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A History and Status of Wind Energy Potential in Arkansas, Pre and Post COVID-19

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Part 1: History

The modern history of wind power used to generate electricity began in 1887. The American Charles Brush is often credited with the first wind powered machine that generates electricity. He operated his machine in the winter of 1887, but earlier in July of 1887, the Scottish Professor James Blythe performed similar experiments which earned him a UK patent in 1891 **[1]**.

Early advancements in wind-power came in the beginning of the 20th century. The Danish inventor Poul La Cour made many advancements in wind-turbine technology in the 1890s at the time of his death in 1908, there were 72 wind-powered electric generators in Askov, Denmark where he lived **[2]**. These wind turbines were used for hydrolysis to convert water to hydrogen which used as gas to light schools **[3]**.

Brothers Joe and Marcellus Jacobs opened a factory they named Jacobs Wind in Minneapolis, Minnesota in 1927 that produced small electricity generating wind turbines mostly for farm use powering lighting or batteries. In fact, "in thirty years the firm produced about 30,000 small wind turbines, some of which ran for many years in remote locations in Africa and even on the Richard Evelyn Byrd expedition to Antarctica" **[4]**.

The famous Johannes Juul in 1957 installed a wind turbine near Gedser in Denmark which ran for ten years. The turbine "was three-bladed, horizontal-axis, upwind, stall-regulated turbine similar to those now used for commercial wind power development." **[4]**.

In the USSR, a "forerunner" to modern large-scale wind-turbines with a horizontal-axis was the WIME D-30 which ran from 1931-1942. It was a 100-kilowatt generator with 30-meter blades **[5]**.

Building on these developments, a huge jump in wind-generated electricity came because of the 1973 oil crisis where the Energy Research and Development Agency (now a part of the US Department of Energy) funded NASA in the Lewis Research Center to coordinate the development of wind-generated electricity **[6]**. Despite never producing a commonly used commercial wind turbine design, this program is credited with advancing parts of wind turbine technology. For example, an analytical model developed through this project in 1981 to determine the relationship between wind speed and power has been used in industry to predict wind turbine performance **[7]**.

The growth of wind-generated electricity has been influenced largely by U.S. Federal and State policies. Federally, the Energy Policy and Conservation Act of 1975 was designed to cut energy demand, but this act also encouraged alternative energy sources. The first major policy that impacted the growth of wind-generated electricity was the Public Utility Regulatory Policies Act (PURPA) of 1978. This act required, among other things, that public utilities must interconnect with renewable power production facilities, which includes wind power **[8]**. PURPA also gave small power production facilities whose primary energy source is renewable "special rate and regulatory treatment" **[9]**. Size limits on these facilities were removed through the r of 1990 **[10]**.

The next major development in federal wind-generated electricity policy came in 1992 with the Energy Policy Act (EPACT) **[11]**. This created, among other things, a production tax credit (PTC) along with a performance incentive. Since then, this act has been revised in 2005 to establish new goals. In 2007, the Energy Independence and Security Act (EISA) made awards for different renewable energy research **[12]** and in 2009, the American Reinvestment and Recovery Act (ARRA) extended the PTC and gave grants for renewable energy **[13]**. In 2013, the PTC was planned to be phased out completely by 2019 with decreasing incentives for the last 3 years **[14]**. In December 2019, the PTC was extended one more year **[15]**.

Part 2: Current Status

The United States generated 3,950,331,000 Megawatt-hours of electricity in 2009, 1.87% of which (73,886,000 Megawatt-hours) was generated from wind-power. As seen in **Figure 1**, That percentage has grown steadily and in 2018, of the 4,174,398,000 Megawatt-hours of electricity generated, 6.53% was generated by wind power **[16]**.

