The economic benefits of wind energy in the Southwest Power Pool

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Introduction

Wind energy provides the Southwest Power Pool region (Kansas, Oklahoma, Nebraska, and parts of New Mexico, Texas, Arkansas, and Missouri) with $2.8 billion in societal benefits per year. These benefits include reducing the cost of producing electricity, protecting consumers from increases in the price of other fuels, and reducing public health costs by eliminating harmful pollution. By protecting against electricity and fuel price increases and reducing the need to operate the most expensive power plants, wind energy provides the region's consumers with $1.2 billion per year in gross benefits. These benefits are in addition to the thousands of jobs and billions of dollars in economic development wind energy brings to the Southwest Power Pool (SPP) region.

One MWh of wind energy in SPP, enough to power a typical home for an average month, provides over $109 in economic benefits to society and $47 in benefits to consumers on average. These are calculations of gross benefits, without accounting for the cost of wind generation. However, given that recent utility wind power purchase agreements in SPP are priced well below this amount,[1] and that the cost of the renewable production tax credit is very small,[2] the benefits of new wind generation in the region greatly exceed the costs. These results therefore indicate that adding new wind generation in SPP provides large net benefits to society and consumers.

Wind power's recent cost reductions have played a critical role in making wind into a major source of net benefits. In the last several months, both the Department of Energy[3] and Wall Street investment firm Lazard[4] released data documenting that the cost of purchasing wind energy has fallen by more than half over the last five years. Wind's cost reductions are due to technological advances, such as larger wind turbines providing access to higher quality wind resources at lower cost, as well as the economies of scale associated with creating a wind industry supply chain in the United States, which now has more than 500 manufacturing facilities in 43 states.

These cost reductions translate directly into savings for consumers.[5] As a recent example, a wind purchase by the Grand River Dam Authority in Oklahoma is expected to save its customers about $50 million over the project's lifetime.[6] Iowa utility MidAmerican Energy announced that a new wind purchase would "stabilize electric rates over the long term by providing a rate reduction totaling $10 million per year."[7] Three wind projects under construction for Southwestern Public Service, an SPP utility, will save $590 million in fuel costs over 20 years.[8]

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[1] Pricing information for recent SPP wind power purchase agreements can be found at the following links:
http://emp.lbl.gov/sites/all/files/2013_Wind_Technologies_Market_Report_Final3.pdf (page 59)
http://www.utilitydive.com/news/why-utilities-are-betting-on-wind/201066/

[2] $23/MWh renewable production tax credit (PTC) divided by 2.5 (the typical wind project life is 25 years, while the PTC is only received for 10 years) equals $9.2/MWh. $9.2/MWh over 10 years discounted at 2.6% Treasury yield (as of September 2014) equals $8/MWh in cost to the U.S. Treasury. $8/MWh times 0.25 estimated deadweight loss/marginal excess burden of federal income taxation (0.25 used here http://www.rff.org/RFF/Documents/RFF-DP-11-02.pdf at page 11) equals a $2/MWh societal cost of the PTC.

[3] http://emp.lbl.gov/sites/all/files/2013_Wind_Technologies_Market_Report_Final3.pdf, page 59

[4] http://www.lazard.com/PDF/Levelized%20Cost%20of%20Energy%20-%20Version%208.0.pdf

[5] For additional utility quotes and links to more than a dozen studies from states, grid operators, and other experts documenting how wind energy reduces electricity prices, see http://awea.files.cms-plus.com/AWEA%20White%20Paper-Consumer%20Benefits%20final.pdf

[6] http://www.grda.com/with-potential-to-save-customers-50-million-over-the-projects-lifetime-grda-signs-100-mw-renewable-energy-purchase-agreement-with-apex-clean-energy/

[7] http://www.midamericanenergy.com/wind_news_article.aspx?id=634

[8] http://amarillo.com/news/local-news/2013-07-10/xcel-customers-save-590m-wind-deals

As shown in the table below, wind energy creates large societal benefits by displacing the most expensive, least efficient, and most volatilely-priced power plants with a fixed-priced, zero-fuel-cost, zero-emission energy source. Consumers also benefit from wind energy protecting against electricity price spikes and reducing the use of the most expensive power plants. All of these impacts are purely market driven, occurring exclusively because zero-fuel-cost wind energy is used to displace more expensive forms of energy.

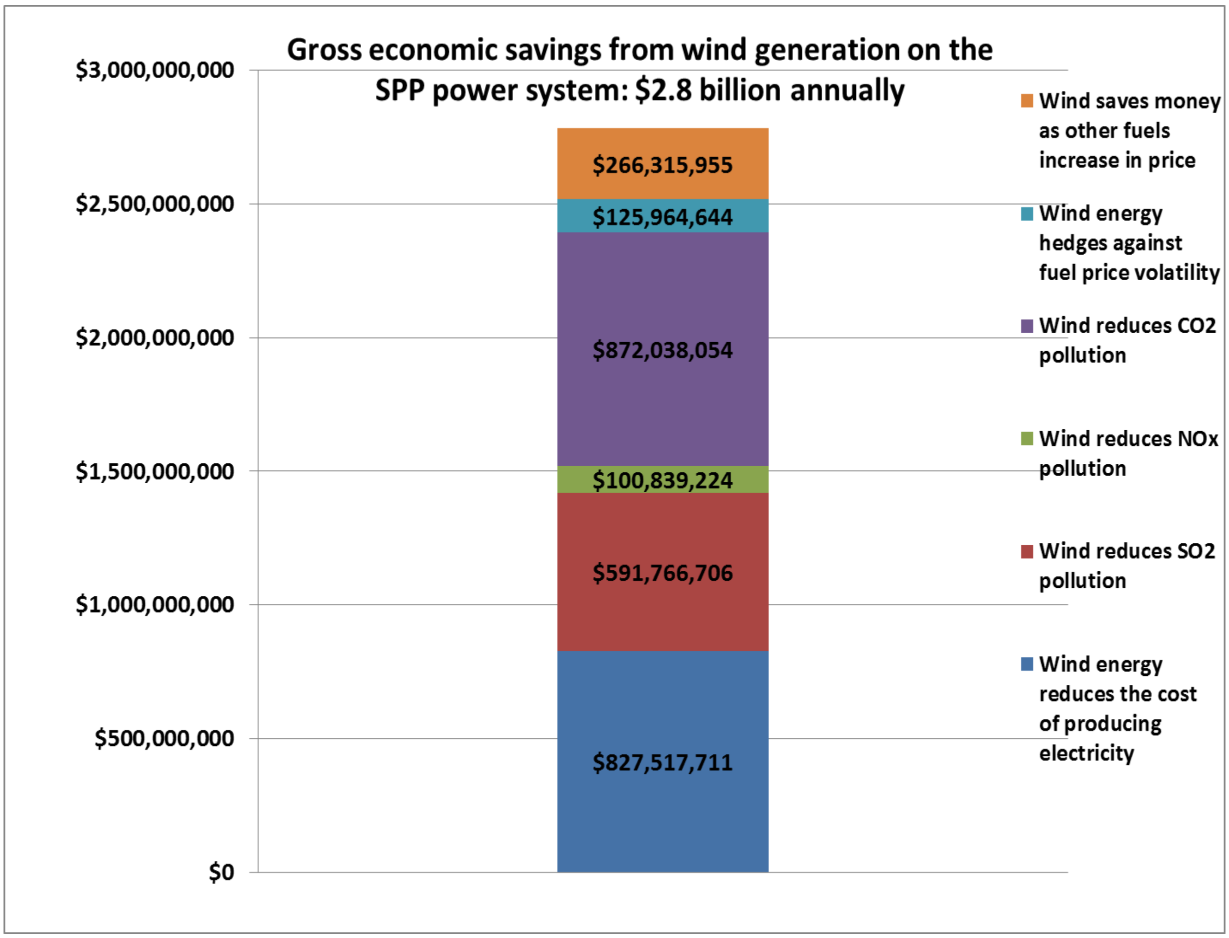
	Wind energy	Power plant displaced by wind energy	Wind's gross economic benefit in SPP, per year
Cost	**Zero fuel cost**	Highest fuel cost	**$828 million**
Fuel price stability	**Fixed price**	Volatilely-priced	**$392 million**
Pollution	**Zero emissions**	Least efficient	**$1.565 billion**

Last year, wind energy provided around 10.8% of the electricity produced in SPP. This report uses hourly wind output data from SPP, power plant production cost data, and a government power system pollution modeling tool to calculate the societal and consumer benefits provided by wind energy in the region. The results show that adding new wind generation in SPP provides significant benefits to society and consumers, and that these benefits will only grow over time.

Results

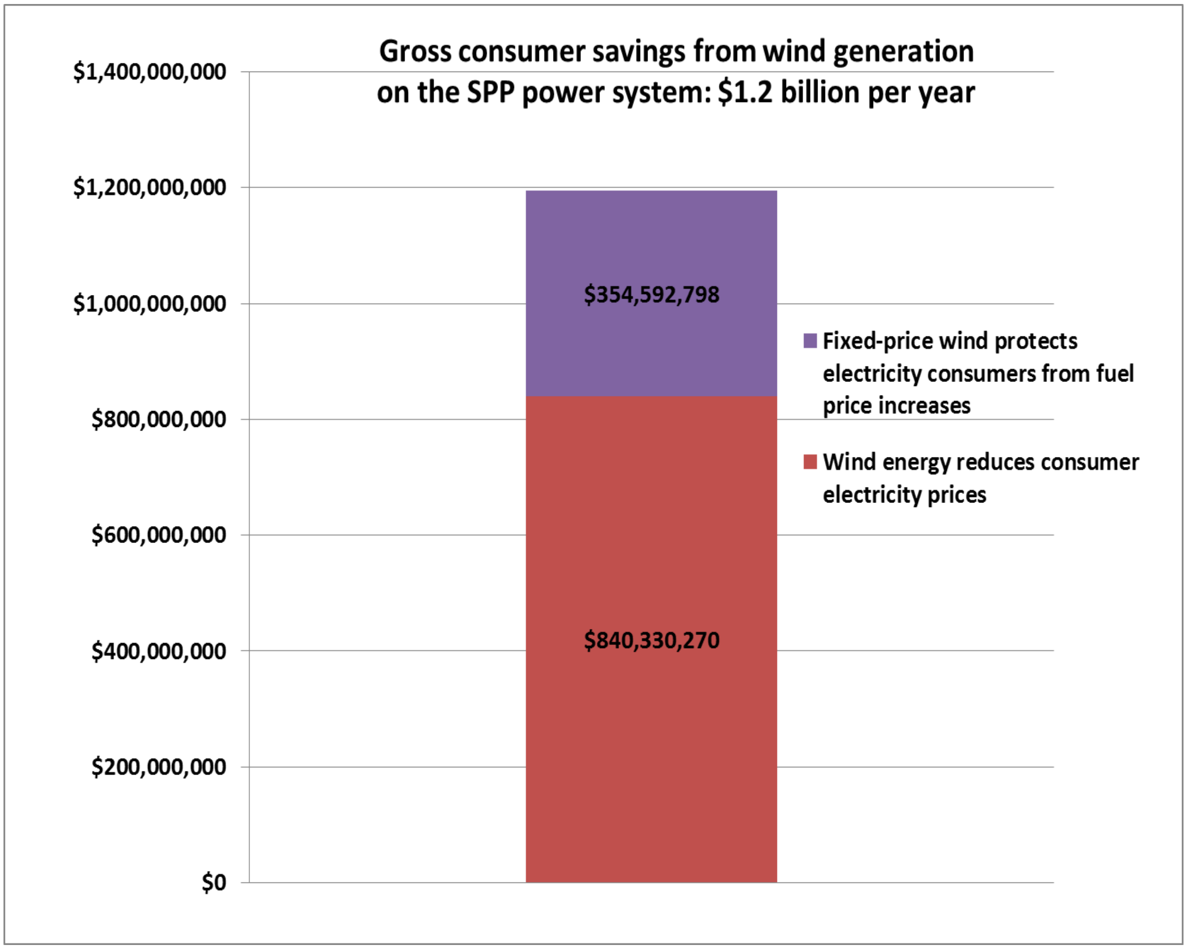
Wind energy provides a number of benefits to society and to energy consumers. On the Southwest Power Pool (SPP) power system, wind energy's gross benefits to society total around $2.8 billion annually, about half from reducing the cost of producing electricity and about half by reducing harmful air emissions of sulfur dioxide, nitrogen oxides, and carbon dioxide. Through market mechanisms, wind energy also provides consumers with gross benefits of nearly $1.2 billion annually by protecting against electricity and fuel price increases. The following tables and charts summarize the societal and consumer benefits wind energy provides on an annual basis in SPP.

