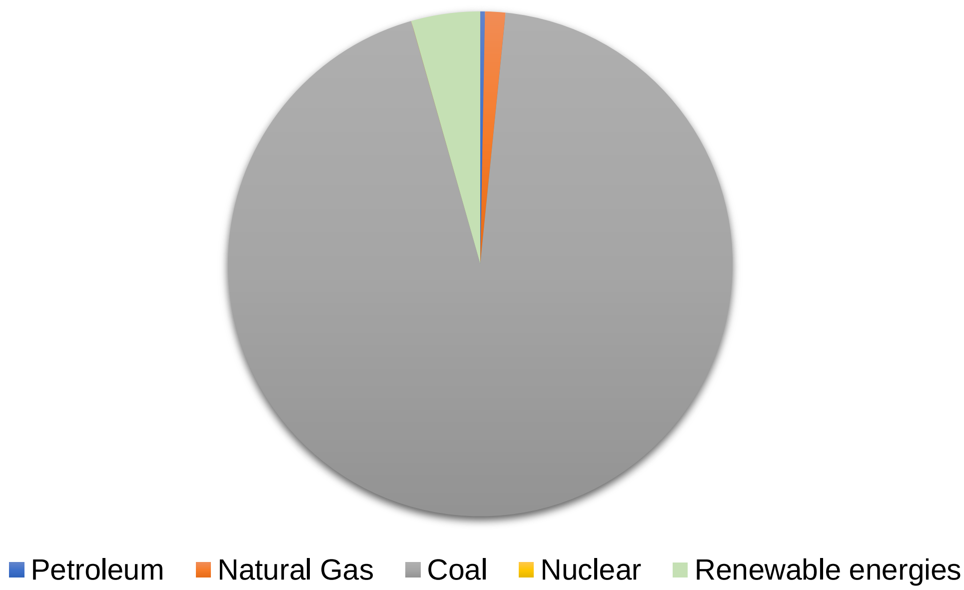


Figure 6. Utility-scale Net Electricity Generation (share of total), EIA (2015). The pie chart describes the percentage of electricity generated by each energy source to the overall net electricity generation.

The situation regarding the energy consumption in the state is quite similar that one of the production. The total amount of energy consumed per capita in West Virginia was 421 million Btu in 2015, ranking No.10 among all the states. From Figure 7, we find that industry consumes 40% of the energy and commercial usage accounts for least, namely 15%. Energy consumption coming from transportation and residential purposes are comparable. In general, the end-use sectors are distributed evenly. When we take a look at the energy sources used for home heating, almost all is coming from traditional resources. We can conclude that the consumption is still mainly supported by traditional sources.

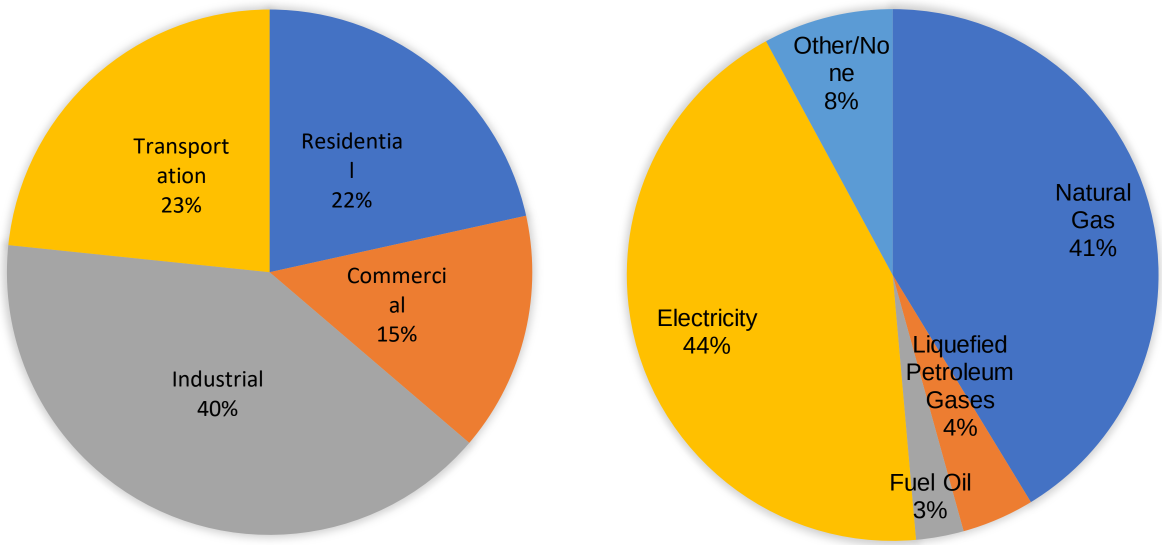


Figure 7. Energy Consumption, EIA (2015). The left pie chart shows energy consumption by end-use sectors in the unit of trillion British thermal units and the right pie chart shows energy sources used for home heating in share of households.

As West Virginia is located in a landscape of mountains and rivers, this offers it the potential capability to develop renewable energies such as wind, solar and etc. However, the current ratio of development and utilization of renewables is quite low. Table 1 shows us the overall electricity generated by renewable energies, around 317 thousand MWh. According to the EIA, there are also only three hydroelectric power plants in operation and only 700 megawatts of installed wind capacity. On the one hand, this shows that there is a large potential to develop renewables since the current production is way below its possibilities. On the other hand, this also indicates that the infrastructure construction for renewables is not enough advanced or not enough invested in.

Table 1.

Utility-scale Net Electricity Generation from Renewable Energies

Type of Renewable Energy	Production Amount (thousand MWh)
Conventional Hydrogen	136
Wind, Solar and Geothermal	180
Distributed (small-scale) Solar Photovoltaic	1

Note: From Energy Information Administration, 2015

In order to make a more comprehensive plan for a West Virginian energy transition, it is necessary to research the historical climate data in West Virginia, especially indicators of precipitation, temperature, sunshine days and etc. After all, the climate decides whether West Virginia is capable of developing renewable energies like wind and solar. According to Table 2 and Figure 8, in general, West Virginia is capable of developing an energy production system based on solar energy, because there are enough sunny days and precipitation trend is quite stable with an annual average of 45 inches over a period of 118 years. The mountainous area is naturally a good location for wind resources and also naturally has les inhabitants, which means wind energy can be developed without having a large impact on local residents. The river areas could focus on developing hydro energy to balance out the limited supply from wind and solar.

Table 2.

Annual Days of Sunshine

City	Sunny	Partly Sunny	Total Days with Sun
Beckley	60	95	155
Charleston	65	111	176
Elkins	48	103	151
Hutington	63	99	162

Note: From "Annual Days of Sunshine in West Virginia - Current Results", 2018

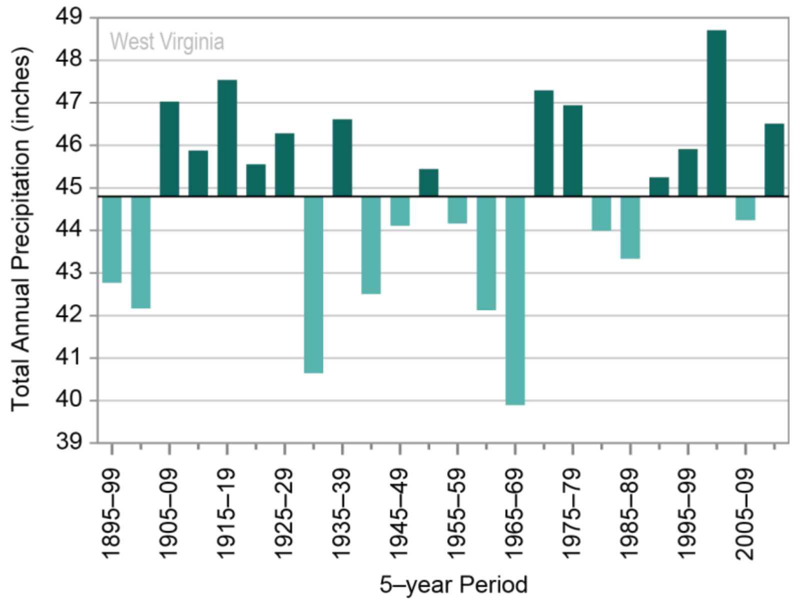


Figure 8. Annual Precipitation of West Virginia, U.S. Climate Divisional Dataset Version 2 (2010). The figure shows the historical data of total annual precipitation in inches of West Virginia from 1895 to 2009.

5.2.2 Wind Energy Investment. Unfortunately for the state of West Virginia, development and utilization of renewable energy sources has been slow and minimal. This can be partially attributed to the laws and regulations, as well as the motivation of the people of West Virginia, for wanting progression and sustainability. Contrary to popular negative labels associated with West Virginia's energy portfolio, there is still some advancement of renewable energy production in the state: "Growth in solar generation, led by installation of medium sized commercial PV (photovoltaic) arrays, also occurred but was outpaced by the large scale of commercial wind development" (Risch, 2017, page 4). However, this growth is still minimal when compared to the total energy consumption of the state. For hydropower, wind, and solar energy production, the total amounted to 25.8 TBtu in 2015. Compared to the total energy consumption of 774.9 TBtu, the use of these renewables stands at just over three percent. To make matters worse, the state government has made changes within the last few years to slow the growth of renewable energy production: In 2015, "West Virginia's Governor Earl Ray Tomblin signed House Bill 2001, making the state the first in the nation to repeal its alternative energy mandate. The bipartisan proposal sailed through both chambers of the West Virginia Legislature earlier this month, passing unanimously in the Senate and by a vote of 95-4 in the House of Delegates" (Eick, 2015). This was known as the repeal of the West Virginia Alternative and Renewable Portfolio Standard and the original rule would have required that at least 10% of the electricity supplied to consumers be supplied from renewables by 2015. Instead, the state is continuing to burn fossil fuels without diversifying its' energy portfolio. It is important, therefore, to analyse where the state currently resides with its' plans and practices of sustainability prior to assessing possible efforts and solutions for the future.

By incorporating both solar and wind energy practices, the state of West Virginia can benefit greatly despite its heavy reliance on coal. Although it is the second largest coal-producing state in the country, with its mining sector accounting for roughly 17.8% of its GDP, West Virginia also exports the majority of its annual electricity production (Van Nostrand, Hansen, Argetsinger & James, 2015). Therefore, by implementing a more diverse energy portfolio, West Virginia could have the potential to generate more revenue from its electric sales while simultaneously creating jobs for the future rather than relying on the dying coal industry. However, the Mountain State is comprised of an assorted energy resource base that can provide for more progressive and efficient economic opportunities while simultaneously meeting more environmental standards and promoting a healthier planet. In the coming sections, the feasibility and potential short-term methods or recommendations are assessed for both solar and wind energies.

Like solar, the government has not been encouraging the development or utilization of wind energy technology. In recent years, the laws were changed: “legislation was introduced to remove the pollution abatement status granted to wind facilities that reduce the effective property tax rate for that equipment. This change would have applied to existing facilities as well as to future wind facilities” (Centre for Business and Economic Research, 2017, pg 9). The tax incentives for businesses incorporating wind as a means of energy production are identical to those of solar: “tax rate on wind-powered turbines is about 30% of the effective tax rate of most other types of newly constructed generating units” (“DSIRE”, 2015, page 1). With government incentives being applied to both wind and solar power production for businesses, renewables will gain popularity as opposed to traditional sources of energy.

In the identical study conducted by Marshall University’s Centre for Business & Economic Research, recommendations were also made for wind. For wind, the following recommendations were made in the report to the Energy Department of West Virginia:

- Maintain current state legislative policy for wind. The two existing state tax incentives for commercial wind development have allowed cost savings for developers while also assisting the development of wind resources in rural areas of West Virginia.
- Monitor national wind integration activities, policies and research.
- Given most of West Virginia wind projects are located on surface-mined lands, extend efforts to determine whether adequate wind resources exist to support commercial wind development on additional surface-mined sites (Centre for Business and Economic Research, 2017, pg 6).

Of these recommendations for wind, some were actually followed by the government in an effort to promote wind energy. In fact, a law was put in place that classified wind power projects as facilities that control and reduce pollution; therefore, a new system was devised to allow these facilities to be available for property tax deductions (Centre for Business and Economic Research, 2017, pg 9). Thanks to the efforts of Marshall University's Centre for Environmental, Geotechnical and Applied Sciences, former surface-mined lands were analysed and evaluated to determine whether or not wind resources could be used. Since 2010, the Appalachian Regional Commission and the WV Division of Energy has funded this project (Centre for Business and Economic Research, 2017, pg 9). If more efforts like these continue to occur, wind power and other renewables will have a smoother transition and old land that was once used to mine materials can still be utilized.

5.2.3 Solar Energy Investment. As mentioned before, West Virginia has taken legislative actions that discourage the use and implementation of certain renewables. In particular, the state of West Virginia also disallowed the incentive of income tax credits for solar PV installations and electric vehicles to expire (Centre for Business and Economic Research, 2017, page 5). Recently in February of 2018, however, the Bipartisan Budget Act of 2018 was signed to allow for a reinstated tax credit. Currently, in West Virginia for residential homes, solar-electric properties can receive up to a 30% tax credit for systems placed in service by the end of the year of 2019. Moreover, the same act applied to and had an impact on the businesses in West Virginia. The Business Energy Investment Tax Credit (ITC) allows for solar technologies implemented by businesses to receive a tax credit of up to 30% (Herholdt, 2018, page 1). If both the people and the businesses are inclined and persuaded to use renewables, it can impact and influence the overall consensus of the state. When government officials reinstate or enact laws such as the ones aforementioned, encouragement and motivation are established amongst the people of West Virginia, promoting a common mind-set that diverts from the past and indicates that times are changing towards a more sustainable future. After all, it is the people of West Virginia that elect the politicians in office who have the power to build and implement positive transformations. Eventually, businesses will hopefully shift away from short-termism and negligibility and instead transform to long-term thinking and sustainability.

In the past, the state and universities in the state have constructed plans and recommendations for renewables. In 2013, a five-year renewable energy plan was developed for West Virginia to propose some of the major recommendations for the state using research acquired in the outline. For solar, the following recommendations were made in the report to the Energy Department of West Virginia:

- Maintain current income tax credit for PV installations.
- Monitor national solar integration activities, policies, and research.
- Review the performance of photovoltaic systems installed at state and local government facilities.
- Monitor and update net metering policies as necessary.
- Provide support for community-based renewable energy activities.
- Continuation of the current 30% residential and business solar energy tax credit (Centre for Business and Economic Research, 2017, p.6) and (Eick, 2015, p.5).

In the same outline constructed by Marshall University's Centre for Business & Economic Research, it was found that there were changes made to the state's net metering policies —although the majority were not followed. Rather than allowing utility companies to profit from making changes in the net metering policies or systems of their customers, the state government passed a recent bill that requires the West Virginia Public Service Commission to prevent such actions. In regards to the solar recommendations, the state behaved in a manner that is not sustainable for the environment. Rather than maintaining the current income tax credit to incentivize and financially back people to be become greener, the West Virginia Legislature allowed these credits for PV installations to expire in 2013.

5.2.4 Nuclear Energy. Nuclear is a typical alternative energy used in the transition from traditional to renewable because it has relatively low carbon emissions and higher productivity than traditional energies. The US owns mature nuclear technology and operates nuclear plants to generate electricity for household and industries. The whole nation has around 99 operating nuclear reactors at 61 nuclear plants in 30 states by 2017 ("U.S. Nuclear Industry - Energy Explained, Your Guide To Understanding Energy - Energy Information Administration", 2018). Additionally, there are two new nuclear reactors currently in construction. The overall trend of the United States nuclear energy industry is increasing though the productivity of generating electricity is under control and quite lower than before. Because its country owns advanced technology in nuclear and operates many reactors, the state of West Virginia should implement nuclear energy in the mountainous areas with low populations. However, there are several obstacles preventing such actions from occurring. Details are as follow.

Firstly, there is no existing nuclear plant in West Virginia. It would cost lots of money and time to set up a new plant. Taking the nuclear energy as an alternative would be economical and feasible only if there were an existing infrastructure to use. Otherwise, it would be a waste of money and time especially if it will only be used as part of the transition from traditional to renewable. Finally, the plant would need to be disassembled adding further costs.

Secondly, legislative resistance exists in West Virginia. There is a 1996 law banning nuclear plants in the state and causing a huge difficulty for activists to abandon the law and utilize nuclear energy. Because the interests of politicians align with those in the coal industry, it is difficult for others to promote nuclear energy in an effective manner. According to the United States Nuclear Regulatory Commission, West Virginia is one of 13 states that haven't signed in the Agreement State Program, a program constructed to organize, regulate, and develop nuclear plants. Due to the resistance in its political and legislative environments, West Virginia will likely continue to resist the adoption of nuclear energy.

Thirdly, cultural conflicts hinder the development of nuclear energy. Coal mining has long history in West Virginia. Many residents of West Virginia have ties to the generations of coal mining families of the past. Besides being one of the largest driving forces of the economy, coal is culture in the state. What's more, switching from coal mining to nuclear energy will also increase unemployment and tension among the residents of the state.

Lastly, social concerns on the safety issues of nuclear technologies are one of the largest obstacles. It is difficult to guarantee zero radiation, deal with the leftover waste emitted by plants, and safely abandon nuclear plants. In order to increase the likelihood of adopting nuclear energy, states, including West Virginia, should put the social issues into consideration.

To conclude, all of these factors make it impossible to use nuclear energy as an alternative during the transition. A combination of higher costs and longer time to construct together with a lack of government and civilian support, reduce the possibility that West Virginia adopts nuclear energy.

5.2.5 Carbon Credit System as Base for new Regulation System. As already discussed earlier in 1.2 and 2.3, the Carbon Credit System is an existing system that regulates the trade of emission rights between countries and companies, for developed countries to be able to comply with the 1997 Kyoto Protocol. This paper recognizes the strengths and weaknesses of this system (2.3 Development of the Carbon Credit System), but does see potential to use some of its basic principles as a base for a new regulation system. This system would be a new approach to tackle the regulation problem around carbon emissions, level the playing field for new renewable energy-focused companies compared with the existing traditional energy giants, and help make sure enough money keeps flowing towards the research and development of renewable energy in general. To demonstrate this innovative regulation system, we will make the following assumptions and adapt the scale from small to large to its working.

