The German Energiewende: Informing Pennsylvania's Clean Energy Policy

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Introduction

Throughout the past half-century, discussions around renewable energy have largely centered on the question of technical capacity to produce enough electricity from renewable sources to replace the electricity generated by conventional power plants. Advancements in renewable generation technologies have shown that under the right conditions, renewables can compete with conventional sources. Thus the question has transitioned from one of technical capacity to a question of how to deliver power where it is needed, when it is needed, and at a reasonable cost.

Discussions on energy policy increasingly turn to the example set by Germany's energiewende, or energy transition. This initiative established ambitious goals to source 80% of electricity from renewable sources and reduce greenhouse gas (GHG) emissions 80-95% by 2050. Among renewable energy advocates, the program has been considered an early success, with 30% of electricity being sourced from renewable sources in 2015. And yet, criticisms abound: residential electricity costs are among the highest in Europe; industrial electricity prices have risen steadily over the past six years; and CO_2 emissions actually increased between 2009-2013, due to greater use of coal following the shut-down of multiple nuclear power plants[i].

While there are undeniable benefits to the environment and human health from this switch to cleaner energy sources, increasing levels of renewables will require changes to the existing electricity business model and infrastructure. Unlike conventional power plants that generate power at a constant, predictable rate, most renewables, specifically wind and solar power, are variable in nature. This means that an electricity system with higher levels of renewable sources must also have either longer-term storage capabilities or back-up generation to produce power during times renewables are not available, leading to redundancies in the generation system. As the penetration of renewables reaches greater amounts, the challenge of providing sufficient capacity and ensuring that capacity is used at the right time and to the extent necessary present technical and financial challenges to all players in the electricity sector.

These questions are already being asked across the U.S. through efforts like New York's Reforming our Energy Vision and Minnesota's e21 Initiative. These conversations are starting in Pennsylvania, as well, in part due to the federal Clean Power Plan. Because Germany is further ahead of the United States in terms of renewable penetration, there are likely lessons to be learned that can inform policy and program development in the U.S. Preparing for the inevitable energy transition in a coordinated, strategic way will enable Pennsylvania to limit costs and maximize benefits. Germany's energy transition may provide important lessons for state-level efforts in Pennsylvania.

This paper will provide background on Germany's energiewende, a summary of the key observations made through study in the country, and finally recommendations for the development of programs and policies in the state of Pennsylvania.

A Note on Comparative Studies

Comparative studies, at the most basic level, evaluate at least two different systems, with the purpose of increasing the knowledge of both. It is important to note that the intention of this research is not to replicate specific German policies or programs in Pennsylvania. Because of differences in culture, government structure, and political and economic systems, it is not likely that transferring policies in whole would be an effective exercise. Rather, the purpose of this work is to learn more about what may be successful in Pennsylvania by studying another system that is further along in the adoption of renewable energy sources.

Research Scope

Due to the time constraints of this fellowship, the scope of research was limited to a focus on the integration of renewable energy into the electricity grid. Because Germany's electricity mix includes a much larger percentage of renewable electricity production than the U.S. (27% vs. 13% in 2014[ii, iii]), it provides a useful case study of successes, challenges, and lessons learned. This research did not include the use of energy in heating fuels or transportation.

There are far more potential research questions regarding Germany's energy policies than could be explored through this fellowship project. Potential areas for additional study include the following:

- Types of renewable energy: an exploration of the different types of renewable energy and the appropriate balance of each; a comparison of the costs and benefits of each to inform how Pennsylvania might consider investing
- Energy efficiency: an assessment of the importance of building-scale energy efficiency (residential and commercial) to meeting renewable energy and carbon reduction goals; an exploration of the role of microgrids, district energy, and combined heat and power applications
- Financial model: an evaluation of financial tools for large scale changes; an assessment of the role of a carbon fee; an investigation of the most impactful areas for government investment
- Social equity: an exploration of the impacts on low-income populations, who are more vulnerable to high prices and less able to afford their own generation systems

Interviews

To complete this research, a series of interviews and site visits were conducted in Germany between October and November 2015. To gauge a variety of perspectives, meetings were held in several cities across multiple regions of the country, including Berlin, Leipzig, Dresden, Munich, Cologne, Dusseldorf, and Essen. A full list of individuals and organizations interviewed is included as Appendix A; however, all information is reported as a summary of all interviews. Assumptions should not be made to attribute any information in this report to specific organizations or individuals.

Key Similarities and Differences

There are many similarities between Germany and the Commonwealth of Pennsylvania. Both enjoy a high standard of living, with an energy-intensive industrial sector, and have a similar climate. While many Americans assume that Germans are more green-minded, and invest in renewable energy because it is the "right thing to do," both Germans and Americans make investments based on the economics and merits of a project.

Certain regions of Germany, such as Saxony and North Rhineland-Westphalia, have historically been home to the coal mining industry, similar to many parts of Pennsylvania which have had economies based on extractive industries, ranging from coal mining, to oil and gas extraction, to timber. However, these same regions are also embracing research and development of new technologies, including fuel cells, smart chips, and energy storage.

The two areas also experience similar climate conditions, leading to comparable weather patterns as it pertains to renewable energy production, as well as similar energy use patterns. However, homes in general are smaller in Germany than in the U.S. and apartment living is more common, influencing electricity use in the residential sector. As well, Germany has much less space cooling than Pennsylvania, resulting in different peak electricity usage. In fact, while annual peak usage occurs in Pennsylvania in the late afternoon and early evening during the summer, the hours of peak demand in Germany are typically between 5:00-9:00 p.m. in the winter.[iv]

Germany's electricity grid is interconnected to those of neighboring countries. Similarly, Pennsylvania shares connections with other states, through the PJM Interconnection.

Perhaps the most obvious difference is that much of the development and implementation of energy programs that occurs at a national level in Germany is under the jurisdiction of the individual states in the U.S., although this does not make a comparison between the two impossible. Germany's energy policies are also impacted by its membership in the European Union.

In terms of differences, most significantly, the two countries differ in their perceptions related to energy and its impact on climate change. Specifically, for many years there has been near universal acceptance of climate change science and strong political will to reduce carbon emissions in Germany, as compared to the United States. This public consensus shifts the conversation from "should we address climate change?" to "how do we address climate change?"[v, vi]

Other differences include the following:

- The German electricity grid infrastructure has been maintained and upgraded over time more than that of the U.S., resulting in greater reliability. However, the U.S. has invested more in advanced metering technologies, leading to better availability of data. For example, in Germany, consumers receive a monthly electricity bill, but actual usage is only measured once per year, making it more difficult to track and manage electricity use. In comparison, in the U.S. actual usage is measured at least every other month, providing more accurate information to consumers.

- Germany does not have a capacity market, whereas PJM, the multi-state electricity grid within which Pennsylvania is located, does. A capacity market can be an important tool for ensuring there is enough energy available to meet demand at all times. Because Germany currently has more capacity installed than is needed, and because of its interconnections with other countries' electricity grids, its energy-only market provides sufficient reliability of supply.
- Germany participates in the EU carbon trading market, whereas Pennsylvania does not currently participate in carbon trading. However, at present the price of carbon in Europe is not high enough to provide a significant incentive to reduce emissions and therefore is not a critical factor. Also, Pennsylvania may begin participating in carbon trading as part of its implementation of the federal Clean Power Plan in the near future.

