RELIABILITY OF RENEWABLE ENERGY: WIND

Jordan Lofthouse, BS, Strata Policy
Randy T Simmons, PhD, Utah State University
Ryan M. Yonk, PhD, Utah State University
The Institute of Political Economy (IPE) at Utah State University seeks to promote a better understanding of the foundations of a free society by conducting research and disseminating findings through publications, classes, seminars, conferences, and lectures. By mentoring students and engaging them in research and writing projects, IPE creates diverse opportunities for students in graduate programs, internships, policy groups, and business.
PRIMARY INVESTIGATORS:

Jordan Lofthouse, BS  
*Strata Policy*
Randy T Simmons, PhD  
*Utah State University*
Ryan M. Yonk, PhD  
*Utah State University*

STUDENT RESEARCH ASSOCIATES:

Michael Jensen  
Jadyn Naylor  
Bracken Allen  
Garrett White  
Camille Harmer  
Ryan Taylor  
Zach Hopkins
# TABLE OF CONTENTS

Table of Contents.................................................................................................................. 2
Executive Summary.................................................................................................................... 1
Introduction............................................................................................................................... 1
  Defining Reliability.................................................................................................................. 2
Economic Reliability.................................................................................................................. 2
  Types of Wind Energy Mandates.......................................................................................... 2
  Wind Energy Tax Credits and Subsidies............................................................................. 3
  U.S. Department of Energy Funding of Additional Wind Projects................................. 5
  U.S. Department of Energy’s “20% Wind Scenario”......................................................... 5
  Wind Power’s True Costs.................................................................................................... 6
  Verdict on Economic Reliability......................................................................................... 6
Physical Reliability..................................................................................................................... 7
  Wind’s Intermittency............................................................................................................. 7
  Increased Need for Cycling................................................................................................. 8
  Space Needed for Wind Power............................................................................................. 9
  Necessary Grid Overhaul..................................................................................................... 11
  What is the Grid?................................................................................................................ 11
  Grid Limitations................................................................................................................ 12
  Costs of Transmission Investment.................................................................................... 13
  Technical Challenges........................................................................................................ 13
Environmental Reliability.......................................................................................................... 14
  Verdict on physical Reliability.......................................................................................... 14
  Wind Turbine Life Cycle Assessments............................................................................. 14
  Environmental Impacts of Cycling.................................................................................... 16
  Effects on Animal Populations......................................................................................... 17
  Verdict on Environmental Reliability................................................................................ 18
Role of New Technology........................................................................................................... 18
  Energy Storage.................................................................................................................. 19
  Electrical Grid Improvements......................................................................................... 19
  Reliable Infrastructure...................................................................................................... 19
  Long-Distance Transmission............................................................................................. 20
Conclusion................................................................................................................................. 20
EXECUTIVE SUMMARY

Government policies, rather than market forces, primarily drive the growth of wind power in the United States. Despite mandates and billions of taxpayer dollars in subsidies, wind power only supplied 4.4 percent of U.S. electricity generation in 2014.\(^1\) Wind power is not a worthwhile investment of tax dollars because it is not a reliable energy source, and the financial investments needed to make it reliable outweigh its limited environmental benefits.

The wind industry has become dependent on government mandates and subsidies for its success. Wind has become one of the most common methods used to reach state-based renewable energy mandates because federal subsidies make wind energy profitable for developers. When policymakers limit subsidies to the wind industry, constructing wind installations ceases to be economically viable. American taxpayers incur the costs of subsidizing the wind industry.

These extensive subsidies are funding a power source that is inconsistent and cannot reliably generate the electricity demanded by consumers. To compensate for the variability of wind, electrical grid managers must use traditionally reliable energy sources like fossil fuels and hydropower to supply energy when wind cannot.

To make wind power more reliable, utility providers will have to invest billions of dollars in infrastructure upgrades and high-capacity transmission lines. The ability to generate wind energy in the United States is outpacing the ability to transmit it, which means that costly infrastructure overhauls will become necessary as the wind industry grows.\(^2\) These costs will be passed on to energy consumers.

Large-scale energy storage may offer solutions to the variability of wind power, but the most promising technologies are not currently economical on a grid-wide scale.

Government officials have mandated and subsidized wind power specifically for its environmental benefits, but wind energy is not as eco-friendly as most people assume. Traditional energy sources like fossil fuels must supply backup power when wind does not blow, limiting wind power’s environmental benefits. Wind power may actually result in more greenhouse gas and pollutant emissions in some cases due to the inefficiency of repeatedly ramping up backup power plants. The manufacture of wind turbines also results in additional environmental degradation, and wind turbines increase mortality rates of birds and bats.

Wind power’s limited environmental benefits are outweighed by the massive costs to make it a reliable energy source. Governments are distorting energy markets and misallocating taxpayer dollars by mandating and subsidizing wind power. Whether wind power will become reliable or economical within the next few decades is an open question best addressed by markets, not subsidies or mandates.

INTRODUCTION

As Americans have grown more concerned with fossil fuel emissions, policymakers have responded to their constituencies by mandating and subsidizing renewable energy sources. Because of these environmentally-focused policies, wind power is growing as an electricity source. Although wind power only supplied 4.4 percent of U.S. electricity generation in 2014, the United States still has one of the largest and fastest growing wind power markets.

---


in the world. The U.S. Department of Energy reported that in 2013, installed wind energy capacity was 22 times greater than it was in 2000. In 2014, wind power comprised 43 percent of all new electricity generation. The influence of wind power on our nation’s energy portfolio will likely increase as energy producers comply with renewable-energy mandates and take advantage of subsidies.

