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When the Wind Blows: An Evaluation of Key Factors that Enabled the Proliferation of Wind Energy Generation in the United States Through 2016

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WHEN THE WIND BLOWS: AN EVALUATION OF KEY FACTORS THAT ENABLED
THE PROLIFERATION OF WIND ENERGY GENERATION IN THE UNITED STATES
THROUGH 2016

by

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ABSTRACT

WHEN THE WIND BLOWS: AN EVALUATION OF KEY FACTORS THAT ENABLED THE PROLIFERATION OF WIND ENERGY GENERATION IN THE UNITED STATES THROUGH 2016

Mary Sodini Bell
Old Dominion University, 2018
Director: Dr. Peter Schulman

Increasing CO₂ emissions have led to extreme weather phenomena labeled as climate change. Energy consumption and the burning of fossil fuels are primary contributors to climate change, which necessitates finding ways to decrease fossil fuel consumption critical to preserving the planet while helping nations reduce dependence on costly fossil fuels. Renewable energy is one part of the solution to reducing CO₂ emissions. Wind energy is the fastest growing form of renewable energy across the world and within the U.S., but the key factors that enabled the U.S. wind industry to grow from zero installed capacity at the beginning of 1981 to enough capacity to power 25 million average U.S. homes by the end of 2016 remain unclear. This dissertation examines the wind industry growth and identifies the factors of public opinion, presidential leadership, state incentives and mandates, technological developments, and fossil fuel prices as crucial to wind energy development in the U.S.

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This dissertation is dedicated to my son, Jaxson, who was four years old when I started my Ph.D. program. He doesn't remember a time when I wasn't working and going to school. He has loved and supported me through this entire process. Nobody is prouder of my hard work, perseverance, and accomplishment than him.

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Words do not suffice in explaining how much my director and mentor, Dr. Steve Yetiv, has meant in guiding me through this challenging process. His brilliance and dedication to the field of education was sometimes hidden behind a façade of light-heartedness. In the final weeks leading up to completion of this project, Dr. Yetiv suffered from severe health issues that led to his passing. It is with incredible sadness and gratitude that I write my thoughts about him and recognize how much he has fostered my academic growth. Without his presence in my life for these last five and a half years, I would be a completely different type of academic. I am grateful to his dedication and am thankful to him for who I have become.

In companion to that grief in losing Dr. Yetiv much too early is my sincerest gratitude to the director of the Graduate Program for International Studies (GPIS), Dr. Regina Karp, for courageously making the difficult decision that propelled me across the finish line of this work. Following suit, Dr. Peter Schulman voluntarily stepped up to serve as my dissertation director at the most difficult time in this process. Dr. Austin Jersild filled out the committee only two weeks before my defense. Dr. Glen Sussman spent hours assessing and improving my work while also suggesting future options for study and publication. The complete dedication of my committee and the program director is apparent in all they do. Their willingness to volunteer their time to help me is a true testament not only to the program, but especially to Dr. Steve Yetiv and how much everyone supported and valued his work. Their efforts to further the education of all students goes beyond any expectation.

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I could not have done any of this without support from my family. My mother, Jimmie Sue Hobert, spent hours reading and editing my work. She was my eyes when my eyes became too bleary to see. She was my logic, when my logic had taken a break. I am thankful to my brother, Charlie Bell, who personifies the quality of grace. The rest of my family cheered me on and celebrated with me through every achievement, big or small. I come from a very, very large family and it would take an entire dissertation to properly acknowledge how much they have meant to me.

My church family has been with me every day. They have kept me sane and helped me continually build a stronger relationship with God. They helped with childcare when I was in a bind. They fed me dinner when I was hungry. They prayed over me relentlessly and the support of their faith kept me moving forward through the valleys and the deserts.

It is due to the grace of God and through the will of God that I have been able to continue to accomplish what He has wanted me to accomplish. Without Him, this accomplishment would be hollow. I close with this verse from Galatians 6:9 (New International Version) – “Let us not become weary in doing good, for at the proper time we will reap a harvest if we do not give up.” I did not give up.

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LIST OF ABBREVIATIONS

ARRA	American Recovery and Reinvestment Act of 2009
ATRA	American Taxpayer Relief Act of 2012
AWEA	American Wind Energy Association
BTUs	British Thermal Units
CAA	Clean Air Act
CAFÉ	Corporate Average Fuel Economy Standards
CCAP	Climate Change Action Plan
CCRI	Climate Change Research Initiative
CO ₂	Carbon Dioxide
COP	UNFCCC Conference of the Parties
COP15	15 th Session of the UNFCCC Conference of the Parties in Copenhagen
COP21	21 st Session of the UNFCCC Conference of the Parties in Paris
DDT	Dichloro-diphenyl-trichloroethane
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EES	Electrical Energy Storage
EIA	U.S. Energy Information Administration
EISA	Energy Independence and Security Act of 2007
EPA	U.S. Environmental Protection Agency
ETA	Energy Tax Act of 1978
FY	Fiscal Year
GDP	Gross Domestic Product
GE	General Electric
GHG	Greenhouse Gas
GW	Gigawatt (a billion watts)
IEA	International Energy Agency
ISIS	Islamic State of Iraq and Syria
ITC	Investment Tax Credit
KW	Kilowatt (a thousand watts)
LCOE	Levelized Cost of Energy
MACRS	Modified Accelerated Capital-Recovery System
MW	Megawatt (a million watts)
MTC	Advanced Energy Manufacturing Tax Credit
NAAQS	National Ambient Air Quality Standards
NASA	National Aeronautics and Space Administration
NCCTI	National Climate Change Technology Initiative
NDCs	National Determined Contributions
NEA	National Energy Act of 1978
NOAA	National Oceanic and Atmospheric Administration
OECD	Organization of Economic Cooperation and Development
OPEC	Organization of Petroleum Exporting Countries
PHES	Pumped Hydroelectric Energy Storage

ppm	parts per million
PTC	Production Tax Credit
PURPA	Public Utilities Regulatory Policies Act of 1978
RES	Renewable Energy Standard
RPS	Renewable Portfolio Standard
TIPA	Tax Increase Prevention Act of 2014
UNFCC	United Nations Framework Convention on Climate Change
USDA	U.S. Department of Agriculture

CHAPTER I

INTRODUCTION

Professor Garret Hardin published an article in 1968 titled “The Tragedy of the Commons” in which he describes society in terms of personal gain prioritized over public good. One area in which he applies the idea of the *tragedy of the commons* is how “the rational man” accepts pollution as “his share of the cost of the wastes he discharges into the commons is less than the cost of purifying his wastes before releasing them.”¹ Hardin’s theory explains why individuals and corporations do not self-regulate the amount they pollute nor they will strive to find alternative energy sources that create less pollution unless they are forced to do so. Unless there is a tax or a method to punish the behavior of polluting, the current system will not change. Therein lies the tragedy. Everyone suffers while trying to maximize their profit and minimize their expenditures; short-term gain overrides long-term consequences.

The dynamic of avoidable suffering is changing slowly as the evidence is mounting that a *tragedy of the commons* unfolds in the upper atmosphere. Only a few nations produce most of the carbon dioxide (CO₂) emissions globally, as represented in Figure 1. Given their high consumption of energy, China and the U.S. emit almost half of all global greenhouse gas (GHG) emissions harmful to our environment.²

¹ Garrett Hardin, "The Tragedy of the Commons," *Science* 162, no. 3859 (1968), 1243-1248.

² Joanna I. Lewis, *Green Innovation in China: China’s Wind Power Industry and the Global Transition to a Low-Carbon Economy* (New York: Columbia University Press, 2013), 169.

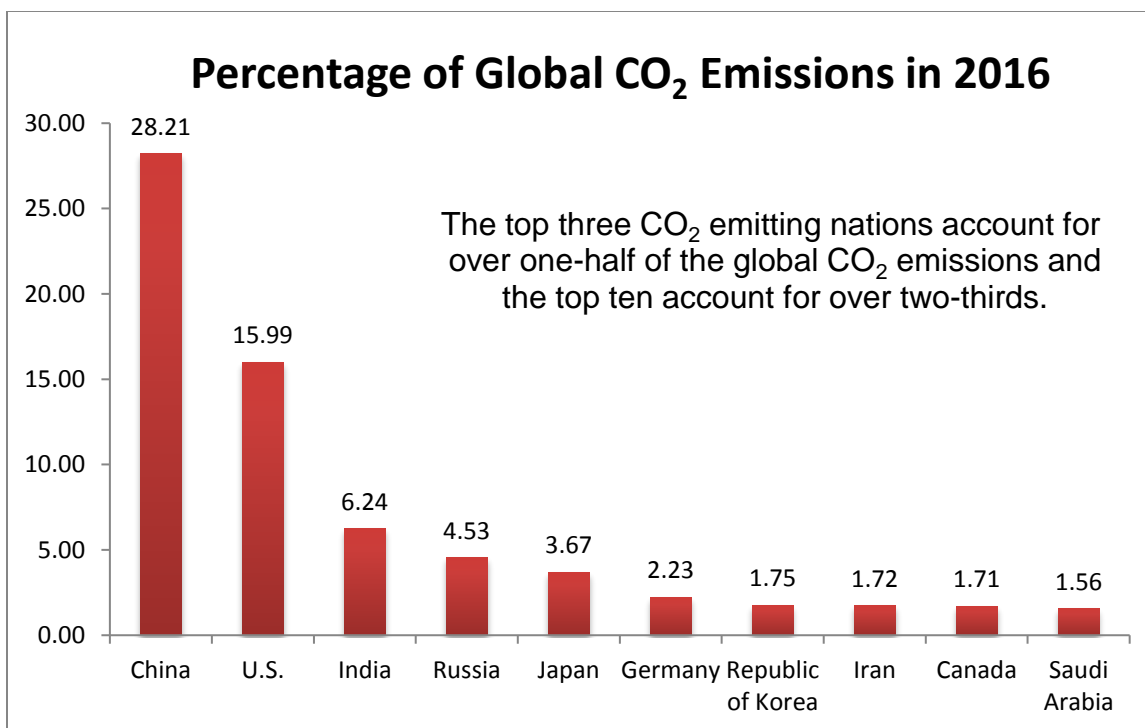


Figure 1 - Percentage of Global CO₂ Emissions in 2016³

Revised from: Statista

Yet, hope remains in the exciting ways people, corporations, and nations are combatting the *tragedy of the commons*. For example, the U.S. began reducing its environmentally harmful CO₂ emissions in 2000.⁴ This is important because CO₂ emissions have been proven to raise the baseline temperature of the earth and that

³ Figure created using data source: "Largest Producers of CO₂ Emissions Worldwide in 2016, Based on their Share of Global CO₂ Emissions," Statista, last modified 2017, accessed July 17, 2017, <https://www.statista.com/statistics/271748/the-largest-emitters-of-co2-in-the-world/>.

⁴ Nate Aden, "The Roads to Decoupling: 21 Countries Are Reducing Carbon Emissions While Growing GDP," World Research Institute, April 6, 2016, accessed July 17, 2017, <http://www.wri.org/blog/2016/04/roads-decoupling-21-countries-are-reducing-carbon-emissions-while-growing-gdp>.

temperature increase has led to increasingly extreme weather as the global climate changes.⁵

Awareness of the tragic changes is on the rise, and the public largely supports measures to reduce the detrimental effects humans are causing to the environment. The development and growth in the use of renewable energy in the U.S. and across the world is encouraging and indicates that nations understand the value, both environmentally and politically, in diversifying their sources of energy. One of the largest growth industries in renewable energy in recent years has been in wind power, utilized to create several different forms of power. This dissertation aims at explaining why the use of wind power in the U.S. has increased dramatically in the last 10 years with a specific focus on electricity created from wind. The unit of analysis for this study is electricity produced from wind in kilowatts (one thousand watts), megawatts (one million watts), or gigawatts (one billion watts).

The amount of electricity created in the U.S. from wind by the end of 2016 was 82,143 megawatts, enough to power 25 million homes.⁶ In just 35 years, the U.S. effectively went from zero wind energy to over 82,143 megawatts produced and consumed annually. Other renewable sources have been utilized for years, but wind energy has experienced the largest growth in the shortest time. Figure 2 provides a good visualization of the dramatic increase in wind energy as compared to other

⁵ "Climate Change Indicators: U.S. and Global Temperature," U.S. Environmental Protection Agency, last modified September 2017, accessed September 13, 2017, <http://www3.epa.gov/climatechange/science/indicators/weather-climate/temperature.html>.

⁶ "Wind Energy Facts at a Glance," American Wind Energy Association, last modified February 2017, accessed July 2, 2017, <http://www.awea.org/wind-energy-facts-at-a-glance>.

renewable sources over the last 10 years. Both hydropower and geothermal power have been produced at the same relative levels while solar power and wind power have been steadily increasing. Historically, hydropower has been the largest renewable energy source in the U.S., but by 2020 wind energy growth is projected to eclipse the amount of electricity consumed from hydropower.⁷

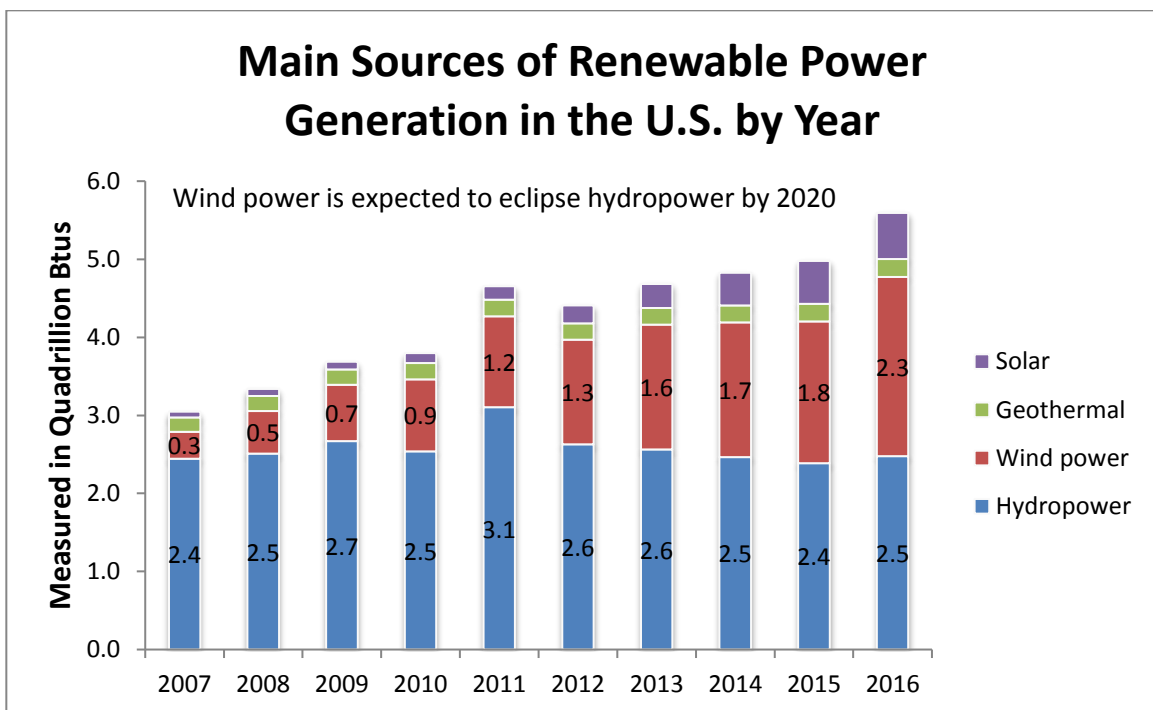


Figure 2 - Electricity Generated from Renewable Power in the U.S.⁸

Data Source: U.S. Energy Information Administration

⁷ "Renewable and Carbon Dioxide Emissions," U.S. Energy Information Administration, last modified July 11, 2017, accessed July 17, 2017, https://www.eia.gov/outlooks/steo/report/renew_co2.cfm.

⁸ Figure created using data source: "Short-Term Energy Outlook," U.S. Energy Information Administration, last modified September 12, 2017, accessed September 13, 2017, <https://www.eia.gov/outlooks/steo/>.

In the U.S., private investors build and produce wind energy and sell it to utility companies. The following investors have created the five largest wind farms in the U.S.: Terra-Gen Power (U.S.), Caithness Energy (U.S.), E.ON Climate and Renewables (Germany), and NextEra Energy Resources (U.S.).⁹ The list of investors also includes big names such as BP and Dominion Resources.¹⁰ All of these companies are highly successful and it is logical to assume that they will continue to pursue investments that give them good rates of return.

Companies in 41 of the 50 U.S. states have developed wind energy. Companies have not invested in all 50 states due to many factors that will be explained in Chapter 6 on State Incentives and Mandates. Even with the extensive growth, companies have only developed a small fraction of the U.S. wind potential. The American Wind Energy Association (AWEA) estimates that there are 10 million megawatts of untapped land-based wind energy. If exploited fully, onshore sourcing could provide all electricity in the U.S. 10 times over.¹¹ Though wind power has incredible room for growth in the U.S., it also has a power density problem. Given today's technology, it takes large amounts of acreage to build wind farms. The U.S. has unused acreage and public opinion mostly supports increases in wind energy, but wind energy is only one aspect necessary to

⁹ These farms are located in California, Texas and Oklahoma. See: "Top 10 Biggest Wind Farms," Power Technology, last modified February, accessed September 7, 2017, <http://www.power-technology.com/features/feature-biggest-wind-farms-in-the-world-texas/>.

¹⁰ Ibid.

¹¹ "Get the Facts," American Wind Energy Association, last modified January 2016, accessed January 3, 2016, <http://www.awea.org/Resources/Content.aspx?ItemNumber=5059>.

create a more balanced energy portfolio to address climate change and reduce the U.S. dependence on fossil fuels.

Methodology and Approach

This dissertation aims at explaining why the use of wind power in the U.S. has increased dramatically in the last 10 years. This study assumes that investors in wind energy make rational financial decisions seeking a positive return on their investment. Due to the nature of this study, using the case study methodology is the best way to determine what conditions and processes drove the public, government, and energy companies to invest in wind energy.

Case study methods are defined as including both comparisons of small numbers of cases (small-*n*) or within-case analysis of a single case.¹² A single case will be used for this project, the U.S., but it will be broken down into two time frames for comparison. In general, observation can include analysis with a large-*n* (many cases to examine) or observation using case-study analysis. Since the development of wind energy in the U.S. is unique and inherently a single-*n*, a case study methodology is the only logical option for this type of work. Due to the possibility of selection bias of cases, or if there is an over-generalization of results, there is a pitfall in using the case study methodology.¹³ However, case study methodology is appropriate for this particular study

¹² Alexander L. George and Andrew Bennett, *Case Studies and Theory Development in the Social Sciences*. (Cambridge, Massachusetts: MIT Press, 2005), 7-10.

¹³ George and Bennett, 80.

because it allows for conceptual validity and the exploration of causal mechanisms.¹⁴ The case study methodology facilitates controlled comparisons and process tracing, which is how the case study methodology is used in this project.¹⁵ Controlled comparisons allow the examiner to infer hypotheses from contrasts or similarities, specifically where the cases resemble each other in every aspect except one.¹⁶ Since the comparison will occur in two distinct time frames from a single U.S. case study, the controlled comparisons of wind development before 2007, and from 2007 through 2016, employ a before/after approach to examine and compare the two periods.

Study of the case uses quantitative indicators as well as a qualitative analysis. The work will employ the historical research method to gain an objective perspective on the development of wind power in the U.S. over the last 35 years to determine causes, effects, and trends to explain the present state and even anticipate future events. Scholars apply the comparative method either cross-nationally or diachronically. The cross-national approach involves a comparison of entirely separate but similar cases, while the diachronic approach involves analysis of one case through time. The advantage of conducting a comparison of a single nation while looking at two distinct timeframes is that inter-unit differences can be held constant. A multiple nation case study has to consider many more factors such as levels of industrialization, cultural traditions, and type of government structure.¹⁷ This dissertation uses a diachronic

¹⁴ Ibid, 19-21.

¹⁵ Stephen Van Evera, *Guide to Methods for Students for Political Science* (Ithaca and London: Cornell University Press, 1997), 68-70.

¹⁶ Van Evera, 68-69; George and Bennett, 151.

¹⁷ Arend Lijphart, "Comparative Politics and the Comparative Method," *The American Political Science Review* 65, no. 3 (1971), 682-693.

approach. The diachronic application of the comparative method offers a better solution to the problem of controlling variables than do cross-national studies because it involves more constants and fewer variables. That is, fewer variables change over time alone than they do over both time and area. This study compares the same variable, wind power development in the U.S., before 2007 and from 2007 through 2016.

The year 2007 is important methodologically because wind energy began to increase rapidly during the time period. Total installed wind capacity at the end of 2006 was 11,450 gigawatts. That amount increased by nearly 50 percent in 2007 with a total installed capacity of 16,701 gigawatts in 2007, which is a growth of 5,251 gigawatts in one year.¹⁸ The average wind energy growth over the study's 10-year span is just over 7,000 gigawatts per year, and makes the 2007 period a distinctive, important methodological period. It helps to see this growth depicted on a map. Map 1 shows that there was only one wind farm in the U.S. in 1981. Map 2 shows the growth that occurred from 1981 through 2006 with an installed wind energy capacity of 11,450 gigawatts in those 25 years. Map 3 highlights the growth in the number of wind farms and installed wind energy capacity created by over 52,500 utility level wind turbines installed by the end of 2016.¹⁹ There was a 618 percent increase in installed wind

¹⁸ See: "Electric Power Monthly," U.S. Energy Information Administration, last modified September 26, 2017, accessed October 7, 2017, [https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_1_01_a](https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_1_01_a;).; "Electric Power Monthly Back Issues," U.S. Energy Information Administration, last modified January 1, 2011, accessed October 7, 2017, <https://www.eia.gov/electricity/monthly/backissues.html>.

¹⁹ "Wind Energy Facts at a Glance."

energy capacity from the end of 2006 to the end of 2016 with a total installed wind capacity of 82,183 gigawatts.²⁰



Map 1 - U.S. Wind Farms in 1981²¹
Source: American Wind Energy Association

²⁰ "Electric Power Monthly."

²¹ "U.S. Wind Industry Map," American Wind Energy Association, last modified January 1, 2016, accessed September 13, 2017.



Map 2 - U.S. Wind Farms at the Beginning of 2007²²
 Source: American Wind Energy Association



Map 3 - U.S. Wind Farms at the End of 2016²³
 Source: American Wind Energy Association

A method for linking possible causes and observed outcomes within and between the two periods is necessary to accomplish the research goals. Process

²² Ibid.

²³ Ibid.

tracing is the method that attempts to find the link between possible causes and observed outcomes.²⁴ By working backwards, tracing the causal process that produces the outcome, the researcher can determine the prime cause of a specific outcome.²⁵ Though it is unlikely that a single prime cause initiated the substantial increase in wind energy development, the method will help identify the confluence of reasons and factors for wind's substantial growth in the last 10 years. This dissertation explores the following five hypotheses before 2007 and from 2007 through 2016.

The first hypothesis for examination is the American public's understanding of the ramifications of climate change and whether it causally relates to their support for wind power innovations and government incentives that led to an increase in wind power production. The hypothesis suggests that the public is more willing to accept some additional costs for wind development, because they are concerned about the negative effects of increasing CO₂ emissions and a lack of resource diversity. The additional costs can be measured in multiple ways, including marginal increases in the cost of electricity (which would be largely transparent to the consumer), increases in the amount of wildlife killed by wind turbines, and changes to landscapes because of the proliferation of wind farms. Public opinion is measured by using polling data on the importance of climate change as a threat to national security and the public's propensity to support development of renewable energy sources. Data on opinions about climate change and propensity to support renewable energy development was not collected by the same independent source at consistent, regular intervals over the last 35 years,

²⁴ George and Bennett, 5.

²⁵ Van Evera, 70.

which limits the study's accuracy but not its overall cogency. Despite some of the limitations, using public opinion as an independent variable is important because public opinion has the power to drive increases in innovation through both direct and indirect support, and support for renewable energy-friendly national policy makes it more financially probable that wind power innovations will be utilized.

The second hypothesis assumes that presidential leadership and policies make a difference in the amount of wind energy proliferation. The hypothesis posits that the perspectives and opinions of the president affect policy and public opinion, and that the amount of emphasis the president places on climate change and the need for energy diversity influences outcomes. After providing a brief policy overview of recent U.S. presidents, there will be a more detailed comparison of the 43rd and 44th presidents, George W. Bush (2001-2009) and Barrack Obama (2009-2017). Bush and Obama serve as the best presidential case study for a multitude of reasons, including the fact that they have similar durations of influence: they both served two terms. And their presidencies coincide with the start and surge in wind energy growth. The close alignment of variables allows for the comparison of their ability to shape policy over eight years and enables the tracing of production lags from their implemented policies. This case touches on, but does not complete an in-depth study of, political party affiliation and the difference that may have made in policy outcomes.

The third hypothesis involves an examination of state policy and mandates supporting wind energy growth. The hypothesis suggests that the more state governments support and promote wind energy development in terms of their policies and incentives, the more energy companies will invest in wind energy. Several key

states within the case created the most wind energy, and the uniqueness of those states will be evaluated to determine why the states experienced such a significant increase in wind energy infrastructure. A more in depth look at several key states before 2007 and from 2007 through 2016 helps explain why every state is different and why some have added significant amounts of wind energy into their electrical grid systems.

The fourth hypothesis reviews advances in wind technology to help explain why wind power in the U.S. has increased significantly in the last 10 years. As technology improves it is easier for investors to build wind farms that function more efficiently and effectively.²⁶ The more efficient and effective a wind farm is the more electricity it produces, in turn the more energy the producing companies can sell to utility companies, and consequently the more return investors receive on their investment. Examining a few key technological improvements helps explain the wind energy boom in the U.S. and tracing of the causes and effects.

The fifth hypothesis posits that external energy factors, such as changes in fossil fuel prices of oil, coal, and natural gas, help explain why wind power in the U.S. increased significantly in the last 10 years. It is logical to assume that as oil and/or natural gas prices increase, wind energy becomes more attractive to the public and investors because it is widely accepted that the public does not want to waste money.

By comparing these five hypotheses before 2007 and from 2007 through 2016, this dissertation compares how public support increased, how presidential leadership fueled change, how individual states took different approaches, how technology

²⁶ "Next Generation Wind Technology," U.S. Department of Energy, last modified Summer 2017, accessed October 25, 2017, <https://energy.gov/eere/next-generation-wind-technology>.

improved, yet still faces, many challenges, and how fossil fuel price fluctuations affected wind energy growth in those two distinct time frames.

Contribution to the Literature

Although there are articles written on each of these topics independently,²⁷ there is not a single work that compares each of these areas while seeking to determine their collective effect on wind industry growth. This work builds a holistic view by including multiple factors that affect wind energy growth. Inherent in understanding this growth is having an understanding of the interrelated concepts and causes.

First, this work is a diachronic case study comparing wind energy growth in the U.S. before 2007 and from 2007 through 2016. The inclusion of time as a variable elevates currently available analysis on the growth in wind energy that does not use the diachronic approach because it recognizes time as an intrinsic variable to understanding change.

Second, this work explores how presidential leadership affected policies and attitudes towards promoting the increased production and use of renewable energy.

²⁷ See: Robert S. Erikson, "Constituency Opinion and Congressional Behavior: A Reexamination of the Miller-Stokes Representation Data," *American Journal of Political Science* 22, no. 3 (August, 1978), 511-535.; Lori Bird et al., "Policies and Market Factors Driving Wind Power Development in the United States," *Energy Policy* 33, no. 11 (July, 2005), 1397-1407.; Joel Darmstadter, *The Economic and Policy Setting of Renewable Energy: Where do Things Stand?* (Washington D.C.: Resources For the Future,[2003]); "Wind Turbine Technology Played Key Role in Wind Energy's Record-Breaking Growth and Cost Decline," American Wind Energy Association, last modified March 14, 2014, accessed September 20, 2017, <https://www.awea.org/MediaCenter/pressrelease.aspx?ItemNumber=6218>.

Though earlier presidents set some conditions that allowed renewable energy to grow, this work will focus on the presidential leadership of George W. Bush and Barack Obama. President Bush's terms of office were from 2001-2009, and President Obama's terms of office were from 2009-2017. It becomes apparent that their terms of office do not fit perfectly into the years best suited to a diachronic analysis of wind energy growth (up to 2007 and from 2007 through 2016), but it is still possible to conduct a comparative analysis of how their leadership affected wind energy growth while they were in office.

The current literature does cover, in articles, U.S. wind energy policy, and the articles cover the promises and perils of wind turbines,²⁸ offshore wind policies,²⁹ national policies,³⁰ state mandates,³¹ and mitigating the negative impacts of wind

²⁸ See: "How Effective are US Renewable Power Policies?" The Energy Collective, accessed December 23, 2015, <http://www.theenergycollective.com/jemillerep/311406/how-effective-are-us-renewable-power-policies.>; Johannes Mauritzen, "Now Or Later? Trading Wind Power Closer to Real-Time: How Poorly Designed Subsidies can Lead to Higher Balancing Costs," *Energy Journal* 36, no. 4 (10, 2015): 149-164; Derek Bell et al., "Re-Visiting the 'social Gap': Public Opinion and Relations of Power in the Local Politics of Wind Energy," *Environmental Politics* 22, no. 1 (February, 2013), 115.

²⁹ See: Benjamin Fox, "The Offshore Grid: The Future of America's Offshore Wind Energy Potential," *Ecology Law Quarterly* 42, no. 3 (08, 2015), 651-698.; Frank Gottron, "Off-Shore Energy Development Technologies," *Congressional Research Service: Report* (05/23, 2017), 18-19.; Katherine A. Roek, "Offshore Wind Energy in the United States: A Legal and Policy Patchwork," *Natural Resources & Environment* 25, no. 4 (Spring 2011, 2011), 24-28.

³⁰ See: Michael J. Berry, Frank N. Laird and Christoph H. Stefes, "Driving Energy: The Enactment and Ambitiousness of State Renewable Energy Policy," *Journal of Public Policy* 35, no. 2 (August, 2015), 297-328.; Roek, *Offshore Wind Energy in the United States: A Legal and Policy Patchwork*, 24-28.

³¹ See: Jenna Goodward and Mariana Gonzalez, *Bottom Line on Renewable Energy Tax Credits* (Washington D.C.: World Resources Institute, 2010).; "Today in Energy: Most States have Renewable Energy Portfolios," U.S. Energy Information Administration, last modified February 3, 2012, accessed October 18, 2017, <https://www.eia.gov/todayinenergy/detail.cfm?id=4850>.; "State Renewable Portfolio

energy production on wildlife.³² The next most frequently covered topic is scholarly articles on wind energy technology. Topics include the importance of improved land and offshore wind energy turbines,³³ hidden challenges of energy innovation,³⁴ and electrical energy storage (EES).³⁵ There is also emerging literature on the effect of fossil fuel prices on the willingness of investors to continue and increase investment in wind energy development.³⁶ This study takes a fresh look at this relationship, thus

Standards and Goals," National Conference of State Legislators, last modified April 6, 2017, accessed June 22, 2017, <http://www.ncsl.org/research/energy/renewable-portfolio-standards.aspx>.

³² See: "Will Wind Turbines Ever be Safe for Birds?" Audubon Society, last modified March 16, accessed July 2, 2017, <http://www.audubon.org/news/will-wind-turbines-ever-be-safe-birds>.; Meera Subramanian, "The Trouble with Turbines: An Ill Wind," *Nature*, 486, no. 7403 (June 20, 2012), 310-311.

³³ See: "Wind Turbine Technology Played Key Role in Wind Energy's Record-Breaking Growth and Cost Decline."; Craig S. Brooker, "Frame Versus Aero: Who Wins in Simple Cycle? Mid to Large-Size Combustion Turbines," *Power Engineering* 121, no. 7 (July, 2017), 28-32. <http://www.power-eng.com/articles/print/volume-121/issue-7/features/frame-versus-aero-who-wins-in-simple-cycle-mid-to-large-size-combustion-turbines.html>.; Justin Martino, "Advancements in Wind Turbine Technology: Improving Efficiency and Reducing Cost and Reducing Cost," *Power Engineering* 118, no. 3 (03, 2014), 46-49. <http://www.renewableenergyworld.com/articles/2014/04/advancements-in-wind-turbine-technology-improving-efficiency-and-reducing-cost.html>.

³⁴ See: Subramanian, *The Trouble with Turbines: An Ill Wind*, 310-311.; Ted Nordhaus and Michael Shellenberger, "Better Energy Innovation," *Issues in Science & Technology* 29, no. 3 (Spring2013, 2013), 13-16.; Michael Levi, "The Hidden Risks of Energy Innovation," *Issues in Science & Technology* 29, no. 2 (Winter2013, 2013), 69-78.

³⁵ See: Panagiotis Papadopoulos et al., "Maximizing the Value of Large Energy Storage: The Smarter Network Storage Project Optimizes the use of Large-Scale Energy Storage for a Variety of System Benefits," *Transmission & Distribution World* 69, no. 4 (April 12, 2017), 28-33.; Wadim Strielkowski, Evgeny Lisin and Manuela Tvaronaviciene, "Towards Energy Security: Sustainable Development of Electrical Energy Storage," *Journal of Security & Sustainability Issues* 6, no. 2 (December, 2016), 235-244.

³⁶ See: Nicholas Apergis and James E. Payne, "The Causal Dynamics between Renewable Energy, Real GDP, Emissions and Oil Prices: Evidence from OECD Countries," *Applied Economics* 46, no. 36 (December 22, 2014), 4519-4525.; Ed Crooks and Kiran Stacey, "Big Oil: From Black to Green," *Financial Times* (June 28, 2016, 2016), September 8, 2017. <https://www.ft.com/content/922add24-3d12-11e6-9f2c-36b487ebd80a>.; David Timmons, Jonathan M. Harris and Brian Roach, *The*

contributing to the literature. The literature, however, does not examine these as interrelated nor in terms of the broader relationships.

This dissertation, as its third goal, provides an updated perspective on how public opinion, supportive state policy, improved technology, and fossil fuel prices cause a variation in wind energy growth. The research explores how these areas overlap. Two of the topics, policy³⁷ and technology³⁸, are covered extensively in current literature but do not show a comprehensive causality. An initial root-cause analysis was created using the proposed hypotheses and is depicted in Figure 3. Most of the current literature on wind energy only looks at one or two of the possible reasons wind energy production is increasing. The literature does not attempt to explain the causality between multiple concepts.

Economics of Renewable Energy (Medford, Massachusetts: Global Development and Environment Institute, 2015).

³⁷ See: "Today in Energy: Most States have Renewable Energy Portfolios." ; Goodward and Gonzalez, *Bottom Line on Renewable Energy Tax Credits*; "Renewable Energy Production Tax Credit (PTC)," U.S. Department of Energy, last modified Unknown, accessed October 13, 2017, <http://energy.gov/savings/renewable-electricity-production-tax-credit-ptc>.; "Key Federal Legislation," U.S Department of Energy, last modified May 27, 2017, accessed September 14, 2017, http://www.afdc.energy.gov/laws/key_legislation.; Robert W. Righter, *Windfall: Wind Energy in America Today* (Norman, Oklahoma: University of Oklahoma Press, 2011).

³⁸ See: "Wind Turbine Technology Played Key Role in Wind Energy's Record-Breaking Growth and Cost Decline."; Brooker, *Frame Versus Aero: Who Wins in Simple Cycle? Mid to Large-Size Combustion Turbines*, 28-32.; Page Kyle et al., "The Value of Advanced End-use Energy Technologies in Meeting U.S. Climate Policy Goals," *Energy Journal* 32, no. Special Issue 1 (10/02, 2011), 61-87.; Martino, *Advancements in Wind Turbine Technology: Improving Efficiency and Reducing Cost and Reducing Cost*, 46-49.; Tim Miser, "Taller Towers and Better Blades: The Cutting-Edge Technologies in Modern Wind Turbines," *Power Engineering* 120, no. 7 (July 20, 2016, 2016), 20-25. <http://www.power-eng.com/articles/print/volume-120/issue-7/features/taller-towers-and-better-blades-the-cutting-edge-technologies-in-modern-wind-turbines.html>.

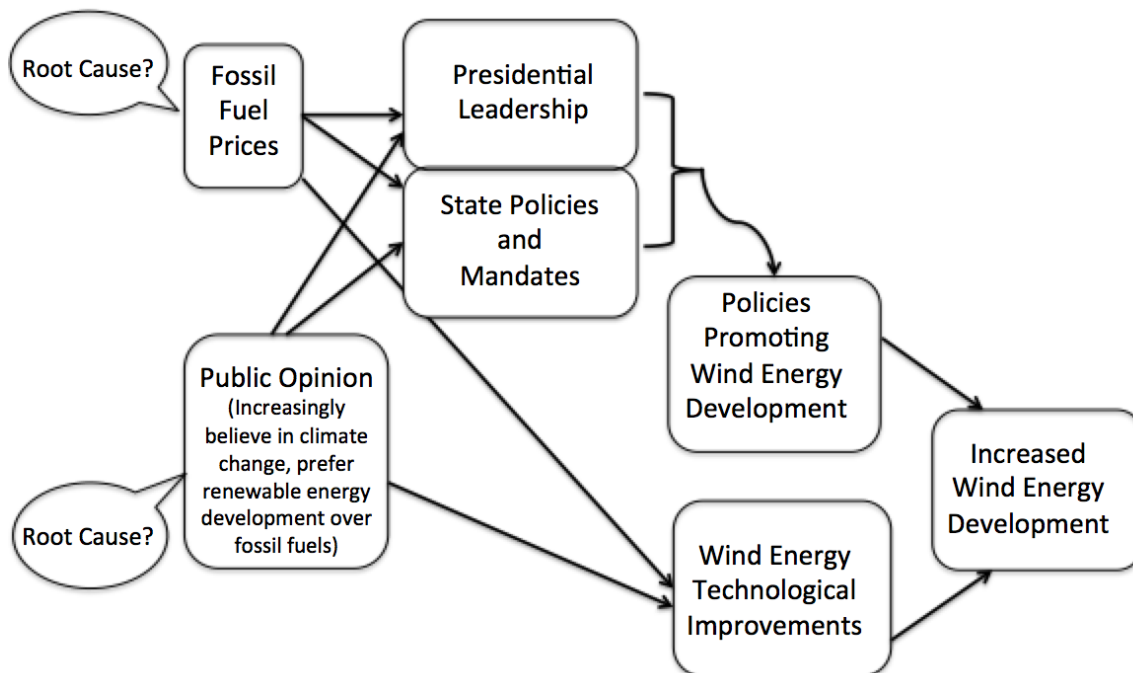


Figure 3 - Increased Wind Energy Development: Initial Root Cause Analysis

Fourth, there is surprisingly little analysis of energy in political science and certainly not much on wind energy. As wind energy continues to grow in the U.S., it will have an even greater impact on the domestic economy, which will then affect strategic and political challenges and developments. As some scholars have noted, energy crosscuts and informs some of the most vital subjects in world affairs, but it is comparatively ignored in the literature.³⁹ A review of the current literature helps discern why these hypotheses were chosen and where there are gaps in the current literature that this work helps fill.

³⁹ Steve A. Yetiv, *Myths of the Oil Boom* (New York, NY: Oxford University Press, 2015), 12.

CHAPTER II

LITERATURE REVIEW

The vast majority of the literature on wind energy development is written by scholars, organizations, and government agencies and published in articles or handbooks, yet none of the literature offers a holistic view of the multiple factors that affected wind energy growth. However, inherent to understanding the growth is having an understanding of how these topics inter-relate. Using the existing topics, the literature is discussed vis-à-vis five different categories: the first on public opinion towards renewable energy; the second on how presidential administrations' views differed towards the changing climate, the growth of renewable energy, and how that created policy; the third discusses state policies, mandates and incentives; the fourth covers technological innovations that allowed major leaps in wind energy production; and, finally, literature that discusses potential connections between fossil fuel prices and the willingness of companies to invest in renewable energy.

Overview of Wind Energy

Renewable energy is energy created by sources that can be replenished faster than they are diminished. Wind energy is energy created by converting wind into electricity. The uneven heating of the earth by the sun, varying terrain, and the rotation of the earth create wind. Wind turbines convert wind to energy. When turbines are placed in the path of blowing wind, the turbine blades rotate, causing the rotation of a

rotor that drives a shaft to power an electric generator. Wind can also be harnessed directly to do things such as move water. Windmills are designed for this type of work. A windmill converts wind to energy, but does not convert wind to electricity. By definition, only wind *turbines* convert wind into electricity. This work will focus on electricity created by wind turbines. Turbines typically generate usable amounts of power over 90 percent of the time they are rotating. Turbines are designed to generate electricity when wind speeds reach six to nine miles per hour, and current technology causes them to disengage at about 45-56 miles per hour to prevent equipment damage. Wind turbines can be interconnected on wind farms that then serve as power plants. Wind energy created from wind farms is fed into the electric power grid to deliver it where it is needed.⁴⁰

The U.S. utilizes more wind energy than any other nation in the world. In fact, by the end of 2016, six of the 10 biggest onshore wind farms in the world were located in the U.S. The largest land-based wind farm in the world at the end of 2016 was in China, and while China's large wind farms have almost double the wind power capacity of U.S. wind farms, the U.S. utilizes more wind energy. This means that China is not able to convert as much of its wind production into usable energy. China's poor infrastructure severely limits the nation's ability to utilize its full capacity. Vast blowing wind and production-based policies in the U.S. have led to the creation of some of the most

⁴⁰ See: Daniel Cusick, "China Blows Past the U.S. in Wind Power," *Scientific American*, sec. Sustainability, February 2, 2016.; "Beware Windpower's "Homes Served" Claims," Master Resource, last modified February 4, accessed July 5, 2017, <https://www.masterresource.org/false-claims/windpowers-homes-served-misdirection-media-beware/>.; "Wind Energy 101," American Wind and Energy Association, accessed July 2, 2017, <http://www.awea.org/wind-energy-101#What%20is%20wind%20power>.

productive wind farms in the world. In addition to building wind farms, companies in the U.S. have invested in the infrastructure used to transmit electricity, helping to relieve congestion in the electric power grid while bringing more low-cost wind energy to the most densely populated parts of the nation. In 2015, there was enough electricity produced in the U.S. to provide power to 17.5 million typical U.S. homes. That number grew to 25 million households in 2016. The total electricity utilized from wind energy in the U.S. increased from 1.5 percent in 2008 to 5.6 percent in 2016 and continues to grow. It is estimated that wind could provide as much as 20 percent of U.S. electricity by 2030.⁴¹

To install that much wind energy requires entrepreneurs, scientists, and technicians. The fastest growing occupations in the U.S. in 2016 were both solar photovoltaic (solar panel) installers and wind turbine service technicians.⁴² This shows that wind energy is not the only renewable energy that is experiencing high levels of growth. In 2016, the number of people employed in the U.S. wind industry grew to over 100,000. The U.S. Bureau of Labor and Statistics predicts that number will double by 2026.⁴³ This is an indication that the U.S. government estimates that wind energy will continue to flourish in the next decade.

⁴¹ See: "Wind Energy 101."; Cusick, *China Blows Past the U.S. in Wind Power*.; "U.S. Number One in the World in Wind Energy Production," American Wind Energy Association, last modified February 29, accessed July 2, 2017, <http://www.awea.org/MediaCenter/pressrelease.aspx?ItemNumber=8463>.; "Wind Energy Facts at a Glance."

⁴² "Fastest Growing Occupations," U.S. Bureau of Labor and Statistics, last modified October 24, accessed November 24, 2017, <https://www.bls.gov/ooh/fastest-growing.htm>.

⁴³ Ibid.

In the U.S., the development of wind energy occurs in an open market. The American Wind Energy Association (AWEA) is the leading trade association on wind energy in the U.S. Most available data on wind energy development in the U.S. is produced by the AWEA, and key governmental organizations such as the International Energy Agency (IEA), U.S. Department of Energy (DOE), U.S. Energy Information Administration (EIA), and the U.S. Environmental Protection Agency (EPA). There are a handful of books published on wind energy, but most books are written to explain the basics of wind energy development and how wind turbine technology works. None of the books take a comprehensive look at why wind energy has grown so prolifically in the U.S. in the last decade. They do not delve into the focus of this work, which is to determine the primary drivers of increased wind energy production in the U.S. The most numerous types of resources on wind energy are scholarly articles, trade magazines, and national and international agencies with a focus on energy. Using all resources as a baseline for research, a good starting place for determining where the desire to increase wind energy production comes from implicates the need to better understand U.S. public opinion.

Public Opinion

Public opinion on the importance of developing renewable energy has steadily grown over the years. This dissertation provides an updated perspective on how public opinion might affect the growth of the renewable energy sector. Public opinion has been an important part of wind energy development and there are many theories exploring

the challenges related to how public opinion drives policy changes.⁴⁴ But the predominant theories and studies vary greatly on the impact of public opinion on policy formation. The results of one study summarized that the relationship between the public and Congress was different based on the policy being discussed. Sometimes elected politicians vote based on their constituencies' expressed opinions and sometimes elected politicians vote based on party affiliation.⁴⁵ These two areas could create very different results in the U.S. and these possibilities are explored further in both Chapters 4 and 5. Based on these political theories, it is likely that public opinion supporting the growth of alternate energy sources was intertwined with presidential administrations and the type of leadership each president provided in the energy sector.

To fully explore public opinion, this dissertation heavily relies on polling data from Pew Research Center, Gallup News, Yale University Research Center, and George Mason University Research Center.⁴⁶ Ideally, polling data would have been consistently collected on the topics of climate change, renewable energy, and wind energy at the

⁴⁴ See: Penny S. Visser, Allyson Holbrooke and Jon A. Krosnick, "Theories of Public Opinion Formation and Change; Knowledge and Attitudes," in *The SAGE Handbook of Public Opinion Research*, eds. Wolfgang Donsbach and Michael Traugott (London: SAGE Publications, Ltd, 2008), 123-140.; Paul Burstein, "The Impact of Public Opinion on Public Policy: A Review and an Agenda," *Political Research Quarterly* 56, no. 1 (March 3, 2003), 29-40.; Kay Ward, "The Role of Salience on the Relationship between Public Policy and Public Opinion" (PhD Student Paper, 2008).

⁴⁵ Erikson, *Constituency Opinion and Congressional Behavior: A Reexamination of the Miller-Stokes Representation Data*, 511-535.

⁴⁶ "Fewer Americans See Solid Evidence of Global Warming," Pew Research Center, last modified October 22, 2009, accessed June 16, 2015, <http://www.people-press.org/2009/10/22/fewer-americans-see-solid-evidence-of-global-warming/>; Zac Auter, "In U.S., 73% Now Prioritize Alternative Energy Over Oil, Gas," *Gallup News*, sec. Politics, March 24, 2016.; Anthony Leiserowitz et al., *Climate Change in the American Mind: March, 2016* (New Haven, CT: Yale Program on Climate Change Communication and George Mason University Center for Climate Change Communication, 2016).

same time each year over consistent intervals. Unfortunately, the data is not this consistent. The polling data is still useful because it is consistent enough to show a series of trends.

One trend shows that public opinion about wind energy is dependent on the belief in climate change and varies between race, age, and education.⁴⁷ Opinions on anthropogenic causes of climate change also vary widely between political party affiliations, and the gap has widened over the years. The second notable trend is that Americans, unlike the people of most developed nations around the world, do not rate climate change as high of a threat to national security compared to public opinion in 57 other nations surveyed.⁴⁸ Though polls show that the vast majority of Americans want a variety of renewable energy sources developed, when citizens are assessed along party lines and age there are significant contrasts. Within their parties, Democrats fairly consistently believe that renewables should have priority while Republicans are sharply divided.⁴⁹ Other polling data shows how Americans have different perceptions of the biggest threats to national security than people from around the world. Americans

⁴⁷ "Views on Climate Change, by Key Demographics," Pew Research Center, last modified February 11, 2015, accessed February 19, 2017, http://www.pewinternet.org/2015/02/12/how-different-groups-think-about-scientific-issues/pi_2015-02-12_science-issues-06/.

⁴⁸ Richard Wike, *Many Around the World See Climate Change as a Major Threat* (Washington D.C.: Pew Research Center, 2014).

⁴⁹ See: "Political Ideology Drives Opinions on Key Energy Issues," University of Texas, last modified April 29, accessed June 10, 2015, <https://news.utexas.edu/2015/04/29/political-ideology-drives-opinions-on-key-energy-issues>.; "Public Opinion Estimates, United States, 2016," Yale Program on Climate Change Communication and the George Mason Center for Climate Change Communication, last modified February 2017, accessed March 3, 2018, <http://environment.yale.edu/ycom/factsheets/MapPage/2017Partisan/?est=fundrenewables&group=rep&type=value&geo=cd>.

consistently show that they are less concerned about climate change than global citizens.⁵⁰ These are a couple of examples of how polling data is used in this project.

Presidential Leadership

This dissertation undertakes a comparative analysis of the emphasis Presidents George W. Bush and Barack Obama placed on renewable energy development. Though the first U.S. wind farm was created in 1981 during President Ronald Reagan's administration, there was a lag between the genesis of an idea, the raising of funds, and the building of a wind farm. Understanding the lag, one can see that the concept of this first wind farm began under President Jimmy Carter's administration (1977-1981). To understand the importance of presidential leadership in shaping domestic policy on renewable energy growth, this work will give a brief overview of the most significant policy decision starting with President John F. Kennedy. It was under Kennedy's administration that the first Clean Air Act was created.⁵¹ Concern about the environment grew substantially until President Richard Nixon,⁵² but it wasn't until 1992 that national

⁵⁰ See: Wike, *Many Around the World See Climate Change as a Major Threat*; Jacob Poushter and Dorothy Manevich, "Globally, People Point to ISIS and Climate Change as Leading Security Threats," *Pew Research Center*, sec. Global Attitudes and Trends, August 1, 2017.

⁵¹ "Overview of the Clean Air Act and Air Pollution," U.S. Environmental Protection Agency, last modified April 28, 2017, accessed September 14, 2017, <http://www.epa.gov/clean-air-act-overview>.

⁵² See: "Richard Nixon on Environment," *On the Issues*, last modified June 17, 2017, accessed March 4, 2018, http://www.ontheissues.org/celeb/Richard_Nixon_Environment.htm.; "Richard Nixon's Top Domestic and Foreign Policy Achievements," *Nixon Foundation*, last modified January 2018, accessed March 4, 2018, <https://www.nixonfoundation.org/richard-nixons-top-domestic-and-foreign-policy-achievements/>.

incentives were created to promote renewable energy growth in the form of Production Tax Credits (PTCs).⁵³ PTCs gave tax breaks to investors in several renewable energy industries including the wind industry. The literature consistently shows that government incentives were critical for investment in wind energy.⁵⁴ Though the PTC was first established in 1992, growth began to accelerate in earnest starting in 2001.⁵⁵ With these timelines in mind, it is interesting to do a more detailed comparison of the attitudes and policies of Presidents George W. Bush (2001-2009) and Barack Obama (2009-2017).⁵⁶ Though the terms of office of these two presidents do not fit perfectly into the diachronic comparison of the two timeframes being evaluated in this dissertation, there are many advantages to comparing these presidents. They are from different political parties, but they both served for two terms, which helps to account for the lag effects associated between public attitudes and policy implementation. The leadership effect of these two presidents on increased wind energy development is explored in more depth in Chapter 5.

⁵³ Righter, *Windfall: Wind Energy in America Today*, 31-33.

⁵⁴ See: Righter, *Windfall: Wind Energy in America Today*, 31-33.; Richard W. Caperton, *Good Government Investments in Renewable Energy*, (Center for American Progress, January 2012).

⁵⁵ "Electric Power Monthly."

⁵⁶ See: "Meeting President Bush's Climate Change Challenge to Business and Industry," U.S. Department of Energy, last modified Unknown, accessed January 5, 2016, <http://energy.gov/sites/prod/files/edg/news/archives/documents/ClimateFactSheet.pdf>.; *President Obama's Climate Action Plan: One Year Later* (Arlington, VA: Center for Climate and Energy Solutions, 2014).

State Mandates and Policy

One of the most important aspects in the amount of increased wind energy production is when individual states create ways to encourage initial or further development. This dissertation holistically evaluates state mandates and policy, and seeks to understand how governmental policies affected the growth of the wind energy sector. The literature shows that government incentives are critical for continued investment in wind energy.⁵⁷ PTCs are the national level incentive, but many states also created incentives called Renewable Portfolio Standards (RPSs), or renewable energy credits. The final level of incentive is at the county or municipal level in which wind energy companies can ask for tax abatements.⁵⁸ This dissertation does not explore incentives at the county and municipal level. There is literature concluding that state government incentives have been critical to increase wind energy development and some state governments chose to use RPSs and other policy mandates to encourage wind energy development.⁵⁹ Other state governments did not use RPSs and the wind industry still grew in those states.⁶⁰ There are also many states with little to no wind energy development.⁶¹ In Chapter 6, these state mandates and policies are explored in

⁵⁷ Woodward and Gonzalez, *Bottom Line on Renewable Energy Tax Credits*

⁵⁸ Righter, *Windfall: Wind Energy in America Today*, 31-33.

⁵⁹ "U.S. Wind Energy State Facts," American Wind Energy Association, last modified April 2017, accessed July 2, 2017, <http://www.awea.org/state-fact-sheets>.

⁶⁰ Galen Barbose, *U.S. Renewables Portfolio Standards 2017 Annual Status Report* (Berkeley, CA: Lawrence Berkeley National Laboratory, 2017).

⁶¹ "State Wind Energy by Year," U.S. Energy Information Administration, last modified September 2017, accessed October 19, 2017, <https://www.eia.gov/electricity/data/state/>.

depth through an overview of a few states representing different levels of wind energy development.

Technological Developments

Advances in wind turbine technology have also been crucial in the proliferation of wind energy in the U.S. in the last 10 years. This dissertation provides an updated perspective of how the technology enabled exponential growth in the industry. American public opinion in the 1970s helped drive innovations in turbine technology, because the public wanted industry to find alternatives to spiking oil prices.⁶² Shrewd investors sought improved turbine technology and gained efficiencies in wind farms to maximize their investments.⁶³ One researcher wrote, “In the early 1970s, long gas lines, politics, conservation, and a new environmental awareness converged to shift American thinking.”⁶⁴ As part of that new thinking, the U.S. DOE gave large grants for companies such as Boeing, McDonnell Douglas, and General Electric to develop high output wind turbines. Although great strides were made in the research and development of turbines, there were also some big failures. Engineers learned a lot from these failures, but the U.S. public and politicians lost faith in the program, and it was shut down in

⁶² Ibid.

⁶³ See: Zachary Shahan, "History of Wind Turbines," *Energy World*, sec. Featured News, November 21, 2014.; Christine M. Kreiser, "Megawatt Wind Turbine," *American History* 48, no. 6 (02, 2014), 15.

⁶⁴ Righter, *Windfall: Wind Energy in America Today*, 31-32.

1992. The failures of the program reinforced the belief that wind energy did not have a commercial application.⁶⁵

Other important aspects of technology are computer-aided design and nanotechnology. Sophisticated algorithms were created to develop computer programs that aid in the optimal design of wind turbine rotor blades while also enhancing other elements of wind turbines.⁶⁶ There have also been innovative applications of nanotechnology. Application of nanotechnology has improved wind turbines in many ways. It has also been useful in finding ways to more effectively transmit electricity.⁶⁷ These advanced applications of technology were made both domestically and internationally. Without these technological improvements it would not be possible for the U.S. energy industry to have made such great advances in wind energy production.

Though the U.S.-based General Electric was the leading provider of wind turbines through 2015, companies in European nations made some of the most significant technological advances.⁶⁸ Chapter 7 explores these advances and examines the widely held belief that the one-megawatt turbine developed in the year 2000 was its optimal configuration. By 2008, however, the common size of turbines was in the 1.5-megawatt to 3.6-megawatt range.⁶⁹ Wind turbine technology drove the ability to create

⁶⁵ Ibid.

⁶⁶ See: Serhat Duran, *Computer-Aided Design of Horizontal-Axis Wind Turbine Blades* (ResearchGate, 2017).; Seyed Hosseini and Behnam Moetakef-Imani, "Innovative Approach to Computer-Aided Design of Horizontal Axis Wind Turbine Blades," *Journal of Computational Design and Engineering* 4, no. 2 (November, 2017).

⁶⁷ Stavros Philip Thomas, "Nanotechnology in Wind Energy Engineering," *Wind Engineering*, March 7, 2013.

⁶⁸ Tim Miser and Mark Bolinger, *2016 Wind Technologies Market Report* (Oak Ridge, TN: U.S. Department of Energy, 2017).

⁶⁹ Righter, *Windfall: Wind Energy in America Today*, 33.

effective wind farms in the U.S., but there could be another major breakthrough in how much wind energy can be used in the electric grid if energy storage is improved.⁷⁰ Right now natural gas serves as the primary back-up power for most American power plants when wind is not producing enough energy. Natural gas is and has been less expensive than other back-up energy sources, such as improved storage capacity.⁷¹ Storage capacity is not currently cost effective, but it is possible that technological advances in storage could change this calculus.⁷² Accordingly, it is worth examination of storage technology, its current status and likely areas of future development. These advances in technology are analyzed in Chapter 7.

Fossil Fuel Prices

A priori assumptions may lead one to believe fuel prices would not affect the cost of electricity, but it has been proven that there is a correlation between the pricing of different types of energy.⁷³ This dissertation evaluates the effect of fossil fuel pricing on the growth of renewable energy. A 2014 study conducted by N. Apergis and J.E. Payne of 25 Organization for Economic Cooperation and Development (OECD) nations showed direct causality between per capita renewable energy consumption, CO₂

⁷⁰ See: "Wind Energy and Storage," American Wind Energy Association, last modified July 2017, accessed September 11, 2017, <http://www.awea.org/wind-energy-storage>.; Papadopoulos et al., *Maximizing the Value of Large Energy Storage: The Smarter Network Storage Project Optimizes the use of Large-Scale Energy Storage for a Variety of System Benefits*, 28-33.

⁷¹ Ibid.

⁷² Ibid.

⁷³ Apergis and Payne, *The Causal Dynamics between Renewable Energy, Real GDP, Emissions and Oil Prices: Evidence from OECD Countries*, 4519-4525.

emissions, and oil prices. Their study showed that higher CO₂ emissions led to more renewable energy consumption and that more renewable energy consumption led to lesser CO₂ emissions.⁷⁴ The research also noted that an increase in oil prices led to an increase in the use of renewable energy.⁷⁵ Chapter 8 delves further into the relationship between wind energy growth and the price of oil, coal, and natural gas.

