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Wind Energy in Oklahoma: A Costly Solution in Search of a Problem

Primary Author
Robert Michaels
Professor of Economics
California State University, Fullerton

Contributions from
Per Bylund
Assistant Professor of Entrepreneurship and
Records-Johnston Professor of Free Enterprise
Oklahoma State University

Paul C. Knappenberger
Assistant Director, Center For The Study Of Science
CATO Institute

Byron Schlomach
Scholar in Residence, Institute for the Study
of Free Enterprise, Oklahoma State University
Director, 1889 Institute

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Edited and Supervised by the
Institute for the Study of Free Enterprise
Oklahoma State University

Robert J. Michaels is an adjunct scholar at the Cato Institute and the Daniel P. Hann Distinguished Scholar in Law and Economics, California State University, Fullerton. His past positions include Staff Economist at the Institute for Defense Analyses and various consultancies.

Dr. Michaels writes extensively on deregulation and competition in the electricity and natural gas industries. He has advised state commissions, electric utilities, power marketers, natural gas producers, pipelines, public interest groups, and governments on regulatory and antitrust matters. He has participated in electricity restructurings in California and other states, served as expert witness in utility mergers, and testified before state regulatory agencies, the Federal Energy Regulatory Commission, and the U.S. House Commerce Committee. His biweekly column "Power Moves" appears in New Power Executive and Energy Risk Desk. His writings on competition, market power, deregulation, and a range of restructuring issues have appeared in industry, academic, and legal publications. He has chaired and spoken at numerous conferences on emerging competition and trends in power and transmission markets.

Michaels holds an A.B. from the University of Chicago and a Ph.D from the University of California, Los Angeles, both in economics.

This paper, in its entirety, can be found at
http://www.1889institute.org/corporate-welfare.html.

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Executive Summary

As Oklahoma's legislature debates ending the state's tax incentive for wind-generated power, arguments continue to be made that wind is good for the state's electricity consumers as well as for the state's economy. This paper examines the impact of wind on the state. It finds:

- Today, Oklahomans enjoy the benefits of an excess supply of electrical energy. There does not appear to be the need for construction of new generation facilities of any type in the near future.
- The construction of wind turbines in Oklahoma has been driven by the federal production tax credit, not any Oklahoma state policy.
- Oklahoma reached its *voluntary* renewable portfolio standard some time ago.
- Wind power does not provide environmental benefits to the state.
- Wind power does not provide significant financial resources to K-12 schools.
- The Oklahoma Zero-Emissions credit presents significant risk to the state's fiscal outlook.

The strongest arguments to support the claim that wind is a boon to the economy are that wind, as a form of energy, is free, and that wind power producers often offer their power at a zero or even negative price. But wind's true economic impact is so blurred by state and federal tax and energy policies that it is nearly impossible for a casual observer to put together an accurate picture of wind's impact. This paper is an attempt to sharpen the picture with the hope that policy decisions will be improved. The bottom line, however, is stated in Chapter 2, where the analysis strongly suggests that "the utility-scale wind industry will not survive in competitive power markets unless it is subsidized."

Wind Power is currently subsidized through state and federal tax policy. At the state level, new wind producers are effectively paid $5 for every megawatt-hour they produce for ten years. This is in addition to the $23 per megawatt-hour the federal government pays these producers for ten years (though the federal subsidy is being phased down). At the wholesale level, the federal subsidy alone is sufficient, under some circumstances, to allow wind producers to pay, rather than receive payment, to load their generated power onto the electrical grid. Properly understood, this economically unsustainable practice alone makes it clear that low prices for wind-generated power, made possible by government interference, obfuscate the real cost wider society is actually paying for that power.

Economists have long shown in a variety of ways, theoretical and empirical, that a free-enterprise system, where government plays only referee and regulator of last resort, yields the greatest possible benefits from mankind's natural urge to exchange with one another. Active government interference through misguided and excessive regulation, direct subsidies, unequal tax treatments, and generous legal rules only for the privileged, make society poorer than it could otherwise be. Per Bylund, an OSU entrepreneurship professor, reinforces this point in a separate essay provided in the paper. In fact, Bylund argues that government attempts to stimulate innovation often actually reduce innovation.

The primary author of this work, economist and energy expert Robert Michaels, shows that wind power is much more costly than often thought. Michaels' argument can be summed up as follows. Once a basic, but thorough, understanding is gained of how modern electrical grids work and how important it is that energy sources be highly reliable, it becomes clear that wind-generated power has little, if any, cost advantage over other power sources, despite appearances to the contrary. What's more, the main advantage wind has, which is to reduce carbon emissions, is not clear at all, given wind's intermittent nature and the need for fossil-fuel backup power plants. This last point is reinforced by an essay included in the paper from climate expert, Paul Knappenberger.

Chapter 1 provides an overview of electric power in the United States and Oklahoma. It describes how the mix of electrical power sources has changed over

time, as well as the regulatory and legal frameworks within which power generators operate. It also points out that there are laws of nature that must be taken into account in order to maintain a stable electrical grid that reliably provides power. Part of what makes this possible for Oklahoma is the Southwest Power Pool (SPP), a large, multi-state electrical network of which Oklahoma is only a part, which is described. Finally, a basic explanation is provided of how power flows within the SPP, and how it is that this somewhat artificial but remarkable market, with its many mandates and regulators, insulates us from some of wind power's worst potential effects.

In Chapter 2, Dr. Michaels explores whether wind power is actually economically valuable, given its intermittency (i.e., that the wind does not blow steadily 100 percent of the time), using methodology developed by a Brookings Institution economist. The fact is that a wind plant rated to produce a given maximum amount of electricity can only be counted on to produce a fraction of that amount over time. Even that fraction, however, cannot be reliably expected to be delivered as needed. This is because wind, even that as seemingly reliable as Oklahoma's, is not reliable enough as a source of power to produce the constant voltage needed on a modern electrical grid. Wind cannot reliably be instantly called up to cover unexpected loads, grid interruptions, or unexpected power interruptions from other generators.

Yet, because of the far-flung nature of the SPP and the ability of that market to accept nearly any power source that bids low enough and is willing to pay to be admitted onto the grid, wind has been integrated into the system. Nevertheless, this has happened at a cost as the SPP has had to create a special side market to keep subsidized wind's artificially low prices from destabilizing the grid. What's more, Dr. Michaels shows that when wind replaces older fossil-fuel generation, it often does not produce the value (in reduced fuel and capital costs) or even the reduction in CO_2 emissions that more modern fossil fuel technologies often accomplish since wind does not always blow and reserve generation must therefore be maintained.

In Chapter 3, the fact that wind might have helped to lower electricity prices in Oklahoma is acknowledged, but only on a short-sighted, short-term basis. It is also argued that there is a hidden cost to these lower rates. As already noted in Chapter 2, much of this cost is in reserve generation, not to mention the impact on Oklahoma's tax revenue picture. There has also been a large investment in new grid extensions and upgrades of the current SPP grid, partly to accommodate wind. Wind's low prices are, in no small part, made artificially possible by mainly federal, and to a much smaller degree, state tax subsidies. Ultimately, given that SPP gives wind generation only 5 percent credit as part of its reserves that can be called up when needed, it would take 10,000 megawatts of wind generation to replace only 500 megawatts of, say, coal units. Wind can only be absorbed as a generator up to a very limited point.

Chapter 4 argues that given the costs of its absorption and the federal subsidies wind has received, it is arguable that the future of wind is higher costs, not lower, for consumers. At best, wind power has made a very limited contribution to property tax revenues and is not likely to make a large contribution in the future. Instead, wind presents a significant risk to Oklahoma's future state revenue outlook due to the subsidies.

Chapter 1
Introduction to Generation Policy

I. Overview

Electricity is undergoing transitions that promise to leave posterity with an industry that today's citizens would scarcely recognize. On one side, technological change and politics are altering the mix of resources that produce the nation's power. The technologies include hydraulic fracturing that virtually assures centuries of inexpensive, secure, and clean natural gas, alongside inventions that improve the efficiency of "renewable" power generated from wind and the sun. At the same time, concerns about climate change have disfavored the coal that once produced over 50 percent of the nation's power.

The industrial organization of electricity was once the near-exclusive domain of regulated monopoly utilities that owned and operated the preponderance of generation and transmission. Now, utilities are de-integrating into entities that increasingly obtain their power through contracts and market transactions with independent generators. They have ceded control over their high-voltage transmission to regional transmission operators (RTOs) that are responsible for reliable and economical power flows over large geographical areas. RTOs that comprise two-thirds of the nation's power consumption now administer competitive power markets whose prices give generators and consumers minute-by-minute signals that can better guide their choices of near-term exchanges and investments in future generation and transmission.

All of these forces operate in a federalized political system. This means that the energy futures of Oklahoma households and businesses will result from both national and state forces. Oklahoma's power suppliers are no longer exclusively local utilities. Instead, its utilities obtain power for their customers on an hourly basis from generators as distant as the Dakotas. Oklahomans pay electricity prices that reflect forces of supply and demand beyond the local level in addition to local developments. Oklahoma's region, covered by the Southwest Power Pool, is a unified market into which a generator can only sell if it bids prices that are lower than those of its competitors, who today number in the hundreds.

An Oklahoman still pays a light bill to a familiar utility corporation or municipality, still regulated by the Oklahoma Corporation Commission to guard local reliability and to decide on power sources with which it will build or contract. In little more than a decade those sources have been transformed. Giant wind turbines, whose existence is significantly owed to the federal Production Tax Credit, worth one-third of the retail price of electricity in Oklahoma, cover Oklahoma's western area. With federal policy's assistance, wind turbines exploit Oklahoma's abundant wind at a pace that sees it ranking third among the states in wind power generation. Oklahoma, however, is beginning to face engineering limits on its ability to absorb that power, and political limits on feasible transfers of wealth from its households and businesses to power producers.

The values of wind-related assets and the future importance of renewable power both matter for Oklahoma, but the intrinsic complexity of the power industry and its governmental relationships are understandably confusing to non-specialists. This document attempts to provide an overview of important facts and decisions that must be made in the near future. Reliable electricity is not currently threatened, but Oklahomans have been left largely in the dark about important choices being made for them.

This chapter begins with an overview of power technology and markets, then explains the regulations and laws that administer the state's electrical system. Chapter 2 explains the economics of choices among alternative sources of power and factors to be considered. Instead of being costless because air is "free," wind is among the costliest of generation methods. To understand how power bills come to be, Chapter 3 examines the markets

operated by the Southwest Power Pool (SPP) and how they distribute the benefits of competition over Oklahoma and states interconnected with it. Chapter 4 attempts to summarize issues surrounding the costs and benefits of Oklahoma's electricity policy, an intrinsically frustrating task because markets and regulation render dollars-and-cents comparisons nearly impossible to make. The chapter concludes with an economic critique of wind power and sums up the issue in a state context.

II. Introducing Electricity

A. Generation

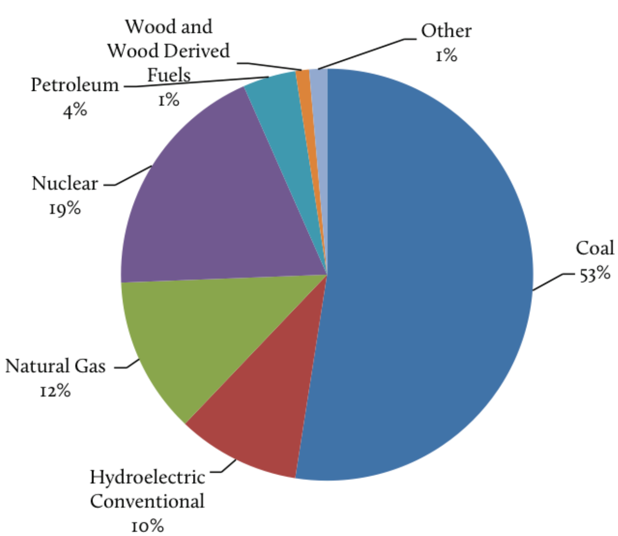
Electricity starts with a generator, most likely one that uses a heat source such as coal, gas, sunlight, or radioactivity to boil water. Steam turns a turbine, converting heat energy into rotary motion, which, through windings and coils, induces an alternating current into the grid by way of transmission (high voltage) and distribution (low voltage) lines. The generators of greatest interest for this study are exceptional in that they do not burn fuel. Rather, they harness strong winds to move large rotors to ultimately send out power.

The production resources of America's electric utilities vary regionally, but are almost uniformly dominated by hydrocarbon fuels. Figure 1-1 shows the 1990 percentage shares of generation by coal (53%), natural gas (12%), nuclear (19%), hydroelectricity (10%), and a small aggregate of miscellaneous fuels, which includes some renewables whose presence as a group was too small to be graphed. By 2015, the mix had changed substantially. Figure 1-2 shows a 20 percentage point drop in coal (to 33%) a rise in gas (33%), little change in nuclear and hydroelectric shares, and a still-small role for renewable power.

Oklahoma's story has both similarities and differences with the national one. Between 1990 (Figure 1-3; next page) and 2015 (Figure 1-4; next page) it had no in-state nuclear generation, and hydropower was only a tiny presence. Oklahoma also mirrored the 20 percentage point national decline in coal's share of power generation. Gas-fired power also rose, but by relatively less than the national rate. The most striking difference is Oklahoma's increasing use of wind power, which rose from nearly zero in 1990 to 18 percent of the state total in 2015 and continues to grow. This change alone is bringing important political and economic issues to the fore.

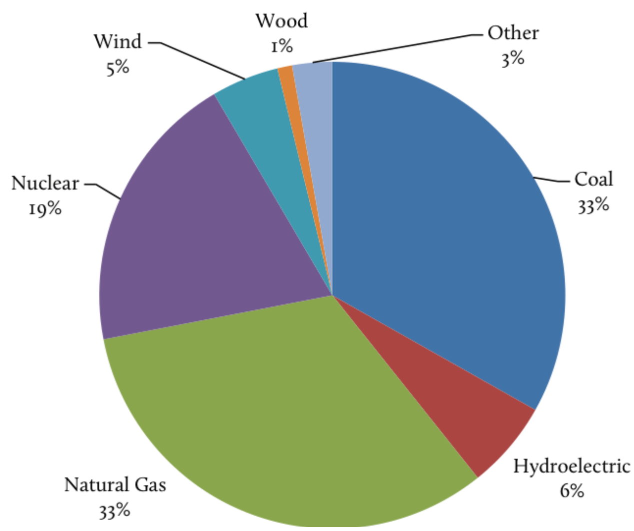
It is easy to explain the changes. In the 1970s, gas was commonly seen as on the brink of exhaustion, a belief that proved monumentally mistaken. Federal

Figure 1-1
U.S. Total Power Generation by Source, 1990



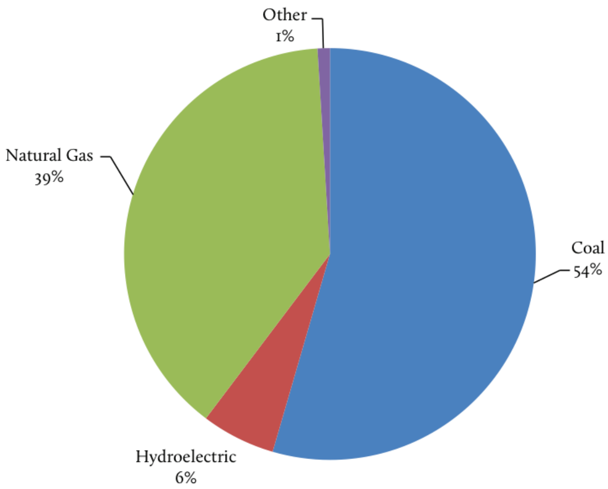
Source: U.S. Energy Information Administration

Figure 1-2
U.S. Total Power Generation by Source, 2015



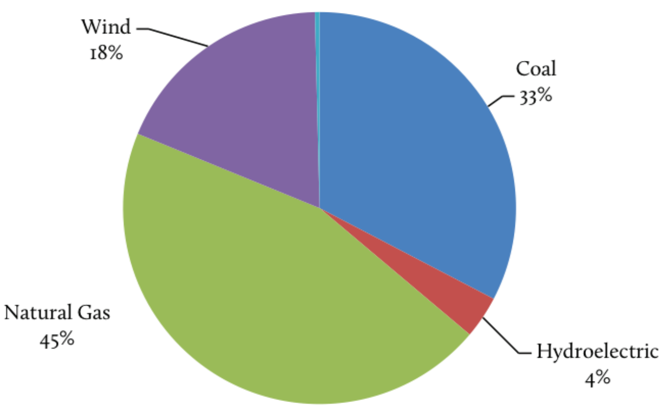
Source: U.S. Energy Information Administration

Figure 1-3
Oklahoma Power Generation by Fuel, 1990



Source: U.S. Energy Information Administration

Figure 1-4
Oklahoma Power Generation by Fuel, 2015



Source: U.S. Energy Information Administration

wellhead price controls from the 1950s created a shortage that ended in the mid-1980s with price decontrol and restructuring of pipelines. Since decontrol, new discoveries in the U.S. and Canada have steadily increased reserves. After 2010 the resource base grew even more with the development of hydraulic fracturing ("fracking") and related extraction techniques.

Coal's abundance and deliverability made it the dominant generator fuel for much of the previous century. It did, however, have one major problem: unlike gas, its combustion released harmful emissions, most importantly oxides of nitrogen and sulfur, mercury and particulate matter. Controlling them was feasible, but as environmental regulations increased, the costs rose. Newly abundant gas was an alternative whose capital costs of generating a megawatt (power plant construction) were well below coal's, and whose emissions (primarily oxides of nitrogen) was cheap to abate.

As for the other fuels, hydroelectric production was maintained between 1990 and 2015, but a scarcity of environmentally acceptable dam and lake sites foreclosed future growth. Spectacular construction cost overruns in the 1980s and public fears of disaster doomed nuclear power. Over the period, however, many aging reactors continued to produce so efficiently that its percentage share of total generation remained nearly constant.