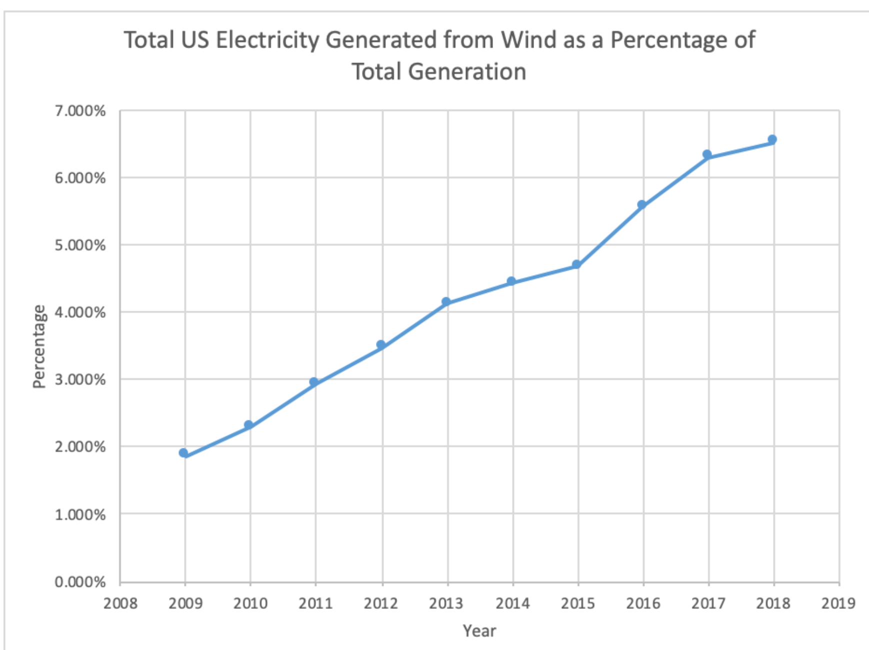

Figure 1: Wind Generated Electricity as a Percentage of Total Electricity Generation 2009-2018

In the West South-Central Region, which comprises of Texas, Oklahoma, Arkansas, and Louisiana, of the 685,020,000 Megawatt-hours of electricity generated in 2017, 13.2% was generated by wind-power. This percentage grew in 2018 to 14.0% of the 733,704,000 Megawatt-hours generated. However, as seen in **Table 1**, all the wind power generated came from Texas and Oklahoma, there are no utility scale wind-powered electricity generators in Arkansas or Louisiana. Low wind speeds leave limited area ripe for wind farms in these states. In spite of this limitation, there have been previous attempts to establish wind farms in Arkansas.

State	2017 Total Generation (Thousand MWh)	2018 Total Generation (Thousand MWh)	Total Generation Growth	2017 Wind Generation (Thousand MWh)	2018 Wind Generation (Thousand MWh)	Wind Generation Growth	2017 Wind Percentage	2018 Wind Percentage	Wind Percentage Growth
Texas	452,794	477,352	5.4%	67,061	75,700	12.9%	14.8%	15.9%	1.0%
Oklahoma	73,732	86,224	16.9%	23,599	27,338	15.8%	32.0%	31.7%	-0.3%
Arkansas	60,775	67,999	11.9%	0	0	0.0%	0.0%	0.0%	0.0%
Louisiana	97,719	102,129	4.5%	0	0	0.0%	0.0%	0.0%	0.0%
Total	685,020	733,704	7.1%	90,660	103,038	13.7%	13.2%	14.0%	0.8%

Table 1: Electricity Generation in the West South-Central U.S. 2017-2018 **[16]**

TradeWind Energy, a Kansas based company, attempted to build wind turbines in Searcy and Benton county Arkansas in 2008 but cancelled the project in Searcy county because of lack of buyer interest and in Benton county because of environmental concerns **[17]**. In 2015, the Frisco, Texas-based Dragonfly Industries alleged to try to build a windfarm in Elm Springs. This attempt, however, turned out to be a fraud and in June 2019 two Dragonfly executives were indicted on "multiple accounts of wire fraud, aiding and abetting wire fraud, money laundering, and aiding and abetting money laundering" **[18]**. The new technology claimed to have been invented by Dragonfly Industries and the return on investment claims were all fraudulent.

Even in more wind-rich regions there are hurdles to developing wind farms in the region. For examples, the Windcatcher project from American Electric Power (AEP) was planned to be built in Western Oklahoma and would serve much of Oklahoma, parts of the Texas panhandle, parts of east Texas, Northwest Louisiana, Texarkana, and Northwest Arkansas. This 2,000-megawatt wind farm would have been the largest in the nation by far; the current largest is the Alta Wind Energy Center in California. However, this project was canceled in 2018 after the Texas Public Utilities Commission rejected AEP's request for a Certificate of Convenience and Necessity. Concerns from locals coupled with the declining PTC and concerns about financial success informed the decision **[19]**.