Before exploring the five hypotheses on key factors influencing the growth of wind energy in the U.S., it is important to set a foundation of understanding on both climate change and renewable energy.

⁷⁴ Ibid.

⁷⁵ Ibid.

CHAPTER III

CLIMATE CHANGE AND RENEWABLE ENERGY IN REVIEW

To understand why nations should build more balanced energy portfolios one must first understand the basics about climate change and renewable energy. The Earth's climate has been changing throughout history, well before human civilization arose. There were seven cycles of glacial melting and regrowth in the last 650,000 years before the modern climate era, which is defined as the last 7,000 years.⁷⁶ Rising CO₂ levels caused rising temperatures in the modern climate era and most climate scientists agree the trapped gases are forcing climate change.⁷⁷ The relatively recent understanding of global warming and climate change shows that this is not a new problem for the world. Rather, it is an ongoing and significant challenge for the global population.

Climate change affects agriculture, energy, water supplies, health, plants, wildlife, ecosystems, recreation, and coastal areas.⁷⁸ Though there may be some positive outcomes of climate change, the negatives are already expected to far outweigh the positives. An example of a positive effect is warmer temperatures in the northern parts of the U.S. could allow people there to grow crops they could not

⁷⁶ "Climate Change: How do we Know?" National Aeronautics and Space Administration, last modified September 18, 2017, accessed September 18, 2017, <https://climate.nasa.gov/evidence/>.

⁷⁷ "A Blanket Around the Earth," National Aeronautics and Space Administration, last modified September 18, 2017, accessed September 18, 2017, <https://climate.nasa.gov/causes/>.

⁷⁸ "Effects on People and the Environment: How Will Climate Change Affect You? Your Community? The Environment Around You?" U.S. Environmental Protection Agency, accessed January 3, 2016, <http://epa.gov/climatestudents/impacts/effects/index.html>.

previously grow. On the negative side, people in the southern states, however, may no longer be able to grow crops they rely on and for which they have fully developed infrastructure to support and maintain farms. Some parts of the U.S., such as northern California, have used predictable water supplies to create hydropower, but as weather patterns shift it is possible hydropower may no longer be utilized or that hydro-production may be greatly reduced. Another negative effect of warming temperatures is on the spread of infectious diseases. "As winter temperatures increase, ticks and mosquitoes that carry diseases can survive longer throughout the year and expand their ranges, putting more people at risk."⁷⁹ Warmer temperatures will continue to reduce the range of colder habitats, and birds are migrating further north. The U.S. EPA estimates continued warming could result in one-fourth of all the plants and animals on Earth becoming extinct. As more of the ice cap melts, sea levels are rising, coastlines are eroding, and some beaches and wetlands may disappear completely.⁸⁰

Having a basic concept of the effects of climate change and how human behavior is contributing to a degradation of the planet is critical to understanding why it is so important for nations to explore renewable energy. Indeed, the link between renewable energy and climate change is one of the most important questions of this dissertation. Therefore, it is important to analyze the dynamics of climate change and renewable energy.

⁷⁹ Ibid.

⁸⁰ Ibid.

How Has Human Behavior Affected Climate Change?

Even the earliest recorded history indicates that people believe human behavior can alter local climate. For example, “Theophrastus, a pupil of Aristotle, told how the draining of marshes had made a particular locality more susceptible to freezing, and he speculated that lands became warmer when the clearing of forests exposed them to sunlight.”⁸¹ Scholars of the Renaissance determined that grazing, irrigating, and deforestation altered the land around the Mediterranean Sea.⁸²

The measuring of CO₂ levels is a continuation of the methods by which researchers have accounted for human’s impact on the environment, and measuring CO₂ levels has a long history. To understand the significance of increased CO₂ in the atmosphere, it is important to compare historic CO₂, from CO₂ trapped in ice cores to current levels of CO₂ in the atmosphere. Starting in the early 1900s, scientists began to study ice. They have been able to study the Earth’s climate as far back as 800,000 years by taking ice core samples gathered by drilling deep underneath the ice in places such as Greenland and Antarctica. Some of the samples are from more than a mile deep, and contain detailed information on air temperature and CO₂ levels over thousands of years. Using this type of analysis, called paleoclimatology (the study of past climates), and using deep-sea sediment analysis, scientists at the National Oceanic and Atmospheric Administration (NOAA) have determined there is a strong, direct correspondence between temperature and the concentration of CO₂ in the

⁸¹ Spencer R. Weart, *The Discovery of Global Warming*, Revised and Expanded Edition ed. (Cambridge, MA: Harvard University Press, 2008), 1.

⁸² *Ibid.*

atmosphere.⁸³ Although determining the specifics of that relationship is challenging, scientists agree there is a relationship.⁸⁴ When one goes up, the other follows. As CO₂ goes up, temperature goes up. When CO₂ goes down, temperature goes down.

In 1932, G.S. Callendar became well known for his attempts to connect the burning of fossil fuels to the emission of CO₂.⁸⁵ Callendar, an engineer specializing in steam and power generation, began measuring global temperature and CO₂ levels.⁸⁶ He hypothesized that CO₂ emitted by humanity traps radiation.⁸⁷ He took his amateurish research and findings and presented them before the Royal Meteorological Society in London in 1938.⁸⁸ This effect was called the "Callendar effect" until it became known by its modern name, the "greenhouse effect."⁸⁹ Several scientists before Callendar had explored this concept, and although the Royal Meteorological Society was not convinced, the concept had enough merit to drive further research.⁹⁰

It was not until later in the 20th century that evidence began mounting that human behavior can alter global weather patterns. The U.S. EPA defines greenhouse gases (GHG) as gases that "trap heat and make the planet warmer."⁹¹ GHG include water

⁸³ "Temperature Change and Carbon Dioxide Change," National Oceanic and Atmospheric Administration, last modified January 2016, accessed January 3, 2016, <http://www.ncdc.noaa.gov/paleo/globalwarming/temperature-change.html>.

⁸⁴ William Ferguson, "Ice Core Data Help Solve a Global Warming Mystery," *Scientific American*, March 1, 2013, accessed September 14, 2017. <https://www.scientificamerican.com/article/ice-core-data-help-solve/>.

⁸⁵ Ibid.

⁸⁶ Ibid.

⁸⁷ Ibid.

⁸⁸ Ibid.

⁸⁹ Ibid.

⁹⁰ Weart, 2-10.

⁹¹ "Sources of Greenhouse Gas Emissions," U.S. Environmental Protection Agency, accessed January 2, 2016, <http://www.epa.gov/climatechange/ghgemissions/sources.html>.

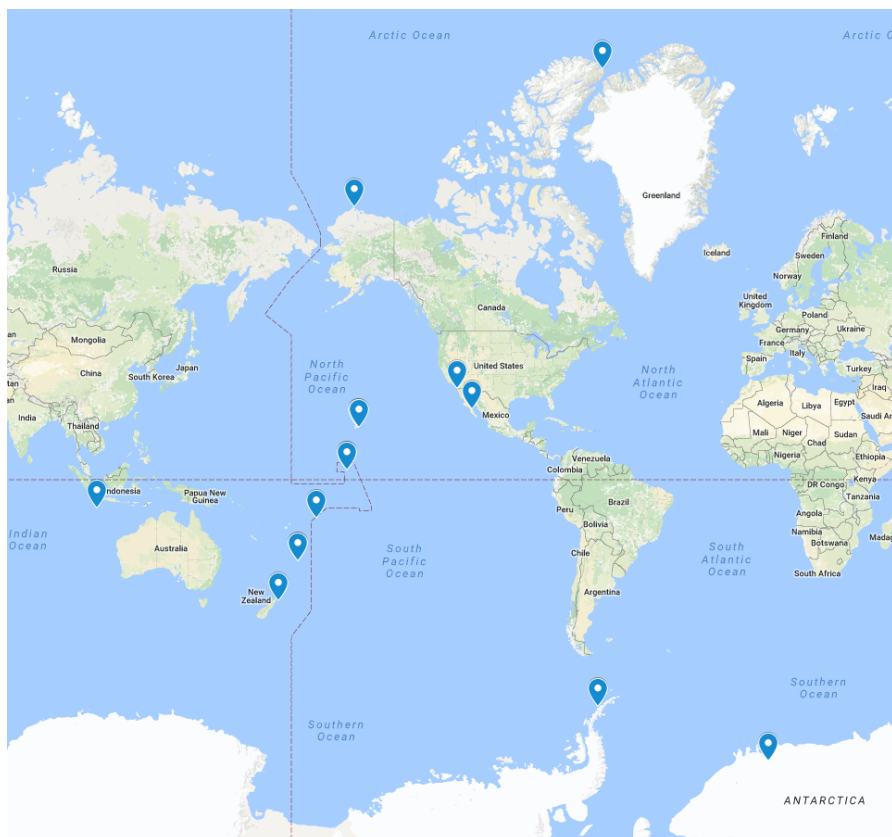
vapor, CO₂, methane, nitrous oxide, ozone, and halocarbons. The primary GHG emitted by human activity is CO₂. Some GHG emissions are critical to sustaining life, because without this warming effect life could not be sustained on Earth. However, the industrial revolution led to excessive GHG emissions.

A scientist by the name of Charles David Keeling developed a way to measure atmospheric CO₂ levels. His graphs depicting the change in CO₂ levels are known as the Keeling Curves. Keeling took his readings from several locations using specially designed sensors, and since 1958, there have been daily readings at the Mauna Loa Observatory on the Big Island of Hawaii. Mauna Loa serves as the ideal location and altitude for measuring CO₂ because of its isolation in the Pacific Ocean that means a lack of interference from factories and vegetation. There can be some effect of volcanic activity on the readings, but scientists are able to make corrections for volcanic activity.⁹² The globally collected readings are used to create a global average of CO₂ and oxygen and nitrogen readings. Map 4 shows the array of atmospheric sampling stations from the Arctic to the Antarctic used to make the Keeling Curve.⁹³

⁹² R. F. Keeling et al., *Atmospheric Carbon Dioxide Record from Mauna Loa* (La Jolla, California: Carbon Dioxide Information Analysis Center, 2008).

⁹³ "Atmospheric CO₂ Data," Scripps Institution of Oceanography, accessed January 3, 2016, http://scrippsco2.ucsd.edu/data/atmospheric_co2.html.

Sampling stations are: Alert, Canada; Point Barrow, Alaska; Station P, Alaska; La Jolla Pier, California; Baja California Sur, Mexico; Mauna Loa Observatory, Hawaii; Cap Kumukahi, Hawaii; Christmas Island, Fanning Island; American Samoa; Kermadec Islands, Raoul Island; Baring Head, New Zealand; Palmer Station, Antarctica; and the South Pole.



Map 4 - Atmospheric Sampling Stations⁹⁴
Data Source: Scripps Institution of Oceanography

The EPA estimates that 84 percent of all CO₂ emitted annually comes from human activities and most of that comes from the use of fossil fuels (coal, natural gas, and oil) burned for energy and transportation.⁹⁵ Figure 4 makes it clear that there are natural cycles of CO₂ increases and decreases, but the figure also makes it clear that a dramatic increase in CO₂ emissions occurred since the industrial revolution.

⁹⁴ Map created using data source: "Atmospheric CO₂ Data," Scripps Institution of Oceanography, last modified September 2017, accessed September 12, 2017, http://scrippsco2.ucsd.edu/data/atmospheric_co2.html.

⁹⁵ "Overview of the Clean Air Act and Air Pollution," U.S. Environmental Protection Agency, accessed December 27, 2015, <http://www.epa.gov/clean-air-act-overview>.

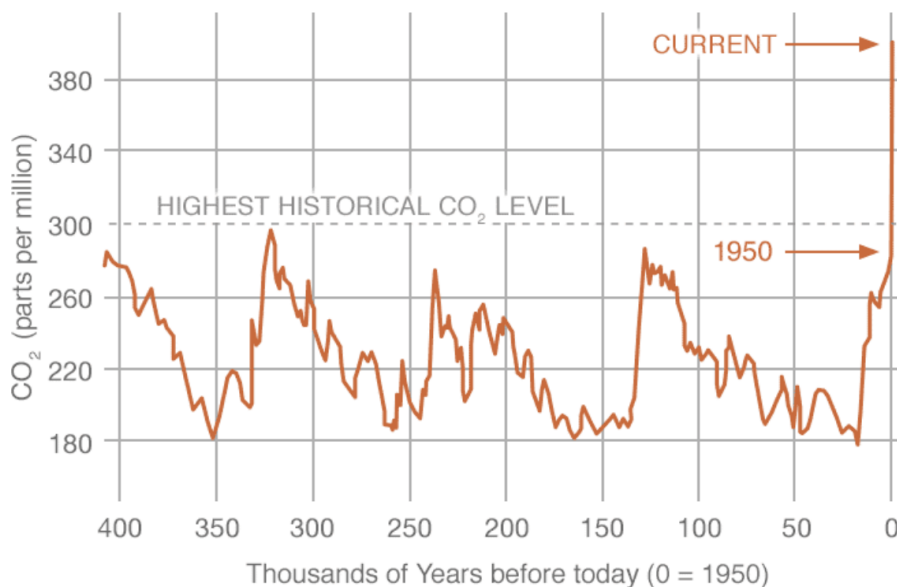


Figure 4 - CO₂ Measured Over Thousands of Years⁹⁶

Source: National Aeronautics and Space Administration

So while there are natural fluctuations in CO₂ emissions, human behavior caused a distressing increase in CO₂ emissions that started with the industrial revolution.

When Keeling first began making his readings in 1958, the atmospheric CO₂ level was 316 parts per million (ppm). At the end of 2016, the global CO₂ level was 404.1 ppm. According to the Scripps Institute, “The last time Earth’s atmosphere contained 400 parts per million of carbon dioxide was more than 2.5 million years ago.”⁹⁷ Figure 6 shows that CO₂ levels have not exceeded 300 ppm in the last 800,000 years.⁹⁸ The annual average rise of CO₂ in the last 120 years has been 2 ppm.

⁹⁶ Figure created using data source: “Carbon Dioxide,” National Aeronautics and Space Administration, last modified July 2017, accessed September 13, 2017, <https://climate.nasa.gov/vital-signs/carbon-dioxide/>.

⁹⁷ Geoffrey Mohan, “Carbon Dioxide Levels in Atmosphere Pass 400 Milestone, Again,” *Los Angeles Times*, May 20, 2013.

⁹⁸ “What does this Number Mean? The Keeling Curve,” Scripps Institution of Oceanography, last modified January 2, 2016, accessed January 3, 2016,

There are also natural seasonal changes in CO₂ emissions. The seasonal changes are due to the natural freezing then thawing of vegetation in the Northern Hemisphere. When the vegetation thaws in the spring it absorbs great quantities of CO₂ from the air, causing the level of CO₂ to drop starting in June. The primary source of this seasonal vegetation is in Siberia. When the biomass produced in the summer begins to die and decompose it releases large quantities of CO₂ back into the atmosphere starting in October and causes CO₂ levels to rise even higher by the end of the year.⁹⁹ The highest seasonal changes of CO₂ emissions are depicted in Figure 5. Understanding the seasonal cycle is critical to distinguishing natural causes of CO₂ rise from mostly or completely man-made CO₂ emissions.

<https://scripps.ucsd.edu/programs/keelingcurve/2015/05/12/what-does-this-number-mean/>.

⁹⁹ "Atmospheric CO₂ Data," Scripps Institution of Oceanography, accessed January 3, 2016, http://scrippsc02.ucsd.edu/data/atmospheric_co2.html.

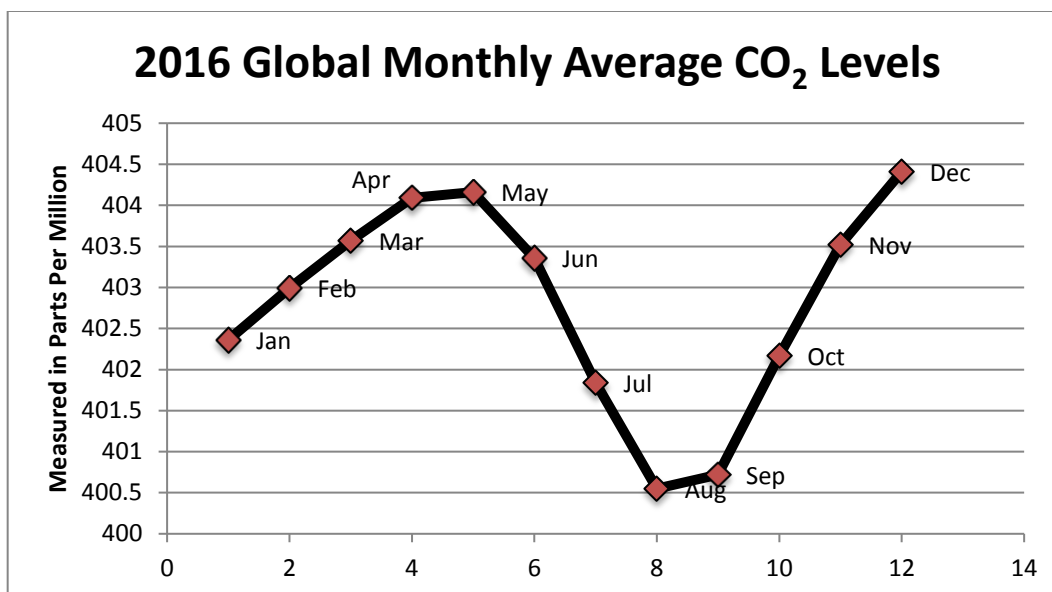


Figure 5 - 2016 Global Monthly Average CO₂ Levels¹⁰⁰

Data Source: National Oceanic and Atmosphere Administration

The question that nobody can answer definitively about rising CO₂ levels is: How does that rise affect Earth? It is not an easy question to answer because there is no time this planet has seen such a drastic rise in CO₂ in such a short period of time. Although temperatures have been rising since accurate statistics have been maintained, the average temperatures in the U.S. have risen even more since the late 1970s. Increasing temperatures continue to set new records with 2012 and 2015 as the two warmest years ever recorded. The U.S. is not alone in this trend. 2015 was the warmest year worldwide and the decade of 2006-2015 was the warmest decade ever recorded across the globe.¹⁰¹ Figure 6 depicts the increase in global temperature from 1880 to 2015. But, it is notable that the U.S. has warmed even faster than the global rate. This

¹⁰⁰ Figure created using data from: "Trends in Atmospheric Carbon Dioxide," National Oceanic and Atmospheric Administration, accessed September 12, 2017, <http://www.esrl.noaa.gov/gmd/ccgg/trends/weekly.html>.

¹⁰¹ "Climate Change Indicators: U.S. and Global Temperature."

alarming trend is not spread evenly across all states with the North, West, and Alaska all experiencing the greatest warming trend with some parts of the Southeast having experienced very little fluctuation.¹⁰²

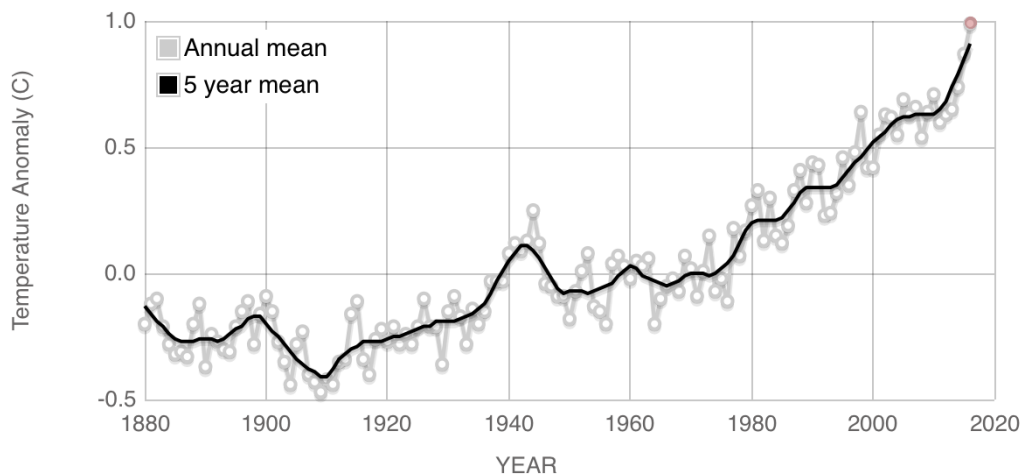


Figure 6 - Global Temperature Rise from 1880 - 2015¹⁰³

Source: U.S. Environmental Protection Agency

The data is conclusive and shows a clear correlation between increases in CO₂ emissions and global temperature increases. This correlation between CO₂ increases and overall worldwide temperatures is as factual as the gravitational pull on Earth. The United Nations' establishment of the Framework Convention on Climate Change (UNFCCC) in 1992 to address the global rise in temperatures was the first important set of agreements for the international community. The UNFCCC's goal is to find ways to mitigate climate change. There are several key agreements that have come out of the UNFCCC.

¹⁰² Ibid.

¹⁰³ Ibid.

The first of the UNFCCC agreements is the Kyoto Protocol, agreed upon by member nations in 1997 to establish legally binding obligations for developed countries to reduce their GHG emissions. Unfortunately, the controversy surrounding the Kyoto Protocol references the members who chose not to adopt it, namely the U.S., China, and India. All three are among the top CO₂ emitters in the world. The Kyoto Protocol's first commitment period began in 2008 and expired in 2012, and the second commitment began in 2013 and is scheduled to end in 2020.¹⁰⁴ Although these countries did not agree to join the Kyoto Protocol, they have all made some progress in reducing their CO₂ emissions.

The second key set of agreements from the UNFCCC are called the Cancun agreements, which were signed in 2010 to confirm the international consensus that future global warming should be limited to a level that would prevent dangerous anthropogenic interference with the climate system. This critical temperature is commonly believed to be around two degrees Celsius above the pre-industrial global average temperature and it is currently estimated that it may be too late to contain at that level.¹⁰⁵ Scientists argue that the world has waited so long to make the cuts necessary to maintain the pre-industrial global temperatures that it would require extremely harsh cuts that could damage economics or rely on technologies that have not yet been invented.¹⁰⁶

¹⁰⁴ "Kyoto Protocol," United Nations Framework Convention on Climate Change, accessed December 28, 2015, http://unfccc.int/kyoto_protocol/items/2830.php.

¹⁰⁵ Chris Mooney, "The Magic Number: Holding Warming Under Two Degrees Celsius," *The Washington Post*, November 29, 2015.

¹⁰⁶ Ibid.

However, temperature is not the only thing affected by changes in CO₂ levels.¹⁰⁷

The evidence is clear. Rising global temperatures have been accompanied by changes in weather and climate. Many places have seen changes in rainfall, resulting in more floods, droughts, or intense rain, as well as more frequent and severe heat waves. The planet's oceans and glaciers have also experienced some big changes – oceans are warming and becoming more acidic, ice caps are melting, and sea levels are rising.¹⁰⁸

The global sea level has risen an average of eight inches since 1880, but the rise accelerated since 1993 to 90 percent above the 20th century average. Two of the most significant rises since the 1880s have been in the New Orleans coastal area and in Hampton Roads.¹⁰⁹ The shifting weather patterns have led to increasingly violent hurricanes and warming coastal waters. As the coastal waters warm, temperature-sensitive species shift northward. Several types of fish and snow crabs in Alaska as well as mangrove trees in Florida have already begun to move north.¹¹⁰ Increasing acidity in the oceans caused by the higher acidity of CO₂ rich air is also affecting many marine

¹⁰⁷ "Temperature Change and Carbon Dioxide Change," National Oceanic and Atmospheric Administration, accessed January 3, 2016, <http://www.ncdc.noaa.gov/paleo/globalwarming/temperature-change.html>.

¹⁰⁸ Ibid.

¹⁰⁹ "Causes of Sea Level Rise: What the Science Tells Us," Union of Concerned Scientists, last modified April 15, accessed June 20, 2013, http://www.ucsusa.org/global_warming/science_and_impacts/impacts/causes-of-sea-level-rise.html and <http://www.centerforsealevelrise.org/about-sea-level-rise/2nd-largest-population-at-risk/>.

¹¹⁰ "Climate Impacts on Coastal Areas," U.S. Environmental Protection Agency, accessed January 3, 2016, <http://www3.epa.gov/climatechange/impacts/coasts.html>.

species. Ultimately, the effects of the dramatic increase of CO₂ emissions on the planet cannot be predicted.

The newest and most significant international agreement coming out of the UNFCCC is known as the Paris Agreement. The Paris Agreement became legally binding on November 4, 2016. The main purposes of the Paris Agreement were to obtain more global support in response to climate change with a goal of keeping global temperature rise below two degrees Celsius, increase efforts to decrease the rise even further to 1.5 degrees Celsius, and to help nations deal with the negative effects of climate change.¹¹¹ This agreement is unlike any previous attempts by the UNFCCC to gain global support for addressing climate change. The Paris Agreement was supported by 196 nations and was ratified by 175 nations.¹¹² The Paris Agreement was able to garner more support than previous agreements because this agreement allowed each individual nation to determine the best way for it to participate.¹¹³ Each signatory nation determined how it could best address climate change in what is called *national determined contributions (NDCs)*.¹¹⁴ Some parts of the agreement are binding and others are not.¹¹⁵ Giving nations more latitude on levels of participation through NDCs set the conditions for more nations to support the agreement. The Paris Agreement was considered a landmark diplomatic achievement for President Obama's environmental

¹¹¹ "The Paris Agreement," United Nations, last modified December 30, 2017, accessed March 3, 2018, http://unfccc.int/paris_agreement/items/9485.php.

¹¹² Ibid.

¹¹³ "Climate Change: The Paris Agreement," The Nature Conservancy, last modified March 10, 2017, accessed March 3, 2018, <https://www.nature.org/ourinitiatives/urgentissues/global-warming-climate-change/the-paris-agreement-what-does-it-mean.xml>.

¹¹⁴ "The Paris Agreement."

¹¹⁵ "Climate Change: The Paris Agreement."

agenda.¹¹⁶ These international agreements have been important globally, but they have not made as much of an impact domestically for reasons that will be discussed in Chapter 5 on Presidential Leadership.

The U.S. as Energy Consumers and Producers

The amount of energy consumed in the U.S. far exceeds most other nations. For example, the 19.5 million residents of New York state consume as much energy as the 800 million in Sub-Saharan Africa (excluding South Africa).¹¹⁷ The U.S. is the largest consumer of energy in the world, but it is also the second largest producer of energy.¹¹⁸

Back in the early 1970s when President Nixon declared that the U.S. needed to end its addiction to imported petroleum,¹¹⁹ he was referring to other sources such as coal and nuclear, but his argument still applies today. In his 2011 State of the Union address, President Obama declared that clean energy would be a key factor in his presidency. He was not able to make as much progress as he wanted in this area due to competing demands, including domestic economic issues. However, like Nixon, he believed the U.S. must decrease its reliance on imported fossil fuel. On March 15, 2012 he said, "We can't have an energy strategy for the last century that traps us in the past.

¹¹⁶ Jonathan Ellis, "The Paris Climate Deal: What You Need to Know," *New York Times*, sec. Climate, June 1, 2017.

¹¹⁷ Elisabeth Rosenthal, "Life After Oil and Gas," *New York Times*, sec. Sunday Review, March 23, 2013. <http://www.nytimes.com/2013/03/24/sunday-review/life-after-oil-and-gas.html?pagewanted=all&r=0>.

¹¹⁸ "The World Factbook: United States," CIA, accessed January 7, 2016, <https://www.cia.gov/library/publications/the-world-factbook/geos/us.html>.

¹¹⁹ E. Donald Elliott, "Why the United States does not have a Renewable Energy Policy," *Environmental Law Institute* (2013), December 23, 2015.

We need an energy strategy for the future – an all-of-the-above strategy for the 21st century that develops every source of American-made energy.”¹²⁰

Although the U.S. has an energy plan, it does not have an energy policy on par with the European Union policy creating binding obligations. “Under the 1977 law that created the federal U.S. Department of Energy (DOE), every two years the president and DOE are required by law to put together a ‘national energy policy plan.’ ... For 35 years, these semi-annual national energy plans have been ignored. They are written, announced, and go directly into the dustbin of history.”¹²¹ The U.S. has no enforcement mechanism to keep policy makers and presidential administrations accountable for what they say they will do in their national energy plans.

Given the technological advances and increased production of both oil and natural gas, it is not surprising that legislators across the nation are debating proposals to curtail current environmental rules allowing further exploitation of fossil fuels. “The new rules would trim or abolish climate mandates – including those that require utilities to use solar and wind energy, as well as proposed Environmental Protection Agency rules that would reduce carbon emissions from power plants.”¹²² At the end of 2016, 18 states had such debates ongoing. By early 2017, only one of the 18 states, Kansas, had approved legislation to force the reduction of human activity on the environment. The head of a clean-energy think tank in Washington D.C. argues that Americans want to

¹²⁰ "Energy, Climate Change, and our Environment," The White House, accessed January 7, 2016, <https://www.whitehouse.gov/energy>.

¹²¹ E. Donald Elliott, "Why the United States does not have a Renewable Energy Policy."

¹²² Steve Mufson and Steve Hamburger, "A Battle is Looming Over Renewable Energy, and Fossil Fuel Interests are Losing," *The Washington Post*, sec. Business, April 25, 2014.

increase clean energy usage and that desire is a driving force for more political discourse, but the resources of the fossil fuel industry are still eclipsing both policy and action in renewable energy.¹²³ The U.S. government has historically been interested in increasing U.S. total renewable energy usage. In 2016, the U.S. DOE issued a draft plan to guarantee loans for innovation in renewable energy and energy efficient projects located in the U.S. The total estimated size of loan guarantees is up to \$4 billion. The U.S. DOE stated, "The Renewable Energy and Efficient Energy Projects Loan Guarantee solicitation is intended to support technologies that are catalytic, replicable, and market ready."¹²⁴ As humankind continues to increase the amount of CO₂ and other GHGs emitted, it is important to understand that the importance of decreasing harmful emissions must be accomplished by adopting many strategies, one of which is increasing the use of renewable energy in concert with reducing the use of fossil fuels.

What is Renewable Energy?

Terminology in this field can be confusing. Some organizations use terms interchangeably while other organizations are more specific. For example, even different U.S. state governments use the terms alternative and renewable to include different types of energy. For the purposes of this dissertation, the following terms will be defined as follows:

¹²³ Ibid.

¹²⁴ "Department of Energy Issues Draft Renewable Energy and Efficient Energy Projects Solicitation to Foster Clean Energy Innovation," U.S. Department of Energy, accessed January 7, 2016, <http://energy.gov/articles/department-energy-issues-draft-renewable-energy-and-efficient-energy-projects-solicitation>.

Alternative Energy: Energy that does not produce GHG and can replace or supplement traditional fossil-fuel sources such as coal, natural gas, and oil. This includes nuclear energy and renewable energy.¹²⁵

Sustainable Energy: Used interchangeably with Alternative Energy.

Clean Energy: Energy sources that are replenished at a faster rate than they are consumed AND their production creates minimal or no negative effect on the environment. Some forms of renewable energy may not be very clean. For example, there are many who criticize solar energy because toxic chemicals and significant GHG are emitted during the production of solar panels. The manufacturing side of solar panels can be very “un-clean” or “un-green.”¹²⁶

Green Energy: Used interchangeably with Clean Energy.

Renewable Energy: natural energy sources that can replenish at a faster rate than they are consumed. This does not include nuclear energy.¹²⁷

Renewable energy is used to supplement fossil fuels in the production of both fuel and electricity. The primary forms of renewable energy in the U.S. are: biomass, hydropower, wind power, solar power, and geothermal.

The Types of Renewable Energy

The breakdown of all renewable energy usage by types in the U.S. as a percentage of total energy use is: Biomass – 46 percent,¹²⁸ Hydro – 24 percent, Wind –

¹²⁵ "Alternative Energy," Dictionary.com, accessed January 3, 2016, <http://dictionary.reference.com/browse/alternative-energy?s=t>.

¹²⁶ Jennifer Grayson, “Eco Etiquette: How Green are Solar Panels?” *Huffington Post*, May 25, 2011, accessed August 22, 2015, http://www.huffingtonpost.com/jennifer-grayson/eco-etiquette-how-green-a_b_554717.html.

¹²⁷ "Renewable Energy," International Energy Agency, accessed January 7, 2016, <http://www.iea.org/aboutus/faqs/renewableenergy/>.

¹²⁸ Biomass includes biomass waste (5%), biomass fuels (22%), and wood (19%).

21 percent, Solar – three percent, and Geothermal – two percent.¹²⁹ When doing the same comparison just for electricity, the percentages are: Biomass – 1.6 percent, Hydro – 7.5 percent, Wind 6.3 percent, Solar – 1.3 percent, and Geothermal – 0.4 percent.¹³⁰

Biomass

Biomass includes the burning of wood and using plants as a fuel source.

Although biomass is renewable in the sense that it is possible to grow another tree or another plant, it is not necessarily environmentally friendly. For example, it takes years to grow a tree that only takes hours to chop up and burn.

U.S. consumption of biomass and biofuel products was 46 percent of all renewable energy consumed by the end of 2016. This type of fuel saw a surge of growth of over more than 60 percent between 2002 and 2013 mostly due to the increased use of ethanol in motor fuel. Biodiesel production also saw a significant increase due to approximately 60 percent of energy in feedstocks being converted to this type of renewable energy. Biodiesel is similar to ethanol, but it is usually consumed through adding it to regular diesel fuel. Other types of biomass such as wood and waste (solid waste, landfill gas, sludge waste, agricultural byproducts, and other) are experiencing increased consumption levels. Wood is mostly used in industrial

¹²⁹ "Renewable Energy Explained," U.S. Energy Information Administration, last modified April 2017, accessed September 13, 2017, https://www.eia.gov/energyexplained/index.cfm?page=renewable_home#tab1.

¹³⁰ Ibid.

processes and waste energy is mostly used for electric generation in industry.¹³¹

Biomass fuels accounted for just over 1.5 percent of all electricity generation in the U.S. in 2016.¹³²

Hydropower

Hydropower is electricity created using the movement of water. There are several ways of doing this including running rivers and using dams to create more movement of water. The lasting ecological effects of damming rivers and creeks to create the movement are largely unknown. It is known that fish and plants are dying at high rates where extensive hydropower is exploited.

Hydropower was just surpassed at the end of 2016 by wind power and is now the second most developed renewable source of energy in the U.S. The U.S. is the fourth largest hydroelectricity producer behind China, Brazil, and Canada. The very first hydroelectric power plant in the world began operation in the U.S. in 1882 in Appleton, Wisconsin. Another hydropower plant, a massive four-year project called the Hoover Dam, was completed in 1935. It was one of the largest projects during the Great Depression, employing approximately 20,000 people. The dam supplies enough hydropower to power electric plants in California, Arizona, Nevada, Utah, and New

¹³¹ "Biofuels Production Drives Growth in overall Biomass Energy use Over Past Decade - Today in Energy," U.S. Energy Information Administration, accessed January 7, 2016, <https://www.eia.gov/todayinenergy/detail.cfm?id=15451>;

¹³² "What is U.S. Electricity Generation by Energy Source?" U.S. Energy Information Administration, last modified August 11, 2017, accessed September 11, 2017, <https://www.eia.gov/tools/faqs/faq.php?id=427&t=3>.

Mexico.¹³³ As previously mentioned, the Niagara Falls Power Plant provides a significant amount of hydropower to both Canada and the U.S. and remains the largest source of electricity for New York state.¹³⁴ In total, the U.S. has approximately 2,400 dams that produce power on a macro scale consisting of large facilities powering multiple states to those that produce power on a micro scale consisting of micro-facilities powering a single home.¹³⁵ Last month the government released the results of a research project conducted by the U.S. DOE and the Oak Ridge National Laboratory that assessed potential in the U.S. to develop new hydropower plants. "The report estimates over 65 gigawatts (GW) of potential new hydropower development across more than three million U.S. rivers and streams – nearly equivalent to the current U.S. hydropower capacity."¹³⁶ It is unlikely all this potential will be exploited, but the report highlights how much the U.S. could put more effort into developing this renewable resource. Hydroelectricity accounted for 6.5 percent of all electricity generated in the U.S. in 2016.¹³⁷ It is the renewable energy that currently generates the most electricity. With the current wind power development projects, hydroelectricity will soon be eclipsed by wind as the largest renewable electricity provider in the U.S.

¹³³ "Reclamation, Managing Water in the West," U.S. Department of the Interior, accessed 2014, May 6,

https://www.usbr.gov/projects/Powerplant.jsp?fac_Name=Hoover+Powerplant.

¹³⁴ "Niagara Power Plant," U.S. Department of Energy, accessed May 6, 2014, <http://www.nypa.gov/facilities/niagara.htm>.

¹³⁵ "Types of Hydropower Plants," U.S. Department of Energy, accessed May 6, 2014, <http://energy.gov/eere/water/types-hydropower-plants>.

¹³⁶ "Energy Dept. Report Finds Major Potential to Grow Clean, Sustainable U.S. Hydropower," U.S. Department of Energy, last modified April 29, accessed May 6, 2014, <http://energy.gov/articles/energy-dept-report-finds-major-potential-grow-clean-sustainable-us-hydropower>.

¹³⁷ "What is U.S. Electricity Generation by Energy Source?"

Wind Power

A study recently published by the U.S. DOE declared that wind energy is the fastest-growing energy source in the world.¹³⁸ By the end of 2016, the total installed wind capacity in the U.S. was just over 82,000 megawatts with wind providing enough power to the equivalent of over 25 million average American homes. Figure 7 shows how much wind energy has grown since the first wind farm was installed in the U.S. in 1981.

¹³⁸ Lee Dye, "Wind is Fastest Growing Energy Resource," *ABC News*, December 31, 2016.

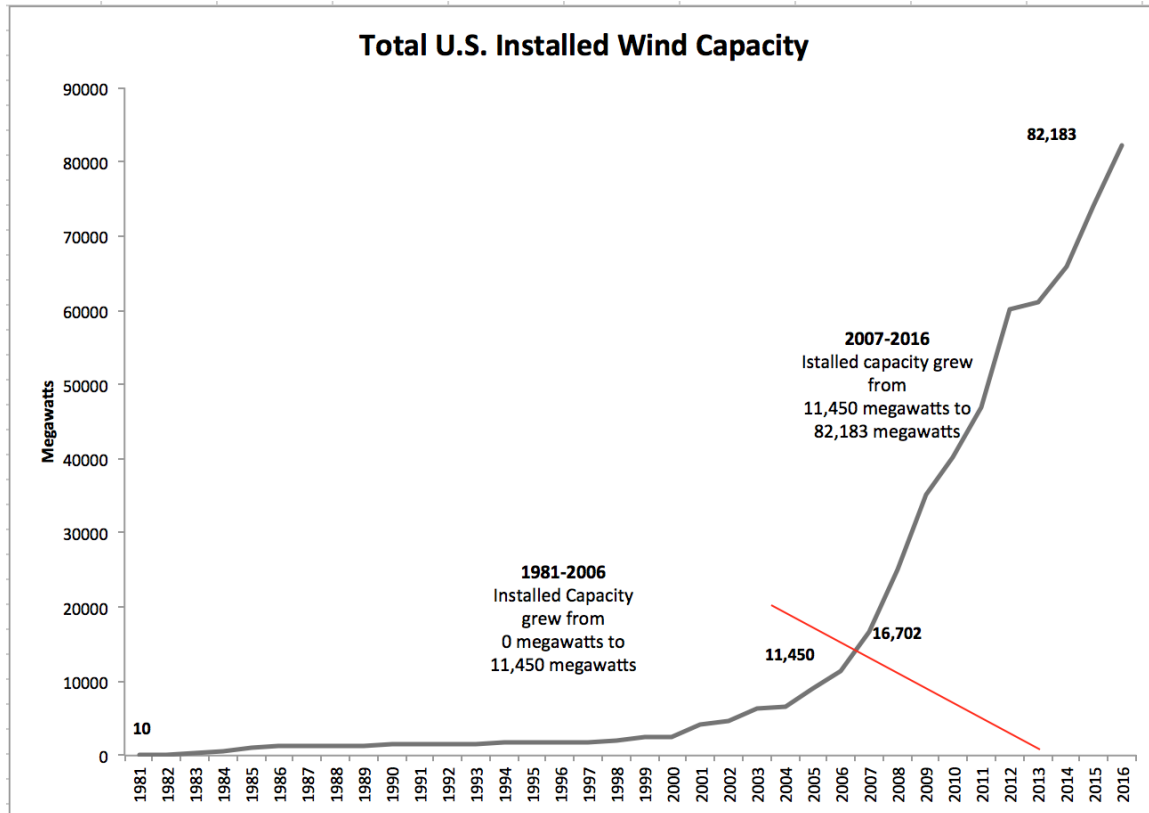


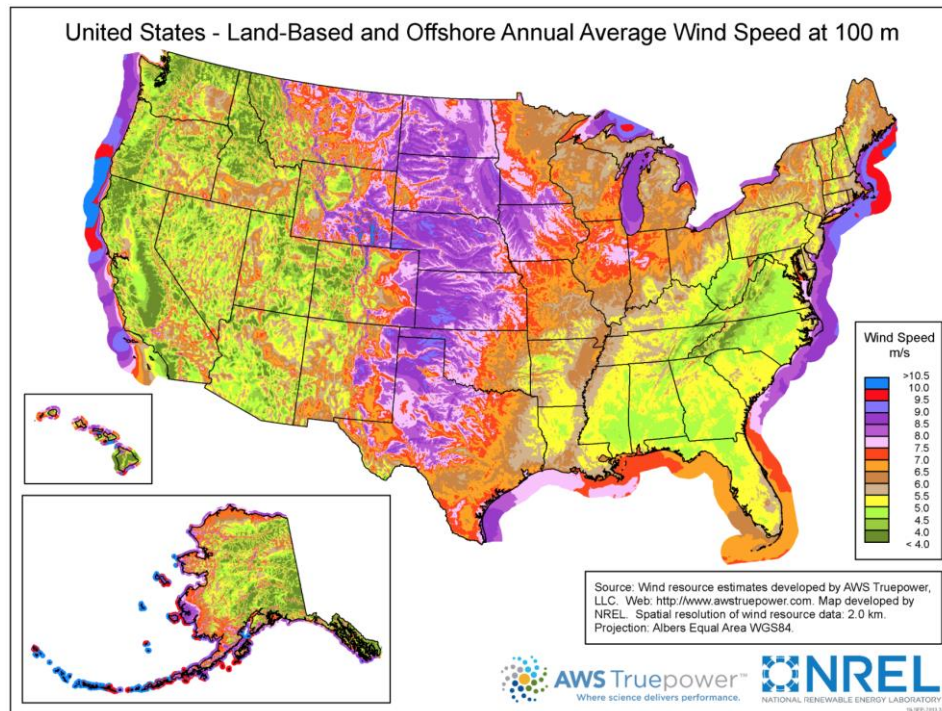
Figure 7 - U.S. Cumulative Installed Wind Energy Capacity from 1981 to 2016¹³⁹
Data Source: U.S. Energy Information Administration

Forty-one states have developed some wind power with 14 states producing more than 10 percent of their electricity from wind. However, the U.S. has only developed a small fraction of its wind potential. Scientists at AWEA estimate there is untapped potential of 10 million megawatts in land-based wind farms alone. If exploited fully, this could power the U.S. 10 times over.¹⁴⁰ The other problem with wind is that it does not blow everywhere all the time. Map 5 depicts where the wind blows the most. The windiest areas of the U.S. are depicted in blue, red, and purple. Brown, yellow, and

¹³⁹ Figure created using data sources: "Electric Power Monthly."; "Electric Power Monthly Back Issues."

¹⁴⁰ "Get the Facts," American Wind Energy Association, accessed January 3, 2016, <http://www.awea.org/Resources/Content.aspx?ItemNumber=5059>.

green are used to show where there is less wind. Just like with hydropower, wind can only be capitalized on where it already exists.



Map 5 - Where the Wind Blows Over the U.S. ¹⁴¹

Source: National Renewable Energy Laboratory

Understanding where the wind blows makes it easier to see why wind farms have been built where they are built. Most wind farms are in the middle of the U.S. where the wind blows the most. Although wind is the fastest growing form of energy in the world, wind power still has incredible room for growth in the U.S. Map 6 depicts the location of all commercial wind farms at the end of 2016.

¹⁴¹ "United States Land-Based and Offshore Annual Average Wind Speed at 100 M," National Renewable Energy Laboratory, accessed July 20, 2017, http://www.nrel.gov/gis/images/100m_wind/awstwsdpd100onoff3-1.jpg.



Map 6 - U.S. Wind Farms at the End of 2016¹⁴²

Source: American Wind Energy Association

Solar Power

Although solar power is only a small total percentage of total renewable power in the U.S., “[e]nergy harvested from the sun was the second-biggest source of new electricity generation capacity in 2013.”¹⁴³ There are large solar power projects such as the Ivanpah Solar Power Facility in California’s Mojave Desert, but the biggest market demand in this field is small-scale residential systems. Residential systems increased by 60 percent in 2012 largely because the cost of the technology dropped significantly. Certain companies created a market for the lease of solar panels, which makes the initial investment very low. Ironically, the reason the solar panels have become so inexpensive is because China’s heavy investment in this market is allowing them to put

¹⁴² "U.S. Wind Industry Map."

¹⁴³ Bryan Walsh, "A Bright Year for Solar in the U.S. – but there are Clouds on the Horizon," Time, last modified March 5, 2014, accessed January 7, 2016, <http://time.com/12952/solar-energy-surges-concern-over-china/>.

their products on the market for 15 percent cheaper than U.S. companies. People are investing in solar energy for many reasons including the federal investment tax credit (ITC) on solar power equipment which can allow those who invest to recoup as much as 30 percent of the cost of the project.¹⁴⁴ In December 2015 Congress approved the Consolidated Appropriations Acts extending the ITCs until 2020.¹⁴⁵ These tax incentives will help people and companies invest in this source of renewable energy.

Geothermal Power

Geothermal power is created using reservoirs of hot water and steam beneath the earth's surface. This is one of the least exploited renewable energy sources thus far. Two percent of renewable energy in the U.S. comes from geothermal power. The largest single source of geothermal power in the U.S. is located in California. *The Geysers* are natural steam reservoirs that were developed starting in 1921 into 15 power plants generating 725 megawatts of clean energy daily. This is enough to power a city the size of San Francisco, making it the largest geothermal plant in the U.S. Because geothermal plants do not have to wait for the wind to blow or the sun to shine, they are one of the most reliable renewable energy sources. Another benefit of the power plants at *The Geysers* is an innovative technology they use to recycle eight

¹⁴⁴ Pete Danko, "U.S. Solar Power Surges Ahead in New Report, but Tax Credit Battle Looms," National Geographic, accessed January 7, 2016, <http://energyblog.nationalgeographic.com/2014/03/06/u-s-solar-power-surges-ahead-in-new-report-but-tax-credit-battle-looms/>.

¹⁴⁵ "Business Energy Investment Tax Credit (ITC)," U.S. Department of Energy, last modified January 2016, accessed September 14, 2017, <https://energy.gov/savings/business-energy-investment-tax-credit-itc>.

million gallons of wastewater per day by pumping the water through 29 miles of pipelines into the steam reservoirs beneath the earth's surface. The steam naturally cleans the water. As of 2010, this conglomeration of geothermal plants provided 40 percent of U.S. geothermal power.¹⁴⁶ The U.S. uses more geothermal energy than any other nation in the world. It has the potential to increase this form of renewable energy to 100,000 megawatts within the next 50 years. That is enough energy to power the entirety of France when it is at its peak consumption. However, geothermal power has a large barrier and that is initial investment costs, which are hefty. The benefit of making this investment is the reliability and quick payback once a plant is functional.¹⁴⁷ The company that built the power plants at *The Geysers*, Calpine, faced bankruptcy in 2010, but they turned their situation around with innovative technologies.¹⁴⁸ Other firms seeking to invest may look at the Calpine example and either be inspired or they may decide the investment is too risky.

¹⁴⁶ Paul Lester, "Calpine: America's Largest Geothermal Energy Producer," U.S. Department of Energy, last modified October 6, 2010, accessed January 7, 2016, <http://energy.gov/articles/calpine-americas-largest-geothermal-energy-producer>.

¹⁴⁷ Ysabel Yates, "U.S. Geothermal Energy Potential is Heating Up - Renewable Energy World," Renewable Energy World, accessed January 7, 2016, <http://www.renewableenergyworld.com/articles/2012/08/u-s-geothermal-energy-potential-is-heating-up.html>.

¹⁴⁸ Lester, *Ibid*.

Power Density and the Grid

One overarching issue with wind energy is power density. “Power density refers to the energy flow that can be harnessed from a given unit of volume, area, or mass.”¹⁴⁹ The best way to understand this is to think how much space it takes to create one unit of energy. It takes a wind farm the size of Rhode Island (1,200 square miles) or cornfields the size of West Virginia (21,000 square miles) to produce enough corn ethanol (biomass) to match the amount of power that one nuclear power plant occupying 19 square miles in South Texas produces.¹⁵⁰ In a world of competing demands, trading that much land mass to create clean, renewable energy must take careful consideration.

Another problem with the use of renewable energy is how it feeds into *the grid*. The grid is the system of electrification in which electricity flows from one place to another. The U.S. has a relatively reliable grid system of electricity and Americans tap into it daily with the flick of a switch. The grid is “a web of power stations, transformers and transmission lines that span the continent, distributing electricity like veins and arteries distribute blood.”¹⁵¹ Americans are easily able to tap into the grid because large power plants run constant power to the grid. Given current technology, electricity cannot

¹⁴⁹ Robert Bryce, "The Real Problem with Renewables," Forbes.com, last modified May 11, 2010, accessed January 7, 2016, <http://www.forbes.com/2010/05/11/renewables-energy-oil-economy-opinions-contributors-robert-bryce.html>.

¹⁵⁰ Ibid.

¹⁵¹ "Power Grid must Adapt to Handle Renewable Energy: NPR," NPR, last modified March 12, 2012, accessed January 7, 2016, <http://www.npr.org/2012/03/12/148318905/renewable-energy-throws-power-grid-off-balance>.

be efficiently stored to be used later; it is used as it is produced. Although battery technology is rapidly improving, storing electricity is currently cost prohibitive.¹⁵² Generally, that means that electrical energy must be produced when demand requires it.

Renewable energy is not very consistent. For example, wind turbines produce more energy than can be used because the energy is produced on the wind's schedule.¹⁵³ Sometimes the wind does not blow, clouds block sunshine, and rivers stop flowing. One critic stated, "We've moved to a system focused on resources that provide energy when they want to."¹⁵⁴ A renewable energy advocate disagreed with this criticism and argued that planners, regulators and utility companies will not leave themselves short on capacity. He argued that the growth of renewable energy is really "changing the valuation of baseload plants."¹⁵⁵ Nuclear and coal plants cannot rapidly change their output of energy and are not much more flexible to the grid than renewable energy. Grid systems that are able to compensate for the rise and fall of renewable power generation are more flexible and that flexibility makes them more valuable.¹⁵⁶ One scientist uses a probability theorem to explain how renewable energy makes the grid more stable rather than less stable. The theorem, the Law of Large Numbers, "states that the aggregate result of a large number of uncertain processes becomes

¹⁵² "Wind Energy and Storage."

¹⁵³ Matthew L. Wald, "How Grid Efficiency Went South," *New York Times*, sec. Energy and Environment, October 7, 2014.

¹⁵⁴ *Ibid.*

¹⁵⁵ *Ibid.*

¹⁵⁶ *Ibid.*

more predictable as the total number of processes increases."¹⁵⁷ This theorem dictates that by adding additional energy-generating sources such as wind turbines and solar panels, the grid is more stable than it is using an individual generator.¹⁵⁸

Even with the stability that renewable energy provides to the grid, grids using renewable energy must have other forms of back-up energy to provide constant power. Most power plants use natural gas for back-up power. Natural gas is an ideal back up because it can be turned on and off easily. The problem is the natural gas plants are competing against the renewable plants they are backing up and gas plant revenues are declining where renewable energy plants' revenues are increasing. If the gas plant sits by idly waiting for a rainy, cloudy, or windless day, it is not a cost-effective back-up system. The decreased demand and on-call demand causes an increase in gas costs. Coal and nuclear plants are not good back-up solutions because they are costly to start and stop on short notice. There is a counter-argument to the costs of requiring back-up sources since a large power grid cannot be generated solely from renewable sources. One wind expert believes the old rules of energy and running a power grid don't apply to the use of renewable energy. He argued, "I think there are a lot of misconceptions about backup power. The reality is that all power plants are backed up by all other power plants."¹⁵⁹ Although there is validity to his argument from the macro level, power plants primarily rely on natural gas and coal as their back-up energy source.

¹⁵⁷ Robert Fares, "Renewable Energy Intermittency Explained: Challenges, Solutions, and Opportunities," *Scientific American*, sec. Plugged In, March 11, 2015.

¹⁵⁸ Ibid.

¹⁵⁹ Christopher Joyce, "Power Grid must Adapt to Handle Renewable Energy: NPR," *National Public Radio*, March 12, 2012, accessed January 7, 2016. <http://www.npr.org/2012/03/12/148318905/renewable-energy-throws-power-grid-off-balance>.

Both problems of power density and power distribution through the grid can be solved through innovation and gained efficiencies. An examination of specific case studies on the use of different forms of renewable energy will help the reader understand both potential and roadblocks to increased renewable energy.

How is Electricity Generated in the U.S.?

Natural gas, coal, and nuclear power are the most used fuels to generate electricity. As shown in Figure 8, renewable energy is the energy source for just under 15 percent of electricity in the U.S.

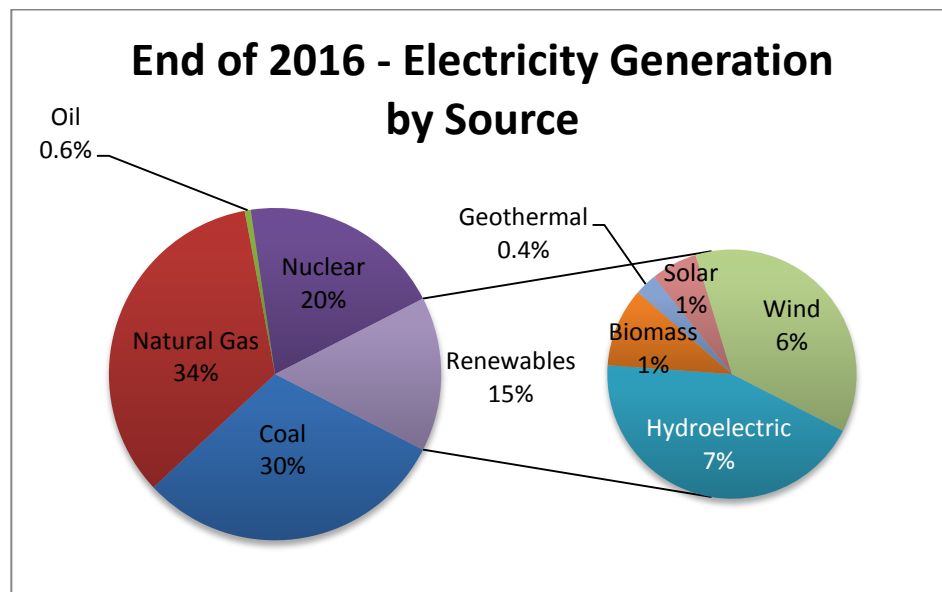


Figure 8 - U.S. Electricity Generation by Energy Source in 2016¹⁶⁰

Data Source: U.S. Energy Information Administration

¹⁶⁰ Figure created using data source: "What is U.S. Electricity Generation by Energy Source?"

Investing in renewable energy is one of the best ways to reduce harmful CO₂ emissions. Renewable energy increases have a positive direct impact on the environment. Although wind energy produced is slightly over 6.5 percent of total electricity generated in the U.S., the industry has delivered 30 percent of all new electricity generating capacity in the last five years. In windy states such as Indiana and South Dakota, wind energy is the source of over 25 percent of all electricity.¹⁶¹ The growth in wind industry has been so significant that understanding the causes of this much growth will help both the industry, policy makers, and users more aware of the possibilities of a diverse energy portfolio.

¹⁶¹ “American wind power reaches major power generation milestones in 2013,” American Wind Energy Association, last modified March 5, 2014, accessed June 14, 2015, <http://www.awea.org/MediaCenter/pressrelease.aspx?ItemNumber=6184>.

CHAPTER IV

PUBLIC OPINION

Public awareness on climate change has steadily risen since it was first assessed in the late 1960s and early 1970s. That awareness has grown even more significantly in the last decade. There has been a corresponding increase in public awareness in anthropogenic effects on the Earth and the growth of renewable energy, most notably, the growth of wind energy.

Taking a diachronic approach to evaluate the influence of public opinion on wind energy development will help demonstrate how public opinion has changed over time. This chapter will be broken down into four distinct parts. The first section will evaluate theories on how public opinion may or may not lead to policy change. The second section will evaluate the American public and its opinions on climate change. The third section will evaluate American opinions on renewable energy. Public opinions will be studied before 2007 and then evaluated for changes between 2007 and 2016. The final section will take a deeper look at the critical years just before and after 2007 to seek to determine what happened in those years that started the surge of wind energy development and what kept it going.

Why Analyzing Public Opinion Matters

Changing views of Americans on climate change and the importance of creating more renewable energy sources can have significant policy implications. Disputes over the validity of climate change vary depending on the forum in which it is being discussed. These debates often do not even reach the level of an informed policy or ideological debate mostly because few people have a deep enough understanding of the issues to suggest useful policy reforms that are beneficial for the nation.

The closest that such bipartisan engagement came was in 2009 and early 2010, when the Democratic-controlled House of Representatives narrowly passed climate legislation, which then died in the Senate after opponents mobilized, even pressuring co-sponsor Lindsay Graham to pull his support... Since the 2010 midterm elections and the emergence of the Tea Party and supportive lobbying organizations, there has been no progress in Congress.¹⁶²

According to psychological researchers, one of the biggest challenges to the conservative right believing in climate change is the perception that climate change response requires government regulatory expansion, application, or embracing of United Nations protocols on climate change. Because climate change has become so politicized, some analysts argue that without policy 'diversity,' climate science will remain highly politically polarized. They write, "The basic problem boils down to this: For

¹⁶² Terrence M. O'Sullivan and Roger Emmelhainz, "Reframing the Climate Change Debate to Better Leverage Policy Change: An Analysis of Public Opinion and Political Psychology," *Journal of Homeland Security & Emergency Management* 11, no. 3 (September, 2014), 317.

many climate skeptic and denier politicians and members of the public, any significant revision of their position on climate change is threatening to their broader sociopolitical identity, and challenging that identity often makes them that much more entrenched in their positions.”¹⁶³

Dealing with climate change in the political realm continues to be a fundamental public communications challenge. Even terminology tends to invoke different reactions. Some people promoted the issue using the term *global warming* and then others spent decades ridiculing the concept using the term as the vehicle for that ridicule. Terms such as *environmental adaptation* or *global climate disruption*¹⁶⁴ have been used in an attempt to remove the politics from the debate. Scientists have been learning how critical it is to use the right terms and find the right venues to increase public support on the issue. As the average U.S. citizen becomes more aware and more concerned about the negative effects of climate change, the question becomes, “How does that concern translate into action?”