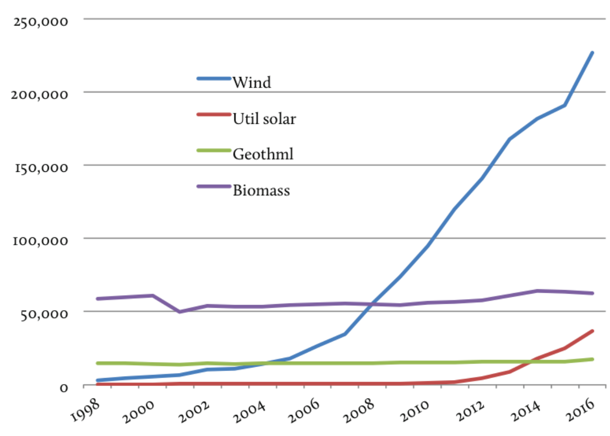
B. Renewables

Turning to the new century, policy makers increasingly accepted scientific claims that the accumulation of carbon dioxide and other "greenhouse gases" (primarily methane) could bring about catastrophic increases in the planet's average temperature. After people and animals, fossil fuel power plants have been the most important carbon emitters worldwide. Concerns about future environmental policy discouraged coal-fired plants, whose carbon emissions per megawatt-hour (MWh) of power generated significantly exceeded those of gas.[1] Starting in the 1980s, the operating efficiencies of gas generators grew while those of coal plants stagnated. The stage was set for gas to rise and coal to fall. If carbon was the problem, there was wealth to be made by finding politically acceptable (i.e., non-nuclear) power sources that did not emit it. Renewables had been in operation long before carbon became a policy concern, but they could only grow in political and economic importance.

Figure 1-5 (next page) shows annual power generation from resources legally defined as renewable since 1990,[2] although there is little value in claims that coal and oil are "finite" or "exhaustible." They are continually renewed by

discovery and innovation, activities that will continue as long as they have economic value. Hydroelectric power renews itself after rain or snow falls, stored as water behind dams and dispatched as needed. Farm and forest waste ("biomass") return after each harvest to be burned in generators that a grid dispatcher can control as needed, and the same holds for heat from geothermal wells. Sunlight and wind will never be exhausted, but arrive so randomly that they cannot by themselves produce the steady power flows that most consumers want. Storage technologies that can be applied to sunlight and wind power, such as compressed air, flywheels and batteries, remain too costly for all but a handful of applications. This said, wind now dominates production capacity for renewables, although solar power's slower development has recently risen sharply.

Figure 1-5
Oklahoma Power Generation by Fuel, 2015



Sources: U.S. Energy Information Administration, *Electric Power Annual*, 2009, and *Electric Power Monthly*, various issues.

III. Regulation and Law

A. Regulation

State. Any study of Oklahoma energy policy must be informed by a discussion of the opportunities and constraints that governments place on power markets. Although there are 51 state regulatory agencies (Including the District of Columbia), all have similar basic procedures and the same relationships with federal regulators. All power producers and consumers are also within the

Mitigating Climate Change Is No Reason to Justify Wind Power in Oklahoma

Paul C. "Chip" Knappenberger

A major thing to keep in mind when contemplating wind power in Oklahoma is that its necessity does not stem from climate concerns although likely its existence does. If it weren't for those climate concerns, wind power would almost certainly not enjoy the levels of assistance (federal/state subsidies, or other forms of production requirements) that enables it to exist in today's energy market.

But, the potential contribution of wind energy towards relieving these climate concerns is so minimal as to be inconsequential. In other words, the basic argument for wind power's existence does not hold up in the first place.

Let's look at the case of Oklahoma. In 2014, according to data from the Energy Information Administration, Oklahoma energy-related emissions of carbon dioxide (a key driver of human-caused climate change and the focus of most government attention) were 105 million metric tons. This amounted to about 2 percent of the US total and 0.32 percent of the global total. From a climate change standpoint, Oklahoma's carbon dioxide emissions each year add about 0.00007˚F to the global temperature change from year to year. By the end this century, assuming constant emissions, this sums up to 0.006˚F—an temperature change that is physically meaningless and undetectable and, not to mention, swamped by natural temperature variability.

And this is the maximum amount of climate change than could be mitigated if Oklahoma now and forever replaced all its fossil fuel power production with wind (or other non-CO2-emitting sources). This scenario is not even under consideration, which means that the actual contribution to the supposed mitigation of global warming of Oklahoma wind power generation is even less than this already infinitesimally small number.

Even if the entire US were to immediately and permanently close down all of its carbon dioxide-emitting energy production, the amount of global warming that would be avoided by the year 2100 adds up to just about two-tenths of a degree Fahrenheit—again, a value of little, if any, environmental meaning, but one which would require a complete transformation of our energy system (and potentially our economy).

I should point out that in the above climate change calculations, I am being somewhat generous. A collection of recent scientific research strongly suggests that the earth's average temperature is less sensitive to changes in carbon dioxide concentrations than the mainstream "best guess," perhaps by as much as one-third to one-half. And despite the headline-grabbing run of record global average temperatures in recent years, the observations over the past several decades confirm that the rate of global temperature rise is considerably less than that projected by the world's leading climate models. If these findings continue to hold up, it would mean that the tiny climate change mitigation potential described above would have to be even further reduced.

The bottom line here is that the link between Oklahoma wind energy and climate change is little more than a symbolic one—and one that is not deserving of the special favors that it has engendered.

If you want to judge the value of wind energy, you should properly do so without consideration of its role in mitigating climate change—locally, regionally, or globally. That said, however, climate change and climate change policy are two different beasts, with the latter not always following the best science of the former. It's the changes in the policies, much more so than the climate, that bear watching when fully evaluating the economics of wind energy.

jurisdiction of numerous federal and state statutes (e.g. environmental and health). Individual states introduced regulation over the first four decades of the twentieth century.[3] Appointed regulatory commissions (elected ones in a minority of states) took over some local functions and replaced the near-anarchy of local land use and franchise laws. Today, a commission has jurisdiction over rates and service practices of its state's distributors, who are generally granted monopolies on electricity sales in defined areas.

Important aspects of the electricity industry, including high-voltage transmission and low-voltage distribution lines, are acknowledged to be "natural monopolies," meaning that a single high-capacity transmission line can move power between two points more cheaply than two competing ones. If so, the regulatory agency must set rates and service practices that allow the lower costs to be enjoyed by consumers. It does so by setting rates that recover the regulated firm's prudently incurred costs of service while allowing it to earn returns sufficient to attract capital. The firm thus regulated has a "public utility" obligation. Beyond rate regulation, it cannot price discriminate among otherwise similar customers, cannot refuse to serve a customer willing to pay the rate, and must provide for the future by building facilities in anticipation of demand. The utility can be retrospectively penalized for poor performance, but few utilities have ever incurred significant penalties for investments that were subsequently deemed imprudent.

Federal. State regulation was well-adapted to the simple electrical technologies that characterized the first half of the twentieth century. Generators were relatively small and engineering limits on transmission effectively required that most utilities be self-sufficient in generation. Within their service territories, utilities monopolized virtually all aspects of power production and distribution. During the twentieth century, the onset of long-distance transmission, large efficient generators, and advances in controlling frequency (60 cycles per second) brought issues that crossed state lines and impinged on functions of the federal government. In the 1930s, these functions came under the jurisdiction of the Federal Power Commission, now the Federal Energy Regulatory Commission (FERC).

All utility sales of electricity to final ("retail") consumers are subject to state regulation, while FERC regulates access and rates for interstate transmission, hydroelectricity, and the regional transmission operators discussed below. Its jurisdiction is misleadingly called "wholesale" transactions, which are defined not by volume but by law: power sales intended for resale by the purchaser are under FERC, even if they are between a generator and a utility in the same state. Unlike many state regulators, FERC has taken an active interest in fostering competitive power markets under both Republican and Democrat administrations.

B. The Legal Environment of Wind Power

The 1970s saw the advent of "energy crises" – shortages that in the main had resulted from price controls on energy. Perhaps misunderstanding supply and demand, politicians who hoped to fend off resource exhaustion and encourage new power sources enacted the Public Utility Regulatory Policy Act of 1978 ("PURPA"). This seemingly minor law would determine important aspects of electricity's future. PURPA impinged on state regulation by requiring utilities to purchase power generated by non-utilities with whom they could have previously refused to deal. The purchase price was set by state regulators as the "avoided cost" of power from generation, including renewables, they would otherwise have had to buy or build.[4] Government's expectation that renewable power would be of little commercial importance turned out to be wrong, as the law soon established a new industry of non-utility generators whose output utilities could not refuse if priced right. In those early days, producers of wind and solar power found PURPA's purchase requirements to be valuable financial support.

PURPA compelled utilities to purchase non-utility ("independent") power but let states determine the avoided cost. A few states, most importantly California and New York, based their payments on astronomical expectations of higher future gas prices that stimulated a crush of

renewable producers. PURPA, however, did more than change the types of power and identities of the generators utilities would deal with. It also encouraged environmentalists to join the regulatory process, sometimes as matters of state law, and their coming would change the basic criteria for power procurement.

Utilities' practice had long been to choose investments in regulated generation and transmission that would minimize the cost of power to their customers. Environmentalists argued that this view was seriously incomplete, because low-cost measures to reduce power demand might leave consumers with even lower costs than investments in generation. As of 2011, 27 states (including Oklahoma) used variants of "Integrated Resource Planning" (IRP) that intended to examine all alternatives and take account of hitherto neglected costs such as environmental pollution and visibility.[5] Factoring in asserted dollar values for such environmental amenities could change a decision from construction to conservation.

States can set rules that encourage investment in renewable power, and they can also specify quotas for renewable power. As of today, 29 states and the District of Columbia have enacted renewable portfolio standards (RPS) that impose compliance timetables for renewable power as a proportion of the state's power mix. A utility can often satisfy its state requirement by purchasing renewable power from a distant generator or by providing regulators with evidence that it has obtained the required number of state-issued Renewable Energy Credits. It is generally acknowledged that RPS has been an important influence on the growth of investment in renewables.[6] Oklahoma does not have an RPS, but has enacted non-binding goals for future renewables. Its 15 percent renewable energy goal came with legislation in 2010. By 2013 it had already met its 2015 goal.[7]

IV. Electricity's Uniqueness

A. The Economic Properties of Power Flows

Thus far, we see a large and complex industry, but there are idiosyncrasies that might make it truly exceptional. On the demand side, interruptions in service can be very costly, or at minimum consumers who lose service typically find it annoying. Small users have no ready ways to fill unpredictable service gaps. Some larger users can avail themselves of backstop arrangements or postpone production until an outage is corrected, but this too is inconvenient and costly. Power cannot be stored except at high costs, in facilities that include batteries and hydroelectric dams, and consumption must coincide with production because it moves at the speed of light.

Physics imposes other limits. An alternating current grid requires that production equal consumption with zero discrepancy at all times. If production exceeds demand the grid will soon encounter thermal limits and fall victim to a regional outage. If demand exceeds production the grid becomes unstable and will also collapse. Adding to the difficulty, a power system is not like a network of water or gas pipes with valves that can limit flows along a particular segment. Power flow is governed by Ohm's and Kerchoff's laws, which determine power losses in a network's links according to its relative resistances.

These technical points have important consequences for wind and solar power. Integrating their random outputs into the grid while maintaining reliability can increase the total cost of power delivered to users as compared to a system that has no such intermittent resources. Many wind power producers claim these costs are irrelevant because all power requires reserves, and in any case, wind adds power to the grid with none of the production costs incurred by fossil fuel generators. We consider these issues in more detail later.

With or without wind resources, access to a grid cannot be a free-for-all. Instead, there must be someone (at times, a computer) whose commands are law in order to match supply to demand at all times. Hazards of generation and transmission failures require the existence of reserve generators whose output can adjust instantly. Reserves are also necessary to meet predictable daily consumption. Demand in most systems peaks in the late afternoon, after which generation must be reduced for the night. Complications abound. Some low-cost

generators with long startup times can be valuable tomorrow afternoon, but leave the system operator to manage fluctuating "minimum load" conditions in the predawn hours using higher-cost, fast-start generators. For Oklahoma, all of these functions are the responsibility of the regional transmission operator, to whom we turn next.

B. The Regional Operator and Its Markets

Advances in electrical and computer technology over the last half-century have dramatically changed how power is produced and reliably maintained. Instead of localized islands, all transmission in the U.S. is integrated into three grids – the Eastern Interconnection, the Western Interconnection, and the Electricity Reliability Council of Texas, of which the latter does not cross state lines.

Interconnections and coordinated operation make it possible to lower the costs of delivered power in many ways. A market participant (possibly a utility or independent power producer) whose generators burn a cheaper fuel than another can exchange energy with a higher cost participant. The purchaser will pay less for the power than otherwise and the seller will recover more than the incremental cost (marginal cost) of generating it. When fuel prices change, trade can flow in the other direction. Trade also allows us to take advantage of seasonality. Utilities in the desert southwest import power in summer from hydroelectric facilities in cooler Oregon, and when Oregon's electrical heating demand rises during the winter, the southwest can profit. Under regulation, utilities must channel some of the savings into customers' bills.

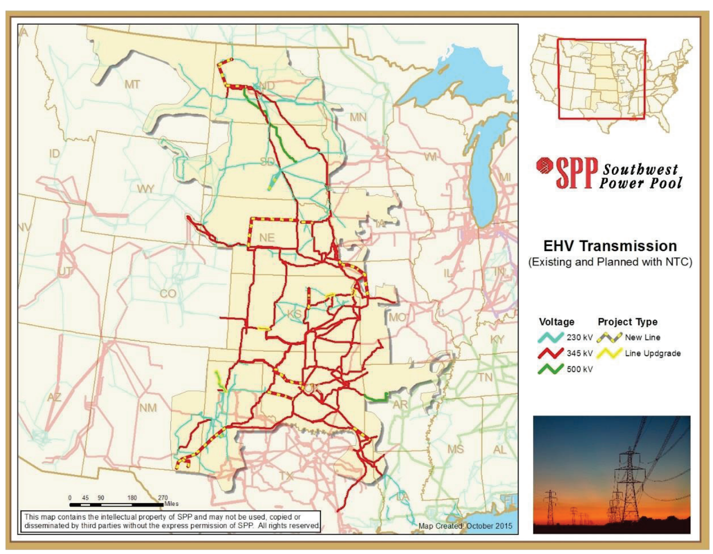
There are numerous other activities that benefit both parties. Two interconnected utilities can (if they have transmission capacity) reduce expenses by sharing reserves to call upon in emergencies. They can plan new transmission and jointly construct new transmission that increases and broadens the exchanges they can make with each other. An economical large generator may be too costly for a single utility to own, but be worth building under a sharing contract.

Oklahoma's two largest utilities, Oklahoma Gas & Electric and Public Service Company of Oklahoma (which is part of the American Electric Power holding company) now obtain virtually all of their high-voltage ("bulk") power through the Southwest Power Pool, a nonprofit entity headquartered in Little Rock and regulated by FERC. The SPP is a Regional Transmission Operator (RTO), one of several whose grids cover most of the nation's territory (and Canada's), with the conspicuous exceptions of the mountain west and southeast.[8]

Utilities in an RTO continue to own transmission but surrender operating control of it to the RTO, which is chartered to minimize the costs of power in its territory through nondiscriminatory measures. The transmission owners are paid in accordance with established federal and state rules that allow recovery of their costs and a return sufficient to attract capital. RTOs have certain requirements (e.g. that a member utility own or have generation capacity under contract sufficient to serve its peak load). SPP's membership and market participants include 172 utilities, independent power producers, independent transmission companies, power marketers, and state agencies and municipal utilities.[9]

Over 75 years, the SPP evolved as opportunities arose in power technology and the law to facilitate exchanges and deliveries under contracts. Its

Figure 1-6
The Southwest Power Pool Footprint



Source: Rew, Bruce, SPP Integrated Marketplace Benefits, power point document, Southwest Power Pool, 2016, 6, http://www.occeweb.com/pu/SPP_ElectricTransmission/OCCUpdateJuly28_SPP.PDF.

territorial footprint (see Figure 1-6) is dense with high voltage lines, but until recently the available technology often limited transactions to subsets of the footprint. The limits were partly due to line (voltage or power) losses that made long-distance transmission impractical, and in part due to operational problems caused by extensive and uncontrollable flows. Instead of a unified entity with authority over a wide area, until 2014 the SPP consisted of 16 "balancing authorities," each under the control of a transmission-owning utility. All that changed in October 2014 when the SPP introduced its "Integrated Market." The Integrated Market is a single organization to operate the entire area and maintain reliability as necessary. In effect, the introduction of the Integrated Market opened a complete market to facilitate mutually beneficial transactions between generators and distributors that had previously not been possible.

The SPP has also taken over authority for expansion of transmission capabilities over the entire area, and has introduced competition into the process. The SPP plans new lines by consensus, but the builder is determined by bidding rather than (as in former times) defaulted to the incumbent utility in its area. The value of unification has been clear and widespread. During 2014 the net savings in power costs for SPP members as a group was $380 million, and 2015 savings were expected to be $422 million. Total settlements (payments for power flows) in 2015 were $14.6 billion.[10]

To understand wind power in Oklahoma requires an introduction to some of the SPP's markets, through which the preponderance of power in it passes (financially rather than physically) and is priced by bidding. Like other RTOs, SPP operates under a "two-settlement" system that facilitates reliability and price discovery. In the 24-odd hours before a given date, there is a "day-ahead" market in which generators submit bids to sell energy. Combining bid information with system forecasts (including weather and other particulars) allows the RTO to determine day-ahead prices. As in any competitive market, all winning bidders are paid the highest-price-accepted offer.