Societal benefits



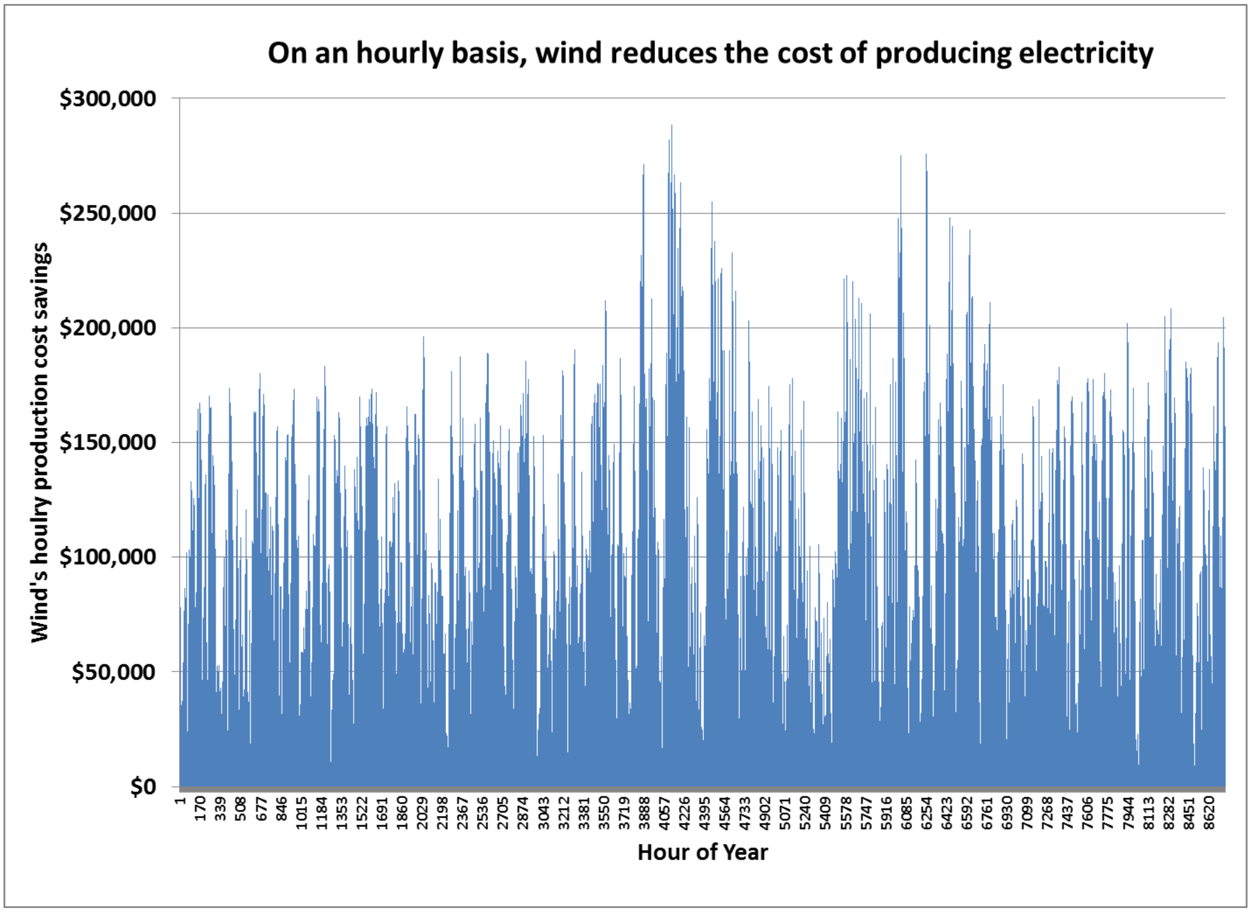
Consumer benefits

Wind energy provides large benefits to energy consumers. Through market mechanisms, wind saves SPP consumers $1.2 billion annually by protecting against short- and long-term increases in energy prices.

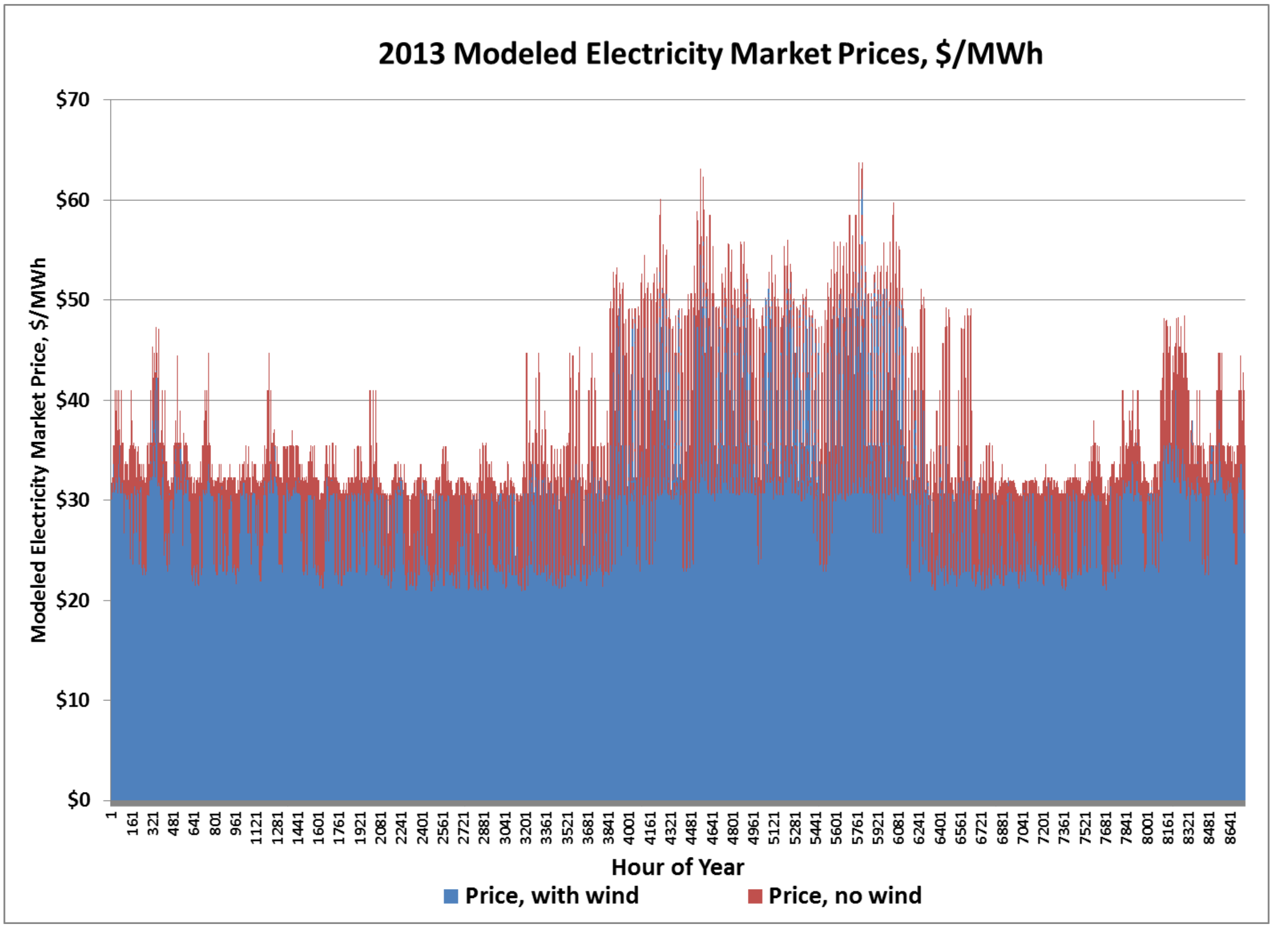


An hourly look at wind's benefits

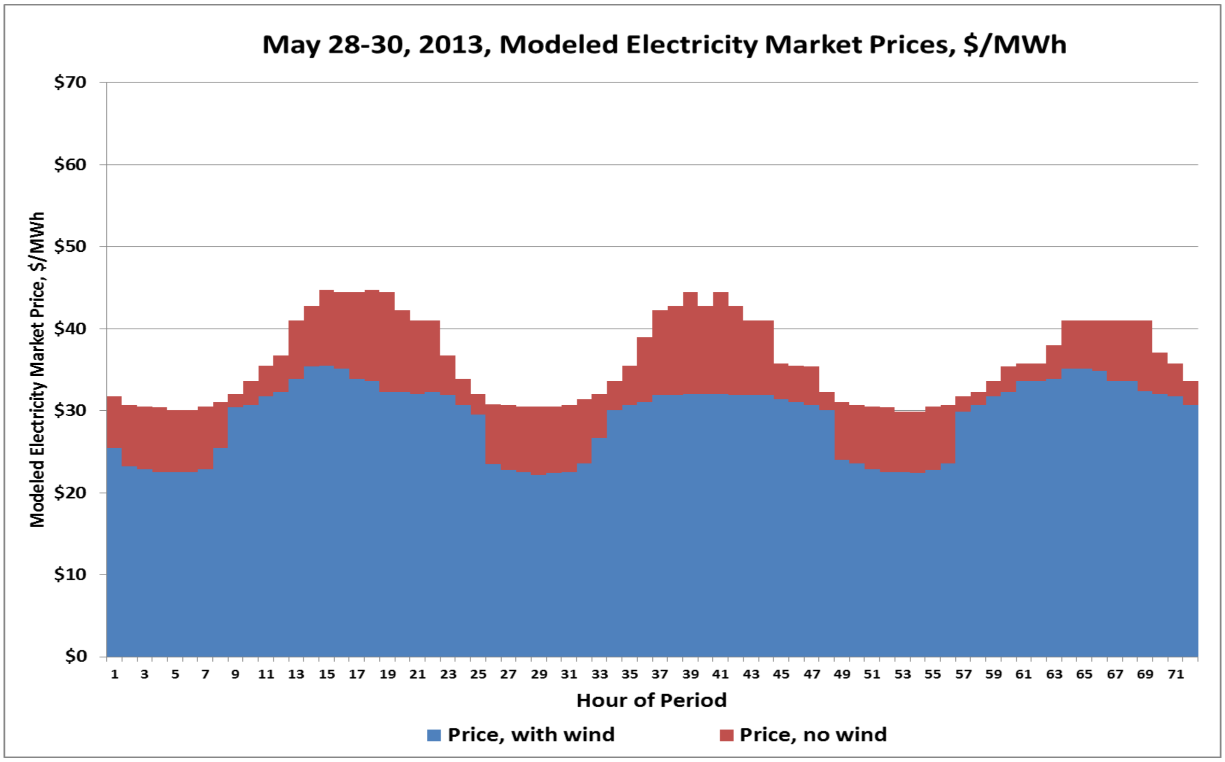
Wind energy reduces electricity costs and hedges against electricity and fossil fuel price spikes. As shown in the charts below, wind energy protects SPP consumers by reducing the cost of producing electricity in nearly all hours of the year.