Scenario 1: Imagine the United States of America, with an energy industry only consisting out of two companies: company A which is a traditional oil/gas/coal energy company and company B, which is a renewable energy producer. In the system, the US government is responsible for issuing a certain number of credits each year to the entire energy industry. Let's assume this number of credits is set at 100 per year, which means that these 2 companies together will receive a sum of 100 credits. Each year or pre-determined period, it will the government's task to give a certain "weight" or "value" to these credits, based on and taking into account the macro-economic environment, tax deficit, and many other things. Practically, 1 credit would come down to a certain advantage for the company receiving it, for example, one or more credits could represent a certain tax benefit or subsidy for the receiver. Credits in this system would be awarded based on carbon emissions. In this scenario, where company A and B are the only two providers of energy for the country, company A will account for the significant majority of carbon emissions in the energy industry. Let's assume this numerically comes down to 90% of carbon emissions in the sector are coming from company A and just 10% are coming from company B, this would result in company A receiving 10 credits while company B receives 90 credits. Both company A and B could use these credits to their advantage, namely receive tax benefits, subsidies, social benefits etc. and the credits end back up with the government, ready to be re-distributed the next year. Although a large-scale study by the United Nations Development Group (UNDP) and the Global Centre for Public Service Excellence (GCPSE) in 2015 found no conclusive evidence that one model of ownership (public, private or mixed) is more efficient than the others, many still argue that the private sector is faster, more agile and more efficient when it comes to innovative technologies. Neither agreeing or disagreeing with this statement, we believe this system should be able to give both public and private sectors a chance with regard to the credits and their overall value creation towards more R&D of renewable energy and contributing to a more sustainable energy industry, which is the final objective. Therefore, just like the credits can be swapped with the government for certain pre-determined benefits of their choosing, they can be sold and bought directly from each other. While one of the biggest drawbacks with the carbon credit system is that this buying/selling practice keeps less developed countries and companies small (Winterhalder, 2018, Appendix D), we believe this will not be an issue in this system since the market will automatically generate prices that are so high, that when a credit is sold from a renewable to a traditional energy producer, its monetary value will help grow the renewable company equally as much or even more in terms of R&D, development, infrastructure, etc. that what would have been possible through a credit-for-benefits exchange with the government. Thus, there exists a 3-way flow of credits and money: between the government and traditional energy companies, between the government and renewable energy companies, and between traditional and renewable energy producers themselves. To illustrate scenario 1, we refer to Figure 9 below.

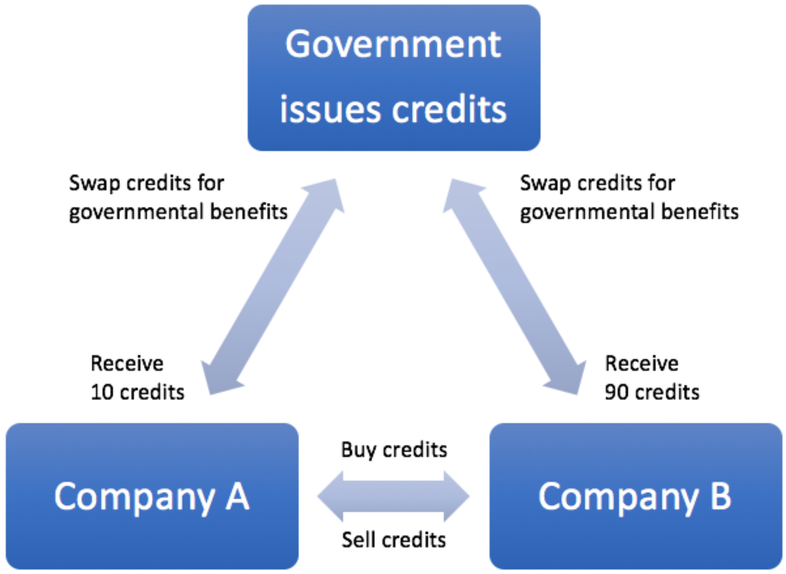


Figure 9. New carbon credit system - Scenario 1. The figure illustrates the mechanism of new carbon credit system in scenario of there is only two companies in the industry and how the government plays their role in allocating credits.

Scenario 2: For the second scenario, let's assume the US energy industry still only exists out of company A and B from scenario 1. Going forward, company A will be incentivized by the amount of credits received by company B, to become more sustainable and hence be eligible for more credits. Over a certain period of x time, the traditional company A, incentivized by credits, will have done such investments and the renewable company B, profiting from the credits, will have grown its business and infrastructure as well as its carbon footprint. When we look at the new distribution of the 100 credits, of which the value could have but not necessarily has been re-determined by the government, after x time, we assume to see the following shift. While company A's carbon emissions would have gone down for above-mentioned reasons, company B's would have gone up, resulting in a change of their contribution to the energy industry's total carbon footprint. At this point, hypothetically, company A would contribute still 80% of the carbon emissions, and company B's contribution would have grown until 20%. Whereas company B received 90 credits last time, it will receive 80 credits in this round. Company A has been rewarded for its efforts to become more sustainable, and receives 20 instead of 10 credits. These credits can be used in the same way every year, exchange for governmental benefits or sold for money to industry colleagues and competitors.

Scenario 3: For the last scenario, we assume a more complicated but also more realistic market situation. Instead of only 2 companies in the US energy industry, we now have 2 segments. The first being the traditional energy segment consisting out of hundreds of companies, and the second is the renewable energy segment consisting out of hundreds of companies as well. In a market situation where there are hundreds of companies instead of 2, the number of issued credits by the government will be probably be higher than 100, but the principle remains the same. First, the government looks at both segments and their contribution to the energy industry's carbon emissions. Assuming that the traditional segment contributes 80% of the emissions, 20% will be contributed by the renewable segment. This results in 80% of the credits going to the renewable energy companies, and 20% to the traditional ones. How this 20% and 80% is divided among the companies of that segment, will depend on their individual contribution to the segment's carbon footprint.

We recognize that a lot of research is necessary to convert this theory into a practical and feasible system, to determine the right amount of credits to be issued, allocate an appropriate "value" for each credit from a government perspective – socially, economically and financially responsible – and for this reason the paper does not include the system's potential benefits into its calculation of the sustainability date. However, we do believe this theory and this system have great potential to offer real contribution to a faster transition towards a more sustainable US energy industry, as well as help to regulate carbon emission on the long-term.

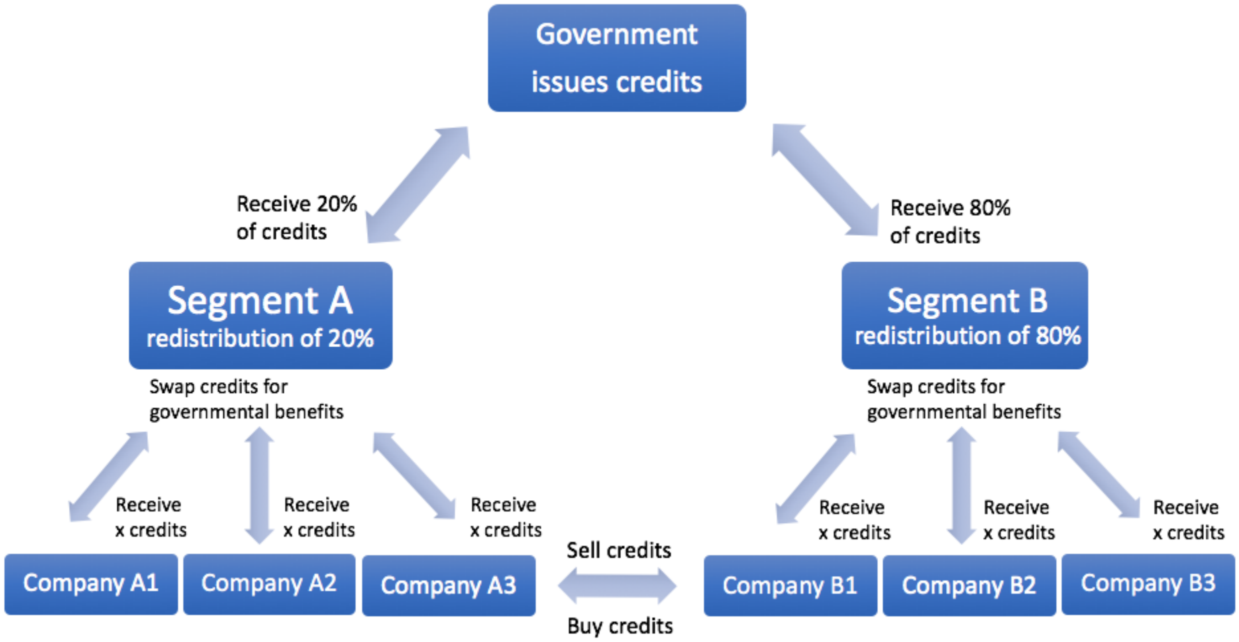


Figure 10. New carbon credit system – Scenario 3. The figure shows the detailed process of new carbon credit system in scenario 3 that assumes there are two segments in the market and how carbon credits influence the transition.

5.2.6 Government Influence. As discussed above, many investments need to be made to help build and accelerate the process towards a more sustainable energy industry. This is an argument that we not only validate through our own predictions, estimates and concepts, but also is shown by the results from our survey. As mentioned in chapter 4, 45% of the survey respondents believe that effective incentives to stimulate the US energy industry to transition towards a more sustainable model, should come from the government. Although the United States is a free market and has always promoted this system, we believe that regulation is needed and the government should play the role of incentivizer for the energy industry. To illustrate the power of the government, and by extension the president who leads that particular administration, we look at the current and former leadership. Under Barack Obama (US president 2009-2017) there was a significant drop in the use of coal, a boom in domestic oil and gas development from fracking as well as the spread of renewable energy (King, 2016). This spread of renewable energy can be seen in Appendix G, Table 1. By 2016, EPA regulations regarding reduced air pollutants were favoring the move-away from coal, and also the cost to renovate relatively old coal power plants were becoming an issue. Experts expected that coal would only further decline, but then came the next president. President Trump (20017-now) has pledged to revive the coal industry and has taken measure to make this happen (DiChristopher, 2018). Coal production and exports in 2017 have increased because of this change of presidents, but coal-fired plants keep continue to close and industry watchers claim this increase was more due to market forces than White House policy (DiChristopher, 2018). Although the effect is not there quite yet, this example clearly illustrates the influence of the ruling government on the energy industry. Overall trends are pointing towards a decline in coal and increase of renewable energies, but with this thesis and approach we would like to suggest an increase of the pace at which this is going to happen, and to do so, the government needs to be on the same side. Journalists, industry experts, industry itself and we all believe that the government has played and should play a role in the development of the energy industry, it depends on the beliefs and policies of that government which direction that development is going to be in. As mentioned in 5.2.5, we recommend the government to take control in creating incentive schemes to be tied with the new carbon credit emission system. This scheme would be a so-called "hybrid approach", which is a combination of setting standards and pricing (US EPA, 2018). Currently the EPA has already defined many different schemes as tools for the US government to use, our recommendation comes down to a combination of these tools, namely emissions taxes, fees and charges; and subsidies for pollution control, which is called a Deposit-Refund System (US EPA, 2018). The tools and methods are in place, now they need to be slightly adapted and combined into a feasible and efficient system which stimulates a transition towards more sustainability.

5.2.7 Short Term Predictions.

In the United States, the majority of the people support increasing the amount of money invested into renewable energies. In fact, Americans agree that electric utilities should produce at least 20% of their electricity from renewable energy sources, even if it costs the average household an extra $100 a year (56% support). This support includes 58% of Republicans, 64% of Independents, and 82% of Democrats (Leiserowitz, Maibach, Roser-Renouf, Feinberg & Rosenthal, 2013). In the short-term, the state should be allocating more money towards the research and development of renewables. In 2010, the mining industry contributed 40,000 jobs and $3.5 billion to the economy of the state. The Mountain State also collected close to $400 million in coal severances taxes alone (Paalborg, 2011). This money should be funneled right back into renewables. In the short-term, it is easy for coal companies to see the return on investment of continuing their operations. However, one study found alternative results for the long term:

> “The study assessed many specific sites in West Virginia, including Coal River Mountain, and compared potential economic and energy benefits derived from future mountaintop removal to the proposed placement of a 164-turbine, 328-megawatt wind farm. Although the energy potential of the mountain's coal and the money that would accrue to the companies that own the land greatly weigh in coal's favour, the long run portrays a very different story.”

The researchers concluded that a wind farm of the size proposed for Coal River Mountain would generate $1.74 million in annual tax revenue for Raleigh County, while the county would gain only $36,000 per year with an additional mountaintop removal mining site. (Paalborg, 2011) Moreover, cost analyses have been conducted to compare the differences in price between traditional and alternative forms of energy (See Figure 11).

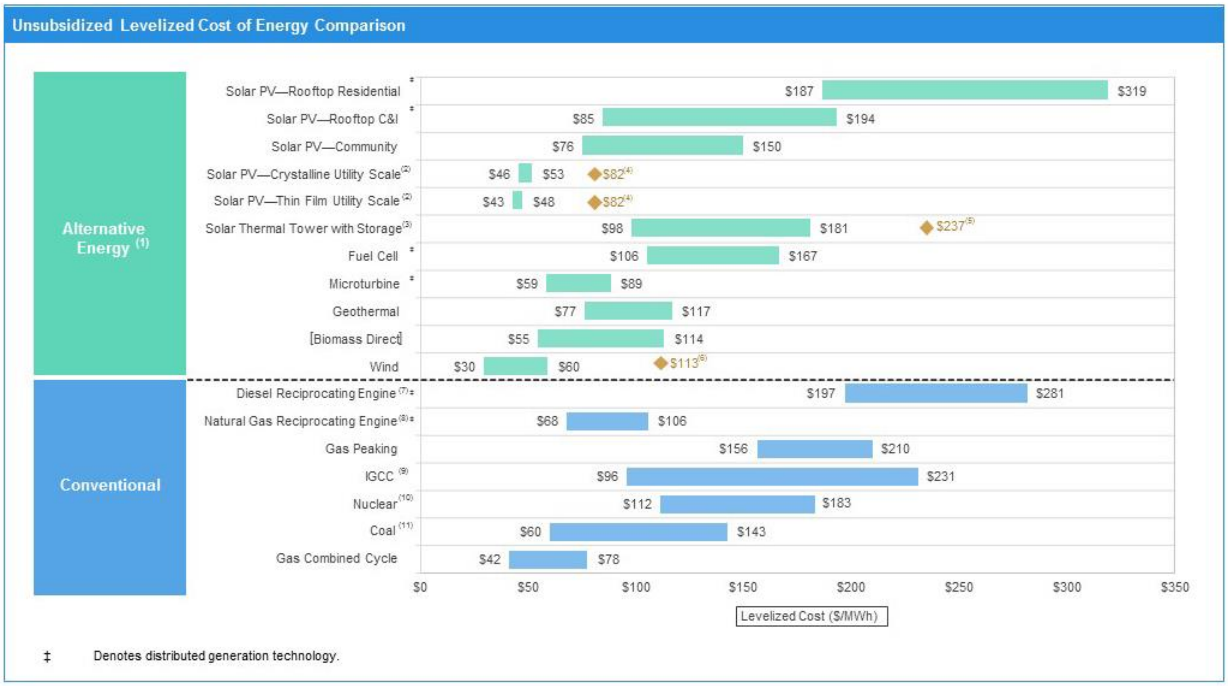


Figure 11. Cost analysis of traditional and alternative forms of energy, Levelized Cost of Energy (2017). The figure compares the differences in price between traditional energies like coal, gas, nuclear, natural gas and etc. and alternatives like renewable energies.

It was concluded that the Levelized Cost of Energy Analysis illustrates that the cost of energy generated from alternative energy technologies, specifically utility scale solar and wind, have continued to decline (“Levelized Cost of Energy 2017”, 2017). It is clear that the cost of wind and solar beat traditional with all costs considered; therefore, it is up to the people and the government to push for more spending in research and development as well as implementation if renewables are to be used in place of traditional energy.

In order to make substantial changes in the short-term, the United States needs to invest much more money than it currently does into renewable energy development. Currently, the country is on a steady pace as it spends billions each year to finance new large-scale wind and solar projects. See Figure 12 for the annual financing for wind projects in the United States:

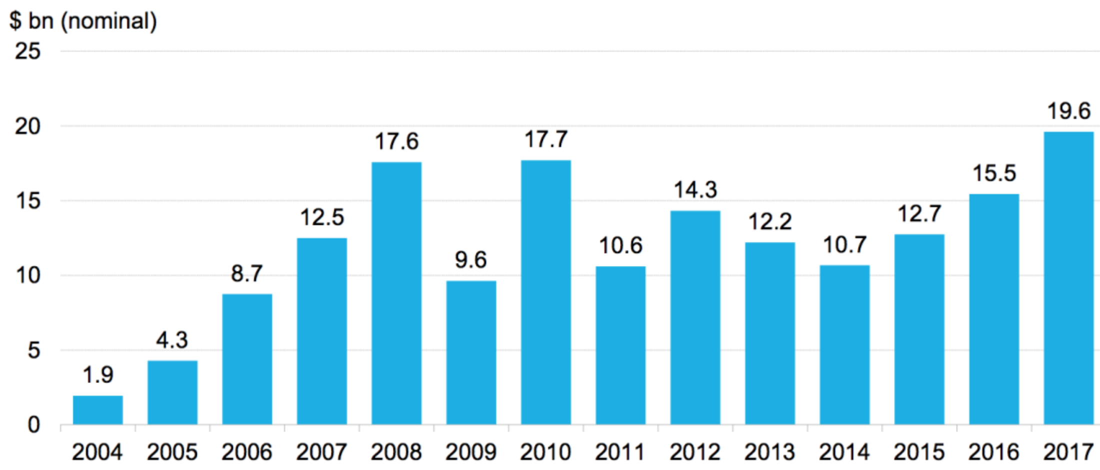


Figure 12. Annual financing for wind projects, 2018 Sustainable Energy in America Factbook #CleanEnergyDelivers (2018). The bar chart shows the exact numbers of financing support in wind projects in the US.

In 2019, $19.6 billion dollars were spent on new wind projects. However, the investment in solar declined significantly by about 20% due to drawbacks from anticipated policy changes (“2018 Sustainable Energy in America Factbook #CleanEnergyDelivers”, 2018). The proportion of renewables to traditional energy has made drastic changes in the last 10 years.

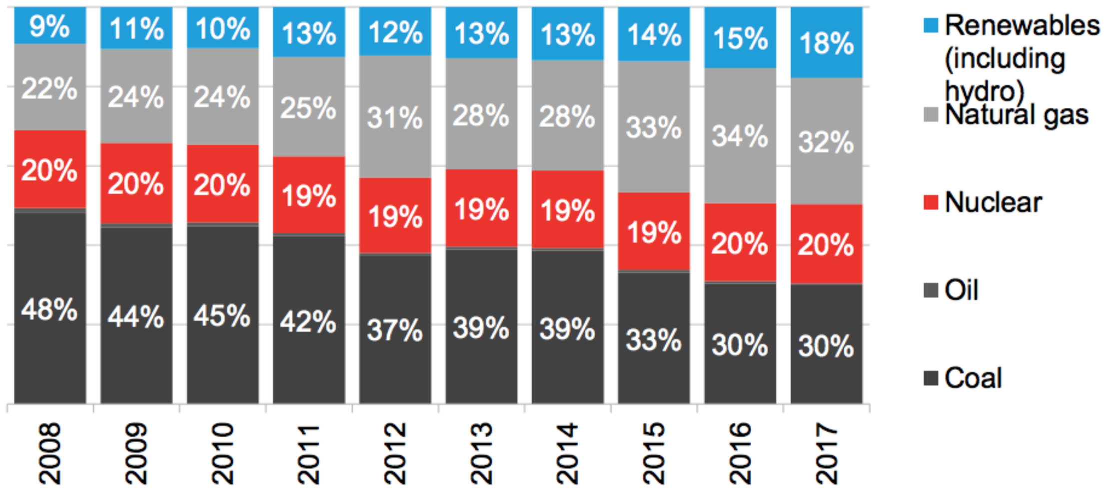


Figure 13. US electricity generation by fuel type, Energy Information Administration (2017). The figure shows percentage of renewables and traditional energies in total electricity generation.