Political scientists began evaluating the linkage of public opinion and public policy in earnest in the 1950s. Dr. H.L. Childs made one of the early linkages in the 1950s. Childs determined that “the relationship between public opinion and public policy varies greatly from issue to issue. The influence of public opinion varies from virtually no

¹⁶³ O'Sullivan and Emmelhainz, "Reframing the Climate Change Debate to Better Leverage Policy Change: An Analysis of Public Opinion and Political Psychology," 325.

¹⁶⁴ See: "What's in a Name? Global Warming Vs. Climate Change," National Aeronautics and Space Administration, last modified Unknown, accessed September 21, 2017, <https://pmm.nasa.gov/education/articles/whats-name-global-warming-vs-climate-change>.; "Glossary of Climate Change Terms," U.S. Environmental Protection Agency, last modified August 9, 2016, accessed September 21, 2017, <https://www3.epa.gov/climatechange/glossary.html>.

influence to enormous influence.”¹⁶⁵ Childs also came to the conclusion that the “extent of the influence depends on a number of factors including: the degree of agreement within the public; the intensity with which opinions are held; and the extent of organized support for and against public position.”¹⁶⁶ The field of study on this has grown, and many more models and studies have been conducted to assess the relationship between public opinion and public policy. Dr. Norman Luttbeg framed a useful set of models. His five models are: the Rational-Activist Model, the Political Parties Model, the Pressure Group Model, the Belief-Sharing Model, and the Role-Playing model. Luttbeg stated that it is important to have a way to systematically distinguish between the models to help explain leader-follower linkages in a democratic society.¹⁶⁷

The Rational-Activist Model is when voters use elections to tell candidates how they want them to conduct business while in office and what issues are important to them. This model assumes voters are informed on the issues, that they are rational, and, most importantly, voters must be politically active in the issue.¹⁶⁸

Luttbeg’s second model is the Competitive Political Parties Model. This model is defined where the political parties act as the intermediary between the public and the elected officials. The public holds the party responsible and the party exerts pressure on the politicians to create and vote on policies for the good of the party.¹⁶⁹

¹⁶⁵ H. L. Childs, *Public Opinion: Nature, Formation, and Role* (New York, NY: Van Nostrand Reinhold Inc., 1965), 18.

¹⁶⁶ Ward, *The Role of Saliency on the Relationship between Public Policy and Public Opinion*, 1.

¹⁶⁷ Norman R. Luttbeg, *Public Opinion and Public Policy: Models of Political Linkage* (Homewood, IL: Dorsey Press, 1968), 6.

¹⁶⁸ *Ibid*, 11.

¹⁶⁹ *Ibid*, 77.

The Pressure Groups Model is Luttbeg's third model. This model theorizes that politicians respond to public opinion especially when there is a strong constituency in favor of the issue. The model posits that there is strength in both numbers and resources when attempting to influence a politician. Groups such as labor unions and interest groups have more influence on politicians than do individual voters.¹⁷⁰ Scholars have said that the "the most common objection to the claim that public opinion influences public policy is that policy is really determined by interest organizations, political parties, and elites, particularly economic elites."¹⁷¹

Next is the Belief-Sharing Model, which hypothesizes that politicians may listen to the public who elected them, but they are most likely to listen close to election times. For example, a conservative politician who is generally more conservative than his/her constituency will vote according to his/her conservative beliefs until it is election time. During election periods the politician is more likely to vote according to the desires of the constituency. The rest of the time the politician is likely to vote according to his/her own beliefs.¹⁷²

The final model is the Role-Playing Model. In this model, the elected official does what he/she thinks is best for the constituency. Politicians anticipate the desires of their public and proactively act the way they think their public wants them to act.¹⁷³

To do anything other than an objective look at how Luttbeg's five models would apply to both climate change and politics, and renewable energy development and

¹⁷⁰ Ibid, 119.

¹⁷¹ Burstein, *The Impact of Public Opinion on Public Policy: A Review and an Agenda*, 29-40.

¹⁷² Luttbeg, *Public Opinion and Public Policy: Models of Political Linkage*, 245.

¹⁷³ Ibid, 245.

politics, is beyond the scope of this dissertation. As interesting as those subjects are, they would be full works unto themselves. With that in mind, it still helps to make an objective analysis based on the validity of the data available.

Luttbeg's first model, the Rational-Activist Model, does not fit well in the issue of climate change and the increased production of renewable energy because of the inconsistency of the public's opinion on climate change and the varying levels at which the public values renewable energy growth. The polling data that will be shown later in this chapter will highlight the inconsistencies of public opinion even though the opinion became relatively stable by the end of 2016 with 70 percent of Americans believing in climate change. Given the high number of Americans who believe in climate change, one would think that there would be a high demand for action from citizens. However, there are decades of research on how much ordinary citizens know about political matters. The results are resounding: citizens know very little.¹⁷⁴ Even with the majority of citizens believing in climate change, the willingness or knowledge of those same citizens to demand change through politics has not been evident as it has through lobbies, action groups, or political parties.

Given the increasingly bipartisan political climate over the last few decades, it is likely that the Political Parties Model accurately represents what frequently occurs in the U.S. The controlling party has great influence on policy. This model would be strongest when the president's political party control controls both the House and the Senate. Even though there is likely some validity to this model, there are also some public policy

¹⁷⁴ Visser, Holbrooke and Krosnick, *Theories of Public Opinion Formation and Change; Knowledge and Attitudes*, 123-140.

successes that can be attributed to partisan desires to increase jobs and improve economic stability. Those mutual goals have led to some policy advances that directly contributed to growth in renewable energy, specifically wind energy.

Given the strength of the lobbies by the big energy companies, it is likely there is validity that the Pressure Group Model is applicable when evaluating the impact of public opinion on policy formation. For example, the American Wind Energy Association is one of the largest lobbyists for renewable energy.¹⁷⁵ Given the diachronic nature of this dissertation, it is interesting that the level of lobbyist spending for increased investment in alternative energies jumped dramatically between 2006 and 2008 during the presidential election cycle. In 2006 the levels were relatively even between the Democratic and Republican parties with around \$250,000 in contributions to each party. In 2008, the contributions made to the Democrat Party by Alternative Energy lobbyists skyrocketed to almost \$1.8 million. The number also doubled in contributions to the Republican Party, with a total of just under \$600,000. That is still one-third of what was contributed to the Democrats.¹⁷⁶ This demonstrates the validity of the Pressure Group Model. It also demonstrates that clean energy lobbyists believe they are more likely to have success when the Democrat party has control of the executive and legislative branches of government.

Without empirical data and an empirical study, it is hard to assess the validity of both the Belief-Sharing Model and Role-Playing Model in this topic area. It would take

¹⁷⁵ "Alternative Energy Production and Services," Open Secrets.org: Center for Responsive Politics, accessed September 21, 2017, <https://www.opensecrets.org/industries/indus.php?ind=E1500>.

¹⁷⁶ Ibid.

significant efforts, research, data collection, and statistical models to determine if elected politicians voted according to their beliefs, as a reflection of their constituency's desires, or if they are proactive in trying to represent predictions on what their public may want. The ability to evaluate these models is outside the scope of this work.

Only two of Luttbeg's five models are applicable in this study without a detailed empirical study of the subject areas. They are the Pressure Group Model and the Political Parties Model. There is easily accessed information that shows the validity of these two models.

Public Opinion on Climate Change

Before 2007

American awareness of what we now call *climate change* largely began surfacing in the 1970s. Several activities highlight this awareness. On April 22, 1970 the U.S. held its first *Earth Day*. On that day, 20 million Americans took to the streets, parks, and other venues to demonstrate their growing concern about the environment. These activities pushed the environmental agenda to the forefront of the media and politics.¹⁷⁷ President Nixon also established both the U.S. National Oceanic and Atmospheric Administration (NOAA) and the U.S. Environmental Protection Agency

¹⁷⁷ "Earth Day: The History of a Movement | Earth Day Network," Earth Day Network, last modified January 5, 2016, accessed January 10, 2016, <http://www.earthday.org/earth-day-history-movement>.

(EPA) in 1970.¹⁷⁸ NOAA has become the world's leading funder of climate research and although the EPA was established to deal with human health risks to pollutants such as smog, its establishment helped draw attention to the ways human behavior was negatively affecting the planet.

During this same time, President Nixon lifted import restrictions on oil and American oil imports doubled between 1970 and 1973. Most of the oil came from the Organization of the Petroleum Exporting Countries (OPEC). In response to the U.S. support for Israel in the Yom Kippur War, OPEC began an oil embargo against the U.S.¹⁷⁹ This embargo started the first U.S. energy crisis. These details are important because they greatly affected Americans' view of energy usage, and although they do not tie in directly to views on climate change, they do impact the public's desire to develop alternate fuel sources. Additional points about how oil prices and imports affect the growth of the renewable energy sector will be made later in Chapter 8. The timing of the oil crises juxtaposed over the growing awareness of climate change helped catapult public awareness on the usage of fossil fuels and the negative effects of CO₂ emissions.

By the beginning of the 1980s, the question of climate change had become prominent enough that public opinion polls on it began to surface. A 1981 poll showed

¹⁷⁸ See: "NOAA Legacy," National Oceanic and Atmospheric Administration, last modified June 8, 2006, accessed September 20, 2017, <http://www.history.noaa.gov/noaa.html>.; "EPA History," U.S. Environmental Protection Agency, accessed September 20, 2017, <https://www.epa.gov/history>.

¹⁷⁹ Meg Jacobs, "America's Never-Ending Oil Consumption," *The Atlantic*, May 15, 2016, <https://www.theatlantic.com/politics/archive/2016/05/american-oil-consumption/482532/>.

that almost one-third of all adults in America had heard of the greenhouse effect. “When pollsters explicitly asked people what they thought of ‘increased carbon dioxide in the atmosphere leading to changes in weather patterns,’ nearly two-thirds replied that the problem was ‘somewhat serious’ or ‘very serious.’”¹⁸⁰ However, a deeper understanding of the relationship between CO₂ emissions and the burning of fossil fuels was not widely understood for many more years.

Climate change models started rapidly improving in the 1980s and modelers started saying, with confidence, that global warming was occurring. They predicted an increase of a few degrees across the globe in the 21st century. Although a few degrees sounded trivial to the regular citizen, scientists understood the significance of the warming trend. With models demonstrating the possible effects of the warming trend, climate scientists became more aware of the detrimental effects of increased CO₂ emissions, and even slight temperature rises on the planet. The models improved and more groups and institutions studied the problem.¹⁸¹ For example, a 2004 NASA study estimated that it would only take a rise of three degrees Celsius to melt the ice cap in Greenland.¹⁸² The melting of the ice cap would put the world’s coastal cities underwater. As the scientific community became more aware of the issues surrounding climate change, it was more frequently discussed in public forums. The more the public became aware of what climate change was doing to the planet, the more the issue was

¹⁸⁰ Spencer R. Weart, *The Discovery of Global Warming*, Revised and Expanded Edition ed. (Cambridge, MA: Harvard University Press, 2008), 112-113.

¹⁸¹ Ibid.

¹⁸² Kendall Haven, "Greenland's Ice Island Alarm," *NASA Earth Observatory*, sec. Features, August 28, 2007.

discussed publicly.¹⁸³ Even though awareness was raised, there is little polling data about public opinion on climate change before 2007. This has changed dramatically as people in the U.S. and around the world are more concerned about anthropogenic effects on the earth.

2007 to 2016

Polling results from 2007 to 2016 show Americans were as concerned about environmental issues as other national security threats. Before the economic downturn of 2008, a full 70 percent of Americans believed there was solid evidence that Earth's temperatures were rising – that global warming was occurring. However, by late 2009, that number had dropped to 57 percent, a 14 percent drop within 18 months.¹⁸⁴ That percentage of Americans has steadily risen to the early 2008 levels and the overall percentage of Americans believing in anthropogenic-driven climate change has remained relatively stable since then. The most recent surveys show that Americans' belief in global warming climbed back up to 70 percent and it stayed there for four years between 2012 and 2016. Approximately half of Americans think the changing climate is a very serious threat and half also think climate change is mostly caused by human behavior.¹⁸⁵

¹⁸³ Weart, *The Discovery of Global Warming*, 112-113.

¹⁸⁴ "Fewer Americans See Solid Evidence of Global Warming."

¹⁸⁵ See: Leiserowitz et al., *Climate Change in the American Mind: March, 2016*.; Anthony Leiserowitz et al., *Climate Change in the American Mind: May 2017* (New Haven, CT: Yale Program on Climate Change Communication and George Mason University Center for Climate Change Communication, 2017).

Several notable points are easily distinguishable from aggregating polling data.¹⁸⁶ First, most Americans believe in climate change. However, the belief in anthropogenic causes of climate change varies when key demographics and political party affiliation are reflected. Second, most Americans, unlike the people of most developed nations around the world, do not believe climate change is a major threat to national security.

Figure 9 depicts some of the views on climate change broken down by key demographics and shows that there are clear lines of beliefs.

¹⁸⁶ Aggregating survey results from Pew Research Center, Gallup Polls and Yale and George Mason University research centers on climate change.

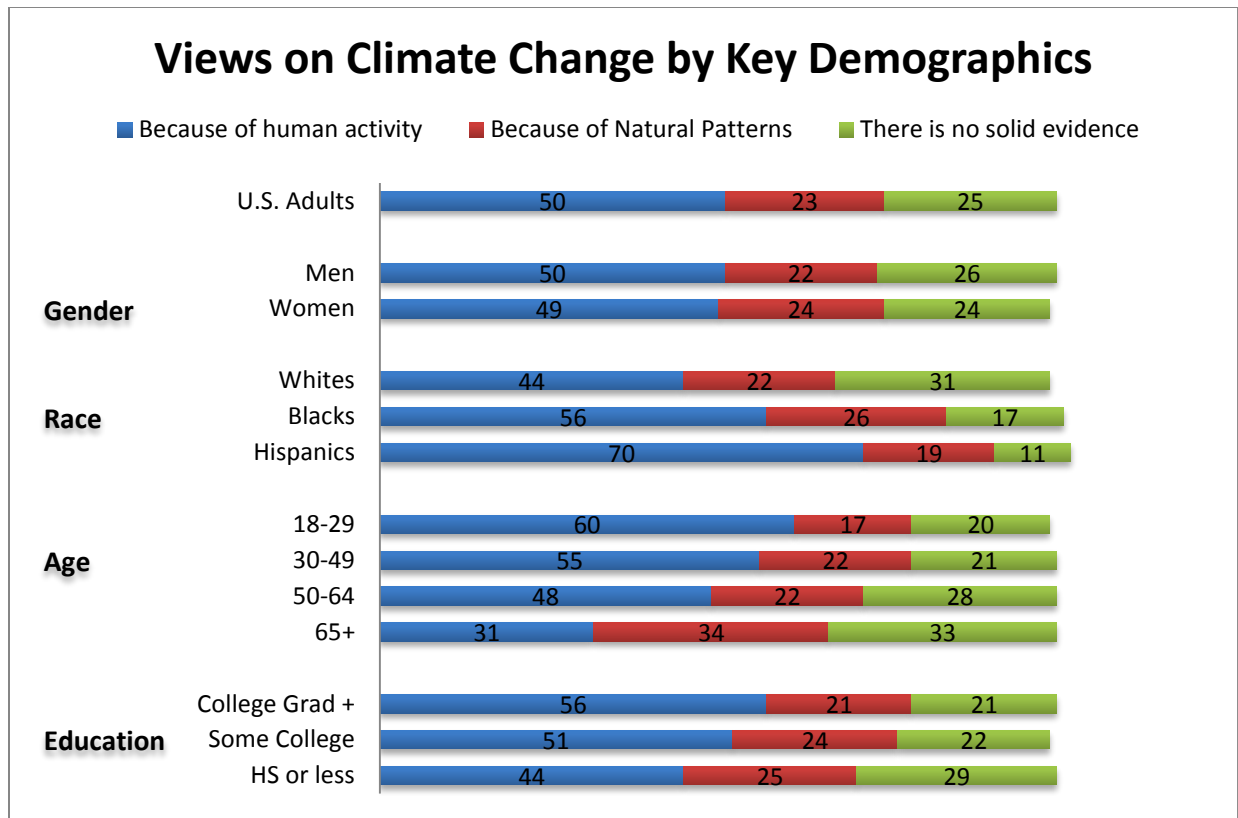


Figure 9 - Views on Climate Change by Key Demographic¹⁸⁷

Data Source: Pew Research Center

The beliefs of men and women are very close, but the above polling data shows there is a sharp divide between Whites (44 percent), Blacks (56 percent) and Hispanics (70 percent).¹⁸⁸ Researchers trying to understand why Hispanics are more convinced that climate change has anthropogenic causes have found that they are more worried about its effects on the planet and offer more support for policies to reduce its effects than any other demographic group in the U.S.¹⁸⁹ Studies show that Hispanics are most

¹⁸⁷ Figure created using data source: "Views on Climate Change, by Key Demographics."

¹⁸⁸ Ibid.

¹⁸⁹ "Engaging Latinos in the U.S. on Climate Change," Yale Program on Climate Change Communication, last modified November 1, 2016, accessed March 4, 2018,

concerned because they are especially vulnerable to the negative effects of climate change due to where they tend to live and work. The majority of Hispanics live in states that are among the most affected by extreme heat, air pollution, and flooding, such as California, Texas, Florida, and New York. Hispanics also make up the single biggest population that works in crop growing, livestock production, and construction. They are three times more likely to die from excessive heat than any other population group. Finally, they generally have less health insurance than other Americans, so they have less access to health care when afflicted by climate-related illnesses.¹⁹⁰ One study stated, "Latinos are at Ground Zero for climate impacts."¹⁹¹

There are also clear gaps in beliefs between age ranges with younger adults believing more strongly in climate change (60 percent), with the group believing the least in climate change falling in the 65 and over age range (31 percent).¹⁹² This is likely because younger Americans grew up surrounded by knowledge on climate change, whereas older Americans were not exposed to this knowledge until the 1970s when it became more clear what the effects of the industrial revolution were doing to the planet.

Those with higher levels of education believe more in the correlation of human behavior on the environment (56 percent) than those with some high school attendance (44 percent).¹⁹³ This is likely due to the fact that those who have more education are

<http://climatecommunication.yale.edu/about/projects/engaging-american-latinos-climate-change/>.

¹⁹⁰ "NRDC Report: Latinos are especially Hard-Hit by Climate Change," National Resources Defense Council, last modified October 13, 2016, accessed March 4, 2018, <https://www.nrdc.org/media/2016/161013>.

¹⁹¹ Ibid.

¹⁹² "Views on Climate Change, by Key Demographics."

¹⁹³ Ibid.

more likely to understand the causes and negative effects of GHG emissions on the climate while also understanding how rising global temperatures are wreaking havoc across the globe through effects such as sea rise and extreme weather fluctuations.

Another important distinction when evaluating public opinion on climate change is political party affiliation. Figure 10 highlights some of the key differences. The polling data shows that Democrats are most likely to be worried about global warming, that global warming has anthropogenic causes, and that global warming will harm Americans. Republicans are much less concerned about global warming and its effects on their lives.

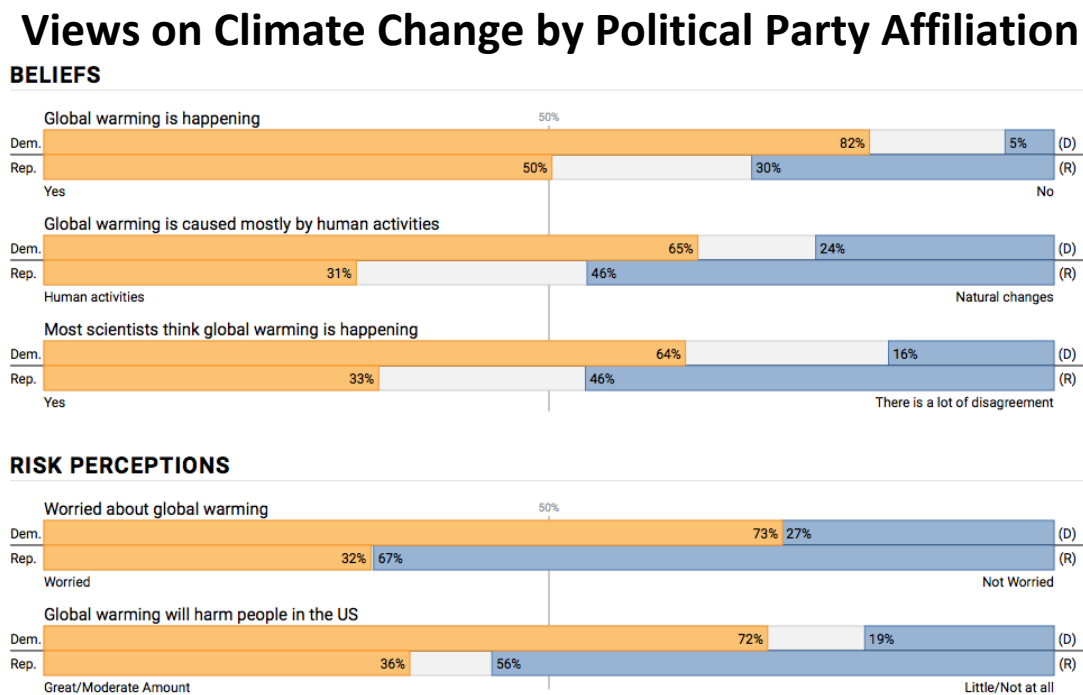


Figure 10 - Views on Climate Change by Political Party Affiliation¹⁹⁴
Source: Yale Program and George Mason Center on Climate Change Communication

¹⁹⁴ "Public Opinion Estimates, United States, 2016."

In summary, polling data shows that Hispanics, younger adults, Americans with more education, and Democrats are most likely to believe human behavior is detrimental to the environment such that global climates are shifting.

Americans do not just differ on opinions domestically. The gap is closing, but American opinions on the threat of climate change to national security have been noticeably lower than the opinions of citizens in other nations. Figure 11 shows that American opinions are changing, but Americans still are not quite as concerned about climate change as people across the globe. In just two years the number of Americans *very concerned* about the threat of global climate change grew from 40 percent to 56

percent. Surveys from both 2014 and 2017 depicting the perception of the biggest national threats are shown in Figure 11.

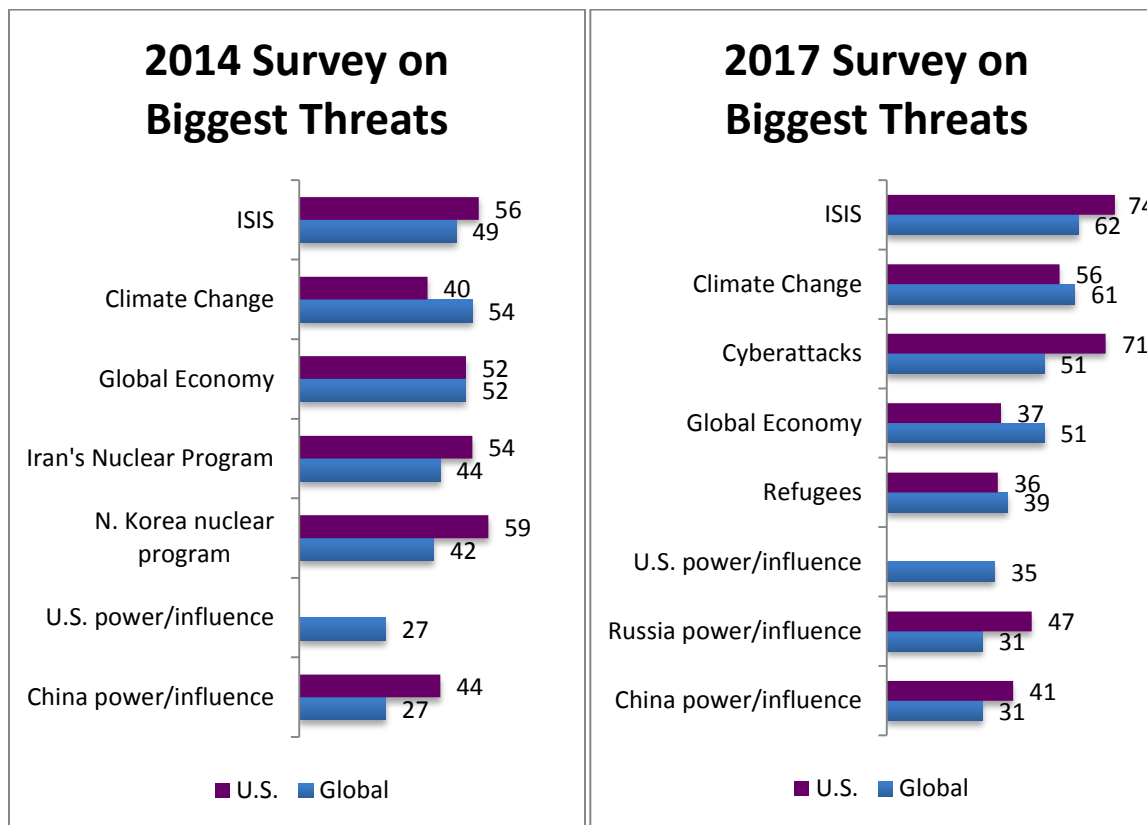


Figure 11 - 2014/2017 Polling Data on Public Perception of Global Threats¹⁹⁵
Data Source: Pew Research Center

¹⁹⁵ Figure created using data sources: Richard Wike, "Many Around the World See Climate Change as a Major Threat," Pew Research Center, March 31, 2014.; Jacob Poushter and Dorothy Manevich, "Globally, People Point to ISIS and Climate Change as Leading Security Threats," Pew Research Center, sec. Global Attitudes and Trends, August 1, 2017.

In the latest survey Americans were most concerned about ISIS, with cyber-attacks from other nations close behind. People in other nations also believe ISIS is the biggest threat, but climate change was perceived as the next biggest threat.

Section Summary

This section has highlighted how U.S. citizens have become more concerned about the changing climate once conclusive scientific data became more publicly available. Awareness of the problem became visible by changes in American behavior, displays of public support, and governmental policy changes in the 1970s. Awareness ebbed and flowed but grew steadily until the 2007-2008 years with a big drop after the 2008 economic crisis where Americans had far greater immediate concerns. As the economy recovered, American attitudes on climate change leveled back out, holding steady at the rate of 70 percent. The next section will evaluate how public opinion about the development of renewable energy has also changed.

Public Opinion on Renewable Energy and Wind Energy

Before 2007

With Americans becoming more aware of the effects of harmful GHG emissions in the 1970s and 1980s, there was a shift in energy supply preferences. At the time, Americans preferred a national energy policy that emphasized energy efficiency and demand reduction. Surveys provided considerable evidence that if price was not a

factor, and increased efficiency was being achieved, the American public supported the development of renewable energy. A 1987 poll asked respondents which energy they would like to see developed to reduce the reliance on foreign oil and 54 percent selected solar energy, 30 percent selected hydropower, 22 percent selected wind power, and 16 percent selected energy created from ocean tides. These surveys concluded that the public trend toward supporting renewable energy was steady even if actual development in this time frame was not reflective of public willingness to support these renewable energies.¹⁹⁶

A study published in 2000 found that the public's concern over the environment did not translate into a heightened knowledge of renewable energy. Survey respondents who exhibited a very high level of concern for the environment (above six on a seven-point scale) had very little understanding of renewable energy (scoring in the threes on the same seven-point scale).¹⁹⁷ It is hard to get people to support something they do not understand. This study demonstrated the increasing concern about the environment, but the respondents did not necessarily see renewable energy development as a way to address these concerns.

Another study that looked at public opinions across multiple nations determined that there was a broad base of support for wind energy in this time frame, but that people did not have the same support in the development of wind power projects. They

¹⁹⁶ Barbara C. Farhar, *Trends in Public Perceptions and Preferences on Energy and Environmental Policy: Executive Summary* (Golden, CO: National Renewable Energy Laboratory, 1993).

¹⁹⁷ Hae-Kyong Bang et al., "Consumer Concern, Knowledge, Belief, and Attitude Toward Renewable Energy: An Application of the Reasoned Action Theory," *Psychology & Marketing* 17, no. 6 (June, 2000), 449-468.

liked the idea of greater wind power capacity, but not the idea of more wind farms. This hesitation is also known as the *Not-In-My-Back-Yard*, or NIMBY, syndrome.¹⁹⁸ Although generally positive, other noted disadvantages of wind power were noise pollution, spoiled scenery, interference with natural habitats, unreliability of wind, and the expense of developing wind projects.¹⁹⁹

Overall, studies conducted before 2007 concluded that Americans were becoming more aware of the negative anthropogenic effect on the environment. This awareness led to a growing knowledge of the advantages of developing renewable energy. People perceived these sources as environmentally advantageous especially when compared with traditional energy sources such as coal and nuclear energy.²⁰⁰

2007 to 2016

Although recent polls show that the vast majority of Americans want a variety of renewable energy sources developed, there are contrasts of opinion when citizens are assessed along party lines and age. The first difference can be found based on political party affiliation. Overall, 83 percent of Americans support the development of more wind farms with 93 percent of Democrats supporting further development and 75 percent of Republicans supporting the same.²⁰¹ In contrast, when asked where development

¹⁹⁸ Maarten Wolsink, "Wind Power and the NIMBY-Myth: Institutional Capacity and the Limited Significance of Public Support," *Renewable Energy* 21 (2000), 49-64.

¹⁹⁹ Ibid.

²⁰⁰ Barbara C. Farhar, "The Polls - Poll Trends: Public Opinion about Energy," *Public Opinion Quarterly* 58, no. 4 (January 1, 1994), 603-632.

²⁰¹ Cary Funk and Brian Kennedy, "Public Opinion on Renewable and Other Energy Sources," *Pew Research Center*, sec. Internet and Technology, October 4, 2016.

priorities should be, 81 percent of Democrats believe renewable resources should have the priority of development while only 45 percent of Republicans believe renewables should have priority over fossil fuels. This gap stayed relatively consistent across the last five years of available polling data. Within their parties, the Democrats fairly consistently believe that renewables should have priority while Republicans are sharply divided. Fifty-four percent of conservative Republicans believe fossil fuels should have development priority while 33 percent of conservative Republicans believe renewables should have priority. This divide is greater among moderate Republicans with 28 percent of moderates believing fossil fuels should have priority and 65 percent of moderate Republicans believing renewables should have priority. Among moderate Republicans, the support to develop renewable energy is closer to Democrats than it is to conservative Republicans. These numbers are depicted in Figure 12.

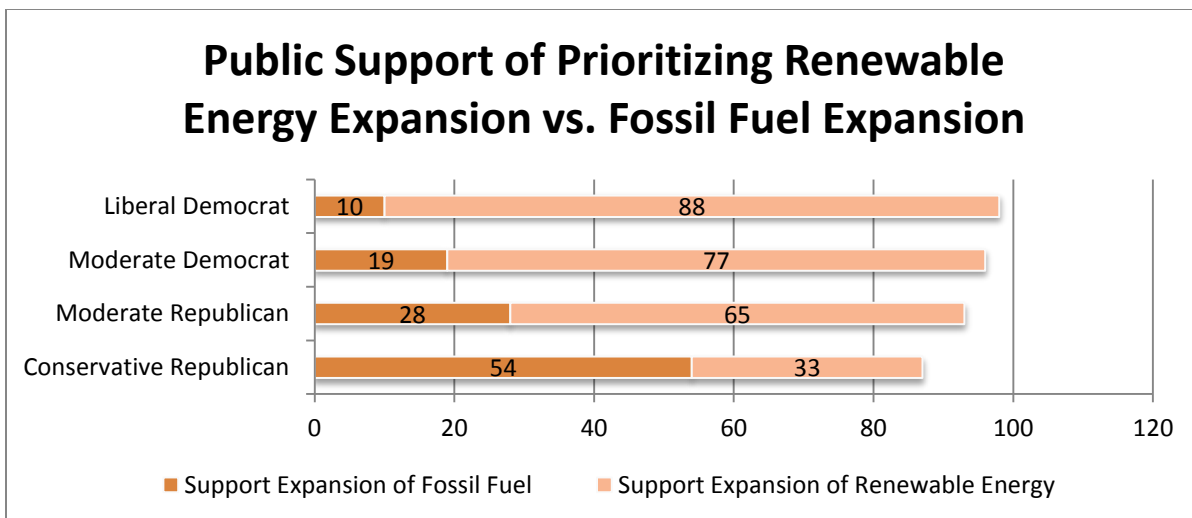


Figure 12 - 2017 Public Support of Energy Expansion²⁰²
Data Source: Pew Research Center

The divide among priorities is also significant when broken down by age. As depicted in Figure 13, younger Americans are much more likely to prioritize the expansion of growth in renewable energy than they are the expansion of fossil fuels.

²⁰² Figure created using data source: Brian Kennedy, "Two-Thirds of Americans Give Priority to Developing Alternative Energy Over Fossil Fuels," *Pew Research Center*, sec. Fact Tank: News in the Numbers, January 23, 2017.

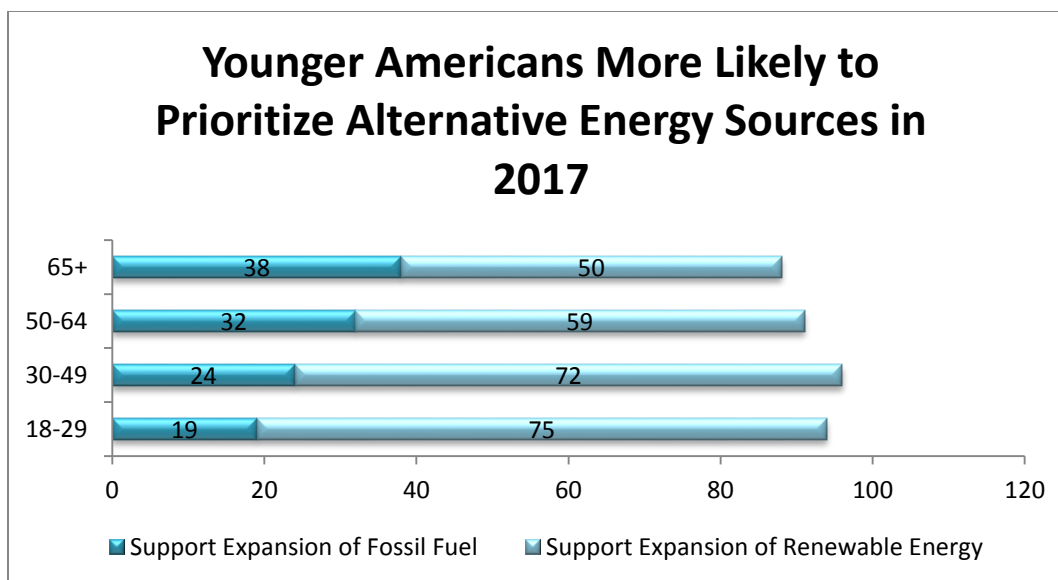


Figure 13 - Views on Prioritization of Renewable Energy Growth by Age²⁰³
Data Source: Pew Research Center

Although most Americans believe wind energy growth is a good thing, there are small pockets of opposition from both environmentalists who are concerned about the effects of wind farms on ecosystems and from people concerned about negative health effects on humans. There are many unanswered questions on how wind turbines affect wildlife and the ecosystems around them. One of the biggest voices of opposition against wind turbines has been due to the number of bird deaths attributed to them. Approximately 140,000 to 328,000 birds are killed each year by turbines. Because of this, the National Audubon Society once called wind turbines the most threatening form of renewable energy.²⁰⁴ Nobody disputes the number of birds killed. Facts are facts, but counterarguments tend to be effective. One recent study compared estimated turbine-

²⁰³ Figure created using data source: Kennedy, "Two-Thirds of Americans Give Priority to Developing Alternative Energy Over Fossil Fuels."

²⁰⁴ Bryce, *Will Wind Turbines Ever be Safe for Birds?*

related bird deaths at 1.4 billion, to the number of birds killed annually by cats at 3.7 billion.²⁰⁵ The comparison has been used to show that the natural food chain reduces bird populations much more than wind turbines.

Conservation groups criticize government policies promoting wind energy growth, but counterarguments focus on the importance of addressing climate change. Although the Audubon Society called turbines dangerous, it recently released a report highlighting how climate change is much more of a threat to birds than are wind turbines. The Audubon Society emphasized that many species of birds are at serious risk, because there are forecasts showing that those species will lose more than 95 percent of their current habitats because of climate change. The Audubon Society lauds growth of the renewable energy as the best way to reduce the impacts of climate change. By working closely with the government, they are helping create guidelines for wind power to minimize harm to wildlife.²⁰⁶ Generally, when environmentalists compare negative effects of wind turbines to the positive gains to the environment due to decreased GHG emissions, they choose to support wind energy growth.

In addition to complaints about the threat of wind turbines to wildlife, there are also complaints that wind turbines harm humans who reside within close proximity to the turbines. Although there have been no conclusive scientific studies on the negative effects, *wind turbine syndrome* is blamed for symptoms such as disturbed sleep, ear problems, headaches, irritability, and loss of cognitive function. Dr. Nina Pierpont, a medical doctor who studied the effects of wind turbine noise on humans, concluded that

²⁰⁵ Wendy Koch, "Wind Turbines Kill Fewer Birds than do Cats, Cell Towers," *USA Today*, sec. Money, September 15, 2014.

²⁰⁶ *Ibid.*

“infrasound—noise at frequencies below the level of human hearing—could be interfering with the balance organs of the inner ear and causing people’s internal organs to vibrate.”²⁰⁷ However, the available scientific evidence finds that wind turbines are not likely to affect human health.²⁰⁸ Through careful consideration to future development, negative effects on both animals and humans can be mitigated.

To contrast these arguments against wind energy growth is a 2016 survey in which 83 percent of Americans said they support expanding the number of wind turbine farms.²⁰⁹ This illuminates the fact that the pockets of opposition to this form of renewable energy are extremely low. To dissect this even further, of the 83 percent of Americans who support expanding wind farms, party affiliation is not as influential as it is in understanding what audiences believe in anthropogenic climate change. Seventy-five percent of the most conservative group of Americans believes in expanding wind energy. That increases all the way up to 93 percent of liberal Democrats who support increasing wind energy in the U.S. The only type of energy that is even more publicly accepted than wind energy is solar energy, with 89 percent acceptability.²¹⁰ The survey results are depicted in Figure 14.

²⁰⁷ Amy Crawford, "Bad Vibes in Kingston, Mass." *Boston Magazine* (January 28, 2014), <http://www.bostonmagazine.com/news/article/2014/01/28/wind-turbines>.

²⁰⁸ Loren D. Knopper et al., "Wind Turbines and Human Health," *Front Public Health* 2, no. 63 (May 13, 2014), 1-20.

²⁰⁹ Funk and Kennedy, *Public Opinion on Renewable and Other Energy Sources*.

²¹⁰ *Ibid.*

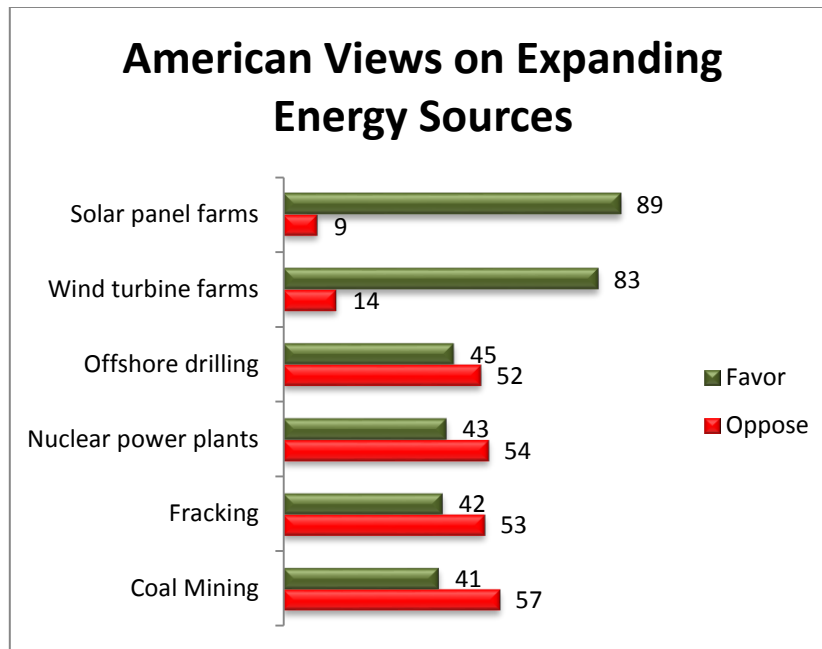


Figure 14 - Percent of U.S. Adults Who Say They Favor or Oppose Expanding Energy Sources²¹¹

Data Source: Pew Research Center

Overall, American perceptions of the value of adding renewable energy sources have shifted considerably in the last ten years. One report states, “Ten years ago people widely acknowledged the potential of renewable energy, but large-scale deployment still had to be demonstrated. Now 10 years on, continuing technology advances and rapid employment of many renewable energy technologies – particularly in the electricity sector – have amply demonstrated their potential.”²¹²

²¹¹ Figure created using data source: Ibid.

²¹² Christine Lins et al., *10 Years of Renewable Energy Progress* (Paris, France: REN21: Renewable Energy Policy Network for the 21st Century, 2014).

Section Summary

American public opinion on the importance of increasing renewable energy has changed, and most Americans recognize the need to diversify to protect the environment. It is interesting how public opinions can change when faced with domestic economic problems like they did in 2008. It is also interesting that public opinions change when evaluated by demographic. A better understanding of this could help both lobbyists and politicians target specific groups to increase support for wind energy development.

The Critical Years

The U.S. public opinion toward climate change was foundationally strong by 2002. At that time, approximately 71 percent of all Americans believed that climate change was a problem. This number grew steadily until 2008.²¹³ During the critical years when the wind energy industry saw significant growth, public opinion was strongly behind ways to mitigate climate change. However, when contrasting strong public opinion on climate change with an interpretation that the reelection of President George W. Bush in 2004 was a moratorium against renewable energy, there was an anticipation that Bush would not be good for the wind industry. Those in the renewable energy industry quickly reversed that opinion when government policies supporting renewable

²¹³ Jon Greenberg, "Scarborough: Americans have Cooled on Climate Change," *PunditFact*, sec. Articles, May 13, 2014.

energy were extended under the Bush Administration. At the same time, oil prices were soaring to new highs, which also helped drive public opinion in favor of promoting renewable energy sources. All these factors aligned at the right time during the most critical years starting about 2002. Between growing concern about climate change, a presidential administration that helped promote renewable energy growth, and rising oil prices, public opinion solidified to back the growth of the wind industry.

Chapter Summary

Though there are decades of studies on how public opinion affects the formation of policy, the two most applicable models come from influence of the political parties and special interest groups. Public opinion helped influence the growth of the wind industry. Although public opinion varies by demographic, there was enough consistent support behind wind energy development to make a difference. These factors all aligned in the critical years leading to a wind industry boom that started in 2007 and continued through 2016. The following chapter evaluating the presidential leadership will help illuminate the influence of the public on presidential administrations and how those administrations created policies to increase or decrease the viability of renewable fuel sources.

CHAPTER V

PRESIDENTIAL LEADERSHIP

The core descriptive word in the title of this chapter is *leadership*. When researching the definition of leadership, or more importantly, traits that make a good president, there are no succinct answers. The Merriam-Webster dictionary defines leadership as the *capacity to lead* or the *act or an instance of leading*.²¹⁴ This is not very helpful when seeking answers on what traits the best presidents possess. Aggregating multiple sources, the best traits for a U.S. president to possess are political skill, ability to manage, persuasiveness, an even temperament, flexibility, consistency, personal discipline, decisiveness, moral compass, vision, charisma, intellect, focus, honesty, confidence, ability to communicate, ability to inspire, intuition, and love for the nation.²¹⁵ If a chart was created and literature was used as a methodology to give each president a score in each of these categories, it still would not explain why some presidents were more successful in creating federal policy and promoting renewable energy than others. The best way to understand presidential leadership within the context of this study is to look at what they set out to do as assessed from speeches, activities, and supported legislation.

²¹⁴ "Leadership," Merriam-Webster, last modified March 2, 2018, accessed March 4, 2018, <https://www.merriam-webster.com/dictionary/leadership>.

²¹⁵ See: John Dickerson, "How to Measure for a President," *Slate*, sec. Politics, September 26, 2012.; Paul Edmondson, "What Skills does a President Need?" *Tough Nickel*, sec. Business, April 22, 2016.; Jake Miller, "What Traits and Attributes make an Effective President?" *CBS News*, sec. Face the Nation, November 3, 2016.

Every president has had to deal with difficult issues. Recent presidents have dealt with oil crises, economic crises, terrorist attacks, threat of nuclear war, and increasing natural disasters. To understand environmental politics one must first understand domestic and international politics. A deep understanding of each presidential administration is beyond the scope of this dissertation, but including some of the overarching issues will help frame why some presidents improved environmental politics and why others did not.

Before evaluating progress on environmental issues at the national level, it is important to understand the platform of the two main political parties in the U.S.: the Democratic perspective and the Republican perspective. The previous chapter highlighted public opinion polls on climate change as viewed by citizens. Generally, Democrats believe in the anthropogenic causes of climate change while Republicans do not have as strong of a belief in it.²¹⁶ Even though there are quite a few Republicans who do believe in climate change, the Republican Party as a whole has a different view on federal government involvement in regulating private industry. Republicans believe in a small federal government, but the most important factor driving party platforms on the environment is geographic. From Congressional seats to the president, the Republican Party relies on states that are most deeply invested in fossil fuels. Because of this, the Republican Party feels threatened by initiatives to reduce carbon emissions. The states that typically elect Republicans are both producers of fossil fuels such as oil and coal, but so are states that consume large quantities of coal-generated electricity. On the other hand, the Democratic Party is supported by states that have the lowest per capita

²¹⁶ Funk and Kennedy, *Public Opinion on Renewable and Other Energy Sources*.

CO₂ emissions.²¹⁷ Understanding political party affiliations of each president gives one a basic understanding of what that president is likely to support in terms of federal environmental policies.

Sometimes national leaders create policy because of overwhelming public support for the issue. Sometimes they create policy because they believe it is in the best interests of the nation to do so, so they work to win public support during the process. Presidents promote national policies that protect the environment. They also promote policies that support renewable energy development, because they believe these policies are in the best interest of the nation. To get the best understanding of the criticality of national leadership in these areas it is important to review how policies were developed. This chapter is divided into two parts. The first part will review important legislation and policies enhancing protection of the environment and encouraging renewable energy growth prior to 2001. This first part will be a quick overview of perspectives of Presidents John F. Kennedy (1961 – 1963) through Bill Clinton (1993 – 2001) on climate change and environmentally friendly federal policy.

The second part of this chapter will show a more detailed comparison of how Presidents George W. Bush (2001 – 2009) and Barack Obama (2009 – 2016) conceptually and legislatively approached both climate change and renewable energy. This section will provide a more thorough perspective on how presidential leadership made a difference. A diachronic analysis based on a look at leadership before 2007 and then from 2007-2016 is not as obvious in this chapter because President George W.

²¹⁷ Ronald Brownstein, "Why Republicans are Frozen on Climate Change," *CNN*, sec. Politics, September 12, 2017.

Bush left office in 2008, but the comparisons will still be drawn in the concluding section of this chapter.

Presidents Kennedy to Clinton

To understand how the U.S. was able to become the nation with the greatest amount of wind generated electricity by the end of 2016, it is essential to study the attitudes of presidential leadership and how presidents created both legislation and programs to address climate change and renewable energy. The first key legislation addressing polluted air was the Clean Air Act (CAA) of 1963.²¹⁸ It was inspired by President John F. Kennedy's (1961-1963) concerns about pollution, and was passed shortly after his assassination. President Kennedy had external political pressure during the height of the Cold War and led the U.S. through the Cuban Missile Crisis. Domestically he supported the Civil Rights Bill, income tax cuts and started the Peace Corps.²¹⁹ President Kennedy was influenced by the importance of Rachel Carson's 1962 book, *Silent Spring*, and appointed a Science Advisory Committee to research the efficacy and safety of pesticides.²²⁰ Carson, a marine biologist and scientist with the U.S. Fish and Wildlife Service, helped galvanize the environmental movement in the

²¹⁸ "Overview of the Clean Air Act and Air Pollution."

²¹⁹ "John F. Kennedy," History.com, accessed March 4, 2018, <http://www.history.com/topics/us-presidents/john-f-kennedy>.

²²⁰ "John F. Kennedy on Environment," On the Issues, last modified June 17, 2017, accessed March 4, 2018, http://www.ontheissues.org/Celeb/John_F_Kennedy_Environment.htm.

U.S.²²¹ Due to her educational and experiential background, Carson was uniquely qualified to understand the dramatic effect of an insecticide created in 1940s called dichloro-diphenyl-trichloroethane (DDT).²²² She chronicled how DDT entered the “food chain and accumulated in the fatty tissues of animals, including human beings, and caused cancer and genetic damage.”²²³ Carson wrote a compelling argument that represented a watershed moment linking the environment, pollution, and public health.²²⁴ Though Carson’s book was focused on DDT, there was a greater net effect that her argument made on the importance of protecting the environment. The 1963 CAA did not address pesticides; rather it focused on plant emissions, yet did not include transportation industry emissions.²²⁵ The 1963 CAA set a firm legislative foundation that led to subsequent amendments in 1965, 1966, 1967, and 1969, which created stricter regulations.²²⁶

However, mainstream America was largely oblivious to environmental concerns through the 1960s and early 1970s. During this time, “Americans were slurping leaded gas through massive V8 sedans. Industry belched out smoke and sludge with little fear

²²¹ Eliza Griswold, "How 'Silent Spring' Ignited the Environmental Movement," *The New York Times Magazine*, September 12, 2012, <http://www.nytimes.com/2012/09/23/magazine/how-silent-spring-ignited-the-environmental-movement.html>.

²²² "DDT - A Brief History and Status," U.S. Environmental Protection Agency, last modified January 19, 2017, accessed March 4, 2018, <https://www.epa.gov/ingredients-used-pesticide-products/ddt-brief-history-and-status>.

²²³ "The Story of Silent Spring," National Resources Defense Council, last modified August 13, 2015, accessed March 4, 2018, <https://www.nrdc.org/stories/story-silent-spring>.

²²⁴ Griswold, *How 'Silent Spring' Ignited the Environmental Movement*, October 11, 2017.

²²⁵ Glen Sussman and Byron W. Daynes, *US Politics and Climate Change: Science Confronts Policy* (Boulder, CO: Lynne Rienner Publishers, Inc, 2013), 78.

²²⁶ "Overview of the Clean Air Act and Air Pollution."

of legal consequences or bad press. Air pollution was commonly accepted as the smell of prosperity. 'Environment' was a word that appeared more often in spelling bees than on the evening news."²²⁷ Paradigm shifts take time. It took ten years from the time Carson's book was published before the EPA cancelled the use of DDT.²²⁸ The public mindset change in which U.S. citizens saw that human actions had negative effects on the environment started in the early 1970s.²²⁹ Americans began to understand that their individual, and corporate, actions had global consequences.

Galvanized by the idea that human behavior "could create harm all over the globe,"²³⁰ Americans began changing their rhetoric and behavior. President Richard Nixon (1968-1974) was an astute politician who, during his 1969 State of the Union address, laid out a 37-point message on the environment that ranged from monitoring vehicle emissions to halting dumping in the Great Lakes.²³¹ President Nixon had major international achievements to include several key negotiation successes with the Soviet Union, he was the first U.S. president to visit the People's Republic of China, he signed the Paris Peace Accords in 1973 which ended the U.S. involvement in the Vietnam war, he negotiated Middle East peace talks that eliminated Soviet dominance in the region, and he supported Israel in the 1973 Yom Kippur War.²³² His international successes do not overshadow his domestic successes. In 1970, four significant events happened under the Nixon administration that began changing the way America dealt with climate

²²⁷ "Earth Day: The History of a Movement | Earth Day Network."

²²⁸ "DDT - A Brief History and Status."

²²⁹ "Earth Day: The History of a Movement | Earth Day Network."

²³⁰ Ibid.

²³¹ "Richard Nixon on Environment."

²³² "Richard Nixon's Top Domestic and Foreign Policy Achievements."

change: Earth Day was established; NOAA²³³ was founded; the EPA²³⁴ was founded; and the Clean Air Act (CAA) of 1970 was passed. All four of these events paid homage to the public's increasing awareness of anthropogenic effects on the earth and Nixon's mounting concerns about negative effects on the environment.²³⁵ Nixon said, "I think that 1970 will be known as the year of the beginning, in which we really began to move on the problems of clean air and clean water and open spaces for the future generations of America."²³⁶ From 1918 until 1970 energy policy was focused on promoting oil and gas production. There still were no tax incentives for energy conservation for the development of alternative fuels.²³⁷

There are many activities in the 1970s that set the stage for increased legislation protecting the environment and also led to the wind energy boom in 2007. On the very first Earth Day, 20 million Americans demonstrated with the purpose of acknowledging the importance of creating a healthy, sustainable environment. The start of Earth Day many not seem like an important event, yet in 1990 Earth Day went global with 200 million people in 141 different countries pushing environmental issues to the forefront.²³⁸ It took an entire generation to change the way people saw the Earth.

Understanding that awareness of the detriments of human activity on the environment led to the creation of NOAA. NOAA was the first federal agency specifically

²³³ "NOAA Legacy."

²³⁴ "EPA History."

²³⁵ "Richard Nixon on Environment."

²³⁶ Sussman and Daynes, *US Politics and Climate Change: Science Confronts Policy*, 79.

²³⁷ Salvatore Lazzari, *Energy Tax Policy: History and Current Issues* (Washington D.C.: Congressional Research Service, June 10, 2008).

²³⁸ "Earth Day: The History of a Movement | Earth Day Network."

dedicated to atmospheric science and it was also America's first conservation agency.²³⁹ The idea of conservation of natural resources was new to most people.

The EPA was founded because of the public concern about environmental pollution.²⁴⁰ History shows that it takes momentous events to drive a president to create a new agency. They do not do so lightly. The EPA was given daunting challenges in an effort to change the way Americans saw the environment and how industry interacted with it.

The 1970 CAA defined the EPA's role in protecting and improving air quality and authorized the development of both federal and state regulations. When Nixon signed the bill he stated it was "the most important piece of legislation, in my opinion, dealing with the problem of clean air that we have this year and the most important in our history."²⁴¹ Although several key pieces of legislation followed the CAA, the CAA by itself raised national awareness and led to controls established at both the federal and state levels. Pursuant to the CAA, the EPA created quality air standards and helped enforce emission controls making a dramatic improvement in air quality. Figure 15 shows that although many factors negatively impacting the environment increased, CO₂ emissions did not correspondingly increase. For example, vehicle miles traveled increased 172 percent, yet CO₂ emissions only increased 27 percent.²⁴² The CAA was

²³⁹ "NOAA Legacy."

²⁴⁰ "EPA History."

²⁴¹ Sussman and Daynes, *US Politics and Climate Change: Science Confronts Policy*, 79.

²⁴² "Overview of the Clean Air Act and Air Pollution."

key in legislating emissions that kept CO₂ emissions at lower levels than if the controls had not been in place.²⁴³

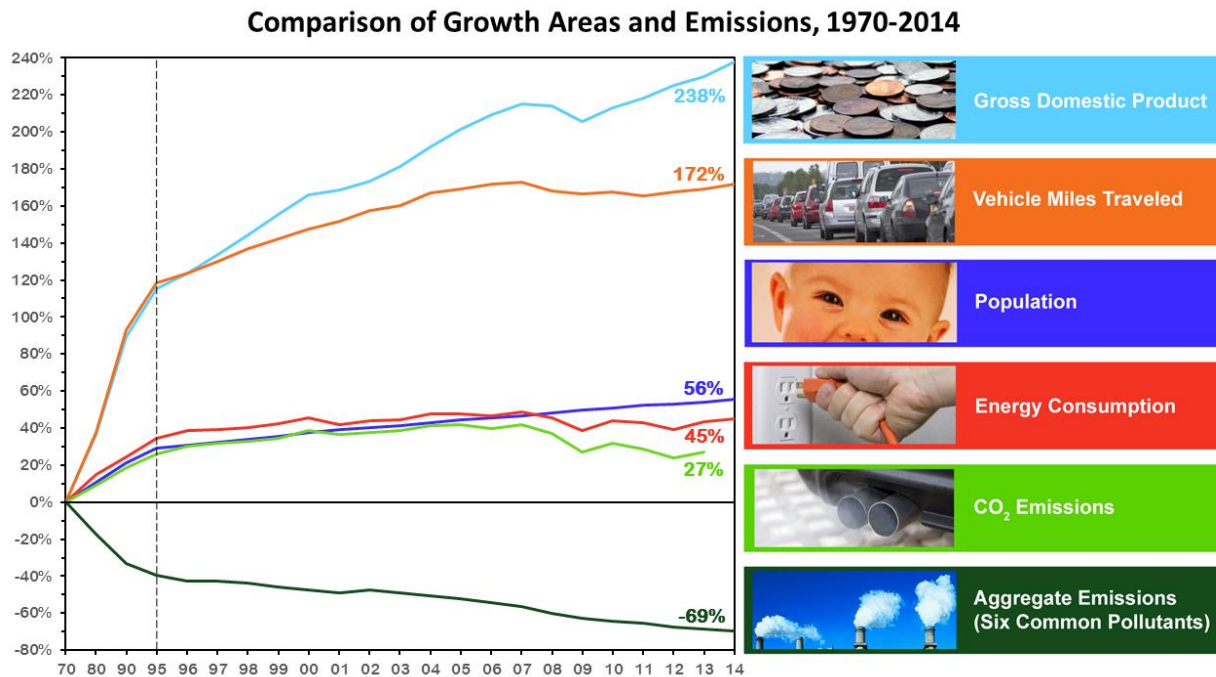


Figure 15 - The Effects of the Clean Air Act of 1970²⁴⁴

Source: U.S. Environmental Protection Agency

In an effort to create new ways of using natural resources, Nixon created the Federal Wind Energy Program in 1973 “to implement a wide range of research and development tasks and to coordinate the efforts of the government, private industry, universities, and laboratories.”²⁴⁵ The program was focused on the development of large-scale wind energy generation and its budget grew from \$2 million in fiscal year

²⁴³ Ibid.