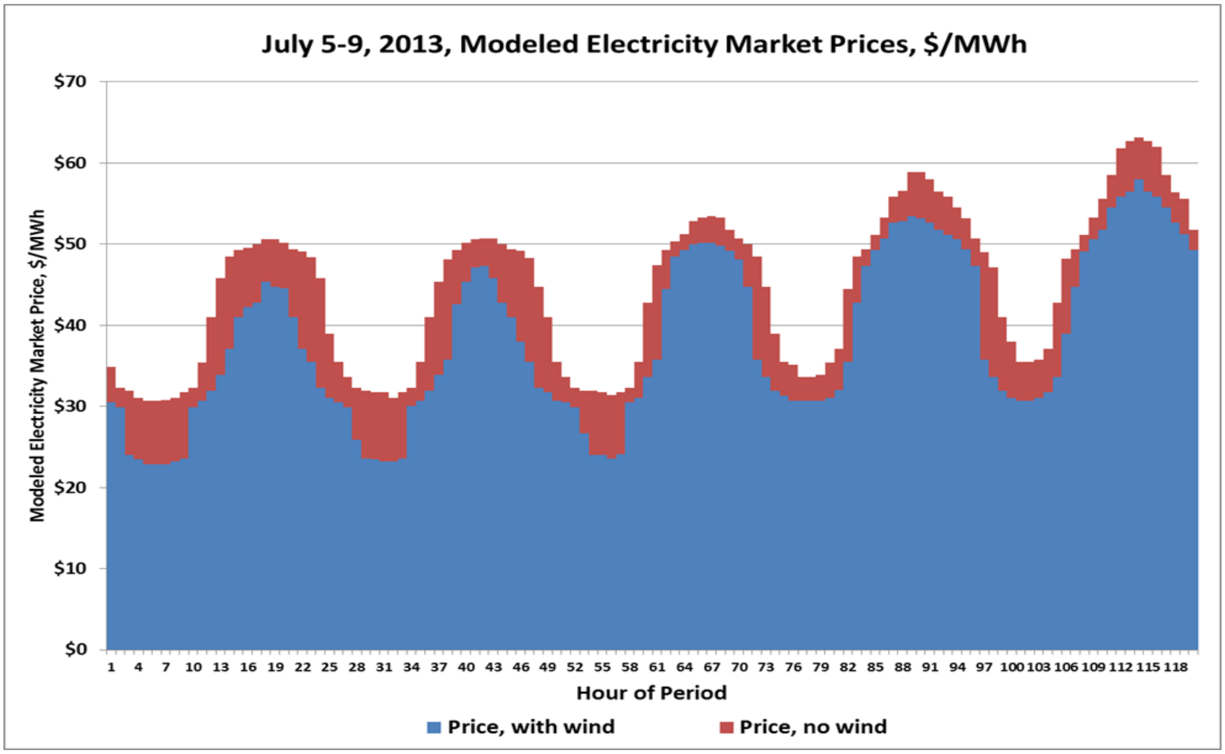


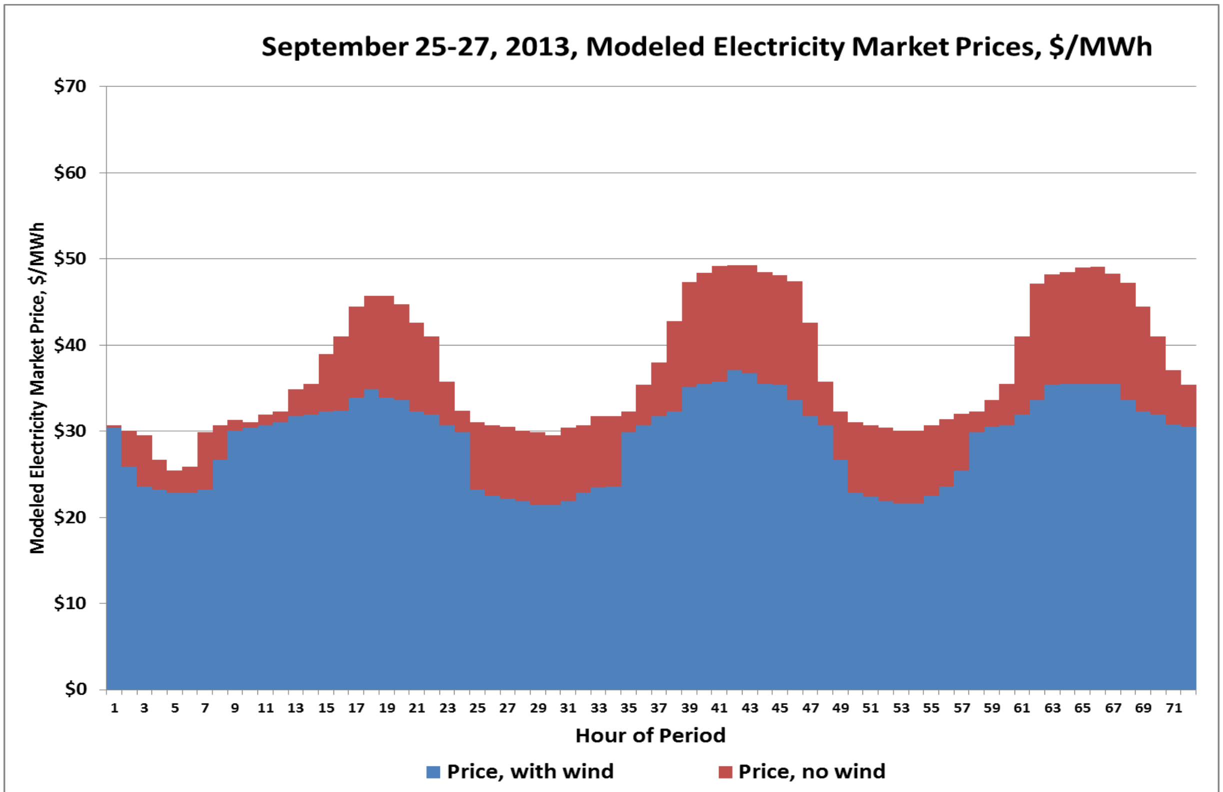
Wind energy reduces the impact of electricity price spikes, as shown in the following chart. Wind energy also benefits consumers throughout the year by reducing the use of the most expensive power plants, all through market mechanisms.

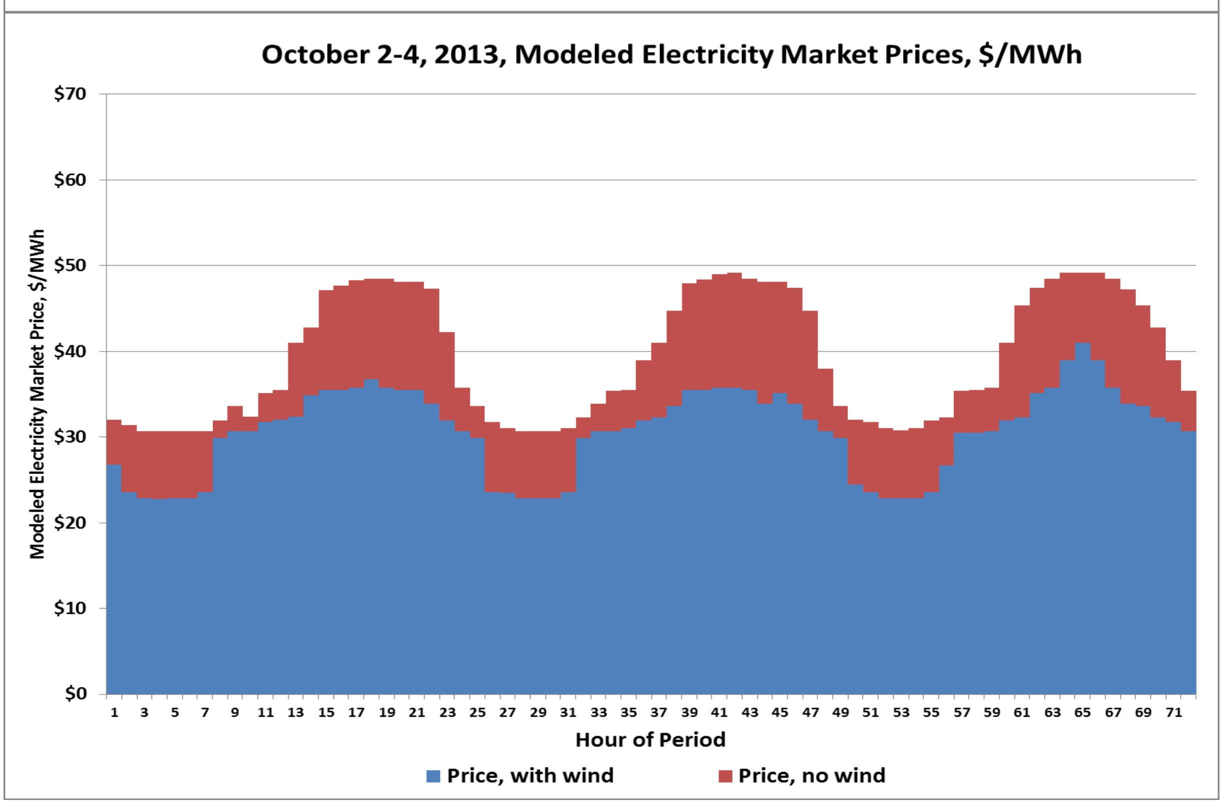


Wind's consumer benefits are particularly pronounced during hours in which the market experiences price spikes. Wind's impact during some of the largest electricity price spikes of 2013 are highlighted in the following charts. This trend can also be seen in the full hourly data for all months included in Appendix C.






September 25-27, 2013, Modeled Electricity Market Prices, $/MWh
Modeled Electricity Market Price, $/MWh
$70
$60
$50
$40
$30
$20
$10
$0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59 61 63 65 67 69 71
Hour of Period
Price, with wind
Price, no wind


October 2-4, 2013, Modeled Electricity Market Prices, $/MWh
Modeled Electricity Market Price, $/MWh
$70
$60
$50
$40
$30
$20
$10
$0
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59 61 63 65 67 69 71
Hour of Period
Price, with wind
Price, no wind

Background

Wind energy benefits society and consumers through a number of mechanisms:

Societal benefits

1. Wind reduces the cost of producing electricity. Zero-fuel cost wind energy directly displaces the output of the most expensive and least efficient power plants that are currently operating. Like the functioning of almost any market, electricity market operators rank power plants based on their cost of producing an incremental amount of electricity. They then start by using the least-cost power plants first, and then move up the supply curve until they have enough electricity to meet demand. The power plant rank order is based on the cost for that plant to produce an incremental amount of electricity, so only fuel costs and variable operations and maintenance costs are considered. As a result, wind energy and other low fuel cost resources are always used first, and they are used to displace the most expensive power plants that otherwise would have operated. Because that is almost always the least efficient fossil-fired power plant, adding wind energy greatly reduces fossil fuel energy costs and pollution.

2. Wind energy reduces pollution. Pollution from fossil-fired power plants harms public health and the environment in a number of ways, and these costs are not currently reflected in electricity market prices. This analysis accounted for how wind reduces the cost to society from only three forms of pollution: health-harming sulfur dioxide, smog-forming nitrogen oxides, and the greenhouse gas carbon dioxide.[9] Accounting for the other negative externalities of fossil fuel use, such as air pollution from mercury and other toxins, water use, water pollution, and other impacts, would make wind's benefits even larger.

3. Wind energy hedges against fuel price volatility. Wind energy also protects consumers from uncertainty about the price of fossil fuels. The risk of fossil fuel price volatility makes consumers worse off, and one of the most effective tools for reducing that risk is by diversifying the energy mix with zero fuel cost wind energy. Wind energy helps to hedge against volatility in the price of fossil fuels much like a fixed-rate mortgage protects consumers from interest rate fluctuations. In the second chart on the following page, the grey area indicates the large uncertainty about future fuel prices. The cost of this uncertainty is distinct and in addition to the cost of the expected increase in fuel prices, indicated by the black line in the chart. As explained in the Methodology section, to separate the cost of this uncertainty from the cost of expected increases in fuel prices, experts simply find the premium at which forward gas contracts, which set a fixed price for future delivery, trade relative to current projections of gas price increases. This market price premium indicates the value provided by a contract providing a certain future price.

4. Fixed-price wind energy becomes an even better deal as other fuels increase in price over time. Even if fossil fuel prices were known with perfect certainty, their prices are still expected to increase over time and those costs are borne by consumers. Almost all of a wind plant's costs are fixed up front, and many wind power purchase agreements remain at the current cost for the life of the contract. In contrast, the cost of conventional generation changes significantly based on fuel costs, and these costs are passed on to consumers. While the cost of the uncertainty itself was accounted for above, one must also account for the fact that fossil fuel prices are expected to increase, and that this will tend to increase wind's production cost savings in the future. The growing value provided by SPP's existing wind generation as other energy sources increase in price is illustrated in the following two charts. The first chart shows that the benefits of existing wind energy increase over time as fuel prices increase, as the societal and consumer benefits of wind expand at higher fuel prices.

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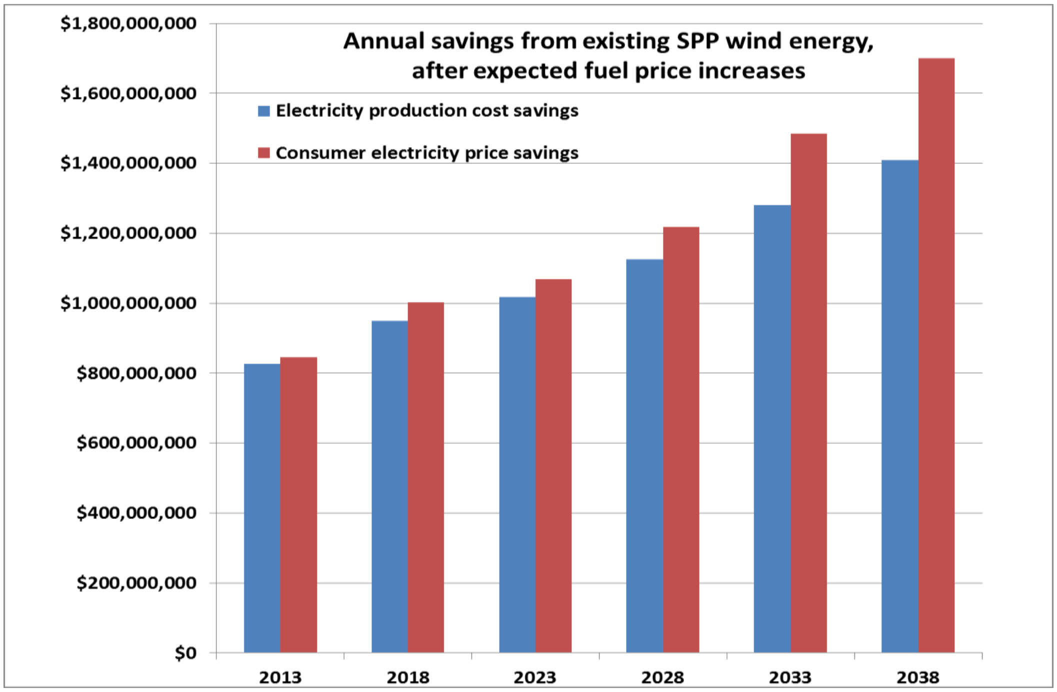
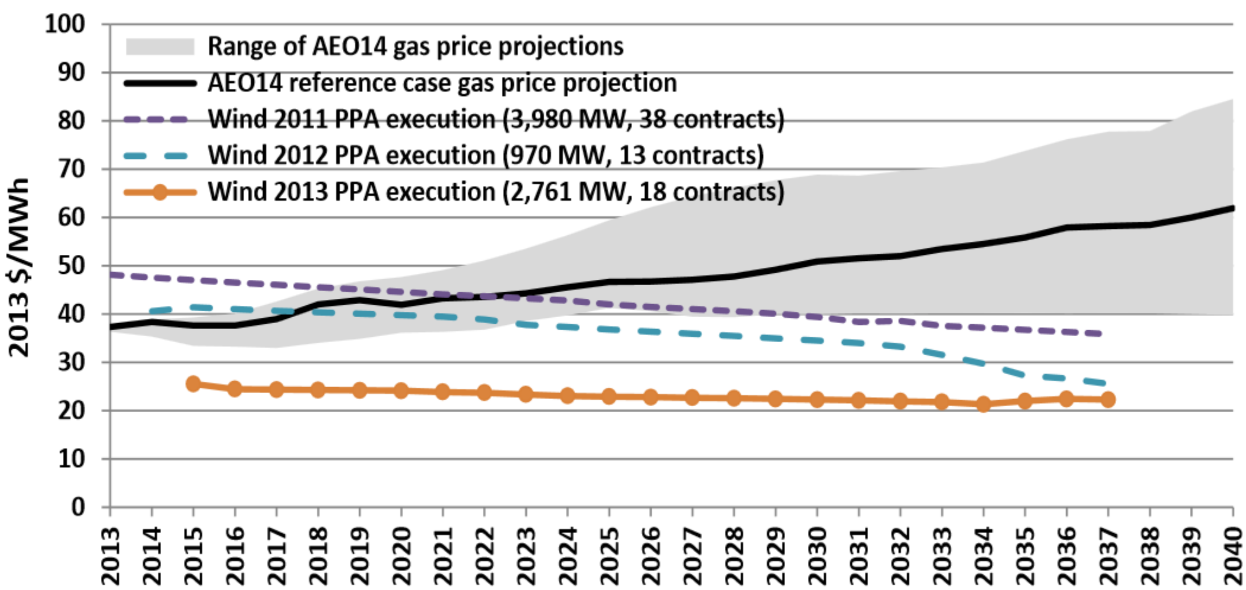
[9] Even if one does not accept the costs of human-induced climate change, pending EPA rules to regulate carbon dioxide emissions from existing power plants will in effect impose a cost on carbon dioxide emissions, and using zero emission wind energy will offset that cost. Market analysts' estimate for the implicit cost of reducing carbon emissions under EPA's Clean Power Plan closely approximate the cost of carbon dioxide emissions assumed in this analysis, validating the value of wind's carbon benefit. http://www.brattle.com/system/publications/pdfs/000/005/025/original/EPA%27s_Proposed_Clean_Power_Plan_-_Implications_for_States_and_the_Electric_Industry.pdf?1403791723