While the energiewende is widely supported and a source of pride for many Germans, several interviewees indicated it was not a one-size-fits-all strategy. Instead, a common sentiment was that while most countries have realized they will need to find a way to decarbonize their economies, the German energiewende is only one way, and every country has to design its own strategy.

Advantages for Pennsylvania

Surprisingly, many of the Germans with whom I met expressed an opinion that the U.S. had many advantages in embarking on an energy transition, as compared to Germany, several of which apply directly to Pennsylvania. These include:

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- Domestic natural gas supply, which, paired with policies to encourage shifting to low- or zero-carbon energy sources, can be an affordable bridge fuel towards a renewable energy future. In contrast, Germany must import natural gas, increasing its dependence on other nations.
- Nuclear power, of which Pennsylvania has five plants, producing over one-third of the state's electricity, providing a zero-emissions baseload power source to rely on as it embarks on decarbonization efforts. In contrast, Germany is in the process of retiring its entire nuclear fleet, to be completed by 2022. Although this move is widely supported by the public, many experts recognize that it makes it more difficult for Germany to reach both its renewable energy and GHG reduction targets.
- More space for energy development, production, and transportation. As well, the diversity of energy sources available across the country, and even within the PJM territory, is a benefit to energy transition efforts in Pennsylvania.
- Smart grid technologies, in which the U.S. has seen greater investment than Germany. In fact, 43% of homes in the U.S. are equipped with smart meters, far more than in Germany.[vii] Having this technology already in place better lends itself to utilizing time-variant or even real-time pricing to send accurate market signals to users, facilitating more demand-side flexibility.

A Note on Political System
Germany has a bicameral legislative system, the Bundestag and the Bundesrat, comprised of representatives of Germany's 16 federal states. The country has a multi-party system. The political parties of the Bundestag are the Free Democratic Party, Christian Social Union, Free Democratic Party, Social Democratic Party of Germany, the Left Party, and Alliance90/The Greens. Because of this multi-party system, it is difficult for one party to have complete control of government. Instead, it is very common for parties to form coalitions, towards certain goals and outcomes. Germany also has a federal president, who acts as the formal representative of the country and who appoints several high-ranking government positions, and a federal chancellor, who determines the number of federal ministries and the responsibilities of each, as well as appointing ministers. The responsibilities and authority of the chancellor are similar to those of the U.S. president.

Background: Germany's Energy Transition
Germany's energiewende establishes multiple goals related to GHG emissions reductions, renewable energy production, and reductions in energy consumption, as follows:

- By 2020,
  - achieve a GHG reduction of 40% below 1990 levels
  - achieve a 20% reduction in energy consumption below 2008 levels
- By 2025, renewables will account for 35-40% electricity production
- By 2035, renewables will account for 55-60% electricity production
- By 2050,
  - achieve a GHG reduction of 80-95% below 1990 levels
  - achieve a 50% reduction in energy consumption below 2008 levels
  - achieve an 80% share of renewables in electricity production

While Germany's energy transition is often thought of as a recent endeavor, the country's energy mix has been shifting over the past 40 years. Primary energy consumption has remained nearly constant over that period, but the composition of energy has changed greatly.[viii] In 1973, the year of the first oil crisis, oil accounted for 47% of primary energy consumption in Germany. Combining oil, gas, hard coal, and lignite, fossil fuels comprised 97% of the energy mix.

During the first oil crisis (1973-74), the price of oil rose from three U.S. dollars to twelve U.S. dollars per barrel. Energy regulations and efficiency incentives were adopted in response to these price spikes. During the second oil crisis (1979-80), when the price per barrel rose to thirty-eight U.S. dollars, support for these rules only increased. Also during this time period, large public demonstrations were held against the construction of new nuclear power.

The reunification of the former East and West Germany in 1990 also impacted energy consumption and mix, as greater efficiencies were experienced and tax incentives and statutory requirements expanded. In order to increase investment in renewable energy, the first feed-in-tariff (FIT) in Germany was adopted in 1991. This law provided a tariff of 90% the retail, not wholesale, rate of electricity for solar and 80% for hydro.[ix] Because the rate varies with the market, there is not a guaranteed return. By 1997, oil's share of primary energy use had decreased eight percentage points, while natural gas and nuclear rose. In this same year, European energy markets were liberalized and the 1998 election resulted in the first Social Democratic Party/Green Party coalition in Germany, with a new focus on energy policy. This coalition had two major energy goals: the gradual phase out of nuclear energy and rapid increase in renewable energy.[x]

The original FIT was replaced by the Renewable Energy Act (EEG) of 2000, which, among other things, established a fixed rate for the FIT, rather than one based on market rates, for a term of 20 years. The EEG also guarantees connection to the grid and off-take of all power produced.

In addition to national policies, Germany's energy systems are also impacted by European Union policies, including European carbon trading, launched in 2005, which initially shifted investment away from coal plants.[xi] Germany also committed to the EU's 2020 Climate and Energy Package, enacted in 2009, which established the following targets: a 20% reduction in EU GHG emissions from 1990 levels; a 20% share of energy consumed from renewable sources; and a 20% improvement in energy efficiency.[xii]

In addition to growing renewable energy, there has been significant public will since the 1970s to phase-out nuclear power in Germany. In 2000, the same year as adoption of the EEG, an agreement was reached with the country's nuclear operators, under Chancellor Schroeder's coalition, to phase out nuclear energy by 2022. In 2010, the coalition led by Chancellor Merkel extended the timeline for decommissioning the remaining 17 nuclear power plants by eight to fourteen years. However, following the Fukushima accident in 2011, Chancellor Merkel returned the country to the initial timeline, under which all nuclear plants will be decommissioned by 2022. Within a week, 40% of nuclear generating capacity was shut down permanently,[xiii] representing eight gigawatts (GW) of power.[xiv]

A 2015 PricewaterhouseCoopers study found that 92% of German consumers supported the energiewende, but the reasons for doing so varied.[xv] Forty-three percent of respondents indicated the nuclear phase out was the primary reason for supporting the transition, as compared to 27% for shortage of fossil fuels, and 18% for reducing carbon dioxide emissions.

Under energiewende 1.0, significant successes have been achieved in renewable energy. However, at the same time, the use of coal also increased, slowing progress towards GHG reductions. In fact, a Deutsche Bank report in 2014 found fossil fuel's share in primary energy consumption only five-percent lower than in 1997, despite the increase in renewable energy, with much of that drop resulting from decreased use of oil as a heating fuel, as well as efficiency gains in transportation.

It was assumed that natural gas would comprise the largest share of electricity generation, due to the following: the phase out of nuclear by 2022, a planned phase out of domestic mining of hard coal by 2018, and the assumed decline of lignite. However, the global economic downturn led to reduced production by companies and thus a weakened demand for EU CO_2 emissions certificates. As a result, the market has an excess of over two billion certificates.[xvi] Carbon credits dropped from an historic high of €30 per ton in 2008 to just over €3 per ton in 2013, making it affordable for power plants to burn more lignite.[xvii]

Because carbon prices are so low, despite its low energy content, lignite has been a cheaper energy source.[xviii] Lignite CO_2 emissions are one-third greater than hard coal and three times as much as natural gas per ton burned, hampering Germany's efforts to reduce GHG emissions.[xix]

According to Otmar Edenhofer, professor for the Economics of Climate Change at the Technical University of Berlin, "without the collapse of CO_2 certificate price, Germany's emissions would most probably not have increased."[xx]

Interview participants also pointed out the role of inexpensive and abundant U.S. shale gas, which allowed hard coal to become cheaper and available for export to Europe.