The SPP also takes steps to ensure the system's electrical security and reliability. It may order some otherwise uneconomic activity that is necessary to maintain the grid's flows, such as readying otherwise uneconomic generators to run ("must-run" contracts due to their electrical situations, made whole from SPP revenues), or reprioritizing generation to satisfy transmission constraints.

The day-ahead market is one of a number of markets. Like other RTOs SPP operates bid-based markets for "ancillary services" that will be called upon for reliability, ensuring that supply equals demand at all times and everywhere on the grid. Among the services are "regulation" or "load following" that precisely adjust inflows and outflows at hundreds of junctions. To assure costs are minimized, generator outputs all over the SPP's footprint are optimized as often as every four seconds, from North Dakota to Texas. As the day passes or emergencies occur, other ancillary services markets operate. They include "spinning reserves," whose power can be made available instantly, and non-spinning reserves that may be called upon (and paid) to begin operation if it looks like they might be needed. Units like these receive a payment (also bid-based) for availability as well as the SPP energy market price if they run.

Things can change between the day-ahead market and the "real time" market. New information about market or grid conditions will arrive and may induce some generators to change their bids and some others to startup and sell into the market. An expected weather-sensitive load may not materialize or a generator that was idle may unexpectedly become operational. Real-time markets process the shortest-term increments of supply and demand, producing a market-clearing energy price several times an hour. There are still other transactions that help ensure that markets function efficiently.

An eligible market participant (whether or not it owns a generator) can further facilitate price discovery and efficiency by "virtual bidding." For example, assume that a generator whose bid in the day-ahead market was cleared (committed to run), now thinks weather conditions indicate that real-time prices tomorrow will be lower. The generator generally cannot withdraw the bid from the day-

ahead market, but can buy it back in the real-time market, at a profit if the guess was right. (Someone who does not own generation and is financially qualified can also make such a transaction.) Research in other RTOs have shown that virtual bidding generally brings about convergence between day-ahead and real-time prices, thereby facilitating market efficiency.

A final function of the SPP is a valuable byproduct of its grid operation and extremely important in places like Oklahoma where transmission capacity has not kept pace with generation. Like other RTOs, the SPP uses Locational Market Prices (also called nodal prices) – prices generators must pay to access the grid and send out power – to regulate generator access to transmission lines at various points in the grid. When the wind is up, wind generators want to send out more power than there is transmission capacity, and links of the system will become congested. To prevent congestion, SPP recalculates nodal prices at 3,000 points on the grid where generators or loads are located every five minutes. When a link goes out, prices all over the grid change to reflect the new scarcity situation. A transmission path whose price is frequently high signals to the RTO and transmission owners that an expansion of capacity would be a productive investment.

There are still other financial and operational dimensions of transmission. A generator (or its creditors) may value a predictable income stream, and the SPP allows hedging against adverse nodal price movements. Parties that want predictability in transmission charges can hedge in the market for "congestion revenue rights." Here, the RTO studies flows in order to determine safe loadings on an important transmission path and then auctions off rights to use the link, generally for a year. The holder of such a right may use the link for its own power flows, or sell or rent the rights to that revenue.

C. Why Regulation and the SPP Market Matter for Oklahoma

In the old world of utility regulation, a single company owned generation, transmission and distribution. Essentially, the utility would estimate the rates needed to recover expenses and make prudent investments in new facilities. That revenue requirement would then be approved by its state regulatory commission. It was relatively easy for an interested citizen to determine the impact of a given generation project on rates. The vertical de-integration of utilities remains a strong force, and so does the independent power industry, which often competes with utilities to construct new plants. One common arrangement between an independent generator and a utility is a longer-term contract to buy a plant's power, with adjustments to account for fuel prices and changes in environmental requirements, among other things. Whether the plant's owners make a profit is not a concern of either the utility or its regulators.

The situation of a wind generator is more difficult to analyze. The owner of the unit almost certainly has a power purchase agreement for its output, possibly with the regulated utility. Being in a competitive market, the detailed terms of the contract may well be confidential. If this is a typical wind unit, it will be under a long-term fixed price contract with the utility. This is reasonable because the wind unit brings few pricing surprises with it; most importantly there are no fuel costs. Now assume that this is taking place in the SPP. Whatever the terms of its contract with the utility, the wind unit's output will get the SPP price. The wind unit's income will bear no necessary relationship to its construction cost as would have happened under traditional regulation. Other aspects of wind power also contribute to the opacity. The unit will be able to utilize the federal production tax credit, but the cost of this stream of benefits is not borne directly by either the utility or its customers. Whether we compare the costs of the wind plant with a utility investment, a simple purchased power agreement for its output, or a generator that burns another fuel, we are dealing with apples and oranges, making accurate full-cost comparisons difficult.

V. Conclusions

This introductory chapter has necessarily touched on a large number of topics. Electricity is one of the most necessary of commodities in a modern

economy, and among the most idiosyncratic. Power markets create the same benefits as other markets. They allocate scarce resources to where they can create the most economic benefit and distribute goods and services in accordance with the public's preferences and budgets. Investment risks are borne, in the main, by investors themselves, who have stronger incentives to create economic value than government bureaucrats. The benefits to consumers and producers of emerging competitive electricity markets exist in the here and now.

Renewable power policies, on the other hand, are largely in search of a rationale beyond politics. Their roots lie in the "energy crises" of the 1970s and 1980s, when mismanagement of important markets led policymakers to believe that the world would soon exhaust its hydrocarbon resources. Renewable power quotas and regulatory preferences for wind power are hard to rationalize economically but are straightforward in their politics. This study attempts to shed new light on wind-generated electricity, an energy source so often misunderstood because it seems intuitive that the wind is free. It is not.

A generator is said to be dispatchable if its output can be raised or lowered with certainty when ordered by the system operator. If a new dispatchable generator is added to a grid, its strengthens the performance of the entire system because it adds reliability. An intermittent wind generator performs no such service because the operator cannot count on it. That generator degrades the performance of the system in important ways, and profits from a regulatory pricing system that fundamentally misapprehends its costs and benefits. The next chapter discusses these points in more detail.

Chapter 2
The Economic Value of Wind Power

I. Introduction

A. Is the Wind Free?

Whether from wind, gas or coal, almost all of Oklahoma's power passes through the markets of the Southwest Power Pool (SPP), and like any competitive market, SPP's converges to a single price, adjusted for transmission conditions and charges. Wind power advocates often argue for its superiority by claiming that "the wind is free, just like air," but wind and air are critically different. Air is reliably available at all hours of the day, and (disregarding pollutants) is of dependable quality. Wind's randomness makes it unreliable over any intervals that matter for power consumers.

Wind advocates often make statements about how a wind generator "will produce enough power to light X thousand homes." The problem is that hardly anyone would voluntarily live where the only energy source was local wind. Many people will probably say that they would rather have reliable power for several hours of the day and darkness for the remainder. Human activities that range from reading to cooking require steady flows of quality power (no flickering) if they are to deliver their promised benefits. If wind power is to be of any value, it must be embedded in a grid that can instantaneously recognize, accommodate and neutralize the effects of unpredictable interruptions.[11]

In this chapter we examine the costs of producing a reliable power supply in realistic settings. Specifically, we examine the choices between renewable and nonrenewable generators in the "production" of reliability. We will see that the two are substitutes in some ways and complements in others and, within limits, can reduce delivered power costs and improve reliability. Those limits, however, are surprisingly stringent. To understand them requires that we ask and answer some fairly simple questions about generator choice that have, until recently, been largely neglected or misstated by advocates of renewables. The opportunity cost of replacing efficient fossil-fueled generators with renewables is often remarkably high. Even if we assign high value to the avoided carbon emissions, it remains quite difficult to make a case for renewable investments on environmental grounds.

B. Types of Intermittency

The only plausible ways to rectify wind's intermittency are to supplement or replace it with power from a dependable and dispatchable resource. Batteries or other storage media are too costly to be useful substitutes for wind, and any cell phone owner knows their limits all too well. Other renewables such as geothermal or biomass could step in for wind, but they generally have high capital costs and limited availability.

There are also quality issues. The owner of a sawmill in Maine can generate power by burning abundant wood chips, but will seldom choose to disconnect from the grid. Instead the mill will contract to sell the unsteady power source to a regional utility that will turn it into one component of a reliable package. The wood-burner's low availability ensures that it will only run when its power is needed, but that could be when its contribution is the difference between reliability and blackout. The wood-burning generator is dispatchable, its power output alterable by the system operator as necessary. Other renewables like hydroelectric and geothermal generators are capable of following orders in ways that wind and solar are not.

In some ways it is more helpful to view system costs as made up of three components enumerated by German economic consultant Lion Hirth.[12] The first are "profile costs." Electricity is demanded in varying quantities during a day, which plots a time profile of electricity demand. When generation becomes more variable in response to demand, costs are greater. If power were demanded at the same rate at all hours on all days, these costs would be minimal, but as intermittent renewables

grow, the system operator must dispatch a set of generators that are increasingly difficult to manage for reliability and efficiency. Second, if power is produced and demanded at different locations, there are "grid costs" that originate in transmission constraints (distance and wire capacity). Their abatement can require investment to strengthen existing links or redesign and rerouting of a regional network. Finally, there are "balancing costs" associated with adjustments in dispatchable generator output that must be made to cope with randomness in renewable generation.

The numerical values of these costs in a particular case will depend on the details of both generation choices and transmission investment in a given region. Hirth (2016) summarizes a large literature to estimate each of the three. Using primarily European data, he estimates that profile costs of a system with 30 to 40 percent wind penetration are in the range of 25€ to 35€/MWh (MWh = megawatt hour). He also notes that when renewables are below 10 percent of the system's resources, their profile costs are small relative to generation costs. Despite often-encountered concerns, balancing costs also depend on the penetration of intermittent generation and are surprisingly low, from 2€/MWh at low levels to 4€/MWh at high ones. His survey of the research also shows that grid costs are below 15€/MWh under most operating conditions.

It should be noted that Hirth's estimates were gleaned from a large collection of case studies that are intrinsically difficult to compare. If, however, the actual costs resemble these estimates, we arrive at a sobering conclusion: if the average price of electricity is 70€/MWh, after we net out profile, grid, and balancing costs the net value of electricity from wind is 35-45€/MWh. This is between 35 and 50 percent *below* the typical European price, and implies that the optimal investment in wind resources should be significantly less than the actual amount.[13] That is, while wind generation receives the market price for the power it produces, it is actually worth much less because of the costs it imposes on the grid due to its intermittency. These costs do not accrue to wind producers, so they over-invest in the wind commodity. The costs and benefits of a particular wind installation may render it cost-effective, but there is thus far little guidance as to which non-market characteristics would make it preferable to conventional generation.

II. Standards for Comparison

A. Which Costs, Which Values?

Everything has a price. Adding up the funds spent to construct, fuel and operate a power plant yields a dollar total. That total of the recorded ("booked") costs, however, may bear no relation to the value consumers place on its output because the plant is only useful as a component of a reliable network, which is what consumers actually value. A kilowatt-hour (KWh) of electricity is worth buying if it generates more benefits to the consumer than the best alternative he could have purchased. All electricity consists of electrons flowing along wires, but like so many economic goods, its value to the buyer depends on where it is available, when it is available, and the certainty with which it is available. The cheapest, greenest and most reliable electricity is worth little to a consumer who cannot access the transmission line carrying it. The same holds true if it is not available at midnight or if it is subject to random interruptions that make it impossible to tell time or to decode the signals sent from a stoplight.

The disconnect between consumer value and generation cost seems clear, but it largely escaped electric system planners and utilities for much of their industry's history. Even today, they often evaluate a proposed generator by estimating its "levelized cost of energy."[14] LCOE is the sum of capital (generator) costs and operating (e.g., fuel etc.) costs, discounted over a generator's expected lifespan, and then annualized. In an industry dominated by fossil fuels, LCOE was an imperfect but helpful tool for comparisons.

Fossil-fueled generators were dispatchable, i.e. the grid operator (or a computer) could order a plant to raise or lower its output and obtain the expected response almost in real time. If the grid is potentially a megawatt-hour in deficit, any generator could dependably make up the shortfall.[15] Before intermittent wind and solar generation, the grid still faced risks that could bring it down (generation

outages from weather events, for example, that required workarounds) and unavailable resources (a hydroelectric facility may run out of water). If all generators are dispatchable, planners must still optimize their mix of investments in baseload, intermediate, and peaking facilities, but here too, LCOE is generally a valid standard. With the coming of markets, some systems now choose new resources using auctions whose effective standard is LCOE.

B. How Valuable Is Intermittent Power?

Applying the "no free lunch" standard, it is clear that solar and wind generation add both resources *and* costs to the grid. The worth of a "free" megawatt hour generated by wind, however, depends on market conditions, most importantly the "wholesale" price of power that the distribution utility pays to generators and recovers from customers. Reliability is extremely valuable, but intermittent resources can sometimes degrade it and sometimes enhance it. Solar generators, for example, produce the most power in mid-afternoon when the sun is high, coincidentally the same hours that daily demand for power typically peaks. A cloud that temporarily blocks the sun can reduce production, but so can an outage at a dispatchable plant. In most regions, wind strength is not well-matched with load, because wind blows more strongly and persistently at night. Neither the capital nor operating cost of a wind unit can by itself determine whether wind beats fossil fuel generation, and the same may hold for the two taken together.

Table 2-1 presents a simple example from Joskow (2011). Its numbers are "ballpark" approximations to today's industry figures. Assume a dispatchable generator with annualized capital and fixed operating costs of $300,000 per megawatt (MW) per year. Its operating cost is $20/MWh and its capacity factor is the 90 percent, which roughly characterizes coal- and gas-fired generators. Capacity factor is the percentage of hours over the year when it operates at full capacity, here 7,444 of a possible 8,760 hours. Using these figures, its levelized cost is $58.10/MWh.[16] The intermittent (wind or solar) plant is assumed to have only half the annualized capital costs, $150,000 per MW, and its operating costs are zero thanks to the wind or sun. With a capacity factor of 30 percent, it can produce 2,628 MWh per year, which levelizes to $57.10/MWh.[17] *Intermittency reduces the seemingly massive cost advantage of the renewable plant to nearly zero.*

Some sensitivity tests provide additional insight into both generation and markets. Table 2-2

Table 2-1
Hypothetical Levelized Value Calculations

	Dispatchable	Intermittent
Construction + Fixed O&M Cost	$300,000/MW/year	$150,000/MW/year
Operating Cost	$20/MWh	$0/MWh
Capacity Factor	90 percent	30 percent
MWh/MW/year	7,884	2,628
Levelized Cost/$/MWh	**$58.1/MWh**	**$57.1/MWh**

Note: Values are hypothetical, but approximate, averages.
Source: Paul L. Joskow, "Comparing the Costs of Intermittent and Dispatchable Electricity Generation Technologies," American Economic Review 100 (May, 2011): 238 – 241.

assumes a market run by a Regional Transmission Operator into which generators sell their power at time-varying prices. Column 2 of Table 2-2 shows a dispatchable generator with a 90 percent capacity factor in a market with an on-peak price of $90/MWh and off-peak price of $40. For simplicity, off-peak demand is assumed to be 50 percent of on-peak and all outages occur off-peak. Under these assumptions our fossil-fuel plant approximately breaks even. By comparison, column 3 depicts an intermittent renewable plant with a capacity factor of 30 percent. This allows it to operate for 2,628 off-peak hours and zero on-peak. Its revenue per MW per year is $105,120, which compared with its $150,000 cost, yields a loss of $44,800 per MW per year. This is an extreme version of a wind generator that we assume sells nothing on-peak.

Making a less extreme peak/off-peak assumption has a surprisingly small effect, shown in column 4

Table 2-2
Comparing Dispatchable and Intermittent Generation

	Dispatchable all cases	Intermittent Case 1	Intermittent Case 2	Intermittent Case 3
Peak Period MWh Supplied	3,000	0	50	2,628
Off-peak Period MWh Supplied	4,884	2,628	2,578	0
Revenue $/ MW/year	$465,360	$105,120	$107,320	$256,520
Total Cost $/ MW/year	$457,680	$150,000	$150,000	$150,000
Profit $/MW/ year	**$7,680**	**($44,800)**	**($42,380)**	**$86,520**

Note: Values are hypothetical, but approximate, averages.
Source: Paul L. Joskow, "Comparing the Costs of Intermittent and Dispatchable Electricity Generation Technologies," American Economic Review 100 (May, 2011): 238 – 241.

of Table 2-2. Suppose 50 megawatt hours more were sold in peak hours and 50 fewer sold off-peak. This only slightly reduces the loss per MWh. Assuming more generation at the peak leaves the basic result intact. If it generates a somewhat unrealistic 500 MWh on-peak and 2,128 off-peak (not shown in the table), there is still a loss per MWh per year of nearly $12,000. Only if the intermittent plant has the good fortune to run for 1,000 of the 2,628 on-peak hours does it break even.

The final column in Table 2-2 assumes a solar plant with a capacity factor of 30 percent that runs only during 2,628 on-peak hours. Solar is now valuable because it operates disproportionately at peak hours. Table 2-2 assumes the costs of solar and wind are the same, but even if the solar capacity costs much more per MWh than wind, it remains the more profitable investment. The example suggests (but does not prove) an important point, which depends in part on numerical details: *the utility-scale wind industry will not survive in competitive power markets unless it is subsidized.*

It is important to note that thus far we have omitted any affirmative case for policies that grow intermittent generation. Specifically, wind and solar generators do not emit carbon. Some experts believe that climate problems will soon materialize (others feel differently), and when this happens they will impose huge economic losses worldwide through a variety of mechanisms. If so, the harms from fossil-fuel generation must be factored into the analysis. Examining carbon policies could change the above outcome in ways that recommend the deployment of additional intermittent generation. We next turn to this topic.