As seen above, the percent of renewables to traditional forms of energy generation in the United States has doubled since 2008 while the amount of coal has tapered modestly. If the amount of money invested in renewables increases, this rate would only increase. The average annual growth of renewable energy electricity generation in the past 10 years was roughly 9%. If the annual increase in electricity generation continues at this average incremental rate in a linear fashion, the United States could see the renewable energy electricity generation percent climb to 50% by 2044. (Appendix G)

Wind and solar technologies are constantly improving their performance and yields. The United States Department of Energy published a report estimating the potential of wind power technology in the United States. Although these estimates do not consider factors such as the availability of infrastructure, costs, or policies, they are still relevant for understanding how crucial it is to tap into the resource. In the study, the government analyzed and found that “the

20-year average of total US primary energy use in all sectors combined is 96.2 quadrillion British Thermal Units (quads) per year, and was 95.0 quads in 2012… Of this, end-use electricity consumption was roughly 13 quads" ("Wind Vision: A New Era for Wind Power in the United States", 2015). The study then goes on to estimate the wind power for producing electricity, finding that wind is capable of potentially producing 170 quads per year as illustrated by the table below. At this level, the United States would be able to produce roughly 13 times the required level of electricity produced in 2013 (Energy Information Administration, 2017).

Table 3.

Annual Days of Sunshine

	GW	TWh/Year	Quad/Year[a]
Land-based wind	11,000	95	155
Offshore wind	4,200	111	176
Total United States	15,200	99	162

Note: From Wind Vision: A New Era for Wind Power in the United States, 2015

Similarly, the EIA projects that electricity from wind will be paired with solar to produce a large majority of the total generation. Below, EIA illustrates the shares of electricity generation from both wind and solar. With both solar and wind technologies, costs, and efficiencies continue to constantly improve in the United States which ultimately makes for a more feasible short-term outlook and sustainable future.

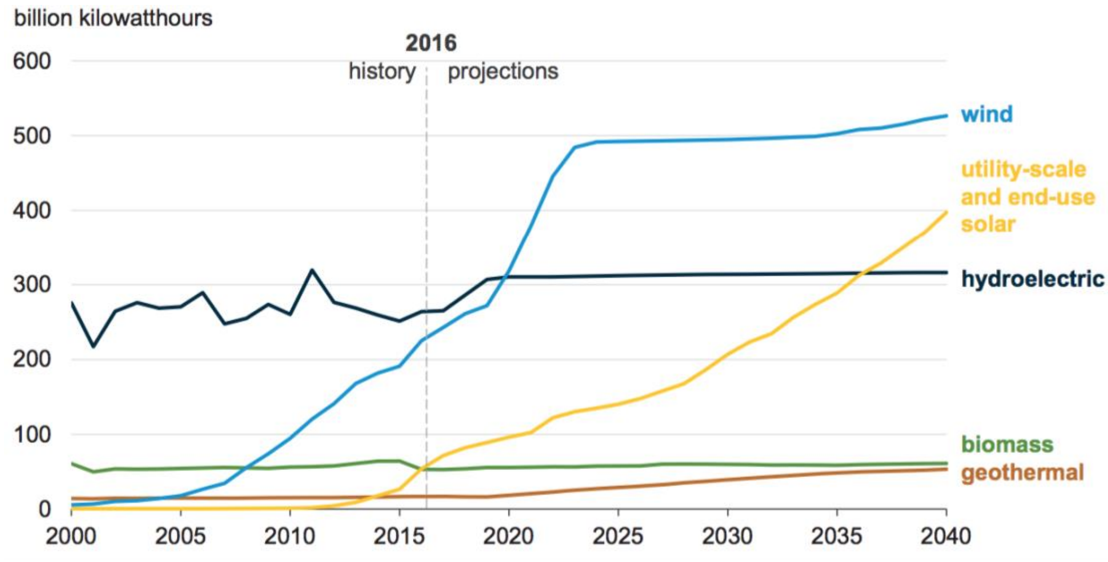


Figure 14. Renewable electricity generation, *"Annual Energy Outlook 2018"*, EIA (2018). The line chart shows the trend of electricity generation from renewable energies.

5.3 Long-term Approach

5.3.1 Future Energy Consumption Forecast. With a growth of population and increasing gross domestic product (GDP), there will be more and more energy consumed in all three sectors – residential, commercial and industrial. On the one hand, the long term energy consumption forecast could help set the stage for energy production because demands are driven by changes in supply. Therefore, production forecasts could be based on this. On the other hand, the long-term energy consumption forecast could also be analysed in a "business as usual" or "best" scenario cases. In this sense, we can identify the goals and assess the efficiency of potential solutions for the energy transition. Because West Virginia is one of largest energy suppliers in the entire nation, the country's energy consumption forecast could offer information to be used to consequently assess the same for the production plan of West Virginia.

According to the information from the EIA shown in Figure 15, the general growth trend for energy tends to be stable. During high economic growth, where GDP growth rate is at 2.6%

per year, the consumption will reach *120 quadrillion* British thermal units. During periods of low economic growth, where the rate is 1.5%, the consumption will reach only 80 quadrillion British thermal units. Because the current trend for GDP growth is the around 2.5% per year and policies published by the government are rapidly increasing GDP, it is more likely that the consumption will mirror levels during high economic growth. At this point, as our short-term approach tends to aim at making changes in production side, it has fewer impacts on consumption. But the high consumption could be mitigated by higher oil and gas prices caused by the carbon credit system because customers need to pay more. Moreover, by educating customers to be more aware of their influence on traditional energy consumption and its effect on climate change, the growth of energy consumption and the speed for growth will likely slow down. To conclude, based on our analysis, the energy consumption will be back to the levels experienced at peak times during 2007; looking into the future, we believe consumption will reach 100 quadrillion and 110 quadrillion during 2030 and 2050, respectively.

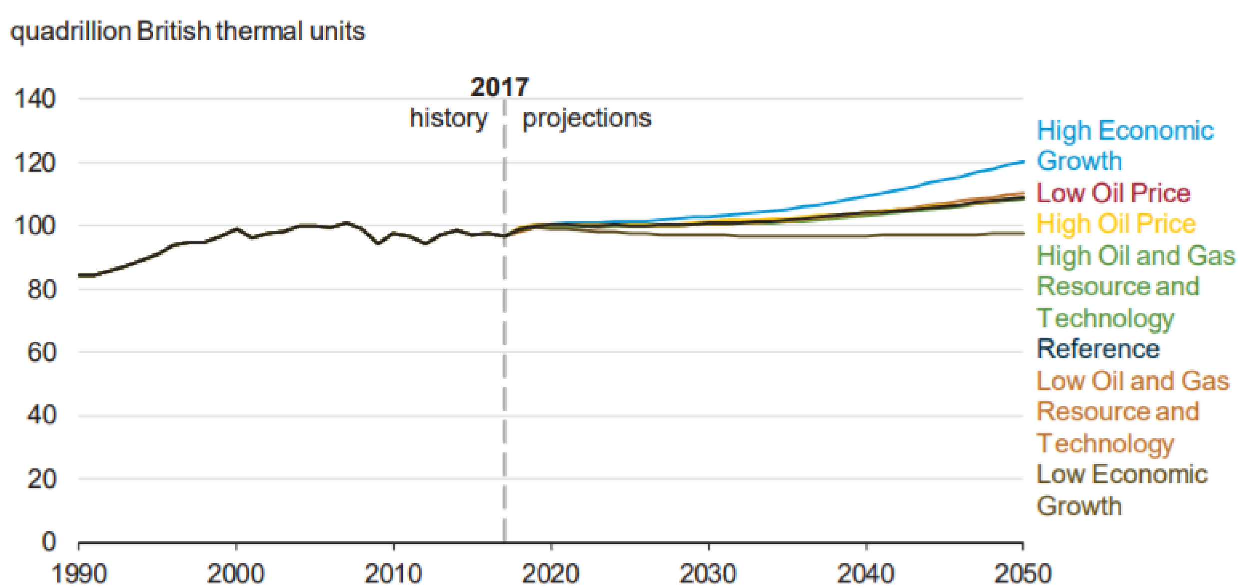


Figure 15. US Energy Consumption Prediction, "*Annual Energy Outlook 2018*", EIA (2018).

The line chart shows the trend for overall energy consumption prediction from 2017 to 2050.

Based on Figure 16 and data from EIA about energy consumption in different sectors, it is clear that the trend is that residential and commercial sectors will be decreasing and converging around 5 quadrillion British thermal units. However, there are significant growths in both the electric power and industrial sectors, where levels from 2017 to 2050 increase around 13.3% and 36.4%, respectively. Finally, for the transportation sector, it is clear that the energy will decrease before experiencing levels around 25 quadrillion British thermal units.

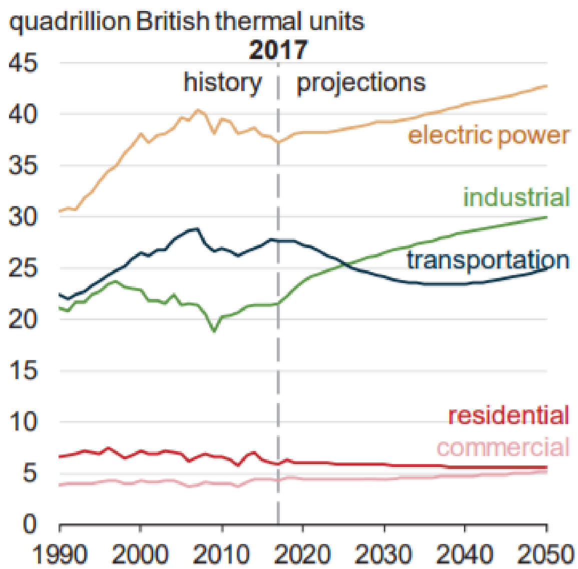


Figure 16. Energy Consumption by Sector, "*Annual Energy Outlook 2018*", EIA (2018). The figure shows the trend of energy consumption in different sectors and the prediction to 2050.

Considering the resources of consumption, Figure 17 illustrates that traditional energies (petrol, natural gas and coal) will still be dominant in the market and account for about 78% of the overall consumption in 2018, according to the EIA. When comparing this to the 80% levels experienced in 2017, there is a minimal difference. The most important change here is in the supply of the traditional energies is experienced by natural gas, which is expected to become one of the majority resources. Specifically, gas and petroleum will both account for 42% while the coal will be decreased and stabilized at around 13 quadrillion units. Nuclear, hydrogen, and liquid biofuels will be stabilized at around 6.5, 2.5, and 1.5 quadrillion units, respectively. Other renewable energies (mainly wind and solar) will increase to 13 quadrillion units by 2050 and account for around 12% of the overall consumption. Furthermore, renewable energies will likely result in 15-16% of the total energy consumption by the year 2050. However, our prediction will be more aggressive than the EIA because of the short-term approaches we suggest. Due to the government incentives and new investments in renewables, customers' awareness and perceptions are expected to increase. Thus, we estimate and hope that renewable energies, including hydrogen, will make up around 35% of overall consumption by 2050.

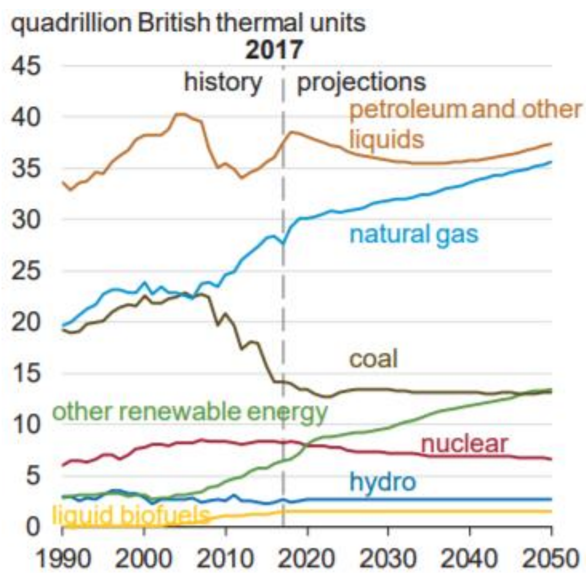


Figure 17. Energy Consumption by Fuel, "*Annual Energy Outlook 2018*", EIA (2018). The line chart shows the historical and predicted trend for energy consumption of all kinds of energies.

To conclude on the basis of our analysis, we believe the US energy consumption forecast reflect the number and structure found in Table 4. In general, we strongly believe the consumption structure will gradually shift towards a majority share of renewable energies.

Table 4.

US energy consumption forecast (Unit: quadrillion British thermal unit)

Time	Overall consumption	Traditional energies (gas, petrol and coal)	Renewable energies (wind, solar and hydrogen)	Other energies (nuclear and liquid biofuels)
2017	97	87%	9%	4%
2030	102	75%	20%	5%
2050	110	60%	35%	5%

Note: From Energy Information Administration, 2018

5.3.2 Future Wind & Solar Production Forecast. To be able to predict how wind and solar energy would or would not be feasible in the future, we look at how these renewables did in Denmark, how West Virginia is clearly different from Denmark, their respective feasibility in the US and consider the long-term political outlook.

1) Long-term Outlook on Solar and Wind in Denmark: As stated earlier on, Denmark implemented many new political and economic policies with regards to energy over forty-five years ago. This was because of the nature of the oil crisis. In order to contain a competitive advantage, Denmark held “consistent, determined, and long-term political objectives” to transition to a low-carbon country (The Danish Energy Agency, 2015, page 5). The government has been instituting practices and encouraging its energy portfolio to become more renewable with each passing year. It does not plan on stopping this progress. Through growth of wind production through offshore sites and use of other sustainable energies, Denmark plans to contain an energy portfolio comprised of more than 70% renewables by 2020. By 2050, the government of Denmark hopes to achieve its goal of complete self-reliance on renewable energy. (The Danish Energy Agency, 2015, page 2) As stated throughout this study, it is important to recognize that Denmark is a leading country in the renewable energy transition whose situation was unique.

2) Denmark's Circumstances are Unique: Although Denmark has taken the lead to be more sustainable and their progress is impressive, several conditions allow for the transition of their energy portfolio. Many believe it is due to the permitting resource endowment of the Nordic countries with an advanced integration of power grids in Europe. Others may point to the impressive synergy of the NordPool power exchange, the largest running market for electrical energy in Europe. The NordPool allows Denmark to buy or sell electricity, which is helpful for a country that has fluctuating renewable energy productions. But, the Danish Energy Agency believes that it is a combination of the efforts of several innovative and complex features. One feature of the system deals with the innovation of their thermal power plants. Because of a high level of innovation and efficiency, the plants can adapt to fluctuating power from wind, only producing electricity when needed. Moreover, Denmark regulates this production more highly than other countries to allow for optimal energy production levels. Denmark also has highly innovative wind forecasting systems that can predict and integrate wind power into the electric grids. Other countries have difficulties matching the supply and demand of electricity productions solely sourced by traditional means. Finally, by increasing the total share of renewables in the energy portfolio, Denmark will continue to benefit from a flexible and diversified energy portfolio while serving an exemplary role for other countries. (The Danish Energy Agency, 2015, pages 10-11)

3) West Virginia's Circumstances are Clearly Different: In Denmark, the country was required to have a diversified energy portfolio to compete with other countries and supply its own country with an adequate energy supply. In the United States and specifically West

Virginia, coal has been the resource of choice for decades with little to no incentives to change. Therefore, the transition towards renewables has only recently begun to take place and its rate of change has been slow and gradual. To begin, government policies were not instituted. The people of West Virginia, including those in policy-making positions, were proud of their coal industry because of its large impact on the state economy. The state's energy portfolio still contains a small fraction of renewables and the implementation of these resources is very low compared to some other states in the country. Specifically, for solar, West Virginia ranked 47th with only 0.01% of the total electricity generated by means of solar ("Solar Spotlight West Virginia", 2018). For wind power, the current share of the potential power generation for wind is less than 2 % ("WINDExchange: Wind Energy in West Virginia", 2018). However, the potential annual generation from wind power could be as high as 152,192 gigawatt hours by 2050. At this level and time, wind could account for more than 50% of the state's total electricity generation.

4) Feasibility of Wind Power in the United States: In 2017, the United States consumed 97.7 quadrillion British thermal units (Btu) of energy, but only produced 87.5 quadrillion ("U.S. Energy Facts - Energy Explained, Your Guide To Understanding Energy - Energy Information Administration", 2018). This is due to the fact that roughly 10% of the energy consumed in the US was imported. As stated earlier, by 2050, it is predicted that the United States renewable energy production will account for 50% of the total energy produced. Also predicted earlier, the total consumption of the United States is estimated to be 110 quadrillion. Assuming that ten percent is still imported by 2050, the United States renewable energy will need to account for 49.5 quadrillion Btu in order to achieve the goal of 50% of the share of the total. According to the American Wind Energy Association, the average annual electricity consumption during 2015 was 4.082 billion megawatt-hours. If one wind turbine produces 7,008 megawatt-hours of energy per year, then the United States would require roughly 583,000 onshore turbines to amount to the total consumption of energy for the year (Hensley, 2018). In similar terms, one wind turbine is capable of producing 24 billion Btu's per year. Moreover, one wind turbine costs roughly $3 to $4 million to complete; therefore, in order to power the predicted consumption of 49.5 quadrillion Btu, the United States would need to spend roughly $6-8 trillion. To further put this into perspective, $14.5 billion was invested in wind turbine installations in 2015. At this rate of investing, it would take over 400 years to fund an energy portfolio comprised entirely of wind energy. Finally, there are less than 32 years between now and 2050; in order to build this infrastructure, 62,500 wind turbines per year or roughly 171 per day will be required to be deployed in order to reach the goal. Clearly, this does not seem feasible. However, the United States continually improves the technology and, therefore, the efficiency of wind turbines with each passing year. Hopefully, the more advanced the technology becomes the lower both the number and price of wind turbines that will be required. Since the 1980s, the cost of installing wind energy has fallen by 90% (Hensley, 2018). Although it does not appear to be unfeasible, the United States must invest in renewable energies if it hopes to limit the amount of carbon emissions emitted and decrease its dependence on fossil fuels to ultimately come closer to the goal of a 50% renewable energy production portfolio.

5) Feasibility of Solar Power in the United States: Recently, the Office of Energy Efficiency & Renewable Energy found the average utility-scale cost of solar to be roughly $0.06 per kilowatt-hour ("2020 Utility-Scale Solar Goal Achieved", 2018). Because the term is used quite often in many contexts, "utility-scale solar" can encompass a wide range of sizes: anywhere from 25 kilowatts to 50 megawatts or 50,000 kilowatts. However, the University of Michigan's Renewable Energy in the California Desert report used 50 megawatts as the threshold for “utility-scale” ("Technology & Environment - Utility-Scale Solar Technologies - Solar Technologies | Drupal", n.d.). Again, if the total energy consumption in 2015 was 4.082 billion megawatt-hours, and a comparable 50-megawatt solar power plant can produce 128.5 gigawatt-hours per year or 128,500 megawatt-hours, then it would cost $7.71 million for one power plant and quarter of a trillion dollars for almost 32,000 plants of this size would be required for just one year (Aldali, Henderson & Muneer, 2011). Clearly, the required number of plants and the cost required to deploy the plants would be unbelievably high and therefore not feasible to achieve the goal of the 50% renewable energy share described earlier. Instead, the United States must continue to work on improving both the cost and efficiency of these technologies, but at a higher intensity, if they hope to achieve the goal.