Energiewende Results

The energiewende has achieved tremendous successes. However, it also has resulted in unintended consequences which the so-called energiewende 2.0 attempts to address. Primary among these is ebbing the rise in energy costs.[xxi] The 2014 amendments to the EEG made a number of adjustments, several to encourage a move away from the FIT, towards a market-based system. These changes include limiting the annual expansion of biogas and wind energy and charging self-generators a fraction of the EEG surcharge, to which they had previously been exempted.

In 2014 and 2015, Germany contemplated whether a capacity market would need to be formed to ensure adequate capacity as the percentage of variable energy sources (i.e. wind and solar) increases. Germany's "Green Paper," a public document produced by the Energy Ministry Federal Ministry for Economic Affairs and Energy in October 2014, cited the end goal as "an efficient power system overall where flexible generators and consumers as well as storage systems respond to the intermittent supply of wind and solar energy." Over 700 responses to the "Green Paper" were received. Based on the findings of expert consultants hired by the Federal Ministry of Economic Affairs, as well as public comment, it was decided that a capacity market would add significant costs without any benefits in the near term. As discussed more below, Germany's interconnection with the electricity grids of its European neighbors helps to ensure adequate capacity.

Instead of a capacity market, Germany's "White Paper" announced the creation of an "Electricity Market 2.0," which will include a four GW capacity reserve. The power stations that comprise this reserve will not participate in the electricity market, but rather will receive payment for sitting idle to be called into service if needed.

This capacity reserve is an alternative means to cutting emissions from lignite, or brown coal, plants, as compared to the climate levy, proposed in March 2015, which would have allowed lignite plants to continue operating, but charge a fee for carbon emissions. Plants within the capacity reserve, of which over half (2.7 GW) will be lignite power stations, will sit idle unless needed in emergency situations. It is anticipated that the wholesale market will send accurate price signals allowing for demand to be adjusted to avoid utilizing the capacity reserve except in very rare cases, resulting in CO_2 savings. Critics suggest this system is a "gift" to the coal industry in that it pays them, rather than charging a fee for pollution emitted. But others insist this is a step towards shutting down coal for good. Approximately 800-1,000 jobs will be impacted but the capacity reserve represents a compromise that gives companies time to transition.

Part One: Observations

Importance of a Clear Goal

The overarching observation that emerged through this work is the importance of a clearly defined goal. Germany's energiewende sets forth multiple goals. Policies and programs established to meet one goal may not drive progress towards another. Many interviewees pointed to Germany's feed-in-tariff (FIT) as an example. Perhaps the best known policy outcome of Germany's energiewende, the FIT provides a financial incentive for the production of renewable energy, both for commercial and residential projects, ranging in size from utility-scale wind farms to home rooftop solar installations.

If a goal is to increase the production of solar power, the FIT can be considered very successful. However, it is not clear that growth in renewables alone necessarily leads to GHG reductions. Many individuals interviewed expressed concern that the FIT has been a very expensive mechanism with uncertain results towards lowering GHG emissions.

While Germany is on track to meet its aggressive renewable energy targets, it will likely fall short of its short-term GHG emissions reduction targets. Reasons include the phase out of nuclear, export of power to other countries, and low prices for carbon credits.[xxii]

Destroying the Myth

Arguably one of the most important outcomes of Germany's energiewende is that it debunked the notion that wind and solar at any penetration will disrupt grid service. Several individuals interviewed vividly remembered advertisements run by the big four electricity generators warning that it was technically impossible to achieve penetration levels of renewable energy in excess of 8-9%. Others remembered the transmission system operators (TSOs) warning that the whole system would crash, and yet today renewable capacity is at 30% without any significant problems. The German experience would suggest that embracing aggressive renewable energy capacity does not lead to significant service disruptions, as feared by many.

Electricity Costs

Much of the criticism of the country's energy transition has centered around the increase in electricity costs. In fact, Germany has the second highest consumer electricity prices in Europe, after Denmark.[xxiii] Only a small fraction of the price per kilowatt-hour (kWh) paid by the consumer, however, is the actual cost of electricity. The wholesale cost of electricity continues to fall, and is at a 12-year low. This decrease is, in large part, due to the influx of renewable energy into the grid.

Because conventional generation cannot be shut off and turned back on easily or cost-effectively, at times of over-capacity renewable generators may be curtailed or prevented from feeding their power onto the grid. At times of curtailment, these producers are still paid a fee equal to 90% of what they would receive if producing power, further driving up the costs of the overall generating system.

Of the price paid by consumers per kWh, 25% or less reflects the cost of energy. About one-quarter is for transmission and distribution, and the remainder is comprised of taxes and fees, including the FIT levy, which in 2014 was 6.24 eurocents/kWh.[xxiv] This rate structure leads to confusion for consumers, who hear in the news that the cost of electricity continues to fall, yet their electricity bills continue to rise.

In August 2015, the Cologne Institute for Economic Research (IW) released a paper estimating that the energy transition costs consumers €28 billion annually, or €270 for the average household per year.[xxv] This study includes not only the EEG surcharge, but also additional costs of the energiewende, including expansion of the grid, capacity reserve, and increases in combined heat and power. A 2012 Deutsche Bank report provided the following estimates of the costs associated with the German energiewende:

- Annual investment in renewables of €17-19 billion
- Investments at fossil fuel stations (for baseload) of €4 billion per year through 2015; €2 billion euro per year from 2015-2020; and €1 billion euro per year thereafter
- Transmission and distribution improvements of €40 billion per year through 2030
- Investments in energy storage of €30 billion over the next two decades
- Building energy efficiency upgrades of €3-10 billion per year through 2030

However, others have argued that the economic benefits of the energiewende have outweighed the increases in residential electricity. For example, record energy exports resulting primarily from low wholesale prices (in part due to the contribution of renewables) earned Germany €1.75 billion from power trading in 2014.[xxvi] In addition, a Siemens study released in 2015 found that in 2013, renewable energy offset €31.6 billion of conventional electricity. With an estimated savings of €33 billion per year, when compared to costs of €28 billion, the energiewende results in a net savings of €5 billion euro, not counting health and environmental savings.

It is worth noting that renewable energy in Germany has created jobs, especially in more remote or depressed areas, such as dockyards near offshore wind farms, in eastern Germany, and in the former coal mining regions of North Rhineland-Westphalia.[xxvii] However, interviews indicated job creation is not as significant of a motivator in Germany, as compared to the U.S., as German employment is at a 20-year high and is greater than that of many of its European neighbors.

While energy-intensive industrial consumers can qualify for exemptions to the surcharges, these exemptions are widely critiqued from both sides of the issue. Critics complain these exemptions result in burdening other consumers, like families and small businesses, with a greater share of the costs of the energy transition. On the other hand, some industry representatives claim that because the exemptions are only good for three to four years, it does not provide sufficient certainty to make investments in the industrial sector which will have lifespans much longer than the exemption. There is also concern that the exemption causes disproportionate damage to the mittelstand, businesses with 500 or fewer employees, which are smaller in size and revenue but must pay the surcharges, while larger companies are exempted.[xxviii]

Interviews and casual conversations indicated that energy costs are not a significant percentage of the average household's costs, therefore increases in electricity costs have not been of concern among the general public. Most people estimated the additional cost was approximately €5 per year, although some approximated it was closer to €30 annually. Partially this is due to the smaller size and greater efficiency of German homes. In addition, most homes do not have air conditioning, which significantly decreases electricity costs.