Since this decision, AEP has moved forward on a smaller project entitled North Central Wind Initiative. They are currently in the process of getting this project approved by Texas, Oklahoma, Arkansas, and Louisiana regulatory bodies. If the project continues as planned, it would establish three wind farms in central Oklahoma with a 1,485-Megawatt capacity. One facility seeks to be operable by the end of 2020 to obtain the 60% PTC while the other two plan to finish in 2021 **[20]**. Southwestern Electric Power Co (SWEPCO), a subsidiary of AEP will own 54.5% of the power generated while Public Service Company of Oklahoma (PSO) will own the other 45.5% **[21]**.

Part 3: Technology Advancements and Hurdles

In June 2002, the American Wind Energy Association (AWEA) released a 20-year "Roadmap" for the future of small wind turbine technology **[22]**. The AWEA identified five technological barriers to the growth of small wind turbine technology: high costs of small wind turbines, lack of small wind turbine reliability, the high cost of reliable power electronic converters, the loud turbine noise, and expensive cost of designing more efficient furling mechanisms.

Much research and progress in wind turbine technology has been made since the publication of the aforementioned report. Vertical axis wind turbines (VAWTs) are now a viable option for small wind turbine technology. In 2019, the Hi-VAWT DS3000 became "the first vertical axis turbine to gain certification by the ICC-Small Wind Certification Council and demonstrate conformance with AWEA standards" **[23]**. VAWTs have the potential to manage effectively the problems that afflict horizontal axis wind turbines (HAWTs) including noise, turbulent winds, and low wind speeds.

Vertical axis wind turbines can "handle turbulent and unconventional wind and generate energy at slower speeds" **[24]**. Additionally, evidence suggests that VAWTs are quieter and the noise they do generate more closely matches the background noise, essentially masking much of the turbine's noise **[25]**. These advantages make VAWTs more suitable for residential and urban settings. The quieter sound and potentially smaller impact on wildlife **[26]** can potentially shift public perception away from hostility toward small scale residential and urban wind generated electricity. Furthermore, this technology may be viable in less wind rich areas such as Arkansas. Northwest Arkansas in particular, with some wind resources, could be a candidate for future implementation of this technology.

However, many challenges still plague vertical axis wind turbines. Low performance and poor stability threaten the economic viability of VAWTs **[27]**. While these issues continued to be solved, others are turning to even more unconventional designs. In 2011, US patent US7695242 was issued to Howard J. Fuller for a wind turbine based on the Tesla turbine which does not have any blades **[28]**. However, Warren Rice, Professor Emeritus at Arizona State University notes many inefficiencies with using Tesla turbines **[29]**. However, the much lower cost of manufacturing disks rather than blades suggests there may be a use case for wind turbines based on this technology **[30]**.

Part 4: Future

Growth from projects like the North Central Wind Initiative promise growth of wind-powered electricity in the West South-Central region. However, sustained growth will depend on several factors: natural gas prices, governmental incentives like the production tax credit, the compliance of regulatory bodies, competition with solar, and of course the price per megawatt-hour of wind-generated electricity to name a few factors.

Natural gas prices will determine the competitiveness of wind-generated power. Information in 2017 from the U.S. Energy Information Administration predicts that the average over the year price of natural gas will stay relatively constant at around $3 per MMBtu until around 2022 when the price will begin to steadily rise. Real data from 2018 and 2019 show that the average price per MMBtu of natural gas in 2018 was around $3.18, but the 2019 price significantly to $2.56 and continues to trend downward **[31]**. An article from Reuters in August 2019 suggests that this is because as shale oil operations boom in the U.S., natural gas is also extracted, flooding the market with natural gas that outpaces the increasing demand **[32]**. This rapid increase in oil production, spurred on by a price war with OPEC, appeared in January 2020 to be leveling off. As prices rise and production slows, natural gas prices would be expected to rise as well. In a January 2, 2020 article in Reuters, Raoul LeBlanc, an IHS Energy Market Analyst notes “Our view is that rapid growth is kind of over.” **[33]**. However, there is no way to tell for certain when political events will spark price wars. An expected rise in natural gas prices over the next few decades would be good news for wind power as it would mean that wind power is relatively cheaper to natural gas electricity production. However, as will be discussed in Part 5 of this report, a high oil and gas supply appears to be the foreseeable future. **Figure 2** shows the EIA estimate for the price of natural gas until 2050 based on the supply of oil and gas and the price of oil.