6) Long-term Political Outlook on Solar and Wind in the United States: In the past presidential term, President Obama pushed for the implementation of renewable energy production systems. In 2011, at the State of the Union Address, Obama declared that 80% of the United States’ electricity production should come from clean energy sources by 2035 (Paalborg, 2011). Now, a new president sits in the oval office, and his plans are not exactly the same as his predecessor. Although many believe that Trump is against renewable energies because he defended the coal industry, the United States was still the second largest investor in clean energy during 2017 (“Clean Energy Investment 2016 | Bloomberg New Energy Finance”, 2018). That is not to say that Trump’s policies and actions will have no impact on the future of renewables; a recent post by the World Economic Forum explains the impact of the United States backing out of the Paris Accord: “One of the most troubling long-term impacts of these actions will be a declining global view of America as a source of innovation and investment…Unfortunately, the president’s actions look backward toward a fading horizon, rather than forward toward a bright and promising future (Ritter Jr, 2017)." But, there is still hope for the United States energy to be produced from renewables. In fact, the country is not too far off: "According to utility integrated resource plans, by 2026, just shy of half of the total energy in the West will be generated from zero-emitting resources" (Ritter Jr, 2017).

5.3.3 Aspirational versus Actual Sustainability Date. The above-mentioned information enables us to make predictions about the future, more concretely about when this model would allow the sustainability date (>50% of energy production comes from renewables, see 1.6) to be reached in West Virginia. Before we look at the numbers and the math behind this reasoning, some flaws and shortcomings of the numbers need to be mentioned. First of all, this research was conducted based on numbers which are predicted, thus meaning they are assumptions for the future. There is no guarantee these numbers are 100% correct. Secondly, collecting reliable data to make predictions was a rather complicated process, as can be found in Appendix G, we based our calculations of two large data samples. One data sample coming from the EIA (Energy Information Administration), and the other one coming from Statista (an online statistics, market research and business intelligence portal). Thirdly, it needs to be mentioned that we cannot link production quantity directly at consumption quantities. This study aims for a more sustainable energy production, meaning that we look at production numbers which are not equal to consumption numbers (in 2013 the US production accounted for 84% of the total US energy consumption (Joyce & Repice, 2013), and in 2017 domestic energy production was equal to about 90% of energy consumption (EIA.gov, 2018)). Lastly, we truly believe the progression of the usage of renewable energy sources on the production side, goes hand in hand with the ability to store them. As overproduction of wind and solar energy for example cannot be efficiently or on large-scale be stored right now, this means they can be responsible for a larger percentage of the production, than that percentage would equal to on the consumption side.

For the entirety of the following reasoning, we refer to Tables and Graphs found in Appendix G. Starting with Table 1, which represents what % of total energy production is coming from renewables, according to both sources. To demonstrate the differences in data even further, we refer to Graph 1, which comes from IEA (International Energy Agency), which shows us yet another different split of renewable vs. traditional in 2015 (13.35% EIA, 16.7% Statista & 7% IEA). As mentioned, we focus on the data of the EIA and Statista for our calculations.

Next, we calculated the annual growth rate of the renewable’s percentage, compared to the previous year (Table 2). We can see that both sources show almost exclusively positive annual growth rates for the Obama administration (2009-2017). Since these growth rates are somewhat volatile and inconsistent – due to domestic and foreign politics and macro-economic trends – this study decided to use the average annual growth rates as basis for predictions (Table 3). We point out that although Statista’s data shows a bigger obtained percentage of current energy production for renewables already, its annual growth rate is more conservative than that of the EIA, 3.34% and 4.07% respectively.

Based on these averages, we predicted how long it would take to reach our estimated sustainability date. As Table 4 shows, the results are not that far apart, namely 2044 according to EIA data and 2047 according to Statista data. According to these calculations, the US energy industry should have a production coming for more than 50% from renewables by at least 2050.

To continue on this calculation, some final remarks need to be made. Firstly, we recognize this a very positive outlook and not necessarily feasible, that is why it is the aspirational sustainability date and not the actual one. The actual one will probably come many years after 2050, since the next 10% growth are always harder to achieve than the previous 10% growth (Carfagno, 2018, Appendix D), and this is something this model does not take into account. The decreasing rate of growth is not taken into consideration, while in reality this will happen. Next, we do believe and hope for more technological advancements in the renewable energy area. This is a factor that could further enhance the process. Lastly, the growth rate is also clearly dependent on the investment made. How higher the investment in renewables in the coming years, how more likely the estimated growth rate could be obtained (referring to 5.3.2). There are factors bound to happen in the future – investments, technological advancements, macro-economic factors – which will either slow down or help increase the growth rate of renewable energies, we assume that these will more or less balance each other out, leading to why we did not include them numerically in the calculations.

To conclude this chapter, we state that the aspirational sustainability date for West Virginia should be at least 2050, but since West Virginia is one of the most traditional energy based states and because of possible factors mentioned above, the actual sustainability date is likely to happen later. This study also used numerical data of the entire United States to calculate renewable energy growth rates and percentages, which don't necessarily reflect the situation in West Virginia. This is another reason why the study estimates the actual sustainability date to be for the second half of the 21st century.

5.4 Recognition of Drawbacks

5.4.1 Resistance to Change. For many years, companies have reaped the benefits of having what seems like an almost unlimited amount of fossil fuels to burn at artificially low levels. The term artificially is used because the price at which humans burn these types of resources completely exclude the external impact and cost imposed on the environment. Companies in the United States are resistant to changing to renewable forms of energy because they believe these types of resources are more expensive than traditional forms of energy such as coal or gas. However, companies should recognize the benefits of changing. Andrew Winston, a well-known author and consultant who advises companies on how to navigate and profit from environmental and social changes, makes a fair point on the matter: "That said, organizations could recognize that the additional benefits from a larger, quicker move to onsite renewables — including having a hedge on fuel prices, inspiring employees and customers, and building resilience to extreme weather and grid outages — adds up to real value, even if it's hard to measure. Companies and consumers could also decide it's cool to use clean power. The Toyota Prius sold millions of units not because it saved money on fuel, but because of what detractors noticed was a certain smugness or pride in driving it (I'm guilty as charged)." (Andrew Winston HBR February 5, 2014) It is true that, in the past, the price to burn fossil fuels was much lower and therefore a more economic choice as opposed to renewables. However, as resources diminish and demand rises, the price of burning fossil fuels increases. As time goes on, the average cost to implement renewables becomes cheaper and more attractive: "The average cost in 2017 to install solar systems ranged from a little over $2,000 per kilowatt (kilowatts are a measure of power capacity) for large-scale systems to almost $3,700 for residential systems. A new natural gas plant might have costs around $1,000/kW. Wind comes in around $1,200 to $1,700/kw." (Union of Concerned Scientists, Barriers to Renewable Energy Technologies, December 20, 2017) For the renewable industry, getting financial institutions to back the renewable projects is more difficult than their non-renewable counterpart: "Higher construction costs might make financial institutions more likely to perceive renewables as risky, lending money at higher rates and making it harder for utilities or developers to justify the investment. For natural gas and other fossil fuel power plants, the cost of fuel may be passed onto the consumer, lowering the risk associated with the initial investment (though increasing the risk of erratic electric bills).” But, when considering the long-term lifespan of the projects, “…wind and utility-scale solar can be the least expensive energy generating sources, according to asset management company Lazard.” (Union of Concerned Scientists, Barriers to Renewable Energy Technologies, December 20, 2017)

5.4.2 US Politics. Another considerable fallback that makes the transition towards a more renewable United States deals with the issues revolving around the lack of proper domestic and national laws and regulations on carbon emission. There is, as Winston puts it, a lack of political will: “President Obama said that climate change was a fact and touted the growth of solar energy in America. But he also bragged about increased production of natural gas and oil. Very few politicians will take on those powerful lobbies, so a price on carbon is likely a fantasy in the US for now. And partly because of America’s intransigence, 19 years of global negotiations on binding limits on carbon have led nearly nowhere.” (Andrew Winston HBR February 5, 2014) The singing of treaties with other nations, political speeches on the need to reduce emissions, and other past efforts are simply not enough to promote and enforce change. The government needs to change its current laws, both domestically and nationally, and put in place punishments such as fines or restrictions in order for people and businesses to comply. Currently, the competition amongst renewable and non-renewable industries is unfair and the government has done little to promote an equal competitive environment. If governments get on board with this process, the manner in which competition exists between traditional and alternative energy industries would change for the better: “This in turn means that renewables aren’t entering an equal playing field:

they're competing with industries that we subsidize both directly (via government incentives) and indirectly (by not punishing polluters). Emission fees or caps on total pollution, potentially with tradable emission permits, are examples of ways we could use to help remove this barrier." (Union of Concerned Scientists, Barriers to Renewable Energy Technologies, December 20, 2017) In West Virginia, if incentives were provided to renewable energy companies and coal companies were punished by restrictions on carbon emissions, the government would promote a positive transition towards a more renewable and diversified portfolio of energy. Although this may sound simple and easy to do, there are political, social, and economic drawbacks that are specific to an area such as West Virginia. According to Jeremy Richardson, a West Virginia native and the brother, son, and grandson of West Virginia coal miners, many West Virginians are proud to be a large part of the coal industry: "In coal country, mines have often been the economic anchor for communities, as well as a source of pride and cultural identity" (Fred Pace, Altering Clean Power Plan may not reverse coal trend, October 15, 2017). If the people of West Virginia are against transitioning towards renewable energies, it is likely that their politicians in state and local governments are also against the transition.

5.4.3 Government Spending. Instead of promoting efforts towards renewable energies, there has been a dark past relationship between the government and the fossil fuel industry. Rather than spending money on improving R&D or government efforts in the renewable energy sector, past reports expose that governments in the world "were still spending far more money to subsidize fossil fuels than to accelerate the shift to cleaner energy, thus encouraging continued investment in projects like coal-burning power plants that pose a long-term climate risk" (Justin Gillis The New York Times January 16 2014). With less capital being allocated towards the renewable energy industry, a sustainable state and nation is far less feasible. Moreover, this signals that the relationship between renewable energy companies, the government, and the people is not strong and that pressure to lower carbon emissions is weak. Moreover, one of the largest pressing issues facing the clean energy industry concerns the barriers to market entry: “Solar, wind, and other renewable resources need to compete with wealthier industries that benefit from existing infrastructure, expertise, and policy. It’s a difficult market to enter. New energy technologies—start-ups—face even larger barriers. They compete with major market players like coal and gas, and with proven, low-cost solar and wind technologies. To prove their worth, they must demonstrate scale: most investors want large quantities of energy, ideally at times when wind and solar aren’t available. That’s difficult to accomplish, and a major reason why new technologies suffer high rates of failure.” (Union of Concerned Scientists, Barriers to Renewable Energy Technologies, December 20, 2017) Without capital and government backing to demonstrate the feasibility, efficiency, and economic impacts of clean energy, the barriers to entry remain high, making it difficult to progress the transition.

5.4.4 Imperfect Renewable Technologies. Because of several factors, the current position on technologies pertaining to renewable energies is one that is developed although behind its time. It is still possible to increase the efficiency of renewable energy systems and further strengthen the returns that the technologies permit. There is still a lot of investment and R&D needed to move towards more perfect systems. Carfagno paraphrases an important point made by Hans Henrik Brandenborg Sørensen, a specialist on large-scale scientific computing software: “he explains the difficult choice to be made between keeping a wind turbine which is currently profitable, or taking it down and replace it by a new one that will be 4 times as profitable, but which will need a payback term.” For a first mover in the renewable energy industry, one of the challenges they exist pertains to keeping up with the best technology and knowing when to change from old to new to generate the optimal return on investment. Luckily, technologies are improving with time. However, there is a large margin for improvement.

Although humanity has made a lot of process in its development of technologies, there is still a long way to go: “Renewable energy does provide 21% of electricity globally, but *modern* renewables (like solar and wind, not hydro), which would really displace coal and natural gas, only provide 5%. Renewables are a long way from dominating electricity enough to make fossil fuel energy a bad investment.” (Andrew Winston HBR February 5, 2014) Moreover, the issue worsens with each passing day. The longer the globe waits to transfer a fossil fuel burning environment to one that is clean, the more expensive and irreversible the outcome becomes. Nations need to invest more in research and development and quickly make changes to current practices: “Nations have so dragged their feet in battling climate change that the situation has grown critical and the risk of severe economic disruption is rising, according to a draft United Nations report. Another 15 years of failure to limit carbon emissions could make the problem virtually impossible to solve with current technologies, experts found.” (Justin Gillis The New York Times January 16 2014) Those who argue against the use of clean energy systems, tend to claim that they are unreliable; however, “Solar and wind are highly predictable, and when spread across a large enough geographic area—and paired with complementary generation sources—become highly reliable. Modern grid technologies like advanced batteries, real-time pricing, and smart appliances can also help solar and wind be essential elements of a well-performing grid.” (Union of Concerned Scientists, Barriers to Renewable Energy Technologies, December 20, 2017) In the past, renewable energy systems were still being practiced and demonstrated; however, as time goes on, additional investments are needed to pursue a nation that is closer to becoming 100% sustainable.

5.4.5 Optimal Transition Rate. If there were an optimal transition rate that is simple to calculate, the United States would likely allocate the exact amount of capital and resources needed. However, no one knows or will know this rate or required investment that will leave the least damaging effects while promoted the most efficient transition. It makes sense, however, that in order for a transition to happen and to be “smooth” all forces that wish to promote it must work in coordination with one another. “That’s why we need all of these efforts to work in conjunction — movement on any one of them will give momentum and credibility to the others. The social and government pressures will accelerate investment and thus improve the economics. And in return, if companies start buying a lot more renewable energy, they will help build the market, improve the economics, and give cover to politicians to take action.” (Andrew Winston HBR February 5, 2014) At first glance, the decision to eliminate an economic driver, such as the coal industry, that accounts for much of the economy and replace it with a new system that has little to no experience seems to be expensive and foolish. Those who refute the transition towards a clean energy industry reiterate that this transition would be too costly. In the short run, there would be a lot of added costs to shut down plants and open new ones. However, proponents of this clean transition argue that, in the long run, the reform would be economically beneficial by increasing economic growth. Policies must be constructed to “phase out inefficient fossil fuel subsidies. One concern is that in the short term this could lead to higher energy prices and a decrease in economic growth. But the money governments save could be invested in ways that would reduce the cost of renewable alternatives and encourage a more rapid transition away from fossil fuels” (David Timmons, Jonathan M. Harris, and Brian Roach, The Economics of Renewable Energy, 2014, page 35).

6. Conclusion

The United States, as an economic and political global leader, serves an exemplary role to the rest of the world. In times of destructive climate change and increasing urgency to mitigate carbon emissions, a framework to transition towards a more sustainable economy is required. Though the US attempted to become a hydrogen-driven, thus renewable, society, this approach failed. Currently there exist no guidelines or framework to guide a transition towards renewables. This study provides such a framework for the US energy industry: the country's most polluting industry. The model is based on The Danish Initiative, described as the successful initiative taken by Denmark to become the world's leading country on renewable energy and a reinvented and US-tailored version of the existing Carbon Credit System. Because of demographic similarities between the US and Denmark and an international need for transitioning towards renewables, this study believes that the US can partly follow Denmark's approach. Within the United States, lies West Virginia, one of the biggest energy producing and polluting states of the country. When West Virginia successfully incorporates its transition towards renewable energy, it will serve as a prime example for all other states in the country. If a state that is 95% reliant on fossil fuels can transition, any other state can do the same. Ultimately, this would drive the entire country in a more sustainable direction because of West Virginia's large impact on the US energy industry and its current lack of renewable energy.

To build this framework, case analyses on Denmark's history and transition were conducted, as well as data collection through expert interviews and surveying West Virginia (and surrounding areas) energy companies. This research established that the US energy industry is still highly reliant on traditional energy sources and discovered unfavourable policies regarding renewable energies, but with large potential to improve and grow. Experts confirmed the potential of the implementation of the Danish Initiative and the adapted new carbon credit system in the US. Although, both the experts and the surveys identified issues and possible drawbacks: 1) a lack of motivation for companies to be highly and proactively involved in the transition; 2) a lack of expertise regarding technologies of renewable energies and their production methods; 3) an uncertainty towards a transition with unstable policies and an immature market; 4) cultural factors and historical bundles of interests pertaining to traditional energy sources.

The proposed framework introduces both a short-term and long-term approach. To begin with the short-term, this study recommends large infrastructure and R&D investments in both solar and wind, since these are the renewable energies identified by the paper to be the most profitable and easiest to implement. These investments will be contributed by not only the private sector, but also by the government, through the implementation of the new carbon emission regulation system. This system provides the energy industry with incentives to transition and invest in renewables, by means of tax benefits and subsidies, as well as encouragements, based on the amount of carbon emissions emitted by a company. By continuing to shut down coal-fired plants, the government will make a positive impact and raise consumer and industry awareness of the damaging effects of nonrenewable energies and the lasting positives associated with renewables.

The long-term goal of this framework is to reach the sustainability date for West Virginia, which the paper defines as the date on which 50% or more of energy production comes from renewable energy sources. In addition to continuing the efforts of the short-term plan, the long-term framework should also consider the potential investments and opportunities of other renewables. Based on the Danish Initiative, wind should and will continue to play a main role in this transition, but it is also important to recognize that the United States is too big and diversified to only focus on two types of renewable energy. The study predicts the nation's energy consumption to increase at a decreasing rate, giving technology improvements time to catch up and renewables time to represent a larger percentage of the total energy production. Since the US energy consumption is higher than its production, the sustainability date on the production side will be reached sooner than the one on the consumption side. The thesis predicts that by 2050 the United States will have an energy production that comes from 50% from renewable energy sources (wind, solar, hydrogen, biomass). For West Virginia, the study recognizes the state will have a slower transition rate and a later sustainability date.

Although the experts have verified our framework as feasible, several drawbacks should be considered. Because of the magnitude of the change that will be experienced, some companies, politicians, and citizens will be reluctant to change. In addition, governments and industries need to be completely on board with spending efforts to promote the use of renewable energies. Finally, both governments and industries need to improve the current technologies and implement improved technologies at optimal times.

To conclude, it is possible and feasible for West Virginia to transition to a more sustainable energy production era. Its successful transition will have impacts on the whole country and the entire world. The implementation of this framework based on the Danish Initiative and new Carbon Credit System will face obstacles in an economy driven by financial gain and politics, but it has great potential for success through its feasibility. As researchers, we are required to be objective and unbiased, although we do hope this transition happens in an efficient and timely.

For future research, the study recommends analyzing the impact of energy consumption behavior on the energy production in the US, and how the consumption side can leverage the production side to become more sustainable.