While the average home may not perceive the additional fees to be problematic, there is the concern of a disproportionate burden on low-income populations. In Germany, household electricity use tends to be fairly consistent regardless of the size of home or income level. The EEG surcharge does not currently incorporate an "ability to pay" principle, except in the case of very low-income customers who receive public assistance. However, as one interview participant phrased it, prices must not be *too* high, as energy efficiency programs are still difficult to sell.

Costs associated with the FIT

Several of the individuals consulted described the country's investment in solar, via the FIT, as "Germany's gift to the world." The huge growth in solar in Germany resulted in a drastic drop in prices for solar technology worldwide. Some people, including some renewable energy advocates, have questioned, however, whether it makes sense for a country with a relatively low solar irradiance to be the world leader in installed capacity, whether this is the wisest use of financial resources, and whether the costs of the transition disproportionately impact lower-income populations.

RWI, a leading economic-research firm, has explored this issue. Because the FIT was more widely subscribed to than anticipated, between 2009-2015, the surcharge for renewable energy almost quintupled, from 1.31 eurocents per kWh to 6.17.[xxix] At the time of its launch, the FIT represented an excellent investment. For example, in 2008 the average return on solar systems installed in 2007 was 7.18% which was greater than the interest rates for the same year, in part due to the worldwide economic downturn. The FIT represented a solid investment when other options were not available. Some people even transferred money from traditional retirement savings accounts to the installation of solar panels. The FIT rate at the time of installation is locked in for a term of 20 years, regardless of future changes to the rate.

Between 2009-2011, installation costs decreased significantly, while the FIT remained the same, leading to a solar "boom" between 2010-2012, when yearly installed capacities exceeded seven gigawatt annually.

Of those households receiving subsidies, about half are from the top three deciles of income distribution. Individuals who rent their homes and/or live in apartments are less likely to be able to produce power. There is also a question of regional equity, as the former East Germany, on average, has lower wages than "old Germany" but pay the same surcharges for electricity. A prevalent stereotype in that region is that renewables are for "Volvo drivers with big houses."

The issue of subsidies and exemptions is not clear cut and there is not a simple answer from Germany's experience. The costs for all solar modules installed between 2000-2014 was nearly €112 billion, yet only 5% of electricity came from PV production.[xxx] According to one estimate, the growth of solar in the country has cost €716 euro/tonne CO_2 reduction[xxxi]. To put that number into perspective, the price of carbon on EU trading system has never exceeded €30/tonne.

Public Acceptance

Based on interviews and experiences during my time in Germany, it appears that issues of public acceptance of energy infrastructure may be of more significance than rising electricity prices. Despite very strong public support of the energiewende, there is a sentiment of "not in my backyard," or NIMBY as it is commonly known. As one interview participant phrased it: "everybody wants renewables; just not by their house." This has not been a significant barrier in achieving levels of up to 30% renewable energy penetration, but moving forward it will be. During my time in Germany, a particularly relevant issue was the need for expansion of the transmission grid, particularly from wind farms in the north to areas of high demand in the south.

In 2005, the Deutsche Energie-Agentur (DENA) determined an additional 850 kilometers of transmission grid would be required by 2020; yet in 2010, only 90 kilometers had been constructed. By that time, an additional study by DENA had expanded this figure to 3,600 kilometers of new high voltage line required, equivalent to 10% of the existing electricity transmission grid.[xxxii] According to Germany's 2014 Green Paper, "The grid situation in the south of the country is expected to remain tense even after 2020."

Much of the opposition to new grid infrastructure has been in Bavaria, a region with significant political strength. Bavaria has its own political party (the Christian Social Union) that at the federal level participates as part of the Christian Democratic Union. In addition, Bavaria is typically a more wealthy part of the country. Because the wealth is spread to other regions through taxes, it allows Bavaria to hold more clout. There is an urgency to completing this north-south connection before the phase out of nuclear power plants in 2022. In fact, some skeptics have suggested part of Bavaria's protest of new transmission lines is to delay the phase-out of nuclear plants, of which there are several in the region. In 2015, it was decided that this extension would be installed underground. While this increases the cost by three to eight times, some believe it is money well-spent in order to not hold the project back any longer.

It is worth noting that the problem of public acceptance is not limited to southern Germany. An example from northern Germany is a line through Mecklenburg-Vorpommern built by grid operator 50Hertz that could not be used because of an uncompleted connection in Schleswig-Holstein in northern Germany.[xxxiii] In part, the Renewable Grid Initiative was founded to help facilitate the public process for new infrastructure development. The public process for new transmission infrastructure can take three to four years of planning, or up to ten years if there is significant resistance from landowners. Similarly, the planning process and required ecological studies for new wind farm development can take five to eight years.

Need for Clear Market Signals

A consistent theme in many of my meetings was the need for clear market signals. Today, the retail price of electricity in Germany is not driven by the wholesale price, but rather by subsidies. Clearer market price signals could be a simpler way of achieving desired outcomes. One interview participant offered this succinct advice: "Price the externalities and get out of the way."

While liberalization of the electricity market has been successful, a common sentiment in meetings was whether the market was truly liberalized, when some energy sources have priority access to the grid or receive subsidies that skew price signals. While most critics of subsidies point to the FIT for renewables, just like in the U.S., *all* energy sources receive government subsidies. In fact, there is significant criticism of the simultaneous subsidies for coal and renewable energy, which are seemingly in opposition to one another.

Some researchers have concluded that the challenges of the energiewende, and the expansion of government to address them, may signal the re-regulation of the power market, suggesting the German government may need to take control of and fund aspects of the transformation rather than placing the full burden on the power sector.[xxxiv] In contrast to re-regulation, adjusting price signals may lead market participants to achieve the desired outcomes.

Carbon Trading

One popular market-based mechanism for reducing GHG emissions is a carbon trading system. While Germany does participate in the European Union's Emissions Trading System (ETC), the price of CO_2 in recent years has been too low to adequately drive disinvestment in coal due to the economic downturn.

While many interview participants favor a higher CO_2 price in order to incentivize the use of natural gas, others believe the CO_2 price required to push coal out of the market is simply "politically unimaginable." It is unrealistic to think that the strong industry lobby would allow CO_2 prices to get that high. Further, because the country's GHG emissions targets are more stringent than that of the EU, Germany will have to develop alternative mechanisms to the European trading system to achieve the incremental reduction above the EU target.

Energy Market Products

In addition to CO_2 pricing, market instruments that incentivize flexibility will need to be a part of the solution. Because of the intermittency of renewable energy sources, electricity generation that is dispatchable, or able to be turned on and off, like natural gas-fired turbines, should be preferable to huge coal generation units that are uneconomical to turn off. However, under current market conditions, natural gas turbines cannot operate. In fact, Siemens has recently laid off 800 workers at a facility near Berlin due to a lack of market demand for its most efficient gas turbine.

A key point expressed in interviews, that is also true in Pennsylvania, is that many political stakeholders do not have an adequate understanding of how the energy market works. Electricity in Germany is either traded via over-the-counter (OTC) trades directly between a generator and a consumer, or traded on the European Energy Exchange (EEX), via the forward, day-ahead, or intraday markets.