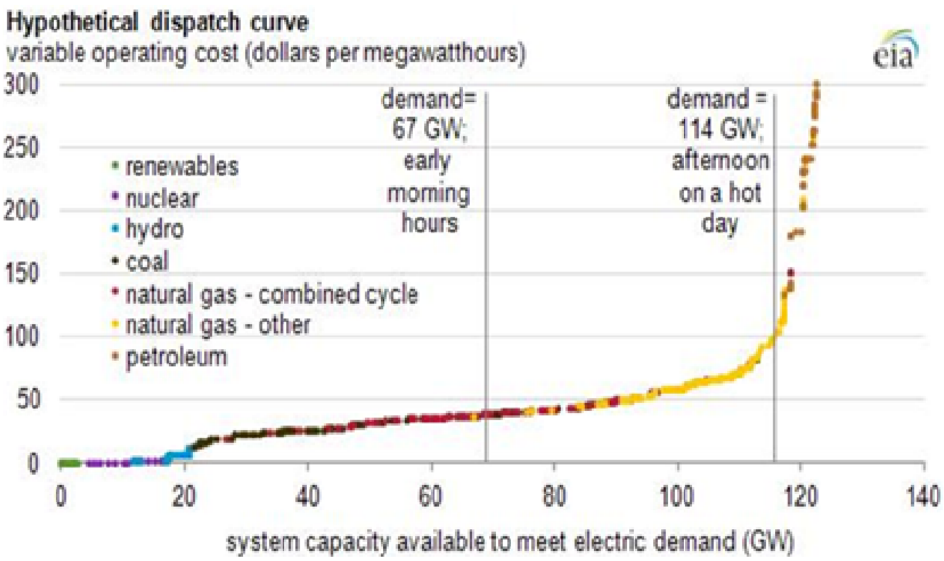
The following chart from a recent report by the Department of Energy and Lawrence Berkeley National Laboratory also shows how the value of wind energy increases as fuel prices increase over time.[10] Wind energy's costs are largely fixed at their current level for the life of the power purchase agreement and can even decrease due to inflation (as seen in the purple, teal and orange lines), while the cost of natural gas generation grows over time as the price of natural gas increases (as seen in the black line with the grey uncertainty area). When evaluating the costs and benefits of fixed-price wind energy, one must factor in the costs and risks of future fuel price increases for the alternatives, just as one would when comparing fuel efficiency to determine which car to purchase.



[10] http://emp.lbl.gov/sites/all/files/2013_Wind_Technologies_Market_Report_Final3.pdf

Consumer benefits

1. Wind energy protects consumers by reducing use of the most expensive power plants. The reduction in the need for conventional generation described above also allows demand to be met by conventional generators with lower fuel cost, and therefore a lower cost of producing electricity. This is known as the "merit order" effect because it allows the market operator to move down the merit order, or supply curve, to use generators with a lower marginal production cost to meet demand, which results in a lower market clearing price. Wind energy has a low marginal production cost because it has zero fuel costs.[11] This drives down the market price for all electricity that is being purchased in the market, not just the wind electricity, as the market price for all electricity purchasers is set by the last and most expensive power plant that was chosen to operate. As an example, the following chart shows a hypothetical electricity supply curve for a fictitious grid operating area.[12] Adding low marginal cost generation like wind to the left side of the curve will push the supply curve out to the right, allowing electricity demand to be met by a lower cost power plant and therefore reducing the price of electricity. Because some parts of the generation supply curve can be quite steep, even a modest amount of additional supply can greatly benefit consumers.



2. Fixed-price wind energy reduces consumer prices more as other fuels get more expensive. Even if fossil fuel prices were known with perfect certainty, their cost is still expected to increase. While a wind plant's costs are fixed, and most wind power purchase agreements remain at the current cost for the life of the contract, the cost of electricity from fueled power plants changes based on their fuel costs, which are passed on to consumers. While the cost of this uncertainty was accounted for above, one must also account for expected increases in the price of fossil fuels, which expands wind's benefits for consumers.

[11] Wind reduces electricity prices because it has no fuel cost; the myth that wind reduces market prices because it receives the renewable Production Tax Credit (PTC) was debunked here: http://awea.files.cms-plus.com/FileDownloads/pdfs/AWEA%20white%20paper-Cutting%20through%20Exelon%27s%20claims.pdf Other low-fuel-cost forms of energy, such as nuclear, have the same impact on market prices. Because wind almost never sets the market clearing price, it has the same impact on markets regardless of whether it offers a price that includes the value of the PTC. While the PTC is important for driving new wind development, the PTC is almost never reflected in market prices.

[12] http://www.eia.gov/todayinenergy/detail.cfm?id=7590

Methodology

Societal benefits

The following tables describe the method that was used to calculate each component of wind energy's gross societal and consumer benefits, with further detail on these methods provided in the following Appendices.

Component	Result	Assumptions and method
Wind energy reduces the cost of producing electricity[13]	$827,517,711	Explained below in "Appendix A"
Wind reduces SO_2 pollution	$591,766,706	AVERT calculated emissions reductions[14] for 2013 SPP wind generation, multiplied by $19,000/ton, median value of negative health harm from SO_2 from U.S. power plants[15]
Wind reduces NO_x pollution	$100,839,224	AVERT calculated emissions reductions for 2013 SPP wind generation, multiplied by $4,800/ton, median value of negative health harm from NOx from U.S. power plants[16]
Wind reduces CO_2 pollution	$872,038,054	AVERT calculated emissions reductions for 2013 SPP wind generation, multiplied by $39.7/short ton, based on converting from $38/metric ton[17] 2015 social cost of carbon at 3% discount rate from 2007$ to 2014$ and from metric ton to short ton.
Wind energy hedges against fuel price volatility	$125,964,644	Lawrence Berkeley National Laboratory found that fixed price gas futures contracts trade at an average premium of $0.6/MMBtu (2003$) relative to gas price predictions, with a range of $0.4-0.8/MMBtu, indicating that this is the cost of fuel price risk for a futures gas market trader.[18] $0.6 was converted to $0.776/MMBtu in 2014 dollars, which was added to the gas price input used in Appendix A below to calculate the additional impact on wind's production cost savings.
Fixed-price wind energy becomes an even better deal as other fuels increase in price	$266,315,955	Explained below in "Appendix B"
Total:	**$2,784,442,295 per year**	

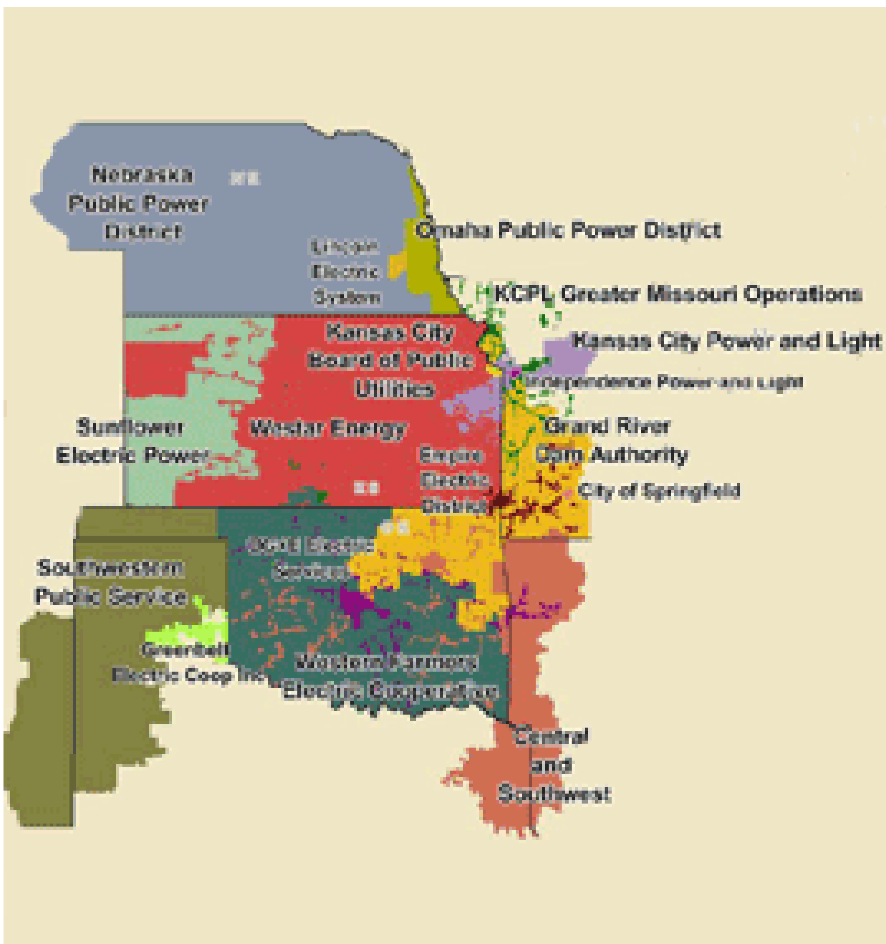
[13] While this analysis is focused on gross benefits, data from ERCOT confirm that wind has minimal impact on the need for the operating reserves that are used to accommodate all sources of variability on the power system. In fact, wind's impact is less than 1/17 of the cost of reserves used to accommodate the abrupt failures of large conventional power plants. This result likely holds for other regions with efficient grid operating procedures, including SPP. http://aweablog.org/blog/post/fact-check-winds-integration-costs-are-lower-than-those-for-other-energy-sources Moreover, SPP treats all energy sources the same with regard to how transmission and integration costs are paid for, out of recognition that all sources of supply and demand use these resources.
[14] AVERT avoided emissions modeling tool, available at http://epa.gov/avert/, applied to SPP 2013 wind generation here http://awea.files.cms-plus.com/FileDownloads/pdfs/AWEA_Clean_Air_Benefits_WhitePaper%20Final.pdf.
[15] http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2009.01227.x/full. The full negative externalities of SO2 and NOx emissions are not currently priced in the electricity market, particularly after the Clean Air Interstate Rule (CAIR) was struck down, so these societal costs must be accounted for separately. http://www.realclearenergy.org/charticles/2012/02/06/the_trading_price_of_sox_and_nox_emissions_has_fallen_dramatically___.html
[16] *Id.*
[17] http://www.whitehouse.gov/sites/default/files/omb/inforeg/social_cost_of_carbon_for_ria_2013_update.pdf
[18] http://emp.lbl.gov/sites/all/files/REPORT%20lbnl%20-%2053587.pdf, at page 60

Consumer benefits

Component	Result	Assumptions and method
Wind energy reduces consumer electricity prices	$840,330,270	Explained below in "Appendix A"
Fixed-price wind energy becomes an even better deal as other fuels increase in price, benefiting electricity consumers	$354,592,798	Explained below in "Appendix B"
Total:	**$1,194,923,068 per year**	

Map of the Southwest Power Pool

The Southwest Power Pool (SPP) operates the power grid for Kansas, Oklahoma, Nebraska, and parts of New Mexico, Texas, Arkansas, and Missouri, as shown below. This report relies on data from SPP, so the results of this analysis apply to this area.[19]



[19] http://www.ferc.gov/market-oversight/mkt-electric/spp.asp

Conclusion

Thanks to a drastic decline in the cost of wind energy, adding new wind generation to the power system results in significant net benefits to society and consumers. Technological advances and the economies of scale created by growing domestic wind energy manufacturing capacity have reduced the cost of U.S. wind energy by more than half over the last five years, making wind energy a leading source of new generation.