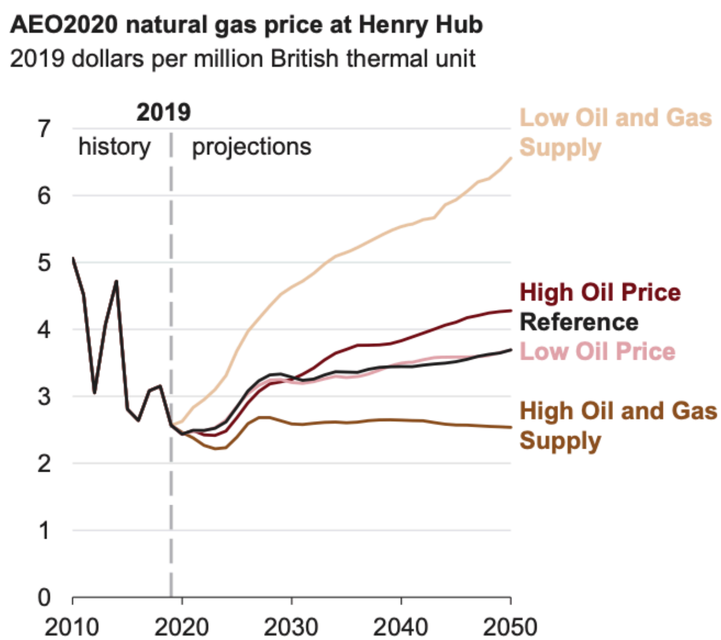

Figure 2: Projected Natural Gas Prices based on Oil and Gas Supply and Oil Price **[31]**

Another large factor affecting the future of wind-generated electricity production is the production tax credit which is currently being phased out. In 2013, the last time the production tax credit was in renewed, companies that start construction before 2017 are eligible for the full 2.3 cents per kilowatt-hour tax credit for their first 10 years of energy production **[34]**. Those beginning construction in 2017 receive 80% of the inflation adjusted tax credit, construction beginning in 2018 receives 60%, and construction beginning in 2019 receive 40%. After that, not tax credit is available. However, on December 20th, under section 127(c) of H.R. 1865, the PTC was extended to allow facilities that begin construction in 2020 to be eligible for 60% of the inflation adjusted tax credit with no tax credit given for construction beginning in 2021 **[15]**.

Continued extensions are possible, which would provide more incentive to develop wind farms. However, in their tax policy statement and their press release following the PTC extension, the American Wind Energy Association (AWEA), while praising the history of the PTC, does not explicitly advocate its renewal **[35]**. Instead, the AWEA advocates a carbon pricing model as seen in their press release urging New York Governor Andrew Cuomo to support a proposal of this type from New York Independent State Operator (NYISO) **[36]**. This model would force electricity producers who burn fossil fuels to pay a price for each ton of carbon dioxide put into the air. The price would be set by the New York Public Service Commission and would benefit renewable energy sources like wind, making the price of wind-power relatively lower compared to carbon dioxide emitting sources **[37]**.

Another obstacle to wind power growth in the region is regulatory hurdles and local pressures. For example, the Windcatcher project was rejected after the Texas Public Utilities Commission rejected SWEPCO's request for a Certificate for Convenience and Necessity (CCN) which is required under Section 37.051(a) of the Public Utility Regulatory Act in order to "provide service to the public" **[38]**. This certificate "states that the public convenience and necessity requires or will require the installation, operation, or extension of the service." This requirement allows opposition to lobby against granting a CCN and thus can shut down projects that require the extension of public utilities. However, an Independent Power Producer (IPP), which "owns or operates facilities for the generation of electricity for use primarily by the public, and that is not an electric utility," is not required to have a CCN and under PURPA, Qualifying Facilities (QFs), which include many wind producers, are guaranteed sale of their electricity to utilities at their avoided cost **[39]**. This may be why in 2018, 85.6% of all wind power produced was from IPPs **[16]**. With regulations like this, while large wind projects from electric utility companies such as AEP's planned North Central Wind Initiative are sure to continue, most growth in wind-generated electricity is likely to be from Independent Power Producers.