OTC transactions generally cost more than trading on the exchange but provide the benefit of certainty. There is no OTC trading for energiewende products at present. The market was designed to be unidirectional, but with the rise in so-called "prosumers" and the ability to manage demand with the right price signals, this is changing.

There are four electricity markets in Germany. The forward or derivative market allows for trades up to six years in advance. The day-ahead auction allows suppliers and buyers to submit bids by noon the day before electricity is needed. There is also continuous intra-day trading, allowing generators and consumers to bid for 15-minute time slots, up to 30 minutes prior to delivery, when production and use estimates are more accurate.

Finally, a balancing market provides power in the case of plant outages, weather events, or unexpected changes in consumption. There are three types of balancing capacity: primary, which must be fully available within 30 seconds of request; secondary, which will be available within five minutes; and tertiary balancing capacity, which is available within 15 minutes. Negative capacity can also be bid onto the balancing market, in times of overcapacity. The balancing market is the most expensive means of balancing supply and demand; therefore, an ideal market design would limit the amount of balancing capacity needed.

The influx of renewable electricity onto the grid means the cost of wholesale electricity has dropped drastically, from an average of €55 per megawatt-hour (MWh) to a predicted less than €30 per MWh for calendar year 2016. In fact, on very sunny, windy days, there is so much capacity available that prices can actually go negative, as coal-fired generation units pay to have their electricity on the grid, because that is less expensive than the costs of shutting down the plant temporarily. In theory, this situation would lead to the phase out of fossil fuel plants if they cannot compete economically with renewable energy. However, Germany needs the capacity of some conventional units (ideally natural gas due to lower emissions and dispatchability) to cover the residual load, the amount that cannot be provided by renewable sources. These conventional generators cannot survive off of the revenue from only the spot market, but rather need to sell electricity on the derivative market to be profitable.

In the past, renewables were guaranteed grid priority. After the 2014 amendments, wind energy projects will need to participate in direct marketing to sell power. It is very difficult to sell wind energy into the derivatives market, as weather forecasting is not accurate weeks or months, not to mention years, into the future. This makes the long term investment difficult from a risk management perspective.

To address these issues, EEX is developing new products to better meet the changing needs of the market. As wholesale prices are expected to continue to decline, more robust scarcity pricing may help to send accurate signals to the market, without impacting the average cost of electricity significantly. A higher scarcity cost will better support the capacity of conventional generators at times when they are needed for security of supply and will simultaneously better motivate demand management.

Scarcity pricing occurs today but in rare occasions. A recent example was on March 20, 2015 during a solar eclipse, when the intraday market price peaked at nearly €1,000 per MWh.[xxxv]

In September 2015, EEX launched a new product, the German Intraday Cap Futures. This product essentially allows market participants the opportunity to trade price spikes on the intraday market, up to four weeks in advance. The "cap" is a price threshold that allows market participants the ability to hedge risks. Traditional hedging mechanisms only work with day-ahead pricing and fixed delivery profiles, whereas the Intraday Cap Futures hedges against the scarcity prices which are reflected in the ID3-Price index[1] calculated by EPEX SPOT for the German intraday market. It provides protection to renewable energy producers from price spikes and incentivizes generators that offer flexibility, such as gas turbines. While the Intraday Cap Future is the first energiewende product to be introduced by EEX, other are anticipated, including a Wind Power Futures product. In addition, the trading of demand management will likely be offered in the future.

EEX operates as a private, for-profit company. Its role has become much more important as a result of the energy transition. It charges a fee for every MWh traded and cleared.

Democratization of the Grid

An important concept in the German energiewende is democratization of the grid. Just a few years ago, the "big four" electricity generators controlled 89% of the country's generation. Today that share has decreased to 67%, with the remainder being produced by communities and individuals. This is perceived to be a positive step by many Germans, including several of the energy practitioners interviewed. In part, this desire for greater control of energy production stems from public distaste for nuclear. There is a perception among certain parts of the population that despite public subsidies paid for nuclear plants, the private operators have realized high earnings. Now that the plants are being shut down, the public will again bear the costs of clean-up and any accidents. In part, this perception fuels the interest in a more democratic energy system.

There was much excitement among interview participants around the potential for home energy storage, and specifically the Tesla Powerwall home battery. In light of the 2014 amendments to the EEG, which require solar prosumers to now pay 40% of the EEG surcharge, there is a greater interest in storage to allow solar owners to completely disconnect from the grid.

While there is strong support for distributed generation, not all individuals consulted agreed with the desire to disconnect from the grid. The grid is a public resource and the more customers who disconnect from it, the less funding there is to support its upkeep. While microgrids are an attractive option for increasing reliability and better integrating renewable energy and energy efficiency equipment, it may be a much more costly way of utilizing

[1] The ID3 price is a volume-weighted average of all intraday trades in the three hours before delivery.

energy. Some interviewees asked "does it make sense for every city or state to be self-sufficient?" and if not, what boundaries are economically and technically appropriate.

Electricity Generation, Transmission and Distribution

In Germany, the switch away from nuclear and fossil fuels has, at least in the short-term, had an impact on all levels of the electricity market, from generators, to transmission system operators, to distribution systems. A common sentiment expressed was that many energy actors did not initially perceive distributed generation as a threat, believing it could not reach the levels of penetration it has. As such, they may not have prepared or shifted their business models early enough.

In a world with greater distributed energy that places more of a focus on flexibility, both on the generation and demand side, the role of, and business model for, utility companies will unavoidably change. Below, observations from interviews and site visits in Germany are offered on the impact to generation, transmission, and distribution.

Generation

Germany has four large generators: E.On, RWE, EnBW, and Vattenfall. A Deutsche Bank paper in 2014 estimated that approximately one-third of conventional power generators in Germany had operating deficits due to the huge oversupply of capacity, in part caused by renewables with feed-in priority and low operating costs. In fact, RWE AG and E.ON SE were the worst performers on the German DAX stock index in 2015.[xxxvi]

The "big four" have all struggled in recent years for four key reasons: 1) little or no market share in renewable energy.[xxxvii]These companies only own about five percent of the renewable capacity in Germany;[xxxviii] 2) investment in energy efficient natural gas turbines which, under current market conditions, are not economical to run; 3) the phase-out of nuclear plants; and 4) low wholesale electricity prices. One interview participant stated that a price of €32 per MWh would be approximately "break even" for the conventional fleet. Average prices have typically been in the range of €40-45 per MWh, but today are only €28 per MWh.

All four have announced plans to significantly alter their businesses in Germany. For some, this includes a greater focus on renewables, energy efficiency, and energy services. With regard to renewable energy, there is more interest in wind development, both on- and off-shore, than other renewable energies as it is a better fit for operators experienced in running central generating facilities. There was also interest from multiple parties in seeing the large energy companies play a role in advancing energy efficiency, particularly in the industrial sector.

Finally, carbon trading was seen as a more effective mechanism for generators to reduce GHG emissions, even if the price of carbon certificates rises higher than it is currently. A trading mechanism allows generators to determine the most cost-effective way to make reductions. So long as the cap is binding, a trading program will achieve the intended goals.