To determine whether government mandates and subsidies for wind power are beneficial, the Institute of Political Economy (IPE) at Utah State University examined the reliability of wind as an energy source. This report examines wind power in terms of its economic, physical, and environmental reliability and concludes with an assessment of wind power’s overall reliability as an energy source. If wind power is unreliable, then government mandates and subsidies that support it are a misallocation of taxpayer dollars.

DEFINING RELIABILITY

The term “reliability” is ambiguous and goes beyond an energy source’s ability to generate power consistently. To gain a more comprehensive understanding of wind power, IPE considered wind power’s reliability in terms of its economic, physical, and environmental implications.

We first explore wind power’s economic reliability, which we define as the ability of an energy source to be self-sustaining and affordable without government mandates, subsidies, or incentives.

Second, we examine wind power’s physical reliability. For an energy source to be physically reliable, it must be able to consistently meet electricity demands by supplying and transmitting its power without interruption.

Finally, we examine wind power’s environmental reliability. To be environmentally reliable, an alternative energy source must have fewer environmental impacts than traditional fossil fuels.

ECONOMIC RELIABILITY

Federal and state policymakers use mandates and financial incentives to promote wind energy. The wind industry has become dependent on mandates and subsidies to be economically viable. Because the wind industry is not self-sustaining, it is not economically reliable.

TYPES OF WIND ENERGY MANDATES

In the United States, renewable portfolio standards (RPS) are the most common type of mandate for increasing renewable energy production. RPS stipulate that certain percentages of the energy consumed in a state must be supplied by renewable sources by a specific date. Twenty-nine states, the District of Columbia, and two U.S. territories have RPS. An additional nine states and two territories have renewable energy goals.

---

Of the 29 states that have RPS, only Illinois, New Jersey, and New Mexico have specific wind energy mandates. In Illinois, wind power must account for 18.75 percent of electricity sales from investor-owned utilities by 2025-26. Wind power must also account for 15 percent of electricity sales from alternative retail electric suppliers by the same year. Instead of mandating a certain percent of wind power, New Jersey’s RPS requires that 1,100 megawatts of electricity sales be provided by offshore wind. This mandate does not currently have a timeline for compliance. In New Mexico, wind is mandated to account for 30 percent of the state’s renewable energy requirements by 2020.

Even though most states with RPS do not have mandates for wind power in particular, government subsidies and tax credits make wind power artificially cheap, so wind power has become one of the most common ways for utility providers to fulfill RPS requirements. Therefore, the combined effect of government mandates and subsidies help the wind industry grow much faster than it otherwise would.

WIND ENERGY TAX CREDITS AND SUBSIDIES

Policymakers subsidize wind power generation primarily through the Production Tax Credit (PTC), Investment Tax Credit, and accelerated tax depreciation. The most influential of these has been the PTC.

Congress enacted the PTC in 1992 to financially incentivize energy developers to build renewable energy installations, especially for wind power. The PTC provides a credit at 2.3 cents per kilowatt-hour for a renewable energy facility’s first ten years of operation. The PTC has expired several times since its initial enactment, but after each expiration, Congress has reauthorized it.

As seen in Figure 1, wind energy projects depend heavily on the PTC. When the tax credit is allowed to expire, the installation of wind energy facilities drops drastically. For example, the 2013 expiration of the PTC was followed by a 92 percent drop in wind installations. Every reduction in wind energy installation was preceded by the expiration of the PTC, and installation rates rebounded when the PTC was renewed.

---

Without the PTC, private investors clearly do not perceive wind energy to be a profitable investment. Speaking of his own investments in wind energy, Warren Buffett noted, “[O]n wind energy, we get a tax credit if we build a lot of wind farms. That’s the only reason to build them. They don’t make sense without the tax credit.” While the PTC exists, private investors are able to profit at the taxpayers’ expense. For fiscal year 2013 alone, wind received $5.9 billion in subsidies, which comprised approximately 51 percent of total renewable energy subsidies.

The PTC gives wind energy suppliers a 2.3 cent per kilowatt hour pre-tax subsidy, which is equal to a post-tax rebate of 3.8 cents per kilowatt hour. The subsidy allows wind energy suppliers to engage in a government-sponsored price war against traditional forms of energy by underbidding the price of electricity to the point that wind producers can still make a profit while paying the electrical grid to take wind-generated electricity. Underbidding by wind energy producers threatens long-term reliability of the grid by causing traditional producers to run at inefficient levels. Consistent underbidding also has forced some traditional energy producers to close because they could not compete with a subsidized industry.

In 2013, the PTC expired, but a provision was added to the American Taxpayer Relief Act in January of that year. The provision stated that if a project began construction before the year 2014, it would continue to receive the tax credit.

---

17 Union of Concerned Scientists. (n.d.) Production Tax Credit for Renewable Energy. Retrieved from
The Tax Increase Prevention Act of 2014 extended the PTC further so that any project that began work before January 1, 2015, was eligible for the credit. The Act also allowed these facilities to claim the Investment Tax Credit in place of the PTC through the end of 2014.\textsuperscript{18}

The PTC once again faces expiration. President Obama’s proposed 2016 budget seeks for the permanent extension of the PTC.\textsuperscript{19} A permanent extension of the PTC implies that federal policymakers, especially President Obama, do not think that the wind industry can be economically self-sustaining. In other words, wind power will need long-term financial assistance to be viable.