The price of solar, which was initially much higher than wind energy, has dropped significantly and threatens to be comparable in price to wind energy in the future at utility scale **[40]**. Such competition is already seeing its affects. In 2018, the City of Fayetteville announced its plan to operate on 100% renewable energy by 2030 and a deal with Ozark Natural Resources to build a solar farm will bring the renewable energy percentage in Fayetteville from 16% to 72% **[41]**. Additionally, solar is available in regions that wind power is less efficient such as Arkansas and Louisiana. Regions like West Texas which are rich in both wind and solar energy could feel the effects of low solar prices if they continue to drop and pass wind power. However, with the cost of wind energy also dr
opping, this does not seem to threaten wind-rich areas in the near future.

The price of wind generated electricity varies based on what technology is being used (i.e. what hub height), where the wind farm is located, and the price of the land that the turbine is built, to name a few factors. However, in general, the price of wind power has declined dramatically over the years. The EIA estimated in 2019 that the unweighted average levelized cost of energy for onshore wind power without tax credits is \$55.9/MWh, compared to the \$46.3/MWh of conventional combined cycle (natural gas) **[42]**.

Arkansas's capacity for wind-generated electricity is minimal and likely not cost effective. At a minimum, Class 3 winds are "needed for a commercially viable project." **[43]**. The land in Arkansas with this minimum level of winds is minimal. Additionally, in 2015 Frank Kelly, the chairman of the Arkansas Renewable Energy Association advised against attempts to build commercial wind power plants in Arkansas, suggesting solar investments instead **[44]**.

While building wind turbines in Arkansas is unlikely to be effective, companies can purchase wind-generated electricity from the region to support wind power. With 20-year contracts, the Arkansas Electric Cooperative Corporation (AECC) bought 150 MW of wind-generated electricity from the Origin Wind Energy Project in Oklahoma **[45]**, 51 MW from the Flat Ridge 2 Wind Farm in Kansas **[46]**, and 100 MW from the Wildhorse Mountain Wind Farm in Oklahoma **[47]**.

Aside from the sustainable environmental benefit of purchasing wind power, which itself should not be discounted, long-term purchase agreements can set prices and thus mitigate volatility in electricity prices from fluctuating natural gas prices. Additionally, because wind prices fell 67% from 2009 to 2017, it is the cheapest renewable energy source **[40]**. This is why 4,203 MW of wind energy were purchased in 2018 in the form of power purchase agreements (PPAs) by non-utility customers **[48]**. Large companies such as Walmart, Amazon, Apple Facebook, and ExxonMobil have entered PPAs in recent years.

PPAs mitigate variability in prices and while variability in wind power is not as drastic as solar, wind power varies with wind speeds and thus varies throughout the day and year. In fact, different regions of the United States have different peaks in wind power production. For example, on the West Coast of the United States, wind power production peaks in the summer months while in the Center of the United States which includes Oklahoma and Texas, production dips in the summer and peaks in the spring and fall **[49]**. According to a 2008 report from the National Renewable Energy Laboratory, wind production throughout the day is fairly consistent with "91.4% of all hourly changes are less than 300 MW in magnitude (roughly 10% of the wind capacity), and 99.2% of the hourly changes are less than 600 MW in magnitude (20% of the wind capacity)" **[50]**.

Part 5: Adjusted Future, Post-COVID-19 Economy

The recent COVID-19 pandemic has already had drastic impacts on several industries and wind-generated electricity is not likely to be an exception. As previously mentioned, a large factor on the growth of wind-generated electricity is the price of natural gas which itself has been impacted by recent events. The demand for oil is projected to drop to its lowest point since 1995 at the time of this writing because of lockdowns across the globe **[51]**. On the natural gas side, the EIA estimated on April 7, 2020 that the residential consumption of natural gas will fall by 5.8% compared to "the 2019 average, primarily because of warmer-than-normal weather in the first quarter," while the commercial consumption is expected to fall by 7.1% because of "warm weather and the slowing economy." **[52]**. The industrial natural gas consumption is expected to average the same as 2019, but this projection is down from the previously anticipated 6.5% growth. Additionally, the coinciding price war between Russia and Saudi Arabia increased supply of oil, although an agreement was reached with other OPEC+ countries to cut production by 9.7 million barrels per day for the next two months **[53]**. The falling price of natural gas can be seen in **Figure 3** which shows the decline of natural gas prices below their already low price since January 1, 2020.