Wind energy provides the Southwest Power Pool region with $2.8 billion in gross economic benefits per year. These societal benefits include reducing the cost of producing electricity, hedging against volatile fuel prices, and reducing public health costs by eliminating harmful pollution. Wind generation saves SPP consumers $1.2 billion annually by protecting against electricity and fuel price increases and reducing the need to operate more expensive power plants. These benefits are in addition to the thousands of jobs and billions of dollars in economic activity wind energy has brought to the region.

While some of the benefits provided by wind energy are reflected in the payments wind plants receive for producing electricity, others are not. Wind energy creates billions of dollars in economic value by drastically reducing pollution that harms public health and the environment, but wind energy does not get paid for that benefit. Wind energy also protects consumers from increases in the price of other fuels, but that is not accounted for in the highly regulated electricity market because other energy sources are allowed to pass their fuel price increases directly on to consumers. Policies like the renewable production tax credit help correct for failures in our electricity market design that do not value wind's benefits for protecting public health and consumers, allowing the market to reach a more efficient outcome.

Appendices

Appendix A: Societal and consumer benefit calculations

Hourly generation data for 2013 for wind and other fuel sources were obtained from SPP.[20] SPP generation supply curve data, showing the marginal production cost and equivalent available capacity of each generator, was obtained from industry data source SNL Energy, with the modifications indicated in the following table and explained below.

Cost Adjustments	
Natural Gas: ($/MMBtu)	$4.046
Coal: ($/MMBtu)	$1.782
Oil: ($/MMBtu)	$22.371
Capacity Adjustments (%)	
Combined Cycle:	88.54
Combustion Turbine:	88.67
Geothermal:	92.00
Hydraulic Turbine:	1.96
Internal Combustion:	85.00
Nuclear:	66.20
Other:	85.00
Pump Storage:	85.00
Solar:	24.00
Steam Turbine:	84.61
Wind Turbine:	0.00
Announced:	0.00
Early Development:	0.00
Advanced Development:	0.00
Under Construction:	

Gas, coal, and oil prices were set based on DOE EIA's data for the average prices for gas, coal, and oil delivered to SPP power plants in 2013.[21] Generator Capacity Adjustments for gas combined cycle, gas combustion turbine, and fossil steam generators were set based on the NERC GADS generator equivalent availability factor data for ERCOT.[22] Nuclear and hydraulic turbine Capacity Adjustments were set based on EIA capacity factor data (generation/capacity*8760) for SPP for those fuel types in 2013.[23] Pumped storage, other, and internal combustion were set to 85% based on estimated availability factors for those generators, while solar was set based on an estimated capacity factor for the state's utility-scale solar generation. Mothballed, out-of-service, retired, planned,

[20] http://www.spp.org/GenerationMix/
[21] http://www.eia.gov/electricity/monthly/current_year/february2014.pdf
[22] http://www.ercot.com/content/meetings/ros/keydocs/2014/0109/06._ROS_TRE_Review_of_Reliability_Performance_rev.ppt, page 20
[23] http://www.eia.gov/electricity/monthly/current_year/february2014.pdf, applied on a generation-weighted average across the SPP states

and under construction generation was removed from SNL's supply curve. Wind capacity was also removed from the supply curve for this step, as actual hourly wind generation is inserted into the model in the next step.

The total non-wind generation for each hour, which is used to determine the market clearing price and the total production cost in both the wind case and the hypothetical no wind case, was then calculated. In the hypothetical no wind case, the non-wind generation was set equal to the total generation (reflecting that additional conventional generation equivalent to the amount of actual wind generation would have been used in the absence of wind generation), while in the wind case the non-wind generation was calculated as the total generation in that hour minus the wind generation in that hour.

For the production cost savings calculation, a lookup function for the generation supply curve was then used to find the last generator that needed to run to meet demand in each hour. This analysis was run for the wind case and the no-wind case to see how much production costs increased in the no wind case when more conventional generation was needed to replace the wind generation. The cumulative sum of the production costs for all generators up to and including the last generator was calculated for each case, and the result for the wind case subtracted from the no wind case for each hour and the results summed for all hours in the year.

For the consumer electricity price reduction benefit, a similar lookup function for the generation supply curve was used to calculate what the wholesale electricity market clearing price would have been in each hour under each case, by moving up the supply curve to find the marginal production cost for the last generator that needed to run to meet demand net of wind generation. The marginal production cost of the last generator sets the market clearing price. The difference in prices between the wind and no-wind cases, multiplied by the total generation in that hour and summed for all hours, is the consumer price reduction benefit provided by wind.

Model Validation

The accuracy of the supply curve model was validated by comparing modeled results for ERCOT against real-world ERCOT market outcomes. The simple average (i.e., not weighted to account for the different load levels in different hours) of actual hourly ERCOT hub prices for 2013[24] was compared against the simple average of the model's estimated hourly ERCOT prices for 2013 in the wind case, reflecting that the model's results should approximate reality. The simple average price in the model of $29.74/MWh is $0.82/MWh, or 2.7% less than the actual simple average price in the real world of $30.55/MWh. This very small deviation was deemed to be within the acceptable range of error for this type of analysis. Several potential factors could explain why the model would tend to slightly underestimate actual observed prices. For one, the generator availability data used in the model only excludes outage hours; however, there are typically many hours when generators are not experiencing an outage but are still offline for other reasons, primarily economic factors that led the units not to be committed or dispatched. Relatedly, the model's assumption that a generator's full available capacity would be available during all non-outage hours ignores that some generators, particularly inflexible baseload generators, have limited ramp rates and lengthy start-up times, so they may not be fully available. These underestimates could cause a slight underestimate of wind's savings, although because the underestimates would apply in both the wind case and the no-wind case, the impact on wind's savings (the difference between those results) is likely to be limited.

In addition, the calculations of wind's societal and consumer savings are likely to be conservative, as they assumed that generator outages occur uniformly throughout the year. In reality, conventional generator planned outages tend to be scheduled for the fall and spring, when wind output tends to be above average. Removing generators from the supply curve tends to increase prices and production costs, as demand must be met by higher cost plants, so if wind output is above average during periods with more outages than normal, wind's benefits would be larger.

[24] http://mis.ercot.com/misapp/GetReports.do?reportTypeId=13061&reportTitle=Historical%20RTM%20Load%20Zone%20and%20Hub%20Prices&showHTMLView=&mimicKey

For the ERCOT analysis, another test was conducted to determine if electricity market price separation between wind producing areas and the remainder of the grid operating area could have biased the estimate of wind's consumer savings. At times in previous years, West ERCOT (where the majority of the wind generation is located) has had significantly lower market clearing prices than the rest of ERCOT due to transmission congestion. Real-world ERCOT hub pricing data[25] indicate that in 2013, the simple average hub price in West ERCOT was 4.4%, or $1.36/MWh, lower than the simple average for ERCOT hubs as a whole. This likely occurred because transmission congestion caused wind generation to have a greater impact on electricity prices in West ERCOT during a limited number of hours in 2013, and a smaller impact on prices in the rest of ERCOT during those hours. Depending on the shape of the generation supply curves in West ERCOT and the rest of ERCOT, this could have either expanded or contracted wind's actual consumer savings relative to the model, which assumes no transmission congestion. Because the difference in prices between the West Zone and the rest of ERCOT was found to only be $1.36/MWh, or 4.4%, it was deemed that any impact was too small to merit additional analysis.

Appendix B: Accounting for expected fuel price increases

As fossil fuel prices increase in the future, fixed-price wind energy will become an even better deal. Even if fossil fuel prices were known with perfect certainty, there would still be a cost associated with these increasing fuel costs over time relative to fixed-price wind energy. To calculate the savings wind energy is expected to provide as fuel costs increase, DOE estimates[26] for the price of gas, coal, and oil delivered to the electric sector for years 2016-2040 were incorporated into the SNL supply curve described above. If anything these estimates are likely to be conservative, as DOE has historically underestimated future gas prices 67% of the time, coal prices 62% of the time, and oil prices 82% of the time.[27] Wind's production cost and consumer electricity price savings were calculated for each year independently, incorporating the new fuel costs into the methodology outlined in Appendix A above. In reality, power plants will retire and new power plants will enter the market between now and 2040, so the future generation supply curve will change. Because those changes cannot be predicted with any certainty, and will likely tend to replace lower-cost coal generation with higher-cost gas generation, to be conservative the model uses the generators in the 2013 supply curve in all years. The order of generation in the supply curve was not re-sorted after fuel costs were changed in each year, though that should have a minimal impact on the results because the relative changes in fuel price were too small to change the dispatch order among nearly all coal, gas, and oil generators.

The net present value of those savings for 2016-2040 at a 3% discount rate was then compared to the net present value of those savings fixed over the 2016-2040 time period, reflecting the fixed costs of a wind project with a 25-year life versus a fossil fuel generator with increasing fuel costs. The ratio between the net present value of the savings using the increasing fuel costs relative to the net present value of the fixed fuel price savings was found to be 1.32 for production cost savings and 1.42 for consumer electricity price savings. The additional production cost and consumer electricity price savings over time due to fuel price increases were therefore estimated to be 32% and 42% of the values calculated for 2013.

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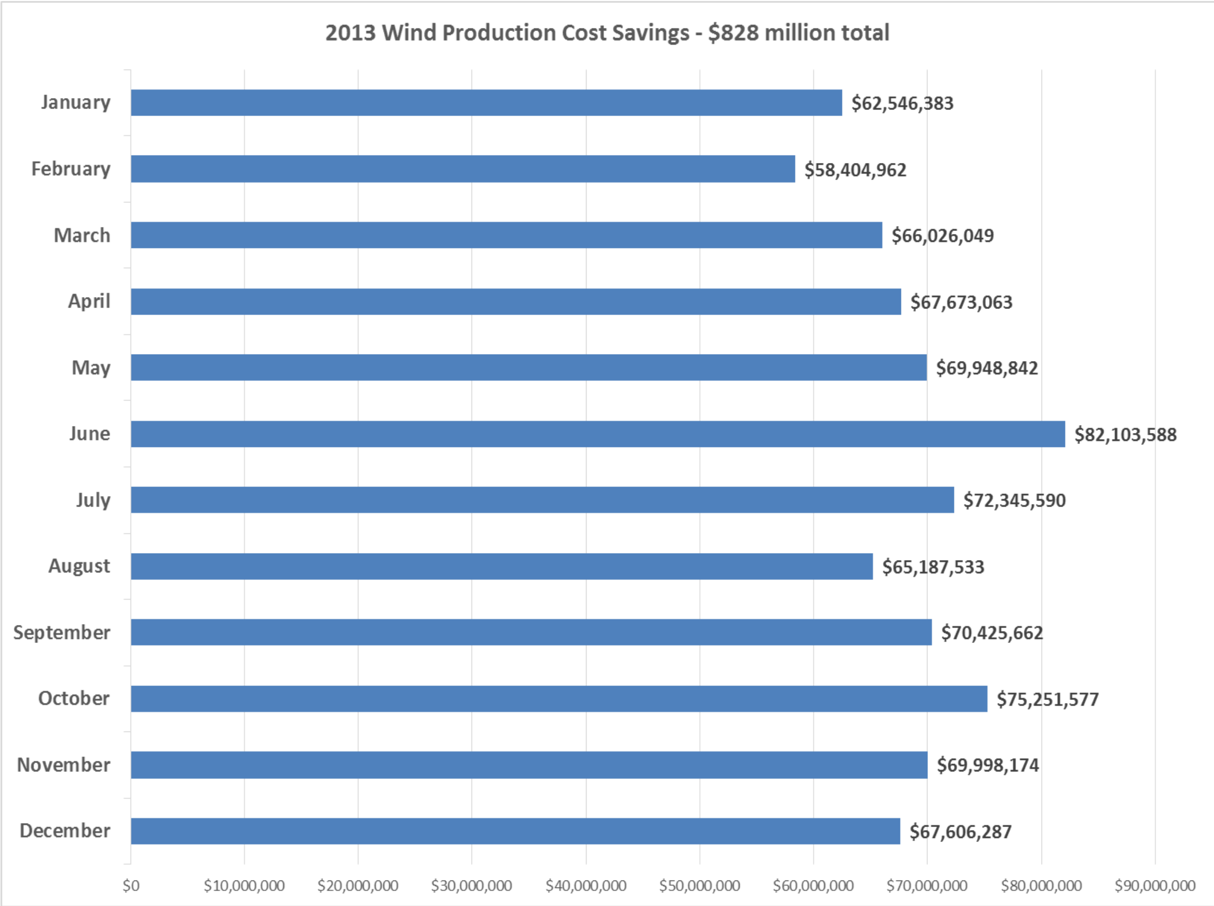
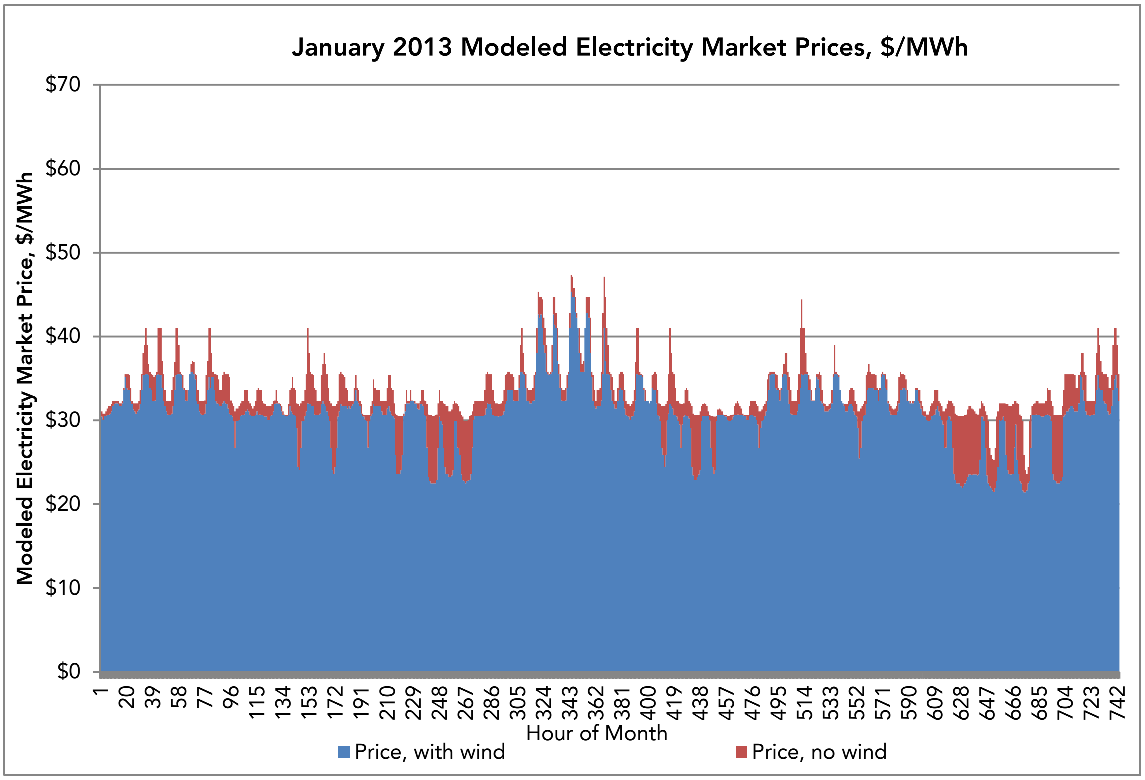
[25] *Id.*
[26] http://www.eia.gov/forecasts/aeo/, table A3, Reference case
[27] http://www.eia.gov/forecasts/aeo/retrospective/