**U.S. DEPARTMENT OF ENERGY FUNDING OF ADDITIONAL WIND PROJECTS**

Offshore wind could potentially produce an estimated 4 million megawatts of electricity in federal and state waters. The U.S. Department of Energy’s (DOE) Wind Program funds the expansion and improvement of offshore wind technologies, which serves as another government incentive for wind production. Specifically, the program seeks to mitigate the prohibitively high costs of offshore wind development, as well as to improve technologies that increase offshore wind capacity. In accordance with these goals, the DOE has allotted over $227 million to various offshore wind projects so far.\textsuperscript{20}

In 2014, the DOE also granted $1.3 million to four companies to improve and increase installments of small and medium-sized wind technology. This grant will apply to wind turbines with a capacity between 5 and 250 kilowatts. The purpose of this grant is to improve wind turbine efficiency and cost effectiveness.\textsuperscript{21}

**U.S. DEPARTMENT OF ENERGY’S “20% WIND SCENARIO”**

In addition to state-based renewable energy mandates, the federal government has set overarching national goals to increase wind power capacity. Responding to President George W. Bush’s call to diversify America’s energy portfolio, the DOE set a goal to meet 20 percent of U.S. energy needs with wind power by 2030. This goal is called the “20% Wind Scenario.”\textsuperscript{22}

In a report analyzing this goal, the DOE recognizes that to accomplish the 20 percent goal by 2030, wind capacity would need to expand from the 2006 wind capacity of 11.6 gigawatts to 300 gigawatts. In other words, in the 24 years between 2006 and 2030, wind energy capacity would have to increase almost 26 fold.\textsuperscript{23} As of March 2015, installed wind capacity in the United States reached 66 gigawatts.\textsuperscript{24} To reach this goal, another 234 gigawatts of wind power

---


capacity must be installed in the next 15 years, which will require the continuation and possible expansion of costly government subsidies.

**WIND POWER’S TRUE COSTS**

Levelized cost estimates are tools to compare the cost effectiveness of energy sources to one another. A levelized cost is “the total cost of building and operating a generating plant over its economic life.”\(^{25}\) Levelized costs, however, are misleading because they do not communicate a complete picture of the costs of energy sources. Wind power’s levelized cost seems comparable to other major energy sources, but wind is actually much more expensive than levelized costs lead people to believe.

In 2015, the U.S. Energy Information Association (EIA) estimated that by 2020, the average levelized cost of onshore wind would be $73.60 per megawatt-hour. The levelized cost estimate of conventional coal is $95.10 per megawatt-hour and the levelized cost estimate of natural gas is $75.20 per megawatt-hour. The EIA estimated that offshore wind would be one of the most expensive energy sources at $196.90 per megawatt-hour in 2020.\(^{26}\)

Levelized costs are inaccurate for a number of reasons. First, wind power depends on backup "cycling" reserves when wind installations cannot produce electricity. Because the inconsistency of wind causes wear and tear on cycling reserve power plants, the cost of operations and maintenance are passed from wind plants to the cycling reserves. This makes the levelized cost of wind power appear lower than it actually is.

Second, the EIA’s levelized cost estimates for wind power were based on a 30-year life cycle for wind turbines, which some critics find extremely optimistic. Willem Post, cofounder of the Coalition for Energy Solutions, is one critic. Calling the 30-year lifespan "grossly excessive," Post determined that wind electricity would actually cost anywhere from $151 to $192 per megawatt-hour, depending on what source of electricity was being used as the backup cycling source.\(^{27}\)

Dr. Gordon Hughes of Edinburgh University completed a study of the United Kingdom’s wind farms and found that “few wind farms will operate for more than 12–15 years.” Hughes stated that this dramatically reduces the benefit of such a capital-intensive energy source, and makes government policies supporting the wind market "unsatisfactory at best."\(^{28}\)

In summary, the true cost of wind power is much higher than levelized cost estimates purport, making wind power look like a better financial investment than it actually is.

**VERDICT ON ECONOMIC RELIABILITY**

The wind industry relies on numerous renewable energy mandates and heavy government subsidies for its survival. Therefore, wind power is not economically reliable. Federal and state governments are misallocating taxpayer money on an energy source that cannot sustain itself.

---

PHYSICAL RELIABILITY

Physical reliability refers to the ability of an energy source to consistently meet electricity demands. Because wind is intermittent, it is not reliable by this definition. When wind cannot produce a sufficient amount of electricity, more reliable forms of generation must provide a backup source of power.

WIND’S INTERMITTENCY

Wind is intermittent and uncontrollable, which makes the potential output of a single wind plant meager compared to a fossil fuel or nuclear power plant of similar capacity. Wind power’s low electricity output can be expressed in terms of its low capacity factor, which is a measurement that compares the amount of energy a plant actually produces to the energy that it would produce if operating at full capacity for the same amount of time. According to the Energy Information Administration, the capacity factors for various energy sources in 2014 were:

- Coal power 60.9%  
- Natural gas fired combined cycle power 47.8%  
- Nuclear power 91.7%  
- Solar photovoltaic 27.8%  
- Wind power 33.9%

Wind productivity varies depending on turbine location and size, influencing capacity factor estimates. Generally, estimates for wind’s capacity factor are between 30-35 percent.

A report by the Adam Smith Institute, however, illustrates that a single capacity factor for wind power is misleading because the energy output of wind plants vary widely. The Adam Smith Institute collected data on wind intermittency from 22 sites across the United Kingdom over 9 years. The study showed that wind turbines operated above 80 percent of full capacity for only 163 hours per year. In contrast, wind turbines operated below 20 percent of full capacity for 3,448 hours per year. In other words, these U.K. wind power plants produced over 80 percent of their potential energy output only 1.8 percent of a given year. For approximately 39 percent of a given year, these wind power plants produced below 20 percent of their potential energy output. These variations average out to wind power’s relatively low capacity factor.