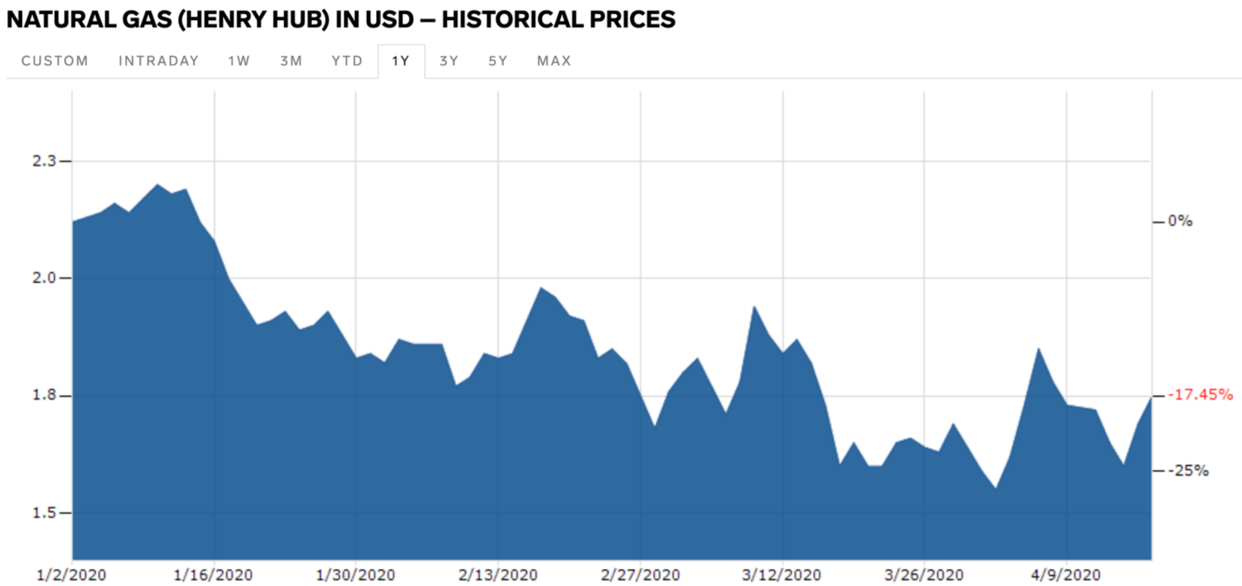

Figure 3: Natural Gas Prices from January 1, 2020 - April 20, 2020 **[54]**

These factors, a slowing economy, warm weather, and a price war, combine so that not only does supply increase, driving the price of natural gas down, but the demand drops which further decreases the price. The longer-term price is not likely to increase either. A worldwide economic depression may lead to desperate attempts by oil producing countries like Russia to increase production while other countries follow suite leading to more spikes in oil production. Commercial, residential, and even industrial consumption is likely to drop or slow because of an economic downturn as well.

Low natural gas prices for the foreseeable future makes new wind resources less attractive for utility companies. Additionally, as natural gas prices stay low, the capacity and number of natural gas fired power plants is likely to increase which may cause further benefits for natural gas like investment into efficiencies and technological improvements. Future electricity generating projects must then compare starting new wind projects to the cost of merely expanding the capacity of natural gas-powered plants.

While this condition seems to be the case, these projection figures assume a moderate economic growth. The EIA also has separate projections for low economic growth. Because a global pandemic seems likely to cause economic trouble, I combined these two projections into a single post-COVID-19 projection that is seen in **Figure 4**.