III. Costs and Benefits of Alternative Investment Decisions

A. Beyond Levelized Costs

Simple LCOE comparisons are inadequate for policy analysis because they do not consider the full costs of power from different fuels and its value at different times and places. Newer economic models can facilitate more complex and inclusive comparisons of generation investments and explicitly include possible values for the harm from and the abatement costs of carbon emissions. Largely due to Charles Frank of the Brookings Institution, these new analyses start from the investment decision and compare both the values and costs of various generators.[18]

Treating opportunity costs in more detail,

the benefits of a generation project include its avoided capital costs, avoided operating costs, and avoided emissions, each relative to some well-defined alternative generator. We carry along some key items from the previous example including capacity factors and peak vs. off-peak operation. We also increase the realism by including backup requirements for intermittent generators and measures of the harm caused by hydrocarbon emissions. We take the three major avoided costs in turn and assemble them into a more complete model. After outlining Frank's basic method, we go on to adjust some of his figures in ways that better apply to Oklahoma.

1. Avoided Costs: Emissions

Suppose a megawatt of newly built gas-fired capacity displaces an equivalent megawatt of capacity from a coal-fired plant. (Standards for equivalence are discussed later.) The replaced unit no longer emits pollutants, which we call avoided emissions. Avoided emissions are high per megawatt when new capacity replaces a baseload coal unit for two reasons: 1) the coal unit is less fuel efficient than the new one, requiring more energy (millions of British thermal units, MMBTU) to produce a MWh, and 2) because coal contains more carbon per MMBTU than gas. Table 2-3 contains data on emissions from three types of plants that might be built or replaced. The first is a combined cycle ("CC") gas-fired generator, the second is a coal-fired unit ("coal"), and the third is a single-cycle ("SC") gas turbine. Each contains data for old and new plants of that type. Data are from the U.S. Energy Information Administration for 2013.[19]

To get emissions per MWh we start from a plant's heat rate, the BTUs that are necessary to produce 1 MWh of power (a lower heat rate is better). Then we adjust it for the plant's efficiency in turning BTUs into megawatts, i.e. For a MWh, a new combined cycle gas plant requires 1/.53 = 1.89 MMBTU (million BTUs) times its heat rate, fewer than an old combined cycle plant that needed 2.07 MMBTU. CO_2 emissions per MWh of power produced are for all of the fuel required to produce it. Gas produces 117 pounds of CO_2 per MMBTU and coal produces 206 pounds.

The efficient choice of generator type depends on costs, capacity factors, and the characteristics of other power plants. Table 2-4 derives avoided emissions per MW/year (lbs. of CO_2) assuming that the new generator (CC, wind, or solar) displaces coal off-peak and a single cycle gas turbine on-peak (because this high cost unit is all that remains after more efficient generators have been committed to operate). The first line of Table 2-4 provides

Table 2-3
CO2 Emissions per MWh, Fossil Fuel Plants

	Gas Combined Cycle	Coal	Gas Single Cycle
Heat Rate (Btu/KWh)			
New Plant	6,430	8,800	9,750
Old Plant	7,050	10,498	10,850
Efficiency			
New Plant	53.1%	38.8%	35.0%
Old Plant	48.4%	32.5%	31.5%
CO2 Emissions: Pounds per MWh			
New Plant	752.3	1,812.8	1,140.8
Old Plant	824.9	2,162.6	1,269.5

Notes: Gas assumed to emit 117 lbs. CO2/MMBTU
Coal assumed to emit 206 lbs. CO2/MMBTU
Source: Charles Frank, The Net Benefits of Low and No-Carbon Electricity Technologies (Washington, D.C.: Brookings Institution Global Economy and Development Working Paper No. 73, May 2014), 3.

Table 2-4
Avoided Emissions per MW/year Displacing Coal On-Peak and Gas Off-Peak

	Wind	Solar	Gas Combined Cycle
New Plant Capacity Factor (Full-year avg)	25.5%	15.5%	92.0%
MWh/year per MW of Capacity (Full-year avg)	2,236.9	1,359.6	8,059.2
Avoided Emissions/ MW/year (tons)	2,133.9	1,390.0	8,330.7
New Plant Emissions/ MW/year (tons)	0	0	(2755.9)
Net Avoided Emissions/year (tons)	**2,133.9**	**1,390.0**	**5,574.8**

Source: Charles Frank, *The Net Benefits of Low and No-Carbon Electricity Technologies* (Washington, D.C.: Brookings Institution Global Economy and Development Working Paper No. 73, May 2014), 7.

capacity factors for each type of plant, averaged over a full year.[20] The table shows a dramatic difference between intermittent renewables and other types of generation. Full-year capacity factors for wind and solar are 25.5 and 15.5 percent, while a CC unit has one of 92.0 percent.[21] The typical photovoltaic generator will operate 15.5 percent of the time, i.e. 1,360 of the 8,760 hours in the year.

Emissions avoided by installing a megawatt of solar capacity depend on what it is replacing, which Table 2-4 assumes are coal off-peak and SC gas on-peak. If it displaces these, the world avoids 1,390 tons of CO_2 per year (calculated from Table 2-3). Whether this is "good" or "bad" has nothing to do with sunshine being "free," and everything to do with the alternatives. Let the alternative be a megawatt of CC gas capacity. Its capacity factor of 92 percent is telling us that in 92 percent of all hours, the world is avoiding emissions from coal (off-peak) and SC gas (on-peak). Idling these units reduces CO_2 emissions over the year by 8,330.7 tons. But here there is also a cost, because unlike wind or solar, the CC gas turbine has to emit 2,755.9 tons when doing its job, but still yielding a net carbon saving of 5,574.8 tons.[22]

2. Avoided Costs: Energy

Table 2-5 calculates avoided energy costs assuming a new unit replaces coal off-peak and SC on-peak. It then nets them out against the fuel cost for the new plant.[23] A new 1-megawatt wind plant then allows avoidance of $74,412 per year in fuel costs, itself a saving because that plant burns no fuel. A solar unit, with its lower capacity factor, avoids only $50,938 of yearly fuel expenses. If, instead of the renewables with low capacity factors, we consider a CC gas unit with a 92 percent capacity factor, we avoid $296,836 per megawatt per year in costs of the displaced plants. The new unit, however, has its own fuel costs ($250,737) for a net difference of $46,099 per megawatt per year. The renewables avoid more energy costs than this fossil-fuel alternative, but their low capacity factors make for a tighter contest than one might expect. This example graphically points up the pitfalls implicit in assertions that energy from the wind or sun is "free" in any meaningful sense.

Table 2-5

Net Avoided Energy Cost/MW/year Displacing Coal Off-Peak and Gas SC On-Peak

	Wind	Solar	Gas Combined Cycle
Avoided Energy Cost / MW/Year	$74,412	$50,938	$296,836
New Plant Own Energy Cost / MW/Yr	$0.00	$0.00	($250,737)
Net Avoided Energy Cost / MW / Year	**$74,412**	**$50,938**	**$46,099**

Source: Charles Frank, *The Net Benefits of Low and No-Carbon Electricity Technologies* (Washington, D.C.: Brookings Institution Global Economy and Development Working Paper No. 73, May 2014), 7.

Table 2-6

Energy Cost per MWh, Fossil Fuel Plants to Be Replaced

	Gas CC	Coal	Gas SC
Fuel Cost per mmbtu average 2013	$4.33	$2.36	$4.33
Fuel Cost per MWH from Old Plant	$30.53	$24.78	$46.98
Variable O&M per MWH from Old Plant	$3.60	$6.24	$15.45
Total Energy Cost per MWh, Old Plant	**$34.13**	**$31.02**	**$62.43**

Source: Charles Frank, *The Net Benefits of Low and No-Carbon Electricity Technologies* (Washington, D.C.: Brookings Institution Global Economy and Development Working Paper No. 73, May 2014), 6.

Table 2-6 shows the fuel costs saved (including variable operation and maintenance expenses) when some type of new generator displaces a CC, SC, or coal unit. (A plant that replaces a coal unit will have a lower avoided energy cost than if it replaces a gas generator.) The estimated values (after accounting for heat rates) are $34.13 per MWh for a CC, $62.43 for a less efficient SC gas unit, and $31.02 for relatively cheap coal. All capacity factors are the same as used to calculate avoided emissions.

3. Avoided Costs: Capacity

Whatever the generator technology, if one megawatt of it is added to the system, it obviates the need for a one megawatt investment with similar

characteristics. Here, the similarity that matters is equality of capacity factors for both plants. Table 2-7 presents the cost of capacity per megawatt per year for single-cycle, combined-cycle and coal-fired plants. In addition to immediate expenses on a plant ("overnight costs") we must consider the cost of capital during construction (at 7.5 percent) and fixed operations and maintenance expenses, and convert them to annualized present values over the plant's 30-year lifespan.[24] Overnight costs and capacity costs per year appear in Table 2-7. A megawatt of combined-cycle capacity is nearly twice as costly as single-cycle but only 35 percent as costly as a megawatt of coal capacity.

Now for the tricky part. For a valid economic comparison, we must adjust the avoided capacity cost of a new 1-megawatt generator to make it equivalent to the capacity factor of an eliminated plant. Starting simply, if the replaced plant has a capacity factor of 100 percent and the new plant's is 50 percent, two megawatts of new capacity would make up for losing one megawatt of old capacity. Adding some necessary complexity, the productivity of a renewable-powered unit also varies randomly with the inconsistencies of sunlight or wind. Assume that one megawatt of baseload CC has a capacity factor of 0.9, i.e. it operates during the 90 percent of hours that it might be wanted. Now let the alternative be an intermittent renewable plant whose capacity factor is 30 percent. We wish to find the number of intermittent plants equivalent to a single plant with a capacity factor of 0.9. The answer is *not* "3" because in an uncertain world the three taken as a group will operate at capacity factor of 0.9 only in the unlikely event that all three of them are running.

Now assume there are four plants, each with a capacity factor of 30 percent. To avoid technical math, we verbalize our quest for equivalent reliability by asking what percentage of the time we will see at least three of the four operating. With a "spare" generator we will certainly see a capacity factor of 0.9 more often than we would without the spare, but there will still be times when fewer than the desired three are running. With five generators, failures that leave two or fewer units operating will be even more rare but still possible.[25]

The math of probabilities allows us to calculate the number of plants required for the group's capacity factor to equal or exceed the replaced plant's factor of 0.9.[26] Because wind and solar plants have low capacity factors taken individually, the avoided capacity cost per megawatt is relatively small. Making the implied corrections, achievement of a capacity factor of 90 percent in one megawatt of replacement plant requires the building of 4.28 megawatts of wind capacity. To duplicate the performance of a 1-megawatt high-capacity-factor plant requires 7.30 megawatts of solar plants, whose individual capacity factors are lower than those of wind units. Small generators with intermittent production will be poor bargains in this sense, since it takes more capital investment in them to produce a power source with reliability equivalent to a single

Table 2-7

Capacity Cost/year/Megawatt, New Fossil-Fuel Plants

		Gas Combined Cycle	Coal	Gas Single Cycle
	"Overnight" Capital Cost/KW	$1,023	$2,934	$676
	Years for Construction	2.5	4	1.5
	Cost of Capital during Construction	$130	$440	$42
	Total Capital Cost	$1,153	$3,374	$718
	Expected Economic Life	30	30	30
Capital Cost/MW/year		$97,663	$285,689	$60,815
Fixed Operation and Maintenance Cost/MW/year		$15,370	$31,180	$7,040
Total Capacity Cost/MW/Year		**$113,033**	**$316,869**	**$67,855**

Source: Charles Frank, *The Net Benefits of Low and No-Carbon Electricity Technologies* (Washington, D.C.: Brookings Institution Global Economy and Development Working Paper No. 73, May 2014), 8.

plant with a high capacity factor.

Having estimated capacity costs for combined cycle, single cycle and coal plants, Table 2-8 shows calculations for one equivalent megawatt of solar and wind plants that do not burn fuel. Using the same annualization techniques as for coal and gas units, it shows annual capacity costs for one equivalent megawatt of wind capacity of $270,195 per year, and $351,427 per year for one equivalent megawatt of solar.

Table 2-8

Capacity Costs/MW/year, New No-Carbon Plants

Baseload		Wind	Solar
	"Overnight" Capital Cost/ KW	$2,213	$3,873
	Years for Construction	1.5	1.5
	Cost of Capital during Construction	$138	$242
	Total Capital Cost	$2,351	$4,115
	Expected Life	20	40
	Annualized Capital Cost/ MW/year	$230,645	$326,737
	Fixed Operation and Maintenance/MW/year	$39,550	$24,690
Total Annual Capacity Cost/MW		**$270,195**	**$351,427**

Source: Charles Frank, *The Net Benefits of Low and No-Carbon Electricity Technologies* (Washington, D.C.: Brookings Institution Global Economy and Development Working Paper No. 73, May 2014), 11.

The upper portion of Table 2-9 shows avoided capacity cost if the new plant (wind, solar, or gas CC) displaces a MW of baseload coal capacity, after also accounting for differing renewable capacity factors on- and off-peak. The wind unit eliminates $69,570 MW/year of coal capacity costs, the solar unit (with its poorer capacity factor) $45,702, and the combined cycle gas unit (94% capacity factor) eliminates $323,577 of coal capacity costs. As expected, the lower portion of Table 2-9 shows avoided capacity cost if the new wind, solar, or gas CC plant displaces baseload gas CC production off-peak and gas CC on-peak. Displacing CC gas capacity avoids lower capacity costs for all three plants, in roughly the same relative proportions as displacing baseload coal.

Table 2-9

Avoided Capacity Cost if Coal or Gas CC Baseload Production Displaced

Coal Displaced

Baseload		Wind	Solar	Gas CC
	Adjusted capacity factor	20.40%	12.00%	89.60%
	Coal baseload capacity replaced (MW)	0.233	0.137	1.024
	Coal Baseload Capacity Cost Avoided	$73,967	$43,404	$324,476
Peak Load				
	Adjusted capacity factor	15.70%	15.90%	94.00%
	Gas SC Capacity Replaced (MW)	0.169	0.171	1.011
	Less Coal Capacity Replaced	(0.233)	(0.137)	(1.024)
	Net Peak Load Capacity Avoided	(0.065)	0.034	(0.013)
	Gas SC Capacity Cost Avoided	($4,398)	$2,298	($899)
Total Capacity Cost Avoided		**$69,570**	**$45,702**	**$323,577**

Gas CC Displaced

Baseload		Wind	Solar	Gas CC
	Gas CC Capacity Replaced	0.228	0.134	0.317
	Gas CC Baseload Capacity Cost Avoided	$25,767	$15,120	$113,033
Peak Load				
	Gas SC Capacity Replaced	0.169	0.171	1.011
	Less: Gas CC Capacity Replaced	(0.228)	(0.134)	1.000
	Net Peak Load Capacity Avoided	(0.059)	0.037	0.011
	Gas SC Capacity Cost Avoided	($4,026)	$2,516	$730
Total Capacity Cost Avoided		**$21,741**	**$17,636**	**$113,763**

Source: Charles Frank, *The Net Benefits of Low and No-Carbon Electricity Technologies* (Washington, D.C.: Brookings Institution Global Economy and Development Working Paper No. 73, May 2014), 9,10.

Table 2-10 summarizes all of the above. Its upper portion considers displacement of one megawatt of baseload coal capacity by a unit of an equivalent wind, solar or CC gas plant. The benefits are as calculated above for each technology's avoided emissions, energy costs and capacity costs. The wind and solar plants have no emissions or energy costs, but for completeness we include their relatively low balancing costs, as discussed above. The annual net benefits if a megawatt of wind capacity displaces a megawatt of baseload coal are negative but relatively small (-$25,333), but strikingly negative (-$188,820) if the alternative investment is a megawatt of solar. The combined-cycle gas generator easily dominates all of the alternatives. Despite incurring fuel costs that wind and solar do not, its annual net benefits are $535,382. The outcome is less sensational on the lower portion of the table, where the alternative is displacement of combined cycle baseload gas capacity. Wind and solar become even more inferior with net annual benefits of - $129,852 and - $252,920. The net value of a combined cycle plant falls but is still quite positive at $106,654 per MW per year. An analysis that incorporates more of the relevant opportunity costs and capacity factors of renewables and conventional generators yields conclusions quite at variance from those based on simple levelized energy costs.

IV. Accounting for Carbon

The analysis above appears to weaken any case for policies aimed at increasing generation from intermittent renewables. It implicitly provides new reasons for reliance on fossil-fuel generation. Table 2-8 shows the energy and capacity costs avoided by building a solar or wind plant and the costs for a new CC gas generator, including fuel. These calculations, however, do not take account of the full cost of a generator, inclusive of the dollar harm that results from emissions. Since wind and solar have zero emissions, the question of interest is to estimate the net benefits lost if we add the emissions costs to the other costs of a fossil generator. The (negative) value of those emissions can reflect any environmental degradation caused by operation. Depending on which harms are considered eligible

Table 2-10

Net Benefits/year/MW

Coal Baseload Displaced

		Wind	Solar	Gas CC
Benefits/MW/year				
	Avoided Emissions	$106,697	$69,502	$416,534
	Avoided Energy Cost	$74,412	$50,938	$298,836
	Avoided Capacity Cost	$69,510	$45,702	$323,577
Costs/MW/year				
	New Plant Emissions	$0	$0	($137,796)
	New Plant Energy Cost	$0	$0	($250,737)
	Capacity Cost Incurred	($270,195)	($351,427)	($113,033)
	Cycling and balancing costs	($5,816)	($3,535)	$0
Total Net Benefits		**($25,333)**	**($188,820)**	**$535,382**

Gas CC Baseload Displaced

		Wind	Solar	Gas CC
Benefits/MW/year				
	Avoided Emissions	$43,552	$29,365	$172,580
	Avoided Energy Cost	$80,868	$55,041	$321,777
	Avoided Capacity Cost	$21,741	$17,636	$113,762
Costs/MW/year				
	New Plant Emissions	$0	$0	($137,796)
	New Plant Energy Cost	$0	$0	($250,737)
	Capacity Cost Incurred	($270,195)	($351,427)	($113,033)
	Cycling and balancing costs	($5,816)	($3,535)	$0
Total Net Benefits		**($129,852)**	**($252,920)**	**$106,554**

Source: Charles Frank, *The Net Benefits of Low and No-Carbon Electricity Technologies* (Washington, D.C.: Brookings Institution Global Economy and Development Working Paper No. 73, May 2014), 15, 16.

for inclusion, their total might be large or small. It is also possible that the renewables are not blameless. (Should degradation of scenic views due to wind turbines be included?) Alternatively, we might reason that harms from pollution are already accounted for because the owner or customers of the CC gas plant must somehow pay the costs of its environmental compliance which are largely capital costs. If so, adding additional damage would be double-counting any harm.