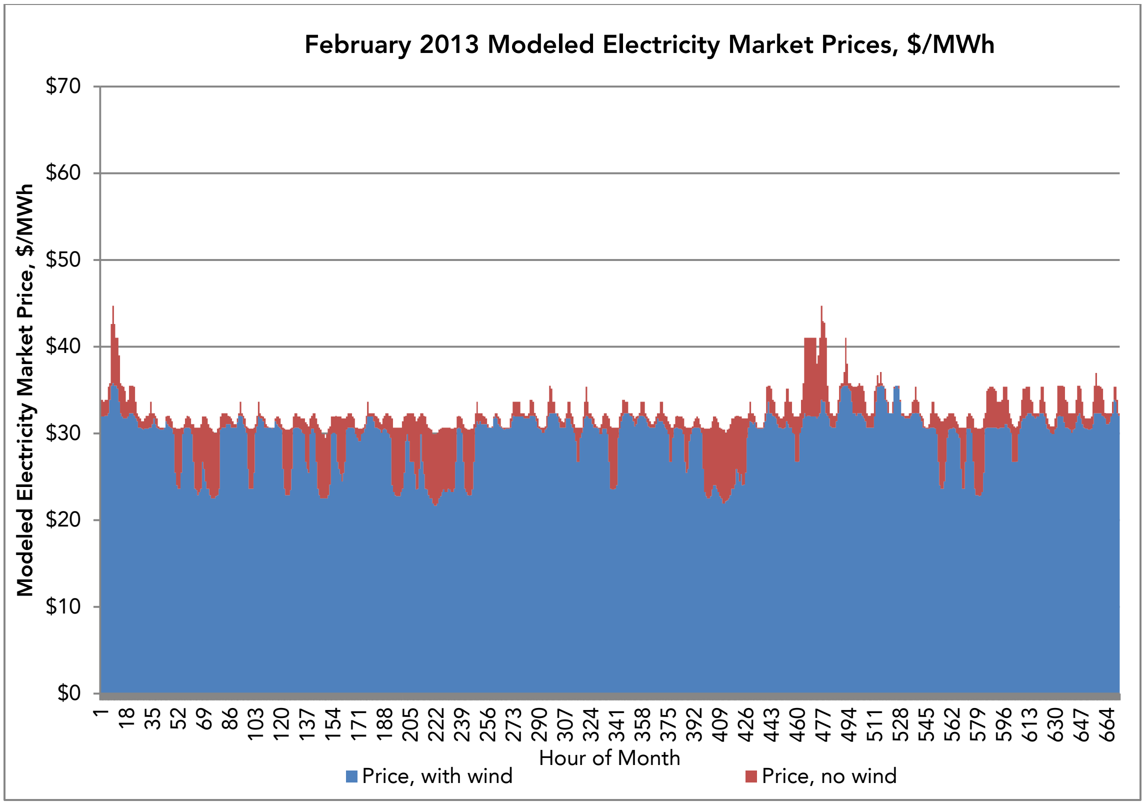
Appendix C: Monthly reductions in the cost of producing electricity and consumer prices

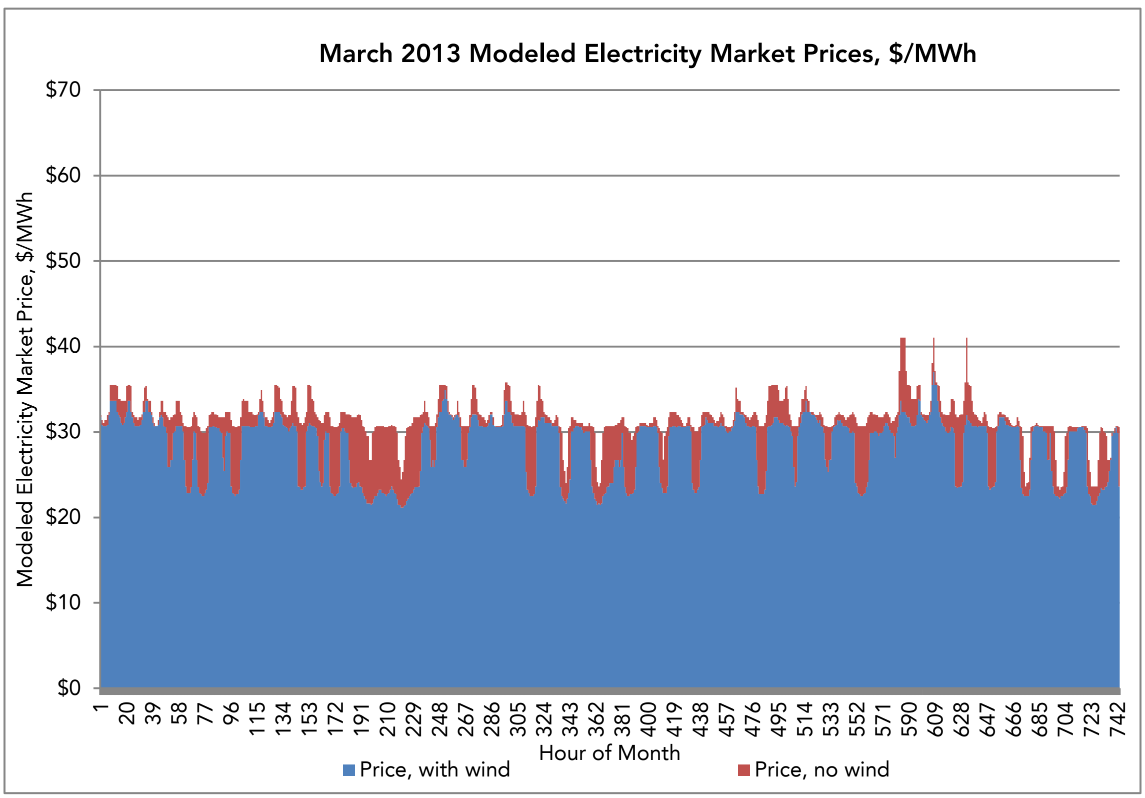
Monthly reductions in the cost of producing electricity