Transmission

Following market liberalization in 1997, generators either sold their transmission systems or put them under separate management. Today, there are four transmission system operators (TSOs) in Germany: 50Hertz, Amprion, TransnetBW, and TenneT. While much of the public conversation around the energy transition focuses on generation, the TSOs play a significant role in the implementation of the energiewende. The energy transition has forced TSOs to adapt in many ways, including developing ancillary services to include renewable energy sources and developing system control methods. Many of these adaptation are specific to the German electricity system, but most relevant to efforts in Pennsylvania are two key responsibilities: expansion of the grid to add more capacity; and responsibility for redispatch, which ensures electricity is available when and where it is needed when either supply or demand deviates from what was predicted.

Traditionally, most transmission lines are operated at 50% capacity or less, so that if a line goes out of service, the other lines nearby can carry the extra power to prevent blackouts. However, today some lines are running at 70% capacity, due to the need for new transmission lines. To plan out what new transmission infrastructure is required, the TSOs produce a Grid Development Plan every two years. This process was designed to encourage more public involvement and acceptance. However, there continue to be strong concerns from the public about the visual aesthetic of transmission lines and the impact on property values, leading to, at times, a lengthy approval process of up to 14 years. Considering that the nuclear phase out will be complete in six years, timely approval is more important than ever.

TSOs are also responsible for handling redispatch, informing generators to ramp up or shut down production to keep the grid balanced. This line of business has been significantly impacted by the energiewende, as renewable energy is more highly variable, leading to a greater need for balancing power. The generators that need to ramp-up are usually the more expensive plants, otherwise they would already be selling onto the grid. This re-balancing is handled in 15-minute intervals.

This greater need for redispatch has required TSOs to make investments, not the least of which is better weather forecasting, to more accurately predict the contribution of renewable sources. The costs associated with redispatch are ultimately passed on to the customer through the grid fee. Construction of new transmission lines will help to alleviate this issue as power can be more easily moved from point of generation to use.

Moving forward, the TSOs could play an important role in data management, including the use of smart meters in homes and businesses. As distributed generation continues to increase and demand-side management becomes ever more important, there will be a need for more cooperation with DSOs.

Distribution

Distribution system operators (DSOs) represent the segment of the power sector closest to the end consumer. They deliver power directly to homes and businesses and provide a bill for usage. In Germany, most renewable energy generation is also connected to the distribution system. Historically, DSOs operated under a “triangle” of priorities: safe, economical, and environmentally-friendly. Today, DSOs are being asked to place a greater focus on the third, without sacrificing the other two.

For decades, many DSOs were operated by municipalities, providing gas and electricity to citizens. However, under liberalization, many municipal utilities sold their assets, often to the big four.[xxxix] Over the past few years, though, a "re-municipalization" trend is noticeable in Germany.[xl] In fact, since 2005, over 120 local municipal utilities were formed. Municipal energy companies own more than 50% of the 860 distribution system operators.[xli]

While some municipal utilities are slow to adopt renewables, 146 communities and regions are implementing 100% renewable energy strategies.[xlii] Stadtwerke Munchen (SWM), the utility provider in Munich, is a notable example, with a goal of 100% renewable energy and an investor stake in RWE's North Wales offshore wind farm.[xliii]

Another example is DREWAG, the utility provider of Dresden and the surrounding region, which has invested in combined heat and power, solar, and battery storage technologies, despite being in a region that identifies itself as "coal country."

While transportation is largely outside of the scope of this research, it accounts for 19% of CO_2 emissions and 29% of final energy consumption.[xliv] It is an area where DSOs, particularly in cooperation with municipalities, may have an impact, specifically through enabling electric vehicle infrastructure.

Business Opportunities

The energy transition creates opportunities for new and existing businesses. Primary among these are third-party aggregators, direct marketers, and virtual power plants. Each plays a role in balancing the increasingly flexible, increasingly bi-directional electricity system. Direct marketers represent generators, and potentially demand management units, to bid this capacity onto the market. An aggregator does the same thing, but by bundling multiple assets together. Virtual power plants, or VPPs, do the same thing, but typically on the balancing market.

One of the most prominent examples of a VPP in Germany is Next Kraftwerke. This company has described itself as "the Air BNB of the energy sector," because they do not own any assets, but rather provide a platform for other parties to use. Because the German electricity market currently has an overcapacity, most often Next Kraftwerke bids negative capacity onto the grid.

The 2012 EEG update allowed the introduction of renewables into the balancing market. This change demonstrated that direct marketers and VPPs can make the overall system less expensive, increase revenue for renewable energy generators, and lower costs for ratepayers.

In addition, several interview participants mentioned interest in expanding services offered to their customers. These largely centered around energy efficiency, advanced metering, and demand management services.

Potential in U.S.

Just as lower solar prices may have been "Germany's gift to the world," several individuals were confident that should the U.S. embrace an energy transition it would have far-reaching impacts. The U.S. was described as a "thought-leader," "innovative," and "entrepreneurial." As a larger, more energy-intensive country, a widespread transition would have much further reaching impacts on technology developments and cost-reductions through economy of scale. Also mentioned, although not as frequently, was the fact that, as a large energy user, a transition in the U.S. would benefit the entire world through the reduction of GHG emissions.

Other Observations

The observations above are those that emerged as most significant, arising in multiple interviews. However, there are a few other observation that, although not as significant, are worthy of being recorded.

- Several interview participants echoed the sentiment that while the early excitement is diminished, the energiewende still has a lot of work to do. Some used the phrase "no man's land" to describe the current status, beyond the exciting launch and initial progress, but not yet to the long-term goal. Any large scale transition over a long timeframe will encounter this middle-ground.
- Similar to concerns often cited in the U.S. is concern over pollution "leakage," the idea that regulations will drive industries to other countries, where there may not be environmental standards, or at least not as stringent. This is particularly relevant to the issue of GHG emissions.
- Energy independence is a part of the conversation, as Germany imports all of its natural gas and much of that comes from Russia. However, energy independence is not currently the most significant issue. Some questioned whether Germany wanted to be so dependent on another nation in general or Russia in particular. Others countered that interdependence is the way the economy works.
- Several participants thought climate adaptation should be a bigger part of the conversation. In particular, the costs of adaptation should be integrated into cost analyses, rather than thinking of simple payback alone. One example was flooding of the Elbe River two times in the past ten years, with predicted continued flooding.
- More than one interviewee suggested both Germany and the U.S. should consider leaving some fossil fuels in the ground, not as a CO_2 emissions mitigation strategy, but rather as an insurance policy. Because fossil fuels are so valuable to our society, it does not make sense to continue extracting and burning them until there are no supplies left, but rather to keep some untouched in case they are needed for unforeseen situations in the future.
- Many interview participants brought up the refugee crisis in Europe as an example of the types of competing issues that cannot be predicted which draw focus and resources away from energy. It is important to remember that even in a country like Germany, energy is only one of several issues.
- In terms of differences between the U.S. and Germany, relevant to energy, an unexpected point that came up a few times was the German reticence to share data.

For example, Germans are less likely to use social media like Facebook and are more concerned about breaches of data. This may present a challenge for more smart grid and advanced metering technologies.

- Finally, while 35 years is not such a long time in comparison to the timeline for development of electricity generation and transmission infrastructure, several interview participants placed emphasis on how far away 2050 is, in regard to achieving the goals of the energiewende. Thirty-five years is a long time and it is nearly impossible to predict what technological advances may occur between now and then. To put this time scale in perspective, one interview participant reminded that just 25 years ago, Eastern Germany was a socialist country.