²⁴⁴ Ibid.

²⁴⁵ Thomas A. Starrs, "Legislative Incentives and Energy Technologies: Government's Role in the Development of the California Wind Energy Industry," *Ecology Law Quarterly* 15, no. 1 (January 1088, 1988), 103-158.

(FY) 1974 to its peak of \$100 million in FY 1981. The program's funding was decreased by 80 percent in FY 1982 under President Ronald Reagan (1981-1989) and effectively became inactive.²⁴⁶ Although the program was not continued, it is still part of the history that led to a successful wind industry. One of President Reagan's main focus areas during his presidency was to deregulate the government.²⁴⁷ The effect of these actions will be more apparent in subsequent issues.

National legislation and consequent actions to protect the environment were created over many years. Some administrations believed there should be more protections and others believed the market place should regulate itself. Kennedy and Nixon started looking at natural resources differently, but it was President Jimmy Carter (1977-1981), who created the first administration to lay groundwork affecting real change in American politics regarding environmental issues. Shortly after taking office, Carter created a twelfth cabinet position with the creation of the Department of Energy (DOE). The DOE was created to be responsible for both the design, construction and testing of nuclear weapons, and for all Federal energy-related programs. The same 1977 law that created the U.S. DOE also mandated the president and the DOE publish a *national energy policy plan* every two years.²⁴⁸ The creation of the DOE and the requirement to publish energy policy plans indicates that Carter and his administration understood the importance of a cohesive approach to addressing energy issues.

²⁴⁶ Ibid.

²⁴⁷ "Ronald Reagan on Environment," On the Issues, last modified June 17, 2017, accessed March 4, 2018,

http://www.ontheissues.org/Celeb/Ronald_Reagan_Environment.htm.

²⁴⁸ "A Brief History of the Department of Energy," U.S. Department of Energy.

What ended up being a seminal work had its impetus in 1977 when Carter announced to Congress that he intended to organize the first comprehensive study of the global environment.²⁴⁹ The results of the study were captured in a report titled, *Global 2000 Report to the President*. It took almost three years to complete, but when it was published in 1980, more than 1.5 million copies were sold including translations into French, German, Japanese, Chinese, Hungarian, Spanish, and Italian. Twelve different U.S. governmental agencies were involved in producing the report and it was a revolutionary approach to how a government-sponsored report would be used. Reports such as this were not new, but earlier studies had taken a short-term view of each issue area individually without looking at how the subject areas were interrelated and how they were global in nature. Previous reports also had relatively little effect on policy. This report changed all that.²⁵⁰

The first legislation that created incentives for energy conservation and the development of renewable energy was the National Energy Act of 1978 (NEA) under President Carter. NEA had five different statutes covering every aspect of the energy sector. The two statutes of NEA that directly affected the wind industry were the Energy Tax Act (ETA) and the Public Utilities Regulatory Policies Act (PURPA).²⁵¹ ETA allowed for a 10 to 15 percent tax credit for qualifying renewable energy to include solar, wind, geothermal, and biomass.²⁵² PURPA established ground rules on how electric utilities

²⁴⁹ Sussman and Daynes, *US Politics and Climate Change: Science Confronts Policy*, 80-81.

²⁵⁰ Gerald O. Barney, *Global 2000 Report to the President* (Arlington, VA: Seven Locks Press, 1980).

²⁵¹ Starrs, *Legislative Incentives and Energy Technologies: Government's Role in the Development of the California Wind Energy Industry*, 103-158.

²⁵² Lazzari, *Energy Tax Policy: History and Current Issues*, 4-5.

would integrate energy created by small power producers.²⁵³ Although most of this legislation expired in 1982 or 1985 under Reagan's leadership, these incentives were the driving force for the first wind farms developed in the U.S.²⁵⁴

President Carter viewed the environment problem from many perspectives which included how Americans see and use energy. He asked the public, "Why have we not been able to get together as a nation to solve our serious energy problem?"²⁵⁵ As the nation reeled from two major oil shocks, his focus was not just on the environment, but also on energy security and ways to diversify the nation's energy supply. Carter was the first president to explore the use of renewable energy while in office by having 32 solar panels installed on the White House roof. He declared, "a generation from now, this solar heater can either be a curiosity, a museum piece, an example of a road not taken, or it can be a small part of one of the greatest and most exciting adventures ever undertaken by the American people; harnessing the power of the Sun to enrich our lives as we move away from our crippling dependence on foreign oil."²⁵⁶ The solar panels demonstrate Carter's mindset and willingness to explore the utility of renewable energy. President Carter's leadership began a change and he proved that leadership matters.

²⁵³ Starrs, *Legislative Incentives and Energy Technologies: Government's Role in the Development of the California Wind Energy Industry*, 103-158.

²⁵⁴ Lazzari, *Energy Tax Policy: History and Current Issues*, 4-5.

²⁵⁵ Peter Dykstra, "Analysis: 35 Years Later, Jimmy Carter's Energy Warning," *The Daily Climate*, last modified July 15, 2014, accessed January 10, 2016, <http://www.dailyclimate.org/tdc-newsroom/2014/07/carter-crisis-speech-anniversary>.

²⁵⁶ Rachel Nuwer, "Obama is Actually the Third President to Install Solar Panels at the White House," *Smithsonian*, last modified August 13, 2013, accessed January 10, 2016, <http://www.smithsonianmag.com/smart-news/obama-is-actually-the-third-president-to-install-solar-panels-at-the-white-house-111247/?no-ist>.

President Reagan had a very different view on how and when policy should be created. He was a true Republican in the sense that he believed the smaller the national government, the better it was for its citizens.²⁵⁷ Overall, he opposed using national-level tax incentives to promote development in energy to include oil, gas, and renewables. He believed that private industry should be responsible for driving energy conservation and developing renewable energy. Because oil prices were at a historical high while he was in office, he believed that was incentive enough to cause industry to change the way they conducted business. It was in their self-interest to become more energy efficient and also to explore development of alternative forms of energy.²⁵⁸ He also did not think environmental issues would damage public perception of his presidency. Contrary to how we view the word today, Reagan considered himself an environmentalist and would say he had a common sense view to environmental issues. He rarely thought about the environment in political terms.²⁵⁹ President Reagan ushered in an era called *New Federalism*.²⁶⁰ Reagan was consistent in his beliefs that the role of the federal government in domestic programs should be reduced while the role of the states should be enhanced. He was a proponent of decentralization of power and federal defunding of domestic programs. Some critics argued that this new federalism was applied to environmental programs to eliminate those programs. State environmental aid was reduced at the same time federal programs were cut.²⁶¹ Understanding Reagan's

²⁵⁷ "Ronald Reagan on Environment."

²⁵⁸ Lazzari, *Energy Tax Policy: History and Current Issues*, 6.

²⁵⁹ "Ronald Reagan on Environment."

²⁶⁰ James P. Lester, "New Federalism and Environmental Policy," *Publius* 16, no. 1 (1986), 149-165.

²⁶¹ *Ibid.*

perspective helps one follow the trend of the national government's role in environmental issues, but it will also help one understand the role each state plays in these issues, as will be addressed in Chapter 6.

During the Reagan administration there were some moderate forms of federal legislation that added to higher air quality standards and emission controls, but it was not until the Energy Policy Act of 1992 (EPAAct 1992) was passed during President George H.W. Bush's (1989-1993) administration that legislators sought to reduce U.S. dependence on imported petroleum and improve air quality by not just addressing emission issues, but also by encouraging the use of alternative fuels, renewable energy and energy efficiency.²⁶² The EPAAct 1992 was absolutely essential in the creation of the wind industry because it established the Federal Renewable Energy Production Tax Credit (PTC) and gave each state the leeway to establish State Renewable Portfolio Standards (RPSs).²⁶³ The next chapter will delve into more detail of how states created legislation complimentary to the EPAAct 1992 and how investors took advantage of these incentives to build wind farms.

As part of this essential process in wind energy development, PTCs were created to promote investment in renewable energy. PTCs are an inflation-adjusted per-kilowatt-hour (kWh) tax credit for electricity generated by specified forms of renewable energy. When first created, the PTC was available to its owner for 10 years beginning the year the project is placed in service.²⁶⁴ This incentive "has been important to the growth and

²⁶² "Key Federal Legislation."

²⁶³ State RPSs will be covered in depth in Chapter Six on state mandates and policies.

²⁶⁴ Patrick M. Cox, *Emergency Economic Stabilization Act Extends Renewable Federal Tax Benefits* (Brown Rudnick LLP: Electric Light & Power, January 1, 2009).

development of renewable electricity resources, particularly wind.”²⁶⁵ The first PTCs allowed turbine owners to claim a federal tax credit equaling approximately two cents per kilowatt-hour produced. This may not seem like much, but one can see how important this tax credit can be to businesses when looking at the example of a Florida-based company that paid no income tax in 2002 and 2003 while reporting a net income of over \$2 billion.²⁶⁶ Another example is of a typical large wind farm that can generate 100 megawatts of electricity. Depending on location, those turbines only spin about 30 percent of the time. That is enough to generate 262.8 gigawatts of electricity, earning the company \$5,781,600 tax credits from the PTCs.²⁶⁷ That is essentially a \$5.8 million government investment in one wind farm. While it is true that the federal government does not collect that as revenue, the incentive would have stimulated the investment, thereby creating economic activity and growth. The additional benefit is the amount of CO₂ that was *not* emitted from the wind farm that would have been emitted from a power plant powered by coal or natural gas.

Data shows there is a direct correlation between PTCs and wind power production. Historical data proves that “When Congress has cut it [PTCs] off, making it unavailable for new turbines, construction has dropped to practically nothing. When the credit has been available, turbine construction surged.”²⁶⁸ The first lapse of PTCs occurred in 1999 under President Bill Clinton’s administration (1993-2001). This lapse resulted in a 93 percent decrease in wind investments in 2000 the year following the

²⁶⁵ Molly F. Sherlock, *The Renewable Electricity Production Tax Credit: In Brief* (Washington D.C.: Congressional Research Service, 2014).

²⁶⁶ Righter, *Windfall: Wind Energy in America Today*, 32-33.

²⁶⁷ Caperton, *Good Government Investments in Renewable Energy*,

²⁶⁸ Righter, *Windfall: Wind Energy in America Today*, 32-33.

lapse of the PTC.²⁶⁹ Again that was a 93 percent decrease in a single year. However, the lapse of PTCs did not just affect wind energy growth; it also had a detrimental economic affect. When the PTC is allowed to expire, industry workers lose work and their paychecks. The lapse in the PTC highlighted the importance of that legislation and PTCs did not lapse again under the Clinton administration.

Through legislation such as the EPAct 1992 and the establishment of PTCs, the 1990s was a decade in which the U.S. was leading by example and the effects of policy adaptations were starting to be realized through increases in renewable energy production. The U.S. was not just working to improve the domestic environment. There were also international environmentally based actions such as George H.W. Bush agreeing to the establishment of the UN Framework Convention on Climate Change (UNFCCC), which entered into force in 1994 under President Clinton.²⁷⁰ The ultimate objective of the UNFCCC was to stabilize GHG concentrations “at a level that would prevent dangerous anthropogenic (human induced) interface with the climate system.”²⁷¹

The UNFCCC laid out an international plan to address the rise in CO₂ levels and in 1993, even before the UNFCCC entered into force, President Clinton laid out a domestic plan to reduce GHG emissions through his Climate Change Action Plan

²⁶⁹ Caperton, *Good Government Investments in Renewable Energy*,

²⁷⁰ Steven C. Beering, *Building a Sustainable Energy Future: U.S. Actions for an Effective Energy Economy Transformation* (Arlington, VA: National Science Foundation, 2009).416-417.

²⁷¹ "First Steps to a Safer Future: Introducing the United Nations Framework Convention on Climate Change," United Nations Framework Convention on Climate Change, last modified 2014, accessed October 12, 2017, http://unfccc.int/essential_background/convention/items/6036.php.

(CCAP). Not only did CCAP promote plans to reduce GHG emissions, it coupled that concept with ways to strengthen the U.S. economy. This was intended to alleviate fears that investment in renewable energy would damage the economy. CCAP was the first presidential action plan based on the acceptance of anthropogenic climate change, but critics argue these plans were not much more than federal rhetoric to appease a growing concern over climate change.²⁷² The main criticisms of Clinton's CCAP are based on the failure of the nation to fulfill his commitment in his action plan to reduce U.S. GHG emissions to pre-1990 levels by 2000. Environmentalists also criticized CCAP because they argued that it did not do enough to make a difference.²⁷³

In addition to CCAP, Clinton issued several executive orders to address climate change. For example, in 1999 he issued both Executive Order 13123 (setting goals for federal energy management) and Executive Order 13134 (establishing the Interagency Council on Biobased Products and Bioenergy).²⁷⁴ Although there is no study demonstrating the direct correlation of the success of Clinton's CCAP and a growth in the renewable energy industry, one can infer how CCAP, these executive orders, and an atmosphere in which the growth of renewable resources is promoted would have moved the growth curve upward.

²⁷² Ronald D. Brunner and Roberta Klein, "Harvesting Experience: A Reappraisal of the U.S. Climate Change Action Plan," *Policy Sciences* 32, no. 2 (June, 1999), 133-161.

²⁷³ Amy Royden, "U.S. Climate Change Policy Under President Clinton: A Look Back," *Golden Gate University Law Review* 32, no. 4 (2002), 415-478. Beering, *Building a Sustainable Energy Future: U.S. Actions for an Effective Energy Economy Transformation*, vi-64.

²⁷⁴ Royden, *U.S. Climate Change Policy Under President Clinton: A Look Back*, 415-478.; Beering, *Building a Sustainable Energy Future: U.S. Actions for an Effective Energy Economy Transformation*, vi-64.

Section Summary

This section showed the progression, and periodic digression, of national support to both climate change and renewable energy growth. In general, Democratic presidents were progressive on climate change issues and Republican presidents were not. The main exception to this predictive political party model was President Nixon. As a Republican president he acted more as one would expect a Democratic president to act.

One cannot assume that party affiliation is as applicable to presidential attitudes toward renewable energy as they are toward climate change. The most important federal legislation to promote renewable energy growth, EPAct 1992, was passed during the George H.W. Bush administration. The EPAct 1992 established the nation's first PTCs, which were proven to be the single most important piece of federal legislation to promote wind energy growth.

Comparison of George W. Bush and Barack Obama Presidential Administrations

The only way to get a sense of the criticality of national leadership as it pertains to protection of the environment and in stimulating wind energy development is to compare the administrations of Presidents George W. Bush and Barack Obama. These two presidential administrations spanned 16 years from 2001 to 2016. In those 16 years, wind energy grew from total installed cumulative capacity of 4,147 megawatts to

82,183 megawatts.²⁷⁵ That is a dramatic increase, and China is the only other nation that had a larger increase.²⁷⁶

The comparison between these two presidents will be made in six different areas: their attitudes toward climate change, key legislation they enacted to help protect the environment, how they interacted with the international community on the climate change agenda, how CO₂ emissions changed during their tenure, and how renewable energy, and specifically wind energy, grew during each administration. The rest of the chapter will show how Presidents Bush and Obama performed differently in each of these areas.

President George W. Bush

George W. Bush was inaugurated as the 43rd U.S. president on January 20, 2001, was reelected for a second term, and left office on January 20, 2009.²⁷⁷ His two-term presidential legacy was riddled with controversy. He was one of a handful of presidents who did not receive the majority of the nation's popular vote and the Supreme Court case of *Bush vs. Gore* was one of the most controversial political issues in decades. However, less than nine months later, following the terrorist attacks of September 11, 2001, and because of his response to the attacks, he became the most

²⁷⁵ "Electric Power Monthly."; "Electric Power Monthly Back Issues."

²⁷⁶ Lester R. Brown, *World on the Edge: How to Prevent Environmental and Economic Collapse* (New York, NY: W.W. Norton & Company, 2011), data accessed March 17, 2017, http://www.earth-policy.org/books/wote/wote_data.

²⁷⁷ "George W. Bush," History.com, last modified June 2010, accessed October 5, 2017, <http://www.history.com/topics/us-presidents/george-w-bush>.

popular president in polling history with an astounding 90 percent approval rating.²⁷⁸

Unfortunately, his approval rating dropped to 34 percent by the time he left office.²⁷⁹ The drop was mostly due to the economic crisis of 2008, but also reflected the nation's weariness with war in Iraq.

Bush's Domestic Climate Change Agenda

Most American citizens understand that presidents are part of both the problem and the solution when dealing with climate change. Presidents want votes from constituents who are at opposing views. Bush's refusal to use the term climate change is indicative of his desire to keep the support of his constituency. When evaluating his presidency from an environmental perspective, there is very little controversy. The most extreme critics of Bush saw his presidency as a "concerted assault" on the environment.²⁸⁰ A spokesman from the Sierra Club, one of America's largest environmental groups, stated, "He has undone decades, if not a century of progress on the environment."²⁸¹ Green organizations such as the Sierra Club have the most extreme liberal views, but even moderate assessments of his presidency discerned that under his leadership there were "profound implications for environmental policy in

²⁷⁸ Gary L. Gregg, *George W. Bush: Impact and Legacy* (Charlottesville, VA: UVA: Miller Center, 2017).

²⁷⁹ "Presidential Approval Ratings -- George W. Bush," Gallup Poll, last modified January 15, 2009, accessed October 10, 2017, <http://news.gallup.com/poll/116500/Presidential-Approval-Ratings-George-Bush.aspx>.

²⁸⁰ "The Worst of Times: Bush's Environmental Legacy Examined," The Guardian, last modified January 16, 2009, accessed October 5, 2017,

<https://www.theguardian.com/politics/2009/jan/16/greenpolitics-georgebush>.

²⁸¹ Ibid.

general, and for global warming and climate change policy in particular.”²⁸²

The Defense Reorganization Act of 1986 (commonly referred to as the Goldwater-Nichols Act) requires that each president annually submit a National Security Strategy (NSS) and incoming administrations have 150 days from taking office to submit their report.²⁸³ The original intent of the NSS was to “force the President and the executive branch to formulate a coherent and integrated strategy for the mid- and long-term defense of those interests most vital to U.S. national security.”²⁸⁴ Although the law is not strictly followed in this area, all recent presidents have published one or more NSSs while in office. Bush published two NSSs in 2002 and 2006. Given the security environment at the time, it is not surprising that his first NSS focused primarily on terrorism and protecting the homeland. However, there were several mentions of the environment and he said that economic growth in the U.S. must occur, while also mitigating the amount of CO₂ emissions. Bush also touted the importance of promoting renewable energy production.²⁸⁵ In both the 2002 and 2006 NSSs, Bush largely avoided use of the term *climate change*. Instead he used the term *environmental degradation*. Climate change is mentioned only once in his 2002 NSS and never in his 2006 NSS. In both NSSs he framed the concept of environmental destruction in such a way that it

²⁸² Sussman and Daynes, *US Politics and Climate Change: Science Confronts Policy*, 89.

²⁸³ "National Security Strategy Reports Overview," U.S. Government, last modified Unknown, accessed October 12, 2017, <http://nssarchive.us/national-security-strategy-reports-overview/>.

²⁸⁴ *Ibid.*

²⁸⁵ George W. Bush, *National Security Strategy of the United States of America* (Washington D.C.: White House, 2002).

could be attributed to either human behavior or natural occurrences.²⁸⁶ An example is when he stated, “Environmental destruction, whether caused by human behavior or cataclysmic mega-disasters such as floods, hurricanes, earthquakes, or tsunamis.”²⁸⁷ By emphasizing the ambiguity of the cause, he emphasized the possibility that human behavior is not the only, or even primary, force creating the cataclysmic events. He specifically avoided implying or stating the fact that human behavior is having a negative effect on the environment.

Bush’s avoidance of penning the words *climate change* in his NSSs match his actions in office as they pertain to the environment. In his second month of office any environmentalist would have thought he had blinders on when it came to the environmental impacts of CO₂ emissions. First, he stopped supporting the establishment of controls for domestic CO₂ emissions, and, second, he rejected the Kyoto Protocol. He claimed supporting both of those would hurt the economy and American workers.²⁸⁸

Another controversial act under Bush was in regard to the 1970 CAA that authorized the EPA to do many things such as establishing National Ambient Air Quality Standards (NAAQS – pronounced ‘nacks’). NAAQS were designed to protect public health and welfare.²⁸⁹ Bush rejected the legitimacy of the CAA and sought to replace it

²⁸⁶ See: Ibid.; George W. Bush, *National Security Strategy of the United States of America* (Washington D.C.: White House, 2006).

²⁸⁷ Ibid.

²⁸⁸ See: Royden, *U.S. Climate Change Policy Under President Clinton: A Look Back*, 415-478.; Armin Rosencranz, "U.S. Climate Change Policy Under G.W. Bush," *Golden Gate University Law Review* 32, no. 4 (2002), 479-491.

²⁸⁹ "Clean Air Act, 42 U.S.C. §7401 Et Seq." U.S. Environmental Protection Agency, last modified May 17, 2000, accessed October 4, 2017, <https://www.epa.gov/laws-regulations/summary-clean-air-act>.

with the Clean Skies initiative.²⁹⁰ The Clean Skies initiative proposed use of market-based cap-and-trade programs with the intent of rewarding innovation, reducing costs, and guaranteeing results. Cap-and-trade agreements are government-mandated, market-based programs in which businesses must hold permits that allow the business to emit certain pollutants. If businesses emit more than allowed, then they must trade for or purchase additional permits. If they emit less, then they can sell or trade their pollutant-emitting permit to a business that requires it. The market rewards businesses for emitting less, thus increasing their profits.²⁹¹ While CAA set clear limits on the quantity of pollutants in the air through the NAAQS, critics of Clear Skies argued it would allow millions of tons of additional pollutants in the air than was allowed under CAA.²⁹² Clean Skies was meant to limit several pollutants, but it would have eliminated the NAAQS, which forced polluting industries to comply with the law. Critics of the Clean Skies initiative, such as former Vice President Al Gore, argued that it “ought be called the dirty skies initiative” because it was less restrictive than CAA.²⁹³ Ultimately, the Clean Skies initiative led to proposed legislation called the Clean Skies Act, but it was never ratified.

Although he attempted to thwart the CAA by replacing it with what he believed was improved legislation, and although he didn’t agree to ratify the Kyoto Protocol, there

²⁹⁰ George W. Bush, *President Calls for Conservation and Stewardship on Earth Day* (Washington D.C.: White House Office of the Press Secretary, 2002).

²⁹¹ A. Leiserowitz et al., *Climate Change 101: Cap and Trade* (Arlington, VA: Pew Center on Global Climate Change, 2015).

²⁹² Douglas Jehl, "On Environmental Rules, Bush Sees a Balance, Critics a Threat," *New York Times*, sec. U.S., February 23, 2003.

²⁹³ Sussman and Daynes, *US Politics and Climate Change: Science Confronts Policy*, 89-90.

were some environmentally friendly initiatives proposed by Bush to include both the Climate Change Research Initiative (CCRI) and the National Climate Change Technology Initiative (NCCTI).²⁹⁴ Both of these programs were extensive and focused on topics such as determining how human activity produced GHGs, what caused those GHGs to be trapped in the Earth's atmosphere, what the long-term effects of those trapped GHGs would be, what cutting-edge technologies could be improved or developed to improve emissions, and ways to develop private-public partnerships to reduce GHG emissions.²⁹⁵

In 2003 Bush announced the Climate Vision Program in which he "committed to reducing America's greenhouse gas intensity – the ratio of emissions to economic output – by 18 percent in the next decade, and challenged American businesses and industries to undertake broader efforts to help meet that goal."²⁹⁶ Businesses from 12 major industries agreed to work with four of his cabinet agencies (DOE, EPA, DOT, and USDA) to reduce their GHG emissions in the next decade.²⁹⁷ One of the most positive aspects of programs such as the Climate Vision Program is that businesses voluntarily work to improve their impact on the environment. The negative aspects are that any decrease, even decreases that are not significant, can be viewed as compliance. There are several reasons businesses volunteer to decrease GHG emissions. They could use

²⁹⁴ George W. Bush, "Speech: Response to Global Warming," *PBS Newshour*, sec. Politics, June 11, 2001.

²⁹⁵ "Press Release: Global Climate Change Policy Book," The White House, last modified February 2002, accessed October 7, 2017, <https://georgewbush-whitehouse.archives.gov/news/releases/2002/02/climatechange.html>.

²⁹⁶ "Meeting President Bush's Climate Change Challenge to Business and Industry."

²⁹⁷ "Press Release: Addressing Global Climate Change," The White House, last modified December 1, 2012, accessed October 7, 2017, <http://georgewbush-whitehouse.archives.gov/ceq/global-change.html>.

this action to improve their public image. They could also volunteer realizing that if they do not, they would likely be subjected to mandatory limits. By volunteering to make even small or incremental changes, they have more control on how, when, and to what extent, they can make the changes.

Programs are helpful in setting environmental protections, but it takes legislation to make a longer-lasting difference. Bush signed three key pieces of energy-centered legislation during his presidency. First, was the Energy Policy Act of 2005,²⁹⁸ which included research in alternative energy sources. This act was primarily intended to increase the supply of energy through subsidies, but it also set standards mandating the increased use of certain types of energy and energy-saving technologies.²⁹⁹

Second was the Energy Independence and Security Act (EISA) of 2007,³⁰⁰ which was designed to move the U.S. toward greater energy independence and security. The three key provisions of EISA were a revision of the Corporate Average Fuel Economy Standards (known as CAFÉ standards), the Renewable Fuel Standard, and the appliance lighting/efficiency standards.³⁰¹ CAFÉ standards were set to reduce energy consumption by increasing the fuel economy of vehicles.³⁰² RFSs were designed to

²⁹⁸ "Summary of the Energy Policy Act," U.S. Environmental Protection Agency, last modified 2005, accessed October 7, 2017, <https://www.epa.gov/laws-regulations/summary-energy-policy-act>.

²⁹⁹ "Summary of the Energy Policy Act of 2005," Center for Climate and Energy Solutions, last modified October 8, 2005, accessed October 7, 2017, <https://www.c2es.org/federal/congress/109/summary-energy-policy-act-2005>.

³⁰⁰ "Summary of the Energy Independence and Security Act," U.S. Environmental Protection Agency, last modified December 27, 2007, accessed October 7, 2017, <https://www.epa.gov/laws-regulations/summary-energy-independence-and-security-act>.

³⁰¹ Ibid.

³⁰² "Corporate Average Fuel Economy," U.S. Department of Transportation, last modified August 24, 2017, accessed October 12, 2017, <https://www.nhtsa.gov/laws-regulations/corporate-average-fuel-economy>.

reduce GHG emissions, expand the renewable fuel sector, and reduce reliance on imported oil.³⁰³

Third was the Emergency Economic Stabilization Act of 2008,³⁰⁴ which, among other things, gave incentives to renewable energy project developers, financial investors, and sponsors. The legislation renewed two key incentives encouraging investors to continue developing both wind power and solar power projects. They were the PTC and the Investment Tax Credit (ITC).³⁰⁵ The ITC is an income tax credit that can be used for a company in the production, distribution or use of energy. Unlike the PTC, the ITC may be taken only once. The percentage of the allowed ITC varied on the energy source. For example, geothermal energy could claim a 10 percent ITC while solar could claim a 30 percent ITC.³⁰⁶

Although Bush was not as aggressive as previous presidents in protecting the domestic environment, there were still some positive legislative outcomes during his time in office.

Bush's International Climate Change Agenda

The creation of a wind industry does not only rely on domestic actions.

³⁰³ "Renewable Fuel Standard Program," U.S. Environmental Protection Agency, last modified September 29, 2017, accessed October 12, 2017, <https://www.epa.gov/renewable-fuel-standard-program>.

³⁰⁴ *Emergency Economic Stabilization Act of 2008*, Public Law 110-343, 110th Congress Public Law 343 (2008): Division B -- Energy Improvement and Extension Act of 2008.

³⁰⁵ Cox, *Emergency Economic Stabilization Act Extends Renewable Federal Tax Benefits*.

³⁰⁶ Ibid.

International attitudes and agreements leading to a more inviting industry make it easier, and more desirable, for wind energy investment. Bush did very little to promote concerns about the environment internationally. The 1997 Kyoto Protocol was an international treaty extending UNFCCC in which signatories committed to reducing CO₂ emissions based on the agreed-upon premise that man-made CO₂ emissions have caused global warming. The Kyoto Protocol recognized that developed nations caused most of the problem due to 150 years of industrialization and placed most of the burden of reducing those emissions on those same developed nations under the principle of *common but differentiated responsibilities*.³⁰⁷ Bush would not support the treaty because he claimed it was inherently flawed. He believed that because of the *common but differentiated responsibilities* principle upon which the treaty was established, 14 of the top 20 CO₂ emitting nations would not have to limit their emissions. He said,

For America, complying with [Kyoto] mandates would have a negative impact, with layoffs of workers and price increases for consumer. And when you evaluate all these flaws, most reasonable people will understand that's it's not sound public policy...America's unwillingness to embrace a flawed treaty should not be read by our friends and allies as any abdication of responsibility. To the contrary, my administration is committed to a leadership role on the issue of climate change.³⁰⁸

³⁰⁷ "Kyoto Protocol," United Nations Framework Convention on Climate Change, last modified December 2014, accessed December 28, 2015, http://unfccc.int/kyoto_protocol/items/2830.php.

³⁰⁸ Bush, *Speech: Response to Global Warming*.

There are critics who argue the U.S. was hypocritical for not ratifying the Kyoto Protocol, but there are also many who believe that Bush made the correct decision. Arguments against joining the Kyoto protocol focused on two main issues. First, the U.S. was experiencing an energy crisis and Bush supporters believed recovery of the domestic economy was more important than agreeing to internationally condoned emission restrictions. Second, and perhaps more important, Bush supporters argued that incomplete scientific knowledge of the causes and solutions to global climate change could result in actions that would hurt American workers and the domestic economy.³⁰⁹

Bush did not support the Kyoto Protocol, but he participated in the development of the Washington Declaration, an international agreement that created the outline of the successor to the Kyoto Protocol.³¹⁰ The Washington Declaration was agreed upon in February 2007 by the G8+5 in which they intended to make official by 2009.³¹¹ The Washington Declaration was a government-mandated cap-and-trade agreement that worked the same as the cap-and-trade system proposed by the Clean Skies initiative but focused specifically on GHG emissions.³¹²

It is apparent that Bush was willing to support international agreements focused on protecting the environment. However, he was very conscientious that those agreements must not hinder economic growth in such a way as to hurt the nation. He

³⁰⁹ Charli Coon, "Why President Bush is Right to Abandon the Kyoto Protocol," *The Heritage Foundation*, sec. Environment, May 11, 2001.

³¹⁰ See: Beering, *Building a Sustainable Energy Future: U.S. Actions for an Effective Energy Economy Transformation*, vi-64.; Rosencranz, *U.S. Climate Change Policy Under G.W. Bush*, 479-491.

³¹¹ Ishita Haldar, *Global Warming: The Causes and Consequences* (New Delhi, India: Mind Melodies, 2011), 190.

³¹² Leiserowitz et al., *Climate Change 101: Cap and Trade*.

believed that it was better to allow companies to voluntarily make changes that were beneficial to the environment rather than those changes being forced upon them by the government.

CO₂ Emissions During Bush Presidency

One of the most critical measures of environmental controls made to protect the environment is limiting CO₂ emissions. Scientists agree that the amount of CO₂ emissions directly corresponds to rising global temperatures.³¹³ One important measure of the Bush administration was looking at energy-driven CO₂ emissions during his presidency. Figure 16 shows that CO₂ emissions were mostly in the high 6,000 metric tons. The emissions rose steadily through the first five years he was in office then there was a short dip in 2006, and then a sharp drop in 2008. The drop of CO₂ emissions in 2008 had more to do with the economic crisis than with positive legislative gains. In 2008 people traveled less and purchased fewer goods. Fewer goods were being transported to markets. Americans were not spending as much and that caused a decline in emissions. Regardless, CO₂ emissions were slightly higher when Bush left office than when he took office. There were not horrible increases, but there also were not notable decreases. While CO₂ emissions fluctuated, Gross Domestic Product (GDP) grew steadily every year he was in office. GDP was \$10.622 trillion his first year of office and grew to \$14.719 by the time he left office. GDP grew a little over \$4 trillion yet CO₂ emissions did not correspondingly increase at the same levels. Although they did not

³¹³ "Temperature Change and Carbon Dioxide Change."

decrease, CO₂ emissions could have increased much more had some controls not been in place.

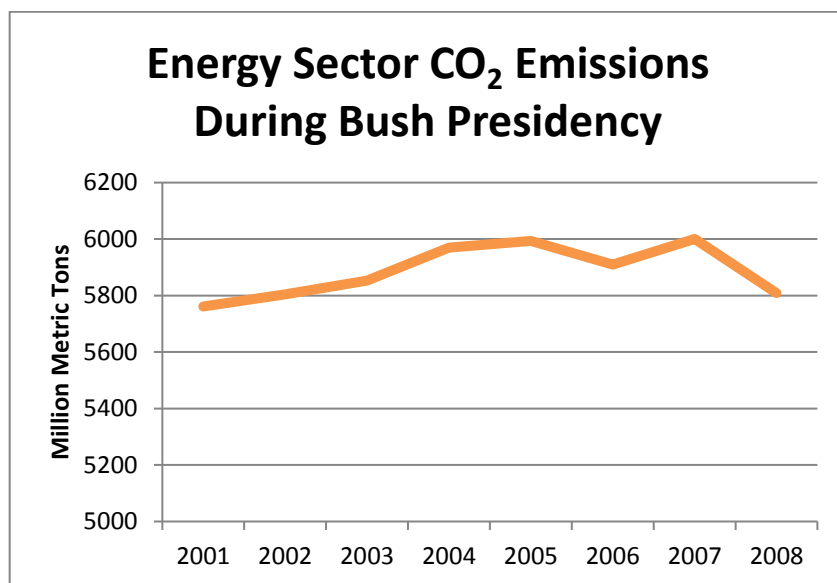


Figure 16 - Energy Sector CO₂ Emissions During Bush Presidency³¹⁴
Data Source: U.S. Energy Information Administration

There were some positive initiatives and legislation that came into existence under Bush's leadership and when Bush first took office, he intimated that he would work to protect the environment. Evaluation of his leadership reveals many lost opportunities that will be explained throughout this section. At the peak of his approval ratings when the nation was most supportive of him, he had the opportunity to give U.S. energy policy a corrective turn. He could have begun shifting the American energy economy away from conventional fossil fuels and toward more efficient energy choices.

³¹⁴ Figure created using data source: "Total Energy," U.S. Energy Information Administration, last modified September 2017, accessed October 13, 2017, <https://www.eia.gov/totalenergy/data/monthly/>.

It is hard to say if those lost opportunities had to do with his ties to big oil or if the challenges of dealing with the terrorist actions of 9/11 captured his attention in a way that caused other areas to be pushed aside.³¹⁵

Bush and Renewable Energy

"I believe wind power has got the opportunity to help... What I am talking about is a comprehensive approach to solving a national issue, which is dependence on oil, and how best to protect this environment. You know, it's time to get rid of the old, stale debates on the environment and recognize new technologies are going to enable us to achieve a lot of objectives at the same time."³¹⁶

George W. Bush
 October 12, 2006
 Remarks at the Renewable Energy
 Conference
 St. Louis, MO

After evaluating policy decisions, the only way to really evaluate President Bush's impact on the growth of wind energy is to see how much it grew during his terms of office. There are many measures of evaluating progress in growth. Three of the most useful measurements are overall wind energy generated into electricity, the amount of annual installed wind capacity, and the amount of cumulative installed wind capacity. Figure 17 shows wind power grew steadily during the Bush administration, but really started to take off in his last year of office.

³¹⁵ Jim DiPeso, "Few Americans are Every Likely to See George W. Bush's Greatest Environmental Legacy," *Grist*, January 17, 2009.; Richard G. Lugar, *Thinking Outside the Barrel*, (Bloomberg, L.P, 2006), 124.

³¹⁶ George W. Bush, *President George W. Bush Speech* (St. Louis, MO: Renewable Energy Conference, October 12, 2006).

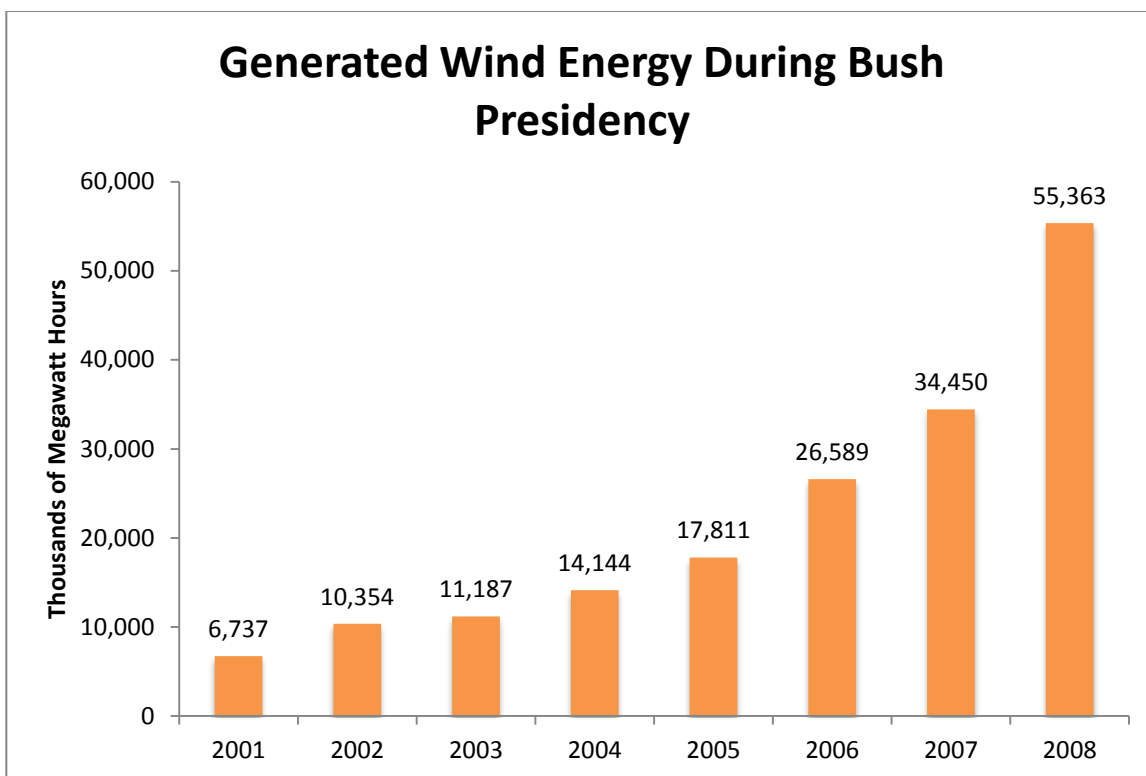


Figure 17 - Generated Wind Energy During Bush Presidency³¹⁷

Data Source: U.S. Energy Information Administration

Taking a closer look at PTCs is another indicator of the administration's support of renewable energy growth. During his terms of office, the PTC was allowed to expire twice in 2001 and 2003 although each time it was retroactively extended.³¹⁸ Each time the PTC expired, the production of wind energy was dramatically affected. The amount of wind energy installed experienced a 76 percent decrease in 2002, and another 76 percent decrease in 2004, the years following the expiration of the PTC during the Bush administration.³¹⁹ These gaps in legislation hampered progress of wind energy

³¹⁷ Figure created using data sources: "Electric Power Monthly."; "Electric Power Monthly Back Issues."

³¹⁸ Sherlock, *The Renewable Electricity Production Tax Credit: In Brief*, 1-12.

³¹⁹ Caperton, *Good Government Investments in Renewable Energy*.

development and “contribute[d] to a boom-bust cycle of development that plague[d] the wind industry.”³²⁰ Figure 18 shows both the cumulative installed wind capacity and the amount of capacity added annually. The dramatic dips in annual installation due to PTC expiration become even more obvious in graphic form.

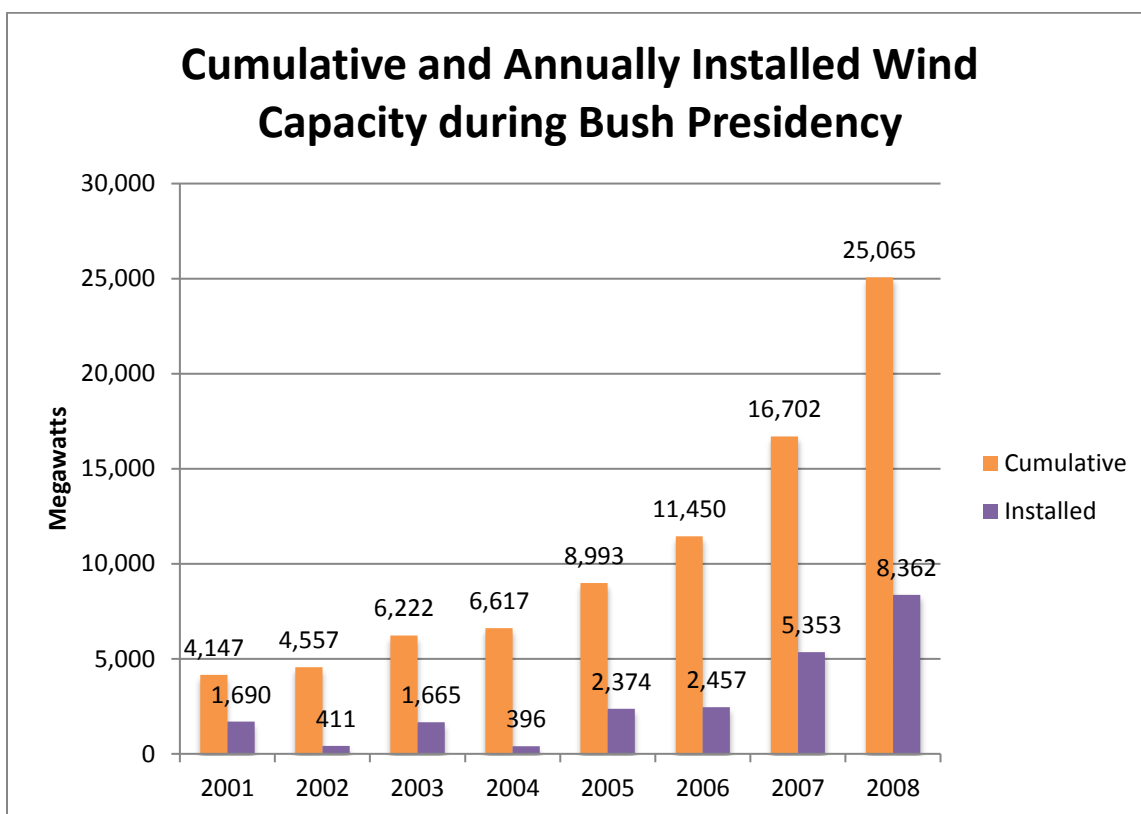


Figure 18 - Cumulative and Annually Installed Wind Capacity During Bush Presidency³²¹

Data Sources: U.S. Department of Energy and American Wind Energy Association

³²⁰ "Production Tax Credit for Renewable Energy," Union of Concerned Scientists, last modified 2015, accessed October 12, 2017, <http://www.ucsusa.org/clean-energy/increase-renewable-energy/production-tax-credit>.

³²¹ Figure created using data sources: Ryan Wiser and Mark Bolinger, *2015 Wind Technologies Market Report* (Oak Ridge, TN: U.S. Department of Energy, 2016).; "2015 PTC Handout," American Wind Energy Association, last modified 2015, accessed November 16, 2017, <http://awea.files.cms-plus.com/2015%20PTC%20Handout.pdf>.

Even though there were lapses of the PTC resulting in decreased investment in the wind industry, the U.S. had the most wind energy growth between 2005 and 2008 than any other nation³²² and actually surpassed all other nations in wind energy growth by the time Bush left office. Figure 19 shows the cumulative wind energy capacity of the top five wind energy producing nations.

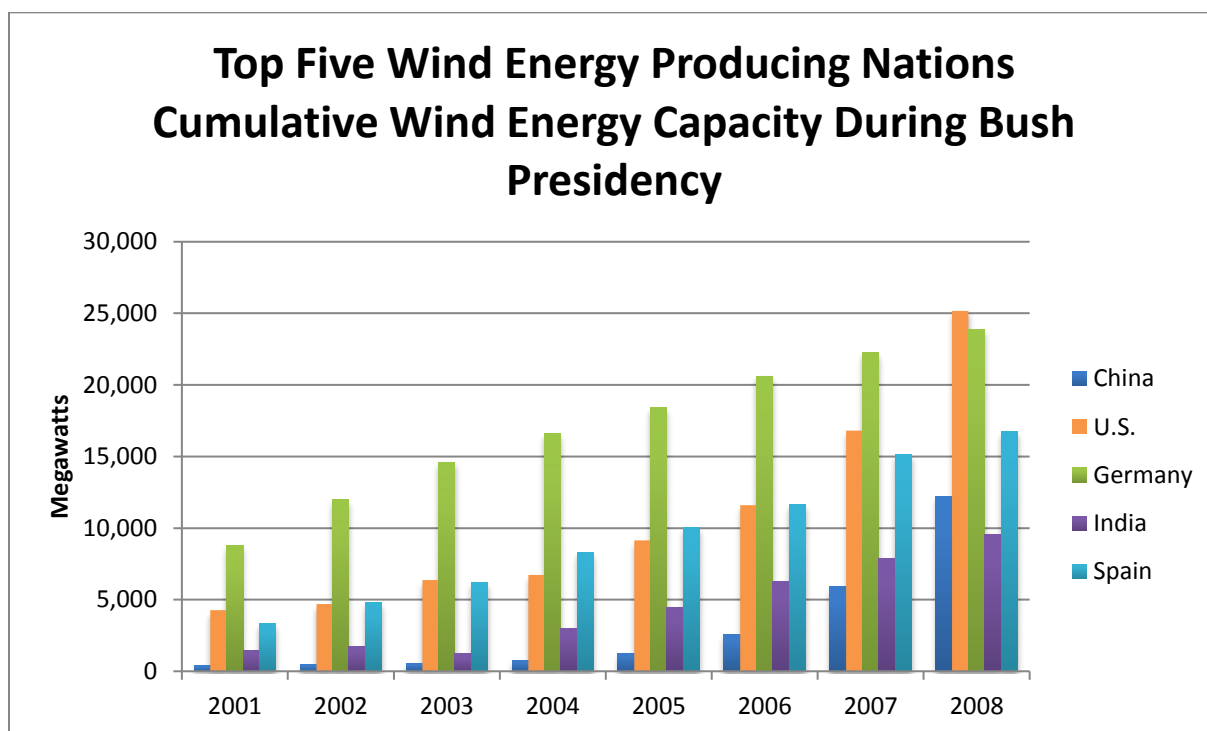


Figure 19 - U.S. Surpasses Other Nations in Wind Energy Growth During Bush Presidency³²³

*Data Source: Brown, *World on the Edge: How to Prevent Environmental and Economic Collapse**

³²² Ryan Wiser and Mark Bolinger, *2013 Wind Technologies Market Report* (Oak Ridge, TN: U.S. Department of Energy, 2014).

³²³ Figure created using data source: Brown, *World on the Edge: How to Prevent Environmental and Economic Collapse*.

Germany had held the lead in wind energy production for years, but the U.S. surge during these years is important in rethinking the narrative of environment-friendly progress during the Bush years.

Looking at wind energy growth is not the only measure to determine progress in the renewable energy field. Although President Carter was the first president to install solar panels on the White House, it was not until this Bush Administration that solar heat was more thoroughly incorporated into the White House's energy system through the installation of a grid of 167 solar panels.³²⁴ It is a small indicator, but it highlights Bush's willingness to seek and incorporate more environmentally friendly energy sources.

Going from the micro (White House solar power usage) to the macro level (national solar power usage) there was some growth in solar energy across the nation during the Bush years, but it stayed fairly even until the last year of his presidency as displayed in Figure 20.

³²⁴ Nuwer, "Obama is Actually the Third President to Install Solar Panels at the White House."

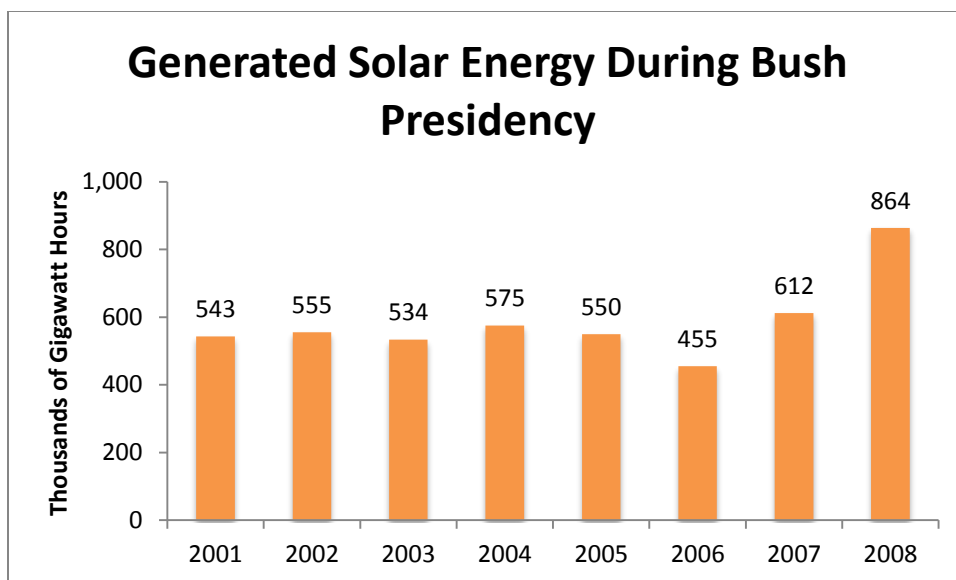


Figure 20 - Solar Energy Grows During Bush Presidency³²⁵
Data Source: Global Wind Energy Council

Acknowledging the significant growth of wind energy and moderate growth of solar energy under Bush is at odds when evaluating the “politicization of climate science and at times the rejection of the research findings of the scientific community. The Bush administration not only challenged the scientific outcomes, but also at times revised the scientific reports to support the White House position.”³²⁶ The wording was revised in final reports to enhance the possibility that scientists were uncertain of the conclusions.³²⁷

In summary, it’s evident that, overall, President George W. Bush’s environmental policies and grudging acceptance of climate change were a step backwards. It is also

³²⁵ Figure created using data source: Steve Sawyer and Klaus Rave, *Global Wind Report Annual Market Update 2015* (Brussels, Belgium: Global Wind Energy Council, 2016).

³²⁶ Sussman and Daynes, *US Politics and Climate Change: Science Confronts Policy*, 91.

³²⁷ *Ibid.* 92.

evident that during his terms in office wind energy surged and there was overall increased renewable energy growth.

President Barack Obama

Barack Obama was inaugurated as the 44th U.S. president on January 20, 2009, was reelected for a second term, and left office on January 20, 2017.³²⁸ As will always be the case when evaluating the success of a president, some say he accomplished a lot during his presidency and others say he was a failure. His approval rating was at 59 percent when he left office.³²⁹ That is quite high compared to most modern presidents. Obama released a video at the end of his presidency in which he lists his top ten accomplishments during his tenure. Making his top ten list was America's global leadership on climate change.³³⁰ The fact that the environment made his top ten signaled how important it was to him.

³²⁸ "President Barack Obama," White House: Office of the Press Secretary, last modified Unknown, accessed October 10, 2017, <https://obamawhitehouse.archives.gov/administration/president-obama>.

³²⁹ "Presidential Approval Ratings -- Barack Obama," Gallup Poll, last modified January 20, 2017, accessed October 10, 2017, <http://news.gallup.com/poll/116479/barack-obama-presidential-job-approval.aspx>.

³³⁰ *Obama's Top 10 Accomplishments -- According to Obama*, Television, directed by White House Press Secretary (White House: 2015)

Obama's Domestic Climate Change Agenda

The attitudes and legislation of national leadership have shown to be important in the creation of newer technologies such as solar and wind power. Obama's campaign platform encouraged activists and they believed that he would promote legislation to protect the environment. However, most critics on Obama's success rate on dealing with environmental issues seem to agree that he did very little in his first term.³³¹ In fact, Al Gore called Obama an abject failure when it came to progress on climate change. Gore was not the only one who disapproved of Obama's lack of progress. A low point of his presidency would likely be when climate activists chained themselves to the White House gate in protest because they believed Obama was going to approve the Keystone Pipeline.³³² There are several reasons given for Obama's lack of progress on the environment during his first term. First and foremost, he was forced to deal with the economic crisis of 2008. Proponents worried that a climate change agenda would hinder recovery and it was largely pushed to the back of Obama's agenda. One critic stated, "[Obama's] environmental achievements, then, have been hamstrung by politics – both the unyielding political opposition as well as his own sense of what's politic in a nation craving economic growth and energy independence."³³³ It is clear he faced strong opposition from Congress on his proposed initiatives and it was suggested "that

³³¹ See: Jonathan Chait, "Obama might Actually be the Environmental President," *New York Magazine*, sec. News & Politics, May 5, 2013.; Juliet Eilperin, "Obama Will have Pushed through One of the most Ambitious Environmental Agendas in U.S. History. Is it Helping?" *The Washington Post*, August 16, 2016.

³³² Chait, *Obama might Actually be the Environmental President*.

³³³ Chris Peak, *Here's what 15 Experts Think of President Obama's Record on the Environment* (Online: Nation Swell, 2015).

the 2011 House of Representatives was the most ‘anti-environmental in our nation’s history’ –and had appeared just as resistant to Obama’s efforts prior to 2011.”³³⁴ One example of an Obama legislative failure was when he proposed cap-and-trade legislation in February 2009. Because CO₂ was one of the gases that would have been regulated in the 2009 proposal, Congress voted it down. They viewed it as an extra tax on business that would hurt economic recovery.³³⁵

Even though most legislation focused on protecting the environment was never passed, there was one important piece of legislation that was passed into law, the *American Recovery and Reinvestment Act of 2009* (ARRA).³³⁶ As part of the stimulus to create more economic investment, ARRA included more than \$90 billion in government investment and tax incentives for renewable energy.³³⁷ Two important incentives enhanced by ARRA were PTCs and Investment Tax Credits (ITCs). Specifically, ARRA extended PTCs until 2012 and gave renewable energy capital-investors the option to turn down PTCs and instead use ITCs. There was a key distinction between PTCs and ITCs. PTCs reduced the federal income taxes of capital investors when electricity was *produced* from the project. Conversely, ITCs reduced the federal income taxes of capital investors when they fulfilled the *investment* threshold. Under ARRA wind energy investors could enjoy the tax break sooner with ITCs. This meant investors could receive governmental benefits when they started investing.³³⁸

³³⁴ Sussman and Daynes, *US Politics and Climate Change: Science Confronts Policy*, 92-93.

³³⁵ *Ibid*, 93.

³³⁶ Christina Romer, *Impact of the American Recovery and Reinvestment Act on the Clean Energy Transformation* (Washington D.C.: The White House, 2010).

³³⁷ *Ibid*.

³³⁸ Woodward and Gonzalez, *Bottom Line on Renewable Energy Tax Credits*

Another benefit the ARRA allowed was a DOT cash grant option, also known as the Section 1603 Grant, in which capital investors in wind and other renewable technologies can receive a cash grant covering up to 30 percent of their capital investment. ARRA also introduced the Advanced Energy Manufacturing Tax Credit (MTC), which awards tax credits to new, expanded, or re-equipped domestic manufacturing facilities that support clean energy development.³³⁹ One final incentive included in ARRA that is worth highlighting is the Modified Accelerated Capital-Recovery System (MACRS). MACRS is a system of rules that grants a five-year depreciation schedule for all ITC-eligible technologies as well as large wind projects.

Each of these different types of incentives appealed to different investors for different reasons. Having a variety of tax benefits encourages investors to take different levels of risks. Given all the criticisms of Obama's lack of progress during his first term, ARRA was critical for renewable energy development.

Understanding that promotion of renewable energy and protection of the environment are interrelated, Obama was able to pass legislation to promote renewable energy growth, but improving regulation on pollution controls was more problematic for him. He talked about protecting the environment regularly and most of his statements about climate change are codified in speeches. Two important documents that promoted his agenda were his NSSs. He released his first NSS in May 2010, and he was bold in his wording. Obama called the danger from climate change "real, urgent, and severe."³⁴⁰ He dedicated an entire section in his 2010 NSS to climate change

³³⁹ Ibid.

³⁴⁰ Barack Obama, *National Security Strategy* (Washington D.C.: White House, 2010).

bringing up issues both domestically and internationally. Climate change is mentioned 28 times in his 2010 NSS.³⁴¹ In his 2015 NSS he listed climate change as the sixth highest national security risk. He elevated the importance and discussion on climate change in his second NSS. Climate change is mentioned 19 times in his 2015 NSS³⁴² and although it is mentioned fewer times than in his 2010 NSS, he emphasized the negative impacts of climate change much more during his second term of office.

He had two successful pieces of legislation that included measures to protect the environment. They were the *American Taxpayer Relief Act of 2012* (ATRA) passed in January 2013, and the *Tax Increase Prevention Act of 2014* (TIPA) passed in December 2014.³⁴³ ATRA was mostly designed to address tax increases associated with the expiration of tax cuts introduced by Obama's predecessor, George W. Bush. However, ATRA also extended PTCs and ITCs, which was proven to be critical in wind energy development. ATRA also revised how PTCs could be claimed. Previously PTCs could only be claimed once a wind power facility was *placed in service*. ATRA changed it so investors could claim PTCs when they *commence construction*.³⁴⁴ For large wind farms, this would be millions of dollars of additional tax credits. TIPA was important in addition to giving incentives for businesses and people to be more energy efficient, it also promoted renewable energy growth by renewing incentives for investors to create more renewable energy.³⁴⁵

³⁴¹ Ibid.

³⁴² Barack Obama, *National Security Strategy* (Washington D.C.: White House, 2015).

³⁴³ "Renewable Energy Production Tax Credit (PTC)."

³⁴⁴ Ibid.

³⁴⁵ Michael Devereux II, "Tax Increase Prevention Act of 2014 Passed on December 16, 2014 | A Summary," *Mueller Prost*, December 18, 2014.