References

Advantages & Disadvantages of Solar Energy (2018) | GreenMatch. (2018). Greenmatch.co.uk. Retrieved 20 April 2018, from https://www.greenmatch.co.uk/blog/2014/08/5-advantages-and-5-disadvantages-of-solar-energy

Advantages and Disadvantages of Wind Energy - Clean Energy Ideas. (2018). Clean Energy Ideas. Retrieved 20 April 2018, from https://www.clean-energy-ideas.com/wind/wind-energy/advantages-and-disadvantages-of-wind-energy

Aldali, Y., Henderson, D., & Muneer, T. (2011). A 50 MW very large-scale photovoltaic power plant for Al-Kufra, Libya: energetic, economic and environmental impact analysis. *International Journal Of Low-Carbon Technologies*, *6*(4), 811-815. doi: 10.1093/ijlct/ctr015

American Wind Energy Association Facts Sheet. AWEA (2017). https://www.awea.org/

Annual Days of Sunshine in West Virginia - Current Results. (2018). Retrieved from https://www.currentresults.com/Weather/West-Virginia/annual-days-of-sunshine.php

Barbir, F. (2009). Transition to renewable energy systems with hydrogen as an energy carrier☆. *Energy*, *34*(3), 308-312. http://dx.doi.org/10.1016/j.energy.2008.07.007

BBC (2017). The Water Cycle. https://www.bbc.co.uk/education/guides/z4bk7ty/revision

Breslau, D. (2013). Studying and Doing Energy Transition. *Nature And Culture*, *8*(3). http://dx.doi.org/10.3167/nc.2013.080306

Bromley-Trujillo, R., Butler, J., Poe, J., & Davis, W. (2016). The Spreading of Innovation: State Adoptions of Energy and Climate Change Policy. *Review Of Policy Research*, *33*(5), 544-565. http://dx.doi.org/10.1111/ropr.12189

Bruenig, M. (2015). United States vs. Denmark, in 17 Charts. http://www.demos.org/blog/10/20/15/united-states-vs-denmark-17-charts

Business Energy Investment Tax Credit (ITC). DSIRE, 1 Mar. 2018, programs.dsireusa.org/system/program/detail/658.

Centre for Business and Economic Research. (2017). *Renewable Energy in West Virginia: Research for 5-Year Energy Plan* (pp. 1-33). Huntington: Marshall University.

Chung, J., & Kim, E. (2018). Public perception of energy transition in Korea: Nuclear power, climate change, and party preference. Energy Policy, 116, 137-144. http://dx.doi.org/10.1016/j.enpol.2018.02.007

Clean Energy Investment 2016 | Bloomberg New Energy Finance. (2018). Retrieved from https://about.bnef.com/clean-energy-investment/

Clean Energy Mind Games | Issues in Science and Technology. (2018). Issues.org. Retrieved 20 April 2018, from http://issues.org/33-4/clean-energy-mind-games/

Curley, A. (2017). A failed green future: Navajo Green Jobs and energy “transition” in the Navajo Nation. *Geoforum*, *88*, 57-65. http://dx.doi.org/10.1016/j.geoforum.2017.11.012

Danish Energy Agency (2016). The Danish Energy Model. https://ens.dk/en/our-responsibilities/global-cooperation/danish-energy-model

DiChristopher, T. (2018). Trump pledged to revive the coal industry, but little has changed one year into his first term. CNBC. https://www.cnbc.com/2018/01/22/trump-pledged-to-revive-coal-industry-little-has-changed-in-a-year.html

Dima, B., & Dima, Ş. (2017). Energy consumption synchronization between Europe, United States and Japan: A spectral analysis assessment. *Renewable And Sustainable Energy Reviews*, *77*, 1261-1271. http://dx.doi.org/10.1016/j.rser.2017.03.042

Eia.gov (2014). Energy-related Carbon Dioxide Emissions at the State Level, 2000-2014. Fig. 2 https://www.eia.gov/environment/emissions/state/analysis/

Eia.gov (2015). Rankings, Total Energy Production (2015). https://www.eia.gov/state/rankings/#/series/101

Eia.gov (2017). Electricity in the United States https://www.eia.gov/energyexplained/index.cfm?page=electricity_in_the_united_states

Eia.gov (2017). What is the United States' share of world energy consumption? https://www.eia.gov/tools/faqs/faq.php?id=87&t=1

Eia.gov (2017). Hydropower explained. https://www.eia.gov/energyexplained/index.cfm?page=hydropower_home

Eia.gov (2018). U.S Energy facts – Energy explained, your guide to understanding energy – Energy Information Administration. https://www.eia.gov/energyexplained/?page=us_energy_home

EIA 2018. Eia.gov. Retrieved 20 April 2018, from https://www.eia.gov/todayinenergy/detail.php?id=31032https://www.eia.gov/todayinenergy/detail.php?id=31032

Eick, J. (2015). West Virginia Becomes First State to Repeal RPS - American Legislative Exchange Council. Retrieved from https://www.alec.org/article/west-virginia-becomes-first-state-repeal-rps/

Energy Information Administration. (2017). *Annual Energy Outlook 2017*. U.S. Energy Information Administration.

EPA (2017). Our Mission and What We Do. https://www.epa.gov/aboutepa/our-mission-and-what-we-do

Fawcett, A., Calvin, K., de la Chesnaye, F., Reilly, J., & Weyant, J. (2009). Overview of EMF 22 U.S. transition scenarios. *Energy Economics*, *31*, S198-S211. http://dx.doi.org/10.1016/j.eneco.2009.10.015

Fawcett, A., Iyer, G., Clarke, L., Edmonds, J., Hultman, N., & McJeon, H. et al. (2015). Can Paris pledges avert severe climate change? Science, 350(6265), 1168-1169. http://dx.doi.org/10.1126/science.aad5761

Friedrich J., Ge M., & Pickens A. (2017). This Interactive Chart Explains World's Top 10 Emitters, and How They've Changed. http://www.wri.org/blog/2017/04/interactive-chart-explains-worlds-top-10-emitters-and-how-theyve-changed

Gibbens, Sarah. (2017) "Renewable Energy Record Set in U.S." *National Geographic*, National Geographic Society. news.nationalgeographic.com/2017/06/solar-wind-renewable-energy-record/.

Gilbertson, T., Reyes, O., & Lohmann, L. (2009). *Carbon trading*. Uppsala: Dag Hammarskjöld Foundation.

Gralla, F., Abson, D., Møller, A., Lang, D., & von Wehrden, H. (2017). Energy transitions and national development indicators: A global review of nuclear energy production. Renewable And Sustainable Energy Reviews, 70, 1251-1265. http://dx.doi.org/10.1016/j.rser.2016.12.026

Grandin, K., Jagers, P., & Kullander, S. (2010). Nuclear Energy. AMBIO, 39(S1), 26-30. http://dx.doi.org/10.1007/s13280-010-0061-0

Gray, W., & Metcalf, G. (2017). Carbon Tax Competitiveness Concerns: Assessing a Best Practices Carbon Credit. *National Tax Journal*, *70*(2), 447-468. http://dx.doi.org/10.17310/ntj.2017.2.08

GreenChipStocks (2017). Special Report: Carbon Trading: The World's Next Biggest Market. https://www.greenchipstocks.com/report/carbon-trading-the-worlds-next-biggest-

Guidolin, M., & Guseo, R. (2016). The German energy transition: Modeling competition and substitution between nuclear power and Renewable Energy Technologies. Renewable And Sustainable Energy Reviews, 60, 1498-1504. http://dx.doi.org/10.1016/j.rser.2016.03.022

Hensley, J. (2018). Here's how much of the US would need to be covered in wind turbines to power the nation. Retrieved from http://www.businessinsider.com/wind-turbines-to-power-earth-2016-9

Herholdt, J. (2015). Tax Exemption for Wind Energy Generation. Retrieved from http://programs.dsireusa.org/system/program/detail/104

Högberg, L. (2013). Root Causes and Impacts of Severe Accidents at Large Nuclear Power Plants. AMBIO, 42(3), 267-284. http://dx.doi.org/10.1007/s13280-013-0382-x

Horvath, A., & Rachlew, E. (2015). Nuclear power in the 21st century: Challenges and possibilities. Ambio, 45(S1), 38-49. http://dx.doi.org/10.1007/s13280-015-0732-y

Hvelplund, F., Østergaard, P., & Meyer, N. (2017). Incentives and barriers for wind power expansion and system integration in Denmark. *Energy Policy*, *107*, 573-584. http://dx.doi.org/10.1016/j.enpol.2017.05.009

Imholte, D., Nguyen, R., Vedantam, A., Brown, M., Iyer, A., & Smith, B. et al. (2017). An assessment of U.S. rare earth availability for supporting U.S. wind energy growth targets. *Energy Policy*, *113*, 294-305. http://dx.doi.org/10.1016/j.enpol.2017.11.001

Joyce, M. & Repice, R. (2018). Domestic Productions Satisfies 84% of total U.S. energy demand in 2013. EIA.gov. https://www.eia.gov/todayinenergy/detail.php?id=16511

Kannan, R., & Turton, H. (2016). Long term climate change mitigation goals under the nuclear phase out policy: The Swiss energy system transition. Energy Economics, 55, 211-222. http://dx.doi.org/10.1016/j.eneco.2016.02.003

King, C. (2016). How much can the next president influence the US energy system? The Conversation. http://theconversation.com/how-much-can-the-next-president-influence-the-u-s-energy-system-55214

Köktürk, G., & Tokuç, A. (2017). Vision for wind energy with a smart grid in Izmir. Renewable And Sustainable Energy Reviews, 73, 332-345. http://dx.doi.org/10.1016/j.rser.2017.01.147

Lattin, W., & Utgikar, V. (2007). Transition to hydrogen economy in the United States: A 2006 status report. *International Journal Of Hydrogen Energy*, *32*(15), 3230-3237. http://dx.doi.org/10.1016/j.ijhydene.2007.02.004

Laurance, W. (2008). Can Carbon Trading Save Vanishing Forests?. *Bioscience*, *58*(4), 286-287. http://dx.doi.org/10.1641/b580402

Leiserowitz, A., Maibach, E., Roser-Renouf, C., Feinberg, G., & Rosenthal, S. (2013). *Public Support For Climate and Energy Policies in November 2013* [Ebook]. Environment.yale.edu.

Levelized Cost of Energy 2017. (2017). Retrieved from https://www.lazard.com/perspective/levelized-cost-of-energy-2017/

Lewis, J. (2010). The evolving role of carbon finance in promoting renewable energy development in China. *Energy Policy*, *38*(6), 2875-2886. http://dx.doi.org/10.1016/j.enpol.2010.01.020

Lund, H. (2010). The implementation of renewable energy systems. Lessons learned from the Danish case. *Energy*, *35*(10), 4003-4009. http://dx.doi.org/10.1016/j.energy.2010.01.036

Lund, H., & Mathiesen, B. (2009). Energy system analysis of 100% renewable energy systems—The case of Denmark in years 2030 and 2050. *Energy*, *34*(5), 524-531. http://dx.doi.org/10.1016/j.energy.2008.04.003

Lund, H., & Münster, E. (2003). Modelling of energy systems with a high percentage of CHP and wind power. *Renewable Energy*, *28*(14), 2179-2193. http://dx.doi.org/10.1016/s0960-1481(03)00125-3

Lund, Henrik (2007). Renewable Energy Strategies for Sustainable Development. https://search.lib.virginia.edu/articles/article?id=edselp%3AS036054420600301X

Mathews, J. (2008). How carbon credits could drive the emergence of renewable energies. *Energy Policy*, *36*(10), 3633-3639. http://dx.doi.org/10.1016/j.enpol.2008.05.033

McDonell, Tim (2015 July 14). America's Dirtiest Power Companies, Ranked. http://www.motherjones.com/environment/2015/07/dirtiest-power-companies-

Mendonça, M., Lacey, S., & Hvelplund, F. (2009). Stability, participation and transparency in renewable energy policy: Lessons from Denmark and the United States. *Policy And Society*, *27*(4), 379-398. http://dx.doi.org/10.1016/j.polsoc.2009.01.007

Mey, F., & Diesendorf, M. (2017). Who owns an energy transition? Strategic action fields and community wind energy in Denmark. *Energy Research & Social Science*. http://dx.doi.org/10.1016/j.erss.2017.10.044

Meyer, N. (2004). Renewable energy policy in Denmark. *Energy For Sustainable Development*, *8*(1), 25-35. http://dx.doi.org/10.1016/s0973-0826(08)60388-9

National Geographic Society (2017). Map Shows Growing U.S. 'Climate Rebellion' Against Trump. news.nationalgeographic.com/2017/06/states-cities-usa-climate-policy-environment/

National Indian Carbon Coalition (2015). The Carbon Credit Market. http://www.indiancarbon.org/the-carbon-credit-market.html

NationMaster (2017). Country vs country: Denmark and United States compared: Government stats. http://www.nationmaster.com/country-info/compare/Denmark/United-States

News, David J. Unger InsideClimate, et al. (2017). “Solar Power in the U.S.: 27.2 Gigawatts but Not Quite a Revolution. Yet.” *InsideClimate News*, insideclimatenews.org/news/24052016/solar-energy-27-gigawatts-united-states-one-million-rooftop-panels-climate-change-china-germany.

O'Connor, P., & Cleveland, C. (2014). U.S. Energy Transitions 1780–2010. *Energies*, *7*(12), 7955-7993. http://dx.doi.org/10.3390/en7127955

OMalley, M., & Kroposki, B. (2013). Energy Comes Together: The Integration of All Systems [Guest Editorial]. *IEEE Power And Energy Magazine*, *11*(5), 18-23. http://dx.doi.org/10.1109/mpe.2013.2266594

Oteman, M., Wiering, M., & Helderman, J. (2014). The institutional space of community initiatives for renewable energy: a comparative case study of the Netherlands, Germany and Denmark. *Energy, Sustainability And Society*, *4*(1), 11. http://dx.doi.org/10.1186/2192-0567-4-11

Oxford University Press (2017). Ripple effect. https://en.oxforddictionaries.com/definition/ripple_effect

Paalborg, A. (2011). West Virginia's Alternative and Renewable Energy Portfolio Act: The "Mountain State's" Latest Attempt to Quit its Addiction to Coal. *Pittsburgh Journal Of Environmental And Public Health Law*, *6*(1). doi: 10.5195/pjephl.2011.57

Padis, G. M. (2011). Carbon credits as collateral. Journal of Technology Law Policy 16(2), 343-366.

Parajuli, R. (2012). Looking into the Danish energy system: Lesson to be learned by other communities. *Renewable And Sustainable Energy Reviews*, *16*(4), 2191-2199. http://dx.doi.org/10.1016/j.rser.2012.01.045

Perdan, S., & Azapagic, A. (2011). Carbon trading: Current schemes and future developments. *Energy Policy, 39*(10), 6040-6054. http://dx.doi.org/10.1016/j.enpol.2011.07.003

Peter Andreasen, K., & Sovacool, B. (2014). Energy sustainability, stakeholder conflicts, and the future of hydrogen in Denmark. *Renewable And Sustainable Energy Reviews*, *39*, 891-897. http://dx.doi.org/10.1016/j.rser.2014.07.158

Ramiah, V., Pham, H., Wang, I., Dang, V., Veron, J., & Duong, H. (2016). The financial consequences of abolishing a carbon trading system. *Applied Economics Letters*, *24*(13), 936-939. http://dx.doi.org/10.1080/13504851.2016.1243201

Residential Renewable Energy Tax Credit. DSIRE, 23 Mar. 2018, programs.dsireusa.org/system/program/detail/1235.

Riley, C. & Sherman, I. (2017). World's Largest Economies. http://money.cnn.com/news/economy/world_economies_gdp/index.html

Rinkesh (2017). What are Carbon Credits? https://www.conserve-energy-future.com/carbon-credits.php

Rintamäki, T., Siddiqui, A., & Salo, A. (2017). Does renewable energy generation decrease the volatility of electricity prices? An analysis of Denmark and Germany. *Energy Economics*, *62*, 270-282. http://dx.doi.org/10.1016/j.eneco.2016.12.019

Risch, C. (2017). Renewable Energy in West Virginia: Research for 5-Year Energy Plan. Retrieved from http://energywv.org/assets/files/EnergyPlan/Renewable-Energy-Opportunities-for-West-Virginia-2017-Update.pdf

Ritter Jr, B. (2017). What's the future of renewables in the US?. Retrieved from https://www.weforum.org/agenda/2017/04/why-renewable-energy-isnt-going-anywhere-in-the-united-states-despite-president-trumps-executive-order

Rocky Mountain Institute, Guevara-Stone, L. (2016). Denmark, The Little Country With Big Renewable Energy Goals. https://cleantechnica.com/2016/03/09/denmark-the-little-

Rubin, J., & Leiby, P. (2013). Tradable credits system design and cost savings for a national low carbon fuel standard for road transport. *Energy Policy*, *56*, 16-28. http://dx.doi.org/10.1016/j.enpol.2012.05.031

Rüdiger, Mogens. *The 1973 Oil Crisis and the Designing of a Danish Energy Policy*. Historical Social Research, DEU, 2014, www.ssoar.info/ssoar/handle/document/40489

Saikku, L., Tainio, P., Hildén, M., Antikainen, R., Leskinen, P., & Koskela, S. (2017). Diffusion of solar electricity in the network of private actors as a strategic experiment to mitigate climate change. Journal Of Cleaner Production, 142, 2730-2740. http://dx.doi.org/10.1016/j.jclepro.2016.11.003

Seljom, P., & Tomasgard, A. (2015). Short-term uncertainty in long-term energy system models — A case study of wind power in Denmark. *Energy Economics*, *49*, 157-167. http://dx.doi.org/10.1016/j.eneco.2015.02.004

Shen, Feifei, et al. (2017). China to Move Closer to Starting National Carbon Market.*Bloomberg.com*, Bloomberg. www.bloomberg.com/news/articles/2017-10-31/china-seeks-to-avoid-excessive-speculation-in-carbon-trading

Shum, R. (2015). Where constructivism meets resource constraints: the politics of oil, renewables, and a US energy transition. *Environmental Politics*, *24*(3), 382-400. http://dx.doi.org/10.1080/09644016.2015.1008236

Siler-Evans, Kyle, et al. “Regional Variations in the Health, Environmental, and Climate Benefits of Wind and Solar Generation.” Proceedings of the National Academy of Sciences, National Academy of Sciences, 15 May, 2013. www.pnas.org/content/110/29/11768.abstract

Solar Spotlight West Virginia. (2018). Retrieved from https://www.seia.org/sites/default/files/2018-03/Federal_2017Q4_West%20Virginia_3.12.2018.pdf

Solomon, B., & Krishna, K. (2011). The coming sustainable energy transition: History, strategies, and outlook. *Energy Policy*, *39*(11), 7422-7431. http://dx.doi.org/10.1016/j.enpol.2011.09.009

Sovacool, B. (2013). Energy policymaking in Denmark: Implications for global energy security and sustainability. *Energy Policy*, *61*, 829-839. http://dx.doi.org/10.1016/j.enpol.2013.06.106

Sovacool, B., Lindboe, H., & Odgaard, O. (2008). Is the Danish Wind Energy Model Replicable for Other Countries? *The Electricity Journal*, *21*(2), 27-38. http://dx.doi.org/10.1016/j.tej.2007.12.009

Sperling, K., Hvelplund, F., & Mathiesen, B. (2011). Centralisation and decentralisation in strategic municipal energy planning in Denmark. *Energy Policy*, *39*(3), 1338-1351. http://dx.doi.org/10.1016/j.enpol.2010.12.006

State Energy Profile Data. (2018). Retrieved from https://www.eia.gov/state/data.php?sid=WV

Stillman, Jessica (2008). What is Carbon Credit? https://www.cbsnews.com/news/what-is-carbon-credit/

Stokes, L., & Breetz, H. (2017). Politics in the U.S. energy transition: Case studies of solar, wind, biofuels and electric vehicles policy. *Energy Policy*, *113*, 76-86. http://dx.doi.org/10.1016/j.enpol.2017.10.057

Talberg, Anita, and Kai Swoboda. (2013). Emissions Trading Schemes Around the World. *Parliament of Australia*, Commonwealth of Australia, parlinfo.aph.gov.au/parlInfo/download/library/prspub/2501441/upload_binary/2501441.pdf;fileType=application/pdf

Technology & Environment - Utility-Scale Solar Technologies - Solar Technologies | Drupal. Retrieved from http://webservices.itcs.umich.edu/drupal/recd/?q=node/154

The Danish Energy Agency. (2015). *The Danish Energy Model*. Copenhagen: The Danish Energy Agency.