Part Two: Recommendations for Pennsylvania

Set a Clear Goal

While the German energiewende has multiple metrics for measuring progress towards a transition of the energy system, a similar transition in Pennsylvania may be more effective if it has a clearly defined goal. Based on conversations in Germany, decarbonization of the energy mix—and quickly—may be the most appropriate goal for efforts in the U.S. and Pennsylvania, specifically. There is urgency to making this transition, as study after study shows that the global climate is already changing and predicted to increase with potentially catastrophic consequences if action is not taken. Because of the long lifecycle of power plants, infrastructure decisions today could have the effect of locking our state into a certain pathway.[xlv]

While energy efficiency and renewable energy must be an important part of the strategy for meeting this goal, they are merely a means to the end. By clearly recognizing this fact, programs and policies can be developed in Pennsylvania to most effectively achieve the goal.

Cost should not be the only factor considered when determining an energy strategy, but it must be remembered that money spent on energy programs cannot go towards other issues, like childhood education, public health programs, or other worthy public priorities.

Expect Public Acceptance Issues

Experiences in Germany suggest Pennsylvania should be realistic about what can be accomplished, and in what timeframe. Germany did not anticipate the public acceptance issues it is facing regarding development of transmission lines and future renewable energy generation. Pennsylvania should expect to encounter challenges like these, which may delay the growth of renewable energy.

Models have shown that achieving 100% renewable energy in the U.S. is achievable, paired with deep energy efficiency and energy storage projects.[xlvi] However, this research may not adequately account for strong NIMBY issues, like those being experienced in Germany. If Pennsylvania embarks on new renewable energy generation projects, it will need to recognize that some sites may have long development timelines due to ecological or public acceptance concerns. To achieve CO_2 reductions as expeditiously as possible, renewable energy development at the sites with the least expected acceptance issues should be prioritized for short-term implementation.

A recommendation in light of public acceptance issues in Germany is to prioritize renewable energy development at existing disturbed sites, such as brownfields and rooftops. In addition, large scale installations may be appropriate at existing or former power plants, where transmission infrastructure already exists.

Preserve Low-Carbon Baseload Power
Interviews in Germany indicated that clean energy policies and programs should be designed in such away as to avoid unintended impacts on existing low-carbon generators. As described above, natural gas turbines are lower-emissions than coal plants and have the ability to be cycled on and off to meet the peaks and valleys of renewable energy generation. In Germany, however, they are presently not economical to run, due to current market conditions.

In addition, discontinuing the use of nuclear power is a huge priority for Germany with overwhelming public support, as evidenced by large public demonstrations in recent years. In contrast, in the U.S. there is not the same level of activism against existing nuclear power plants. Although the German public does not support nuclear power, interview participants suggested that if the American public is more accepting of nuclear, existing plants should be kept online, as long as they are licensed, safe, and economical, to provide zero emission base load power, serving as a bridge to a future with higher penetrations of renewable energy sources. To further explore this recommendation, the state could engage expert stakeholders in a discussion around the future of nuclear power in Pennsylvania, including public acceptance and economic viability.

Develop Policies and Programs to Encourage Private Investment
Pennsylvania state government is resource constrained, with limited funding for clean energy programs. State funding alone will be insufficient to meet necessary carbon reductions. Thus, any investments of public funds should be done in such a way as to attract as much private investment as possible, to incentivize zero-carbon energy and energy efficiency investments. Examples of potential state investments could include creation of low-interest loans, a loan-loss reserve, a clearinghouse matching investors to projects, or facilitation of a carbon trading system.

Germany's FIT is a very successful example of a tool that provided sufficient certainty to attract private investment. However, it was so successful that the costs increased rapidly. Interview participants suggested that any similar mechanisms adopted in Pennsylvania should be crafted with an upper limit and a regular review schedule for adjusting the rates. Further, incentives should encourage continued innovation and cost-reductions. Germany's FIT remained at a high rate for a long time, which some interviewees felt did not adequately incentivize private industry to work to continually bring down the costs of installations.

Provide Accurate Market Signals; Create a System that Rewards Flexibility
An overwhelming recommendation from meetings in Germany was to design a system that provides accurate market signals to incentivize the desired outcomes. In some ways, this is outside of the jurisdiction of Pennsylvania, as existing subsidies for both fossil fuels and renewables are largely established at the federal level. However, one option that is within the jurisdiction of the state is creation of a CO_2 trading system.

Establishing a CO_2 trading system presents the challenges of ensuring the correct structure and price to achieve the desired outcomes. As long as the trading system is established with a binding cap, CO_2 trading results in guaranteed reductions. In addition, certificates can be auctioned, contributing a revenue source that may be used to reduce other taxes, which makes it more appealing to conservative political leaders.

CO_2 trading is not the only option for providing accurate price signals; rather, the need for accurate pricing should be a consideration in any programs or policies developed.

Closely related to the need for accurate price signals is the need for a system that incentivizes flexibility. In the past, both generation and demand were steady and followed predictable patterns. In fact, steady demand was valued. Today, however, production is constantly fluctuating. Flexibility on both the generation and demand side is increasingly more valuable, but rate structures do not adequately incentivize flexibility.

As Pennsylvania achieves greater penetration of renewable sources of electricity, conventional generators will need to be able to ramp-up or ramp-down production in response to electricity production from renewables, which can vary minute-to-minute depending on weather. Flexibility will be a desirable attribute of electricity generation that should be rewarded.

Further, many interview participants suggested that rate mechanisms be created to reward flexibility on the demand side. While demand response programs exist for industrial and commercial customers, these programs will need to be strengthened and preserved as Pennsylvania's electricity system evolves. Time variant and, perhaps eventually, location variant pricing of electricity could be an important part of balancing generation sources with electricity demand across all customer classes. These types of programs help to shave peaks, reducing the redundancy required and thus also the cost of the system. As energy storage technologies become more commonplace, the electricity rate structure will be very important to incentivizing when customer-generators feed onto the grid and when they use electricity generated on-site (i.e. charge batteries).

Too often there is a stereotype of "us against them" with regard to the relationship between customer-generators and utility companies. Rate mechanisms must be developed to encourage cooperation between consumers, customer-generators, and utilities to allow for the most cost-effective approach to an energy transition. While interview participant opinions varied somewhat, several recommended that an energy transition must discourage grid defection by making it lucrative for prosumers and storage users to stay on the grid, while lowering costs of grid operation overall so that operators and other consumers all benefit.

Invest in Energy Efficiency Early

Even in a country like Germany, with a stronger environmental ethic and the incentive of higher energy prices, energy efficiency is at least as much of a challenge as in the U.S. The higher prevalence of rental units, in which tenants do not have significant control over their energy savings, and the lack of regular meter readings, making it difficult to measure and manage energy use, exacerbate this challenge.

Because energy efficiency, particularly in small businesses and the residential sector, is difficult to implement, efforts should start early. Reducing electricity demand will be a critical component of reducing GHG emissions and enabling a transition to greater percentages of renewable energy. Further, because of line-losses in transmission and distribution, overall electricity savings are ultimately greater than what is measured at the consumer site alone.

Furthering energy efficiency will require technical, policy, and financial approaches, including greater deployment of smart metering and smart home technologies; greater recognition of the value of energy efficiency in real estate appraisals and transactions; and availability of more attractive financing options, which may include on-bill repayment, property-assessed financing, and access to low-interest long-term loans.