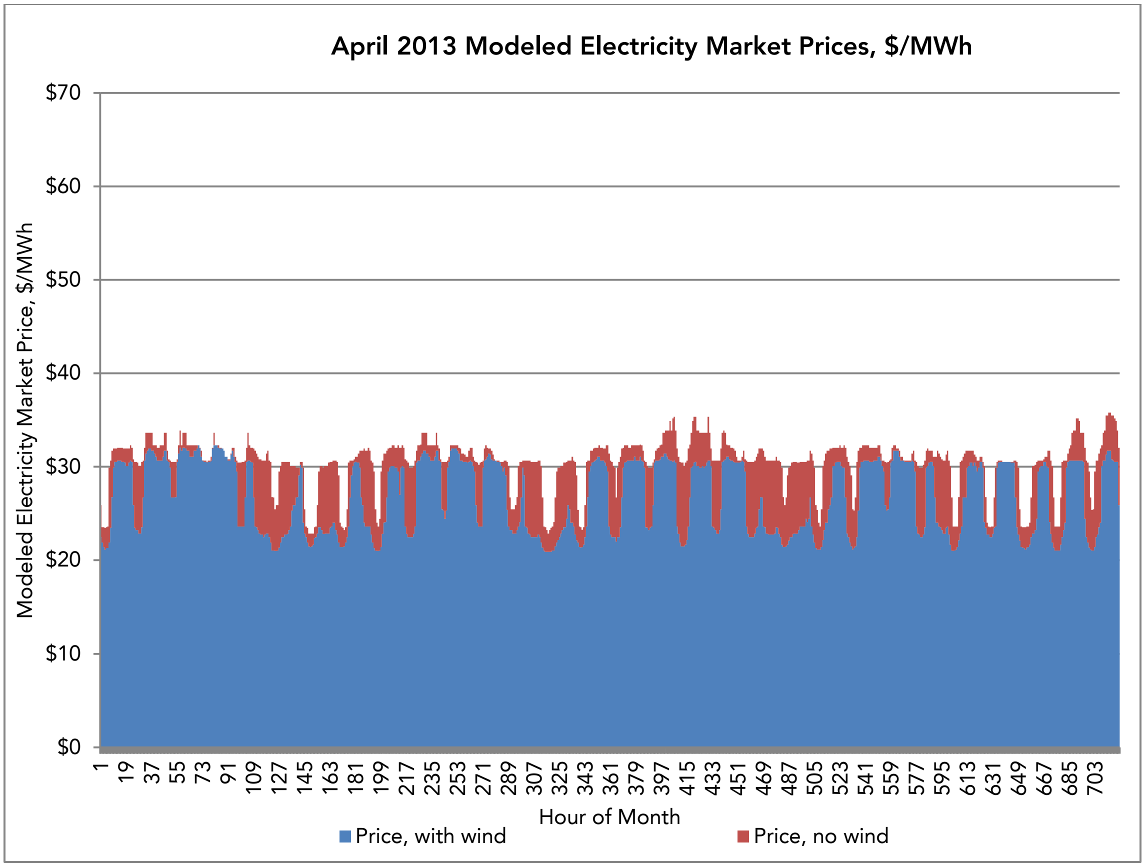


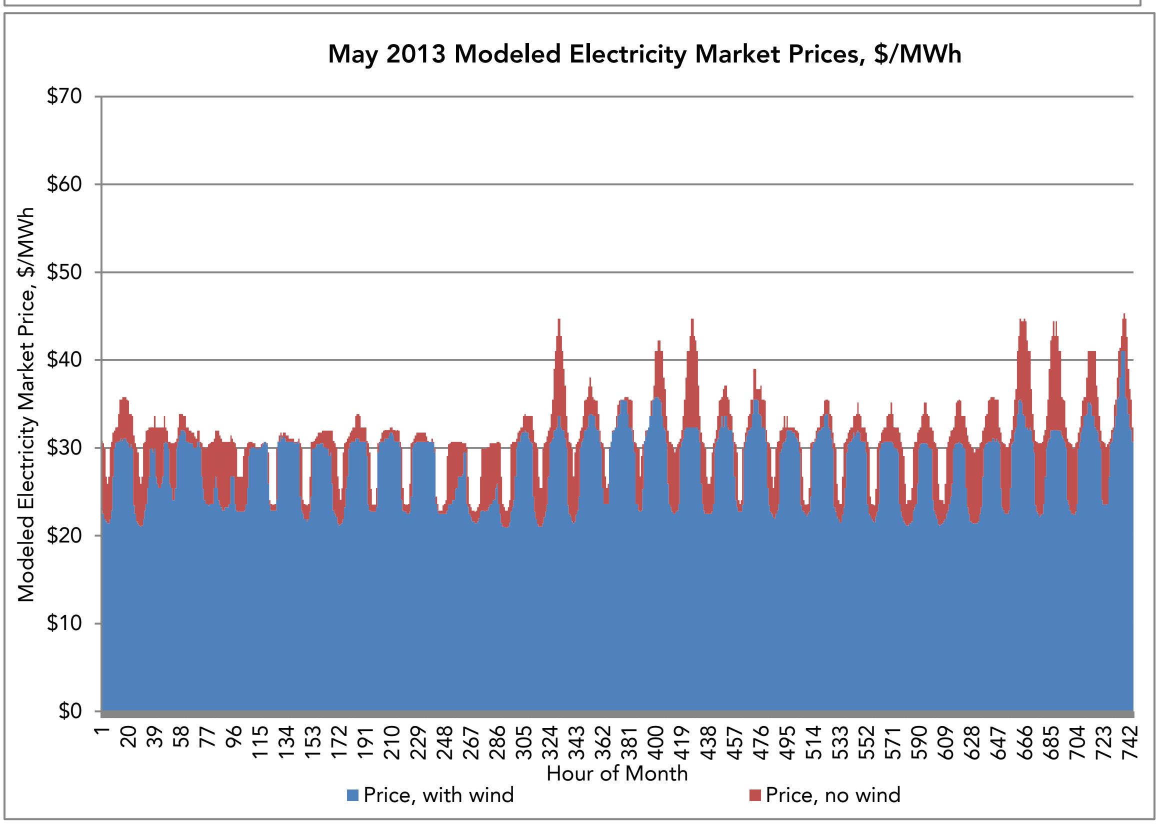
Monthly consumer benefits

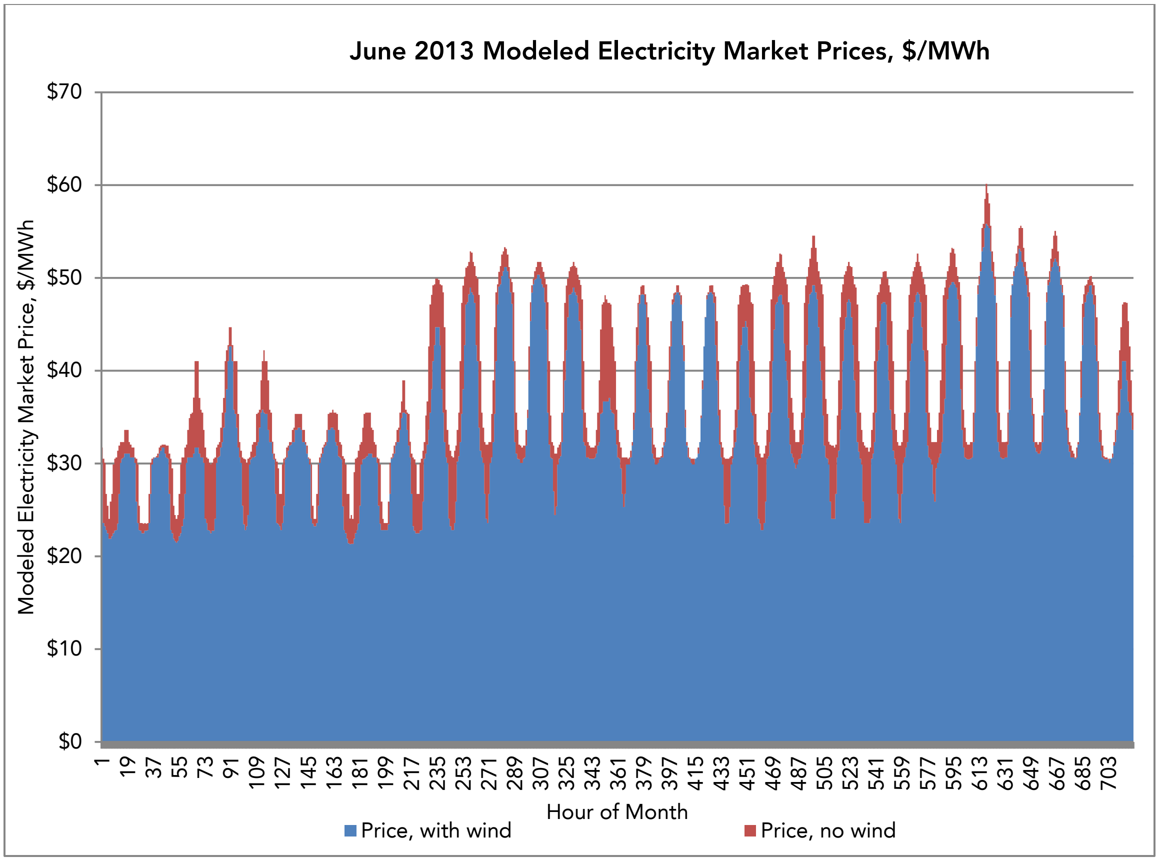


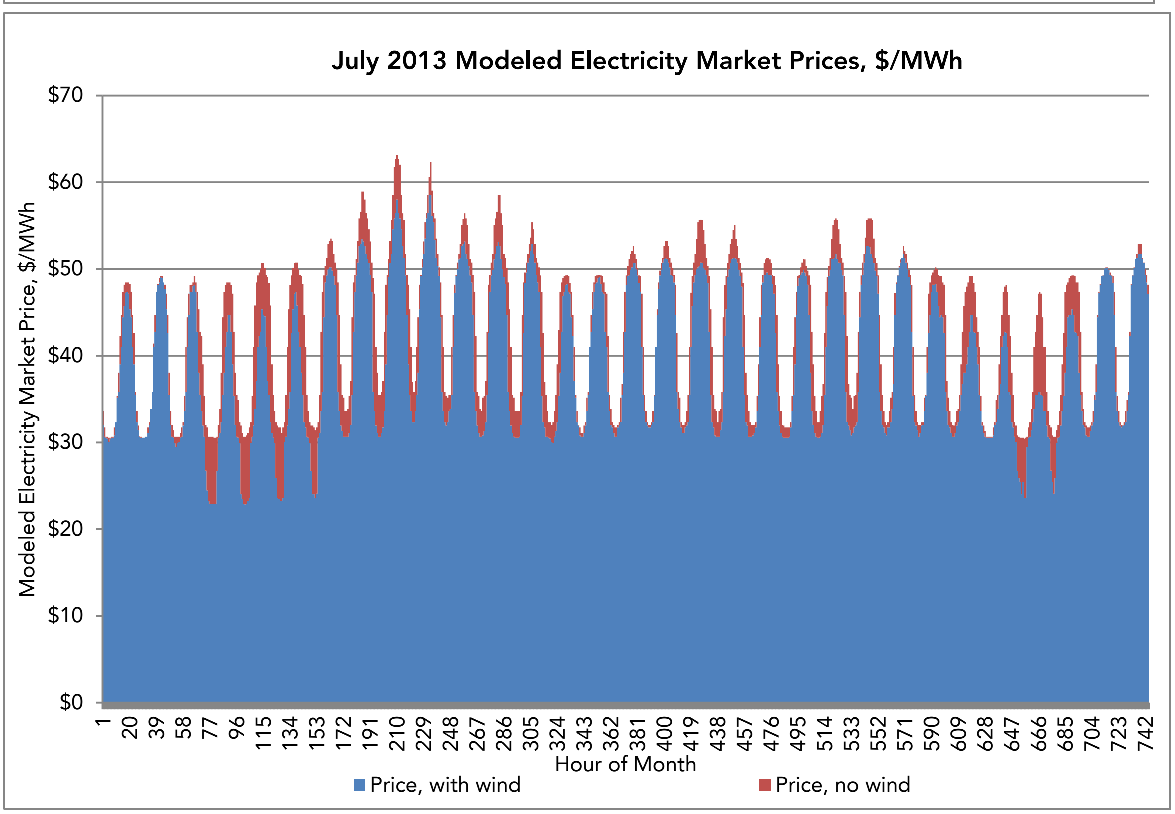

February 2013 Modeled Electricity Market Prices, $/MWh
Modeled Electricity Market Price, $/MWh
$70
$60
$50
$40
$30
$20
$10
$0
Hour of Month
Price, with wind
Price, no wind

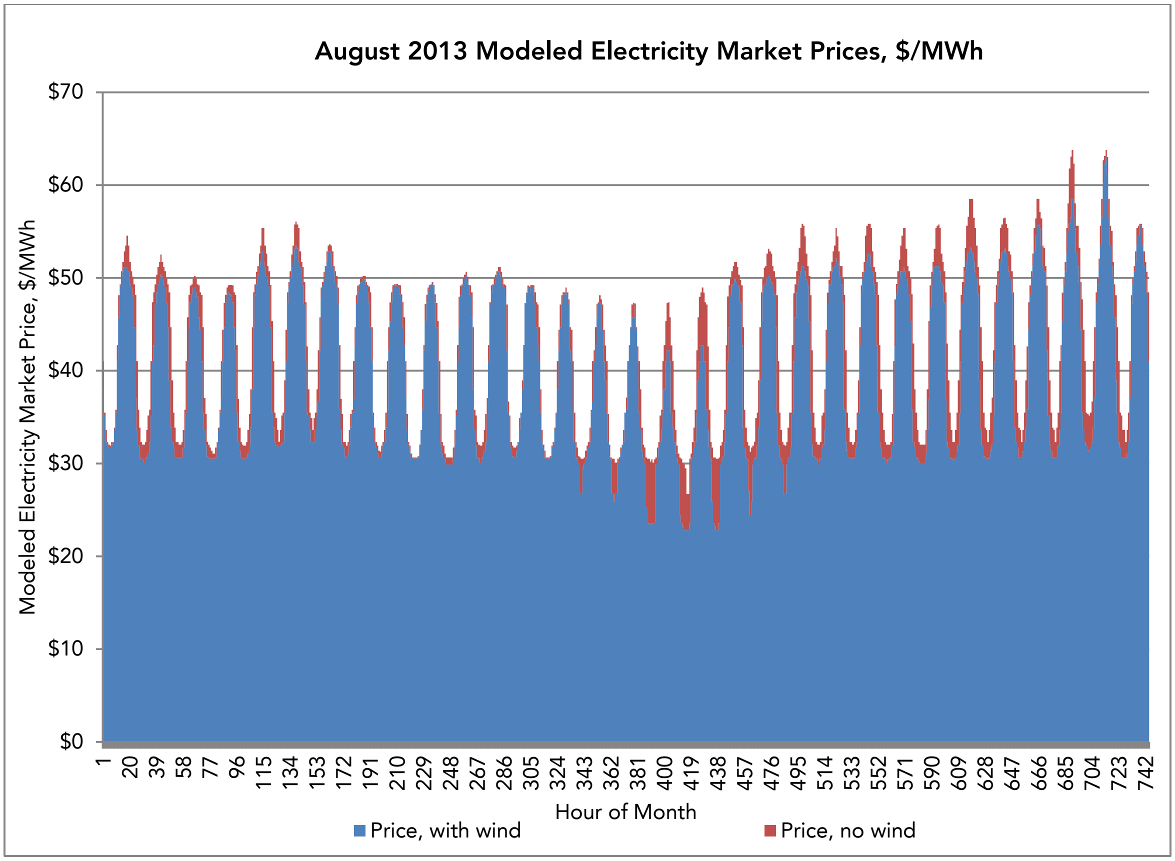

March 2013 Modeled Electricity Market Prices, $/MWh
Modeled Electricity Market Price, $/MWh
$70
$60
$50
$40
$30
$20
$10
$0
Hour of Month
Price, with wind
Price, no wind

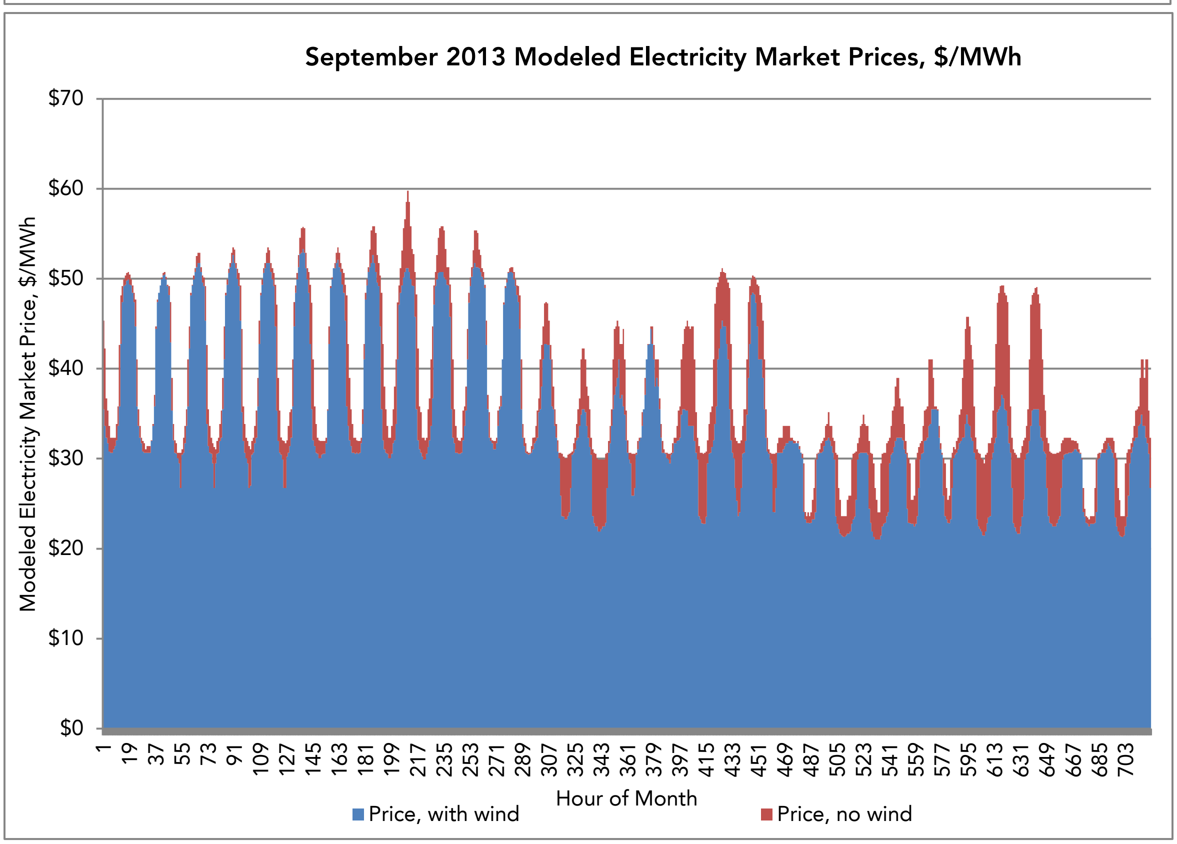

April 2013 Modeled Electricity Market Prices, $/MWh
Modeled Electricity Market Price, $/MWh
$70
$60
$50
$40
$30
$20
$10
$0
Hour of Month
Price, with wind
Price, no wind