Wind is also extremely variable in the short term. When looking at energy production within 30 to 90 minute intervals, there are frequently swings of 10 percent electricity output. Grid operators must monitor the supply and demand of

31 Ibid.
33 Ibid.
34 Ibid.
electricity and adjust electrical output accordingly to prevent power outages. More variability in electrical production due to wind power will mean that grid operators must monitor the supply and demand of electricity more closely. Not only do high levels of variability make it more difficult for grid operators to keep supply and demand in constant balance, they can also strain the infrastructure of the grid. Strategies are being developed to mitigate these problems, and they are discussed in "Role of New Technology" section.

Wind energy advocates argue that wind's intermittency can be mitigated by interconnecting multiple wind plants across a broad geographic region. The argument is that, even if the wind stops in one area of an interconnected system, it is likely that there is enough wind in another area to fill the energy gap. Scientists at Carnegie Mellon University completed a study of 20 wind plants in Texas, which found that interconnecting four wind plants resulted in a variability reduction of 87 percent. The study also showed, however, that there are limits to the consistency that can be achieved by interconnecting numerous wind plants. Interconnecting 16 more wind plants, for example, resulted in a further variability reduction of just 8 percent. The scientists who conducted this study concede that these results do not prove that wind power can provide baseload power.

The previously mentioned study by the Adam Smith Institute concluded that interconnecting multiple wind installations across Europe will do very little to decrease the intermittency of the system’s power output. Although analysts disagree on the effectiveness of interconnecting wind installations to overcome wind power’s variability, the costs of installing interconnection infrastructure will be costly, and those costs will be passed on to energy consumers.

INCREASED NEED FOR CYCLING

Because wind is variable, backup sources of energy must be available to provide electricity when wind power cannot. Traditional energy sources like fossil fuels are physically reliable because electricity producers can use those fuels as needed to accommodate changes in electricity demand. Until electricity can be stored on a large scale, intermittent energy sources like wind will rely on these backup sources of energy to meet electricity demand.

Building wind energy facilities does not necessarily require additional conventional sources of energy. The electrical grid already relies on conventional energy sources for backup power in case a particular generator goes offline. Backup power plants used in the electrical grid are called “operating reserves” and are subdivided into two types, cycling and non-cycling.

Cycling reserves are power plants that can quickly increase or decrease their electrical generation. These plants continue producing electricity throughout the day, but at a level lower than they are capable of. Whenever demand increases unexpectedly, grid operators increase the output of cycling reserves. Hydroelectric and natural gas plants are ideal cycling reserves because they can increase and decrease their generation more quickly than nuclear and coal power plants.

---

39 Ibid.
43 Ibid.
Non-cycling reserves are designed to compensate for expected changes in energy demand through the day. These are plants that are held idle until they are needed and can start production within 10-30 minutes to meet increased demand. As is the case for cycling reserves, hydroelectric and natural gas plants are typically the best options for non-cycling reserves.44

Because of the variability of wind, increasing the amount of wind power also increases the need for operating reserves. For example, a 2005 study by the National Renewable Energy Laboratory suggested that New York’s electrical grid would need a larger capacity of operating reserves to cope with expanded wind power installations. If wind supplied the state with just 10 percent of its 33,000-megawatt system, New York would need an additional 36 megawatts of cycling reserves. These 36 additional megawatts of capacity would supplement the 250 megawatts of potential operating reserves within the state.45

Increasing cycling to compensate for inconsistent wind will result in higher operation and maintenance costs for conventional power plants. Because most traditional power plants are designed to provide a steady baseload of energy, they are not equipped to ramp up and down quickly to compensate for wind’s variability. Fossil fuel power plants will most likely emit more pollution and require more maintenance due to the added stress from renewable energy sources like wind. Cycling plants also requires more fuel for every megawatt-hour generated than their non-cycling counterparts.46

SPACE NEEDED FOR WIND POWER

Wind energy requires massive tracts of land to generate significant amounts of electricity. If the United States were to meet total 2005 electricity demands with wind power, for example, it would require a wind farm roughly the size of Texas with consistent wind blowing at optimal speeds. Because wind is inconsistent, this estimate is highly inaccurate.47 Much more space would be needed.

Approving wind farm locations is difficult, often due to community opposition. Though wind energy garners popular support, many people do not want wind farms near their homes or spoiling their views. This mindset has been coined “NIMBY” — not in my backyard. People have this attitude for two reasons, economic and environmental. Economically, people do not support wind farms because they fear that the turbines will lower the value of their property. Environmentally, people may also oppose wind installations if the installations will harm something that they value more, such as wildlife or specific landscapes.48

One of the most prominent examples of NIMBY took place at Cape Cod, Massachusetts. Some of the most ardent opponents of a wind installation near Cape Cod were the Kennedys. Though the members of the Kennedy family support wind energy and other renewables, they were firmly against the Cape Cod installations for fear of negative effects on their property values.49

44 Ibid.
Offshore wind provides a possible solution to the NIMBY problem. Offshore wind has the advantage of being out of sight and in locations with higher amounts of wind than onshore. Because it is difficult to get approval to construct turbines in inhabited areas, offshore wind farms are strongly supported by many advocates of renewable energy. Offshore wind’s high cost, however, outweighs its possible benefits.

As shown previously, the EIA estimates that the costs of utilizing offshore wind are more than double the costs of utilizing onshore wind\(^5\). Offshore wind power, while perhaps less visually intrusive, is much more expensive to deploy, maintain, and transmit.

Figure 2 demonstrates the higher levelized cost of offshore wind in comparison to onshore wind and also the quantity of potential gigawatts that can be produced offshore versus onshore. Although offshore wind offers a greater capacity of available wind, the cost is prohibitively high without massive government subsidies.