To add to his environmentally focused legacy, in June 2013, Obama announced his Climate Action Plan (CAP) in which he outlined 75 goals in three key areas: cut domestic carbon pollution, prepare the U.S. for the impacts of climate change, and be a leader in international efforts in addressing climate change.³⁴⁶ One of the most ambitious goals of CAP was to reduce GHG emissions by 26-28 percent by 2025. CAP included many strategies to reach this ambitious goal, ranging from reducing GHG emissions from the power industry that had traditionally used fossil fuel to promoting more energy efficiency. CAP included executive actions, increased regulations, investment strategies, increased budget requests, and international agreements. CAP led to visible progress. Just like every other presidential plan or action, there are those who laud President Obama for CAP and those who claim it is not bold enough.³⁴⁷

The final key piece of legislation affecting the environment and wind energy growth during the Obama Administration was the FY 16 Omnibus Appropriations Bill, which passed on December 18, 2015.³⁴⁸ The FY 16 bill finally gave predictability for investors in renewable energy in the form of a five-year extension. One leader in the renewable power industry lauded the benefits of the legislation when he said, "This is one of the most significant stimulus policies for the renewable sector I have seen in the past 10 years."³⁴⁹ The FY16 Bill extended PTCs and ITCs at their current levels through

³⁴⁶ "Fact Sheet: Timeline of Progress made in President Obama's Climate Action Plan," Environmental and Energy Study Institute, last modified August 15, 2015, accessed October 13, 2017, <http://www.eesi.org/papers/view/fact-sheet-timeline-progress-of-president-obama-climate-action-plan>.

³⁴⁷ Ibid.

³⁴⁸ "Production Tax Credit," American Wind Energy Association, last modified 2016, accessed October 13, 2017, <https://www.awea.org/production-tax-credit>.

³⁴⁹ Daniel Cusick, "Renewables Boom Expected Thanks to Tax Credit," *Scientific American*, sec. Energy, August 15, 2015.

2015 and 2016. After that, credits are scheduled to be stepped down from their original value through the remaining three years. The step down is scheduled to be 80 percent for 2017, 60 percent for 2018, and 40 percent for 2019. Considering the PTC eligibility period was supposed to end in 2014, this incentive gave investors five additional years of tax and investment credits.³⁵⁰

The increased attention Obama gave climate change during his second term is recognized by critics and there is general agreement that he was increasingly successful in his second term.³⁵¹ There are more dramatic statements, but at a minimum, “President Obama will be remembered for strong leadership on climate change.”³⁵²

Obama’s International Climate Change Agenda

Obama struggled more domestically than he did internationally when promoting the climate change agenda. He was seen as an international leader in promoting the climate change agenda. This was important for his supporters who believed more needed to happen to protect the environment. Obama started promoting his agenda with alliances in North America by making public announcements with both the Canadian prime minister and the Mexican president to advance technology to counter

³⁵⁰ Diane Bailey, *US Approves Five-Year PTC Phase Out* (Online: Wind Power Monthly, December 15, 2015).

³⁵¹ See: Chait, *Obama might Actually be the Environmental President.*; Eilperin, *Obama Will have Pushed through One of the most Ambitious Environmental Agendas in U.S. History. il it Helping?*

³⁵² Peak, *Here’s what 15 Experts Think of President Obama’s Record on the Environment.*

CO₂ emissions, strengthen infrastructure to handle renewable energy better, and create a framework to bolster clean energy production and reduce the effects of climate change.³⁵³

Bilateral agreements and discussions were important for the region, but arguably the most significant international action by Obama while he was president was when he signed the Copenhagen Accord in 2009. The Copenhagen Accord was groundbreaking and in Obama's own words, "For the first time in history, all of the major – the world's major economies have come together to accept their responsibility to take action to confront the threat of climate change."³⁵⁴ The key provisions of the accord include limiting global temperature increase to two degrees Celsius and broad terms for nations to report and have verified their actions. The accord also set the basis for funding to help nations meet the requirements and for a panel to help track progress.³⁵⁵ The problem with the Copenhagen Accord is that it was all bark and no bite – there were no enforcement mechanisms on an accord that looked good and felt good but it really did very little in verifiable progress.

There were other important international agreements that supported the UNFCCC and Kyoto Protocols such as the Cancun Accord of 2010, which took the Copenhagen Accord and tried to add some muscle and money to it. Another was the

³⁵³ Sussman and Daynes, *US Politics and Climate Change: Science Confronts Policy*, 94-95.

³⁵⁴ Barack Obama, *Remarks on Health Care Reform and Climate Change, Remarks on Health Care Reform and Climate Change*. online by John Wooley and Gerhard Peters, December 19, 2009, The American Presidency Project, <http://www.presidency.ucsb.edu/ws/index.php?pid=87007>.

³⁵⁵ "Summary: Copenhagen Climate Summit," Center for Climate and Energy Solutions, last modified December 20, 2009, accessed October 16, 2017, <https://www.c2es.org/international/negotiations/cop-15/summary>.

2011 Climate Summit in Durban, South Africa did not lead to an international agreement, but the UNFCCC declared it significant since it “accounted for the mitigation efforts of all countries under one agreement.”³⁵⁶ In summary, these accords, agreements and summits were important because Obama ensured America was shown as a leader in this issue and each time more and more nations participated. Talks were intense and often agitated, but progress was made each time. Leaders learned from each summit and each step of progress led to the U.N. Climate Change Conference in Paris in December 2015. Many critics consider the Paris Conference to be a do-over of Copenhagen talks. In Copenhagen the negotiators set tentative agreements but the world leaders did not participate until the last few days. There was a perception that the final deal was forged by the most powerful leaders behind closed doors and the smallest and poorest countries were not able to voice their concerns. The Paris Conference was designed to include world leaders from the beginning.³⁵⁷ Critics believe there were four substantive advances from Copenhagen to Paris. The Paris Agreement, which was reached during the 21st session of the UNFCCC Conference of the Parties (COP 21), had less differentiation between nations, it created more durability, it created more rules, and it was more aspirational.³⁵⁸ The French president, Francois Hollandé, summed up the agreement when he stated, “In Paris, there have been many revolutions

³⁵⁶ Sussman and Daynes, *US Politics and Climate Change: Science Confronts Policy*, 96-98.

³⁵⁷ "The Road to a Paris Climate Deal," *New York Times*, sec. Environment, November 30, 2015.

³⁵⁸ "Outcomes of the U.N. Climate Change Conference in Paris," Center for Climate and Energy Solution, last modified October 16, 2016, accessed October 16, 2017, <https://www.c2es.org/international/negotiations/cop21-paris/summary>.

over the centuries. Today it is the most beautiful and the most peaceful revolution that has just been accomplished – a revolution for climate change.”³⁵⁹

Although world opinion on how Obama handled climate change declined over his presidency, the world was still relatively satisfied with his leadership. Figure 21 depicts how opinions changed from his first term to his second, but it was still higher than most previous U.S. presidents.³⁶⁰

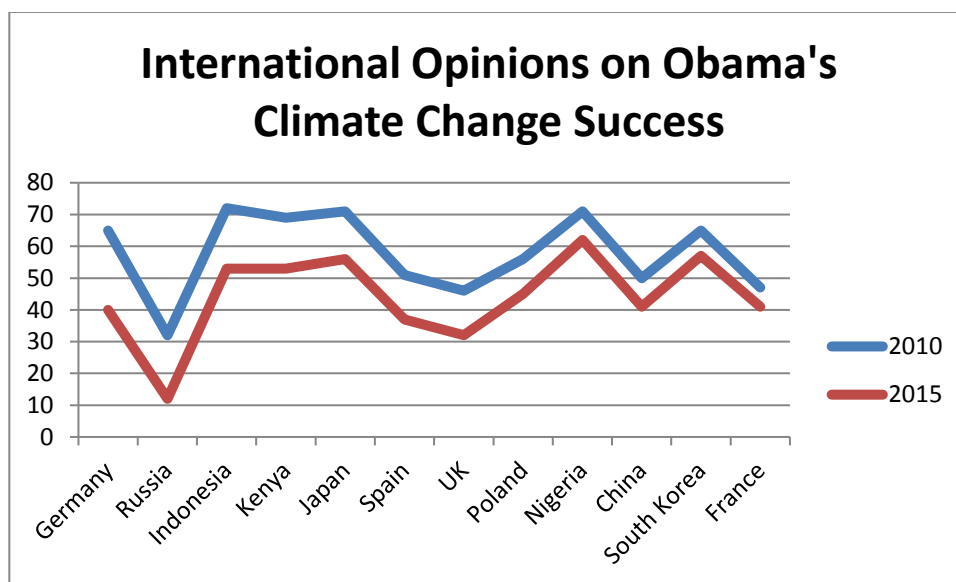


Figure 21 - International Opinions on Obama's Climate Change Success³⁶¹
Data Source: Pew Research Center

³⁵⁹ Ibid.

³⁶⁰ Richard Wike, *7 Charts on how the World Views President Obama* (Washington D.C.: Pew Research Center, June 24, 2015).

³⁶¹ Figure created using data source: Richard Wike, *7 Charts on how the World Views President Obama*.

CO₂ Emissions During Obama Presidency

Since CO₂ emissions correspond to rising global temperatures,³⁶² and the U.S. is one of the worst offenders in terms of quantity of emissions,³⁶³ it is important to see how CO₂ emissions change over time. This pertains to this dissertation because the use of wind energy instead of fossil fuels helps reduce CO₂ emissions. Figure 22 shows that there were increased emissions at the beginning of Obama's presidency, but they were lower when he left office than when he took office. It is important to note that GDP grew every year starting at \$14.419 trillion in 2009 and increasing to \$18.569 trillion by the time Obama left office in 2017. GDP grew every year yet CO₂ emissions were less by the time he left office than when he took office.

³⁶² "Temperature Change and Carbon Dioxide Change."

³⁶³ "Largest Producers of CO₂ Emissions Worldwide in 2016, Based on their Share of Global CO₂ Emissions."

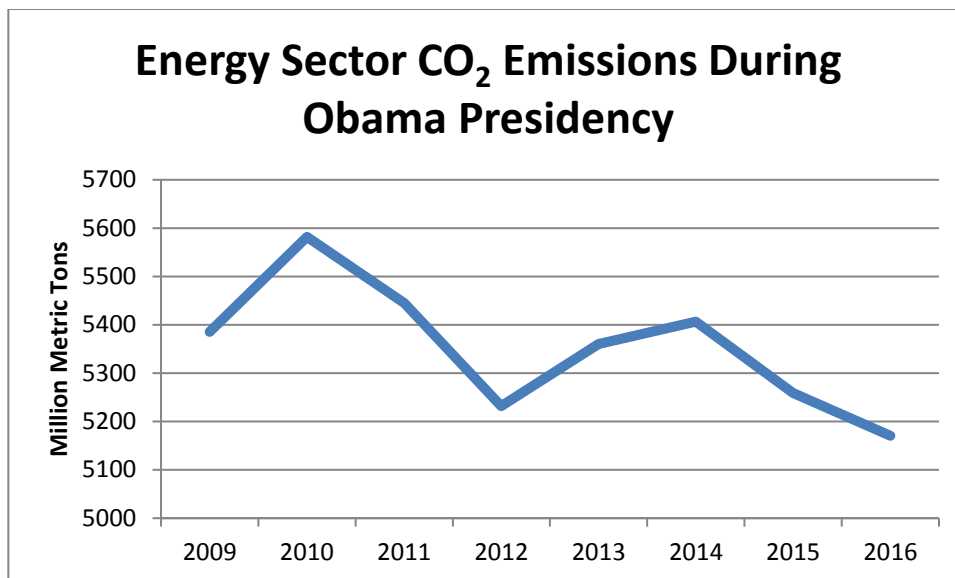


Figure 22 - Energy Sector CO₂ Emissions During Obama Presidency³⁶⁴
Data Source: U.S. Energy Information Administration

There were some good initiatives and legislation that came into existence under Obama's leadership. In fact, Obama included a climate change agenda in his first presidential campaign. When he took office in 2009 the economy was in crisis and his focus during his first term was on decreasing inflation and creating jobs. Evaluation of his leadership reveals many lost opportunities. Although he did not make as much progress as he wanted on restricting pollutants, under his leadership there were multiple key pieces of legislation that promoted renewable energy growth.

³⁶⁴ Figure created using data source: "Total Energy."

Obama and Renewable Energy

“Over the last four years, we’ve doubled the amount of electricity America can generate from wind – from 25 gigawatts to 50 gigawatts. And to put that in perspective, that’s like building 12 new Hoover Dams that are powering homes all across the country...That’s not imaginary. That is real... with the help of these wind energy tax credits, every farmer, every landowner in this area, is benefiting. And all of us are benefiting from clean, American energy.”³⁶⁵

Barack Obama
August 14, 2012
Remarks at the Heil Family Farm
Haverhill, IO

In his 2011 State of the Union address, President Obama declared clean energy would be a key factor in his presidency. He believed the U.S. must decrease its reliance on imported fossil fuel to help reduce CO₂ emissions while also creating a more balance energy portfolio. On March 15, 2012 he said, “We can’t have an energy strategy for the last century that traps us in the past. We need an energy strategy for the future – an all-of-the-above strategy for the 21st century that develops every source of American-made energy.”³⁶⁶ His *all-of-the-above* strategy was focused on building the foundation for a clean energy economy, addressing the issue of climate change, and protecting the environment.³⁶⁷

³⁶⁵ Barack Obama, *Wind Energy Speech* (Haverhill, IO: White House: Office of the Press Secretary, August 14, 2012).

³⁶⁶ "Energy, Climate Change, and our Environment," The White House, accessed January 7, 2016, <https://www.whitehouse.gov/energy>.

³⁶⁷ Ibid.

After evaluating policy decisions, the only way to really evaluate President Obama's impact on the growth of wind energy is to see much it grew during his terms of office. There are many measures of evaluating progress in growth. Three of the most useful measurements are overall wind energy generated into electricity, the amount of annual installed wind capacity, and the amount of cumulative installed wind capacity. Figure 23 shows wind power grew steadily during the Obama administration.

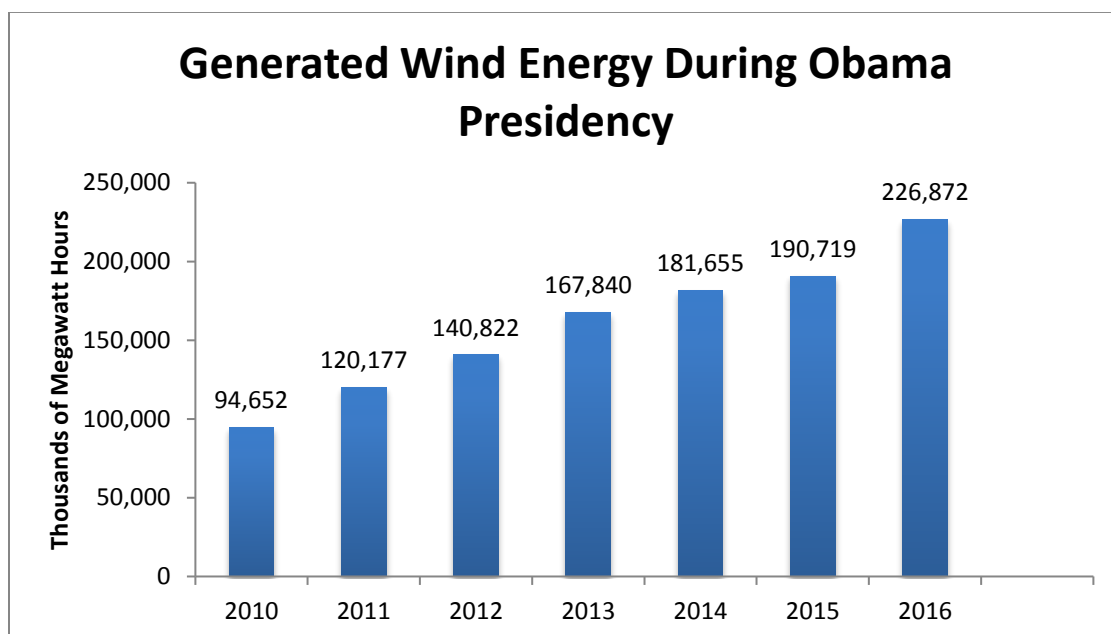


Figure 23 - Generated Wind Energy During Obama Presidency³⁶⁸

Data Source: U.S. Energy Information Administration

Under Obama key incentives were renewed and improved to encourage more wind energy development. Two pieces of legislation, the American Recovery and Reinvestment Act (ARRA) in 2009, and the American Taxpayer Relief Act (ATRA) of

³⁶⁸ Figure created using data source: "Electric Power Monthly."; "Electric Power Monthly Back Issues."

2012, and the Tax Increase Prevention Act (TIPA) of 2014, helped stimulate more renewable energy growth.³⁶⁹ One key issue not discussed was the fact that PTCs were allowed to lapse in 2013 before they were renewed again in TIPA. The pattern of a lapse in the PTC should be familiar by now. This lapse was no different from the previous three lapses and the 2013 lapse led to an 83 percent decrease in production as evidenced in Figure 24 showing both the cumulative and annually installed wind capacity during Obama's presidency. The boom of wind energy production in 2012 was from investors who rushed to get wind farms into production before the PTC expired.

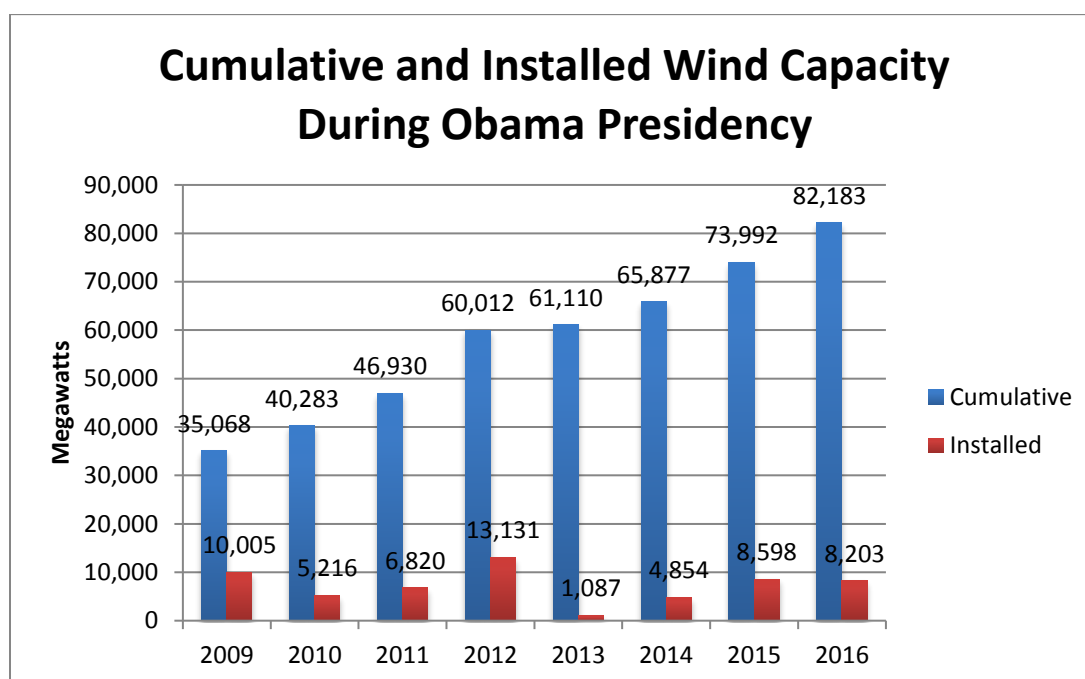


Figure 24 - Cumulative and Installed Wind Capacity During Obama Presidency³⁷⁰

Data Sources: U.S. Department of Energy

³⁶⁹ "Renewable Energy Production Tax Credit (PTC)."

³⁷⁰ Figure created using data source: *Wiser and Bolinger, 2015 Wind Technologies Market Report*, 1-102; "2015 PTC Handout."

Even though there were lapses of the PTC resulting in decreased investment in the wind industry in 2013 and 2014, the U.S. wind industry grew significantly and actually surpassed all other nations except for China.³⁷¹ Figure 25 shows the cumulative wind energy capacity of the top five wind energy producing nations. The U.S. led the world when Obama became president, but China surpassed the U.S. in cumulative wind energy capacity in his second year of office. Although China created more wind energy capacity than the U.S., the U.S. had more wind energy generation than China because of the efficient American markets and a relatively efficient grid system.³⁷² Although China may have had more impressive growth, the amount of U.S. growth cannot be discounted.

³⁷¹ Brown, *World on the Edge: How to Prevent Environmental and Economic Collapse*.

³⁷² Cusick, *China Blows Past the U.S. in Wind Power*.

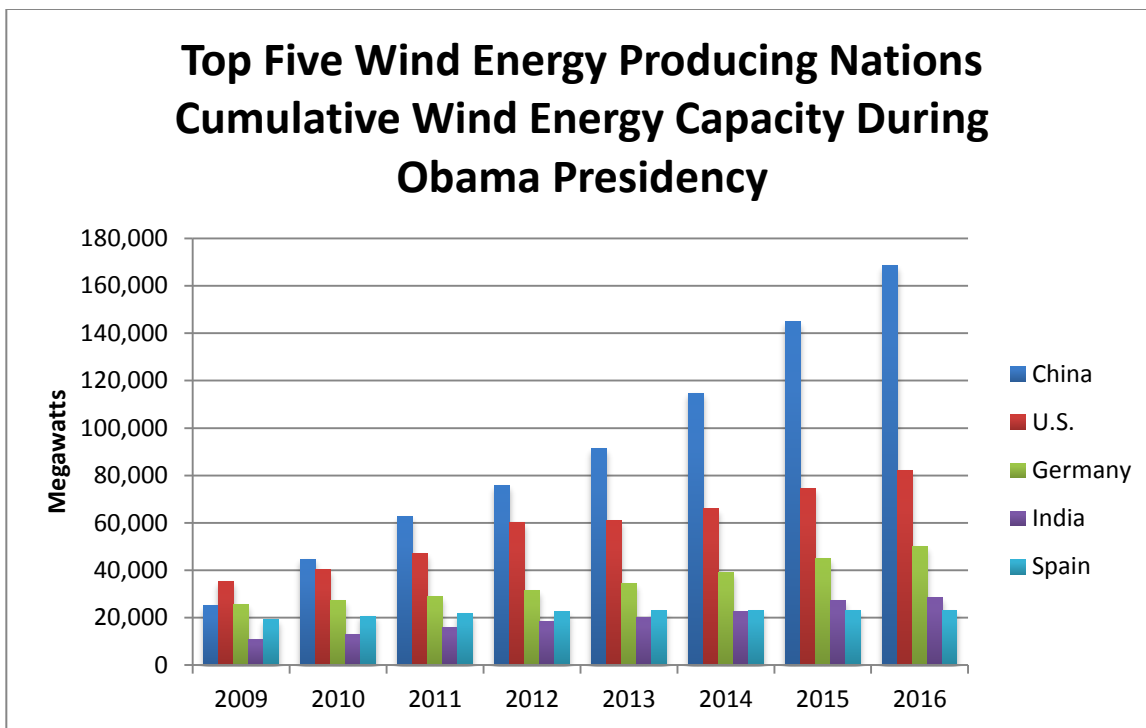


Figure 25 - U.S. Wind Energy Capacity Surpassed by China During Obama Presidency³⁷³

Data Source: Brown, World on the Edge: How to Prevent Environmental and Economic Collapse

Because the legislation that incentivizes wind energy growth also incentivizes solar power growth, it is interesting to see how solar power grew under Obama's leadership. Figure 26 is very telling and if one were conducting a similar study to this one for solar power, 2014 is clearly the year that solar power experienced historic growth. Solar power grew over 630 percent during Obama's terms of office.

³⁷³ Figure created using data source: Brown, *World on the Edge: How to Prevent Environmental and Economic Collapse*.

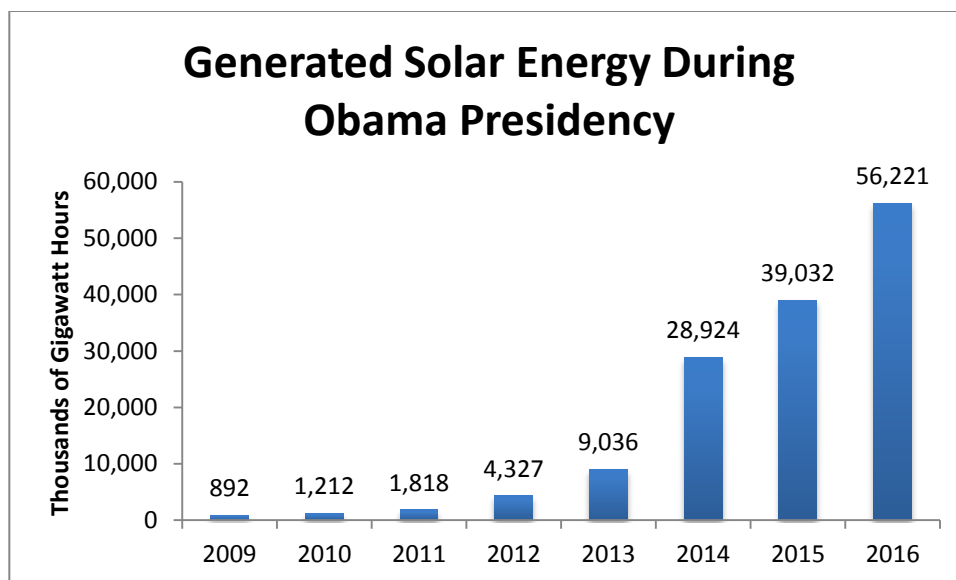


Figure 26 - Solar Energy Grows During Obama Presidency³⁷⁴
Data Source: Global Wind Energy Council

Part of that historic growth was in solar panels that were added to the White House. Carter had thermal solar panels installed on the White House in the 1970s that produced hot water for the cafeteria and laundry services; Reagan had the panels removed; George W. Bush installed solar panels again; and Obama increased the amount of solar panels in his second term of office.³⁷⁵ For security reasons it is unknown how many panels adorn the White House since Obama's additions, but they are expected to generate 6.3 kilowatts of electricity for the residence when the sun is shining.³⁷⁶

³⁷⁴ Figure created using data source: Sawyer and Rave, *Global Wind Report Annual Market Update 2015*, 1-76.

³⁷⁵ "The Tumultuous Saga of Solar Panels on the White House," Understand Solar, last modified November 2, 2016, accessed October 16, 2017, <https://understandsolar.com/white-house-solar-panels/>.

³⁷⁶ "White House Solar Panels Finally Installed," New York Post, last modified May 10, 2014, accessed October 16, 2017, <http://nypost.com/2014/05/10/white-house-solar-panels-finally-installed/>.

In summary, it is evident that, overall, President Barack Obama was a progressive president when it comes to a climate change agenda and promotion of renewable energy. Although he will be remembered more for his progress internationally, there is no denying how CO₂ emissions decreased and renewable energy grew under his leadership. Critics argued that he did not do enough to create legislation protecting the environment,³⁷⁷ but he faced a Republican-controlled Congress that mostly blocked his green agenda. Critics generally agree he tried to do more than most previous presidents. One critic stated, “As President Obama’s administration came to a close, he cemented his legacy as our greenest president.”³⁷⁸ Arguably, President Nixon made the most dramatic changes in national policy and governmental agencies that continue to make a difference today. Presidents Nixon and Obama should both be lauded as setting the most progressively green agendas, although Obama was not as successful at changing national policies.

Comparative Summary During the Critical Years

Comparing Presidents Bush and Obama and the change that occurred during their 16 years of collective leadership, shows the conditions that were established to promote the American wind industry boom. The years most critical to understanding the U.S. wind energy boom that started in 2007 and continued through 2016 are covered by these two presidential administrations.

³⁷⁷ Chait, *Obama might Actually be the Environmental President*.

³⁷⁸ Seth Stein, *2016 National Environmental Scorecard Reveals Assault on Bedrock Environmental Protections*, (League of Conservative Voters, February 23, 2017).

Both Presidents Bush and Obama had crises to deal with that shaped the first terms of their presidencies. Bush led the response to the 9/11 terrorist attacks and Obama led the response to the economic crisis that he inherited. It is impossible to know what would have characterized their first terms of office had they not had those crises to deal with.

Although President Carter was forward thinking in terms of energy diversification, the actions of Presidents Bush and Obama demonstrate different styles of leadership to a more informed public who thought about and were concerned about the environment. Bush did not speak much of climate change and when he did he was vague about asserting how human activity was negatively affecting the environment. On the other hand Obama spoke frequently about climate change and was strong in his language asserting that humans must change their behavior to save the environment. On the other hand Bush had some of the most progressive legislation on creating opportunity for renewable energy growth. Internationally Bush took a big step back while Obama was an international leader in promoting the climate change agenda.

Both presidents had positive GDP growth throughout their presidencies although there was a drop in GDP in 2009 due to the economic crisis.³⁷⁹ Figure 27 shows the steady rate of growth in the U.S. economy over the 16 years they collectively served.

³⁷⁹ "Gross Domestic Product of the United States," World Bank, last modified January 2017, accessed October 16, 2017, <https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?end=2016&locations=US&start=2001>.



Figure 27 - U.S. GDP Between 2001 and 2016³⁸⁰

Data Source: World Bank

If controls were not in place, an increase in GDP would normally lead to a corresponding increase in CO₂ emissions. This is where it is evident that regulations controlling emissions of pollutants made a difference. The following two figures depict CO₂ emissions from the energy sector from 2001 through 2016. Figure 28 shows the emissions on a continuum and helps one to see that CO₂ emissions started dropping in 2007 and dropped steadily throughout Obama's presidency. Without regulations limiting emissions, the line would have correspondingly risen as GDP rose.

³⁸⁰ Figure created using data source: Ibid.

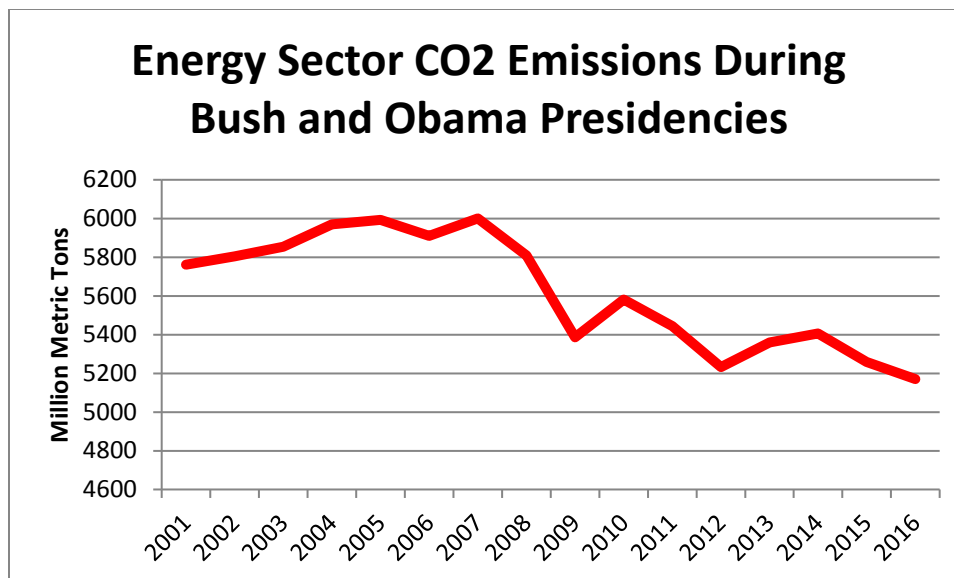


Figure 28 - Energy Sector CO₂ Emissions During Bush and Obama Presidencies³⁸¹

Data Source: U.S. Energy Information Administration

Although legislation to promote renewable energy growth was relatively stable between the Bush and Obama administrations, other shifting policies between administrations hurt many initiatives. For example, Bush had an initiative to develop the hydrogen-powered fuel cell car. Five years later when Obama took office, he cut 80 percent of the funding for the hydrogen car that was sponsored by Bush and chose to promote electric-powered cars instead.³⁸² Although this specific example highlights the inconsistencies of presidential policies between administrations, wind energy has steadily grown due to investors who were willing to accept that the risk was worth the payoff.

³⁸¹ Figure created using data source: "Electric Power Monthly."

³⁸² See: "Fact Sheet: Timeline of Progress made in President Obama's Climate Action Plan."; Elliott, *Why the United States does Not have a Renewable Energy Policy*, December 23, 2015.

In a comparison of the growth of renewable energy between presidencies, it is helpful to look beyond wind energy. Figure 29 shows how solar energy generation was mostly flat until 2011, and then it surged between 2011 and 2016.

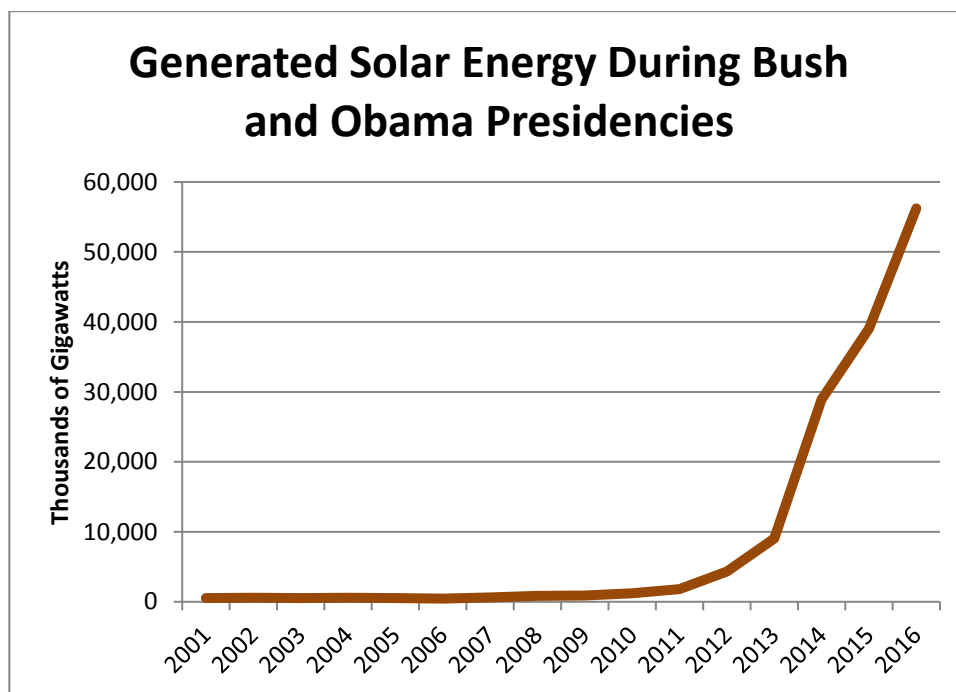


Figure 29 - Generated Solar Energy During Bush and Obama Presidencies³⁸³
Data Source: Global Wind Energy Council

Solar power was much slower to take off than wind power, but this graph shows how that industry experienced significant growth in just five years.

The EPAct of 2002 signed into law by Bush was arguably the most important piece of legislation that set the framework of incentives for investors to produce electricity-generating wind farms. It is impossible to guess how much wind energy the

³⁸³ Figure created using data source: Sawyer and Rave, *Global Wind Report Annual Market Update 2015*, 1-76.

U.S. would have experienced without PTCs, but it is clear that growth would not have occurred at the rates they did without those national tax incentives in place. The amount of wind energy generated during the Bush and Obama presidencies is depicted in the following two charts. Figure 30 shows the amount of wind-generated electricity in gigawatt hours, and Figure 31 shows the change in cumulative installed wind capacity in megawatts.

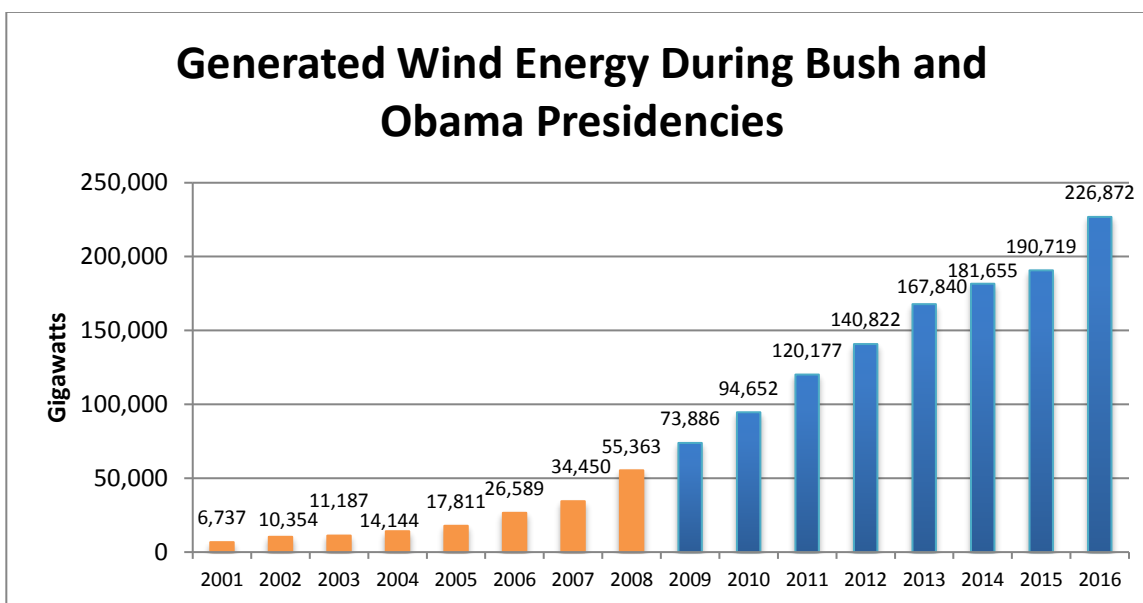


Figure 30 - Generated Wind Energy During Bush and Obama Presidencies³⁸⁴
Data Source: U.S. Energy Information Administration

³⁸⁴ Figure created using data sources: "Electric Power Monthly."; "Electric Power Monthly Back Issues."

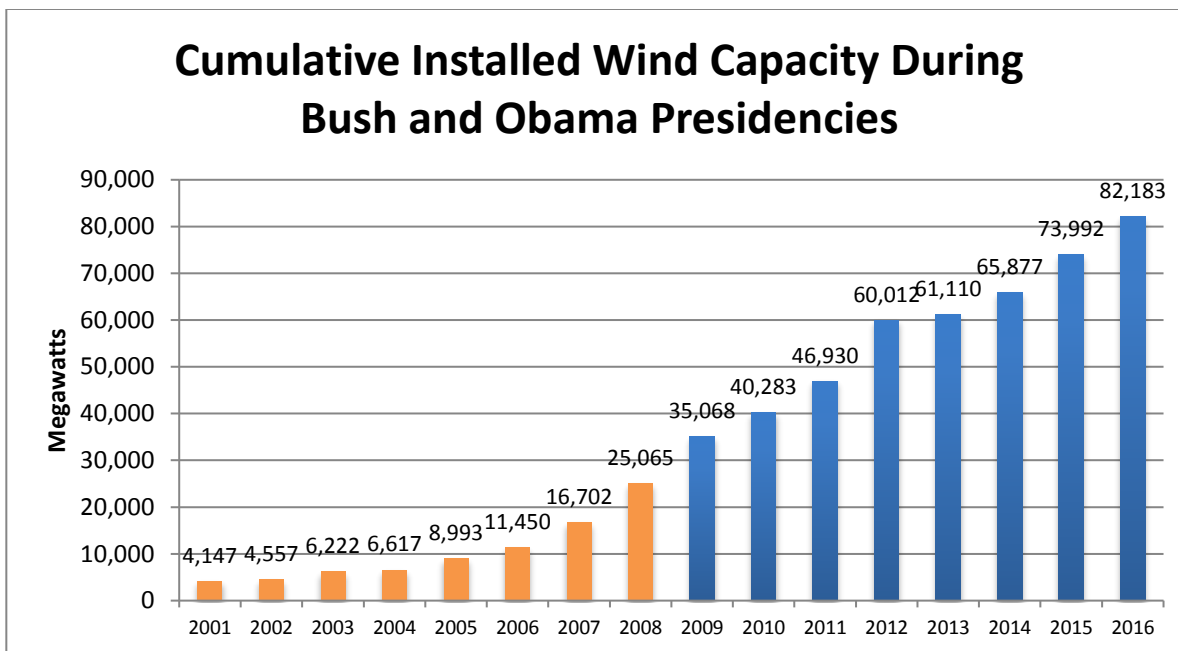


Figure 31 - Cumulative Installed Wind Capacity During Bush and Obama Presidencies³⁸⁵

Data Source: U.S. Energy Information Administration

Looking at a diachronical analysis in this chapter is tricky since Bush's presidency spans both periods of the analysis. The diachronic approach for this study breaks down a study of the U.S. until 2007 and then from 2007 to 2016. The year 2007 was a critical year in the growth of wind energy and that happened under Bush's leadership. However, that growth surged even more under Obama's leadership.

There is a lag effect that varies from issue to issue. For example, one could measure the lag of changing CO₂ emission policies to when there is a measurable difference in atmospheric CO₂. The lag effect can be measured many ways. One type of lag effect is the lag from the time a policy or law goes into place to the time there is

³⁸⁵ Figure created using data sources: "Electric Power Monthly."; "Electric Power Monthly Back Issues."

progress made in the area. Another way to measure lag effect is how long it takes an investor to decide to build a wind farm to the time that farm can produce viable wind energy. The lag effect in wind energy growth varies based on the size and locality of the wind farm. A small wind farm may only take a year and a half to put into production from the genesis of the idea if it is built in a region that is already home to other wind farms. To build a large wind farms in a region that was not previously developed would take much longer to get into production, likely as long as six to eight years.³⁸⁶ There are many steps to building a wind farm and here is an example of the steps investors must take.

1. Find a windy location.
2. Assess the risk to wildlife.
3. Determine costs and financing.
4. Meet all legal requirements.
5. Determine equipment to be used and wind farm design.
6. Determine how generated electricity will be transmitted to the market.
7. Install, test, and run the equipment.³⁸⁷

When overlaying lag effect onto the annual wind capacity additions during the Bush and Obama presidencies (as depicted in Figure 32), it is easy to visualize a two or more year lag effect. That changes the way one looks as presidential effect on wind energy generation.

³⁸⁶ Mark Bolinger and Mary Bell, Question on Lag Time for Wind Farm Development to Wind Expert in the U.S. Department of Energy at Lawrence Berkeley National Laboratory, via e-mail correspondence, October 19, 2017.

³⁸⁷ "Planning a Wind Farm," Canada Wind Energy Association, last modified Unknown, accessed October 10, 2017, <http://canwea.ca/communities/planning-a-wind-farm/>.

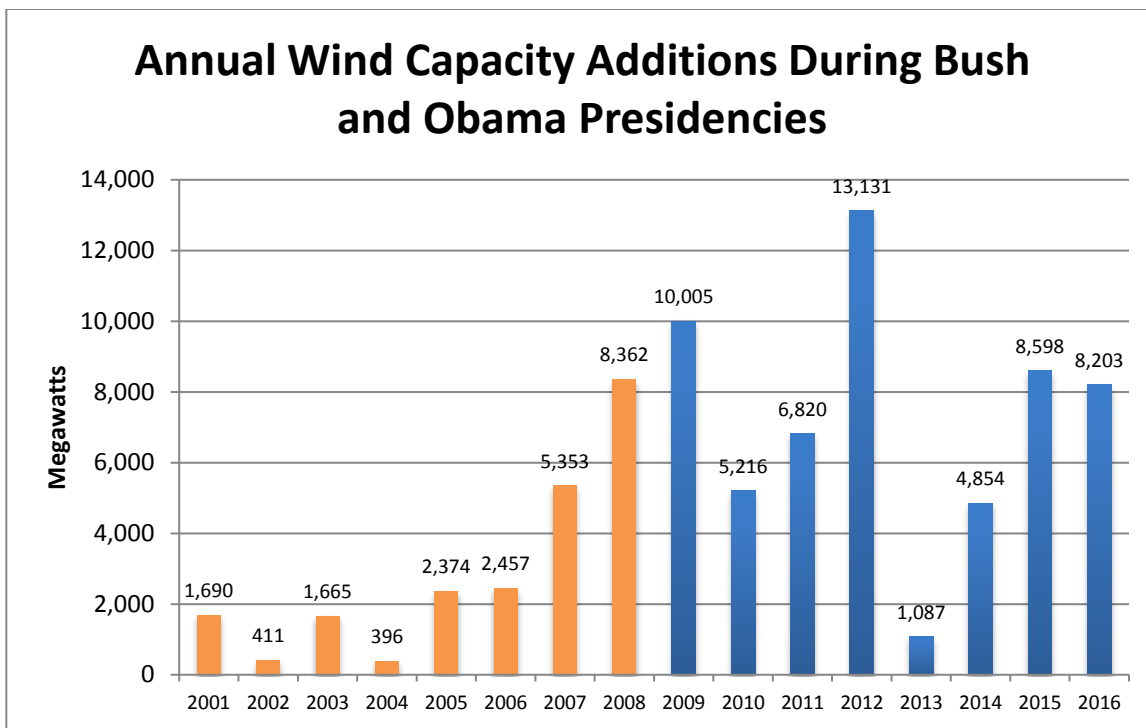


Figure 32 - Annual Wind Capacity Additions During Bush and Obama Presidencies³⁸⁸

Data Source: U.S. Energy Information Administration

Given this lag effect, it is possible that the surge in wind energy growth in 2007 would not have been possible without policies that went into place during the Clinton administration, and that the continued surge of growth during Obama's years could be attributed to Bush's policies. Regardless, it is clear that in this evaluation of wind energy growth comparison between Bush and Obama, Bush should get more credit than he has been given historically. Perhaps Bush's environmental policies were not as progressive as his predecessors or his successor, but his energy policy helped stimulate wind industry growth. Obama is not given much positive credit in his domestic

³⁸⁸ Figure created using data sources: "Electric Power Monthly."; "Electric Power Monthly Back Issues."

progress to protect the environment, but the amount of wind energy growth during his administration shows that his policies and programs made a difference. The good news for the American wind industry is Bush established processes under which wind energy was able to grow and Obama enhanced those processes even further.

It is clear presidential leadership matters in the reduction of CO₂ emissions and renewable energy growth. President Kennedy started the dialogue on anthropogenic effects on the environment in the 1960s; Nixon created government agencies to evaluate the changing climate; Carter heightened awareness; George H.W. Bush signed the law establishing PTCs; Clinton increased the amount of legislation protecting the environment; George W. Bush renewed PTCs; and Obama made the most progress internationally with programs designed to do even more to protect the environment. In the 16 years spanning the Bush and Obama administrations, both presidents made progress domestically by decreasing CO₂ emissions while also growing the economy. Under Bush cumulative wind energy capacity had a larger increase in one year that it had in almost 25 years. It grew from 4,147 megawatts of capacity to 25,065 megawatts during Bush's presidency. Wind energy growth continued under Obama and the U.S. had 82,183 megawatts cumulative capacity by the time Obama left office.³⁸⁹ This chapter shows that national leadership was decisive in the development of the American wind energy industry.

The final comparison between Presidents Bush and Obama will be made based on their leadership. Data showed that wind energy grew substantially during President Bush's terms of office. However, there is little evidence that showed this growth

³⁸⁹ Ibid.; "Electric Power Monthly."

occurred because of his concern for the environment. President Bush understood energy and he was not against policies that would help diversify the American energy market, but he was not actively lobbying for ways to reduce carbon emissions. Wind energy capacity grew even more during President Obama's terms of office and he had campaigned on a platform that was dedicated to addressing climate change. He actively lobbied for ways to improve the future of our planet, but domestic politics and a Republican-controlled Congress prevented him from doing much of what he set out to do. President Bush did not stand in the way of environmental progress, but he did little to promote it. President Obama worked to promote his climate change agenda, but achieved minimal success. Private industry has a strong-enough foothold and has achieved enough economies of scale in the wind industry that presidential support and presidential leadership is becoming less of a critical factor than it was when the industry was in its infancy.

CHAPTER VI

STATE INCENTIVES AND MANDATES

The previous chapter outlined the importance of national-level tax incentives and examined how national leadership affects the amount of wind energy created. Based on the evidence presented in that chapter, it is clear that national leadership and federal policies matter. This chapter will evaluate how many states have set policy to compliment national policy. This will not be a study of all 50 states, but a look at a few key states to determine why those states have the most or least wind energy. There are multiple ways to assess the success of how a state incorporates wind power into its electric grid. One way is to look at wind energy as a percentage of total electricity and another is to look at the cumulative capacity wind energy produces. By the end of 2016, the top five states in terms of percentage of electricity produced from wind energy were Iowa, South Dakota, Kansas, Oklahoma, and North Dakota. The top five states in terms of total cumulative wind energy produced were Texas, Iowa, Oklahoma, California, and Kansas.³⁹⁰ This chapter will first discuss literature on *Federalism* and the amount that states rely on federal support, and then it will evaluate the key factors that contributed to this growth and will also highlight some of the elements that make each state different. As part of the methodology of this dissertation, it is useful to do a diachronical analysis of state wind energy production before 2007 and from 2007 to 2016.

Federalism

³⁹⁰ "U.S. Wind Energy State Facts."

Researcher James Lester wrote about federal policies and how they translated into action or inaction by states. He discovered through his research that states have varying levels of interdependence on the federal government. Lester concluded that a state's ability to absorb federal reductions in environmental aid is dependent on the state's commitment to environmental reform, and the degree to which the state relies on federal environmental aid.³⁹¹ Figure 33 shows the results of Lester's research.

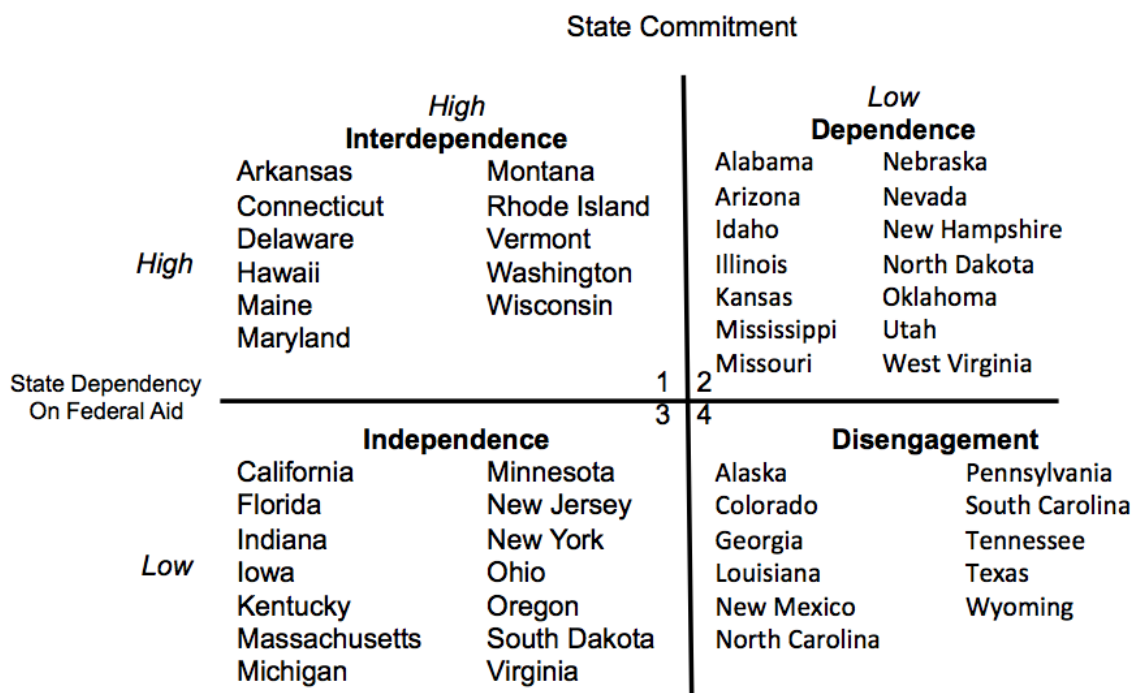


Figure 33 - Typology of State Behavior: Fiscal Dependency and Commitment to Environmental Quality³⁹²

Recreated from Source: James Lester, "New Federalism and Environmental Policy."

³⁹¹ Lester, *New Federalism and Environmental Policy*, 149-165

³⁹² Ibid.

Figure 33 shows states with a high commitment to environmental programs and are highly reliant on federal programs to institute environmental reform in quadrant one; states that have a low commitment to environmental programs yet are highly dependent on federal environmental aid in quadrant two; states with high level of state commitment to environment programs and are also highly independent in instituting those programs; and states with a low commitment to environmental programs and tend to disengage when federal aid is withdrawn in quadrant four.

Understanding the level of interdependence each state has on the federal environmental aid and how decreasing that aid influences a state's ability to promote environmental programs is helpful when evaluating state wind energy programs. Lester's model will be applied throughout this chapter to help explain state behavior.

Before 2007

This section will evaluate several key factors that contributed to the growth in the U.S. wind industry before 2007. The first successful wind farm was built in 1981³⁹³ and the industry experienced an entire decade of relatively slow growth when compared to how much wind grew between 2007 and 2016. The amount of total cumulative wind capacity grew in this time period from eight megawatts in 1981 to 11,450 megawatts by

³⁹³ A wind farm was built in New Hampshire in 1980, but it failed. See: "Turbine Timeline: 1980s," American Wind Energy Association, last modified December 2013, accessed October 25, 2017, <https://www.awea.org/turbine-timeline-1980s>.

the end of 2006.³⁹⁴ Some of the most influential factors in this growth were state tax credits, goals, and mandates.

The state tax credits are called Renewable Portfolio Standards (RPSs).³⁹⁵ RPSs, like PTCs, are designed to increase the amount of electricity generation from renewable sources. States have often filled the role of enacting policies in many fields and state leadership often tries new approaches to policy problems. States designed RPSs to fill a gap created from inconsistencies in federal leadership that led to varying renewable energy policies and also allowed for lapses in PTCs.³⁹⁶ Each state determines its RPSs and some states have chosen to make mandatory minimums and other states have chosen to make wind energy production voluntary. Those states that mandate a minimum use something called *renewable energy credits* to financially punish utility companies that do not achieve the minimum level of renewable energy production required. If a utility does not reach the minimum production rate, it must buy renewable energy credits from other producers that have a surplus. Companies with a surplus sell them at a state auction, so the price is not set by the state but by the open market. While punishing companies that do not produce a set minimum, the process also encourages companies to produce more than required.³⁹⁷ There are three consistencies in RPSs. First, typical RPSs are backed with some type of penalty. Second, a tradable

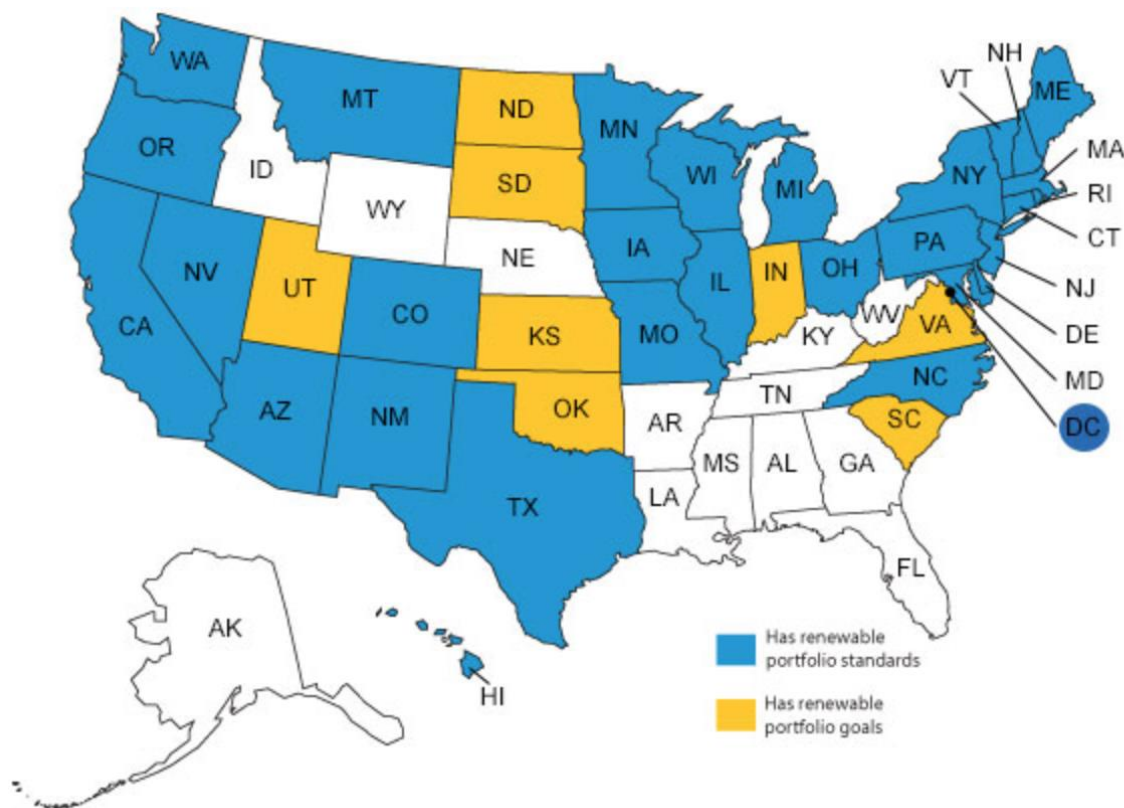
³⁹⁴ See: Brown, *World on the Edge: How to Prevent Environmental and Economic Collapse*.; Miser and Bolinger, *2016 Wind Technologies Market Report*, 1-94.

³⁹⁵ Some states have created variations on the name of their state tax credit. One example is *Renewable Energy Standards* (RES). For the purpose of this work, the terms RPS will be used to represent all state programs that match the definition of RPS.

³⁹⁶ Berry, Laird and Stefes, *Driving Energy: The Enactment and Ambitiousness of State Renewable Energy Policy*, 297-328.

³⁹⁷ Ibid.

REC program to ensure compliance often accompanies RPSs. Finally, RPSs have not been designed the same way in any two states.³⁹⁸ Map 7 depicts states with mandatory RPSs and those with voluntary RPSs or goals.