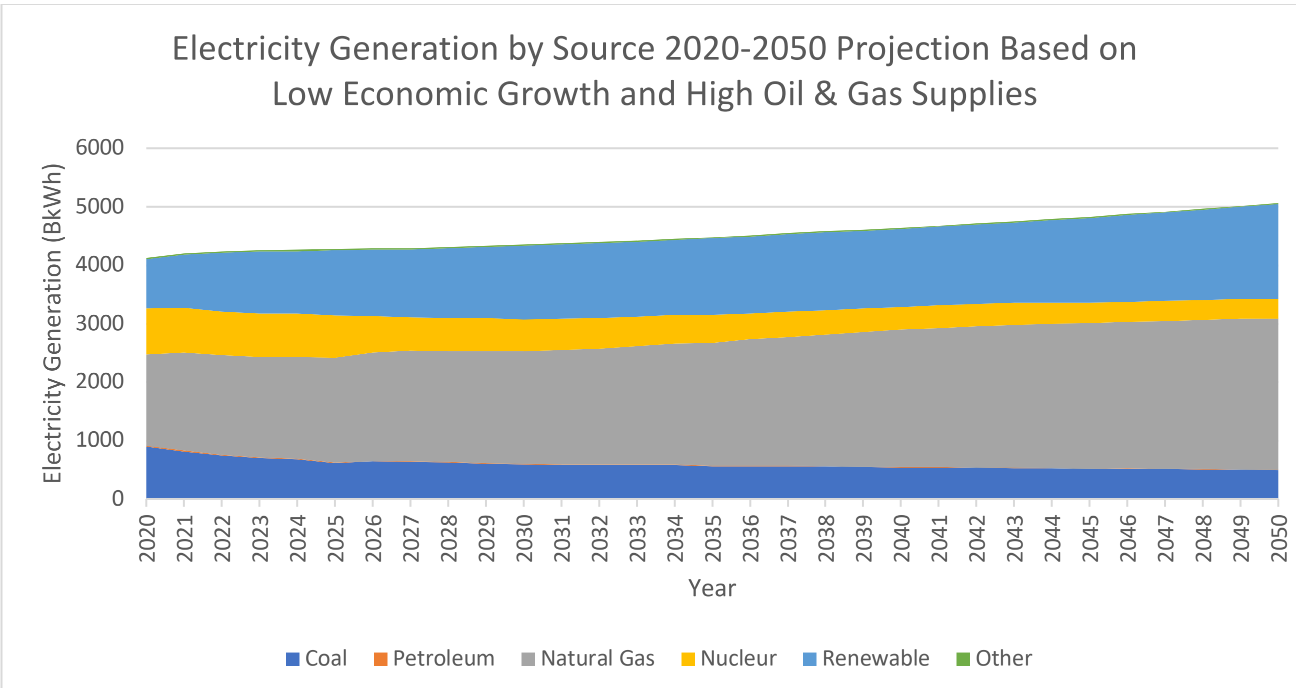

Figure 4: Electricity Generation by Source 2020-2050 Projection Based on Low Economic Growth and High Oil & Gas Supplies

To obtain this projection, I took the EIA 2020-2050 Reference Case (REF) electricity generation by source and determined the percent of total generation per source per year (TG) **[55]**. I performed the same process for the EIA 2020-2050 Low Economic Growth projections and the EIA 2020-2050 High Oil & Gas Supply projections. I subtracted the Low Economic Growth (LEG) percent of total generation per source per year projections from the Reference

Case percent of total generation per source per year projections to obtain what I refer to as the low growth correction factor (LGCF) seen in **Equation 1**.

$$LGCF = \% \frac{\frac{TG_{REF}}{source}}{year} - \% \frac{\frac{TG_{LEG}}{source}}{year}$$

Equation 1: Low Growth Correction Factor (LGCF)

The LGCF is subtracted from the High Oil & Gas Supply (HSO&G) percent of total generation per source per year projections to obtain a breakdown of the percentage of electricity generated (EG) per source per year with a high supply of oil and gas adjusted for low economic growth, or the Adjusted High Supply (AHS), which can be seen in **Equation 2**.

$$\% \frac{\frac{EG_{AHS}}{source}}{year} = \% \frac{\frac{TG_{HSO\&G}}{source}}{year} - LGCF$$

Equation 2: Percent Electricity Generated per Source per Year with a High Supply of Oil & Gas Adjusted for Low Economic Growth

These values are multiplied by the projected total electricity generated per year for the low economic growth model as show in **Equation 3** to obtain the final projection seen in **Figure 4**.

$$\frac{\frac{EG_{AHS}}{source}}{year} = \% \frac{\frac{EG_{AHS}}{source}}{year} * \frac{TG_{LEG}}{year}$$

Equation 3: Electricity Generated per Source per Year with a High Supply of Oil & Gas Adjusted for Low Economic Growth

Figure 5 expands this projection by breaking up the projected renewable energy into wind generated and other renewable sources.