FIGURE 2. SUPPLY CURVE FOR WIND ENERGY—ENERGY COSTS INCLUDE CONNECTION TO 10 PERCENT OF EXISTING TRANSMISSION GRID CAPACITY.\(^5\)

---


NECESSARY GRID OVERHAUL

WHAT IS THE GRID?

An electric grid includes everything needed to generate and transmit electricity. This network includes power plants, transformers, and transmission lines. Three distinct grids provide electricity to the continental United States.

To transmit the electricity a power plant produces, the electricity is first sent to a transmission substation, which contains transformers. The transformers increase the voltage of the power for long-distance transmission. After traveling through the long-distance transmission lines, the power goes through two more transformers, both of which decrease the voltage for household use. Figure 3 illustrates this process.

FIGURE 3. ELECTRIC GRID MODEL.

Energy supplied to the power grid must match energy demanded exactly. Electricity fed into the grid must be constantly and consistently supplied to users because energy cannot be effectively stored for later use. Thus, electricity must be generated, transmitted, and used immediately. If too much electricity is supplied, transmission lines can become congested. If too little electricity is supplied, blackouts will result.

A brownout occurs when the electric grid experiences excessively low voltage. Grid operators may intentionally lower the voltage to avoid a complete blackout, or brownouts may occur unintentionally when electricity demand is higher than the amount of electricity generated. Brownouts may result in the damage or failure of electronics when the voltages are outside the tolerance range for a specific piece of equipment.

---

Blackouts occur when grid operators intentionally shut off sections of the grid to keep the supply of electricity stable. If there is a lack of transmission capability or if electricity supply cannot meet demand, grid operators may use a blackout as a last resort.\textsuperscript{56}

GRID LIMITATIONS

The grid is not designed to handle power sources that are unpredictable and remotely located. Fossil fuels have a specific advantage when used with the grid. Electricity producers know the amount of available fuel and can ship it where it is needed before it is converted into electricity. Wind, on the other hand, is not shippable and its availability is difficult to gauge.

Figure 4 shows where the most accessible wind is in the United States. Offshore wind is more plentiful than onshore wind, yet it is also more complicated and expensive to generate and transmit. The highest concentration of onshore wind is located in the Great Plains, far from the nation’s population centers. The current grid design cannot transmit large amounts of wind energy generated in remote locations because it is designed to supply power at the local and regional level.

FIGURE 4. UNITED STATES—WIND RESOURCE MAP.\textsuperscript{57}

![United States - Wind Resource Map](http://www.nrel.gov/gis/pdfs/windsmodel4pub1-1-9base200904enh.pdf)

Until major upgrades to the grid are undertaken, investments in wind energy will not yield anywhere near their full potential. Entrepreneurs in the wind industry are already facing the hard reality of the transmission problem. Gabriel Alonso, chief development officer of Horizon Wind Energy, said, ”The windiest sites have not been built because there is no way to move that electricity from there to the load centers.” As Alonso explained, as of 2008, turbines in much of...


Wyoming could produce 50 percent more energy than the exact same turbines in more populated areas such as New York. But the transmission grid makes wind electricity generation in parts of Wyoming unfeasible.\(^{58}\)

**COSTS OF TRANSMISSION INVESTMENT**

Because government policies are causing the wind industry to grow, expanded long-distance transmission will be required to accommodate the larger capacity of wind-generated electricity. The National Renewable Energy Laboratory (NREL) estimated that the updated transmission infrastructure needed to reach the 20% Wind Scenario by 2030 will cost at least $60 billion.\(^{59}\) These infrastructure costs will be passed along to average electricity consumers.

In recent years, levels of investment in electricity transmission have reached record highs.\(^{60}\) Much of this growth is attributed to efforts to connect remote sources of wind and solar power to the grid.\(^{61}\) For example, Texas recently completed a $6.8 billion transmission project to connect isolated wind farms to urban areas. From 2005 to 2013, the Texas Public Utility Commission (PUC) contracted private companies to build 3,589 miles of new transmission infrastructure for wind power.\(^{62}\) To cover the cost of the transmission project, utility companies will charge customers higher rates. The PUC estimated that the transmission project would add $3 to $5 to each consumer’s monthly electricity bills for the next ten years. These rate estimates were made when the project was expected to cost $4.9 billion.\(^{63}\) Because the project’s actual cost was $6.8 billion, electricity bills will be even higher. In essence, Texas ratepayers are incurring extra transmission costs to draw power from a remote and inefficient energy source.

**TECHNICAL CHALLENGES**

Renewable energy mandates like RPS and federal subsidies promote the growth of wind power in remote areas. Because remotely-located energy sources require long-distance transmission, scientists are looking for ways to improve transmission capabilities. Currently, electricity is transmitted as alternating current (AC). Physicists at the American Physical Society suggest using direct current (DC) to transmit electricity distances over a few hundred miles is more efficient than AC because DC transmission loses less energy to frictional forces.

Because electricity is generated as AC and consumers use AC, power would have to be converted from AC to DC for transmission and then back to AC for consumers. The process of long-distance DC transmission and conversion between AC and DC could result in electrical losses of up to ten percent. To minimize these losses, the voltage can be increased and the current decreased. Such high voltages strain the capability of semiconductors to convert electricity between alternating and direct current, which drives up the cost of transmission infrastructure maintenance. Long-distance DC transmission will raise costs because it will require the construction of semiconductors that convert electricity between

---


AC and DC and new high voltage DC transmission infrastructure. While utilizing DC would make long-distance transmission more efficient and feasible, its costs are prohibitive.