The Institute for Energy Research. *IER* (2017). instituteforenergyresearch.org/

Tomain, J. (2016). A perspective on clean power and the future of US energy politics and policy. *Utilities Policy*, *39*, 5-12. http://dx.doi.org/10.1016/j.jup.2016.01.007

Tran, T., & Smith, A. (2017). Evaluation of renewable energy technologies and their potential for technical integration and cost-effective use within the U.S. energy sector. Renewable And Sustainable Energy Reviews, 80, 1372-1388. http://dx.doi.org/10.1016/j.rser.2017.05.228

UNDP& GCPSE (2015). Is the Private Sector More Efficient? http://www.undp.org/content/dam/undp/library/capacity-development/English/Singapore%20Centre/GCPSE_Efficiency_Summary.pdf

Union of Concerned Scientists (2017). Smart Energy solutions: Increase Renewable Energy. http://www.ucsusa.org/clean-energy/increase-renewable-energy#.WeEY4LHWD-k

Union of Concerned Scientists (2017). How Hydroelectric Energy Works. http://www.ucsusa.org/clean_energy/our-energy-choices/renewable-energy/how-hydroelectric-energy.html#.WiStda3WD-k

Urban, F., Wang, Y., & Geall, S. (2018). Prospects, Politics, and Practices of Solar Energy Innovation in China. The Journal Of Environment & Development, 27(1), 74-98. http://dx.doi.org/10.1177/1070496517749877

US EPA. (2018). Economic Incentives. https://www.epa.gov/environmental-economics/economic-incentives

U.S. Energy Information Administration. (2018). Annual Energy Outlook 2018 [Ebook]. Retrieved from https://www.eia.gov/outlooks/aeo/pdf/AEO2018.pdf

U.S. Nuclear Industry - Energy Explained, Your Guide To Understanding Energy - Energy Information Administration. (2018). Retrieved from https://www.eia.gov/energyexplained/index.php?page=nuclear_use

Van Der Vleuten, E., & Raven, R. (2006). Lock-in and change: Distributed generation in Denmark in a long-term perspective. *Energy Policy*, *34*(18), 3739-3748. http://dx.doi.org/10.1016/j.enpol.2005.08.016

Van Nostrand, J., Hansen, E., Argetsinger, B., & James, J. (2015). The Clean Power Plan and West Virginia: Compliance Options and New Economic Opportunities. Retrieved from https://energy.law.wvu.edu/files/d/5e3b6938-67c1-402d-be0c-1c50e620c3f1/cpp-final-6-14-2015-1-2.pdf

Vegel, B., & Quinn, J. (2017). Economic evaluation of small modular nuclear reactors and the complications of regulatory fee structures. Energy Policy, 104, 395-403. http://dx.doi.org/10.1016/j.enpol.2017.01.043

Vegel, B., & Quinn, J. (2017). Economic evaluation of small modular nuclear reactors and the complications of regulatory fee structures. Energy Policy, 104, 395-403. http://dx.doi.org/10.1016/j.enpol.2017.01.043

Victor, D. F., & House, J. C. (2004). A new currency: Climate change and carbon credits. Harvard International Review, 26(2), 56.

Wara, M. (2007). Is the global carbon market working? *Nature*, *445*(7128), 595-596. http://dx.doi.org/10.1038/445595a

Weickgenant, J. (2017). America's Role in The World. http://www.realclearworld.com/articles/2017/01/31/americas_role_in_the_world_112200.html

West Virginia - State Energy Profile Analysis - U.S. Energy Information Administration (EIA). (2018). Retrieved from https://www.eia.gov/state/analysis.php?sid=WV

West Virginia - State Energy Profile Overview - U.S. Energy Information Administration (EIA). (2018). Retrieved from https://www.eia.gov/state/?sid=WV

West Virginia | statesummaries.ncics.org. (2018). Retrieved from https://statesummaries.ncics.org/wv

Williams, J. R., Peterson, J. M., & Mooney, S. (2005). The value of carbon credits: Is there a final answer? Journal of soil and water conservation, 60(2), 36A-40A.

WINDExchange: Wind Energy in West Virginia. (2018). Retrieved from https://windexchange.energy.gov/states/wv

Wind Vision: A New Era for Wind Power in the United States. (2015). Retrieved from https://www.energy.gov/sites/prod/files/wv_chapter2_wind_power_in_the_united_states.pdf

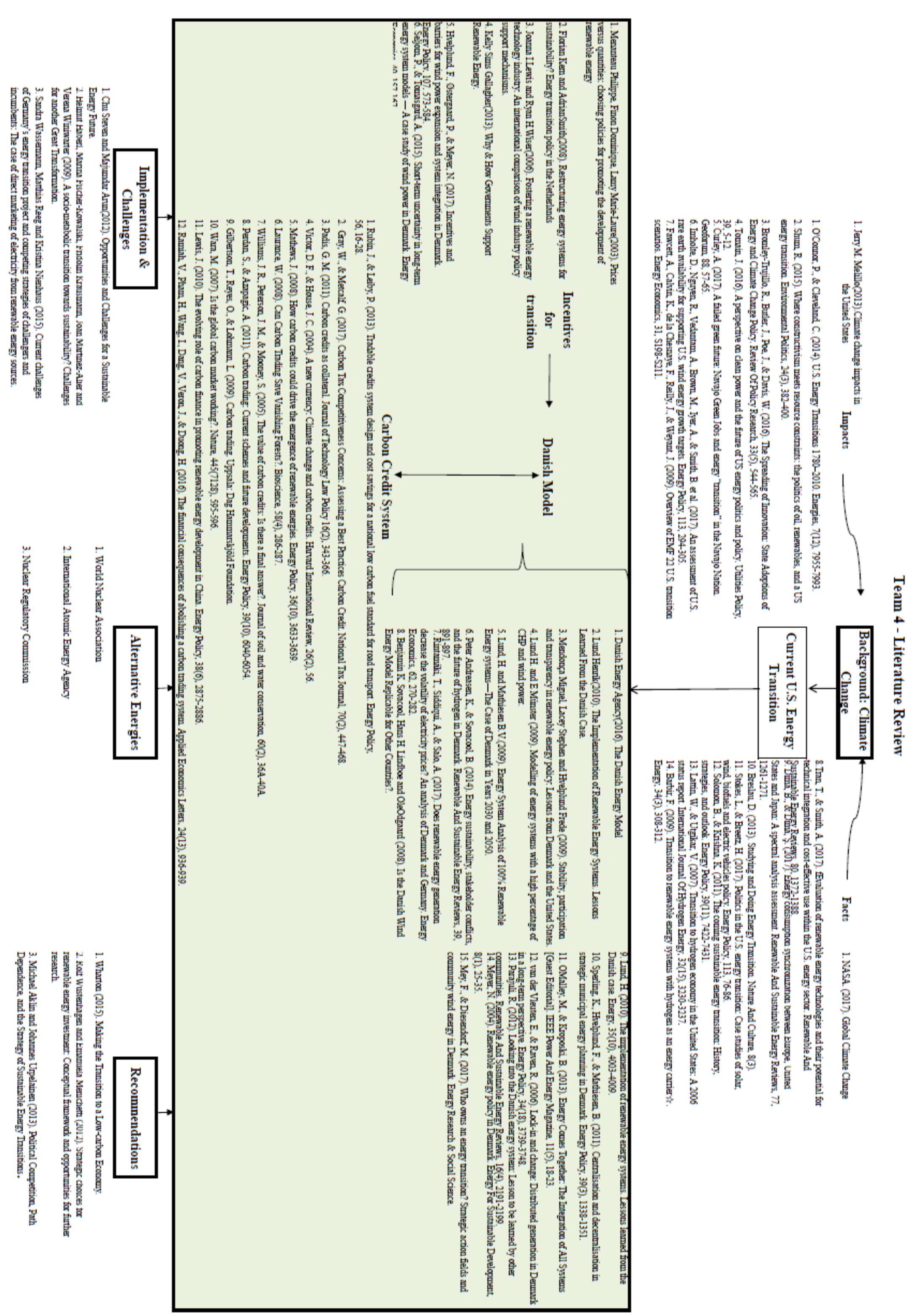
Worland, Justin. (2017). Coal Mining Jobs Are Being Replaced By Clean Energy. *Time*, Time, time.com/coals-last-kick/

2018 Sustainable Energy in America Factbook #CleanEnergyDelivers. (2018). Retrieved from http://www.bcse.org/sustainableenergyfactbook/

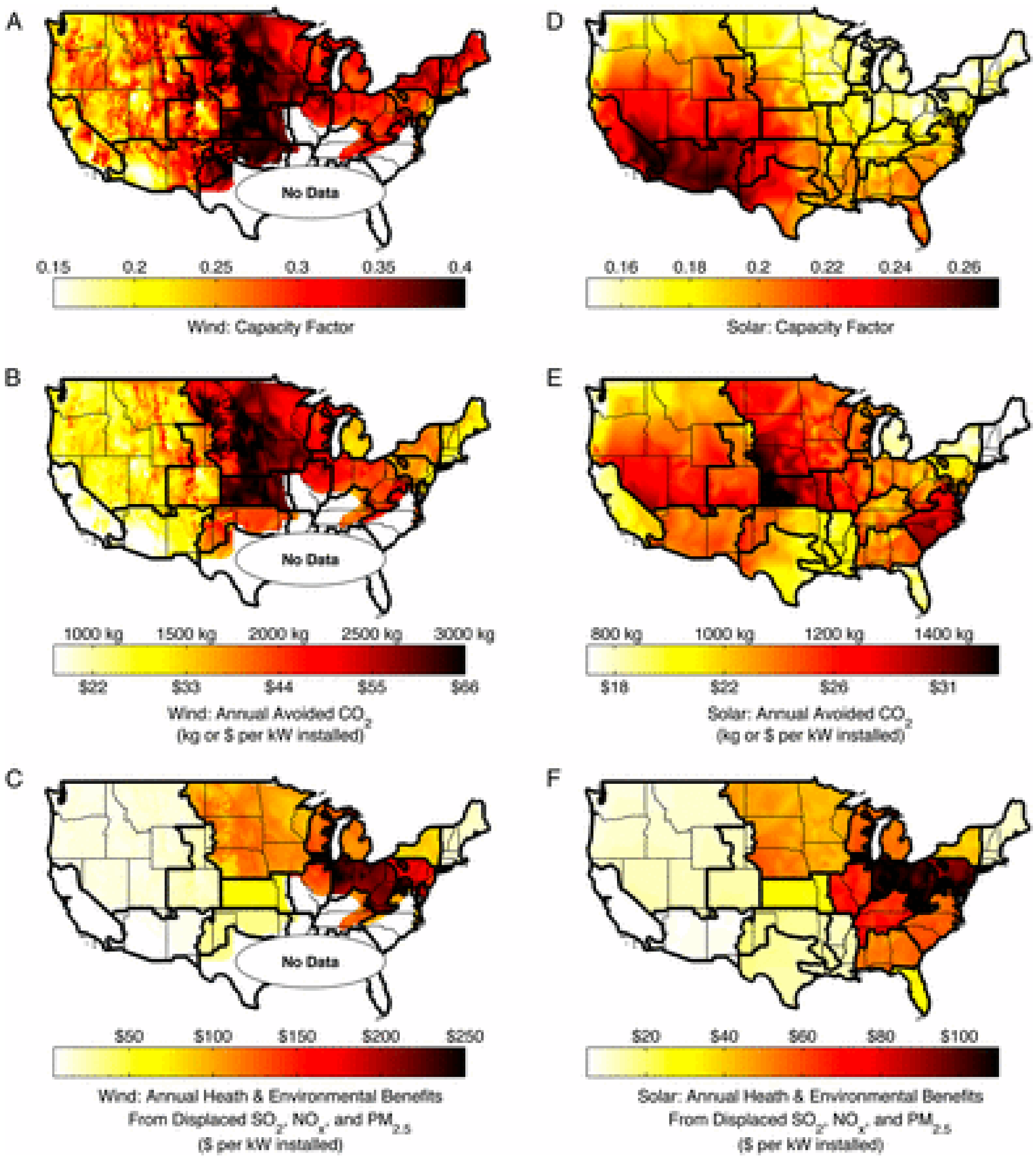
2020 Utility-Scale Solar Goal Achieved. (2018). Retrieved from https://www.energy.gov/eere/solar/articles/2020-utility-scale-solar-goal-achieved

Appendices

APPENDIX A: Literature Tree



APPENDIX B: West Virginia as an Exemplary Region in the United States

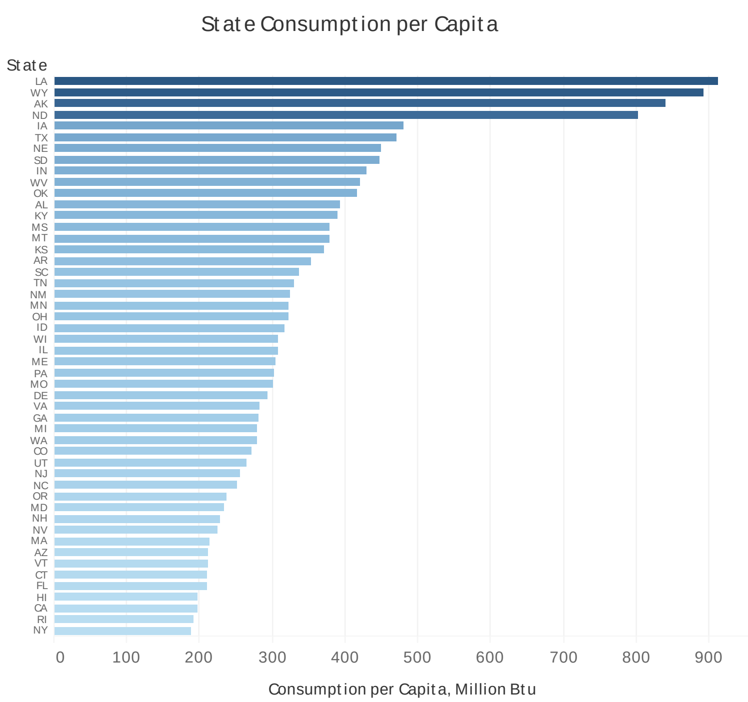


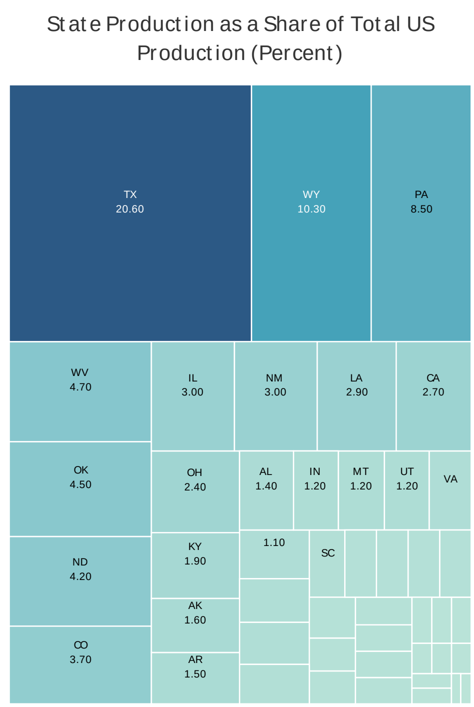
Energy Consumption, Production, and Expenditures of the United States

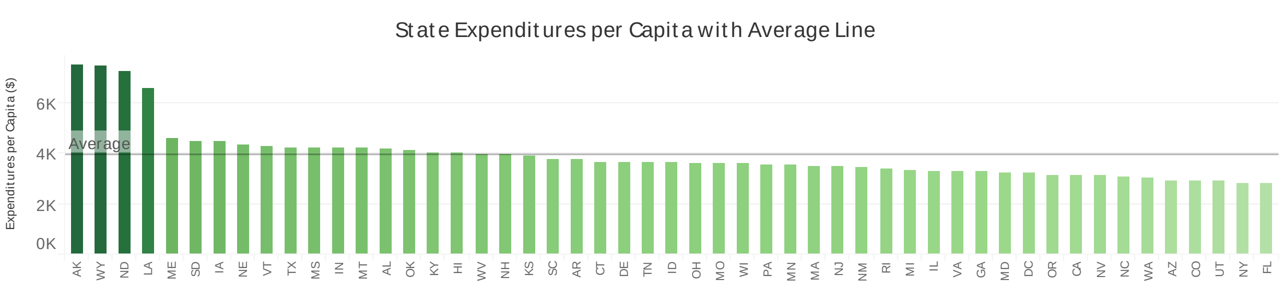
The purpose of this Tableau is to provide an understanding of the consumption, production, and expenditures of each of the 50 United States. This information adds clear and insightful information regarding the consumption, production, and expenditure of energy during 2015.

We found this data source after browsing on the US Energy Information Administration's site which provides multiple different categories of data. The information we used can be downloaded from the following: https://www.eia.gov/state/

Although Texas produces over 20% of the nation's energy (the largest amount of any state) its' expenditures per capita were close to the nation's average; moreover, its consumption was ranked the 6th highest among all other states showing that it exports a lot of the energy it produces.







APPENDIX C: Survey for West Virginia Energy Companies

By conducting a small-scale survey of energy companies in West Virginia this study wanted to gain market insight in how these energy companies are looking at and preparing for the future regarding sustainable energy. The sample collected should be representative for several US regions with a similar energy industry. By keeping the survey short and to the point, the aim was to make the survey accessible and receive a high response rate. Companies and industry experts were contacted with the questions below. This study contacted mainly traditional energy companies located in West Virginia, however because of confidentiality reasons we cannot disclose their identities. The response rate of the Survey was rather low – 14 respondents – but the quality of the answers did provide meaningful insights. The results are discussed in Chapter 4 in the paper.

Questions

Q1: Do you think that by 2050 your company's current primary resource for energy production will still be the same? If not, to which resource do you expect a shift?

Q2: Please answer the following statements:

	Very much disagree	Slightly disagree	Neutral	Slightly agree	Very much agree
My company values sustainability as important or significant. This is reflected in our day-to-day business.					
My company thinks there is a shift towards towards sustainable energy coming in the coming years.					
My company is proactively preparing for this shift to remain competitive in the energy industry as shifts towards sustainable energy.					
My company is remarkably investing in R&D for new and sustainable energy production methods.					
Concern about climate change and helping the environment is high on my company's corporate agenda.					