One type of pollution is probably not covered by calculations like these. Specifically, the accumulation of atmospheric carbon is viewed by some as harmful over the long term because it induces climate change whose effects may not be felt until it is too late. If so, the present value of future harm due to hydrocarbon combustion should be added in. For several years the federal government has attempted to estimate the present value of the stream of future harm, which it calls the "social cost of carbon." The job is surely a tough one, since it must predict the dollar values of future harms due to emissions. Even worse it must account for the fact that the harms (by assumption) will only arrive in the distant future. Their value today depends on the choice of the rate at which the world discounts the future, on which economics offers little advice. At all but the lowest rates, the present value of future losses due to climate change is negligible. At a five percent discount rate, the Environmental Protection Agency claims to have estimated the harm from an emitted ton at $11 for 2015 and $26 in 2050.[27] At a 2.5 percent discount rate the most current corresponding figures were $56 and $95.

In his analysis, Frank attempted to avoid these problems by choosing to assume (without citations) that "reductions [in carbon emissions] are valued at $50 per metric ton."[28] Table 2-11 adds a row that uses these estimates to account for the harms incurred and avoided by tolerating or abating these emissions. Perhaps surprisingly, they do not change the relative rankings of the fuel-consuming and renewable plants. The wind turbine, whose net value was formerly a negative $132,000 remains in the red, but its lack of emissions improves the cost-benefit calculation to yield only a $25,000 loss. The solar plant's low capacity factor also means that it has a low capacity for pollution abatement. Its net value changes from -$251,000 to -$182,000. Accounting for carbon emissions obviously impacts the CC plant, but its net value remains positive, falling from $416,000 not counting emissions to $278,000 if we do.

Table 2-11
Energy and Capacity Benefits, Net of Emissions

	Wind	Solar	Gas CC
Benefits/MW/year			
Avoided Energy Cost	$74,412	$50,938	$296,836
Avoided Capacity Cost	$69,570	$45,702	$323,577
Costs/MW/year			
New Plant Energy Cost	$0	$0	($137,796)
Capacity Costs	($270,195)	($351,427)	($250,737)
Misc Costs	($5,816)	($3,535)	$0
Net Energy and Capital Benefits	($132,029)	($251,252)	$231,880
Emissions/MW/year			
Avoided Emissions	$106,697	$69,502	$416,534
New Plant Emissions	$0	$0	($137,796)
Total Benefits	($25,332)	($182,750)	$278,738

Source: Charles Frank, *The Net Benefits of Low and No-Carbon Electricity Technologies* (Washington, D.C.: Brookings Institution Global Economy and Development Working Paper No. 73, May 2014).

V. Conclusions

The wind power industry has attempted to argue that all generators are subject to interruptions and maintenance.

> Other observers have criticized wind power purchase agreements for factories or data centers by noting that wind doesn't generate electricity all of the time. But the reality is no energy source does. The average wind turbine generates electricity 90 percent of the time, and modern wind farms often have capacity factors exceeding 40 percent. That's close to coal plants and exceeds some

types of natural gas plants. The performance of all power plants can be verified using U.S. Energy Information Administration (EIA) monthly electricity generation data that is provided for individual utility-scale power generators.[29]

This reasoning appears convincing in its assertion that the typical turbine generates 90 percent of the time. A correct statement is that if wind blew steadily for 90 percent of hours, then wind units would also have capacity factors of 90 percent. Coal and gas are readily available and can be inventoried to ensure that the generator can operate with near-certainty during 90 percent of hours, and wind cannot.

Raw capacity factors tell us little about wind power in general, because unless corrected for diurnal and weather patterns they can (and in Oklahoma, do) entail the operations of generators during hours when system conditions can render their output valueless. One survey of RTOs claims to have concluded that on average in the U.S., "each megawatt of wind capacity can replace about one-quarter megawatt of conventional generation capacity."[30] This does, however, vary with underlying geography and wind conditions. In particular it means that more clarification is needed before concluding that the recent rise in Oklahoma's average turbine output strengthens the case for wind, a topic discussed at length in the previous chapter. In the next chapter, we examine the controversy over the capacity equivalence of wind in the SPP. For the record, however, Frank's method of calculating resource equivalence of wind if its capacity factor is 41 percent leaves us with 3.07 one-megawatt wind units rather than the 4.2 that Frank calculated in his basic case. Note that even with this highly favorable development the combined-cycle gas generator still wins the competition with both solar and wind.

Chapter 3
Wind Power for Oklahoma: Benefits Now, Costs Later

I. Introduction

We begin with a basic question: how, if at all, does the addition of wind power to a grid impact consumers? The response is that, for all practical purposes, wind power's cost impact cannot be detected by the typical user. The peculiarities of Oklahoma and the power industry mask a complex story that we outline in this chapter. Our first question will be dollars and cents – What do Oklahoma power users pay in their bills for wind, and what would they have paid if power from conventional generators replaced it? We find that wind power's presence has hardly affected consumers' bills, which is why it may seem a bargain. The maze of subsidies and preferences going to wind producers has sources elsewhere, so that electricity consumers do not perceive the increased cost that wind engenders.

We first draw some comparisons between Oklahoma and other states. Despite the frequency of this approach to regulation, we find them virtually worthless for understanding the causes and consequences of Oklahoma's wind policy. In the process we examine the quality of comparisons that have been made by others and find them wanting, both pro and con. Because simple numerical comparisons do not improve our understanding, we next examine the factors that make them so. One subset of those factors is regional in nature. Oklahoma does not exist in isolation, but it is also not part of a homogeneous mass. Rather, Oklahoma's energy prices are determined in the markets of the Southwest Power Pool (SPP) described in Chapter 1. Simplifying, all generators in the SPP footprint from North Dakota to New Mexico must bid supply offers into a set of computerized auctions. As is typical in auctions, the lowest bids are accepted until the amount of power submitted equals the amount the region is expected to demand. The highest accepted bid sets the price that will be received by all generators.

Consequently, a wind generator receives the same price per KWh for its power as a coal-fired unit. There is an advantage in having lower production costs because the market price will give the efficient generator more return on investment than an inefficient one, but it pays any generator to submit a bid as long as its operating costs are less than the market price. That price is set for the entire SPP region, and Oklahoma utilities will build these prices into the rates they charge to households and businesses. State regulation will still determine the charges for the 50 percent of customer bills that go for other costs like distribution, operation, and maintenance. Wind units will have contracted to sell their outputs to local utilities at prices that were set in the past and are typically fixed for the long term. In short, the payment for wind-generated power was determined earlier, and the market price generators receive and utilities (consumers) pay is set in the SPP. Now comes the paradox: the more wind generators whose bids are accepted by the SPP, the lower the price of all power transacted in it will be. But, this is not the end of the story.

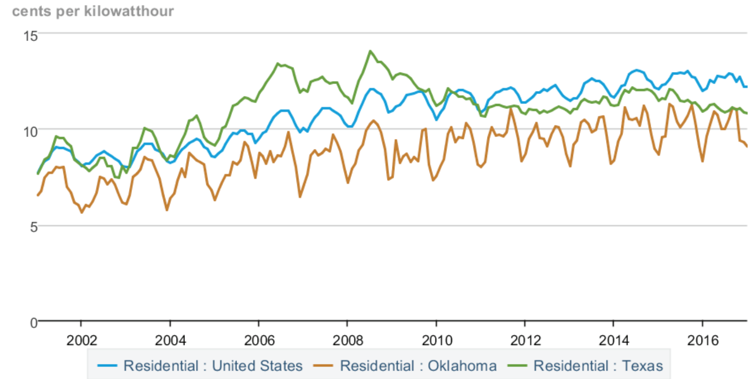
Like all such transfer schemes, the tax treatments of wind power have real economic effects as well as fiscal effects for government (covered in Chapter 4 and in a separate aside), which are in large part concealed and whose explicit effects for consumers will be postponed until the problems become more seriously intractable. Most importantly, our earlier discussions of capacity factors and intermittent generation mean that wind is not paying its full cost of participation in the power market. We consider several studies that have claimed substantial benefits from adding wind to the grid and find that they have seriously understated costs, most of which are borne by non-wind generators and power consumers. That there are costs is clear, but the magnitude of those costs is uncertain and hard to measure, particularly in the context of a regional market like SPP.

Adding wind to the region's resources brings costs, but it also brings benefits of lower prices to consumers in the region. But over the longer term

all Regional Transmission Operators are encountering variants of the same problem, picturesquely known as the "missing money." In a competitive power market, generators have no regulatory guarantee of recovering their costs. Their productivity comes in the form of both power output and system reliability, which are often inseparable in production. A strong wind presence depresses the prices that these generators have hitherto expected for the margin of profitability that makes them worth investing in. In response, dispatchable intermediate generating capacity is coming into short supply.

Figure 3-1

Average Retail Prices per KWh, 2000 - 2007



Source: U.S. Energy Information Administration

Several RTOs (not yet SPP) have responded to wind's pricing and uncertain reliability by devising new rules and new markets whose only reason for existence is to bypass previous markets in order to support necessary investments in generators needed to maintain reliability. In other regions, we are seeing a problem familiar from numerous interventions originally designed to remedy some seemingly small departures from "perfect" markets: It is very hard to make even small interventions without threatening the logic and operation of the entire grid. Perhaps the ultimate irony of subsidized wind power is that it could destroy the very markets that were once expected to function more efficiently because of its presence.

II. Dollars and Cents: Which Comparisons Matter and Which Comparisons Mislead?

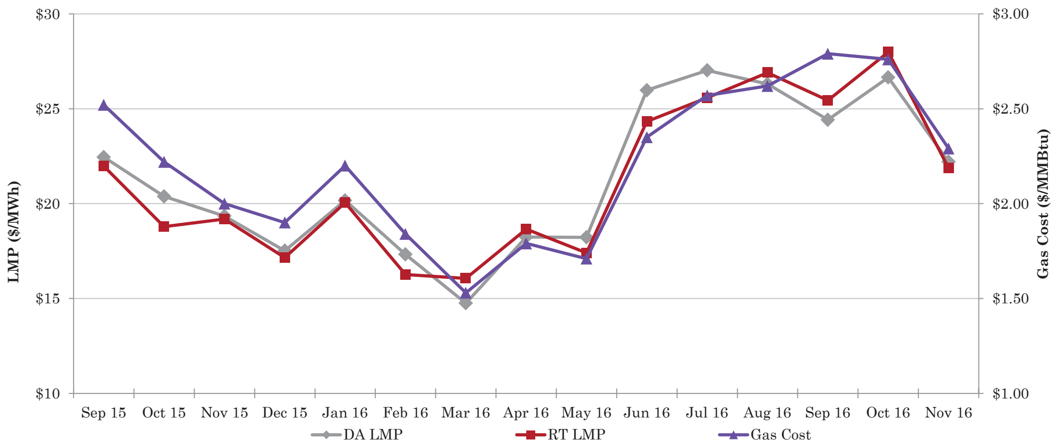
A. Where Power Prices Originate

To understand the consequences of the wind boom we must first understand who pays for what, and where are the rules that govern. The first fact that matters is clear from Figure 3-1. Oklahoma has traditionally enjoyed low power costs thanks to nearby coal and gas. As noted in Chapter 1, the most significant developments of Oklahoma's past 20 years have been a steep decline in the percentage of the state's power from coal, and a nearly equivalent rise in wind power, from zero to 18 percent of the total. Figure 3-1 shows annual average residential rates per KWh in Oklahoma, Texas and the entire U.S.[31] Since before 2000, Oklahoma has invariably had lower residential rates than either Texas or the national average.

Annual peaks and troughs reflect normal seasonality in the region as loads peak in summer and early fall.[32] Figure 3-2 (next page) points up the relationship between SPP energy prices (in both the day-ahead and real-time markets) and gas prices. Gas is most often (not always) the generator fuel "on the margin," and the SPP power price tracks its price quite accurately. Figure 3-2 tells us another fact by omission: the cost of wind power, however we might measure it, is at best only randomly related to the SPP market price. If wind power is adversely affecting Oklahoma, it is not doing so as a result of any direct impact on prices in the region's energy markets.

Average power prices are of little help in diagnosing Oklahoma's energy problems. Nevertheless, average power prices are regularly used on both sides of the wind argument. A 2014 study by Susan Williams Sloan for the American Wind Energy Association (AWEA) claims that prices in the 11 states where wind power accounted for over 7 percent of electricity sales had fallen by nearly 1 percent since 2008. She noted that over the same interval, prices in the remaining 39 lower-wind states rose 7.8 percent and for the nation as a whole, they were up 3 percent from 2008.[33] *Forbes* columnist James Taylor claimed that Sloan's figures did not match federal data, and that, in fact, nine of Sloan's eleven states had experienced "dramatically

Figure 3-2
SPP Energy Prices and Gas Prices



Note: Line with diamond marks is SPP average day-ahead market price, square-marked line is real-time price, and triangle-marked line is index gas cost for the region.

Source: *SPP State of the Market Report*, Fall 2016, 3, https://spp.org/documents/46275/qsom_2016fall.pdf.

rising prices." The increases ranged from Colorado's 14 percent to Idaho's 33 percent, two otherwise highly dissimilar states – Colorado's power is largely coal, and Idaho's hydroelectric. The rest is an *ad hoc* explanation – Taylor claims that Texas' 19 percent drop is due to deregulation rather than wind (with no evidence for either) and Oklahoma's slight drop is due to its lack of a renewable power quota (but Texas is aggressively pushing renewables and Oklahoma has already met its legislated goal). Taylor goes on to say that generation investment in Oklahoma is determined by market forces rather that state government, a claim worth examining later.

Neither of these authors bothered trying to put the data through any statistical exercise, to say nothing of a credibility screen. Further, one fact may be far more important: power does not stay within the state where it was generated. Instead, increasing amounts are traded in competitive markets where all of the region's power sources compete and converge to a near-term energy price that (subject to qualifications) every producer gets. The price of energy in the Southwest Power Pool is a market price that varies with demand conditions, costs, weather, random outages and much more. Utility bills may simply be the wrong vehicles for comparing consumers' well-being.

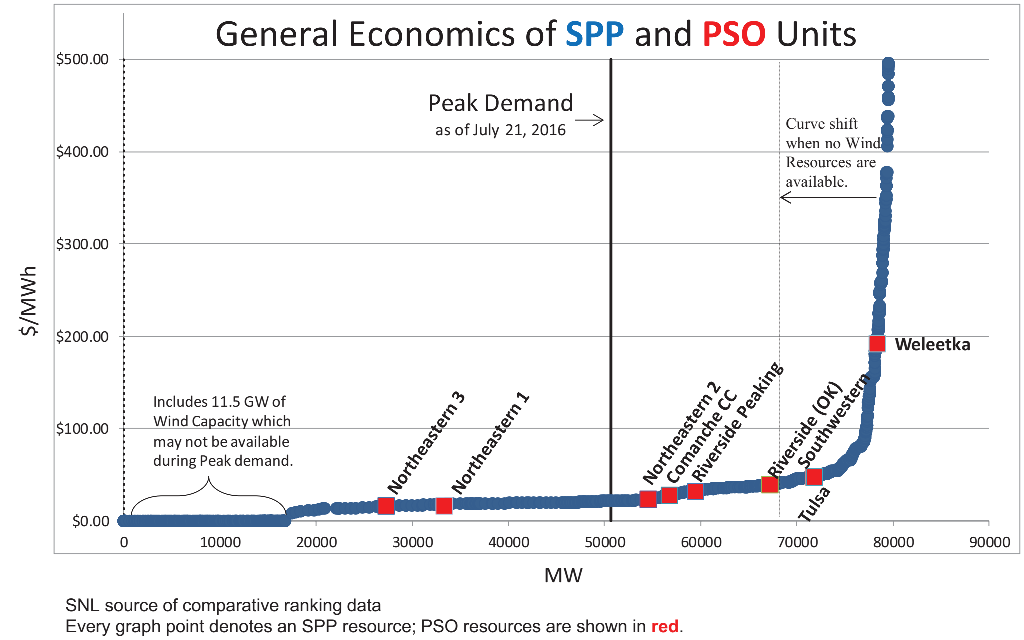
The arrival of renewables in both Oklahoma and Texas is undetectable in these graphs of average prices per KWh to residential customers. Commonly heard arguments that it is expensive power appear to be at variance with the price histories of these two of the three most wind-intensive states. The story of who pays wind power's cost and how it happens is complex. Let us first try to see if there is any more rigorous basis for determining market performance.

B. How the SPP Reduces Costs

Almost every market-driven increase in economic efficiency has, at base, a simple comparison. Generator owner A has an incremental (marginal) cost of 5 cents per KWh for fuel and owner B's plant has a marginal cost of 7 cents. One cannot tell exactly where any bargaining might terminate, but "split savings" is a common rule of thumb. If B pays A 6 cents for a KWh, B may consider it a windfall – power for only 6 cents that would have cost B 7 cents to produce. A may reason that it has made a shrewd profit as the seller, since A would have sold for any amount above 5 cents. Our trade has made both parties wealthier (with greater command over goods) than if they had remained apart and doggedly pursued "independence."