Map 7 - States with Mandatory Standards or Goals³⁹⁹

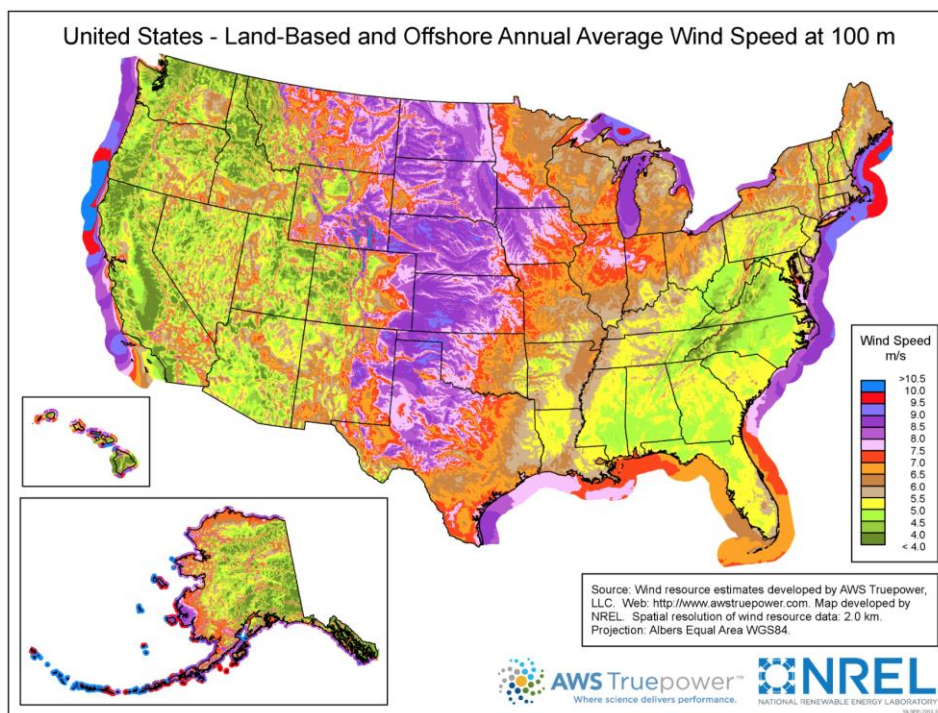
Source: U.S. Energy Information Administration

Another factor that helps one understand which states have produced the most wind energy is to look at wind patterns. It was mentioned in Chapter 3, but it is important

³⁹⁸ Barbose, *U.S. Renewables Portfolio Standards 2017 Annual Status Report*, 1-40.

³⁹⁹ "Renewable Energy Explained," U.S. Energy Information Administration, last modified June 2017, accessed October 23, 2017, https://www.eia.gov/energyexplained/?page=renewable_home#tab4.

to reemphasize that wind does not blow equally across the United States. Map 8 shows an overview of where the wind blows most and where there is most potential for wind energy production. The areas that get the most wind are shown in blue, red, and purple. With the color-coding, it is easy to see that the middle of the U.S. from North Dakota down to Texas are in what is known as the *wind belt*. The areas over water, whether it is the Great Lakes, the Gulf of Mexico, the Atlantic Ocean, or the Pacific Ocean, also have great potential for wind production. Generally speaking, the *wind belt* is where one will find the most wind energy production.



Map 8 - Where the Wind Blows Over the U.S.⁴⁰⁰

Source: National Renewable Energy Laboratory

⁴⁰⁰ "United States Land-Based and Offshore Annual Average Wind Speed at 100 M."

Because of the disparate wind patterns depicted on the wind chart, it is not as economically viable for certain states to develop land-based wind energy capacity. However, California was the early leader in wind energy production. To understand the wind industry development in California requires more investigation. It is notable that California falls into the bottom left quadrant, quadrant three, of Lester's "Typology of State Behavior" (Figure 33).⁴⁰¹ This shows that California is in the most ideal situation to promote wind energy growth since it is least reliant on federal environmental programs. However the first successful wind farm was built in California because government incentives helped compensate investors for the risk of investing in this new technology. It was a combination of national and state level governmental incentives that helped spur development in California. As a review from the previous chapter, two critical statutes of the Federal National Energy Act of 1978 (NEA) that began to offset the risk of investment were the Energy Tax Act (ETA) and the Public Utilities Regulatory Policies Act (PURPA). ETA established a 10-15 percent tax incentive for investment in wind energy and PURPA was the impetus to break the stronghold that the utility companies had on electric power generation.⁴⁰² In response to the oil crises of 1973 and 1978, and as public awareness of climate change grew, many states decided to provide their own incentives for renewable energy growth.

California was one of those states, and the state government established a 25 percent tax credit for qualifying systems, which included wind energy. This tax credit was not what is known today as an RPS, but it was a precursor to the RPS. Due to

⁴⁰¹ Lester, *New Federalism and Environmental Policy*, 149-165.

⁴⁰² Starrs, *Legislative Incentives and Energy Technologies: Government's Role in the Development of the California Wind Energy Industry*, 103-158.

ETA, PURPA, the California tax incentive, and a meteorological report of unceasing winds through Altamont Pass in Northern California, an investor by the name of Alvin Duskin took the risk and built a wind farm that became operational in 1981.⁴⁰³ There was a three-year lag from the creation of the renewable energy friendly legislation in 1978, to the completion of the first wind farm. There are multiple causes of the lag to include courtroom challenges of PURPA's provisions. However, the provisions of the legislation were eventually settled, and in 1981 Duskin successfully installed 144 wind turbines with a combined generating capacity of seven megawatts.⁴⁰⁴ That was not even enough power to meet the annual needs of two average households,⁴⁰⁵ but it was the genesis of the U.S. wind industry.

In the following five years two additional wind farms were built in California and by 1984 California's wind industry employed 14,000 people and had 75 percent of the world's commercial wind energy capacity. By 1985, total investment was \$2 billion, and in 1987 California had a total of 17,000 wind turbines generating 1.7 billion kilowatt hours. There was enough electricity generated from wind energy to meet the annual needs of nearly 300,000 households. This period of rapid growth was possible because of increased productivity, rapid consolidation, and declining costs in development and manufacturing.⁴⁰⁶ Unfortunately the boom cycle turned to bust when the provisions of

⁴⁰³ "Overview of Wind Energy in California," California Energy Commission, last modified 2017, accessed October 17, 2017, <http://www.energy.ca.gov/wind/overview.html>.

⁴⁰⁴ Ranger Lautamo, *Altamont Pass: What's the Story with those Windmills?* (Santa Cruz, CA: Mobile Ranger, August 9, 2016).

⁴⁰⁵ Starrs, *Legislative Incentives and Energy Technologies: Government's Role in the Development of the California Wind Energy Industry*, 103-158.

⁴⁰⁶ *Ibid.*

the Federal ETA were subsequently revoked in 1982 and 1985.⁴⁰⁷ The final blow was in 1985 when the governor of California signed a law reducing the state tax incentive to 15 percent in 1986, and he completely eliminated it in 1987.⁴⁰⁸

The next 15 years yielded significantly less growth in the state's wind industry. California's wind capacity stagnated, but it was reenergized in 2002 when the state developed RPSs.⁴⁰⁹ The 2002 RPS mandated 20 percent of electricity be derived from renewable resources, and was subsequently revised making more achievable interim standards in a step up approach.⁴¹⁰ These incentives made a big difference in creating more opportunities for investors.

Iowa also had an interesting start to its wind industry and was the state with the highest percentage of electricity generated from wind energy in the U.S. by the end of 2016. Iowa is in the *wind belt*, so it is practical for its citizens to harness wind to produce energy. Additionally, Iowa, like California, falls into quadrant three of Lester's "Typology of State Behavior" (Figure 33).⁴¹¹ This shows that Iowa is in the most ideal situation to promote wind energy growth since it is the least reliant on federal environmental programs.

Farmers in Iowa started using windmills to pump water, and power radio and lights as early as the 1880s. This helped shape attitudes that supported wind farm development a hundred years later. Overall the citizens of Iowa have historically been

⁴⁰⁷ Lazzari, *Energy Tax Policy: History and Current Issues*.

⁴⁰⁸ Starrs, *Legislative Incentives and Energy Technologies: Government's Role in the Development of the California Wind Energy Industry*, 103-158.

⁴⁰⁹ "Today in Energy: Most States have Renewable Energy Portfolios."

⁴¹⁰ *Ibid.*

⁴¹¹ Lester, *New Federalism and Environmental Policy*, 149-165.

very supportive of wind energy development. Iowa was the very first state to develop RPSs, which went into effect on January 1, 1983 as part of the Alternative Energy Production Law.^{412,413} The states' RPSs required that Iowa's main utility companies own or contract 105 megawatts of renewable energy. Most state RPSs set a minimum percentage, but a few states such as Iowa set a specific amount rather than a percentage. Iowa utility companies met the mandated goal in 1999, which was 16 years after the requirement was established.⁴¹⁴ The wind energy industry was slow to start in Iowa and 1999 was the year that the industry there really grew. The number of megawatt hours of electricity in 1998 was 89 and that number jumped to 326,354 megawatt hours the next year. By the end of 2006, Iowa wind farms were producing over 2.3 million-megawatt hours of electricity,⁴¹⁵ which was enough to power just over 211,000 homes.⁴¹⁶

Perhaps it is obvious why Texas has the most installed wind capacity of any U.S. state. Other than Alaska, it has the most land mass and there are thousands of wide-open spaces to build wind farms. One look at the wind chart or a quick visit to the panhandle of Texas would help one understand how windy it is across much of the state much of the time. Texas is traditionally known as the big oil state, but its moniker would

⁴¹² "Alternative Energy Law (AEL)," Database of State Incentives for Renewables and Efficiency (DSIRE), last modified December 9, 2016, accessed October 18, 2017, <http://programs.dsireusa.org/system/program/detail/265>.

⁴¹³ Iowa RPSs were amended in both 1999 and 2003 and were still in effect by the end of 2016.

⁴¹⁴ "Iowa Wind Energy," American Wind Energy Association, last modified 2017, accessed October 19, 2017, <http://awea.files.cms-plus.com/FileDownloads/pdfs/iowa.pdf>.

⁴¹⁵ "State Wind Energy by Year."

⁴¹⁶ The amount of energy it takes to power an average American home varies significantly. This number was calculated using a formula provided through AWEA.

more appropriately be the *big energy state*. One might think that such a politically conservative state would have been unwilling to embrace renewable energy, but that is not the case. Interestingly, Texas falls into the bottom right quadrant, quadrant 4, of Lester's "Typology of State Behavior" (Figure 33). This shows that companies in Texas are most likely to disengage from environmental policies if federal aid is not available. The wind industry in Texas flourished because the state government and Texas energy sector chose to not disengage.

There was a program studying wind energy that first began in 1970 at West Texas State University (now West Texas A&M University) and later developed into the Alternative Energy Institute (AEI) in 1977. AEI provided much of the research to help the wind industry develop. In 1999, the governor of Texas, George W. Bush, signed into law the second set of state RPSs (Iowa was the first). The original RPS mandated an additional 2,000 megawatts of renewable energy generation by 2009. The goal was met in 2005, four years earlier than required. Because of its success, the Texas Legislature expanded the RPS goals of the state significantly in 2005, which set a goal of 5,880 megawatts of renewable generation capacity by 2015 and 10,000 megawatts by 2025.⁴¹⁷ These legislative mandates were an important factor in the success of the wind industry in Texas. By the end of 2006, Texas utility companies were providing

⁴¹⁷ "REC Trading in Texas - Lessons Learned & Way Forward," Center for Energy Economics, The University of Texas at Austin, last modified June 2009, accessed October 21, 2017, http://www.beg.utexas.edu/energyecon/thinkcorner/REC_trading_Gulen.pdf.

6.67 million megawatt hours of electricity to its citizens,⁴¹⁸ which was enough to power almost 613,000 homes.⁴¹⁹

The three different case studies of California, Iowa, and Texas highlight how each of those states took different paths to create successful wind industries. California was the early boom state; Iowa and Texas entered the industry later, but never had a large period of stagnation in their wind industry growth like California. Both Iowa and Texas showed very consistent growth from the time wind farms were first created in those states.

This section provided an overview of how the wind industry got its start in the U.S. growing from zero installed commercial capacity to 11,450 megawatts of installed capacity. The incentives, policies, and/or attitudes within each state were crucial to how each state began developing its wind industry. Looking at this second period of the diachronical analysis will help complete the overview of how the U.S. wind industry experienced more growth than in the first period.

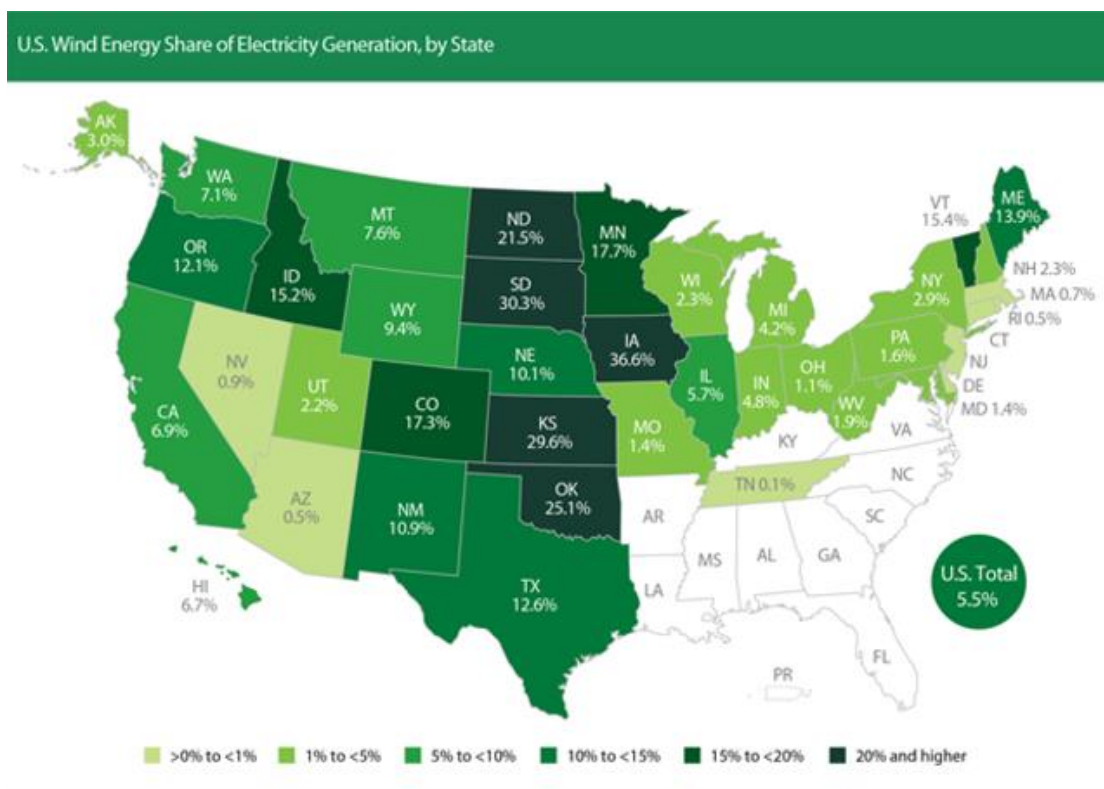
2007 to 2016

The previous section showed how some of the top wind energy producing states took a path that led to a robust wind industry. This section will look at the years 2007 through 2016 and how the wind industry continued to develop to make the U.S. the most prolific nation in terms of electricity generated from wind energy. Map 9 is color-

⁴¹⁸ "State Wind Energy by Year."

⁴¹⁹ This number was calculated using a formula provided through AWEA.

coded to show that 41 states have some wind energy capacity. The states in dark green have the highest percentage of electricity generated from wind and those in white have no commercial wind energy production.⁴²⁰



Map 9 - Wind Energy Share of Electricity Generation by State⁴²¹

Data Source: American Wind Energy Association

As shown in this map in dark green, the following five U.S. states utilized more than 20 percent of all electricity generated by wind by the end of 2016: Iowa, South Dakota, Kansas, Oklahoma, and North Dakota. To show it in a different way, Figure 34

⁴²⁰ This study is only evaluating commercial wind energy, not individual or very small producers.

⁴²¹ Figure created using data source: "U.S. Wind Energy State Facts."

shows the top ten states in order and includes the percentage of electricity in the state that is generated from wind.

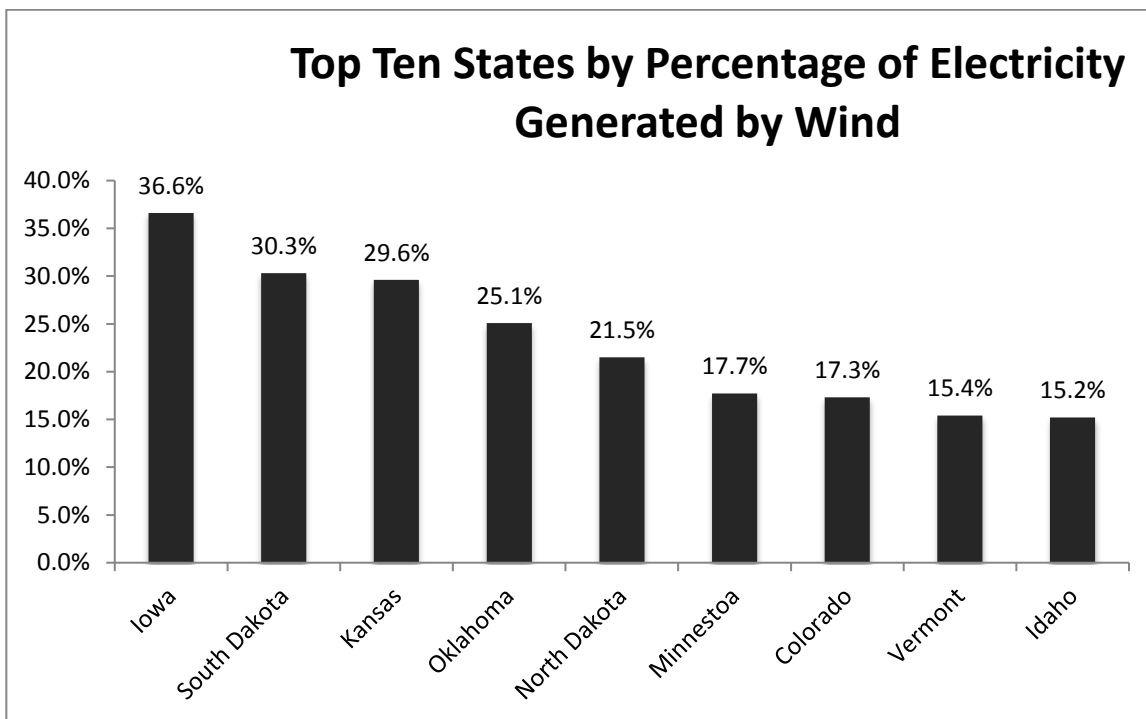


Figure 34 - Top Ten States by Percentage of Electricity Produced from Wind⁴²²
Data Source: American Wind Energy Association

The list changes a bit when looking at the top five states with the most installed wind capacity in terms of total output by the end of 2016. The top five were: Texas, Iowa, Oklahoma, California, and Kansas. Figure 35 shows the top ten states with the most cumulative wind energy capacity. By looking at the data in this way, it is easy to discern that the total installed wind energy capacity of Texas was almost three times as

⁴²² Figure created using data source: "U.S. Wind Energy State Facts."

the next closest state. In fact, the Texas capacity alone would have made it the sixth highest in international rankings if it were its own nation.⁴²³

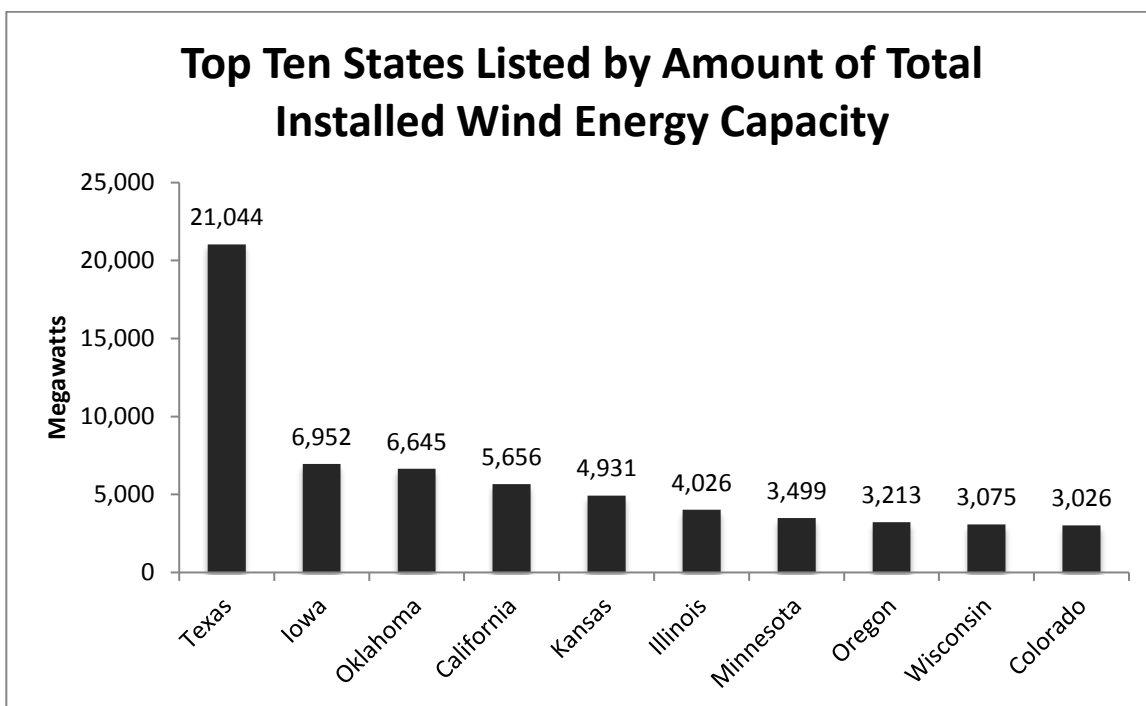


Figure 35 - Top Ten States by Amount of Total Electricity Produced from Wind⁴²⁴
Data Source: American Wind Energy Association

In the previous section, it was discussed how state RPSs made a difference in the amount of wind energy generated in those states. By the end of 2016, RPS policies were in place in 29 states and Washington, D.C. According to the U.S. DOE, “roughly 60 percent of new U.S. renewable generation and capacity additions since 2000 were

⁴²³ Steve Sawyer and Morten Dyrholm, *Global Wind Report Annual Market Update 2016* (Brussels, BE: Global Wind Energy Council, 2017). Spain was fifth with 23,075 megawatts capacity and the UK was sixth with 14,542 megawatts capacity.

⁴²⁴ Figure created using data source: "U.S. Wind Energy State Facts."

driven by these policies."⁴²⁵ It is impossible to underscore the importance of RPSs in the development of the U.S. wind industry. The DOE assessed that RPSs were the most important factor in added wind energy capacity. Figure 36 shows the timeline of when states developed RPSs and when those RPSs were amended.

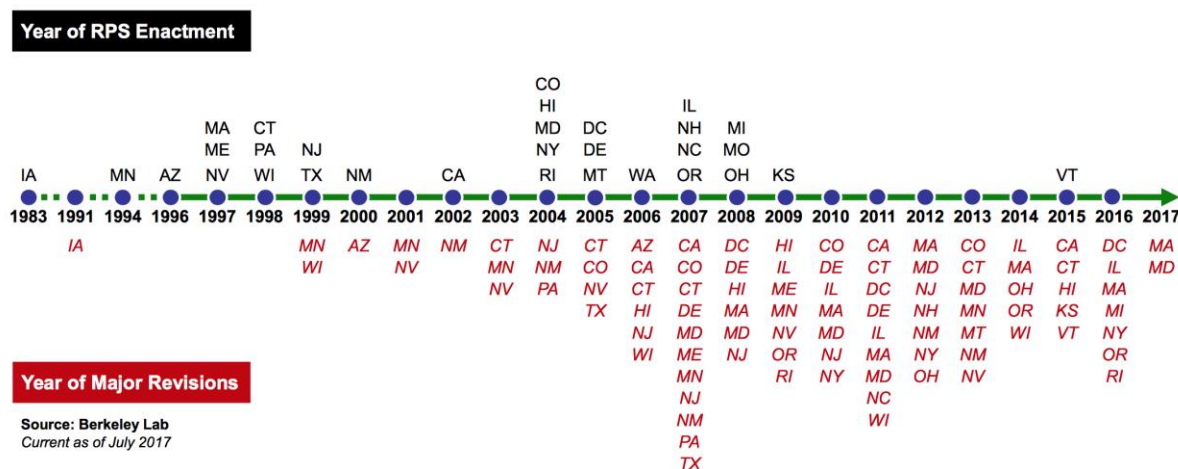


Figure 36 - Timeline of State-Created RPSs and RPS Amendments⁴²⁶

Source: Lawrence Berkeley National Laboratory

Based on the criticality of RPSs in development, *a priori* assumptions would lead one to believe that states with the highest mandatory RPSs coupled with lots of natural wind would have the greatest wind power capacity. Comparing this map to the one that shows the percentage of electricity produced in each state shows this assumption does not hold true. Researchers conducted a statistical analysis and concluded the unexpected statistical outcome is greatly influenced by a few individual states, such as

⁴²⁵ "Renewable Energy for State Renewable Portfolio Standards Yield Sizable Benefits," U.S. Department of Energy, last modified January 17, 2016, accessed October 21, 2017, <https://energy.gov/eere/articles/new-study-renewable-energy-state-renewable-portfolio-standards-yield-sizable-benefits>.

⁴²⁶ Barbose, *U.S. Renewables Portfolio Standards 2017 Annual Status Report*, 1-40.

Texas and Iowa. "Texas has, by far, the most installed wind capacity, but it also has one of the lowest RPS mandates. Similarly, Iowa has the second most wind capacity and a very low RPS mandate. These states show that the relationship between the RPS mandate and wind capacity is not as well defined as expected."⁴²⁷ The results of the statistical analysis demonstrate that policy mandates are not the only determining factor that shapes wind energy development. With that knowledge, it seems logical that harvesting the wind in certain regions is more economical than in others.

Iowa was the very first state to create RPSs and it also utilizes the biggest percentage of wind for electricity generation than any other state. Iowa also has the second largest cumulative wind energy capacity only behind Texas. The first section of this chapter explained how the Iowa wind industry got its start. By the end of 2016, Iowa had enough wind energy to power the equivalent of 1.85 million homes at 6,952 megawatts cumulative capacity. By the end of 2016, the Iowa wind industry employed almost 9,000 people, had 11 active manufacturing facilities, \$13.5 billion had been invested in that industry, and wind was generating enough energy to power the equivalent of 1.85 million homes.⁴²⁸

California legislators continued to update its RPSs and, as of April 2011, its RPSs required California's electric utilities to derive 33 percent of their retail sales from eligible renewable energy resources by 2020. The law also established interim targets of 20 percent of electricity to be generated by wind energy by the end of 2013, and 25

⁴²⁷ Andrea Staid and Seth D. Guikema, "Statistical Analysis of Installed Wind Capacity in the United States," *Energy Policy* 60 (September 2013, 2013), 378-385.

⁴²⁸ "Iowa Wind Energy."

percent by the end of 2016.⁴²⁹ The industry did not make those goals by the end of 2016, but the wind industry continues to grow in California. By the end of 2016, the California wind industry employed almost 4,000 people, had 12 active manufacturing facilities, \$12.5 billion had been invested in that industry, and wind was generating enough energy to power the equivalent of 1.3 million homes.⁴³⁰

Texas set its first RPSs in 1999 and those were amended in 2005.⁴³¹ The 2005 amendment set new goals of having 5,880 megawatts of installed capacity by 2015 and 10,000 megawatts of installed capacity by 2025. Both those goals were met in 2010, and by the end of 2016, the Texas wind industry employed almost 23,000 people, had 40 active manufacturing facilities, \$38.4 billion had been invested in that industry, and wind was generating enough energy to power the equivalent of 5.3 million homes.⁴³²

Texas was in a unique situation by the end of 2016, and not just because it had almost triple the amount of wind energy than any other state. Texas established the Competitive Renewable Energy Zone (CREZ) in 2014. CREZ was a \$6.8 billion initiative to update the electricity grid with new transmission lines that spanned 3,600 miles to tie in the major metropolitan areas of Dallas-Fort Worth, Houston, Austin, and San Antonio.⁴³³ One expert said, "CREZ will turn out to be the most visionary thing this state

⁴²⁹ "Today in Energy: Most States have Renewable Energy Portfolios."

⁴³⁰ "California Wind Energy," American Wind Energy Association, last modified 2017, accessed October 19, 2017, <http://awea.files.cms-plus.com/FileDownloads/pdfs/California.pdf>.

⁴³¹ "REC Trading in Texas - Lessons Learned & Way Forward."

⁴³² "Texas Wind Energy," American Wind Energy Association, last modified 2017, accessed October 19, 2017, <http://awea.files.cms-plus.com/FileDownloads/pdfs/Texas.pdf>.

⁴³³ David Grossman, "Texas is Drowning in Wind Energy," *Popular Mechanics*, sec. Technology, August 8, 2016.

has ever done electricity-wise."⁴³⁴ CREZ created the vital network capable of moving electricity generated in remote areas to the big cities. This is a problem most states have not yet overcome. CREZ was so successful, Texas is looking at exporting wind energy to neighboring states.⁴³⁵

There are three noticeable states, Idaho, Wyoming, and Nebraska that are in generally windy areas, yet they do not have RPSs. Idaho never established RPSs, but over 70 percent of the state's electricity is generated from renewable energy. Hydroelectricity generates over 50 percent, and wind generates 15.2 percent of Idaho's electricity.⁴³⁶ Wyoming is different than Idaho in that it has been fiercely loyal to the coal industry with over 90 percent of its electricity being produced by coal. Not only does it not have RPSs, it actually taxes every megawatt hour of wind energy produced from wind energy at \$1 an hour.⁴³⁷ Nebraska gets 10.1 percent of its electricity from wind energy and that is substantial considering it has no RPSs.⁴³⁸ Nebraska is a state that is friendly to wind energy development, but because its utility companies are publicly

⁴³⁴ Ibid.

⁴³⁵ "Texas: A National Wind Energy Pioneer," Wind Energy Foundation, last modified 2016, accessed October 19, 2017, <http://windenergyfoundation.org/wind-at-work/case-studies/texas/>.

⁴³⁶ See: "Renewable Energy in Idaho," American Council On Renewable Energy (ACORE), last modified September 2014, accessed October 21, 2017, <http://www.acore.org/files/pdfs/states/Idaho.pdf>.; "Idaho: State Profile and Energy Estimates," U.S. Energy Information Administration, last modified July 2017, accessed October 21, 2017, <https://www.eia.gov/state/?sid=ID#tabs-4>.

⁴³⁷ "Wyoming: State Profile and Energy Estimates," U.S. Energy Information Administration, last modified July 2017, accessed October 21, 2017, <https://www.eia.gov/state/?sid=WY#tabs-4>.

⁴³⁸ "Nebraska: State Profile and Energy Estimates," U.S. Energy Information Administration, last modified July 2017, accessed October 21, 2017, <https://www.eia.gov/state/?sid=NE#tabs-4>.

owned, they are not eligible for Federal PTCs.⁴³⁹ Evaluating each of these three states and why they do not have RPSs highlights the uniqueness of each of the 50 states and each state's quest for the best energy portfolios.

Idaho, Wyoming, and Nebraska fall into two different quadrants of Lester's "Typology of State Behavior" (Figure 33).⁴⁴⁰ Both Idaho and Nebraska fall into quadrant two and are considered to have a low dependence on federal environmental aid. The fact that Nebraska's utility companies are publicly owned and they cannot accept federal aid highlights their low dependence on the federal government. Wyoming falls into quadrant four predicting that it would disengage when federal environmental aid was withdrawn. Their state policies outlined above match what Lester predicts with his research.⁴⁴¹

On the opposite end of the spectrum from states with no RPSs are states with the most aggressive RPSs: Hawaii, Vermont, California, and Oregon.⁴⁴² As seen with the states with no RPSs, the situation in each of these four states is unique. Hawaii recently passed legislation setting RPSs at 100 percent by 2045⁴⁴³ largely because it has the highest electricity prices in the nation at about three times the national average.⁴⁴⁴ Hawaii has enough wind energy to power over 56,000 homes,⁴⁴⁵ but

⁴³⁹ Cole Epley, "New Developments Help Nebraska Take Advantage of its Capacity for Wind Power, which Accounted for More than 10 Percent of its Energy in 2016," *Omaha World Herald*, April 28, 2017.

⁴⁴⁰ Lester, *New Federalism and Environmental Policy*, 149-165.

⁴⁴¹ Ibid.

⁴⁴² "State Renewable Portfolio Standards and Goals."

⁴⁴³ "State Wind Energy by Year."

⁴⁴⁴ Davide Savenije, *Hawaii Legislature Sets 100% Renewable Portfolio Standard by 2045*, (Utility Dive, May 6, 2015).

⁴⁴⁵ "State Wind Energy by Year."

investors and utility companies are primarily looking at solar power as the way to achieve their goals of energy independence while also protecting the environment.⁴⁴⁶ Interestingly, Hawaii falls into quadrant one of Lester's "Typology of State Behavior" (Figure 33).⁴⁴⁷ Hawaii is highly dependent on federal environmental aid, as is Vermont.

Vermont set aggressive RPSs and wants to achieve a rate of 75 percent by 2032.⁴⁴⁸ It already derives almost all of its electricity from renewable energy.⁴⁴⁹ Wind energy powers the equivalent of 27,000 homes, which is 15.41 percent of resources used to generate electricity.⁴⁵⁰ There are continued opportunities to build more wind farms in Vermont, but hydropower is the most developed renewable resource in that state.

Since California has previously been evaluated, the next state to evaluate is Oregon, with RPSs of 50 percent by 2040.⁴⁵¹ Oregon is the eighth highest producer of cumulative wind energy in the nation with a total capacity of 3,213 megawatts. By the end of 2016, the Oregon wind industry employed almost 3,000 people, had eight active manufacturing facilities, had \$6.5 billion invested in it, and wind was generating enough energy to power the equivalent of 662,000 homes.⁴⁵² Oregon, like Vermont, has an

⁴⁴⁶ Savenije, *Hawaii Legislature Sets 100% Renewable Portfolio Standard by 2045*.

⁴⁴⁷ Lester, *New Federalism and Environmental Policy*, 149-165.

⁴⁴⁸ "State Wind Energy by Year."

⁴⁴⁹ "Vermont: State Profile and Energy Estimates," U.S. Energy Information Administration, last modified July 2017, accessed October 22, 2017, <https://www.eia.gov/state/?sid=VT#tabs-4>.

⁴⁵⁰ "Vermont Wind Energy," American Wind Energy Association, last modified June 2017, accessed October 22, 2017, <http://awea.files.cms-plus.com/FileDownloads/pdfs/Vermont.pdf>.

⁴⁵¹ "State Renewable Portfolio Standards and Goals."

⁴⁵² "Oregon: Wind Industry," American Wind Energy Association, last modified July 2017, accessed October 22, 2017, <http://awea.files.cms-plus.com/FileDownloads/pdfs/Oregon.pdf>.

abundance of natural rivers and generates most of its electricity by hydropower. Almost 48 percent of electricity in Oregon is generated from hydropower. Oregon falls into quadrant three of Lester's "Typology of State Behavior" (Figure 33) indicating that it is highly independent and does not rely on federal environmental aid.⁴⁵³

Rhode Island falls into quadrant one of Lester's "Typology of State Behavior" (Figure 33), showing that it is highly interdependent on federal environmental aid.⁴⁵⁴ Rhode Island has also done something unique with wind energy that would appear contrary to Lester's model. The state opened the nation's very first offshore wind farm at the end of 2016. The wind farm is very small with only five turbines designed to power the small island community of Block Island. The wind farm cost almost \$300 million to build, and it is estimated that it will produce 90 percent of the island's electricity and only one percent of the state's electricity.⁴⁵⁵ The state is proud of its achievement and the co-founder of the Senate Climate-Action Task Force, Senator Sheldon Whitehouse, stated, "This is a historic milestone for reducing our nation's dependence on fossil fuels, and I couldn't be more thrilled that it's happening here in the Ocean State."⁴⁵⁶

This section shows that each state has its very own story on wind energy development. Since the DOE assessed that 60 percent of the reason wind energy grew as much as it did since 2000 is attributed to state policies and incentives, this factor is the most important in what enabled the wind boom. The industry really took off in 2007 and one of the primary reasons became evident in this evaluation.

⁴⁵³ Lester, *New Federalism and Environmental Policy*, 149-165

⁴⁵⁴ Ibid.

⁴⁵⁵ Tatiana Schlossberg, "America's First Offshore Wind Farm Spins to Life," *New York Times*, sec. Science, December 14, 2016.

⁴⁵⁶ Ibid.

The Critical Years

The critical years that were the prelude to the U.S. wind energy boom that started in 2007 were precipitated by state policies and mandates that incentivized the growth. There were 13 states that had created RPSs by 2002. There were many burgeoning wind energy programs by then, but these programs really began to grow in 2004 with five states adding RPSs, and three more states making significant revisions to their wind energy incentives. Three more states added RPSs in 2005, with four states making significant revisions. One state added RPSs in 2006, with six states making significant revisions. Four states added RPSs in 2007, with 11 states making significant revisions.⁴⁵⁷ This information shows an important trend that was happening across the U.S. State governments created legislation that made it possible for the wind industry to gain economies of scale and install approximately 7,000 megawatts of wind energy capacity per year starting in 2007.⁴⁵⁸ Although some states saw the value of wind energy to mitigate the CO₂ emissions from fossil fuels and better balance their energy portfolios, that number surged starting in 2004. That surge of state support to the wind industry that began in 2004 helped lead to the nation-wide wind energy boom in 2007.

⁴⁵⁷ Barbose, *U.S. Renewables Portfolio Standards 2017 Annual Status Report*, 1-40.

⁴⁵⁸ "Electric Power Monthly."; "Electric Power Monthly Back Issues."

Summary

The total installed wind capacity in the U.S. was 11,450 megawatts at the beginning of 2007 and grew to 82,183 megawatts by the end of 2016. That means it took 25 years to generate the first 11,450 megawatts of installed wind energy capacity and only 10 years to add an additional capacity of 70,733 megawatts.⁴⁵⁹ Each state forged a different path for different reasons. Some states relied heavily on federal and state incentives in the form of PTCs and RPSs for development while some with states with highly developed wind industries did not. Some states are highly dependent on federal environment aid and others are shown to disengage without it. Other states have highly advanced renewable energy incorporated into their electrical grids in the form of solar or hydropower, while others prefer to use fossil fuels such as coal to generate their electricity. One thing that is certain is that no two states are alike and the only way to get a complete and comprehensive understanding of how the wind industry has developed in the U.S. is to conduct an in depth state-by-state analysis that is beyond the scope of this work. This chapter provided enough of the information to get an idea of how important state policies and attitudes were in creating the booming wind industry in the U.S. The DOE assessed that 60 percent of the reason wind grew so much in the last decade was due to state policies and mandates.⁴⁶⁰ Understanding the basics of RPSs, a state's reliance on federal environmental aid, and how each state

⁴⁵⁹ "Electric Power Monthly."; "Electric Power Monthly Back Issues."

⁴⁶⁰ "Renewable Energy for State Renewable Portfolio Standards Yield Sizable Benefits."

operates relative to wind power, is critical to understanding what led to the wind boom that began in 2007.

CHAPTER VII

TECHNOLOGICAL DEVELOPMENTS

The previous chapter outlined the importance of the individual state and examined how states have affected the amount of wind energy created. Based on the evidence presented in that chapter, the significance of RPSs and state attitudes towards renewable energy was profound in creating the conditions for the wind industry to boom in 2007. This chapter will look at how the advances in technology have been another key factor in the American wind energy industry. There are many aspects of wind turbine technology, and they can get very technical with mathematical equations and formulas. This chapter will evaluate the key technological factors that contributed to the growth of the wind industry. As part of the methodology of this dissertation, it is useful to do a diachronical analysis of advances in technology before 2007 and from 2007 through 2016. However, before beginning the diachronical analysis, it is helpful to understand some deep background on wind energy technology.

Deep Background

Before trying to understand these advances, it helps to review both the basic concepts of aerodynamics, and also how wind turbines were first developed. A wind turbine basically works the same as an airplane propeller with the understanding that an airplane engine is what generates the power to create the airflow over the surface of the blade. Since wind turbines are stationery, they must be built in locations where the wind

blows naturally. The uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and the rotation of the Earth create wind. This wind turns the blades, which spins a shaft that is connected to a generator that makes electricity. Simply put, wind turbines convert the kinetic energy from wind into mechanical power. *Windmills* use the mechanical power created from wind to do things such as grind grain or pump water. *Wind turbines* are able convert this energy into electricity due to the generator built into the turbine.⁴⁶¹

To understand the key technological factors that enabled the American wind boom, it is important to trace the history of how the industry developed. 1887 is an important year in this history because that is when James Blyth of Scotland is credited with creating the first wind-powered machine to generate electricity. Both Blyth and an American, Charles Brush, were inventing about the same time. Brush improved upon Blyth's concept, and he built a 12-kilowatt wind turbine that had a rotor diameter of 50 meters, and 144 rotor blades that he built to power his mansion for 20 years.⁴⁶² Blyth used cloth sails in his design and Brush used wood. These initial inventions started a new way to use an established technology that harnessed the wind.

By the turn of the century, there was an estimated six million windmills installed across America. These windmills were built to perform tasks that were time consuming and laborious for people. Windmills saved people time, money, and helped them

⁴⁶¹ "How do Wind Turbines Work," U.S. Department of Energy, last modified Unknown, accessed October 25, 2017, <https://energy.gov/eere/wind/how-do-wind-turbines-work>.

⁴⁶² Pradhnya Tajne, "Wind Energy Timeline – from Persian Windmills Crushing Grains to Vesta's Wind Turbines Churning Out 8 MW of Output," *Altenergymag.Com* (April 4, 2015), October 30, 2017, <https://www.altenergymag.com/article/2015/04/wind-energy-timeline---from-persian-windmills-crushing-grains-to-vesta's-wind-turbines-churning-out-8-mw-of-output/19496>.

complete work that would have otherwise taken a large work force. Most of these early windmills were constructed from wood, but steel was starting to be used more frequently in the 1880s and 1890s.⁴⁶³ Brush's ingenious use of wind to generate electricity was being improved upon, and at the beginning of the 20th century, millions of Americans built small wind turbines to power their homes and businesses.

It was not until 1941 that the first megawatt wind turbine was installed to power a local electrical distribution grid in Vermont.⁴⁶⁴ This first megawatt turbine had a 1.25 megawatt capacity, and was built on a steel-lattice, 36-meter tall tower. It had two blades that were almost 2.5 meters wide and 20 meters long, giving the turbine a diameter just over 50 meters. The blades were built on steel spars, covered with stainless steel skin, and their pitch was controlled by hydraulic cylinders that were built to maintain a constant speed. The design included a generator that converted the spinning blades into electricity.⁴⁶⁵ These may seem like unnecessary and tedious details, but every facet of the design has been improved upon, making turbines more effective, more efficient, and more cost effective.⁴⁶⁶

This quick review of both aerodynamics and the genesis of wind turbines is helpful to understanding the basics of technology in the wind industry. With an understanding of the basic concepts, it is easier to understand the key technological aspects of tower design, turbine design, blade design, and electrical grid design.

⁴⁶³ Ibid.

⁴⁶⁴ Shahan, *History of Wind Turbines*.

⁴⁶⁵ Charles Sulzberger, "A Bold Effort in Vermont," *IEEE Power and Energy Magazine* 7, no. 6 (November-December, 2009).

⁴⁶⁶ Kreiser, *Megawatt Wind Turbine*, 15.

Before 2007

Evaluating key factors of wind energy technology from 1981 through 2006 is important in understanding how the wind industry grew over the years. Other considerations that determine the effectiveness and efficiency are how wind farms are supplying electricity into the electric grid and how this type of energy can be stored.

Most of the turbines installed in 1981 at the Altamont Pass wind farm in California were rated with a 50-kilowatt capacity with a few experimental turbines at 100-kilowatts.⁴⁶⁷ In 1987, a 3.2-megawatt wind turbine was developed by NASA, and it was the first turbine to incorporate a variable speed drive train.⁴⁶⁸ The aerodynamics of those rotors closely followed the applications of technology in airplanes. A variable-speed drive train allows wind turbines to adjust to different wind speeds, making them more effective at producing electricity. Turbines actually become less efficient if they rotate too fast because they become more like a wall than a rotor, and variable-speed drive trains allows the speeds of the rotor to fluctuate. Turbines produce the most efficient power if the wind strikes the blade at the best angle to apply just the right amount of torque to the generator.⁴⁶⁹ As scientists began to understand airflow better, they were able to add improvements to turbine designs. The turbine developed by NASA also had a sectioned rotor, making it easier to transport. The turbines were so large that moving them from the manufacturer to the installment location had become

⁴⁶⁷ Steve Wampler, "Windmills are Growing Along Altamont Hills," *Lodi News Sentinel*, March 9, 1982.

⁴⁶⁸ Shahan, *History of Wind Turbines*.

⁴⁶⁹ David Shultz, "Wind Turbines Inspired by Insect Wings are 35% More Efficient," *Science Magazine*, sec. Engineering, February 14, 2017.

problematic. By sectioning the rotor, it was easier to transport the blades and assemble them on site.⁴⁷⁰

In the 1990s, towers were modified, incorporating different materials such as tubular steel and reinforced concrete towers.⁴⁷¹ These structures supported more weight, allowing for increased heights and weights. Generally speaking, most industrial, commercial-use turbines at this time were 30 meters or taller.⁴⁷² The taller the turbine, the less it is affected by outside forces such as turbulence, variations in wind from rising heat, or other structures. The wind also blows more steadily at higher altitudes. These are all the same reasons airplanes fly more efficiently at higher altitudes. Airplanes fly higher to save gas and time, while turbines are built taller and wider to better create electricity.

In the late 1990s and early 2000s, rotors continued to grow in size with diameters up to 50 meters and turbine capacity increased to 750-kilowatts. That is a growth of approximately 10 times more capacity in 10 years.⁴⁷³ Every year between 1980 and 2003 advances in turbine technology effectively doubled how much energy each turbine could produce.⁴⁷⁴ Although there are other factors that helped reduce the cost of wind-generated electricity, turbine size is the most important factor.⁴⁷⁵ When the first

⁴⁷⁰ Shahan, *History of Wind Turbines*.

⁴⁷¹ Ibid.

⁴⁷² Francesco Miceli, "Wind Turbine Towers - the Bigger the Better," *Wind Farm Balance of Plant*, June 1, 2017.

⁴⁷³ Shahan, *History of Wind Turbines*.

⁴⁷⁴ Victoria Markovitz, "Sizing Up Wind Energy: Bigger Means Greener, Study Says," *National Geographic News*, sec. Energy, July 20, 2012.

⁴⁷⁵ Ryan Wiser et al., *Reducing Wind Energy Costs through Increased Turbine Size: Is the Sky the Limit?* (Berkeley, CA: Lawrence Berkeley National Laboratory, November, 2016).

successful wind farm was built in 1981, the cost of the generated electricity was about 55 cents per kilowatt hour and those advances in technology quickly drove the price down.⁴⁷⁶

There are many ways to evaluate the pricing of wind energy. The cost per kilowatt-hour is how much it costs consumers paying for wind-generated electricity. One of the most useful measures of cost for investors and utility companies is to evaluate the Levelized Cost of Energy (LCOE). LCOE measures the lifetime costs divided by energy production. It represents the per kilowatt-hour cost of the total cost of building and operating a power plant over an assumed lifetime. LCOEs are only estimates, because not all information needed to calculate the LCOE is available publicly. LCOEs used in this project were calculated using 2016 real dollars per megawatt hour. During this time period, LCOE generally decreased until 2005 when LCOE was estimated to be \$51-52 per megawatt hour. Crossing from this time period of evaluation into the next, LCOE rose between 2005 and 2009 to a high of approximately \$81 per megawatt hour.⁴⁷⁷ Capital costs⁴⁷⁸ of wind energy rose in this time period even though performance was improving.

Other factors of technology that helped decrease maintenance cost of wind turbines are computer-aided design and nanotechnology. An example of how computer-aided design helped designers create better rotor blades is by the creation of a

⁴⁷⁶ "Next Generation Wind Technology."

⁴⁷⁷ Eric Lantz, Ryan Wisser and Maureen Hand, *IEA Wind Task 26: The Past and Future Cost of Wind Energy* (Oak Ridge, TN: National Renewable Energy Laboratory, May 2012).

⁴⁷⁸ Capital cost increases were driven by rising commodity and raw materials prices, increased labor costs, improved manufacturer profitability, and turbine upscaling.

computer program that used inputs from “power required from a turbine, number of blades, design wind velocity, and blade profile type” to calculate ideal blade geometry parameters and design conditions.⁴⁷⁹ Computer-aided design has also been used to create a better “skinning” process for rotor blades. Through the creation of sophisticated algorithms, computers are able to calculate the best types of materials to use on the surface of the blades to get the most efficiency from the blades. In this process special attention was paid to construct the smoothest possible surface in the transition area between the root of the blade and the section with the maximum twist.⁴⁸⁰

Nanotechnology is the study and application of extremely small things⁴⁸¹ and has been used in the design of wind turbines. Nanotechnology has been used to improve processes, materials, and devices leading to ways “to prolong the lifespan of wind turbines, mitigate the fatigue failures of structural components, and lower the overall cost of energy generation.”⁴⁸² As discussed earlier, the length of turbine blades and height of towers has increased over the years, leading to greatly improved wind energy capacity. While increasing blade length, it was important to find ways to keep those blades as tight as possible, enabling them to withstand the stresses applied to the larger surfaces. Nanocomposite materials were developed that led to better strength-to-weight and stiffness-to-weight ratios, leading to decreased blade maintenance requirements.⁴⁸³

⁴⁷⁹ Duran, *Computer-Aided Design of Horizontal-Axis Wind Turbine Blades*.

⁴⁸⁰ Hosseini and Moetakef-Imani, *Innovative Approach to Computer-Aided Design of Horizontal Axis Wind Turbine Blades*.

⁴⁸¹ "What is Nanotechnology," National Nanotechnology Initiative, last modified Unknown, accessed March 7, 2018, <https://www.nano.gov/nanotech-101/what/definition>.

⁴⁸² Thomas, *Nanotechnology in Wind Energy Engineering*.

⁴⁸³ Ibid.

Nanotechnology was also used to improve nanoparticles used in materials to achieve novel functions such as improved tensile strength, improved flexural strength, increased distortion temperatures from 65 percent to 152 percent, and to increase the flame retardation properties of blades. However, those same nanoparticles that improved blades have disadvantages such as more difficulty in recycling, increasing blade brittleness, and increasing the price of the turbine components.⁴⁸⁴ Nanotechnology was also used in the creation of better lubricants used on the rotating parts of the turbines. Nanolubricants were designed with extremely low friction coefficients, thereby reducing energy losses and providing extraordinary anti-wear and protection of turbine components.⁴⁸⁵ These examples of ways that nanotechnology has improved turbines started in this time period, but research and development continues.

In summary, the most significant leaps of land-based wind energy technology, thus far, happened by the end of 2006. This is logical when attempting to determine what caused wind energy to boom in 2007, because it takes some time from the genesis of an idea, to building prototypes, to testing and improving prototypes, to manufacturing an approved design, to fielding the new equipment. For the wind boom to start in 2007, the equipment with the improved technology would have had to have been fielded by the end of 2006. The price of wind energy dropped dramatically between 1980 and 2006. This greatly reduced the barrier to entry, setting the conditions for continued investment in the following decade.

⁴⁸⁴ *Ibid.*

⁴⁸⁵ *Ibid.*

2007 to 2016

Although most of the critical technology necessary for wind energy to grow substantially had already been made by the end of 2006, there were continued improvements between 2007 and 2017 that kept the wind industry booming.

Something that became better understood in the last 10 years is how the air from one wind turbine affects other wind turbines. Moving air creates turbulence that affects how the wind moves across other rotor blades. It takes intense research to understand these effects and how to place turbines in a way that makes each turbine as effective as possible.⁴⁸⁶

Turbines have quadrupled in size in 35 years, but there has not been as much growth in size in the last 10 years as there was in the first 25. Figure 37 depicts the growing size of turbines and how the larger turbines have the most generating capacity.

⁴⁸⁶ "Wind Turbine Towers," Other Power, last modified Unknown, accessed October 25, 2017, http://www.otherpower.com/otherpower_wind_towers.html.

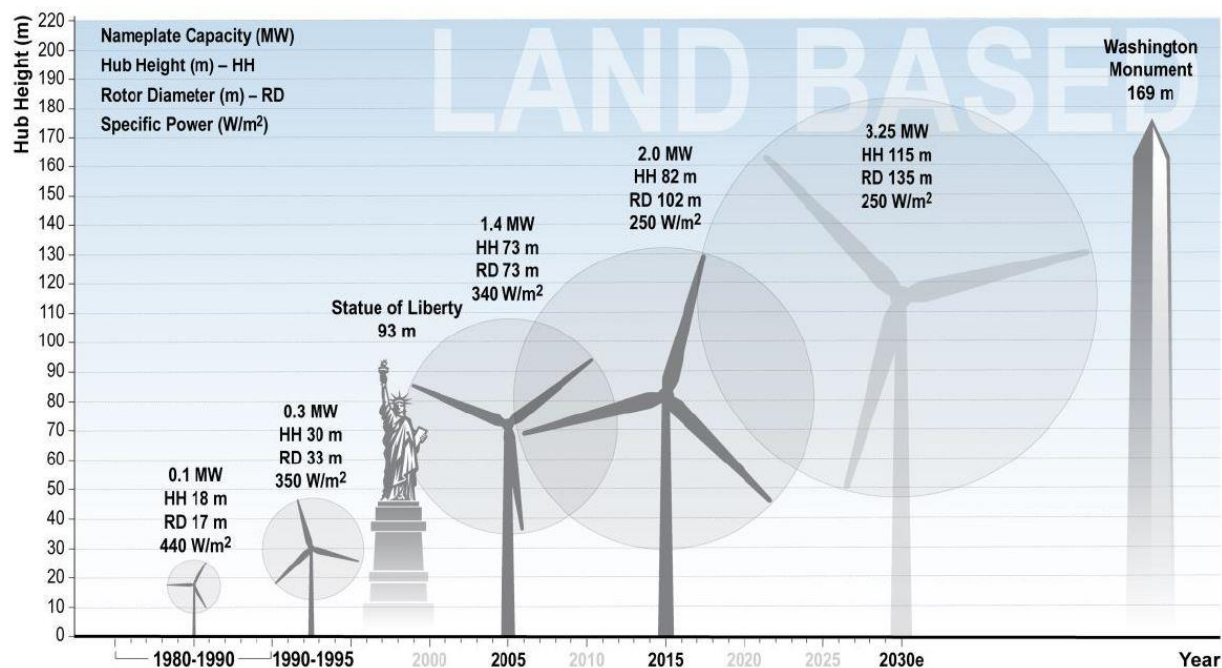


Figure 37 - Land-based Turbine Growth⁴⁸⁷

Source: Lawrence Berkeley National Laboratory

Compared to the first turbines installed at Altamont Pass in the 1980s with a capacity of 50 kilowatts of electricity, by the end of 2016, the largest land-based turbines had a capacity of 3,000 kilowatts (3 megawatts). Some of the offshore turbines currently being built have as much as 10 megawatts capacity. By installing turbines with higher capacities, investors do not need to install as many. Instead of installing 1,000 turbines to get the total desired capacity, only 500 larger turbines are needed to generate the same amount of electricity. The cost benefit is these large turbines do not cost twice as much to produce. In fact, they only cost a small amount more to produce than it costs to

⁴⁸⁷ Wisner et al., *Reducing Wind Energy Costs through Increased Turbine Size: Is the Sky the Limit?*, 1-7.

produce the small turbines. This has been one of the main drivers to the decreasing cost of wind energy.⁴⁸⁸

An interesting challenge that goes along with increasingly tall turbines is that basic physics requires a taller turbine to have a very wide tower base to maintain stability. Logistical constraints of transporting such components are enough to keep transport companies awake at night. This also drove the need for creative uses of construction materials. Towers were traditionally made from steel, but Siemens, a German company, introduced the use of concrete towers in the American market. The concrete components can be cast right on site, eliminating the need for costly transport.⁴⁸⁹ This has helped drive down the costs associated with installing wind turbines.

Towers were not the only components that evolved; blades were also improved at a fast pace. A senior director of research at AWEA said, "One of the biggest evolutions we've seen in wind energy in recent years is longer rotor blades."⁴⁹⁰ Blade diameters increased over 80 meters between the 1980s and the end of 2016. These longer blades represent a significant increase in the swept area of a wind field. That allows the turbine to capture a lot more energy. More captured energy translates into a more valuable turbine.⁴⁹¹ That helps drive the cost of wind-generated electricity down.

By the end of 2016, most blades were made from fiberglass,⁴⁹² which made a big difference from early versions made from wood or steel. Fiberglass blades are more

⁴⁸⁸ Markovitz, *Sizing Up Wind Energy: Bigger Means Greener, Study Says*.

⁴⁸⁹ Miser, *Taller Towers and Better Blades: The Cutting-Edge Technologies in Modern Wind Turbines*, 20-25.

⁴⁹⁰ *Ibid.*

⁴⁹¹ *Ibid.*

⁴⁹² *Ibid.*

durable, and they have more energy-generating capacity. Additionally, many of the newer blades are *smart* blades. Smart blades have a “pre-bend and a twist, which helps them deflect load and maintain structural integrity.”⁴⁹³ Wind changes direction, swirls and gusts. Smart blades twist at the tip when the wind gusts, and this relieves part of the pressure from the gust. This increases both the efficiency of the turbine and also extends the life by limiting the amount of wear and tear on the entire turbine system. Without smart technology, blades would have to be more fortified to withstand the gusts, making them heavier and less efficient.⁴⁹⁴ The smart blades helped decrease the cost of wind-generated energy.

Operational improvements also led to improved efficiency.⁴⁹⁵ Wind farming is an industry where basic physics collides with aerodynamics and atmospheric science. Engineering problems can seem intermittent or unpredictable, because not enough is understood about the effects of moving air and how multiple turbines interact with each other. For example, it may make sense to compromise the effectiveness of turbines on the front row of a wind farm to create a “chain of events that helps turbines in the secondary and tertiary rows to perform more optimally...”⁴⁹⁶

The cost of generated electricity in the U.S. by the end of 2016 was about 2.35 cents per kilowatt-hour.⁴⁹⁷ That is a decrease from about 55 cents per kilowatt-hour in

⁴⁹³ Ibid.

⁴⁹⁴ Ibid.

⁴⁹⁵ "Wind Turbine Technology Played Key Role in Wind Energy's Record-Breaking Growth and Cost Decline."