VERDICT ON PHYSICAL RELIABILITY

Wind power is not physically reliable because it cannot consistently meet electricity demands, and electricity consumers will bear the costs to overcome wind power’s physical limitations. Electrical grid managers must cycle traditional energy sources to compensate for the variability of wind power output. Interconnecting wind power plants may reduce some of the variability of wind power, but the benefits of interconnection are disputed. The transmission infrastructure needed to integrate wind energy into the grid will be costly, and those costs will be passed onto electricity consumers.

ENVIRONMENTAL RELIABILITY

The primary reason that wind power is mandated and subsidized is for its supposed environmental benefits. Because wind turbines do not emit greenhouse gasses or pollution directly, many people see wind power as environmentally benign. While it is true that wind power does not directly cause emissions, it has less obvious environmental costs. These costs include emissions from cycling reserves, as well as harm to wildlife.

WIND TURBINE LIFE CYCLE ASSESSMENTS

A life cycle assessment (LCA) is a tool used to evaluate the overall environmental impacts of an energy source over its lifetime, starting with manufacturing and ending with disassembly and recycling. Scholars and organizations across the world have performed LCAs on wind turbines to determine net environmental effects of wind power. Many LCAs show that wind turbines have a net environmental benefit over their lifetime, but these results may be misleading. LCAs are not necessarily a comprehensive method of measuring the impacts of wind power for several reasons. First, each LCA employs a different methodology and comes to varying conclusions regarding the specific environmental impacts of wind power. Second, LCA models are based on idealized assumptions about the lifecycle of a wind turbine. Third, LCAs are not capable of considering all aspects of wind turbine lifecycles. Because LCAs are an imperfect method of measuring wind power’s overall environmental effects, this technique cannot perfectly determine the net environmental impacts of using wind power.

One of the reasons LCAs are inconclusive measures of wind power’s environmental impacts is because of the variation in LCA calculation methodologies. A study by Anders Arvesen and Edgar G. Hertwich of the Norwegian University of Science and Technology analyzed the methodology of 34 wind power LCAs conducted by international institutions. The only commonality found between all 34 LCA methodologies was the inclusion of the manufacturing stage of a turbine’s lifespan in their analyses. The emissions and energy impacts of manufacturing, however, vary based on the country where turbines are manufactured. Therefore, the single commonality between these 34 LCAs is not a true commonality

---

because the manufacturing process is more environmentally costly in some locations compared to others. Also, each LCA examines a specific type of turbine. Therefore, a single LCA can only be used to generalize the impacts of a specific type of turbine with a specific capacity.

Life cycle assessments may also be misleading because models are often based on idealized assumptions rather than real-world data. For instance, LCAs often assume a wind turbine’s lifespan is around 20 years, but real-world data show that wind turbine lifespans are closer to 12 to 15 years. If analysts performed wind turbine LCAs with a 12 to 15 year lifespan expectancy, estimates of emission reductions would likely be lower. Using real-world data in LCAs will provide a more accurate way for developers and policymakers to gauge wind power’s overall environmental impacts. Idealized models may mislead developers and policymakers into thinking that wind power is more environmentally beneficial than it actually is.

Many LCAs give estimates on how quickly wind power “pays back” the energy required in the manufacturing process of a wind turbine. In other words, many LCAs determine the time it takes a wind turbine to produce enough energy to offset the energy used to manufacture and install the turbines. Analysts from the Environmental Agency of Austria and Verbund, Austria’s largest electricity provider, estimated that a two-megawatt wind turbine’s energy payback time was about seven months. Another LCA from analysts at Risø National Laboratory for Sustainable Energy in Denmark estimated that a small onshore wind farm of ten 500-kilowatt turbines had an energy payback time of roughly three months, illustrating that the energy payback time varies widely for different turbines examined by different groups. It is also important to note that the Risø National Laboratory assumed the turbines were constantly operating at 40 percent efficiency. This efficiency is higher than the average capacity factor for wind turbines, which means that the real payback time would be longer.

Despite the potential rapid energy payback, incorporating wind power is not carbon free over the rest of a turbine’s lifetime. Wind power is naturally intermittent and requires the cycling of other local power plants to meet energy demand when the wind does not blow. The cycling of these power plants increases emissions and decreases the assumed environmental benefits of wind energy.

One of the biggest shortcomings of LCAs is that they do not consider all the environmental costs related to the lifecycle of wind turbines. An LCA for a wind turbine does not capture the full impacts of wind power because wind power is part of a complex system of multiple types of power plants and transmission lines. For example, an LCA of a single wind turbine does not incorporate the complete environmental impacts of cycling or the construction of new transmission lines needed to reliably integrate wind into the grid. Because of the complexity of the manufacturing, transportation, decommission, and recycling processes, it is impossible for an LCA to incorporate all the environmental impacts of an energy source, including wind power. This complexity reduces an LCA’s accuracy because no single analysis could account for all the environmental impacts resulting from the use of wind power. Therefore, environmental impacts are most likely larger than LCA analyses conclude.

Because of all these differences and omissions in the life cycle analysis process, LCAs are not capable of giving a complete or accurate understanding of wind power’s environmental effects. They can be used as a tool to better

---

understand the impacts of wind power, but they have serious shortcomings that developers and policymakers cannot overlook. Wind turbines may have net environmental benefit over the course of their lifetime, but these benefits are not as large as most people assume. The costs of overcoming wind power’s economic and physical unreliability still outweigh the limited and disputed environmental benefits of wind power.

ENVIRONMENTAL IMPACTS OF CYCLING

Because wind power is variable and intermittent, other sources of power must be cycled to provide electricity when the wind is not blowing. These cycling reserves compensate for wind power’s physical unreliability. Traditional energy sources, like natural gas and coal, are commonly-used cycling reserves. While wind power may decrease greenhouse gas emissions as a net result, the emissions benefits are lessened because of the need for cycling. The amount of cycling-caused emissions are unclear and disputed, and in some cases, cycling may even negate the emissions benefits of wind power.