Figure 3-3 (next page) generalizes and refines this reasoning. It shows the "bid stack" that normally prevails in the Southwest Power Pool (SPP) market. Array the generators in order of their marginal costs ("merit order") and have them bid for the right to

Figure 3-3
Merit Order Dispatch: The Effects of Wind Generation



Source: Public Service Company of Oklahoma, *SPP Integrated Marketplace Update to the Oklahoma Corporation Commission*, Presentation Graphics (July 28, 2016).

sell power into the SPP. It is a competitive market (and a closely monitored one) that offers profit to every generator whose marginal costs are below the market price. That price is determined by equality of supply and demand, where supply is the total output of the operating generators and demand is the vertical line at 50,000 (gigawatt-hours) showing the total power that users wish to purchase. The diagram was created by Public Service Company of Oklahoma (PSO) and shows the capacities and marginal costs of most SPP generators. Those owned by PSO are shown in red.

Looking only at PSO, one can see what the company would do if it were isolated. To the extent possible, it would operate its generators in order of marginal cost, because doing otherwise would waste valuable fuel and other resources. If one of its Northeastern units is operable but not on line while its Southwestern unit is generating, the company could add to its profit while fulfilling its obligation to serve load by producing one MWh less in its Southwestern unit and one more in its Northeastern unit. But PSO might do even better if it could find a plant with a lower cost than Northeastern and strike a deal with the alternative to produce the power. The figure already shows a large number of generators who might trade with each other if aware of their opportunities. Those trades might necessitate other actions by the system operator, for example to reconfigure otherwise unrelated generators so that transmission lines between the two parties are uncongested.

Prior to mid-2014, today's SPP footprint was populated by 16 local interconnections that were responsible for facilitating power transactions of the types discussed above. Instead of trades within a footprint that stretched from Montana to Oklahoma, transactions in the SPP area were largely, but not completely, restricted to limited localities. Adding more potential buyers and sellers provided opportunities for both sides to capture more gains from exchange because the universe of transactions available to them would be larger. Since the full unification of the SPP grid, a massive number of cost-saving transactions have materialized. More than simple exchanges, the most valuable of them entail unit commitments for reliability that could not formerly flow securely across the smaller control areas of the past. Even on the scale of the electricity business, these gains are substantial. SPP was able to reduce online generating capacity (and thus fuel use) by 10 percent in 2014.

III. Performance and Wealth Transfers in the SPP Integrated Market

A. The Consequences of Economic Dispatch

It is relatively easy to compare the actual transactions and commitments in the SPP area with those that would have been feasible prior to the Integrated Market. "The first year of experience with the [integrated market] yielded savings over the SPP that averaged $660,000 per day or $240 million per year." SPP's Market Monitoring unit went on to expect net present value (NPV) benefits of $10 billion over the next 40 years, relative to NPV costs of $5 billion.[34] Inclusive of production cost savings, the NPV of all quantified benefits is expected to exceed $16.6 billion over 40 years, for a benefit-cost ratio of 3.5. Centralized unit commitment and dispatch alone allowed SPP to reduce online generating capacity by 10 percent in 2014 and a "somewhat lower amount" in 2015.[35]

Because SPP's institutions are still in process of adapting to these important changes in the operating and market environment the amount of long-run savings remains unclear, but it is well above zero. All of the savings discussed here result from reductions in the real resources that must be used to produce bulk power and maintain reliability. In particular, they do not include any possible gains to ratepayers and others that might arise because a greater presence of wind power reduces market clearing prices for all pool members and their customers.

At first sight, the effects of adding wind power to a grid like the SPP should hardly be different from adding any other power source to the grid. There are, however, difficulties that Figure 3-3 does not touch upon. Omitted from our earlier discussion were 11.5 gigawatts (thousands of megawatts) of intermittent generation capacity (mostly wind and a small amount of solar), whose operating costs are zero. Assuming that this power is bid into the market, it seems clear that the grid operator should accept it prior to any bids from any generators with non-zero marginal costs. Besides producing power at zero marginal cost, the wind resource confers another benefit on the grid: with wind generation, the supply curve in Figure 3-3 meets demand at a lower price and all consumers will enjoy lower energy costs per KWh.

In Chapter 2 we established that this happy story is seriously incomplete. Wind's intermittency implies that voltage and frequency of the grid can only be maintained if adequate reserves can be instantly called upon to maintain them. Since reserves are also necessary to cover the randomness of conventional generation, judging the desirability of wind power requires comparing its full cost with that of dispatchable fossil-fuel power. *In particular, the full cost of wind power serving the grid must include any additional reserves that would not be necessary if wind power did not exist.* This does not mean that wind power should be rejected out of hand, because dispatchable fossil-fuel power has its own costs (most importantly, fuel) that wind power does not.

In Chapter 2 we summarized a large and heterogeneous body of research that examined and attempted to estimate three costs peculiar to wind power: "profile costs" necessary to cope with increased randomness in the time patterns of production and consumption; "grid costs" associated with transmission that relieves distance constraints; and "balancing costs" of quickly altering production by dispatchable generators to maintain voltage and frequency. One survey of research results (described in Chapter 2) estimated that the total of these costs for a grid with 30 to 40 percent renewable penetration is in the range of 35 to 50 percent of the market price. On the other hand, if intermittent renewables are under 10 percent of a system's capacity, they add little to cost because the impact and likelihood of a renewable resource outage are quantitatively similar to those associated with a dispatchable one.

B. Application to the SPP Markets

Questions about the true cost and economic value of wind power are hard to pose and harder to analyze because the numbers are so dependent on particular situations. Ten megawatts of wind power with a capacity factor of 35 percent on a 1,000 megawatt grid pose no reliability problems worth mentioning, but there is some critical percentage of wind dependency that tilts the balance against it. The rhetoric of wind power often makes the economics harder to grasp. As typical examples,

consider these excerpts from testimony submitted to the Oklahoma Corporation Commission by Michael Goggin of The Wind Coalition:

> … Adding wind energy to the power system displaces the most expensive, least efficient, and most volatilely-priced power plants with a fixed-priced, zero-fuel-cost, zero-emission energy source. … Wind energy also benefits consumers by … reducing the use of the most expensive power plants, decreasing the market clearing price for all electricity purchased in the market. … These impacts are purely market driven, occurring exclusively because zero-fuel-cost wind energy is used to displace more expensive forms of energy. …wind energy and other low fuel cost resources [generally displace] the most expensive power plants [and] greatly [reduce] fossil fuel energy costs and pollution. … This "merit order" effect … drives down the market price for all electricity that is being purchased in the market, not just the wind electricity.[36]

In reality, adding wind energy to the system does not eliminate price volatility. It is better described as a way to conceal volatility. The cost of a dispatchable generator's fuel supply does vary as gas market conditions change (and this risk is often hedged by transactions in derivatives), but standard dispatching procedures can often render its output reliable at relatively low cost. The wind that fuels a turbine is highly volatile, capable of switching from full force to zero in seconds. If sufficient power to restore the grid to its former condition is unavailable, a wind unit's failure will bring down a regional grid as surely as the failure of a gas-fired generator.

To be dependable, a wind unit must have a fuel supply other than wind. The only difference is that its fuel supply is consumed by reserve generators that respond to random changes in wind. Adding a wind unit to the generation fleet reduces total power costs only if it does not impose net costs on the system (including those of building the wind generators), such as, if some inefficient generators only exist as defenses against the randomness of wind. It is also incorrect to argue that because all power systems require reserves the addition of wind generation adds few if any extra operating costs.

Below, we note the relationships between on-peak generation by wind and the reserve requirements imposed by various regional transmission operators. Intuitively and in fact, wind generators have a higher probability of going offline than dispatchable fossil-fuel units. There is at this time no generally accepted method for calculating the additional risk due to the presence of wind, a question closely tied to the appropriate reserve percentage that should be attached to it. It does not suffice, however, to argue that wind should be treated like a dispatchable source because every power system requires reserves. Absent countering reasons (e.g. possible harms from unabated pollution) the grid costs discussed in Chapter 2 may restrict investments in wind, or tax its availability. One way to discourage additional investment in wind is to reduce the capacity equivalence of its generation.

The merit order effect is also more complex than may first meet the eye. Prior to the introduction of wind resources on a large scale, all generators of importance were fossil-fueled and had high and roughly similar capacity factors. (Hydro and nuclear are special cases.) Before the coming of independent power producers in the 1980s and 1990s, regulated utilities owned almost all important generation.[37] A typical utility presented the costs of a proposed generator to regulators and received approval to collect those costs within rates that would be charged to customers who had no choice but to take service from the utility. The utility itemized the costs of generators in its rate application, but its customers saw only that they were required to pay these costs in the aggregate, for both good and not-so-good generation investments. The coming of non-utility generators did not change the basics: they competed to obtain contracts from utilities for generation that utilities would otherwise have built, but now the generator was not protected against risk by regulation. Only with the coming of Regional Transmission Operators would there be significant competition, in markets that determined generators' profits or losses (at least for non-utility generation).

Wind power changes this picture in important

ways. In the Southwest Power Pool and other regional markets, it generally "must-take," i.e. if it meets the Regional Transmission Operator's operating standards it has priority for acceptance in the stack. The wind bids (possibly zero or negative) are submitted with all others and a market price determined. Unlike other generators, the financial settlements for wind power are separate from the SPP price formation process, because they reflect prices set in pre-existing contracts between wind producers and utilities.

Wind is hardly a free resource after we consider both the investment costs in wind turbines and the added costs of maintaining reliability in a wind-heavy grid. A 2014 study of the SPP by the American Wind Energy Association estimated massive savings through all of the cost-saving and merit-order channels. It found that wind reduced the cost of producing power by $828 million and the cost of wholesale power purchases by $840 million.[38] The first of these calculations basically asked what costs (not prices) would have been if the most efficient uncommitted fossil-fuel generators had been called upon to produce the output that wind units were producing. The second is the merit order effect, which takes the difference between market prices (actual value inclusive of wind) and prices that would have prevailed in the absence of any wind resources. If any additional operating costs were incurred in order to manage wind's intermittency they are not included in the figures. Of similar importance is the fact that the study assumes that utilities pay nothing for the wind-generated power, a point that Goggin admits. In reality, wind generators are linked with utilities by contracts whose terms contain low prices because the federal Production Tax Credit subsidizes those low bids, a topic we consider below.

C. Operational Issues in the SPP

The SPP is at the forefront of Regional Transmission Operators in accommodating wind turbines and other intermittent generators while paying due attention to reliability issues. The organization distinguishes between "Dispatchable Variable Energy Resources" (DVER) and "Nondispatchable Variable Energy Resources" (NDVER). At the end of 2015 DVERs accounted for 46 percent of SPP's wind capacity and 44 percent of its wind generation.[39] A Dispatchable resource is defined as one "capable of being incrementally dispatched down by the transmission provider (i.e. the SPP)" and an NDVER is not. A DVER's output is under the control of the system computers, while a NDVER must be explicitly ordered to cut its output, known as a call for Out of Market Energy. The controllability of DVERs has helped in congestion management caused by high levels of wind penetration in the western part (largely Oklahoma) of the SPP. As of November 2015, SPP wind production was 3,700 GWh (gigawatt hour = 1,000 MWh), with 2,200 GWh from NDVERs.[40]

The increase in manageability of DVERs has substantially reduced concerns over congestion and allowed higher usable production from wind. These changes have been complemented by numerous transmission upgrades that have facilitated increased exports of power from wind-producing regions, "[c]reating a more integrated system with higher diversity and greater flexibility in managing high levels of wind production."[41] The existing rules are responsible for some operational problems, most importantly "price chasing" by NDVERs. This unexpectedly reduces (increases) output in response to lower (higher) locational prices, triggering transmission congestion and inducing uneconomic production.

Over the longer run, SPP can achieve additional operating economies, but its studies emphasize the continued reliance on fossil generators for meeting unexpected changes in system conditions. In particular, the substantial numbers of NDVERs in its footprint limit available ancillary service capacity and requires thermal resources and DVERs to provide available capacity for ancillary services. The fundamental problem is that renewables, most importantly NDVERS, impose costs on the system that are diffused throughout its footprint and included in general "uplift" payments folded into the charges of all participants. Other new problems may be on the horizon, regarding compliance with new North American Electric Reliability Council standards for reactive power that many wind producers are unaware of or unprepared for.[42]

IV. Looking Ahead

The SPP is in a singular situation regarding its underlying economics. Average reserve margins over its footprint (as measured by the North American Electric Reliability Council) are currently slightly below 30 percent, the highest of all RTO regions.[43] The historical reason is that prior to the SPP Integrated Market, its footprint covered 16 relatively independent control areas whose abilities to share reserves were limited. These reserve margins, in part, accounted for the low average all-in real time energy price of $23.48 per MWh. A 2014 study concluded that revenues would be insufficient to cover the costs of a coal-fired plant, a combined-cycle plant, or a combustion turbine, and the relevant comparison would be even more against building one of these plants in light of 2015's nearly-unchanged load and lower prices.[44]

At the same time, investment in wind generation continues strong, stimulated by the Production Tax Credit and other regulatory preferences detailed elsewhere. The questions before utilities and regulators are to determine the regional mixes of resources and market institutions that are consistent with reliability, and how to induce continuing resource adequacy. It may not be surprising to find that the range of opinions is wide, subject to great uncertainty, and, unfortunately, greatly politicized. The question of interest is one of equivalence, and the capacity factor estimates from Chapter 2 provide a numerical basis for determining equivalence between representative generators. In reality, this is where the argument begins.[45]

Capacity factor is a commonly used criterion but it is specialized to time and place. If an intermittent source is likely unavailable on-peak, a capacity factor that simply looks at the percentage of all hours it might operate can seriously mislead. What matters is availability, which in an integrated grid depends on the overall state of the system and not just local wind conditions. One expert from the American Wind Energy Association largely rests his case on the fact that capacity factors in the southeast (not exclusively Oklahoma) are often from 30 to 40 percent.[46] An environmental witness before the Oklahoma Corporation Commission begins with the truism that "[a] high capacity factor for a wind plant indicates that it produces more on average throughout the year," which leaves open the question of wind's contribution at peak hours. After noting SPP's determination that Oklahoma Gas & Electric's (OG&E) wind resources will receive 5 percent capacity credit unless otherwise determined, she presents data purporting to demonstrate that the true credit should be higher.[47]

The issue is critical for both reliability and the future evolution of wind power in Oklahoma. OG&E rejected wind in its proposal for compliance with the federal Clean Power Plan on reliability grounds, noting the Plan's "absolute requirement that OG&E replace the capacity provided by the existing coal units with a like amount of capacity in order to meet its load obligations."[48] Given that the SPP recognizes only 5 percent credit for wind generation, "10,000 MW of wind would be needed to replace just one of OG&E's 500 MW coal units."[49] The general inverse relationship between wind and load reinforces this reasoning because it too has a substantial random component.[50] Table 3-1 shows wind's capacity factor at annual SPP peak loads in recent years, which range from 5 percent to 34 percent. Another common comparison is between wind volatility and load volatility, and in the SPP the former is three times greater than the latter, a signal that wind induces higher adjustment costs due to its very presence.[51] The consequences for consumers are discussed in the next chapter.

Table 3-1
Wind Generation Capacity Factor at SPP for Peak Hours

2009	34%
2010	25%
2011	16%
2012	5%
2013	5%
2016	14%

Note: 2014 – 2015 unavailable
Sources: 2009 – 2013: SPP 2013 State of the Market Report, 34-36.
2016: "SPP notches new peak load records as heat wave strikes region," Utility Dive, July 26, 2016, http://www.utilitydive.com/news/spp-notches-new-peak-load-records-as-heat-wave-strikes-region/423254/.

Chapter 4
The Bottom Lines

I. Introduction

Thus far, we have determined that the Southwest Power Pool, which subsumes Oklahoma, is a remarkable economic institution. It organizes power supplies and demands much like a competitive market and has proven capable of integrating intermittent generation on an unprecedented scale while maintaining reliability. It is already clear that wind generation substantially affects prices by its very presence, and that the full cost of adding wind generation is not faced by its owners. In this chapter, we examine the behavior of wind generation in more detail. Doing so requires delving into the complex subsidy system that has been the principal impetus for wind's growth. We first consider federal policies, whose impact is the largest and most important. State policies are quantitatively less important, but their local impacts are more than worthy of further scrutiny.

II. The PTC and Accelerated Depreciation for Wind Facilities

A. Their Provisions

Wind generation competes with other power sources on a less-than-level playing field as a result of federal (and to a lesser extent, state) subsidies. The two most important federal subsidies are the Production Tax Credit and accelerated depreciation for wind facilities. The ten-year Production Tax Credit (PTC) for wind generators pays approximately $23 per MWh produced, irrespective of the market value of the power (including negative prices). Under a 2016 phase-down law, the credit drops to 80 percent of its value in 2017, 60 percent in 2018 and 40 percent in 2019.[52]

The PTC is quite significant. It is a subsidy to power producers – generaters – but it is represents a large percentage of the *retail* price of electricity. In 2015, a megawatt-hour (MWh) of electricity in Oklahoma cost $79 at the retail level. Thus, the PTC represents nearly a third of the retail price, and a much higher percentage of the wholesale price.[53] In Texas, the average wholesale price of electricity in January, 2017 ranged from about $25 to $35, so that wind producers, as discussed in Chapter 2, can offer their production at grossly lower prices compared to other producers.[54]

The Institute for Energy Research has estimated that between 2005 and 2014, subsidies under the PTC and related programs totaled $18.5 billion, of which an estimated $1.09 billion flowed to Oklahoma. By their estimate, Oklahomans' share of total taxes spent on the subsidy was $194 million, leaving the state's wind power producers, many of whom are not in Oklahoma, with net benefits of $894 million. Twenty states, by the Institute for Energy Research's math, had positive net effects, and Oklahoma ranked third among them, behind Iowa and Texas.[55]

Accelerated depreciation is determined by federal tax provisions, amended for wind and some other renewable power sources. Most technologies are under rules that depreciate them over 20-year lifespans, but in 1986 wind and some other renewable plants were allowed to claim 5-year amortization.[56] This change defers tax liabilities for six years and loads them into the remainder of the plant's lifespan, reducing their present value. A representative calculation lowers net present tax costs for wind by approximately 10 percent.[57]

B. The Economic Effects

These tax preferences help create some seemingly anomalous characteristics of contracts between wind generators and utilities that purchase their output. The first anomaly is that, unlike almost any other power contracts, most wind agreements carry fixed prices for the contract duration. Contracts for the output of fossil-fuel generators invariably carry automatic adjustment provisions intended to protect both their owners and power purchasers from volatility. By contrast, most wind generators have few variable costs of operation and little need for such treatment. The second anomaly is that

The True Cost of a Tax Credit

Per Bylund

A proper analysis of a specific government policy looks not only at the intended effects, but also at the costs (including unintended consequences), and long-run effects. That is, what otherwise would have been, but for the policy, must be weighed against the policy's actual results. Economists decry the effects of the minimum wage, selective excise taxes, selective tax abatements, subsidies, and much regulation, not for what they gain, but for the costs these policies produce, which economists believe, often outweigh the gains. For a tax credit, economists do not only consider the direct opportunity costs of the credit, or for what these funds could otherwise have been used, but what is lost in innovation and unrealized economic growth.