Q3: What percentage of R&D resources is currently being invested towards R&D for sustainable energy production?

Q4: Which form(s) of renewable energy is your company currently researching to develop?

Q5: What are the reasons for choosing the above-mentioned renewable energy form(s)?

Q6: Does your company, in your opinion, help to contribute to change the energy industry towards a more sustainable one? If not, what would be the main reasons for not pursuing this path?

Q7: Would your company try to put off a shift towards sustainable energy as long as possible in order to be able to maintain current energy production practices to drive revenues?

Q8: How long (if not ever, please state so) do you think it is going to take the current US energy industry to shift from current practices to “green” energy production? (Shift defined as when 50% or more of energy production comes from sustainable energy. Current level is at 15%).

Q9: Which one of the following do you think is going to be affected by the growth of sustainable energy production first, fossil fuels (gas, coal, petroleum) or nuclear energy?

Q10: Do you have any insights or advice on what the US energy industry should or should not be doing/researching at the moment, to be prepared for the future?

Q11: What – in your opinion – needs to change in your organization to stimulate the shift towards sustainable energy production? What could be incentives to stimulate this decision?

Q12: What are the current pressure points and/or the biggest hurdles to overcome when wanting to transition towards sustainable energy as a firm?

Q13: Do you think the cultural embedding of traditional resources for energy production in your firm are impossible to overcome for the future?

Q14: Do you think the current landscape of the US energy industry would allow a transition towards sustainable energy, comparable to the Danish Initiative? *(participants will be provided* *with an attachment which briefly but clearly explains the Danish Initiative to be able to answer this question)*

Q15: Does your firm use the Carbon Credit System? *(participants will be provided with an attachment which briefly but clearly explains the Carbon Credit System to be able to answer this question)*

Q16: How realistic does the Carbon Credit System seem to you to be used widely in the energy industry in order to reduce emissions?

Q17: Why could (or could not) the Danish Initiative serve as an example for your company, the West Virginia and US energy industry as a whole? What are some aspects that might work versus the biggest hurdles for the US of this system?

APPENDIX D: Expert Interviews

1. ***Kerrie Carfagno***

Q1: How would you describe the Danish energy transition process and do you think it is successful until now? Why or why not?

KC: I think the Danish energy transition model is successful, to me one of the reasons is that they did it in a slow logical way. When they saw an opportunity that made sense and there was a better solution and they could encourage people to go towards a renewable solution, they did. It is a good example of how other companies and countries can alter their energy use. They did it in a slow and logical way, which is key. Another key component is that they got buy-in from the local people, they didn't have to worry about NIMB (Not In My Backyard). Because of that people were willing to see turbines from their windows, and hear the noise of them, since it was making them money. For both local people and industrial founders this became profitable.

Q2: Going further on that it is successful, what would be for you the most important things that have slowed down the transition and were the biggest obstacles to overcome?

KC: One of the hindrances was their success, they have taken all the low hanging fruit in terms of the locations that make the most sense to have windturbines and are most profitable, so to get to the next level where they are fully energy independent will be more expensive and might be in some ways harder to achieve. The last little bit could take the most effort, since the most logical things have been done already. Here there could be a need for more technology improvements for example. A good example is Hans Soerensen who explains the difficult choice to be made between keeping a windturbine which is currently profitable, or taking it down and replace it by a new one that will be 4 times as profitable, but which will need a payback term etc. It is a challenge as a first-mover to keep up with new technology. It is a nice problem to have, but could hinder the Danish transition to the next level. If they were to replace all the windturbines in Denmark by new ones, it would be a huge step forward to being completely energy independent, but fiscally it is hard to do.

Q3: What do you think are the most motivating powers behind this transition from a Danish perspective?

KC: Great question. I think the first one is identity. To become the leader in renewable energy and particularly in wind, it becomes part of your identity. It is the same what you have with coal in West Virginia. To become energy independent and the leader in renewable energy is to show who they are as a country and as a people of expertise.

From my connections in Denmark and many travels over there, I know that they see themselves as very practical, and they see this as a practical solution. Not only in wind, it is their main activity, but they do a lot of incinerating trash to generate energy. On the local island of Samso for example, they take hay from a local farmer and burn it to generate electricity, so they don’t have to import electricity to the island. They also focus on other solutions besides wind, big and small, and I believe this is going to get them to overcome the last few miles to become energy independent, still in a financially responsible way. The Danish transition model is not just about them being a leader in wind energy, which they are, they also invest in local micro-solutions that make sense for the local communities. They are tied to what makes sense, environmentally and financially.

Q4: How do you the future of the Danish Model? They are currently scaling their wind energy investments back a bit since it is so expensive, this gives a double signal to other

countries and especially bigger ones, which would need more energy than Denmark. Do you think this is a temporary movement?

KC: Great question. This week it just came out that some Saudi-Arabian oil companies are working very hard to get the price back up to 100$/barrel, they have dropped oil prices to slow down renewable energy growth. When oil prices went up to 140$ or even 170$/barrel, renewable energy becomes a very good option. When oil prices are dropped to 40$/barrel, it becomes less effective. Oil companies have actually admitted to this practice. So, I think the future of the Danish energy model and their transition will continue to happen, the real question is what is the pace? Denmark wants to be independent and not have to adapt, respond and deal with oil prices. They will stay on their course in becoming more renewable. They will only do it when it makes sense, so it will depend on the oil price on how fast it will happen. Once again, they also invest in diverse renewable technologies, for example a company which looks at getting kinetic energy from wave movements of the coast of Denmark. Timing is the big question, but they will continue on their renewable energy path in my opinion, because they don’t want to be beholden to oil.

Q5: Can you share your views and experiences on the historic US energy transition with us?

KC: Denmark years ago, went to less cars on the road and made it very expensive to own a car, to encourage more people to bike. Back in that time they said that would never have work in a country that manufactures cars. I think the same thing goes for energy transition, it is easier for Denmark to transition to renewable energy, because it’s not a country that generates oil or natural gas. Our challenge in the US with energy transition is that we have a number of people and industries, that are in the oil/natural gas business who make a lot of money and use that money to make sure they can continue to make money. So, it is a much slower and more challenging process. There is also an argument to be made, that we don't live in a capitalist society anymore, but in a crony-capitalist environment. In capitalism, what makes the most sense from a business standpoint, but you have incumbents and those incumbents use their close relationships with the government to make their business succeed, this is crony-capitalism.

Another interesting trend, that only happened very recently this past fall, is that Blackrock – investment fund with about $6 trillion under management – recently talked about their investments in Exxon Mobil, and they are forcing them to talk about climate change and I think we are going to see more traditional energy companies diversifying to the point that people consider investing in them because that will be a growth area. Depending on who is in office, there will be policy shifts that we cannot predict, but investment companies putting pressure on energy companies could change what they have to disclose and help in turn people who want to invest in future markets make the decision to invest in that company or not. Even if the short-term gain is coming from oil and gas, if people see companies investing in renewable energies for the long-term, they become a more interesting investment option. As well as these companies would benefit from such investments to keep their energy generation up in the long-term. Google and Amazon for example are already doing their own energy generation, which made big losses for local energy companies and push to start moving to the renewable energy business as well. I think it will happen in the US, but again, how fast? The good news is that there is still low hanging fruit in the US, it can grow aggressively but it won't until oil stays at a low price per barrel, and will explode every time oil becomes more expensive until over 100-110-120$/barrel.

Q6: Do you think that when big energy companies will start diversifying into renewable energy, this will slow the transition to renewable energy because they will have all the control on the market?

KC: It can, it is a risk and a concern. We could see a lot of acquisitions of renewable energy companies. Once traditional energy companies realize they have to grow aggressively to keep generating enough energy, it is an option, but it will depend on the leadership in these companies and if they want to change their identity. Because for them energy means oil, gas and coal. On the other hand, you have the investors, like Blackrock for example, who start saying that if they don't do it they won't invest in their company.

Q7: Do you think in general the transition in renewable energy in the US is going to be drive by the existing energy sector or by other sectors like big investments and tech companies which force the existing energy sector to invest in renewable energy?

KC: I think this is the trillion-dollar question, and it depends. It could go that way, but we don't know. Not only tech companies, but mostly battery companies that focus on cost-effectively and efficiently storing energy will be a big factor to push renewable energy or hold it back. At this point, this is still an issue, because we are still at the mercy of nature with renewable energy but with good batteries this would be solved. This would be the most important factor. Next, the renewable technology also has to be made affordable on an industrial level. Lastly, the price of oil per barrel will remain important and be a big hindrance until the end and have an impact on how fast renewable energy technology and investment are being done. Big companies like JP Morgan and Blackrock that start talking about climate change and these issues, is a step in the good direction to push the transition forwards. In 3 to 5 years, we will see a clear direction.

Q8: How do you think coal will hinder the transition in and around West Virginia?

KC: I don't think coal is a major growth player and it is blowing its last breaths. A lot of the infrastructure is old and it is a not a good bet to invest in restoring coal plants, as well as the people who know how to operate such a plant (baby boomers) are becoming harder to find. It is knowledge-based and interest in investing it dwindling. I don't think coal will stay as a major player, it is more a question of how long coal can hold on. Since China has been shifting away from coal, the US is paying attention to that and will also become more hesitant to invest in restoring coal plants. Even with the current administration it is hard to get legislation for new coal plants.

Q9: What do you think the government's role will or should be in this transition?

KC: The way the EPA is run now, is very coal-friendly. This does give some life back into the coal industry, but I think this is only short-term and it is an industry that is only going to go so far. The expectation right now is that the elections in November could really change the make-up of The House and The Senate, if this happens we will see some changes. Until the next Presidential election though, changes will not be major. Maybe there will be some over-correction as well for the current administration, but we will have to wait and see.

2. ***Francisc Lozano Winterhalder***

Q1: Could you describe the Danish Energy Transition Model? Would you define Danish Model or Denmark Energy Transition as a successful example?

Yes. It is a Model whose objective is to achieve a total energy production from the renewal sources of energy in 2050 or earlier.

Until now we can say yes, but we can follow the evolution of its implementation, cause a 44% of the energy production in Denmark is coming from fossil fuels.

Q2: From your perspective, what factors motivate and hinder the Danish transition?

Factors for motivation: decreasing pollution, including greenhouse gases. Economic and strategic independence. Social pressure.

Factors that hinder the implementation: cost of the transition. Cheaper prices of fossil fuels. Pressure of traditional lobbies of energy.

Q3: How would you see the future of Denmark Energy Transition?

I think that the evolution of the system can be positive and they will be able to achieve a 100% energy production from renewals. Nevertheless, this will be not an easy way:

1) Its neighbors are clean in terms of energy (and others) and this is the general tendency in our world nowadays.
2) However, the economic conditions of Denmark and of the entire world are also important to make possible that process. For example, they need engines more powerful because they have used all land available (including the offshore engines). They have the technology to do that, but they have also to pay a high price to do that.

Q4: What is your attitude towards carbon trading system?

Really it is a controversial issue. This was, apparently, one important way to motivate reach and poor countries for acting against Climate Change, but in fact, it is an important reason to delay the economic growth of poor countries and to allow exceeding in terms of emissions, for the reach countries.

Q5: Do you have any experiences or cases (both successful and failed) related to this system? Yes.

“Winners”: Spain, the most pollutant country in terms of greenhouse gases, of the European Union. Spain bought 800 Million € only in the period 2008-2012.

“Losers”: Poland who sold an important part of its Carbon Credits to Spain for “sales”.

Q6: Could you generally describe U.S. energy transition? Such as its trial, policies, results, future etc.

Currently I suppose that an energy transition in the U.S. is not possible. A National Transition coordinated from the Federal Government is not realistic President Trump has denied the Climate Change, he has abandoned COP 21 Agreement and he has bet for fossil fuels (including fracking).

But the States are much more than a President and the private sector is investing exponentially in renewals. Its costs are reducing at the same rhythm and its rising profitability is unquestioned. Nevertheless, the most important lies in the environmental and social advantages we can get with all of this.

Q7: What hinders the transition? List top 3 factors.

1) Trump’s administration.
2) Traditional lobbies of fossil fuels.
3) Degree of awareness of a part of the Nation’s population

APPENDIX E: Survey Results Part 1

Question 2						
Dimensions	Strongly disagree	Slightly disagree	Neutral	Slightly agree	Strongly agree	Sum
My company values sustainability as important or significant. This is reflected in our day-to-day business.	3	3	5	1	2	14
My company thinks there is a shift towards towards sustainable energy coming in the coming years.	3	2	2	6	1	14
My company is proactively preparing for this shift to remain competitive in the energy industry as shifts towards sustainable energy.	4	3	3	3	1	14
My company is remarkably investing in R&D for new and sustainable energy production methods.	5	5	2	1	1	14
Concern about climate change and helping the environment is high on my company's corporate agenda.	3	7	2	2	0	14

Company	Q1		Q3	Q4			Q5
	YES	NO	%	WIND	SOLAR	OTHERS	
1	√		0				
2	√		0				
3		√	80	√			price-efficient, high yield and low maintenance, weather suitable
4	√		0				
5	√		/	/			
6	√		0				
7		√	5	√	√		practical, mature technology, great ROIs, tax incentives
8	√		0				
9	√		0				
10		√	5		√		subsidy
11	√		2	√			mature technology, lower risks
12		√	10	√	√		feasibility
13	√		5		√	Biomass	company's capabilities(expertise and capital)
14		√	30		√		capabilities, subsidy, feasibility of tech

APPENDIX F: Survey Results Part 2

Company	Q7		Q8	Q9		Q10
	YES	NO	YRS	FOSSIL	NUCLEAR	
1	√		100		√	find more oil
2	√		Never		√	recue taxes on traditional energies
3		√	60-80	√		more research in renewable energies
4	√		150		√	alternative ways of producing traditional energy maybe through chemicals
5			Impossible		√	
6	√		30-50	√		inhibit nonrewable energies; focus on R&D
7	√		50	√		get everyone on board; viable tech;low on maintenance
8	√		50-60	√		research on the improvement of technologies of renewables & research on cleaner methods of burning coal
9	√		50	√		how to make companies accountable for pollutions
10	√		100	√		clean coal
11	√		Impossible	√		focus on technology mitigating carbon emission instead of reducing it
12	√		50	√		research on developing the efficiency of current renewawble infrastructures and technology of storing renewables
13	√		50-80	√		research on improving efficiency
14		√	30-50	√		stable policies, more research on guaranteeing the productivity of renewable energies

Co.	Q11	Q12	Q13
1	tax incentives, subsidies, free market	money (renewable is too expensive and market is too small)	Yes, family inheritaged business
2	run out of oil or the market for it disappeared	cost too much and current business is still profitable	yes, against the culture
3	government support for renewable and more tax on traditional energy	expensive, long-term strategy so unwilling to take risks	it's hard but not impossible
4	I don't know.	market is not ready, demand is too low(price is too high and yield is too low)	yes
5	I don't know.	I don't know.	possible
6	business model needs to be changed; money incentive	not enough knowledge of renewables	yes
7	short-termism; more attractive incentives offered by the government	no enough money in the short term	not impossible but depends on different generations
8	have to restructure the business, incentives could be equal pay and job supply	effectively integrate renewable into the current energy grids	possible to overcome since cultural issue is small
9	money (people need to be motivated by a certain salary compared to current salary and workload)	financial situation of the firm	no
10	top management's attitude; governmet's subsidies	complex relationship among stakeholders	not impossiblee but will be very difficult
11	hard to say	too expensive to abandon the current business	a little biti
12	more experts on new energies and how to balance two departments	capital and technology	no, there should be way to change
13	investment portfolio. Subsidies from government and customers' preferences	not substantial cash flow to support changes	no, have chance
14	shareholders' interests. Need to find a way to guarantee shareholders' interests since renewables are long-term investment.	enough money	no

APPENDIX G: Sustainability Date Calculations

Sources:
EIA (Energy Information Administration): https://www.eia.gov/outlooks/aeo/
Statista: https://www.statista.com/statistics/183420/electricity-generation-from-renewable-sources-in-the-us-from-2000/
IEA:https://www.iea.org/statistics/statisticssearch/report/?country=USA&product=RenewablesandWaste&year=2000

Tables:

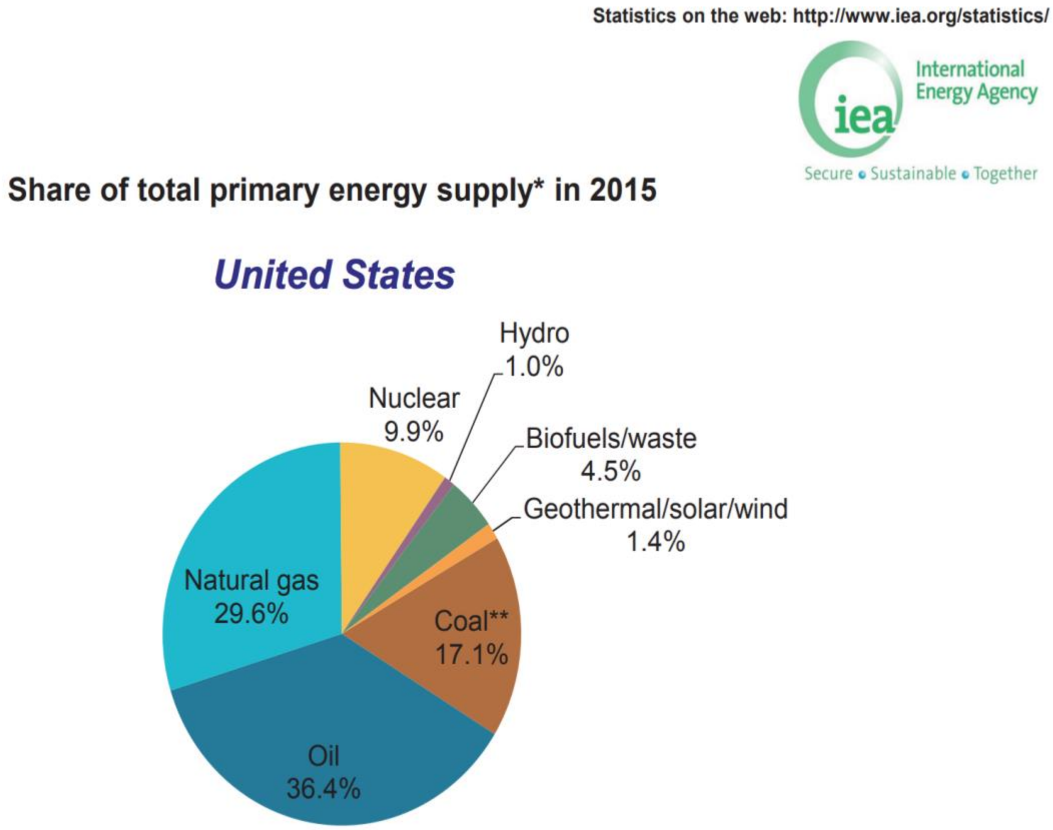
	1. Renewable % of Total Energy Production	
Year	EIA	Statista
2000	9,38	11
2001	7,7	10,6
2002	8,9	10
2003	9,15	9,6
2004	8,85	9,5
2005	8,82	9,6
2006	9,49	9,8
2007	8,49	10,3
2008	9,25	11
2009	10,57	11,8
2010	10,36	12,2
2011	12,52	12,8
2012	12,22	14,1
2013	12,69	14,6
2014	13,19	15,5
2015	13,35	16,7
2016	14,94	18,3
2017	17,12	-