Several studies in both the United States and Europe have assessed the environmental impacts of cycling needed to backup wind power. These studies conclude that the cycling of baseload power plants increases emissions per unit of power generated. Despite these increased emissions per unit of power, wind power displaces enough fossil fuel usage to result in an overall decrease in emissions. In other words, the added emissions from cycling fossil fuels are offset when compared to the avoided fossil fuel emissions from using wind energy. A 2013 study completed by the National Renewable Energy Laboratory, for example, concluded that the carbon emissions caused by cycling are “negligible” when compared to the carbon reductions of using renewable energy sources like wind and solar. These studies, however, are flawed because they rely on simplistic and overly optimistic assumptions, such as perfect forecasting for wind and electricity-demand, high estimates of reliance on clean-burning natural gas turbines for cycling, and optimal usage of transmission capacity.

The results of a study by Bentek Energy suggest that modeling techniques used by many studies on cycling do not account for all the emission impacts of using wind energy. Their study focused on the emissions impacts of incorporating wind power in parts of Colorado and Texas. Because natural gas turbines could not sufficiently provide backup for the wind power in these two locations, utilities began cycling coal power plants, which are ill-equipped to handle the demands of cycling. When forced to cycle, the emission-control equipment for coal power plants operates less effectively, resulting in increased emissions.

Specifically, Bentek found that backing up wind-generated power in Texas increased nitrogen dioxide and sulfur dioxide emissions. In Colorado, adding 700 megawatts of wind power capacity increased nitrogen dioxide emissions for all five power plants studied, and all but one had increased sulfur dioxide emissions. Of the power plants studied in both Texas and Colorado, some had increased carbon dioxide emissions while others had decreased. In either case, the change in carbon dioxide emissions was less than one percent. Such insignificant changes in carbon dioxide emissions negate

---

the main purpose of using wind energy. Bentek’s empirical analysis shows that cycling may have more detrimental effects than hypothetical models suggest.

Even if wind power does provide the emissions benefits that are claimed in studies based on statistical models, the carbon reductions are relatively small compared to the high cost of wind. A 2010 study by the German Institute for Economic Research estimated that doubling Germany’s wind supply would result in a reduction of 17 million tons of carbon dioxide. For perspective, 17 million tons of carbon dioxide equates to the yearly emissions from only 4.5 average American coal power plants. The financial costs of doubling Germany’s wind power capacity would far outweigh the benefits of such a small emissions reduction.

Wind power may result in a net decrease of greenhouse gas emissions in most locations, but some locations may suffer from higher amounts of emissions depending on the amount of wind penetration and the types of energy sources available in an area to back it up. Determining the actual effects of cycling is complex, but even if most wind power results in a net environmental benefit, it is dirtier than most people assume because of cycling. The limited environmental benefits of wind power do not outweigh the massive costs of subsidies, mandates, and infrastructure investments that are necessary to make wind power reliable.

**EFFECTS ON ANIMAL POPULATIONS**

One of the most overlooked environmental impacts of wind power is its effects on bird and bat populations. Wind turbine blades move at speeds of 138-182 miles per hour, which can injure or kill birds and bats.

In North America, wind turbines kill an estimated 214,000–368,000 birds annually. Some threatened species of birds are protected by laws such as the Endangered Species Act, the Bald and Golden Eagle Protection Act, and the Migratory Bird Treaty Act. Killing protected species of birds, even unintentionally, may result in felony or civil charges. These charges can result in thousands of dollars of fines and possible jail time. Wind energy producers have been prosecuted for killing eagles and other protected species. For example, PacifiCorp Energy now faces charges of $2.5 million in fines and community service for killing protected bird species on two of its wind farms in Wyoming.

Federal agencies may provide the wind industry with exemptions from laws regarding protected eagle species. The Executive Office of the President has issued 30-year “take permits” that exempt wind farms from violations of these acts. These permits are issued only if companies “commit to strict adaptive-management measures that include site-specific steps that reduce impacts to eagles.”

---

In 2012 alone, wind turbines killed an estimated 600,000 bats in the United States.\(^8^3\) The high speed of the blades also creates turbulence, which causes rapid pressure changes that can damage bats’ internal organs and even cause their lungs to explode.\(^8^4\) The impact of wind turbines on bat populations is significant because bats have low reproduction rates and may be potentially vulnerable to local extinctions in areas where there are high numbers of wind turbines.\(^8^5\) A decrease in bat populations may negatively affect farmers who rely on bats for as much as $53 billion in pest control every year.\(^8^6\) Certain bat populations may not be able to overcome the current rate of fatalities caused by wind turbines. Bat population sizes are poorly understood, so it is uncertain whether bat deaths caused by wind farms are a significant threat. Despite the lack of data, we can assume that as the wind industry grows, increased bat fatalities will result.\(^8^7\) Smaller bat populations could lead to an increase in insect populations and increased usage of insecticides.

The mortality rates of these animals have been significant enough to result in efforts to minimize the number of bird and bat deaths. One way to reduce the number of fatalities is to use radar so that wind power operators can detect birds and slow down or shut off turbines. To protect flocks of birds, wind power operators can use strike-detection technology, which slows turbines when it detects contact with a bird.\(^8^8\) Slowing down or shutting off turbines to reduce bird and bat fatalities further reduces the ability of wind power to reliably meet consumer demand.