A tax credit produces unrealized opportunities as I discuss in my book, *The Seen, the Unseen, and the Unrealized: How Regulations Affect Our Everyday Lives* (Lexington, 2016). The implementation of a tax credit causes other socially beneficial activities to not happen. This loss, tragically unrecognized by many policy makers but that must be considered for policy to be truly fruitful, primarily consists of (a) innovations that will no longer be pursued within the industry where the tax credit applies, and (b) innovations in other sectors of the economy due to capital being redirected toward the subsidized sector. The latter impact includes direct effects as investors and firms move to the subsidized industry, but also indirect effects as suppliers, customers, employees, and other stakeholders are affected primarily by having available fewer options than otherwise would be the case.

First, a tax credit constitutes an implicit subsidy and therefore an artificial gain for the subsidized activity, which increases its production. This impact is obvious. Tax credits for wind power clearly yields windmills and the economic activity that surround them. Tax credits for the film industry witness movies more likely to be made where the credits are to be had. While these may be beneficial for political or social reasons, the foregone tax funds are redistributed from some other governmental activity that then becomes artificially underfinanced. The state's programs therefore suffer by the same amount of credit offered, unless taxes are increased, in which case the burden is placed on taxpayers.

Second, a tax credit artificially increases the profitability of certain types of actions and therefore attracts capital from elsewhere in the economy. Exactly from what activities these funds are redirected cannot be known beforehand as this depends on individual entrepreneurs' investment decisions although some reasonable speculation is possible. For example, because wind has enjoyed so much investment and innovation due to tax credits, money that might have been invested in developing other technologies such as power cells is diverted. Innovations that might have occurred, which could be even more beneficial than wind power, do not occur.

Third, a tax credit crowds out private investments in the targeted industry that would otherwise have taken place, especially those investments that do not perfectly fit the rules that regulate the credit. This harms innovations within or related to the industry, and can set technological advances on a non-maximizing unintended path for the future that can suffer from higher costs in the longer term. With respect to wind, we learn that investment in newer gas power plants can result in greater efficiency, greater reliability, and even lower emissions under some circumstances, than wind. But investment is turned from gas toward wind under current policy.

Fourth, the specific rules for getting the tax credit incentivize specific behaviors and therefore change actors' behavior. Incumbent firms become more profitable if they can benefit from the tax credit, which means they may redirect funds toward securing the tax credit. These funds would otherwise have been used in production (of goods, not tax credits) and are therefore a loss of production. OG&E, whose expertise is in generating reliable power and transmitting it to customers, has had to divert talent to integrating less-reliable wind.

The last two issues suggest that we cannot truly know whether a tax credit actually increases the quantity of the favored good or service produced over time, as (in the short term) private funds are redirected from production to securing tax credit eligibility and (in the longer term) away from innovations that would be socially beneficial but do not fully comply with the rules of the tax credit.

In all, these effects suggest that the outcome of a tax credit are highly uncertain. Output in the affected industry increases to the extent new businesses enter and existing businesses increase the quantity produced above what they otherwise would have produced. On the other hand, there are output losses within that same industry as funds are redirected toward complying with the stated rules for the tax credit, including employing legal expertise. This may also have effects on the quality of goods produced, as it is perceivable that lower-quality output can increases quantity and qualify the firm for greater tax credits.

In addition, there is a social loss due to the redistributive effects of (a) the tax credit itself and (b) funds redirected from elsewhere in the economy to take advantage of the artificially higher profitability. This translates to a social loss in other sectors of the economy, which likely exceed the gains intended with the tax credit, because economic actors are not responding to value as determined in a market, but to artificial value as determined by politics.

wind generators are generally paid only for their actual power production. Wind's intermittency means that a plant cannot have value as a standby facility as if it were a fossil-fueled unit that could be called upon at any time to operate.

Next, Oklahoma graphically demonstrates that the wind power industry is relatively easy for generation owners to enter. Besides investible funds, new generation requires construction permitting, which could entail environmental issues and questions of need for the facility in states that require such a showing. Wind has an advantage. The typical wind purchase is competitively negotiated with the transmission-owning utility in its area. A fossil-fuel generator will only negotiate an interconnection contract with the utility if it has a reasonable expectation of recovering its variable costs (usually from sales in the RTO's energy markets or under bilateral contracts) and earning a competitive return on its capital. A wind generator is

less constrained because its breakeven is determined by the subsidies it receives. At times in some regions a wind generator will compete against others by offering its power at negative prices, which can be profitable as long as the price is less than the PTC.

It appears clear that wind's typical fixed-price power purchase agreements advantage it as a source, and what arguments have appeared to the contrary are weak. Supporters have claimed that the purchase-related distortions are countered by different subsidies that favor conventional power plants.[58] Comparing the Energy Information Administration's estimated subsidies for wind and fossil fuels, the latter is negligible relative to the former.[59] The Department of Energy's *Wind Technologies Market Report* claims that wholesale power prices do not fully account "for the environmental and social costs of fossil generation," disregarding the importance of environmental controls on fossil plants and costs of integrating wind integration discussed above. Finally, the report notes that prices in wind power purchase agreements are generally fixed and known while wholesale power prices are "short-term and subject to change." This is an odd assertion. Long-term fixed-price contracts are rarities in the business world, because they impede the parties' abilities to adjust for changes in risk as market conditions change. In power markets, they are byproducts of regulatory politics that throws risk on to captive consumers, rather than tools for prudently adjusting to market realities.[60]

III. Federal Policies in the Long-run

A. Investment and Markets

The regulatory treatment of wind entails transfers of important integration costs from investors to household and business power users. Given the large amount of wind capacity which already must be accommodated, incremental additions are unlikely to pass cost-benefit tests. The PTC benefits wind investors and possibly consumers of power from wind generators, but does so primarily by shifting the subsidy costs to taxpayers in general. A survey of research on intermittency costs suggests that an additional wind unit may, in some of today's markets, contribute to the grid as little as half the value of the same dispatchable capacity, and the costs grow disproportionately with further increases in wind capacity.[61] Therefore, federal subsidies for wind power are remarkably perverse. Instead of penalizing intermittency, they reward additional investments in intermittent generators whose output is of lower value to the market.

Adding significant amounts of wind capacity can also bring inefficient investment choices by utilities and investors in conventional generators. Large wind additions may require that the territorial utility invest in plants designed for cycling to anticipate wind generation randomness when it would be long-run least-cost from the standpoint of the system to build baseload capacity that may also burn a different fuel. History suggests that this has yet to happen in Oklahoma, and the changes that have come with the SPP Integrated market may continue to allow postponements and workarounds. There are, however, newer SPP transmission projects whose major purpose has been and continues to be decongesting lines in western Oklahoma. As transmission capacity becomes cheaper to utilize, the additions will reduce delivered power prices over an important part of the SPP's footprint. Transmission additions, however, are multi-functional, simultaneously able to increase reliability, decrease congestion, and improve preparedness for future developments. Without more detailed study of system operations and power supply planning we cannot allocate the costs to these different uses or isolate dollar values for the benefits.

B. Constraints on Growth

The SPP has acknowledged a final constraint on wind power: measures to stabilize voltage that will be costly to implement, increasingly so if wind continues to grow as a proportion of all generation. In 2009 the pool's area (excluding territory added with opening of the Integrated Market) contained 2,000 megawatts of wind generation. By the end of 2016, almost 17,000 megawatts were online throughout the SPP, with 2,000 more expected to open in 2017.[62] Operating the grid with 60 percent

wind capacity will require substantial investments in voltage support, which (unlike fossil-fuel plants) wind cannot produce consistently. An SPP report indicated five major transmission projects that would be necessary. Recent reports about SPP's operation with half of its power generated by wind should not be taken at face value.[63] The system was at minimum load (prior to 5 AM), and SPP did not release data on ready fossil-fuel reserve capacity which could have taken over the load in the event the wind died down.

Another dimension of the long-run investment problem is related to both capacity equivalence described in the previous chapter and minimizing the costs of adjustment to wind's randomness. Specifically, an individual wind turbine in a region must be operated to mitigate incessant fluctuations in its output due to wind speed changes. Looking at a group of generators in an area, it is possible that these small fluctuations often cancel out. If so, interconnecting the plants and operating them as a unit may yield substantial savings. The issues involved include defining the benefits of coordination and comparing them with the costs.

The most important study in this area examined actual and possible interconnections within a region of the Electricity Reliability Council of Texas (ERCOT). There was some good news and some bad. The authors found, perhaps unsurprisingly, that plants with higher capacity factors cost less to integrate into a unit, and that most of the average savings in a 20-plant area ($3.76 per MWh generated) could be achieved by integrating no more than 8 of them. The less favorable news was that savings from interconnection fluctuated substantially from year to year, i.e. the variability cost of a given plant would be high in one year (relative to the group) and low in the next.[64] Here, however, we have a policy suggestion: assuming these results are general, increased interconnections among wind installations would be cost-effective projects that generation owners would have incentives to build *without* subsidies.

C. The Effects on SPP Markets

All grids are built to handle most reliability problems thought to be reasonably probable. When wind first arrived on the SPP footprint, the grid had capacity and capabilities to handle small volumes of it. SPP's abilities can and did grow as its markets evolved. Excess capacity makes the introductory stage easier. But now, the problems come with adaptation to further growth in wind, because if the generation and transmission slack in the grid is gone, adjustments become more costly. The SPP's current ongoing grid buildout is in large part a recognition that wind is here to stay as a power source. Most of that buildout would probably not have happened absent wind. The funding of wind-necessitated grid expansions is done by formulas that may not match the actual costs and benefits to the various parties who incur the expense.

Wind impacts not only generation and transmission operations, it also affects energy prices. Here the SPP runs into a deeper problem. Absent a contract with a utility (whose value also depends on market events and behavior), a non-utility power producer will usually earn at least part of its profits and provisions for continuing investments as a "merchant" generator, whose fortunes depend on the evolution of the SPP price. Wind generation may now play the role of a bad surprise. Merchant generators often depend on extreme days for much of their profitability. Thus, generators in Texas' ERCOT may bid up to $9,000 per MWh under some system conditions. This occurs very rarely, on days when power is extremely scarce, but extreme prices may mean the difference between financial viability and losses for generators.[65]

The coming of wind into the SPP and other RTOs now becomes problematic, particularly given SPP's substantial legacy reserves from the days prior to the Integrated Market. As wind further reduces on-peak prices, existing fossil-fuel generators (who provide highly reliable power) may find themselves insolvent. As they do, they may trigger a regulatory crisis, since regulators cannot simply expropriate their assets to maintain reliability. As this happens it can only discourage others from capacity investments they would have ordinarily made.

We are witnessing these events in a number of RTOs, which are adopting different strategies to

resolve the problem. Most have an administrative exception to market pricing in the form of "must-run" arrangements. In a typical case, an otherwise uneconomic generator which must operate to ensure reliability will be put under contracts that allow cost-based rates that make up the owner's revenue shortfall. In reality, these exceptions are complex and may set bad precedents for other generators who may wish to plead the same sort of hardship.

The risk of future under investment in reliable energy generation has a straightforward logic. In a competitive market for energy a generator's income will be mostly from sales at marginal cost, save in times of acute shortage. If generators expect markets will only cover their variable costs but not their fixed costs, they will be understandably reluctant to invest, which may lead to "boom-or-bust" situations, credit issues, and unstable prices. Several eastern RTOs have perceived this problem and have attempted more general strategies in the form of markets for "installed capacity."

With an Installed Capacity market, an RTO's governors (who have their own financial interests) decide on the volumes and types of new capacity investments, which will be constructed by auction winners. These markets for capacity are markets only in a narrow legal sense, with most competition foreclosed and important resource decisions made politically rather than by competitive interactions. In practice, capacity markets protect incomes of inefficient generators by foreclosing competition from other potential suppliers. As this happens, market institutions often give way to gaming and end runs around rules which, not surprisingly, entails the setting of still more rules. The Pennsylvania-New Jersey-Maryland Interconnection's capacity market has thus far transferred 93 percent of its funding to owners of existing generators and 1.8 percent to investments in new units.[66]

Economists have often opined about the difficulties of planning a complex economy, allocating its resources efficiently and equitably, and provisioning it with investments for the future. Tweak one subset of it, as has been done by regulations that encourage inefficient development of wind generation, and watch the effects balloon. Wind's effects on market prices adversely impact investments in reliability (conventional power plants), and some new fix will be needed.

The promise of competitive power markets is being lost, and the problem centers on wind resources that do not pay their way. Economists know this quite well, in theory and now in practice in the SPP.

As the federal PTC ramps down and, perhaps, is eliminated, and Oklahoma's own favorable tax treatment for wind turbines expires, we will finally begin to see the true economics of wind power take over.

The likelihood is that some windturbines will persist at least as long as they can be operated without significant component replacement due to wear and tear. Despite Oklahoma's unusually persistent (but still highly uncertain) winds, new investment in wind farms will likely cease. Some existing wind farms, as they wear out, will cease operating and be dismantled. A few might persist and be maintained for decades.

This unhappy scenario could radically change if electrical storage technology were to make a giant leap forward. No one, outside of maybe a few insiders, anticipated fracking technology and the sea change in oil and gas production costs it would usher in. Perhaps there is a technology on the cusp of working that most of us know nothing about. Another possibility for radically changing the scenario above would be a climate policy shift even more radical than that represented by the Obama administration.

Until something like the events just described occur, the true economics of wind energy simply do not support the current level of investment in wind power. Instead, investment is driven by government policy at the federal level, which makes it cost-feasible, and by states who have mandatory renewable portfolio standards. The growing consensus seems that wind subsidies are causing problems economically without helping the environment.

IV. Summing Up Oklahoma State Wind Policy

(This section written by Byron Schlomach)

This paper has shown:

- Today, Oklahomans enjoy the benefits of an excess supply of electrical energy. There does not appear to be the need for construction of new generation facilities of any type in the near future.
- Even from the perspective of a believer in climate change, the environmental benefits from converting all of Oklahoma's energy generation to wind is infinitesimal.
- The construction of wind turbines in Oklahoma has been driven by the federal production tax credit, not any state policy.

Despite these facts, Oklahoma has two costly policies in place to encourage the construction of wind facilities in Oklahoma. These are the Zero-Emissions Tax Credit and the 5-Year Manufacturers' Ad Valorem Tax Exemption. The first is a production tax credit. For every megawatt-hour produced by a wind farm, the state effectively pays $5 to the wind generator during its first ten years of operation. In 2014, this credit cost the State of Oklahoma $58 million in credits for wind and it is estimated to cost over $88 million in 2016.[67]

The ad valorem (property tax) exemption for wind generators, which cost the state almost $30 million in 2016, exempts a windmill from property taxes for its first five years of operation.[68] Since the state does not tax these wind turbines, it reimburses property-taxing local governments who must grant the exemption when it is claimed. As of January 1, 2017, no new wind turbines will be allowed to claim this exemption, but all wind turbines in operation by the end of 2016 can claim it.

As of 2016, the two state tax programs in Oklahoma that specifically benefit wind generation cost the state $118 million. What's more, the tax credit for wind is expected to jump to over $130 million in 2017 and then to $253 million in 2018.[69] This last amount alone is over three percent of the state's general revenues. The additional difficulties caused by this foregone revenue are all-the-more acute when one considers that Oklahoma's tax privileges for wind do almost nothing to incentivize greater investment in that industry over and above what the federal subsidies encourage.

One of the arguments in favor of wind-generation investment subsidies is that property taxes from wind turbines will contribute to school funding throughout the state, since the bulk of school district property tax revenues are rolled into statewide formula funding. These depreciating assets, with falling property values, have been exempted, until recently, from property taxes during the five years when they are most valuable – when they are new. Extrapolating from the cost of the ad valorem exemption and the amount of megawatt capacity that is currently in place and exempt from property taxes as well as county data, it appears that wind generators pay about $6,000 per megawatt of generation capacity in property taxes.[70] If 2016's 6,645 megawatts of wind generation capacity were paying property taxes of $6,000 per megawatt of capacity,[71] the total would be $40 million, only half of which would accrue to school formula funding, with rest going to general state revenue. While $20 million is not a trivial amount of money, it is a mere one-third of one percent of total spending in public education.