⁴⁹⁶ Miser, *Taller Towers and Better Blades: The Cutting-Edge Technologies in Modern Wind Turbines*, 20-25.

⁴⁹⁷ This varies greatly between different markets, but this is a national average.

the early 1980s.⁴⁹⁸ Getting accurate pricing information on wind turbine transaction prices is challenging since only a small amount of the data is released publicly, but overall figures suggest that the price has declined as much as 50 percent since 2008.⁴⁹⁹ As annotated in the previous section, the LCOE generated from wind decreased steadily between 1980 and the early 2000s. Prices rose starting in 2005 due to capital cost increases. They rose steadily until 2009, but then began going back down again. In 2009, LCOE was about \$81 per megawatt hour, but it decreased each year through the end of 2016 to a new low of just over \$40 per megawatt hour. These lower costs make it even easier and more profitable for new wind farms to be built, thus increasing the likelihood of continued growth.

Some of the most advanced wind energy technology was developed in the U.S. and the U.S. exports grew in this time period from \$16 million in 2007 to approximately \$488 million in 2014, but fell back to \$17 million in 2016.⁵⁰⁰ Even though U.S. companies successfully exported technology internationally, the U.S. wind industry is still largely reliant on imports. By the end of 2016, a Danish company, Vestas, had captured 43 percent of the American market for installation of wind turbines. A U.S. company, General Electric (GE), had 42 percent of the market, and German manufacturer Siemens had 10 percent. GE was the nation's leading turbine producer until 2016. In fact, in 2007 GE sold 2,342 megawatts of capacity to Vestas' 948 megawatts. GE's best year was 2012, with 5,016 megawatts capacity sold to Vestas' 1,818 megawatts. Vestas just inched passed GE in 2016 with 3,530 megawatts capacity

⁴⁹⁸ "Next Generation Wind Technology."

⁴⁹⁹ Miser and Bolinger, *2016 Wind Technologies Market Report*, 1-94.

⁵⁰⁰ Ibid.

installed to GE's 3,421 megawatts. In addition to being the market leader in the U.S., Vestas was also the leading global wind supplier followed by General Electric.⁵⁰¹ Figure 38 shows the top five turbine manufacturers in the U.S. between 2007 and 2016 and how much capacity each of them installed.

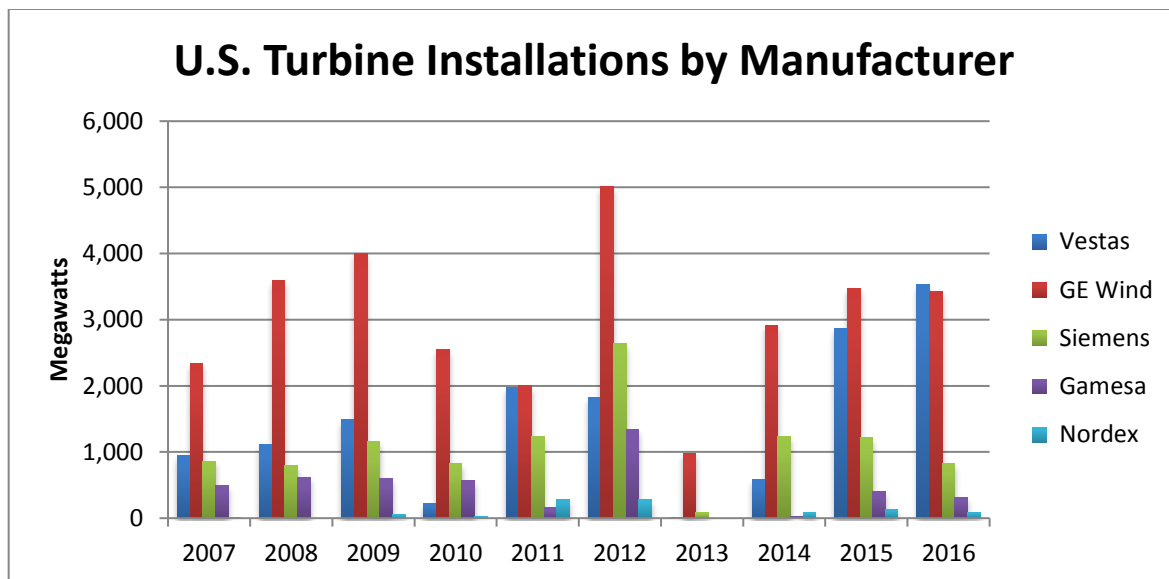


Figure 38 - U.S. Turbine Installations by Manufacturer⁵⁰²
Data Source: National Renewable Energy Laboratory

The technical advances between 2007 and 2016, which drove prices down and increased turbine performance, were key to increasing the penetration of wind energy in the market. Although some of the biggest leaps of technology affecting the proliferation of wind energy happened before 2007, innovators continue to find ways to make wind

⁵⁰¹ Ibid.

⁵⁰² Figure created using data source: Miser and Bolinger, *2016 Wind Technologies Market Report*.

turbines and wind farms more efficient. However, there are still areas that could use more innovation.

The Critical Years

The technological advances in turbine technology that were in place by 2003 were enough to double the amount of electrical energy each turbine could produce as compared to 1981.⁵⁰³ By 2005, a wind turbine could produce 1.4 megawatts of electricity.⁵⁰⁴ All the other technological advancements came together to make that the single most important technological development in the industry. With those advances, the foundation needed to create economies of scale and bring the price of wind-generated electricity down to a very affordable and stable price of just over two cents per kilowatt-hour was impetus enough for investment in the wind industry to boom in 2007.⁵⁰⁵ Without these technological advances, wind farms would not have been as efficient and they would have cost more to build.

The Future

For wind penetration to continue to improve in the U.S., there must be a significant infusion of resources, and new or improved technology, in the U.S. electrical

⁵⁰³ Markovitz, *Sizing Up Wind Energy: Bigger Means Greener, Study Says*.

⁵⁰⁴ Wiser et al., *Reducing Wind Energy Costs through Increased Turbine Size: Is the Sky the Limit?*, 1-7.

⁵⁰⁵ "Next Generation Wind Technology."

grid system. As explained in the previous chapter, Texas had the most comprehensive and aggressive grid enhancement project called CREZ. The state infused \$6.8 billion into the project so that electricity generated from remote wind farms could be transported through the grid for use in their biggest cities.⁵⁰⁶ It will take more projects like CREZ for wind farms, which are generally built in remote locations, to be the most useful. Because most of the grid systems in the U.S. were initially built to run on hydrocarbons, they do not have the flexibility needed to successfully incorporate large amounts of renewable energy. Since renewable energy is intermittent based on things such as the sun shining or the wind blowing, almost all of the grid systems still need fossil fuels, or hydroelectric or nuclear plants to provide constant power.⁵⁰⁷ Even though renewables are becoming relatively inexpensive, they will reach a point at which it is no longer cost effective to increase their use, because the grid was not built to handle them.⁵⁰⁸ These limitations lead to estimates that the highest wind energy market penetration in the U.S. will be approximately 20 percent. Considering that the U.S. was at 6.2 percent market penetration by the end of 2016, the U.S. still has a lot of room for growth even with the limitations of the current grid system. Figure 39 shows that the U.S. is 15th in the world for wind energy market penetration behind leaders Denmark, Portugal, and Ireland, among others.

⁵⁰⁶ Grossman, *Texas is Drowning in Wind Energy*.

⁵⁰⁷ "A World Turned Upside Down: Wind and Solar Energy are Disrupting a Century-Old Model of Providing Electricity." *The Economist*, February 25, 2017, <https://www.economist.com/news/briefing/21717365-wind-and-solar-energy-are-disrupting-century-old-model-providing-electricity-what-will>.

⁵⁰⁸ Ibid.

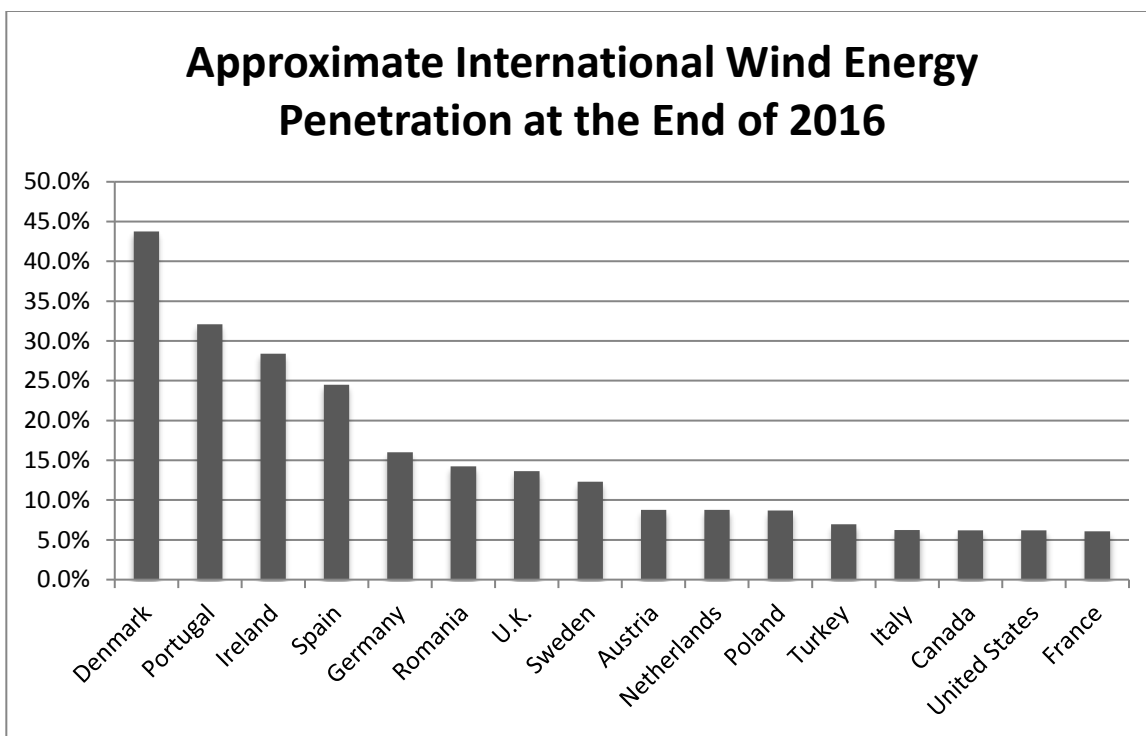


Figure 39 - Approximate International Wind Energy Penetration at end of 2016⁵⁰⁹
Data Source: Lawrence Berkeley National Laboratory

It is important for developers and policy makers who want increased usage of wind energy to look at other nations with higher wind energy penetration. For example, how have Denmark, Portugal, and Ireland incorporated renewable resources into their grid systems? Did they improve grids that were built to harness hydrocarbons, or did they build new grids that were designed to maximize wind? It is possible lessons could be learned from looking at other nations to help increase the possibility of the use of more renewable resources in the U.S.

Additionally, future applications of nanotechnology in wind energy are only limited by the creativity of designers, researchers, and investors. Interesting research from

⁵⁰⁹ Figure created using data source: Miser and Bolinger, *2016 Wind Technologies Market Report*, 1-94.

several Scandinavian institutes and universities into the transmission of electricity through the grid found that copper-based grids leak electricity at a rate of approximately five percent every hundred miles of transmission,⁵¹⁰ which matches the U.S. EIA's estimate.⁵¹¹ They tested a special material developed using nanotechnology called nanotubes that conduct electricity up to 10 times better than copper.⁵¹² Copper is widely used across the U.S. to conduct electricity. Thomas Edison first used it, and it was the primary material used to conduct electricity in the U.S. until the 1900s when most of the market started using aluminum.⁵¹³ Although aluminum is lighter and it is usually less expensive, it also leaks electricity.⁵¹⁴ Future research and application of nanotechnology in ways to more effectively conduct electricity could revolutionize electricity transmission.

The issue of usefulness of wind energy and how it is incorporated in the grid leads to a discussion on storage of electricity. "Electrical Energy Storage (EES) is the process by which energy is stored from the power network to a form which can be used later when converted back to electrical energy."⁵¹⁵ Energy storage is desirable for three main reasons. First, it reduces the cost of electricity by storing energy produced at off-peak times.⁵¹⁶ Land-based winds blow more steadily at night when the demand for

⁵¹⁰ Thomas, *Nanotechnology in Wind Energy Engineering*.

⁵¹¹ "How Much Electricity is Lost in Transmission and Distribution in the United States?" U.S. Energy Information Administration, last modified January 29, 2018, accessed March 7, 2018, <https://www.eia.gov/tools/faqs/faq.php?id=105&t=3>.

⁵¹² Thomas, *Nanotechnology in Wind Energy Engineering*.

⁵¹³ "Electrical," Aluminum Association, last modified 2018, accessed March 7, 2018, <http://www.aluminum.org/product-markets/electrical>.

⁵¹⁴ See: Ibid.; Thomas, *Nanotechnology in Wind Energy Engineering*.

⁵¹⁵ Strielkowski, Lisin and Tvaronaviciene, *Towards Energy Security: Sustainable Development of Electrical Energy Storage*, 235-244.

⁵¹⁶ Ibid.

electricity is lowest. If the electricity produced by wind at night could be stored long enough to be used the next day, wind energy would become much more cost effective and more usable.

Second, power supplies need enhanced reliability.⁵¹⁷ If power supplies fail, then storage systems are needed to support customers. EES would serve as a back up to a community, like a backup generator does to an individual home. Industrial and domestic grids must operate 24 hours a day. Fluctuations of even a minute or two can cause great disruptions that may be valued in the billions of dollars.⁵¹⁸

The third role of EES systems is to maintain and improve the quality of power, frequency, and voltage.⁵¹⁹ The currency flow of electricity can vary and these backup systems help the grid be more constant in its supply.

At the beginning of the 20th century, power stations were closed at night yet people wanted to have power around the clock. Utility companies recognized the need for more flexibility and the first central station for energy was developed in 1929. This first station used pumped hydroelectric storage, which required the use of two reservoirs of water with one at a higher level than the other. When there was an immediate demand for power, the gates were opened, causing the water to flow from one tank to the other. The movement of the water was used to turn turbines that turned a generator. The generator generated electricity. What makes these systems different from a true hydroelectric system is this system is closed, meaning the water is reused while hydroelectric systems use water that continues downstream after use. By 2016, 99

⁵¹⁷ Ibid.

⁵¹⁸ Ibid.

⁵¹⁹ Ibid.

percent of all EES systems around the world used this type of system called Pumped Hydroelectric Energy Storage (PHES). Because these systems use very large volumes of water, they are considered large-scale storage systems. Although these systems require large amounts of land, water, turbines, and pumps, they are safe. They are also quite expensive to set up and maintain.⁵²⁰

Unfortunately, current technology has not been developed to store electricity produced from wind energy or other renewable sources to include solar energy, hydro energy, or tidal energy. The remaining one percent of EES systems are powered using battery energy storage. Batteries currently have relatively low energy storage capacity, especially when compared to PHES. Battery capacity is determined by the amount of active material in the battery. Battery capacity can also vary quite a bit depending on the age, charging, and discharging patterns of the battery. New batteries usually have a much higher storage capacity than older ones. The lifetime of batteries is very short as compared to a PHES. Additionally, batteries can be very dangerous if they are not designed or handled correctly. Batteries are made with materials that are toxic to humans. The recent example of the Samsung Galaxy Note 7 batteries shows the danger. The phone battery had a component that was failing, causing them to explode. As it stands today, battery technology is still very dangerous, but it is relatively inexpensive compared to PHES.⁵²¹

Battery storage improvements have the potential to be transformative. This is an area that is overdue for change. Energy stored in batteries generated from renewable

⁵²⁰ Ibid.

⁵²¹ Ibid.

energy sources, such as wind turbines, during off peak periods could be used during peak periods rather than using non-renewable sources, such as natural gas or coal powered turbines, which are more expensive.⁵²² Battery improvement may not eliminate the need for fossil fuels to serve as backup power in the current grid system design, but it could greatly reduce it. This is crucial, because as the penetration of wind energy continues to grow, at some point the current system will be fully tapped.

Nanotechnology can also be used to help bridge the gap between energy storage and production by applying techniques. An example of this is carbon nanotube hydrogen storage systems, which can be used to “reduce the storage medium to nanoscale dimensions and effectively address the energy storage challenges.”⁵²³ By decreasing the size of storage facilities, costs can be decreased and storage can be better used to mitigate when wind energy is being generated.

Numerous peer-reviewed studies have concluded that wind energy can provide up to 20 percent of the electricity in the U.S. without the need for EES.⁵²⁴ The reality is that varies greatly from state to state and from community to community depending on the age, capacity, and structure of the grid. Leaders at AWEA argue that storage improvements would help wind energy to penetrate markets further, but that they are not required.⁵²⁵

Another way the U.S. could greatly increase wind energy generation is to continue adding offshore wind farms. Offshore wind power has struggled to take off in

⁵²² Ibid.

⁵²³ Thomas, *Nanotechnology in Wind Energy Engineering*.

⁵²⁴ "Wind Energy and Storage."

⁵²⁵ Ibid.

the U.S. Meanwhile, by the end of 2016, Europe had successfully built 84 offshore wind farms operating around 11 different countries on the continent. The technology has been developed; it simply has not yet been used in the U.S. with the exception of the one small farm in Rhode Island. It is important to note that compared to the national average cost of wind energy at approximately 2.5 cents per kilowatt-hour, the cost of electricity generated from Block Island Wind Farm is 24.4 cents per kilowatt-hour. That is more than 22 cents above the national average and 10 cents more than other Rhode Island residents pay.⁵²⁶ The prices for wind energy were over 50 cents per kilowatt-hour when land-based wind farms were first built in 1980, but not all residents are willing to accept the increased prices today even knowing they will eventually drop if offshore wind farms are able to gain economies of scale.

Given the barriers to entry, companies are still willing to take the risk, believing the reward will be great enough. There are plans in place to add more farms off the east coast. Wind projects such as Cape Wind, faced staunch opposition because of their negative effects on ocean views and commercial fishing. Cape Wind was a \$2.6 billion project, but after years of legal battle, the companies that had committed to buying electricity from Cape Wind backed out. The Massachusetts legislature passed an energy bill in August of 2016 that includes provisions for the largest commitment by any U.S. state to invest in offshore wind.⁵²⁷ The Long Island Power Authority in New York approved the nation's largest offshore wind farm in January 2017. The farm is planned to have 15 turbines capable of powering 50,000 average homes, but is expandable to

⁵²⁶ Katie Fehrenbacher, "This is Where the First U.S. Offshore Wind Turbines were just Installed," *Fortune*, sec. Tech: Future of Work, August 8, 2016.

⁵²⁷ *Ibid.*

up 200 turbines.⁵²⁸ The project's cost is estimated at \$740 million and the cost to customers per kilowatt-hour is about 16 cents per kilowatt-hour. That's estimated to add only \$1.19 to the average customer bill.

There are other planned offshore projects, including one off the shore of Virginia Beach, Virginia. The project is currently estimated to cost between \$300 and \$400 million and would supply enough power for two million average homes when complete.⁵²⁹ Projects such as these have been on, then off, then on. Until contracts are in place and construction has begun, it is impossible to predict when or where the next offshore farms will be built.

There are many areas in which wind energy can improve to help increase the amount of electricity generated by renewable and environmentally friendly resources. The examples of ways the electrical grid and storage could be improved and the endless potential for offshore farms demonstrate that there is still a very bright future with continued increases in the use of wind energy.

Summary

The foundational technologies of wind farms such as wind turbines, rotors, and towers, continue to be refined and improved upon. There are still many areas in which

⁵²⁸ Diane Cardwell, "Nation's Largest Offshore Wind Farm Will BE Built Off Long Island," *New York Times*, sec. Energy & Environment, January 25, 2017.

⁵²⁹ See: Dave Mayfield, "Dominion Announces Plan to Revive Offshore Wind Project Near Virginia Beach," *Virginian Pilot*, sec. Business, July 10, 2017.; Dave Ress, "Dominion Revives Offshore Wind Project, Will Build Two Turbines," *Daily Press*, sec. News/Politics, July 10, 2017.

technology can be improved, new technology can be created, or capacity can be added through offshore wind farms, but the main technological advances that enabled the wind boom occurred before 2007. The increased size of rotors and towers coupled with increased height of turbines were the biggest contributor to improved use of wind. Technological improvements in blades and a better understanding of aerodynamics were also important to increasing the efficiency of turbines.

Advances in technology have been the primary driver of decreased costs of wind-generated electricity. These decreased prices have made the use of wind energy more attractive for both investors and consumers. There is still plenty of room for growth since the U.S. only has 6.2 percent of its electricity generated from wind. This chapter explained how advances in technology created the conditions for wind energy to grow as much as it did through 2016. Technology was a critical aspect of that growth.

CHAPTER VIII

FOSSIL FUEL PRICES

The previous chapter explained the importance of technological advances on the development of wind energy. Without a few key technological advances, the U.S. wind boom that began in 2007 would not have been possible. There is less evidence that the price of fossil fuel has an effect on renewable energy development. This chapter will show there is a connection, but there is not enough evidence to show that if fossil fuel prices had not experienced spikes that the wind industry would not have developed anyway.

For some people it seems obvious that the price of one type of energy would affect the price of another type of energy. There are others to whom that connection is less clear. It was previously explained that electricity in the U.S. is generated from multiple types of fuel. The percent of types of each fuel used to create electricity in the U.S. has changed over the years, but they are coal, natural gas, oil, nuclear power, and renewable energy. For pricing purposes, these fuel types can be broken down into two categories: those that have relatively fixed prices, and those publicly traded as commodities.

The most common types of renewable fuels used to generate electricity in the U.S. are hydroelectric, geothermal, biomass, wind, and solar. Nuclear and most renewable energies used to those renewable fuels are priced differently than fossil fuels, because they are not a physical commodity that must be transported from the source to the power plant in the same ways as oil, natural gas, and coal. Generally

speaking, nuclear power and renewables used to generate electricity are infinite in supply. Their prices are based on the costs associated with installation, upkeep and integration into the electrical grid. Their prices are not as vulnerable to daily fluctuations as are fossil fuels. Beyond the benefits to the environment, one of the biggest advantages of renewable energy, and more specifically, wind energy, is that their pricing is not susceptible to market volatility. Wind projects are built on long-term purchase power agreements, which set the price of electricity they generate within a relatively specific range.⁵³⁰

The fossil fuels of oil, gas, and coal are publicly traded on the stock market, and traders who bid on oil futures contracts in the commodities market set their prices. In many markets, the price of natural gas is pegged to the price of oil. The U.S. natural gas industry started to be deregulated in 1978 and was completely deregulated in 1989. Because of the way oil, natural gas, and coal are traded, the prices for these fossil fuels change daily in the U.S.

The U.S. has been one of the world's main producers of fossil fuels. That means that the U.S. has not just produced these fuels for domestic consumption, but the U.S. also exports each of these commodities internationally. This affects how those commodities are priced. The process of pricing has changed over time. In recent times, there are three main factors that go into the setting of prices. First is the amount of oil, natural gas, and coal in the current supply. Second is access to future supply. This varies by source. For example, access to oil and access to coal are very different. The

⁵³⁰ Travis Hoium, "Why Rising Oil Prices are Good for EVs and Renewable Energy," *The Motley Fool*, sec. Investing, December 8, 2016.

future supply of oil includes both what the U.S. maintains in oil reserves, and what has been available in U.S. refineries. The U.S. was a net exporter of coal through the entire time period of this study, so the U.S. controlled more of the coal market than the oil market. The last major factor that is part of the oil, gas, and coal price is estimated future demand for those commodities.⁵³¹

Part of the equation of determining the effect of energy sources on wind energy development is the pricing of electricity. Figure 40 depicts the average price of electricity across the U.S. in 2016 real dollars.

⁵³¹ See: Kimberly Amadeo, "What Affects Oil Prices? 3 Critical Factors," *The Balance*, sec. U.S. Economy, October 10, 2017.; "What are the Different Coal Prices Published by EIA?" U.S. Energy Information Administration, last modified August 11, 2017, accessed November 9, 2017, <https://www.eia.gov/tools/faqs/faq.php?id=18&t=2>.; "Natural Gas Prices are a Function of Market Supply and Demand," U.S. Energy Information Administration, last modified August 23, accessed November 7, 2017, https://www.eia.gov/energyexplained/index.cfm?page=natural_gas_factors_affecting_prices.

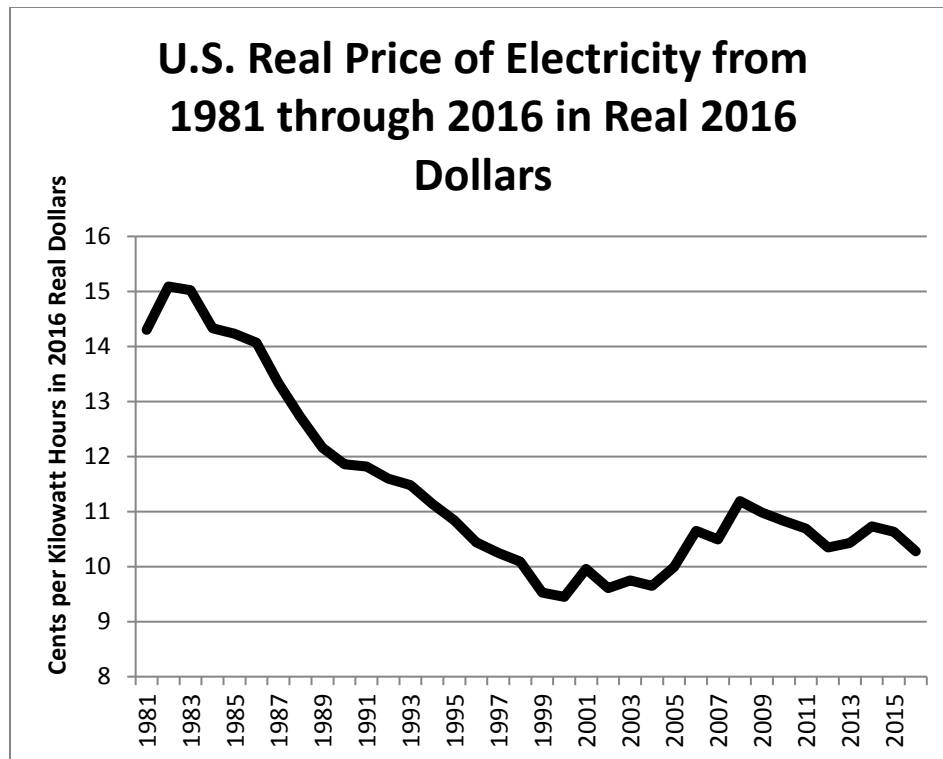


Figure 40 - U.S. Real Price of Electricity from 1981 through 2016⁵³²

Data Sources: U.S. Energy Information Administration and U.S. Department of Labor

The figure shows that electricity declined in price through the year 2000 when it started a slow climb with occasional drops. There are many more market forces determining the pricing of electricity than just fuel source pricing, but fuel source pricing is part of the equation that drives the total price.

⁵³² Figure created from data sources: "Total Energy: Annual Energy Review - Average Retail Prices of Electricity, 1960-2011," U.S. Energy Information Administration, last modified September 27, 2012, accessed November 14, 2017, <https://www.eia.gov/totalenergy/data/annual/showtext.php?t=ptb0810>.; "Electric Power Monthly: Average Price of Electricity to Ultimate Consumers," U.S. Energy Information Administration, last modified October 24, 2017, accessed November 14, 2017, https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_3.; "CPI Inflation Calculator," U.S. Department of Labor: Bureau of Labor and Statistics, last modified October, accessed November 14, 2017, https://www.bls.gov/data/inflation_calculator.htm.

Another important data point is U.S. imports of crude oil. When these figures are laid over the growth of the wind industry starting in the 1980s, one can see why oil imports and oil prices may have influenced the development of the wind industry. Figure 41 shows the volatility of oil imports.

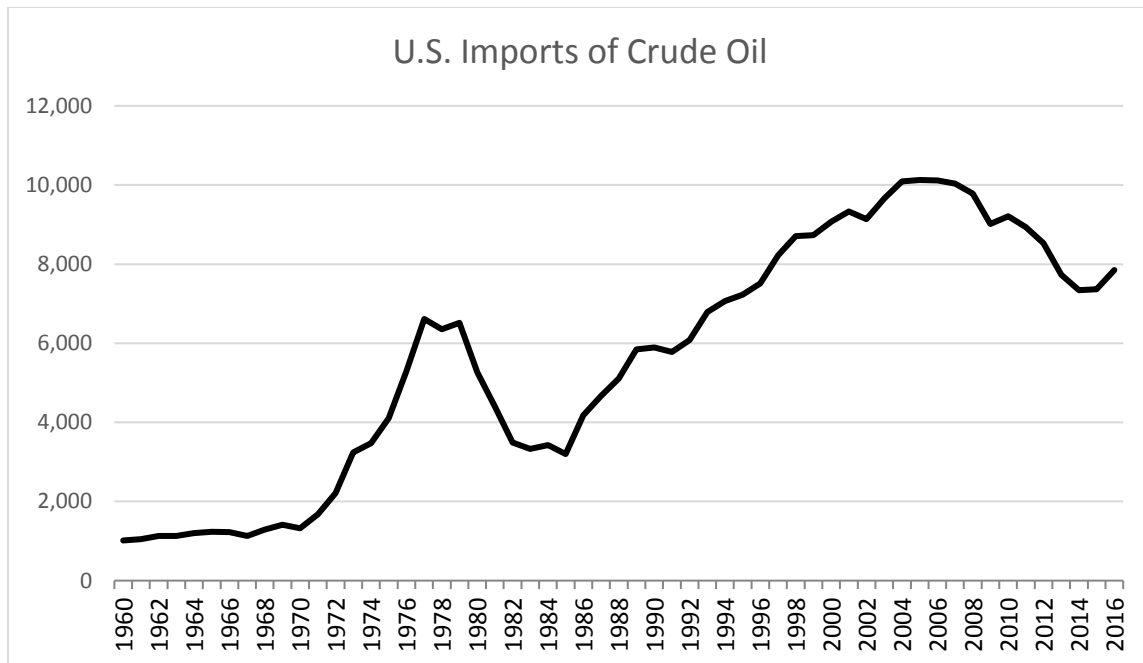


Figure 41 - U.S. Imports of Crude Oil Between 1960 and 2016⁵³³

Data Source: U.S. Energy Information Administration

Why Do Fossil Fuel Prices Matter?

There are a multitude of opinions and studies attempting to prove a correlation between oil prices and the development of renewable energy. When the price of oil is

⁵³³ Figure created using data source: "U.S. Imports of Crude Oil," U.S. Energy Information Administration, last modified September 13, accessed September 22, 2017, <https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=MCRIMUS2&f=A>.

high, there is an interesting dynamic that happens even though oil has not been a main source of electricity generation. When oil is more expensive, people naturally want to invest more in renewable energy. When the price of oil is low, people are less interested in investing in other sources. There are studies of stock market trends that show the impact of oil prices on renewable energy development companies. Oil prices go up and stock in renewable energy development companies also go up.⁵³⁴

A series of statistical analyses on OECD nations, and one focused on just the U.S., were conducted to seek causal dynamics between renewable energy consumption and oil prices.⁵³⁵ The results of these studies showed that in both the short and long term, there was a positive, and statistically significant, impact of oil prices on renewable energy consumption per capita. As oil prices rose, renewable energy consumption per capital also rose. The study concluded that in addition to having a positive impact on the environment, the increased use of renewable energy also has a positive influence on economic development.⁵³⁶

There has been little effort in the scientific and international relations communities to tie the growth of the wind industry to natural gas and coal prices. Looking at data over the entire time period to compare oil, natural gas, and coal prices to wind energy growth helps illuminate the likelihood of the effect of fossil fuel pricing on

⁵³⁴ Hoium, *Why Rising Oil Prices are Good for EVs and Renewable Energy*.

⁵³⁵ The study included two other variables: real GDP per capita and carbon dioxide emissions. Results on those variables were excluded here since they aren't directly related to this section.

⁵³⁶ See: Apergis and Payne, *The Causal Dynamics between Renewable Energy, Real GDP, Emissions and Oil Prices: Evidence from OECD Countries*, 4519-4525.; James E. Payne, "The Causal Dynamics between U.S. Renewable Energy Consumption, Output, Emissions, and Oil Prices," *Energy Sources* 7, no. 4 (2012).

the wind industry. Figure 42 shows fossil fuel pricing between 1981 and 2016. The growth of wind energy surged a couple of years after fossil fuel prices increased starting in 2002. Given the lag time to build wind farms, this shows there is a positive correlation between fossil fuels and wind energy development. Compared to the volatility of oil prices, both the price of coal and natural gas showed smaller changes, but those changes were still important. This will be broken down into more detail in the diachronic time comparisons in the next sections.

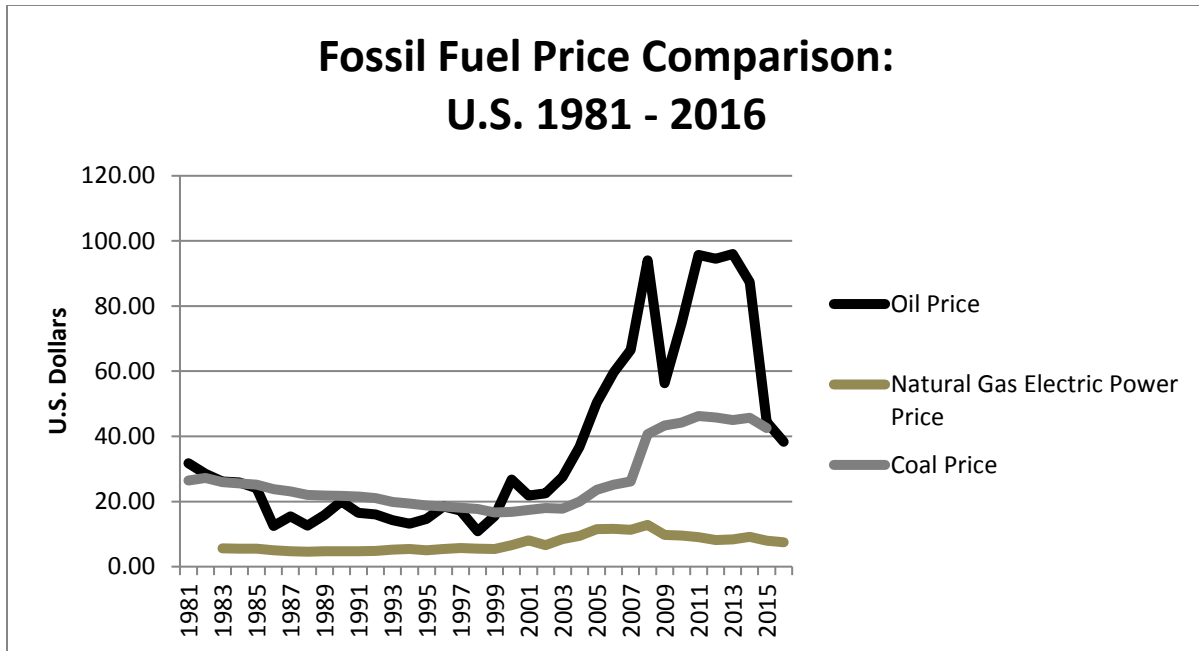


Figure 42 - Fossil Fuel Prices in the U.S. from 1981 to 2016⁵³⁷

Data Sources: U.S. Energy Information Administration

Before 2007

Evaluating how fossil fuel prices affected the development of wind energy during this time period helps one understand the key factors that led to the surge of wind energy installation. In the 1980s, the most common fossil fuels used to generate electricity were coal,

⁵³⁷ Figure created using data sources: "Total Energy: Annual Energy Review, Coal Prices, 1949-2011," U.S. Energy Information Administration, last modified September 27, 2012, accessed November 13, 2017, <https://www.eia.gov/totalenergy/data/annual/showtext.php?t=ptb0709>.; "Average Sales Price of Coal by State and Mine Type, 2015 and 2014," U.S. Energy Information Administration, last modified March 12, accessed November 13, 2017, <https://www.eia.gov/coal/annual/pdf/table28.pdf>.; "U.S. Crude Oil First Purchase Price (Dollars Per Barrel)," U.S. Energy Information Administration, last modified October 2, accessed November 7, 2017, https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=F000000_3&f=A.; "U.S. Price of Natural Gas Sold to Commercial Consumers," U.S. Energy Information Administration, last modified August 15, accessed November 7, 2017, <https://www.eia.gov/dnav/ng/hist/n3020us3m.htm>.

natural gas, and oil, in that order. Nuclear power, an alternative fuel, was also an important source. The only renewable resource that was utilized to a large extent at that time was hydropower. Figure 43 shows the percent of each resource used to generate electricity across the U.S. in 1981.

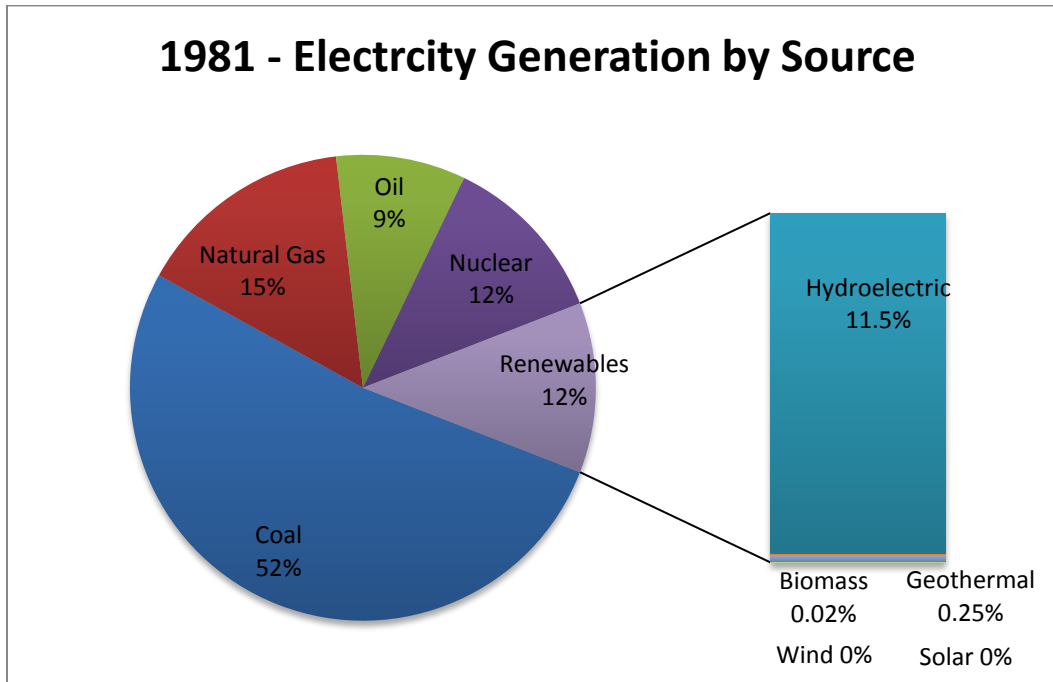


Figure 43 - Electricity Generation by Source in 1981⁵³⁸
Data Source: U.S. Energy Information Administration

To determine the effect of fossil fuel prices on wind energy development, it is helpful to take a closer look at coal, natural gas and oil. The U.S. was the world's leading producer of coal until 1985 when China took the top spot. Since coal was the primary source of electricity generation in the U.S. during this entire time period, the

⁵³⁸ Figure created using data source: "What is U.S. Electricity Generation by Energy Source?"

ease of accessing that supply was critical to how it was priced.⁵³⁹ The pricing figures of coal in the previous section show that coal prices did not experience significant differences. Coal prices dropped the same time wind energy development was starting in 1981. The coal price increases starting in 2002 could have had an impact on wind energy investments. Coal prices went up the same time oil prices were increasing. Smaller differences in coal prices matter to electricity consumers. Figure 44 shows coal prices in better detail. Given the price increases starting in 2002, it is likely that the increasing price of coal had a positive correlation to wind energy development, but this is not enough data to suggest causality.

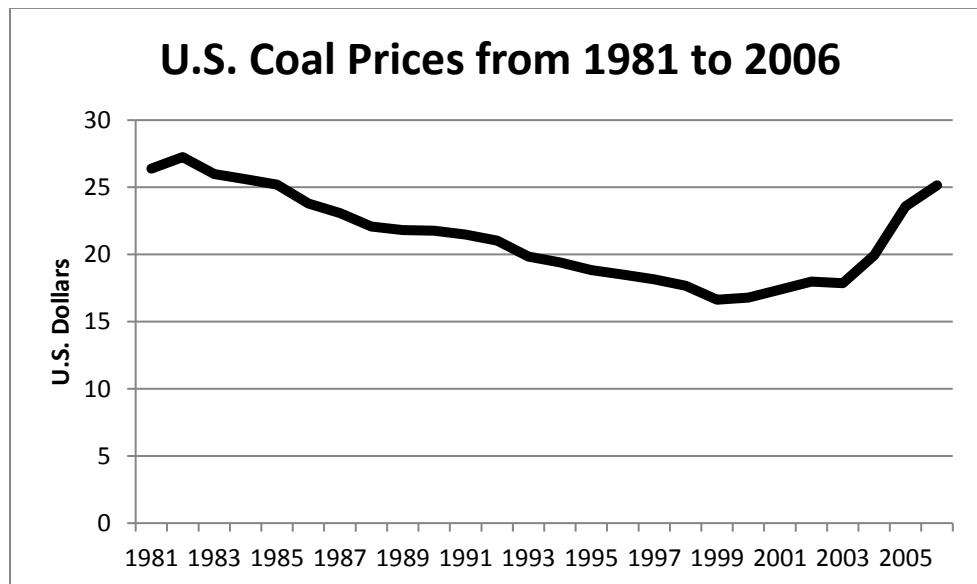


Figure 44 - U.S. Coal Prices from 1981 to 2006⁵⁴⁰

Data Source: U.S. Energy Information Administration

⁵³⁹ "International Energy Source," U.S. Energy Information Administration, last modified November 8, accessed November 9, 2017, <https://www.eia.gov/beta/international/index.cfm>.

⁵⁴⁰ Figure created using data sources: "Total Energy: Annual Energy Review, Coal Prices, 1949-2011."; "Average Sales Price of Coal by State and Mine Type, 2015 and 2014."

The U.S. was the world's leading producer of natural gas at the beginning of this time period and then alternated in and out of first and second place with the U.S.S.R. and Russia.⁵⁴¹ The price of natural gas, like the price of coal, has been less volatile than the price of oil. Like oil and coal, the price of natural gas used to produce electricity began increasing in 2002. Figure 45 shows the price fluctuations in natural gas used to generate electricity.

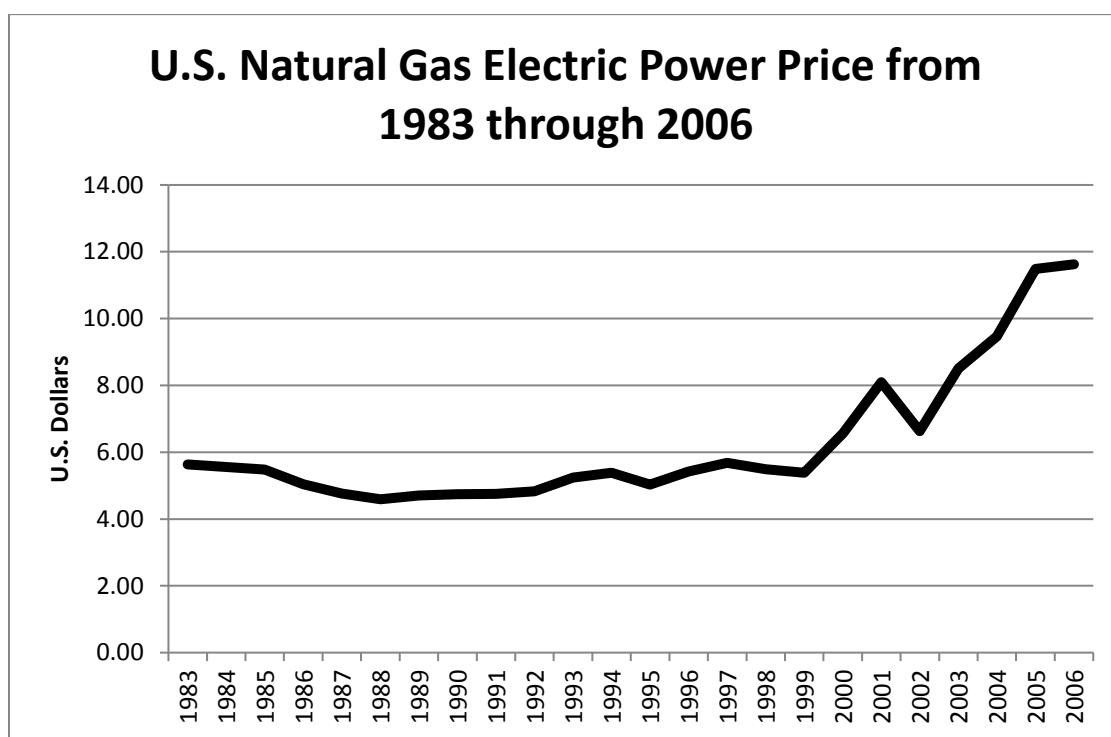


Figure 45 - U.S. Natural Gas Electric Power Price from 1983 through 2006⁵⁴²

Data Source: U.S. Energy Information Administration

⁵⁴¹ The U.S. EIA did not track Russia's production as a separate nation until 1992 since the U.S.S.R. dissolved in 1991.

⁵⁴² Figure created using data source: "U.S. Price of Natural Gas Sold to Commercial Consumers."

The percent use of natural gas to generate electricity increased and the use of both oil and coal decreased between 1981 and 2007. Fossil fuels were used to generate 76 percent of all U.S. electricity in 1981, but that dropped to 71 percent by the end of 2006. One of the primary reasons for the shift was the switch to using more nuclear power.⁵⁴³ Figure 46 shows the breakdown of electricity generated from each fuel source at the end of 2006.

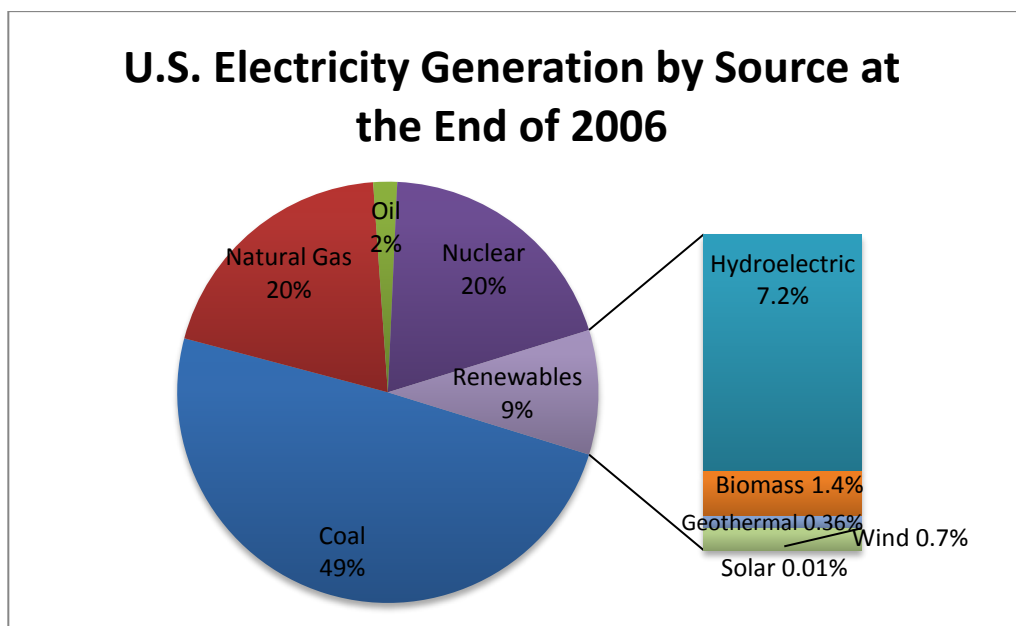


Figure 46 - U.S. Electricity Generation by Source at the End of 2006⁵⁴⁴

Data Source: U.S. Energy Information Administration

The price of oil, coal, and natural gas used to generate electricity all increased in 2002.⁵⁴⁵ This was the same approximate time frame that investors and utility companies

⁵⁴³ "What is U.S. Electricity Generation by Energy Source?"

⁵⁴⁴ Figure created using data source: "What is U.S. Electricity Generation by Energy Source?"

⁵⁴⁵ See: "Total Energy: Annual Energy Review, Coal Prices, 1949-2011." ; "Average Sales Price of Coal by State and Mine Type, 2015 and 2014." ; "U.S. Crude Oil First

were seeking ways to increase diversification of fuel sources for electricity generation. As fossil fuel prices increased in these critical years, the more attractive wind energy development became. Knowing that most wind farms take two to three years from concept to production, these pricing comparisons help explain why the wind industry saw such growth a few years after fossil fuel prices began trending upwards in 2002.

Throughout this time period the U.S. was one of the biggest producers of fossil fuels, but it is an even higher consumer of the same commodities. That made it a net importer of fossil fuels through 2006. The fact that the U.S. remained a net importer of energy means it was more susceptible to market influences. Although dependency on imports is not the only reason for price volatility of fossil fuels, it does have a significant impact. The price volatility of fossil fuels makes the constancy of renewable energy and nuclear energy pricing even more desired.

Although the U.S. is subject to international markets, as renewable energy resources grew in quantity, the effect of fossil fuel prices on the wind industry became less evident. Looking specifically at the linkage between oil prices and wind energy, an investment company determined there were four main reasons why the link between oil prices and renewable energy development began weakening towards the end of this time period.⁵⁴⁶ The assessment stated four reasons for the decreasing influence of oil on renewable energy generation:

1. They operate in different markets.
2. The economies of scale of renewable energy were improving.
3. The global dynamics of energy were changing.

Purchase Price (Dollars Per Barrel)."; "U.S. Price of Natural Gas Sold to Commercial Consumers."

⁵⁴⁶ Scott Nyquist, "Lower Oil Prices but More Renewables: What's Going on?" *McKinsey & Company*, sec. Industries, June, 2015.

4. The science of renewable energy was improving.⁵⁴⁷

The first reason has already been thoroughly explained. Oil decreased as a fuel source to generate electricity from nine percent to only two percent by the end of 2006. As for the second reason, previous chapters discussed the growth of wind energy and how economies of scale take it closer from being an emerging energy resource to it being an established energy resource. Reason three incorporates international attitudes and the desire to decrease CO₂ emissions while simultaneously increasing the use of renewable and clean energies. Finally, the previous chapter covered the key technological advances that helped the wind industry gain economies of scale.

The final assessment from this analysis was that renewables are better for the environment; they enhance the nation's energy supply, and, therefore, enhance national energy security. There are many reasons for developing more wind and other renewable energies.

2007 to 2016

Price volatility of fossil fuels helped spur the development of wind energy leading to the big increases in wind energy capacity starting in 2007. This pricing factor continued to help wind energy grow through 2016 even if fossil fuel prices began to level out.

Although traders bidding on futures contracts determine oil prices, there are several key entities that affect bidding decisions. These include both the U.S.

⁵⁴⁷ Ibid.

government and the Organization of Petroleum Exporting Countries (OPEC). OPEC has the biggest influence on the global supply of oil, but U.S. shale oil production doubled between 2011 and 2014, creating a glut of supply.⁵⁴⁸ OPEC adjusts its supply for several reasons, which includes its desire to keep prices in a certain range. At the time, OPEC had a target price of \$70 per barrel, but allowed the price to drop since most members of OPEC do not lose money until oil is \$20 a barrel or lower. Although each shale oil field is different, generally shale producers need \$40-50 per barrel to make money. When they produced so much shale oil that current supply drove the price lower than \$40, OPEC thought the low oil prices would force them out of business and out of the market.⁵⁴⁹ The evidence that oil prices have started to have less of an effect on the development of wind energy in the last few years is substantiated by the fact that although oil prices dropped, wind energy capacity grew. The comparison shown in Figure 47 helps demonstrate this phenomenon.

⁵⁴⁸ Amadeo, *What Affects Oil Prices? 3 Critical Factors*.

⁵⁴⁹ *Ibid.*

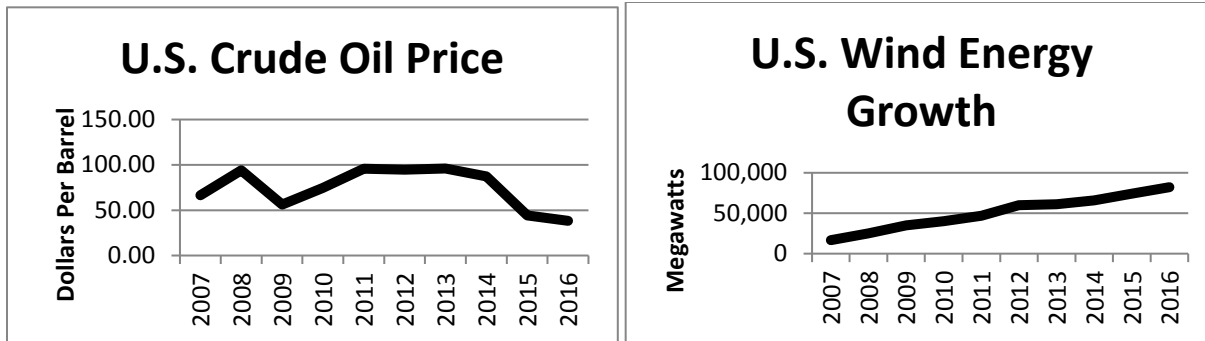


Figure 47 - Comparison of U.S. Crude Oil First Purchase Price and Wind Energy Growth from 2007 through 2016⁵⁵⁰

Data Source: U.S. Energy Information Administration

By the end of 2016, there was another shift of what fuels were used to generate electricity. Natural gas became the largest source of electricity generation in 2016, surpassing coal for the first time in U.S. history. Renewable energy also grew to where it was generating 12 percent of the total electricity for the U.S. Figure 48 shows the break out of sources used for electricity generation at the end of 2016.

⁵⁵⁰ Figure created using data source: Wisser and Bolinger, *2015 Wind Technologies Market Report*, 1-102.

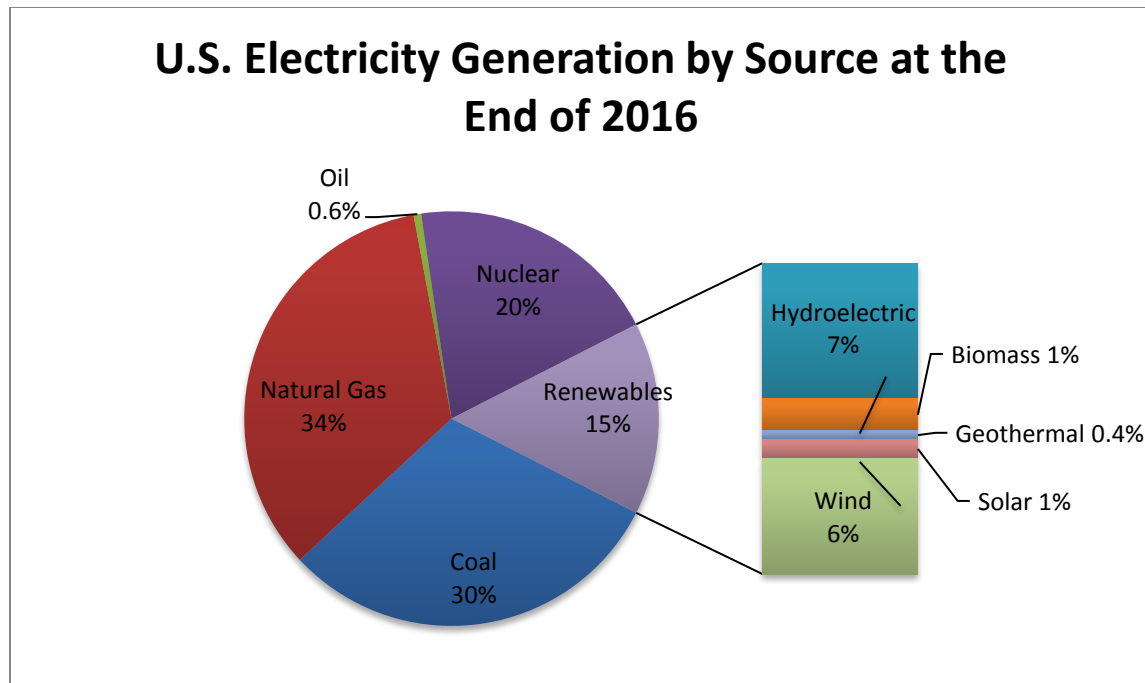


Figure 48 - U.S. Electricity Generation by Energy Source at the End of 2016⁵⁵¹
Data Source: U.S. Energy Information Administration

This change in ratios show how the increased production of natural gas and the increased wind energy capacity were significant to change the way the U.S. uses fuels to generate electricity. In 2009 the U.S. became the world's largest natural gas producer and stayed there through the end of 2016.⁵⁵² This increased use of natural gas complicates, rather than simplifies, the question of how prices of fossil fuels affect wind energy development. As natural gas becomes cheaper, why would wind energy continue to grow at significant levels? Wind and gas are competing in the same market, which makes the comparison different than it is for wind and oil. It is possible that wind

⁵⁵¹ Figure created using data source: "What is U.S. Electricity Generation by Energy Source?"

⁵⁵² "International Energy Source."

energy continued to grow while natural gas also grew because the economies of scale and technology of wind energy improved.⁵⁵³

The Critical Years

The years right before and the years right after 2007 are the most critical in this study. In this case of how fossil fuel prices affect wind energy development, there are two key pricing factors that must be considered. Fossil fuel prices are more volatile than wind energy, and the price increases that started in 2002 encouraged the development of fuels that are not as susceptible to market influences.

In these critical years where wind energy was growing in capacity, the number of kilowatt hours generated from each fuel source shifted. In 2002 coal generated 1,933 megawatt hours and that number continued upward until coal peaked in 2007 at 2,017 megawatt hours. Since 2007, the number of generated hours from coal has decreased. In these same crucial years, the amount of natural gas used to generate electricity climbed steadily each year. Natural gas generated 681 megawatt hours of electricity in 2002, 880 megawatt hours by 2007, and continued to climb to 1,380 megawatt hours by 2016. The only other fuel sources with steady increases every year were both wind and solar energy.