**VERDICT ON ENVIRONMENTAL RELIABILITY**

Although wind turbines cause no direct emissions when they produce electricity, they do have other environmental costs. Because of the variable nature of wind, traditional energy sources must be cycled to provide backup power when wind does not produce enough electricity. Fossil fuels are a common way to generate backup electricity. Scientists disagree on the severity of cycling-caused emissions, but because wind power leads to emissions indirectly through cycling, wind power is dirtier than many people assume. Wind power also increases bird and bat fatalities.

**ROLE OF NEW TECHNOLOGY**

New technology may offer solutions to wind power’s physical unreliability. Emerging technology seeks to mitigate wind’s intermittency by storing large amounts of wind-generated electricity so that it can be used when it is needed. Other technology seeks to improve long-distance transmission capability and increase wind turbine efficiency. With mandates and subsidies driving wind power development at an increasingly fast pace, new technology may not be able to solve wind’s physical unreliability quickly enough. These technologies are not currently viable. Until industrial-size energy storage is available, wind power will continue to be physically unreliable.
ENERGY STORAGE

One of the most obvious ways to address wind’s intermittency is to develop ways to store energy on a large scale. Aside from hydroelectric facilities, energy storage is uncommon at the grid level. Large-capacity batteries are the most prominent form of emerging energy storage technology. To meet grid-level standards, a battery needs to be low cost, able to store large amounts of power, and have a long service life. California has recently adopted the nation’s first-ever mandate for energy storage so that grid operators can more easily accommodate intermittent power sources. In an effort to reach this goal, one of these utilities, called Southern California Edison, has invested $50 million to develop 8 megawatts of power storage with lithium-ion batteries. Southern California Edison warned that California’s new energy storage mandate "could cost up to $3 billion with uncertain net benefits for customers.”

In addition to batteries, compressed air energy storage (CAES) and flywheels attempt to address wind’s physical reliability issues. CAES technology uses power generated from wind or another energy source to compress air into underground caverns when excess power is being generated. When power is needed during a time of peak demand, high-pressure air is released to power a turbine. Because these geologic structures are rare, a company called SustainX is developing CAES technology that utilizes large pipes instead of underground caverns.

In the simplest terms, flywheels store kinetic energy in spinning disks that can be used to power turbines. Wind turbines power motors that spin heavy disks, and that momentum can then be used to spin a turbine to produce electricity when it is needed. Flywheels are most efficient when stored in a vacuum and oriented using powerful magnets rather than conventional axles so that they do not lose their energy to frictional forces.

This is not an exhaustive list of energy storage technology, but these are some of the more popular technologies being explored. Because these technologies are still in development, none are yet being widely utilized and their future is uncertain.

ELECTRICAL GRID IMPROVEMENTS

RELIABLE INFRASTRUCTURE

The variability of wind can significantly strain the grid’s infrastructure and increase the likelihood of power failures. In investigating this problem, GE Energy and the NREL concluded that grid operators can more easily manage wind

---

energy’s variability if turbine output is held back by five percent. When the output of renewables is deliberately held below its full potential, grid operators are given the option to ramp up renewable generation as it is needed, as well as ramp it down. Giving grid operators more ramping options gives them more control over electricity output, making it easier for them to maintain a steady and predictable output over the entire system. Wind turbines require additional mechanical control to operate below capacity. These controls increase the cost of wind turbines, making them an uncommon modification.

LONG-DISTANCE TRANSMISSION

Superconducting direct current lines could potentially solve the problem of electrical losses in long-distance transmission. These lines operate with virtually zero resistance, which eliminates electrical losses. Superconductive lines, however, require expensive refrigeration systems.

Installing superconducting technologies could increase the long-term efficiency and capacity of electrical transmission across the country, if it were economically viable. Despite the potential of superconducting transmission, this technology is not viable in the foreseeable future due to the prohibitively high infrastructure costs. Installing thousands of miles of superconducting power lines and the necessary refrigerants will require billions of dollars. Therefore, it is unlikely that a superconducting, long-distance transmission system in the United States will be viable in the near future.

CONCLUSION

Wind is not consistent and cannot be relied upon to generate the electricity demanded by U.S. consumers. To compensate for the variability of wind, we must use traditionally reliable energy sources like fossil fuels and hydropower to supply energy when wind cannot.

Not only is wind power incapable of providing electricity consistently, the wind industry has also become dependent on government mandates and subsidies for its success. When policymakers limit economic assistance to the wind industry, the construction of wind installations ceases to be economically viable. Policymakers at both the federal and state level have chosen to allocate billions of taxpayer dollars to an energy source that cannot sustain itself on the energy market, which makes wind power economically unreliable.

With government mandates and subsidies causing the wind industry to grow artificially fast, the ability to generate wind energy is outpacing the ability to transmit it. Increasing wind-generated electricity will require extensive upgrades to existing infrastructure and the construction of thousands of miles of new transmission lines. The infrastructure costs will be passed on to average energy consumers.

The widespread support for wind energy rests largely on the idea that wind will result in a cleaner environment. Wind energy, however, is not as clean as most people assume due to the fact that it requires backup forms of electricity generation to compensate for its variability. The backup forms of power are most often based in fossil fuels, which

means that wind energy still results in the emission of greenhouse gasses and other pollutants. Wind power may actually result in more greenhouse gas and pollutant emissions than conventional power generation due to the inefficiency of repeatedly ramping up backup power plants.

The wind industry benefits from being a government favorite without actually delivering on the promise of clean, renewable, and reliable energy. Wind power is not a worthwhile investment of tax dollars because it is not a reliable energy source, and the financial investments needed to make it reliable outweigh its limited environmental benefits. Wind power’s effectiveness as an energy source is a question best addressed by markets, not subsidies or mandates.