Enable Business Opportunities

A point of conversation in several meetings was the opportunity to enable new business opportunities, both for existing players, like electricity distribution companies, as well as for new businesses to emerge. New business opportunities exist in areas such as smart grid technologies, energy efficiency, renewable energy, and battery and other storage technologies.

While Pennsylvania's landscape is scarred with the impacts of historical energy production, renewable energy could provide an opportunity to transform these environmental liabilities into opportunities. An example from Germany is the company RAG, historically a mining company, which has started installing wind turbines on slag heaps, solar panels on old coal sheds, and will begin using water from mine pools for geothermal.[xlvii] It is also exploring potential for pumped storage on its former mine lands.

There will also be opportunities in the transactional side of an energy transition. For example, in Germany, the TSOs have become the "financial managers" of the country's renewable energy system, buying renewable energy at different subsidy levels, then selling it on the European Energy Exchange.[xlviii]

Opportunities also exist for distribution utilities. In the U.S., public utilities regulations and programs sometimes have the real or perceived effect of pitting renewables against utilities' interests. Interviews in Germany suggest that policies should be designed in such a way as to allow distribution companies an opportunity to build new lines of business that further progress towards the state's goals of GHG reduction and clean energy development. Additionally, better collaboration between the distribution companies and the municipalities in which they operate emerged as a recommendation based upon experience in Germany.

A final note on DSOs: in Germany, some municipally-owned utilities manage multiple service areas, including electricity, natural gas, water, and/or district heat. This is less common in Pennsylvania. Having one entity involved in all of these areas facilitates the development of more comprehensive initiatives. While it is unlikely that we will see a similar system developing in Pennsylvania, it suggests there may be a role for the Public Utility Commission in coordinating efforts among the entities it regulates.

Think About Your Neighbors

A key factor in Germany's energiewende to date has been its interconnection to neighboring countries. In times of high wind and solar energy production, this excess electricity can flow into neighboring countries. Some countries have appreciated this inexpensive electricity; others have been unhappy about the impact it has had on domestic electricity generators. A lesson-learned is to anticipate there will be impacts on neighboring electricity grids and to consult with those entities early.

Pennsylvania is part of the PJM grid, which also serves all or part of 13 states and the District of Columbia. A recommendation is for Pennsylvania to think more regionally, especially in regard to the PJM territory. This does not mean consensus must be reached with all partners or that it should hold Pennsylvania back from establishing ambitious goals, but rather that the state should figure out how to best take advantage of being part of this interconnected network.

Conclusion

Insight from one interview participant is that "We will not solve all problems with copper; some (will be solved) with intelligence." Historically, problems in the electricity sector, whether in Germany or the U.S., could be fixed with new infrastructure. Today, what is needed is smart, comprehensive planning and design. There is much that Germany and the U.S. can learn from one another and both efforts will benefit from a sharing of information and experiences.

While much of this paper focuses on the challenges encountered in Germany, in order to inform similar efforts in the U.S., the successes of Germany's efforts should be recognized and respected. Germany continues to set new records for renewable energy capacity and generation, with as much as 78% of electricity being sourced from renewable energy at times of high production. As one interview participant described, Germans are often slow adopters, but when they do, they do it "properly and fully." Any large scale transition takes time and encounters unexpected challenges. The hurdles encountered by Germany to date should not be taken as indicators that the energiewende will not be successful, but rather as bumps in the road on a very long journey.

What emerged most clearly in interviews was the challenge of meeting multiple goals simultaneously. Specifically, progress towards renewable energy targets has not had the effect of significantly furthering progress towards greenhouse gas reduction targets. These findings suggest the need for a central goal in Pennsylvania and/or the United States to steer energy work. Today energy conversations shift from benefits in climate protection, to air quality, to jobs created. Interviews indicated that a clear, ambitious goal empowers actors in all areas of the electricity sector to make informed decisions on how to best reach that goal.

To achieve this goal, programs and policies must be designed to attract as much private capital to projects as possible. Germany's feed-in-tariff provides an excellent example to learn from, not only to replicate its successes at growing renewable energy development, but also to avoid some of the challenges encountered, including unpopular increases in electricity costs. Carbon trading mechanisms and electricity rate structures that reward flexibility were also recommended as tools to achieving a sustainable energy future.

While the intention of this research was to learn from Germany's example, a common theme in interviews was that there is also much Germany could learn from the U.S. An energy transition in the United States will have far-reaching impacts. There are more similarities than differences in the challenges and opportunities both areas face in regard to an energy transition. A continued exchange between the two countries on energy issues will benefit both efforts.

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APPENDIX A: LIST OF INTERVIEW PARTICIPANTS

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Agora Energiewende	Dr. Thies Clausen	Senior Associate
Belectric	Mr. Tim Mueller	Head of Research and Development
BNE – Association of Energy Market Innovators	Mr. Sebastian Schnurre	Speaker Market & Regulatory Attorney
BSW- German Solar Industry Association	Mr. Jan Michael Knaack	Senior Project Manager, International Affairs
BWE- German Wind Energy Association	Mr. Lars Velser	Communication Director
City of Munich, Department of Health and Environment	Mr. David Murphy	Climate Protection and Energy
Cologne Institute for Economic Research	Dr. Thilo Schaefer	Head of Research Unit, Environment, Energy, Infrastructure
DREWAG	Dr. Tilman Werner	Power and Heating Plants, New Energy
DREWAG	Mr. Frank Wustmann	Head of Strategy & Environmental Affairs
EEX- European Energy Exchange	Dr. Maximilian Rinck	Business Development
E.on	Ms. Constanze von Rheinbaben	Regional Coordination, Market & Sales
E.on	Mr. Stefan Ulreich	Political Affairs and Corporate Communications
Federal Foreign Office	Mr. Hans Koeppel	Head of Unit, Foreign Policy Issues of Energy Transition
Fuel Cell Energy Solutions	Andreas Froemmel	Vice President of Business and Commercial Development
German Parliament, Green Party, Office of Oliver Krischer	Mr. Titus Rebhann	Office Manager
Institute of Energy Economics, University of Cologne	Dr. Felix Hoeffler	Research Director
University of Cologne, School of Law	Dr.Kirk Junker	Professor of Law
Munich Reinsurance Company	Mr. Gernot Loeschenkohl	Senior Investment Director, Alternative Investments
Next Kraftwerke	Mr. Jan Aengenvoort	Head of Corporate Communications

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RheinEnergie	Ms. Kristin Buerker	Energy Sector
RWE	Dr. Peter Engelhard	Senior Advisor Energy Politics
RWI- Rheinisch-Westfaelisches Institut fuer Wirtschaftsforschung	Dr. Colin Vance	Deputy Division Chief, Environment and Resources
SAENA- Saxon Energy Agency	Ms. Antje Fritzsche	Energy Efficiency
SAENA- Saxon Energy Agency	Ms. Cathleen Kloetzing	E-Mobility and Intelligent Transport Systems
Siemens	Mr. Peter Grossmann	Head of Global Installation and Commissioning HV GIS
Siemens	Dr. Udo Niehage	Senior Vice President, Head of Government Affairs Germany
SMWA- Saxon State Ministry for Economic Affairs, Labor, and Transport	Mr. Florian Schaefer	Head of Division, Energy Policy
SMWA- Saxon State Ministry for Economic Affairs, Labor, and Transport	Mr. Steffen Thie	Desk Officer, Energy Policy
World Energy Council	Ms. Nicole Kaim-Albers	Head of Office