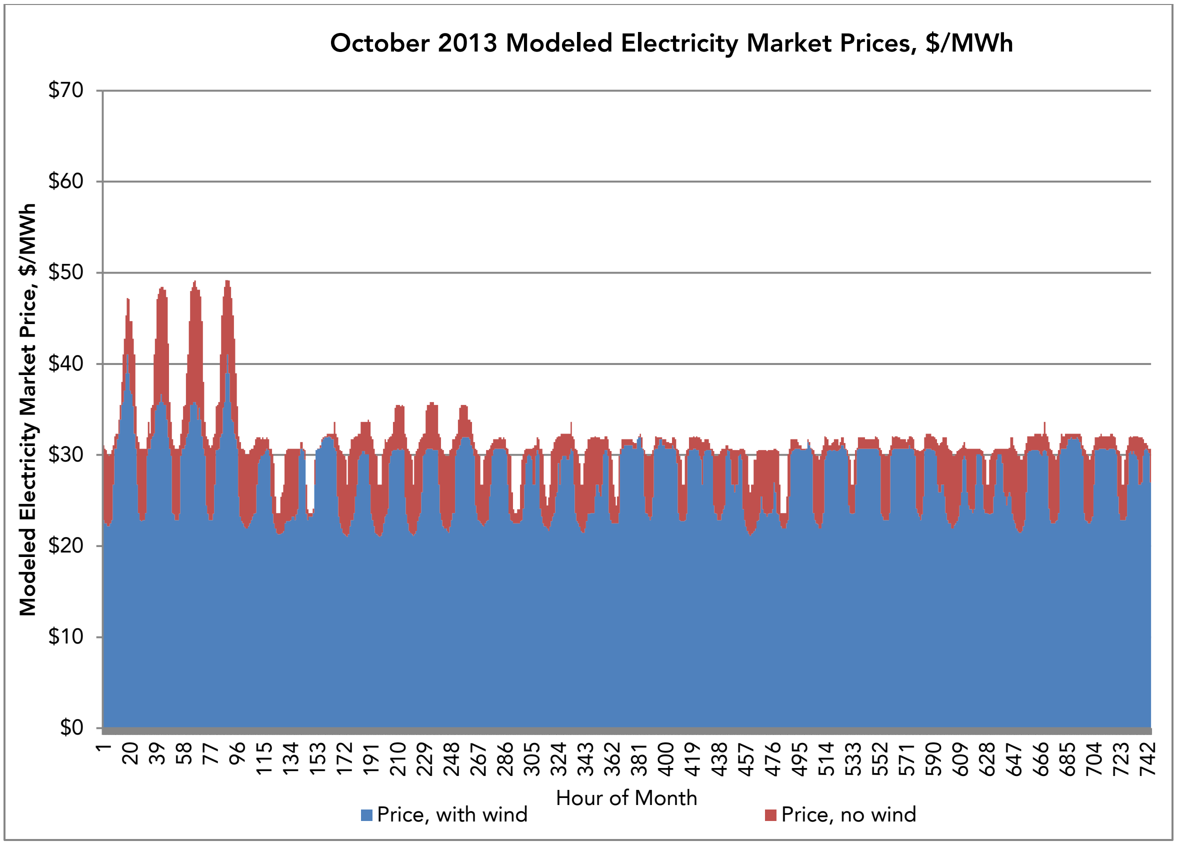

May 2013 Modeled Electricity Market Prices, $/MWh
Modeled Electricity Market Price, $/MWh
$70
$60
$50
$40
$30
$20
$10
$0
Hour of Month
Price, with wind
Price, no wind


June 2013 Modeled Electricity Market Prices, $/MWh
Modeled Electricity Market Price, $/MWh
$0
$10
$20
$30
$40
$50
$60
$70
Hour of Month
Price, with wind
Price, no wind

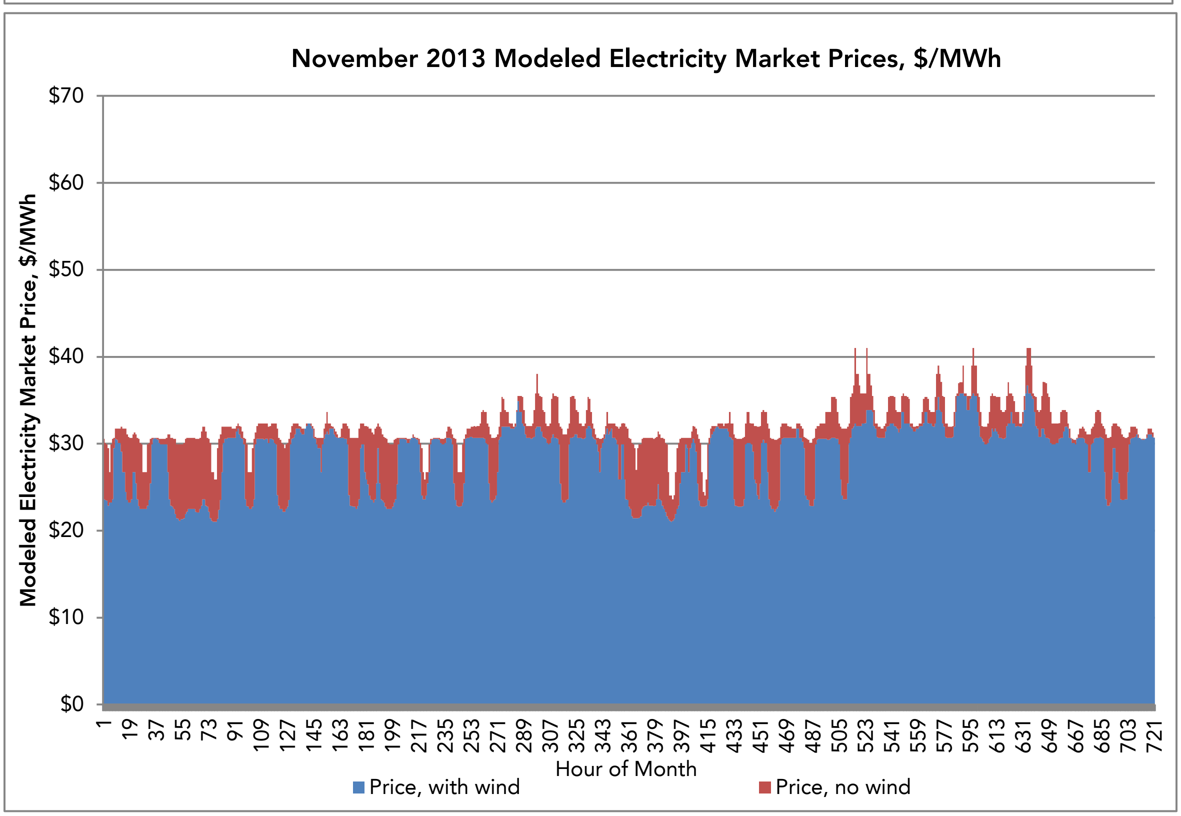

July 2013 Modeled Electricity Market Prices, $/MWh
Modeled Electricity Market Price, $/MWh
$0
$10
$20
$30
$40
$50
$60
$70
Hour of Month
Price, with wind
Price, no wind


August 2013 Modeled Electricity Market Prices, $/MWh
Modeled Electricity Market Price, $/MWh
$70
$60
$50
$40
$30
$20
$10
$0
1 20 39 58 77 96 115 134 153 172 191 210 229 248 267 286 305 324 343 362 381 400 419 438 457 476 495 514 533 552 571 590 609 628 647 666 685 704 723 742
Hour of Month
Price, with wind
Price, no wind

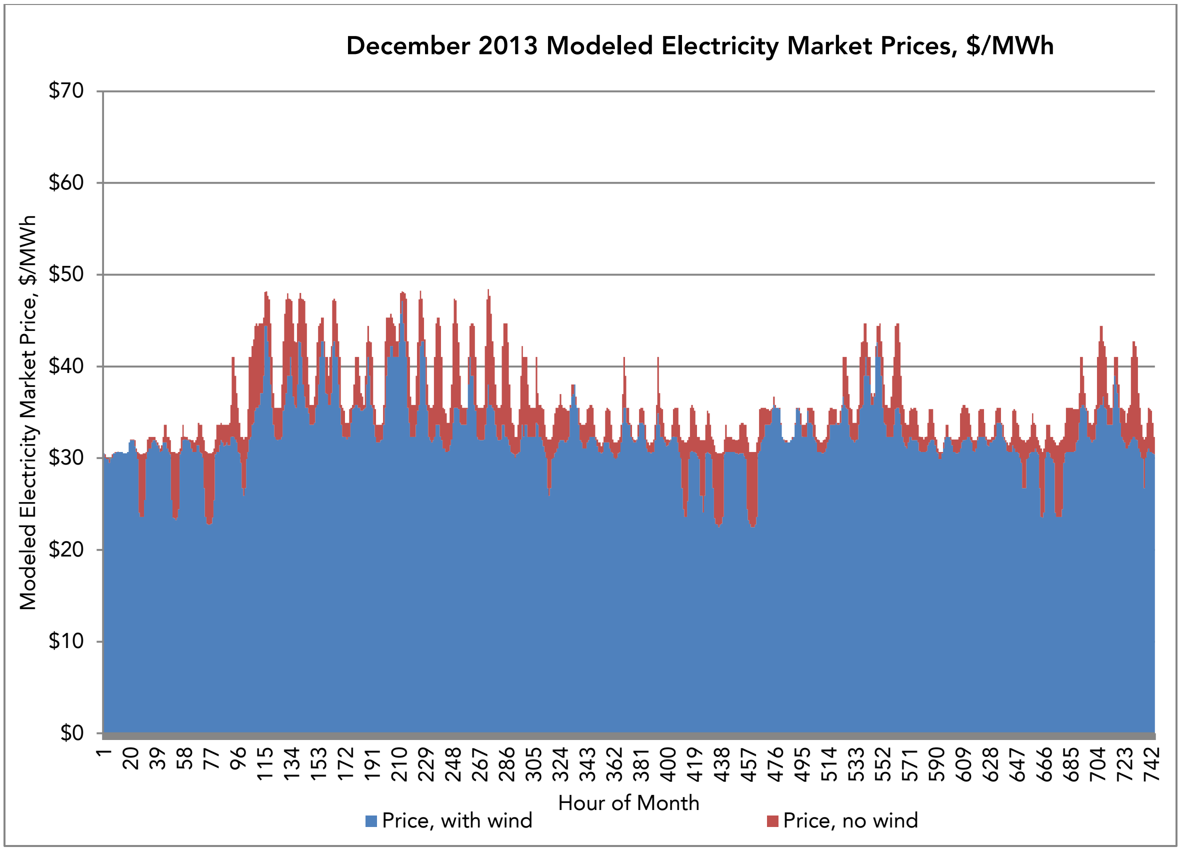

September 2013 Modeled Electricity Market Prices, $/MWh
Modeled Electricity Market Price, $/MWh
$70
$60
$50
$40
$30
$20
$10
$0
1 19 37 55 73 91 109 127 145 163 181 199 217 235 253 271 289 307 325 343 361 379 397 415 433 451 469 487 505 523 541 559 577 595 613 631 649 667 685 703
Hour of Month
Price, with wind
Price, no wind



October 2013 Modeled Electricity Market Prices, $/MWh
Modeled Electricity Market Price, $/MWh
$70
$60
$50
$40
$30
$20
$10
$0
Hour of Month
Price, with wind
Price, no wind



November 2013 Modeled Electricity Market Prices, $/MWh
Modeled Electricity Market Price, $/MWh
$70
$60
$50
$40
$30
$20
$10
$0
Hour of Month
Price, with wind
Price, no wind


December 2013 Modeled Electricity Market Prices, $/MWh
Modeled Electricity Market Price, $/MWh
$70
$60
$50
$40
$30
$20
$10
$0
1 20 39 58 77 96 115 134 153 172 191 210 229 248 267 286 305 324 343 362 381 400 419 438 457 476 495 514 533 552 571 590 609 628 647 666 685 704 723 742
Hour of Month
Price, with wind
Price, no wind