Pricing of fuel sources and how they are interrelated will always be a consideration, but in the case of wind energy, the effect on the environment is a larger

⁵⁵³ Nyquist, *Lower Oil Prices but More Renewables: What's Going on?*

concern. Some prices are hard to calculate in dollars and cents. The reduction in CO₂ emissions is one of those prices that fall in that hard-to-calculate category.

Ways to Use the Pricing Connection Between Fossil Fuels to Aid in Renewable Energy Development

An assessment from the Global Development and Environment Institute at Tufts University states, “Having fossil fuel prices reflect their externality costs is likely the only way to accomplish a rapid renewable energy transition in the near future (though the required political will may be difficult to develop), and may also be the only option with potential to avoid the most disastrous effects of climate change.”⁵⁵⁴ They posit that one of the best ways to force the development of further development of clean energy is to revalue fossil fuel prices to reflect their true cost to society. For example, taxes called Pigovian taxes, named after economist Arthur Pigou, can be used to accomplish this. Current national gas taxes in the U.S. have not increased since 1993 when they were set at 18 cents per gallon. These are some of the lowest in the world, especially compared to nations such as France, Norway, and the United Kingdom, where gas is heavily taxed, costing consumers up to \$8 per gallon. If the U.S. were to increase tax revenues similar to these other nations, the economic law of demand would almost guarantee that as the prices rose, the demand for those types of fuel would decline.

⁵⁵⁴ Timmons, Harris and Roach, *The Economics of Renewable Energy*.

Other suggestions on ways to increase renewable energy development were to add Pigovian taxes on electricity, create national renewable energy targets, and increase research and development.⁵⁵⁵

Summary

The growth of wind energy and the willingness of investors to take risks in investing in that industry were partially driven by the prices of oil, coal, and natural gas. Both coal and natural gas are used as the primary fuels to create electricity, so it is logical that high prices of those commodities would be connected to the willingness of investors to become more involved in wind energy. Since oil is rarely used to create electricity, the connection to wind is less clear until a complete evaluation is made of how energy is traded on the stock market. As wind energy continues to gain better economies of scale, the less it will be susceptible to the pricing of other energies. Because wind generated electricity has a consistent price, it becomes more attractive to investors and power plant owners. Not only does wind energy reduce CO₂ emissions, it also brings more pricing stability to the market place.

⁵⁵⁵ Ibid.

CHAPTER IX

CONCLUSION

People have been harnessing wind energy for centuries. However, it was not until the 20th century that technology was developed enough, enabling it to be used for commercial electricity generation. It is amazing how short the history of this technology is compared to other fuel sources such as coal or natural gas. This study showed the progression of that development throughout the U.S.

In this concluding chapter I will examine the summary of key findings on this study's five hypotheses of what factors were most influential in the development of the U.S. wind industry. I will explain the conclusions I drew from those key findings; then I will explain why this research is important to both researchers and practitioners. I will also make recommendations for future research, and make recommendations to practitioners. Before offering some final thoughts on what I consider to be this project's broader applicability to the world of energy geopolitics, I will give a couple of examples of the dynamism of the political environment at the state and federal levels.

Summary of Key Findings

This study examined five key factors that contributed to the proliferation of wind energy in the U.S. The key findings will first be reviewed in the order that they were explored in this research. Later analysis will show a priority order of the importance of each factor.

The genesis of the commercial market began in California in 1981, and it took 25 years to generate the first 11,450 megawatts of installed wind energy capacity. Once momentum and economies of scale were built, it only took an additional ten years to add 70,733 megawatts of additional capacity.⁵⁵⁶ There is a natural lag time that occurs from when investors decide to pursue the development of a wind farm to the time that wind farm is generating electricity. Generally speaking, that lag time is two to three years, which is why it was so critical to evaluate all key factors starting around 2003 to 2004.⁵⁵⁷ The most critical years of the U.S. wind energy boom began in the early 2000s, leading to a surge that started in 2007, and then continued through the 2010s.

Each of the key factors: public opinion, presidential leadership, state mandates and policy, technological developments, and fossil fuel prices, influenced the development of wind energy. These key factors were interdependent at different levels and they have each proven to be important in understanding why wind energy grew so significantly in the U.S.

⁵⁵⁶ See: "Electric Power Monthly," U.S. Energy Information Administration, last modified September 26, 2017, accessed October 7, 2017, [https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_1_01_a](https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_1_01_a;).; "Electric Power Monthly Back Issues," U.S. Energy Information Administration, last modified January 1, 2011, accessed October 7, 2017, <https://www.eia.gov/electricity/monthly/backissues.html>.

⁵⁵⁷ Ibid.

Key Factor #1 - Public Opinion

Before 2007

Wind energy could not have grown as much as it did in the last 10 years if public opinion had not been changing before 2007. Public awareness of the anthropogenic effects on the Earth began to increase in earnest in the early 1970s.⁵⁵⁸ As models tracking CO₂ emissions and the negative effects of climate change improved, and the oil crises in the 1970s negatively affected the U.S. economy, the American public began to understand the importance of energy conservation. These changing opinions led to changes in how they consumed goods. Tracking consumer behavior is much more straightforward to tracing how public opinion may or may not lead to changes in public policy.

Dr. Normal Luttbeg framed a useful set of models on ways that public opinion can influence public policy, and two of his models, the Political Parties Model, and the Pressure Group Model, are most applicable to this study about how public opinion relates to public policy.⁵⁵⁹ The Political Parties Model is strongest when the president's political party controls both the House of Representatives and the Senate, but even when that is not the case, this model helped explain policy advances that directly contributed to growth in renewable, specifically wind energy.

⁵⁵⁸ "Earth Day: The History of a Movement | Earth Day Network," Earth Day Network, last modified January 5, 2016, accessed January 10, 2016, <http://www.earthday.org/earth-day-history-movement>.

⁵⁵⁹ Luttbeg, *Public Opinion and Public Policy: Models of Political Linkage*, 77 and 119.

The second applicable model is Luttbeg's Pressure Group Model. Organizations that successfully lobby are applying pressure to the political system to achieve a desired outcome. There is strong evidence that lobby groups influenced policy to help proliferate U.S. renewable energy. One example of a powerful lobby group in this field is the American Wind Energy Association (AWEA). In addition to helping the wind industry gain efficiencies, AWEA has helped those in government service become more informed in ways to successfully promote the development of wind energy.⁵⁶⁰

Though public opinion acknowledging the negative effects of climate change on the planet grew during this time frame, evidence showed that this concern did not translate into support of wind energy development until later. There was still a hesitation coined as the NIMBY syndrome.⁵⁶¹ NIMBY syndrome showed that opinion on climate change was not yet changing attitudes to a willingness to accept change in a real way. Quality of life issues were still driving behavior rather than long-term views on sustaining the planet.

However, how public opinion changed before 2007 was critical in setting the conditions under which the wind industry was able to experience such significant growth in the next time period. This led to growing support for renewable fuel development, which was a key factor leading to the U.S. wind energy boom.

⁵⁶⁰ "Get the Facts," American Wind Energy Association, last modified January 2016, accessed January 3, 2016, <http://www.awea.org/Resources/Content.aspx?ItemNumber=5059>.

⁵⁶¹ Maarten Wolsink, "Wind Power and the NIMBY-Myth: Institutional Capacity and the Limited Significance of Public Support," *Renewable Energy* 21 (2000, 2000), 49-64.

2007 to 2016

Starting in 2007, U.S. public opinion polls demonstrated that seven out of 10 Americans believed the science behind climate change. They believed the facts showing that average global temperatures were rising. Research showed that the demographics of who most believe in climate change were Hispanics, young adults, and those with more formal education. The research also showed that Democrats most strongly believe in climate change, the fact that it is mostly caused by human activity, and that it will harm Americans.⁵⁶²

Though there was still hesitation by U.S. citizens to support wind energy growth in this time period, the benefits of renewable energy were becoming more obvious. There were some complaints about the negative effect of wind farms on the local wildlife and ecosystems.⁵⁶³ However, people started to understand that wind farms did more good than harm. A public opinion poll in 2016 showed that 83 out 100 Americans supported further wind energy development.⁵⁶⁴ Even the most conservative people supported further expansion in this market. Wind energy had become almost universally accepted as a positive way to use the planet's abundantly produced resource of wind.

⁵⁶² "Views on Climate Change, by Key Demographics," Pew Research Center, last modified February 11, 2015, accessed February 19, 2017, http://www.pewinternet.org/2015/02/12/how-different-groups-think-about-scientific-issues/pi_2015-02-12_science-issues-06/.

⁵⁶³ "Will Wind Turbines Ever be Safe for Birds?" Audubon Society, last modified March 16, accessed July 2, 2017, <http://www.audubon.org/news/will-wind-turbines-ever-be-safe-birds>.

⁵⁶⁴ "Views on Climate Change, by Key Demographics."

Causality and Analysis

One would have thought that the information that is most relevant in this research is not how many people believe in climate change, but how many people believe that human behavior is the reason the climate is changing. Figure 49 depicts some key demographic polling information. A poll taken at the end of 2016 shows that approximately 55 percent of Americans believe climate change was mostly caused by human behavior.⁵⁶⁵ Of the people who believed that anthropogenic behavior is hurting the planet, how many were willing to change behaviors and work to create ways to decrease the negative effect humankind is having on the planet? Polls showed that people who do not believe in anthropogenic climate change still support wind energy growth. Thus, the research that is most relevant here is not how many people believe in climate change, but how many support further investment in renewable energy. There is a significant amount of overlap in these two areas, but this research shows there are Americans who do not believe in climate change but still support wind energy growth. 2015 polls showed that 73 percent of Americans believe in climate change, while a 2016 poll showed that 83 percent of Americans supported expanding the number of wind turbine farms.⁵⁶⁶ With the acknowledgement that these polls were not taken at the same time, there is a full 10 percent of people who do not believe in climate change who support further development in the wind industry.

⁵⁶⁵ John D. Sutter, "Trump Doesn'T Represent American Views on Climate Change: A Visual Guide," *CNN*, sec. Politics, January 18, 2017.

⁵⁶⁶ Kennedy, *Two-Thirds of Americans Give Priority to Developing Alternative Energy Over Fossil Fuels*.

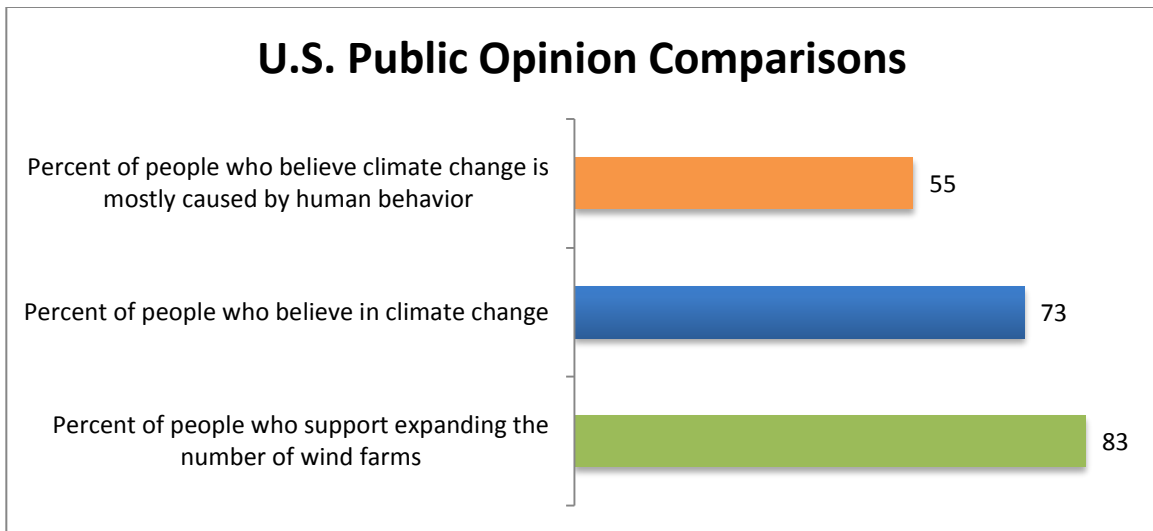


Figure 49 - U.S. Public Opinion Comparisons⁵⁶⁷

Data Sources: CNN, Pew Research Center

The key in evaluating the level of effect public opinion has on wind energy growth is understanding when public opinion influences both private industry and national and state policy decisions. There is not reliable data to show direct linkages on how public opinion caused private industry to grow. It is unlikely that private industry did studies or kept records on how public opinion affected their willingness to expand wind energy investments. If those studies and data do exist, it would require an additional study and quantitative analysis to find cause and effect.

What is within the realm of this study is the use of a methodology in which models are used to determine how public opinion affects policy development. Researchers have developed many models, but the ones most useful to this study are

⁵⁶⁷ See: Cary Funk and Brian Kennedy, "Public Opinion on Renewable and Other Energy Sources," *Pew Research Center*, sec. Internet and Technology, October 4, 2016.; Kennedy, *Two-Thirds of Americans Give Priority to Developing Alternative Energy Over Fossil Fuels.*; Sutter, *Trump Doesn't Represent American Views on Climate Change: A Visual Guide.*

Dr. Norman Luttbeg's Political Parties Model and Pressure Group Model.⁵⁶⁸ These models will be applied in the next section on presidential leadership.

Key Factor #2 - Presidential Leadership

Presidents Kennedy to Clinton

The second key factor evaluated in this study was presidential leadership. There are certain personality traits that all presidents have in common. These are the traits that make them effective leaders. The two main political parties in the U.S. have different agendas when addressing climate change. Generally speaking, members of the Republican party do not believe as strongly in anthropogenic climate change as do members of the Democratic party. The two parties also have different views on the responsibilities of the national government. The Republican party believes a smaller federal government is better, which leaves more decisions and more control at the state level.⁵⁶⁹ However, presidents are not always driven by party politics. Understanding these perspectives helps one understand why different presidents helped shape environmental policy in different ways. This work examined all key legislation and policies, and presidential attitudes towards climate change and energy policy starting with President Kennedy in the early 1960s.⁵⁷⁰ Of the early presidents, Presidents Nixon and Carter were two of the most influential in creating federal systems and policies to

⁵⁶⁸ Luttbeg, *Public Opinion and Public Policy: Models of Political Linkage*, 77 and 119.

⁵⁶⁹ Lester, "New Federalism and Environmental Policy," 149-165.

⁵⁷⁰ "John F. Kennedy on Environment."

protect the environment.⁵⁷¹ President Nixon was a Republican, so the degree to which he changed and enlarged the federal government to address climate change did not follow the typical Republican attitudes that these issues should be handled by the states. To understand Nixon's decisions requires a deeper understanding of domestic and international politics at the time. He was an astute politician who understood what the public wanted and needed.

President Carter's actions to protect the environment fell in line with his Democratic party politics. He enlarged the federal government even more with the creation of the Department of Energy, and he was also the impetus behind a Congressional report that involved 12 different governmental agencies. The report was a comprehensive look at how the global environment was interrelated.⁵⁷² This was the first time that it was shown that human activity on one part of the Earth could affect another life on another part of the Earth.

Presidents Reagan and George H.W. Bush were both Republican, but they handled policy very differently. Reagan opposed using national tax incentives to promote energy development and he ended many federal environmental programs.⁵⁷³ Bush Senior, on the other hand, signed legislation in 1992 that created one of the most

⁵⁷¹ See: "Richard Nixon on Environment."; "Analysis: 35 Years Later, Jimmy Carter's Energy Warning."

⁵⁷² Sussman and Daynes, *US Politics and Climate Change: Science Confronts Policy*, 80-81.

⁵⁷³ "Ronald Reagan on Environment," On the Issues, last modified June 17, 2017, accessed March 4, 2018,

http://www.ontheissues.org/Celeb/Ronald_Reagan_Environment.htm.

important programs incentivizing investment into renewable energy called Production Tax Credits (PTCs).⁵⁷⁴

President Clinton, like Carter, was more predictable from a Democratic party perspective. He laid out a domestic plan to reduce GHG emissions and his plan was the first presidential action plan that was based on the belief in anthropogenic climate change.⁵⁷⁵

Presidents George W. Bush and Barack Obama

The previous section began to show a trend that presidents mostly followed party politics when addressing climate change, but that did not mean that translated into predicting whether they supported legislation that promoted growth in the renewable energy sector. This trend became even truer when applied to a more in-depth study of Presidents George W. Bush and Barack Obama. Bush was not seen as an environmentally friendly leader, but wind energy grew substantially during his terms of office. In fact, the commercial wind industry quadrupled in size under his leadership.⁵⁷⁶ Although he did not make policy decisions that were environmentally friendly, he made policy decisions that helped renewable energy grow. During his presidency the U.S. became the highest wind energy producing nation in the world.

⁵⁷⁴ "Renewable Energy Production Tax Credit (PTC)."

⁵⁷⁵ Royden, "U.S. Climate Change Policy Under President Clinton: A Look Back."; Beerling, *Building a Sustainable Energy Future: U.S. Actions for an Effective Energy Economy Transformation*.

⁵⁷⁶ See: "Electric Power Monthly."; "Electric Power Monthly Back Issues."

True to his Democratic party platform, President Obama was a very pro-environment leader who sought ways to fulfill his campaign promises to become a more environmentally friendly nation. By the time he left office, CO₂ emissions decreased to levels lower than where they were when he took office.⁵⁷⁷ That was a big achievement, especially since the economy was growing the same time emissions were dropping. Even with this indicator that the U.S. was doing a better job of reducing dangerous emissions, Obama did not accomplish as much as he would have liked domestically due to a Republican-controlled Congress that blocked most of his environmentally friendly programs.⁵⁷⁸ Obama had more success addressing climate change within the international community. He was seen as an important leader in bringing the world together to draft and approve the UNFCCC's Paris Agreement.⁵⁷⁹ It was the most successful international agreement on the importance of reversing the amount of dangerous emissions that are driving the Earth's temperatures up. Obama left office with moderate successes in domestic environmental politics and great successes in international environmental politics.

Even though his domestic environment programs were not as successful as he wanted, the commercial wind industry grew more while he was president than it had ever grown before. Obama's pro-renewable energy attitude translated to policies that helped the American wind industry.

⁵⁷⁷ "Total Energy."

⁵⁷⁸ Sussman and Daynes, *US Politics and Climate Change: Science Confronts Policy*, 94-95.

⁵⁷⁹ "The Road to a Paris Climate Deal."

Causality and Analysis

The impact of presidential leadership on both the nation's response to anthropogenic climate change and wind energy growth is important. It has also been shown in this work that a president's perspective on anthropogenic climate change is not the only driving force behind his willingness to support legislation and incentives that promote renewable energy growth. The earliest presidents to acknowledge the dangers of human behavior and the negative effects of the industrial revolution on the Earth's atmosphere were Presidents Kennedy, Nixon, and Carter. Each of these presidents were influenced by the science and they all took action to offset the amount of CO₂ being released into the atmosphere. It is also evident that the oil crises of the 1970s captured the attention of the nation and its leaders.⁵⁸⁰ People were seeing that it was an economic and security risk to be so reliant on oil imports. The first Clean Air Act⁵⁸¹ was passed shortly after President Kennedy's assassination and it was an important impetus in the U.S., forcing private industry to be more responsible.

President Kennedy set into motion a change of attitude on the importance of governmental regulation that President Nixon understood. Nixon did not just focus on ways to regulate private industry to be more environmentally friendly, he also started the first national program, the Federal Wind Energy Program, to help coordinate efforts by the government, private industry, universities, and laboratories to research the development of commercial-scale wind farms.⁵⁸² This program cannot be traced as one

⁵⁸⁰ Jacobs, "America's Never-Ending Oil Consumption."

⁵⁸¹ "Overview of the Clean Air Act and Air Pollution."

⁵⁸² Starrs, "Legislative Incentives and Energy Technologies: Government's Role."

of the most important factors in bolstering the U.S. wind energy industry, but it certainly demonstrates adaptive attitudes and the importance of presidential leadership in this field. The program grew until 1981 when President Reagan defunded it.⁵⁸³

Reagan decreased the size of federal programs with the intent that state responsibility would increase. Not only was Reagan responsible for defunding many federal programs responsible for regulating dangerous emissions, he also defunded programs that were designed to help infant industries, such as wind energy, grow.⁵⁸⁴ The eight years Reagan was president represented a big step backward in addressing climate change issues and the promotion of wind energy. The nascent wind industry would find the actions of the next president, President George H.W. Bush, were not as stifling to their cause.

One of the most important pieces of legislation in helping wind energy grow was the Production Tax Credit (PTC) program that was signed into legislation under President George H.W. Bush.⁵⁸⁵ The evidence is indisputable on how investors used PTCs as a way to break through barriers in building wind farms. At this point, the barriers to entry into this market were mostly financial. PTCs gave investors the tax incentive they needed to take risks in this market. As figures in Chapter 5 showed, it is clear that when PTCs were in effect, wind energy grew. When PTCs were allowed to expire, very little wind energy capacity was added.

A detailed analysis of Presidents George W. Bush and Barack Obama showed how two presidents from two different political parties greatly influenced the ways the

⁵⁸³ Ibid.

⁵⁸⁴ "Ronald Reagan on Environment."

⁵⁸⁵ "Key Federal Legislation."

U.S. government addressed climate change. Although President Bush backed away from international commitments developed to reduce CO₂ emissions, there was a surge of wind energy growth during his presidency. President Obama promoted climate change both domestically and internationally, and wind energy continued to surge under his administration. To fully understand the effect of both Presidents Bush and Obama on the domestic wind market requires more analysis.

President George W. Bush did not use the terms global warming or climate change publicly. Instead he used the term *environmental degradation*,⁵⁸⁶ which was a strong indicator of his unwillingness to accept the fact that human behavior had more to do with the changing environment than natural cycles. He used ambiguous language and put domestic economics before concerns about the environment. This was indicated through his rejection of the Kyoto Protocol, an international agreement making it legally binding for nations to reduce GHG emissions.⁵⁸⁷ Bush was not as unfriendly to the environment as Reagan, but he certainly could not be called environmentally friendly. Even though Bush was not a proponent of international agreements, he tried to replace the Clean Air Act with initiatives such as the Clean Skies initiative,⁵⁸⁸ and he supported programs and legislation that incentivized further wind energy development. Bush understood the value of using Earth's natural resources in a responsible way to create energy. He did not discriminate between fossil fuel usage and renewable energy usage. In 1999, when he was Governor of Texas, he signed state wind energy incentive

⁵⁸⁶ Bush, *National Security Strategy of the United States of America* (2002).

⁵⁸⁷ Coon, "Why President Bush is Right to Abandon the Kyoto Protocol."

⁵⁸⁸ "The Worst of Times: Bush's Environmental Legacy Examined."

programs into law.⁵⁸⁹ Texas has quadrupled the wind power of any other state and it was largely due to initiatives instituted while Bush was governor. In only 10 years, Texas went from having virtually no commercial wind energy to being the nation's wind energy leader.⁵⁹⁰ The leading trade association on wind energy, AWEA, hired Bush to be the keynote speaker at their annual conference in 2010, just a year after he left office. Although one would not use any of Bush's initiatives as environmentally friendly, he is considered to be a hero in the wind industry.⁵⁹¹ Bush's leadership in wind energy is one of the most important factors why the wind energy industry boomed while he was president.

President Obama does not have as strong a record as being friendly to the wind industry, but he was touted by many as the greenest president on record.⁵⁹² He was not able to achieve his domestic goals of improving legislation to control the level of GHG emissions, but he still made great strides in the right direction. The Republican-controlled Congress opposed much of what Obama tried to accomplish in this arena, but the fact remains that he tried. Most of Obama's strengths in addressing climate change are reflected in his successes internationally. Obama had a global reputation for his strong leadership in this field. His leadership and participation in the UNFCCC Conference of the Parties (COP) in Paris (COP 21), was a landmark achievement for him and the first time the U.S. ratified such an important international agreement.⁵⁹³

⁵⁸⁹ "REC Trading in Texas - Lessons Learned & Way Forward."

⁵⁹⁰ "Texas: A National Wind Energy Pioneer."

⁵⁹¹ Gregg, *George W. Bush: Impact and Legacy*.

⁵⁹² Chait, "Obama might Actually be the Environmental President."

⁵⁹³ "Outcomes of the U.N. Climate Change Conference in Paris."

Though President Obama does not have as strong a record as George W. Bush had in supporting the wind industry, he still has a strong record. PTCs were allowed to elapse while Obama was president, but that was due to bipartisan politics and not because of his lack of leadership. Wind energy grew more during Obama's terms of office than any other president. Though it is not the focus of this dissertation, solar energy had the most significant growth under Obama. This is important because federal legislation that incentivizes wind energy also incentivizes solar energy. They are intertwined in almost all legislation. It is helpful to use solar energy as a second barometer to measure the effect of legislation.

In summary, Presidents Bush and Obama had similar effects on the wind industry while they were president. However, Bush's presidential leadership coupled with his leadership while governor of Texas made him the most positively influential leader on the wind industry. President Obama took Bush's successes in this field and expanded on them. Both these presidents were critical in setting the necessary conditions for wind energy to have grown as much as it has. It is true, presidential leadership matters.

Key Factor #3 - State Incentives and Mandates

The third key factor analyzed was that of individual states. The DOE assessed that 60 percent of the reason wind grew so much in the last decade was due to state policies and mandates.⁵⁹⁴ What is not clear is what factors the DOE considered in that

⁵⁹⁴ "Renewable Energy for State Renewable Portfolio Standards Yield Sizable Benefits."

assessment, but the fact still emphasizes the importance of the individual states' approach to dealing with climate change and energy policy. Some states created policies that encouraged wind energy growth while others did not. An evaluation of the states that generate the most wind energy helped show how each state approached the use of wind energy to produce electricity. No two states have the same policies or the same results. The wind industry in some states relied heavily on federal and state incentives in the form of PTCs and Renewable Portfolio Standards (RPSs) for development while wind industries were able to succeed in other states without these benefits from the government.⁵⁹⁵ Because PTCs have only been developed at the federal level, they apply universally to all investors in the 50 states. Of the states that have RPSs, there are no two states that designed them the same, so each state wind energy program has to be evaluated separately to get a true understanding of why wind energy flourished or never took off. This dissertation only evaluates key states to get an understanding of how vast those differences are. Using researcher James Lester's "Typology of State Behavior" to explain why states behave the way they do is helpful in understanding why some states have mature renewable energy programs and why others do not.⁵⁹⁶ Lester broke states down into four categories as determined by their level of commitment to environmental policy and their dependency on federal aid. In Chapter 6, the four categories are explained and applied to state renewable energy programs.

⁵⁹⁵ See: "2015 PTC Handout."; Barbose, *U.S. Renewables Portfolio Standards 2017*.

⁵⁹⁶ Lester, *New Federalism and Environmental Policy*, 149-165.

Another external factor that makes a big difference in the size of a state's wind energy industry is how much the wind is typically blowing over land. The central states reaching from North Dakota down to Texas have the most wind and would logically be the best situated to develop wind energy.⁵⁹⁷

Before 2007

California is not as windy as states in the wind belt, but there are parts of California that are windy enough to support the development of commercial wind farms. California is in the ideal category of Lester's "Typology of State Behavior," and an investor there took advantage of federal and state programs and built the world's first wind farm in 1981.⁵⁹⁸ By today's standards it was small and not very efficient, but it was a successful venture that still generates electricity for Californians today. This first farm predates both PTCs and RPSs, but the investor utilized programs that were precursors to those programs.⁵⁹⁹ The California wind industry continued to grow for the next five years, but then it stagnated when federal programs were revoked during President Regan's administration.⁶⁰⁰

There were other key states that took advantage of federal programs and developed strong state RPSs. There was a long history of citizens in Iowa using windmills to ease the burden of farm work. They were used to harness wind, so the idea

⁵⁹⁷ "United States Land-Based and Offshore Annual Average Wind Speed at 100 M."

⁵⁹⁸ Wampler, "Windmills are Growing Along Altamont Hills."

⁵⁹⁹ Ibid.

⁶⁰⁰ "Overview of Wind Energy in California."

of building wind farms to generate electricity was a very natural development. Iowa created the very first RPSs in 1983.⁶⁰¹ Texas did not enter the wind energy market until the 1990s,⁶⁰² but the wind industry in both Iowa and Texas has grown steadily with no stagnation periods like California experienced.⁶⁰³ All three of these states were key in the development of the U.S. wind industry before 2007.

2007 to 2016

State programs grew in both breadth and depth in this time period. Iowa led the nation with the highest percentage of electricity generated by wind with South Dakota, Kansas, Oklahoma, and North Dakota closely behind.⁶⁰⁴ Texas has the largest wind energy program as measured by the amount of wind energy generated and utilized, but it is also the second largest state in terms of geographical size, second only to Alaska. In addition to having the most productive wind farms, Texas also renovated much of its electrical grid system to make transmitting electricity from remote areas to large urban areas possible.⁶⁰⁵

The states that run contrary to the models that California, Iowa, and Texas established are Idaho, Wyoming, and Nebraska.⁶⁰⁶ All three of these states have an abundance of wind, but they have very underdeveloped wind energy programs. The

⁶⁰¹ Lorenzsonn, "Wind Takes Iowa by Storm."

⁶⁰² "Texas: A National Wind Energy Pioneer."

⁶⁰³ Oatman, "The Gust Belt."

⁶⁰⁴ "U.S. Wind Energy State Facts."

⁶⁰⁵ "6 Reasons Why Texas Leads the Nation in Wind Power."

⁶⁰⁶ "U.S. Wind Energy State Facts."

reasons these states have not utilized wind energy as effectively as they could vary. Idaho has an extremely mature renewable energy program in the form of hydroelectricity.⁶⁰⁷ When the majority of their electricity is already generated from renewable sources, there is less need and incentive to develop wind energy. Wyoming is vastly different than other states because it is fiercely loyal to the coal industry. It is so loyal to coal that not only has it not incentivized the generation of renewable energy, it actually levied a charge against electricity generated by wind.⁶⁰⁸ Nebraska has publicly-owned utility companies, which means they are not eligible for PTCs or RPSs.⁶⁰⁹ To completely understand Idaho's hydroelectric industry, Wyoming's loyalty to coal, and Nebraska's public utilities, requires more study into their history. These three examples show the vast variety of state attitudes toward wind energy.

The states with the most aggressive RPSs with the key purpose of increasing the size of renewable energy programs are Hawaii, Vermont, California, and Oregon.⁶¹⁰ The resolve of these states to reduce reliance on fossil fuels to both stimulate their economies and reduce CO₂ emissions is indicative in these high levels of incentives.

As a final note on progress made during this time period, Rhode Island opened the first offshore wind project at the end of 2016.⁶¹¹ The project was very expensive and also only serves a small island population, but it is important because offshore wind in the U.S. had previously been non-existent. European nations have extensive offshore

⁶⁰⁷ "Renewable Energy in Idaho."

⁶⁰⁸ "Wyoming: State Profile and Energy Estimates."

⁶⁰⁹ Epley, "New Developments Help Nebraska Take Advantage of its Capacity for Wind Power, which Accounted for More than 10 Percent of its Energy in 2016."

⁶¹⁰ "U.S. Wind Energy State Facts."

⁶¹¹ Schlossberg, "America's First Offshore Wind Farm Spins to Life."

wind and they have already decreased the financial barrier to entry into the market. They have also developed the technology needed to build offshore wind farms.⁶¹² This is a market that will likely substantially flourish in the coming decades.

Causality and Analysis

The evaluation of a few key states with the most and least developed wind energy programs demonstrates the importance of state attitudes and policies in wind energy development. California is a very environmentally and wind friendly state. It has one of the most developed programs, yet it did not develop RPSs until 2002. Iowa was the very first state to develop RPSs in 1983,⁶¹³ and it also utilizes the highest percentage of wind-generated electricity in the union. Texas has some of the lowest state mandates, yet the wind industry exceeded the goals set by the state government well before it was supposed to. This shows that development of RPSs is an indicator of how a state worked to develop its wind industry, but it is not the only indicator. The difficulty with evaluating state programs is that it would require an in-depth study of all 50 states to truly understand why some utilize wind energy and why some do not. For example, Wyoming is one of the windiest states in the U.S., but its loyalty to coal has trumped its development of wind farms.

Texas is just as loyal to oil and natural gas, but it took a different perspective. Rather than seeing wind development as something that detracts from the fossil fuel

⁶¹² Gottron, "Off-Shore Energy Development Technologies."

⁶¹³ Barbose, *U.S. Renewables Portfolio Standards 2017 Annual Status Report*, 1-40.

industry, it saw an opportunity to develop another energy source that would help provide reliable electricity.⁶¹⁴ Texas has a more macro perspective on energy. It diversified its energy portfolio in a way that is beneficial to its citizens. Texas is also a leader in fracking and leaders there say they are not expanding into renewable sources to reduce GHG emissions or to save the planet. Thus far, Texans tend to be more politically pragmatic than concerned about climate change. Texas leaders do not want to rely on coal or natural gas to supply all its electricity. By investing in renewable energy, they are better able to guarantee more stable pricing when natural gas prices fluctuate.⁶¹⁵

The states with the most aggressive RPSs created them for different reasons. Hawaii has to import its fuel and sees renewable energy development as a way to free itself from those imports and make it self-reliant. However, they are not looking to become independent from fossil fuels completely. Hawaii is seeking to take control of the fuels used to generate electricity in the form of solar energy. Hawaiians see the sun as the best way to generate electricity.⁶¹⁶ Since solar and wind are closely tied in most government incentive programs, when one goes up, the other does, too.

The importance of political affiliation was explored in the chapter on presidential leadership. Political affiliation for states tends to fall along the same lines meaning that blue (Democratic) states are generally the most concerned about anthropogenic climate change while red (Republican) states are generally the least concerned about climate change and have a weaker belief that human behavior is driving shifting climates. It also seems to hold true that political party affiliation has less to do with wind energy

⁶¹⁴ "6 Reasons Why Texas Leads the Nation in Wind Power."

⁶¹⁵ Drouin, "How Conservative Texas Took the Lead in U.S. Wind Power."

⁶¹⁶ Savenije, *Hawaii Legislature Sets 100% Renewable Portfolio Standard by 2045*.

development than concern about climate change. Both blue and red states have strong wind energy programs. A more detailed evaluation of state behavior may indicate that blue states are more wind energy friendly than red states, but when red states such as Texas are added to that equation, the numbers will likely not support that assumption. The best indicator of how much wind energy a state has developed is its geographic location and amount of undeveloped land over which the wind blows abundantly. Acknowledging that there are exceptions to that then forces one to explore deeper into state politics. It has been shown that wind energy development within a state is not reliant on the citizens of that state believing in anthropogenic climate change. The history of each state, including the number of farmers who historically relied on windmills, is a good indicator of how that state's citizens view the proliferation of wind energy.

In summary, understanding state systems is important when attempting to determine what caused the U.S. wind energy boom. It has been shown that state governments matter in determining the levels of wind energy investment.

Key Factor #4 - Technological Developments

The fourth key factor evaluated was how technological advances played a role in wind energy growth. It is clear that without the significant technological advances made on turbine structure and components, coupled with advances on how wind patterns can best be utilized in a wind farm, there would be much less wind energy generated today. A deep background on technological developments was explored in Chapter 7. This

was relevant to explain how U.S. wind energy was developed and propagated across the nation. Important to understanding how technological improvements were made is a basic understanding of aerodynamics and the importance of understanding how to gain efficiencies through tower design and height, turbine design, rotor blade design, wind farm design, and electrical grid design.

Before 2007

This study showed that technological advances before 2007 were foundational for the U.S. wind energy boom. Research and development in the elements required for wind energy to grow exponentially came in many different forms. Most of the commercial wind turbines installed in the world's first wind farm in California were mostly rated at a 50-kilowatt output.⁶¹⁷ By the end of this time period, commercial turbine output had grown to 1.4 megawatts.⁶¹⁸ That is a gained output of 280 percent. Many factors were involved in improving this output. Examples of gained effectiveness were through the creation of variable-speed drive trains, sectioned rotors, and the application of computer-aided design and nanotechnology.⁶¹⁹ The single most important improvement in this industry at that time was in turbine size because wind blows more regularly at altitude. All these improvements drove the price of wind energy down. The decreased prices were critical in making wind-generated energy competitive with both

⁶¹⁷ "Overview of Wind Energy in California."

⁶¹⁸ Wisler et al., *Reducing Wind Energy Costs through Increased Turbine Size: Is the Sky the Limit?*

⁶¹⁹ "Increasing the Efficiency of Wind Turbine Blades."

coal and natural gas-generated energy. This decreased the barrier to entry for investors and made wind energy more palatable from a pricing perspective.

2007 to 2016

Most of the important technological advances happened prior to 2007, but advances continued to be made. By the end of 2016, turbine output had increased to 3 megawatts, which is more than double the output of turbines at the beginning of 2007.⁶²⁰ The growing height and size of turbines required further research into ways to build turbine towers that were strong enough to withstand the forces of the larger rotors. Examples of innovation to address that problem came in the form of a structure reinforced with steel tubes or concrete towers that were poured on site. Rotors were also increasing in size, which allowed each turbine to capture more wind energy.⁶²¹ The advantage of turbines with a greater output is fewer turbines need be installed on a wind farm to reach the desired electrical output. Since it is not twice as expensive to produce a tower with twice as much output, economies of scale led to even more cost reductions during this time period. Increased turbine performance and increased wind farm performance were critical to the increased U.S. wind energy capacity increases.

Another area that would need further investment is in the electrical grid system. Texas had the most progressive grid that was created and designed to move wind-generated electricity from remote, sparsely populated areas, to urban areas with a large

⁶²⁰ Markovitz, "Sizing Up Wind Energy: Bigger Means Greener, Study Says."

⁶²¹ Miser, "Taller Towers and Better Blades: The Cutting-Edge Technologies in Modern Wind Turbines."

population density.⁶²² Most grids across the U.S. are not as sophisticated and require an infusion of capital to properly utilize wind-generated electricity.

Causality and Analysis

The causality and analysis in reference to the importance of technological improvements is very straightforward. Without the technological advances that have been achieved, there would not have been as much wind energy growth. That is not just true for the U.S. wind industry, but it would also apply to wind energy development across the world. One could ponder and attempt to estimate what would have happened if those technological advances had not occurred, but that is not a helpful use of time or effort. With fewer technological advances, there would not have been as much capacity created. As advances continue to be made, it is reasonable to expect that prices will continue to decrease. Decreased prices reduce barriers to entry even further, which will likely motivate more investment in the industry.

The two areas that will need further research and implementation that will limit wind energy growth are in both electrical grids and Electric Energy Storage (EES). It is estimated that wind energy could grow to approximately 20 percent across the U.S. with minimal changes (standard maintenance) to the electrical grid.⁶²³ This does not mean that 20 percent of every market would utilize wind energy, but it would average out to 20 percent with some states generating much more while others may remain at zero

⁶²² Grossman, "Texas is Drowning in Wind Energy."

⁶²³ "U.S. Number One in the World in Wind Energy Production."

percent. Improvements in the grids would need to be made to continue growth at recent levels. Without those improvements, wind energy growth will slow in future years.

What is not required for short-term (defined as 5-10 years) is improvements in EES. EES is not nearly as important for offshore wind as it is for land-based wind. Offshore wind tends to blow more regularly, whereas land-based wind tends to blow most consistently at night. Improved EES is useful to make land-based wind useful 24 hours a day.

In summary, without the technological advances that improved both wind turbine and wind farm development, the U.S. wind energy boom could not have occurred. It is not possible to know if small improvements would have still allowed the wind industry to grow, but it would have been much less. It is possible that if only small improvements had been made that the wind industry might have never earned a foothold in the U.S. economy. One can argue that the wind industry needed the significant technological improvements to gain the economies of scale that reduced prices and made wind energy competitive with fossil fuels. Continued improvements in technology are also needed to set the conditions under which wind energy can continue to grow at the levels they have been growing.

Key Factor #5 - Fossil Fuel Prices

The fifth and final key factor analyzed in this dissertation was the effect of fossil fuel prices on wind energy development. There is strong evidence that oil prices affected wind energy development in the beginning. Natural gas and coal prices also

correlated positively with wind energy growth meaning that when natural gas prices increased, investors were willing to accept more risk by investing in wind energy. The higher fossil fuel prices were, the more attractive wind energy became. The evidence of this is shown through tracking stock market prices.⁶²⁴ As wind energy started achieving economies of scale and the barriers to installation were reduced, this correlation became less evident.

Before 2007

When the first wind farm was built in 1981, coal was the main fuel source to generate electricity across the nation and only went down slightly by the end of 2006.⁶²⁵ All fossil fuel futures are traded on the open markets, making the nation's energy markets fluctuate accordingly. Wind energy prices are based on initial investment and maintenance costs and are not susceptible to the market in the same way fossil fuels are susceptible. Coal prices dropped steadily until 2002 when they started increasing significantly enough to get the market's attention. Natural gas held a smaller share of the market, but natural gas prices were increasing about the same time as coal. Oil is rarely used to generate electricity, but fossil fuel prices trend similarly on the market. Coal, natural gas, and oil prices were increasing the same time wind energy was gaining economies of scale and wind-generated energy prices were dropping. Because

⁶²⁴ Hoium, "Why Rising Oil Prices are Good for EVs and Renewable Energy."

⁶²⁵ "What is U.S. Electricity Generation by Energy Source?"

the U.S. was a net importer of fossil fuels at that time, energy markets in the U.S. were more susceptible to market influences.

At the beginning of this time period, the energy markets were more closely aligned than they were at the end. Several key factors were identified to explain why oil prices became less relevant to predicting what would happen in the wind industry with the most important based on the improved economies of scale and technological advancements in wind energy.

The decrease of wind energy prices juxtaposed over the increase of fossil fuel prices helps explain why investors were more willing to increase investments in the wind industry in the early and mid-2000s leading to a boom of wind energy in 2007.

2007 to 2016

In this decade, U.S. electricity utility companies shifted their alliance from coal to natural gas. Nuclear power and renewable energy also gained larger shares of the market. Most important for this work is the fact that wind energy grew from generating less than one percent to generating six percent of all U.S. electricity in 10 short years. That is a major market shift.

It is fairly easy to compare the quantifiable numbers of pricing and market percentage, but what is not easy to measure is the difference to the environment when using renewable energy instead of fossil fuels. For every gigawatt that is generated by wind energy rather than natural gas or coal, the better it is for the planet. If one could

find a way to capture this in market pricing, wind energy would become even more desirable to the market.

Causality and Analysis

The research in this area has shown that when fossil fuel prices went up, the market was more favorable to investing in wind energy. These market forces were important for wind to gain the necessary economies of scale, allowing it become the world's fastest growing form of energy. If fossil fuel prices had stayed low throughout the 2000s, it is likely that wind energy would have still grown, but it would not have grown as quickly and as abundantly as it did. Over time, the U.S. wind industry gained enough momentum that it is largely decoupled from fossil fuel prices and will continue to grow even if fossil fuel prices decrease. The fact that wind pricing is stable and based on capital investments, not market fluctuations, makes it attractive.

It seems unlikely that fossil fuel prices will be an important factor to the amount of wind energy investment in the future. They were important early on, but that was much less true by the end of this study.

Conclusions Drawn from Key Findings

Based on all the research and discovery in this dissertation, the key factors listed in order of precedence of how much they positively influenced the growth of the U.S. wind energy industry are: technological developments, presidential leadership, state incentives and mandates, public opinion, and fossil fuel prices. Before analyzing each of

these factors, it is important to recognize that the geographical location of where the wind blows the most was the greatest influence on where wind farms were developed. One does not drill for oil where oil does not exist, and one does not build a wind farm where there is little reliable wind. The map depicting the location of the most U.S. wind farms correlates directly to the map showing where the wind blows the most. This helps explain why wind is relied upon in some areas and not in others. Figure 50 depicts this priority order while also showing that all factors were important.

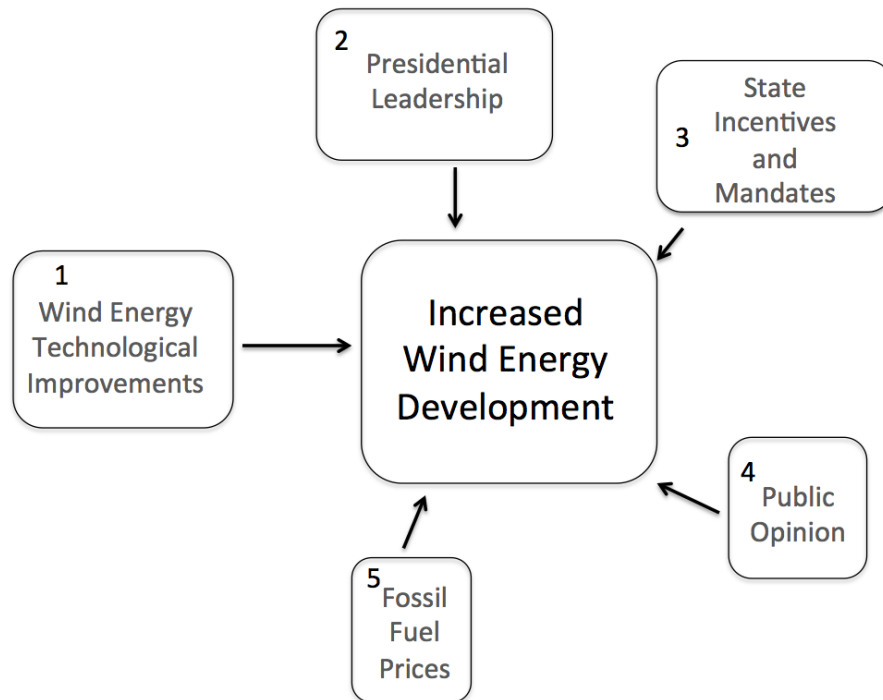


Figure 50 - Priority of Key Factors on Increased U.S. Wind Energy Development

Technology was the most important factor because even with the most pro-wind leadership at the national and state levels, wind energy could not be providing as much electricity as it is. It is the most important factor in how much wind energy has grown. A

nation can have public will and public policy to promote wind energy growth, but without the technology to install into an electrical grid that can transmit it, there would be very little wind energy generation.

The second most important factor was presidential leadership. Without the protections set by the federal government, the barriers to entry into what was an infant industry in the 1980s, 1990s, and early 2000s, would have been too great for wind energy to have grown the way it did. These protectionist policies in the form of PTCs were critical for investors to take the risks they needed to take to help the wind industry become as established as it is today.

State incentives and mandates came in third in importance to wind energy growth, but they are very close behind presidential leadership. To fully understand why some states have a mature wind energy market and why other states have none goes back to the map depicting where the wind blows the most. This is important, because it explains why people and industry in some states who are supportive of renewable energy have not built wind farms. How and when states created RPSs incentivizing the creation of more wind energy is important in understanding why some states have a very well developed wind industry and why other states have not taken advantage of the wind as a commodity.

Public opinion was fourth in importance of the five key factors. Public opinion was still very important, but it is hard to prove how much the public drives the development of a new industry. The public began understanding the importance of taking better care of the planet, but that does not directly correlate to wind energy development. Much of the public was reticent to support wind energy development in the early years. They

liked the idea of developing renewable energy as long as it was not something that interfered with their views and way of life. Public opinion was strong enough to influence politics through political parties and pressure groups, such as the American Wind Energy Association (AWEA), which lobbies Washington for support of wind energy.

Finally, fossil fuel prices were also important, but they were not as critical to wind energy development as the other factors. The pricing of fossil fuel was most important to wind energy in 2003 when fossil fuel prices began rising. However, once wind energy had gained a strong enough market share by the end of second time period of this diachronical study, fossil fuel prices no longer had a strong causal effect on whether wind energy grew.

The Interconnectedness of the Key Factors

It is clear that no single factor was the reason the U.S. wind energy industry began to surge in the mid-2000s. The key factors identified are all interrelated in a complex way. Without all the key factors aligning as they did, it is still possible that there would have been a proliferation of wind energy in the U.S., but the timing could have been very different. It is also possible that the fastest growing form of energy in the world may have mostly bypassed the U.S. if the alignment of these factors had been different. The timing and amount of increased installed capacity was due to the alignment of all the key factors starting around 2003.

Technological developments improving the effectiveness of wind turbines, improving wind farm design, and how wind-generated electricity is transmitted for use

were the most important of the five evaluated factors. However, it is less evident how national and state policy affected technology development, there were some national programs that investigated ways to utilize wind as an energy source. Most of the technological advances came from private industry, private institutions, and research at universities. Public opinion about climate change and renewable energy development would have indirectly helped technological improvements in wind power. People in the U.S. started shifting from a NIMBY (not-in-my-back-yard) perspective to a PIMBY (please-in-my-back-yard) in the 2000s. As education on climate change increased, people became more willing to think of wind farms as attractive rather than a blight on the landscape. Those who did not believe in anthropogenic climate change still supported increased investment in renewable energy. Fossil fuel prices would also have indirectly contributed to technological advances in the wind industry. As fossil fuels became more expensive, the more attractive alternatives became.

Presidential leadership and state incentives and mandates are the most interconnected factors in this study. James Lester's research showed how important national environmental policy was in predicting state behavior. The causality between the two levels of analysis varies and Lester showed how breaking that linkage down into four categories helps explain how states will react to national policy. Of the factors in this study, presidential leadership influence on wind energy development is most affected by public opinion through political party power and lobbyists. The same is true for state leadership, but there is a more direct connection between public opinion at the state level than it is at the federal level. It has been shown that the Democratic party is most likely to support legislation and governmental activity to protect the environment. It

has also been shown that both parties have supported wind energy growth. Renewable energy is not nearly as bipartisan as climate change.

Both presidential leadership and state behavior are heavily influenced by fossil fuel prices. Because fossil fuel prices affect the health of the domestic economy, presidents stay aware of fluctuations in the energy market. This is summed up nicely in a slogan used in Bill Clinton's presidential campaign that read, "It's the economy, stupid."⁶²⁶

Public opinion influenced both state and national leaders in many ways. Activities such as Earth Day helped raise environmental issues to the national level. In that way, public opinion had a direct impact on national leadership. To influence national policy, public opinion is effective through both pressure groups such as lobbyists and through political parties. Public opinion did not directly affect advances made in technology, but the public's shift from NIMBY to PIMBY made it easier for investors to build wind farms.

Each factor affected the other factors, but the levels at which they were interdependent varied between the factors and throughout the years.

Limitations

There are numerous limitations of this study, but none of them invalidate this research. Limitations range from availability of consistent data to the need to scope this research to a reasonable level.

⁶²⁶ John Hart, "It's the Economy, Stupid," *Forbes*, sec. Sites, December 27, 2017.

First, there is not consistent polling data evaluating the same opinions across the years. Different questions were asked across the years, making it hard to have a better determination of when public opinions toward climate change and renewable energy started to change.

There could also be much deeper research into presidential leadership. One could study a president, but to really understand that president's policy-making decisions, one would have to delve deeper into his administration. For each election cycle under each president, were there changes in the balance in the House of Representatives or in the Senate? Answering these questions would provide better insight into questions such as why did wind energy boom under President George W. Bush, but not under his predecessor President Bill Clinton.

As demonstrated in the chapter on state mandates and policy, it was evident that there are numerous factors that affect how a state approaches the inclusion of wind energy in the electrical grid. For example, a dissertation could be written on a single state analysis, such as Iowa or Texas. It would also be interesting to see a quantitative study using wind energy growth as the independent variable with each of the other factors as the dependent variables.

There were also limitations to the chapter on technology. Since this study falls into the field of political science, it was better to keep the discussion on technology at a level that contributed to understanding how it helped or hindered wind energy growth. Gaining a deeper understanding of technological challenges and advances would help better explain the possibilities and limitations of wind energy.

Finally, one could do a much deeper analysis of how fossil fuel prices affected wind energy investments and growth. This factor is becoming less relevant as wind energy gains economies of scale, but more analysis in this area could help other nations create policies that would promulgate deeper investment into renewable energy.

Why this Research is Important

This research and study fills a gap that had not previously been filled. Although there are articles and studies on each individual factor, there is no comprehensive look at these five key factors and how they aligned to create the necessary opportunity for U.S. wind energy to grow. By reading this study, one can quickly get a good understanding of how the U.S. wind industry started, busted, and then boomed. No other single work accomplishes that goal. This work helps both researchers and practitioners. Researchers are able to get a comprehensive understanding from this study while practitioners will have a foundation from which they can determine how to either increase or decrease wind energy proliferation. This study does not just illuminate the path for the U.S., but it would be a good starting place for other nations to quickly ascertain areas they can study to help them build a stronger wind industry.

Recommendations for Future Research

There are many areas that could be researched further to contribute to this field. It would be interesting to see a full application of different models on how public opinion

and public policy are interrelated on this issue. There are many useful models and adaptations to models. Further and more detailed research into how public opinion affected wind energy could show ways to better incorporate wind farms into the electrical grid.

There should be continued research into technological advances and how they help proliferate wind energy. To increase wind energy capacity, many states need to find the money to improve electrical grid systems. The current grids were designed around the use of fossil fuels. New or improved grid systems could be developed that would make renewable energy less costly and more viable. It would also be useful to closely follow advances in Electrical Energy Storage (EES) technology. Finding ways to store both wind and solar energy could elevate the amount of useful capacity from those sources.

There should also be further research akin to this study, using a key factor analysis, within several key states. Also, while Europe has had great success with offshore wind farms, the U.S. has not. This study touched on some of those reasons, but a comprehensive study of the factors that enabled the European offshore wind industry to grow, coupled with a comparison of how those lessons could be applied to the U.S., would fill another gap.

Dynamic World

This case study needed a finite date to effectively analyze the data. However, several important changes occurred in 2017 and the beginning of 2018. One example of

this dynamic environment is the changing attitudes in the state of Wyoming and the value of building a wind energy industry in that state. A recent report found that Wyoming is the nation's leader on new wind energy capacity that has been and will be added between 2016 and 2019.⁶²⁷ Wyoming used to be loyal to coal, but something happened to dramatically change the willingness of the state to diversify into wind energy.

A second example comes with the election of President Donald Trump. Prior to being elected, Trump frequently questioned the validity of climate change science and called it a "hoax."⁶²⁸ He has not been as definitive during his presidency, but in the short time he has been president, he has reversed, or attempted to reverse, as many as 67 federal environmental protections.⁶²⁹ His actions have been called an assault on the environment. However, thus far his actions have not directly negatively affected the wind energy industry. Under the Trump administration, there were attempts to cut the five-year phase out of the PTC. However, the cuts were not made and the PTC remains intact as signed into legislation by President Obama.⁶³⁰

The political environments at both the state and federal levels are rapidly changing. Some changes are beneficial and some may prove to be harmful.

⁶²⁷ Kavya Balaraman, "Red States Rank among Renewable Energy Leaders," *Scientific American*, sec. Energy, April 20, 2017.

⁶²⁸ Ryan Teague Beckwith, "President Trump Won't Say if He Still Thinks Climate Change is a Hoax. Here's Why," *Time Magazine*, sec. Politics, September 27, 2017.

⁶²⁹ Nadja Popovich, Livia Albeck-Ripka and Kendra Pierre-Louis, "67 Environmental Rules on the Way Out Under Trump," *New York Times*, sec. Climate, January 3, 2018.

⁶³⁰ Anthony Adragna, "Sizing Up the Tax Bill's Energy Provisions," *Politico*, sec. Morning Energy, December 18, 2017.

Final Thoughts

The purpose of this research project was to determine the importance of multiple key factors in the proliferation of wind energy in the U.S. This information will be most useful for investors, utility companies, and state government officials in the U.S. who want to find ways to increase the usage of wind energy. People from other nations could use this study to begin to ascertain what key factors should be further analyzed to improve wind energy development in their nation.

The future of U.S. wind energy appears to be very bright and there is significant room for more development. The job of *wind turbine technician* was the fastest growing U.S. occupation in 2016, and the Bureau of Labor and Statistics estimates the field will grow at a rate of 96 percent in the next decade. The U.S. government estimates the wind industry will continue to flourish in that time.⁶³¹ Wind energy generated 5.6 percent of total U.S. electricity by the end of 2016, and it is estimated that wind could be used to generate as much as 20 percent of U.S. electricity by 2030.⁶³² As wind energy continues to grow in the U.S. it will have an even greater impact on the domestic economy, which will then affect strategic and political challenges and developments. It is a field that must be further examined for policy makers to get a real sense of its value in the domestic economy in the short term, but even more so because it emits zero CO₂ into the atmosphere.

⁶³¹ Dennis, "The U.S. Wind Industry Now Employs More than 100,000 People."

⁶³² "U.S. Number One in the World in Wind Energy Production."

Wind energy has limitations and some people consider wind farms a blight on beautiful landscapes. However, “when the wind blows” it can be utilized for good. It is a fact that the extraction and use of fossil fuels is damaging to the environment and much more costly in the long term. It is time for deeper investment in wind and other renewable energies. The goal of the U.S. should be to find ways to continue to increase the use of renewable energies that are better for the environment than the use of fossil fuels. It is possible to have these newer technologies replace the old technology of fossil fuels. “It’s been done before: tapes replaced records, CDs replaced tapes, and MP3s replaced CDs. Cars replaced horses and cell phones replaced landlines.”⁶³³ The climate is continuing to change. We have endless opportunities to attempt to minimize those changes and find ways to preserve the planet. Capitalizing on blowing wind is one of the ways to conserve in order to preserve.

⁶³³ Steven Cohen, "What is Stopping the Renewable Energy Transformation and what can the US Government do?" *Social Research* 82, no. 3 (Fall, 2015), 689-710.

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VITA

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PROFESSIONAL SUMMARY

Experienced educator and career military officer with knowledge and expertise in graduate-level education in strategic and operational-level planning, as well as coordinating Joint, Interagency, and Multinational operations; Also possesses knowledge in planning, implementation, and operation of Department of Defense intelligence systems.

EXPERIENCE

Civilian (2012 – Present)

Associate Professor of Practice in the Joint Advanced Warfighting School (JAWS), of the Joint Forces Staff College, National Defense University; Responsible for educating career military officers and interagency leaders on strategy, operational planning, and operational art.

- Curriculum developer for college exercises to include Homeland Defense/Security, Major Combat Operations, and Humanitarian Assistance.
- Educated more than 1,200 military officers and civilians on fundamentals of unified action, theater campaigning, operational art, and deliberate planning.
- Led an elective on the U.S. Intelligence Community.

Military (1992 – 2012)

Career Army officer and aviator with a secondary emphasis on intelligence. Flew a variety of platforms to include two helicopters, and two fixed-wing airplanes across four continents. Led missions from tactical insertions of infantry and supplies, to treaty missions as the U.S. government's lead negotiator.

EDUCATION

Master of Arts Degree, International Relations, St. Mary's University, San Antonio, Texas. Graduated *Summa Cum Laude*.

Bachelor of Arts Degree, International Business, New Mexico State University, Las Cruces, New Mexico.