	2. Growth Rate % From Previous Year	
Year	EIA	Statista
2000		-
2001	-17,91%	-3,64%
2002	15,58%	-5,66%
2003	2,81%	-4,00%
2004	-3,28%	-1,04%
2005	-0,34%	1,05%
2006	7,60%	2,08%
2007	-10,54%	5,10%
2008	8,95%	6,80%
2009	14,27%	7,27%
2010	-1,99%	3,39%
2011	20,85%	4,92%
2012	-2,40%	10,16%
2013	3,85%	3,55%
2014	3,94%	6,16%
2015	1,21%	7,74%
2016	11,91%	9,58%
2017	14,59%	-

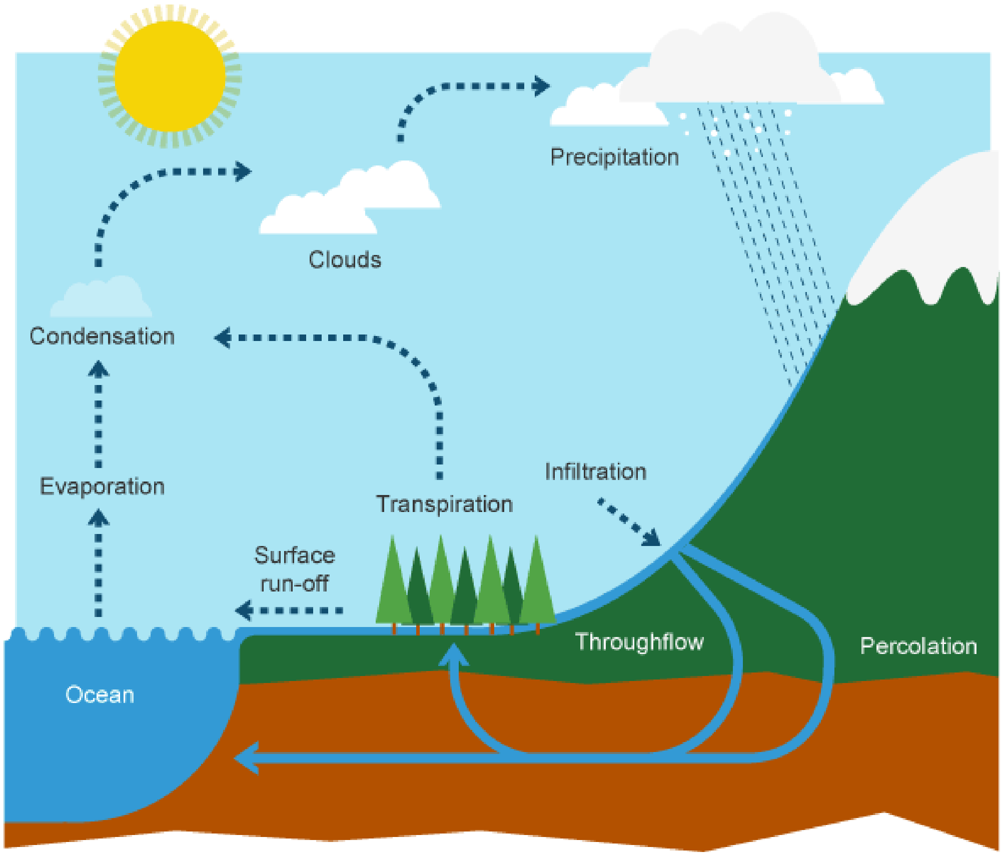
3. Average Annual Growth Rates (%)	
EIA (2000-2017)	Statista (2000-2016)
4,07%	3,34%

	4. Predicted Share (%) of Total Production from Renewables	
Year	EIA	Statista
2017	17,1%	18,9%
2018	17,8%	19,5%
2019	18,5%	20,2%
2020	19,3%	20,9%
2021	20,1%	21,6%
2022	20,9%	22,3%
2023	21,7%	23,0%
2024	22,6%	23,8%
2025	23,5%	24,6%
2026	24,5%	25,4%
2027	25,5%	26,3%
2028	26,5%	27,1%
2029	27,6%	28,1%
2030	28,7%	29,0%
2031	29,9%	30,0%
2032	31,1%	31,0%
2033	32,4%	32,0%
2034	33,7%	33,1%
2035	35,1%	34,2%
2036	36,5%	35,3%
2037	38,0%	36,5%
2038	39,5%	37,7%
2039	41,1%	39,0%
2040	42,8%	40,3%
2041	44,6%	41,6%
2042	46,4%	43,0%
2043	48,2%	44,5%
2044	50,2%	45,9%
2045	52,3%	47,5%
2046	54,4%	49,1%
2047	56,6%	50,7%
2048	58,9%	52,4%
2049	61,3%	54,1%
2050	63,8%	56,0%

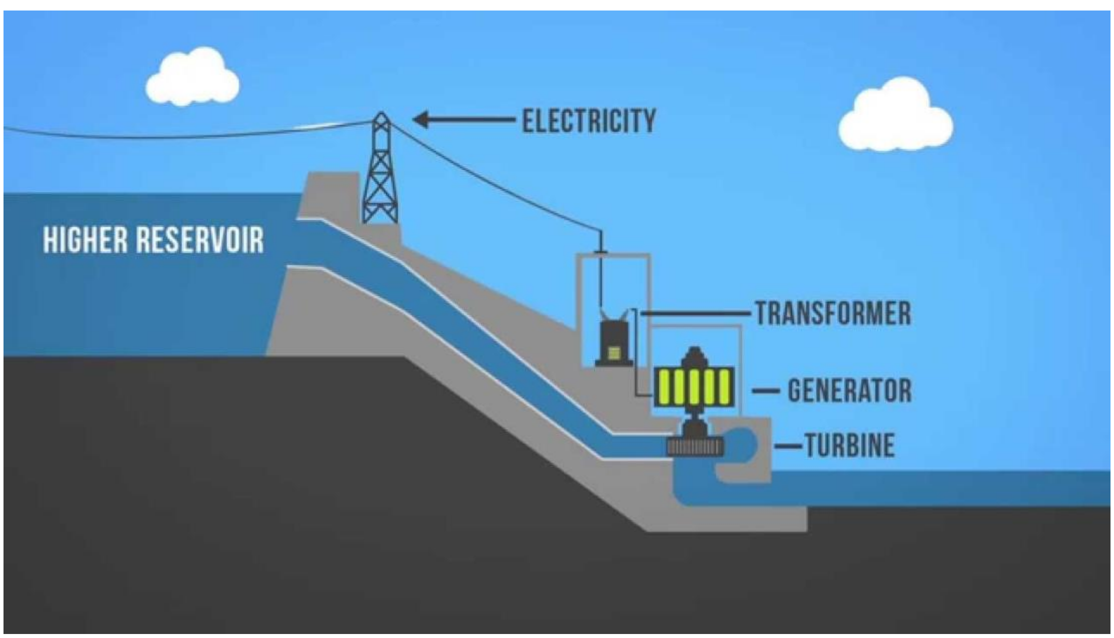
Graph 1:


Statistics on the web: http://www.iea.org/statistics/
iea
International Energy Agency
Secure • Sustainable • Together
Share of total primary energy supply* in 2015
United States
Hydro 1.0%
Nuclear 9.9%
Biofuels/waste 4.5%
Geothermal/solar/wind 1.4%
Natural gas 29.6%
Coal** 17.1%
Oil 36.4%

APPENDIX H: Hydropower Explanatory Images



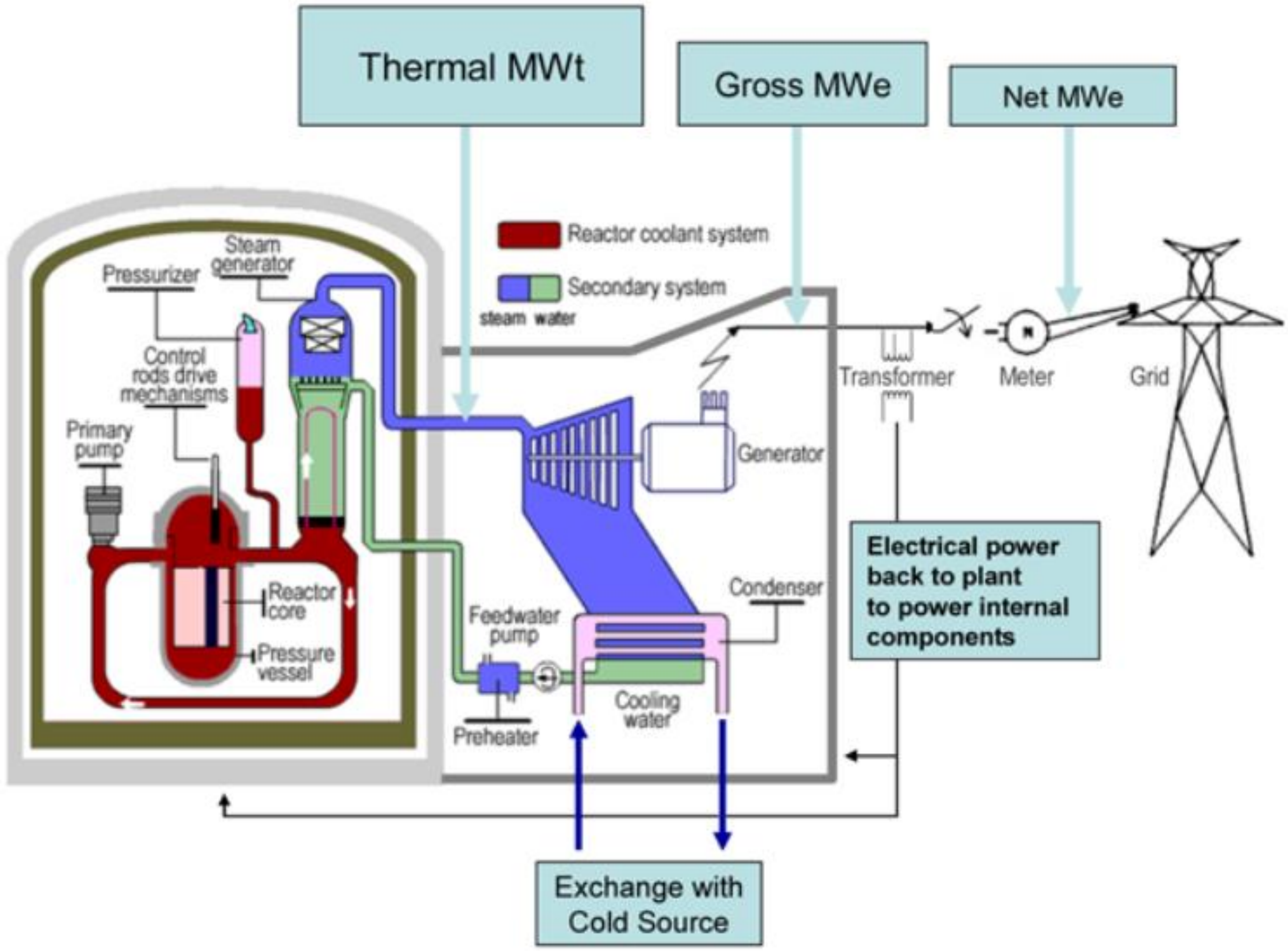
The 3 stages of the water cycle (BBC, 2017)



How to extract electric energy from water's kinetic energy (YouTube, 2015)

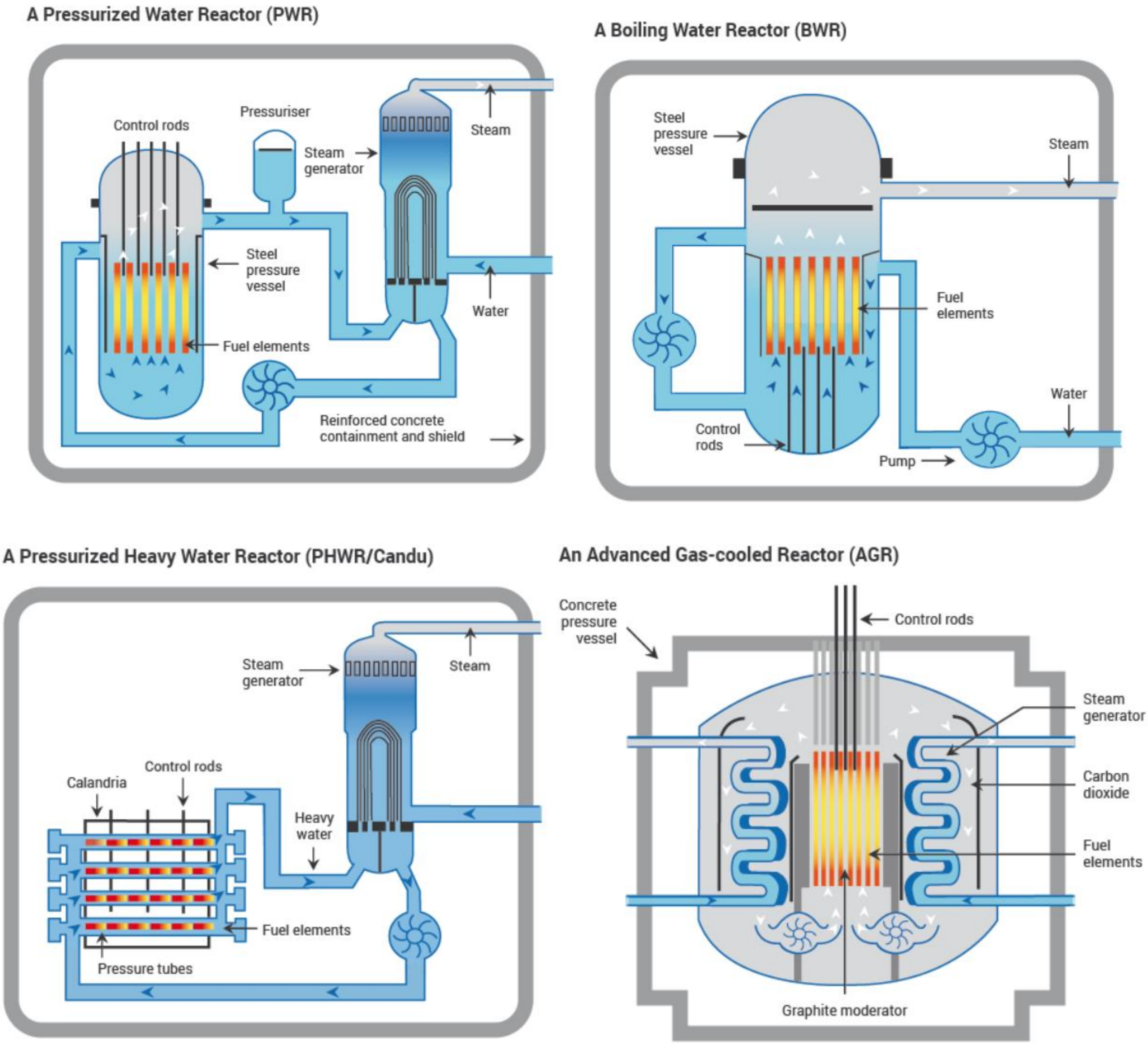
APPENDIX I: Nuclear Energy Explanatory Images

Principles of the reactor



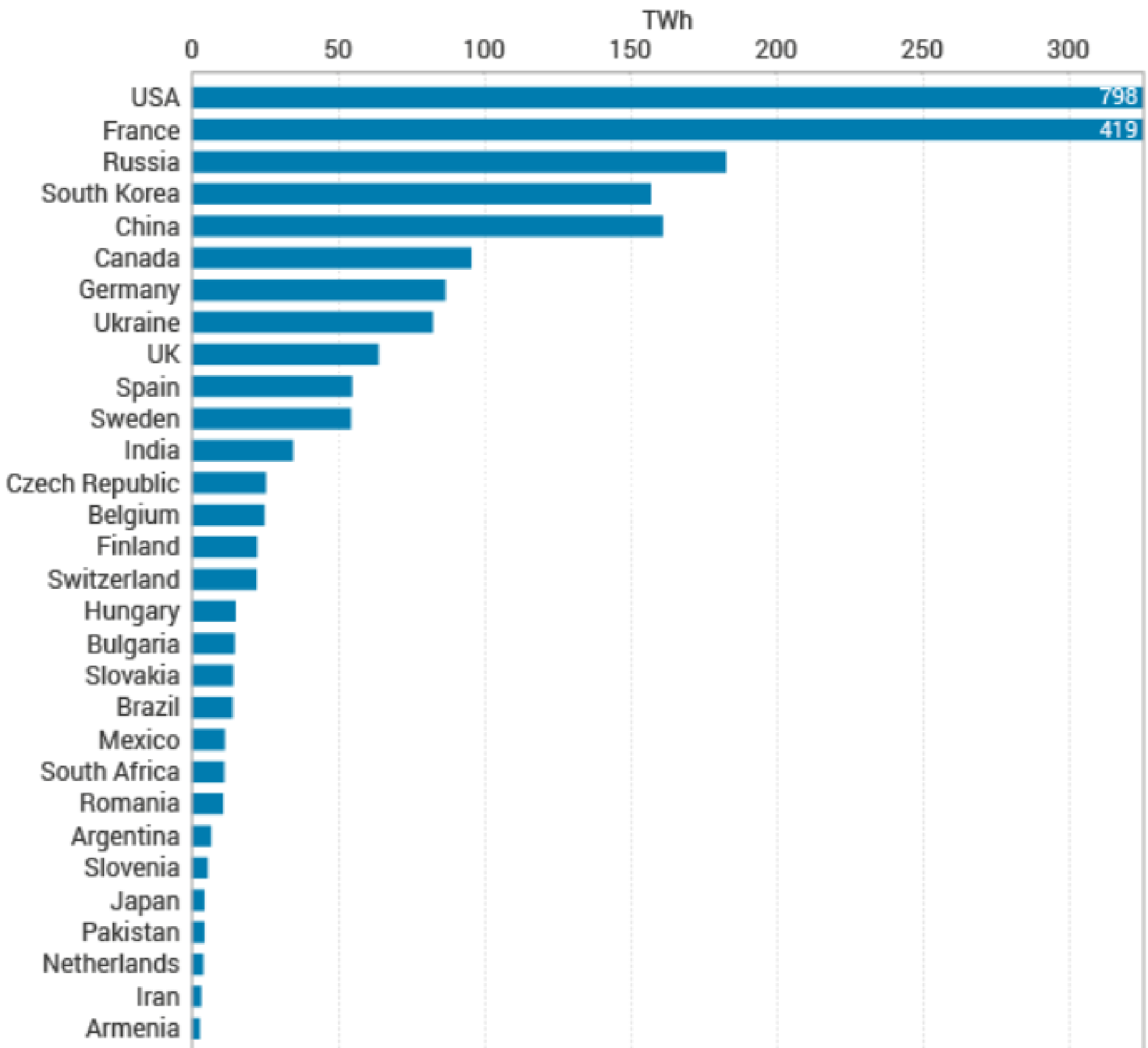
Source: World Nuclear Association

Conventional types of reactors



Source: World Nuclear Association

Nuclear Generation by Country by 2015



Source: IAEA PRIS database