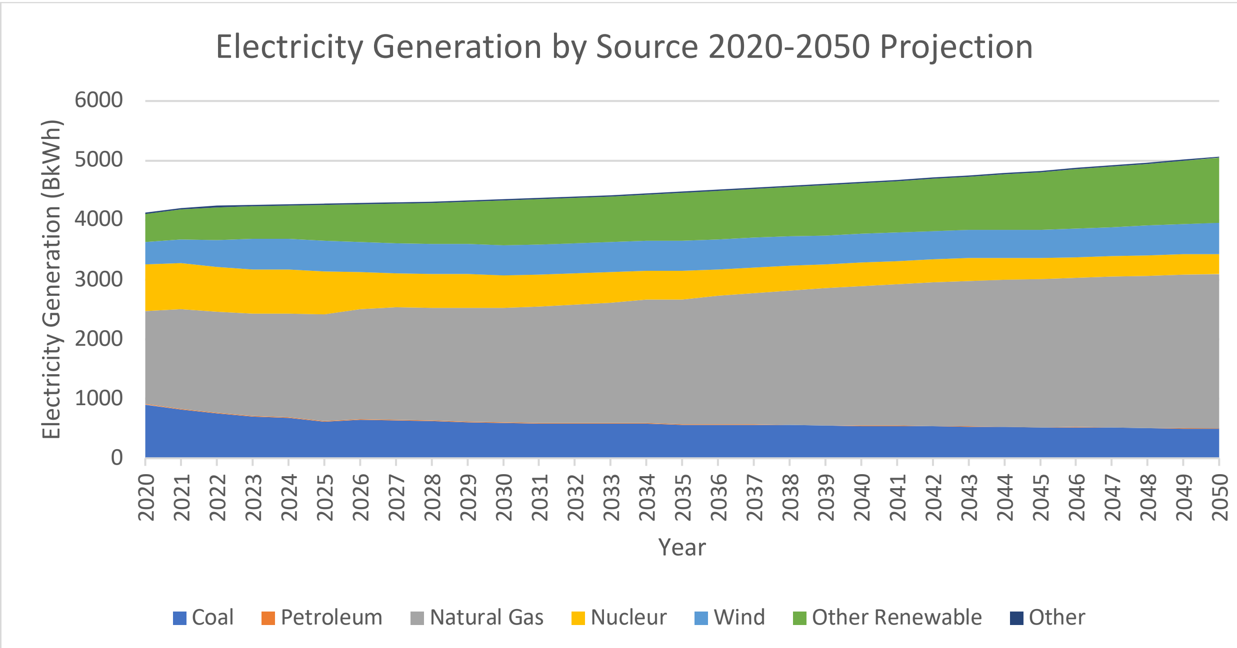

Figure 5: Electricity Generation by Source 2020-2050 Projection

The EIA 2020-2050 renewable energy electricity generation (REG) projections by source were used to find the projected wind-generated electricity as a percent of renewable energy **[56]**. This was multiplied by the projected renewable energy in **Figure 3** to obtain wind energy projections for 2020-2050 seen in **Equation 4**.

$$Wind\ Energy\ Projections = \frac{TG_{Wind}}{TG_{REG}} * \frac{\frac{EG_{AHS}}{REG}}{year}$$

Equation 4: Wind Generated Electricity Projections

Other renewable energy generation projections were obtained by subtracting the fraction of wind energy generated per total renewable electricity generated from 1 seen in **Equation 5**.

$$Other\ Renewable\ Energy\ Projections = \left(1 - \frac{TG_{Wind}}{TG_{REG}}\right) * \frac{\frac{EG_{AHS}}{REG}}{year}$$

Equation 5: Other Renewable Generated Electricity Projections

Part 6: Conclusion

Historically, wind-generated electricity has been the largest renewable energy sources in the United States. Wind-rich regions like Oklahoma and Texas have fueled growth and sold that electricity to electric utilities located in wind-poor states like Arkansas in the form of Power Purchase Agreements. Future technologies such as Vertical Axis Wind Turbines, small wind turbines, and Tesla turbines designed to generate electricity from wind show promise in unlocking more expensive wind resources in regions like Northwest Arkansas by mitigating concerns about low wind speeds and noise. However, more factors than just feasibility influence the growth of wind power. Governmental policies such as ending the Production Tax Credit and decreasing cost of solar power threaten wind power's growth. More than these factors is the low price of natural gas for the foreseeable future. With an already low cost of natural gas being exasperated by an oil price war increasing production and a global pandemic decreasing demand, natural gas is expected to stay low in the short and long run. This means further investment in natural gas generated electricity and delays in investment in wind power.

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