The total amounts of wind tax credits are significantly larger than the amount of income tax revenue that wind generators would contribute to the state if they were not enjoying the credit. This is because the credits are refundable, which means that the credit can be greater than the income tax that the credit eliminates. If a kilowatt hour of wind power is sold in the wholesale market for three cents, there is no way the wind producer would pay five cents in income tax if the credit did not exist, but the credit is still five cents and the state pays that entire amount to the generator as a "refund." Being extraordinarily generous, let us suppose that 75 percent of the $88 million in estimated tax credits for 2016 represent the income tax revenues that those wind generators would have paid. That means wind generators would have contributed $66 million to the state's coffers, not quite one percent of current state general revenues. Less than half of that would have accrued to schools.

The bottom line from this analysis is that an argument in favor of subsidizing wind power in the name of increased revenues for schools is largely meaningless. A few districts might have benefited a great deal, especially with respect to contributions to their tax rates to cover bonded indebtedness. However, if wind turbines were fully paying property and income taxes now, the most that would accrue to schools statewide is around $50 million, enough to provide a $1,000 average pay raise to teachers, but less than one percent of what schools currently spend.[72] In actuality, wind turbines directly contributed, perhaps, $5 million in property taxes to schools and a trivial amount in income taxes in 2016. Wind turbines would have likely been built in this state in response to only the federal production tax credit, the fact of Oklahoma's wind, and ready access to the SPP grid. Realizing this, the ad valorem exemption actually cost school districts $15 million in 2016 in lost tax revenues without attracting wind turbines.

To summarize:

- Oklahoma reached its voluntary renewable portfolio standard some time ago.
- Wind power does not provide environmental benefits to the state.
- Wind power does not provide significant financial resources to K-12 schools.
- The Oklahoma Zero-Emissions credit presents significant risk to the state's fiscal outlook.

End Notes

[1] Any generator has a design or "rated" capacity defined as the maximum sustainable megawatt-hours of energy it can produce in an hour, usually just called megawatts. Since the generator often does not run at full capacity, its hourly output is measured in megawatt-hours. A generator's capacity factor is the ratio of average hourly output to its capacity. These matters are discussed further in the Chapter 2. The definitions apply to both fossil-fuel and renewable generators.

[2] The legalities reflect the politics of time and place. The U.S. Department of Energy calls small hydroelectric facilities renewable, but not large ones that are more likely to arouse environmental concerns. States have their own renewable fuels, including such odd ones as Pennsylvania's scrap coal.

[3] The description of the text applies to utilities that are corporate ("investor-owned") entities. Other organizational forms exist. Approximately 20 percent of electricity is supplied by branches of municipal governments which contribute a fraction of their receipts in lieu of taxes to local governments whose operations and rate-setting are usually much like those of corporate systems. Another 10-odd percent of the nation's power is generated and distributed by rural electric cooperatives which often came into being when no one else wanted to serve a territory.

[4] A summary of Oklahoma's approach to avoided cost appears in *Public Service Company of Oklahoma et al v. State Oklahoma Corporation Commission*, Oklahoma Supreme Court Nos. 100,123, 100,152 (June 21, 2005), http://caselaw.findlaw.com/ok-supreme-court/1467472.html.

[5] Oklahoma's IRP provisions can be found in: Rachel Wilson and Paul Peterson, *A Brief Survey of State Integrated Resource Planning Rules and Requirements* (Cambridge, MA: Synapse Energy Economics, April 28, 2011), http://www.cleanskies.org/wp-content/uploads/2011/05/ACSF_IRP-Survey_Final_2011-04-28.pdf.

[6] Barbose, Galen, *U.S. Renewable Portfolio Standards, 2016 Annual Status Report* (Berkeley, CA: Lawrence Berkeley National Laboratory, powerpoint, LBNL 1005057,2016), https://emp.lbl.gov/sites/all/files/lbnl-1005057.pdf.

[7] National Council of State Legislatures, "State Renewable Portfolio Standards and Goals," website, December 28, 2016), http://www.ncsl.org/research/energy/renewable-portfolio-standards.aspx.

[8] They go under a variety of names, including independent system operator (the New York and California ISOs), power pool (the southwest, including Oklahoma), interconnection (Penn-Jersey-Maryland) and reliability council (Texas).

[9] Rew, Bruce, *SPP Integrated Marketplace Benefits*, power point presentation, 2016, 6, http://www.occeweb.com/pu/SPP_ElectricTransmission/OCCUpdateJuly28_SPP.PDF.
A list of SPP members and details on membership appears at https://www.spp.org/about-us/members/.

[10] Ibid, 6, 7.

[11] As noted in Chapter 1, both excessive and insufficient amounts of power relative to load will result in regional blackouts unless corrected in a fraction of a second.

[12] Hirth discusses the various costs in more detail and says more about their importance for power system planning. Lion Hirth, "Why Wind Is Not Coal: On the Economics of Electricity Generation," *Energy Journal* 37 (July 2016), 1 - 28. A more comprehensive discussion of these matters in the German context appears in https://www.agora-energiewende.de/fileadmin/Projekte/2014/integrationskosten-wind-v/Agora_Integration_Cost_Wind_PV_web.pdf.

[13] Environmental externalities such as health losses due to fossil generation are not reasons to offer any subsidies specialized to wind. Economists almost uniformly agree that to avoid market distortions and inefficiencies any taxes or subsidies should be as general as possible. Environmental compliance is itself built into the cost structures of and there is no evidence that a special treatment for wind generators is warranted.

[14] Joskow, Paul L., "Comparing the Costs of Intermittent and Dispatchable Electricity Generation Technologies," *American Economic Review* 100 (May, 2011), 238 – 241.

[15] Here we are disregarding important locational issues (the transmission lines may lose some of the power coming from a distant source) and "ramping" problems (the generator being called on may not be able to change its output instantly).

[16] A 7.5 percent cost of capital is assumed.

[17] At a capacity factor of 40 percent (a better approximation for Oklahoma) the intermittent plant wins. Later we present more on the sensitivity of such estimates to particular assumptions.

[18] Frank, Charles, *The Net Benefits of Low and No-Carbon Electricity Technologies* (Washington, DC: Brookings Institution Global Economy and Development Working Paper No. 73, May 2014).

[19] EIA has produced 2016 updates for most of the figures, which differ little from 2013 except for solar photovoltaic collectors whose prices have fallen substantially and are discussed later.

[20] Frank (endnote 18) presents on-peak and off-peak figures for each type of generator. Because peak and off-peak issues are of secondary importance for the current study, the table simply shows averages. Frank also examines hydroelectric and nuclear generators, which we omit because in most relevant cases they will not be under

consideration.
[21] Critics have argued that Frank's conclusions stem in part from his assumptions of capacity factors for wind and solar that are below other estimates. These are considered later.
[22] Frank, *The Net Benefits of Low and No-Carbon Electricity Technologies*, 5 (See note 8 in that paper.) Frank also presents results assuming that the alternative is a combined cycle plant on-peak and a single-cycle on-peak. This yields more modest net avoided emissions of 695.7 lbs. of CO_2, an amount that reflects the absence of a coal unit to be displaced.
[23] Frank (endnote 18) derives similar results under the assumption that the new unit displaces CC off-peak and SC on-peak.
[24] Overnight costs are expenses for materials on an assumption that a new plant materializes instantly ("overnight") from them. Capital costs reflect amortization of the overnight total, on an annual basis. This method allows us to separate material and financing costs.
[25] Note that statistically we are assuming that the plant failures are independent events, i.e. the probability that plant A will fail does not depend on whether one or more of the other plants has failed or not. This is not always reasonable, for example if the plants are located in the same neighborhood and all are exposed to bad weather simultaneously.
[26] See Frank *The Net Benefits of Low and No-Carbon Electricity Technologies,* 11 (See note 8 in that paper). The math he uses (based on a continuous Beta distribution) will typically give a number of plants that is not an integer, which can be rounded up or down as the situation warrants. Frank calculates the number of plants whose capacity factors leave the system deficient under 1 percent of the time.
[27] EPA, "The Social Cost of Carbon," website, https://www.epa.gov/climatechange/social-cost-carbon.
[28] Frank, *The Net Benefits of Low and No-Carbon Electricity Technologies*, abstract, unnumbered.
[29] Hunt, Hannah, "Fact Check: The electricity grid relies on diversified sources," *Into the Wind: the AWEA Blog*, February 27, 2017, http://www.aweablog.org/fact-check-electricity-grid-relies-diversified-sources/.
[30] Taylor, George and Thomas Tanton, *The Hidden Costs of Wind Electricity: Why the Full Cost of Wind Generation Is Unlikely to Match the Cost of Natural Gas, Coal or Nuclear Generation* (Washington, DC: American Tradition Institute, December 2012), 26, http://www.atinstitute.org/wp-content/uploads/2012/12/Hidden-Cost.pdf.
[31] The text uses residential figures on an expectation that these are of more interest to policy makers. Because the regulatory process attempts to allocate payments to a class of customers according to the cost of service to that class, we will see correlations over time between amounts paid by different customer classes.
[32] Texas price is above the national average in 2006 – 2008, a consequence of extreme weather-related gas prices over the period.
[33] Sloan, Susan Williams, "Fact Check: New Analysis Rebuts Heartland's Bogus RPS Claims," *Into the Wind: the American Wind Energy Association Blog*, February 13, 2014, http://www.aweablog.org/fact-check-new-evidence-rebuts-heartlands-bogus-rps-claims/.
[34] Southwest Power Pool, *The Value of Transmission* (Little Rock, AR: Southwest Power Pool, Jan. 26, 2016) 5, 11 – 12, https://www.spp.org/documents/35297/the%20value%20of%20transmission%20report.pdf. These figures do not include possible savings that stem from power purchase agreements with wind power generators.
[35] Southwest Power Pool, *2015 State of the Market* (Little Rock, AR: Southwest Power Pool, August 15, 2016), 3, 48, https://www.spp.org/documents/41597/spp_mmu_state_of_the_market_report_2015.pdf. More details on the unit commitment process appear in this document at 48 – 55.
[36] Responsive Testimony of Michael Goggin Submitted on Behalf of the Wind Coalition, Corporation Commission of Oklahoma Cause No. PUD 201400229, Dec. 16, 2014, 13-14.
[37] Municipal utilities and co-ops are under different governance arrangements.
[38] Goggin Testimony, see note 7. The study cited in the testimony was not available to the author.
[39] SPP, *2015 State of the Market*, 42 – 43.
[40] Ibid. The increase in NDVERs was largely to territorial annexations in the north that increased the size of the Integrated Market.
[41] Ibid, 44. SPP goes on to note the importance of inadequate ramping capability to accommodate sudden changes in wind.
[42] "SPP Regional Entity: Wind Farms not Meeting New Standards," *RTO Insider*, March 16, 2017, https://www.rtoinsider.com/spp-markets-operations-policy-committee-33022/.
[43] FERC, *Summer 2016 Energy Market and Reliability Assessment*, May 19, 2016, Slide 4, https://www.ferc.gov/market-oversight/reports-analyses/mkt-views/2016/05-19-16.pdf.
[44] SPP, *2015 State of the Market*, 15, 17, 25.
[45] A usable summary of the capacity equivalence debate appears in Michael Milligan and Kevin Porter, "The Capacity

Value of Wind in the United States: Methods and Implementation," *Electricity Journal* 19 (March 2006), 91 – 99.
[46] Testimony of Michael Goggin on Behalf of the Wind Coalition, Oklahoma Corporation Commission Cause No. 201400229, December 16, 2014, 6.
[47] Direct Testimony of Jennifer Tripp on behalf of Sierra Club, Oklahoma Corporation Commission Cause No. 201400229, December 16, 2014, 37.
[48] Oklahoma Gas & Electric Company, *Integrated Resource Plan* (Oklahoma City, OK: OG&E, 2014), 48, http://www.occeweb.com/pu/ogeirp2014.pdf.
[49] Ibid.
[50] The text does not discuss one potentially important determinant of credit values: An RTO's decisions are made by a choice process that runs on both data analysis and institutional politics. The author has investigated these issues in the context of other RTOs and concluded that political considerations have led different RTOs to institute different rules about virtual trading discussed in Chapter 1. He does not have sufficient familiarity with the SPP to make any statements about its decision processes. See Robert J. Michaels, "Electricity Market Monitoring and the Economics of Regulation," *Review of Industrial Organization* 32 (No. 2, 2008), 197-216.
[51] Southwest Power Pool, *2013 State of the Market* (Little Rock, AR: SPP, May 19, 2014), 34-36, https://www.spp.org/documents/22573/2013%20spp%20state%20of%20the%20market%20report.pdf. Additional problems in operating the wind-heavy SPP grid are discussed in a report by consultants at Charles River Associates, who note that its transmission topology is such that higher wind penetration need not lead to lower marginal prices and lower energy costs for consumers. Charles River Associates, *SPP WITF Integration Study, Final Report*, Jan. 4, 2010.
[52] Under other provisions of the law wind turbine owners have had additional options. Under the American Recovery and Reinvestment Act of 2009 they could choose an investment tax credit or a Section 1603 cash grant from the U.S. Treasury in lieu of the PTC if they began construction before the end of 2011.
[53] "State Electricity Profiles," Energy Information Administration, website, https://www.eia.gov/electricity/state/.
[54] "Regional Wholesale Markets: January 2017," Electricity Monthly Update, Energy Information Administration, website, https://www.eia.gov/electricity/monthly/update/wholesale_markets.cfm.
[55] Institute for Energy Research, *Estimating the State-Level Impact of Federal Wind Energy Subsidies* (Washington, DC: IER, November 2015), http://instituteforenergyresearch.org/wp-content/uploads/2015/11/Estimating-the-State-Level-Impacts-of-Federal-Wind-Energy-Subsidies.pdf.
[56] "Modified Accelerated Cost-Recovery Systems (MACRS)," website, ENERGY.GOV, https://energy.gov/savings/modified-accelerated-cost-recovery-system-macrs.
[57] Taylor and Tanton, *The Hidden Costs of Wind Electricity*, 26.
[58] Wiser, Ryan and Mark Bolger, *2015 Wind Technologies Market Report* (Washington, DC: U.S. Department of Energy, August 2016), 66, https://energy.gov/sites/prod/files/2016/08/f33/2015-Wind-Technologies-Market-Report-08162016.pdf. This is the most recent annual report available.
[59] U.S. Energy Information Administration, *Direct Federal Financial Interventions and Subsidies in Energy in Fiscal Year 2013* (Washington, DC: EIA, March 2015), https://www.eia.gov/analysis/requests/subsidy/pdf/subsidy.pdf.
[60] Ibid. The authors of the *2015 Wind Technologies Market Report* also appear to favor fixed-price contracts on grounds that Department of Energy forecasts of future gas prices are often wrong. Since virtually all forecasts turn out wrong, this point is hardly compelling. See Robert J. Michaels, "Reducing Risk, Shifting Risk, and Concealing Risk: Why Are There Long-Term Gas Contracts?" in Jerry Ellig and Joseph Kalt (Eds.), *New Horizons in Natural Gas Deregulation* (Westport, CT: Praeger, 1996), 195 - 208.
[61] Hirth, Lion, "Why Wind Is Not Coal: On the Economics of Electricity Generation," *Energy Journal* 37 (July 2016), 1 – 28.
[62] Southwest Power Pool, *2016 Wind Integration Study* (Little Rock, AR: SPP, January 5, 2016), https://www.spp.org/documents/34200/2016%20wind%20integration%20study%20(wis)%20final.pdf.
[63] Travers, Julia, "Wind Power Sets New Record: Briefly Provides Majority of Electricity for 14-State Grid," *EcoWatch*, website, February 20,2017, http://www.ecowatch.com/wind-power-record-2274179157.html.
[64] Warren Katzenstein and Jay Apt, "The Cost of Wind Power Variability," *Energy Policy* 51 (December 2012), 233-43.
[65] Surendran, Resmi, William W. Hogan, Hailong Hui, and Chien-Ning Yu, *Scarcity Pricing in ERCOT*, FERC Technical Conference Proceedings, web document, June 27 – 29, 2016, 4, https://www.ferc.gov/CalendarFiles/20160629114652-3%20-%20FERC2016_Scarcity%20Pricing_ERCOT_Resmi%20Surendran.pdf
[66] Andrew Kleit and Robert Michaels, *Does Competitive Electricity Require Capacity Markets? The Texas Experience* (Austin, TX: Texas Public Policy Foundation, February 2013), 4, https://www.texaspolicy.com/library/doclib/2013-01-RR02-ResourceAdequacyElectricityMarkets-CEF-RMichaelsAKleit.pdf.

[67] "Current Oklahoma State Wind Subsidies," The Windfall Coalition, website, http://www.thewindfallcoalition.com/facts.html#hightlights2.
[68] Oklahoma Tax Commission, Ad Valorem Division, *Exempt Manufacturing Reimbursements 62 O.S. Section 193: Annual Report to the Oklahoma Tax Commission* (Oklahoma City, OK: State of Oklahoma, 2016), 14, https://www.ok.gov/tax/documents/2016FiveYrAnnualReport.pdf.
[69] "Current Oklahoma State Wind Subsidies" The Windfall Coalition, website, http://www.thewindfallcoalition.com/facts.html#hightlights2.
[70] From what we could discover by enquiring of county assessors, some wind projects are taxed as high as a little over $12,000 per megawatt of capacity. Others were taxed less than $6,000 per megawatt. Using our best guess as to the megawattage that enjoying the property tax exemption and the total exemption payouts from the state, which is known, it appears the exemption is worth about $6,000 per megawatt. Wind units owned by OG&E are not separately valued and noted by assessors.
[71] Monies, Paul, "Oklahoma Moves Up to Third Place in State Rankings for Wind Power," *The Oklahoman*, February 10, 2017, http://newsok.com/article/5537538.
[72] Schlomach, Byron and Baylee Butler, *Raising Teacher Pay: Things to Consider and Do* (Oklahoma City, OK: 1889 Institute Policy Analysis, March 2017), 2, http://nebula.wsimg.com/8bb72a8448db00663758eba441eb3b2d?AccessKeyId=CB55D82B5028ABD8BF94&disposition=0&alloworigin=1.

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