Iowa’s Wind Potential for Addressing 111(d) Goals

The Potential for Tapping Iowa’s Wind Resource to Reduce CO_2 Emissions

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8/17/2015

Revised

The potential for tapping Iowa’s wind resource to generate clean electricity and reduce carbon pollution in Iowa and the region is evaluated for the period from 2016 to 2030, and assessed in light of the EPA’s initial 111(d) targets. In a conservative scenario it is estimated that Iowa wind could easily contribute a reduction of 15 million metric tons of carbon dioxide annually to the region outside of Iowa, and in a more optimistic but still moderate scenario Iowa’s contribution could easily be over 36 million metric tons annually. Such contributions would go far in helping neighboring states with lower quality wind resources reduce their carbon emissions. As a means of reducing GHG emissions, wind is one of the lowest cost options, and indeed, as a means of generating electricity, it is also one of the lowest cost options, typically being less expensive than any form of fossil fuel generation. Moreover, the cost of generation from wind is declining. Although additional transmission infrastructure would need to be built to accommodate a large increase in wind generation, the cost of that additional transmission would be expected to be modest, when spread across the region benefitting from it. Additionally, the economic benefits from wind development are significant.

I. Introduction & Executive Summary

The primary aim of this study is to evaluate the potential for tapping Iowa's wind resource to reduce CO_2 emissions from electric power plants, not only in Iowa but regionally.

In June 2014, the EPA proposed a rule (111(d)) setting the year 2030 target CO_2 emissions rate reductions for each state's power plants. Emissions reductions are calculated against the baseline year 2012. It is in light of that proposed rule that the present study was undertaken. This report finds that the EPA-proposed target for Iowa as a whole will only require modest changes to achieve the goals. Based just on existing and currently-committed wind development in the state alone, and ignoring efficiency improvements and currently planned changes in fossil fuel energy generation, Iowa will likely achieve at least half of the 2030 target by the end of 2015.

Four scenarios for wind deployment were examined in this review:

1) a scenario where wind is deployed exclusively to meet the 16% CO_2 emissions reduction by 2030 that EPA set for Iowa in its initial rule
2) a scenario where wind is deployed to meet a target of 30% reduction in CO_2 emissions by 2030
3) a conservative deployment scenario that envisaged an addition of, on average, 500 MW of new wind generation annually from 2016 to 2030
4) a moderate deployment scenario which looks at the addition of, on average, 1,000 MW of new wind generation annually over that time frame, along with a very modest increase in turbine performance.

CO_2 emission reductions associated with the latter two scenarios are quite significant, and go far beyond the EPA's initial 111(d) goal for Iowa. Some of Iowa's neighbors, most especially Illinois, but also Missouri and other states to the east have carbon footprints that dwarf Iowa's and also have wind resources of lower quality. By exporting much of its wind-generated electricity, Iowa's wind could play a large role in reducing emissions beyond the state boundaries.

This study also looks at factors affecting the cost of transmission build-outs needed to enable the export of large amounts of Iowa wind power. Although there is uncertainty related primarily to the need and cost of adding transmission capacity, the evidence is that such costs would be reasonable, and an effort to expand Iowa's wind capacity for export would be quite beneficial economically.

II. Historical CO_2 Emissions in Iowa's Electricity Generation Mix

Iowa's CO_2 emissions, emission rates, and electricity generation mix from 1990 through 2012 are charted below in Figures 1 through 3.[i] Annual total CO_2 emissions from electricity generation increased from 1990 to 2010, from about 30 million tons to nearly 47 million tons. Since 2010, annual emissions decreased to approximately 40 million tons in 2012. Fossil fuel emission rates for CO_2 decreased slightly over the period from about 2,300 lbs per megawatthour (MWh) to about 2,200 lbs/MWh. In Figure 2 CO_2 emission rates for all electric energy decreased over the period from about 2,000 lbs/MWh to less than 1,500 lbs/MWh. Figure 3 illustrates that while this emission rate reduction for all energy occurred, Iowa's total generation increased from about 30 million MWh to 57 million MWh. Its generation from fossil sources went from 30 million MWh to about 42 million MWh as shown by the dark gray bars.

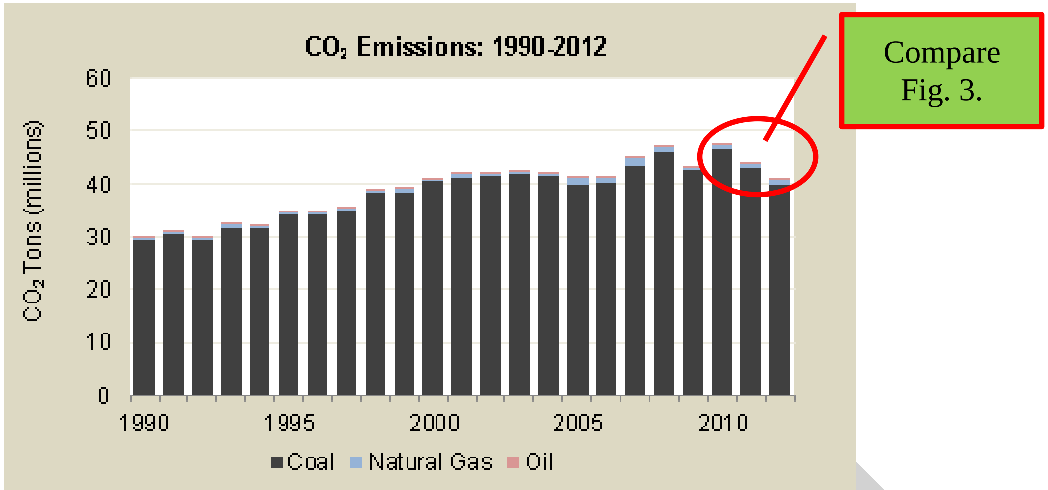

Figure 1: Historical CO_2 Emissions from Electricity Production in Iowa

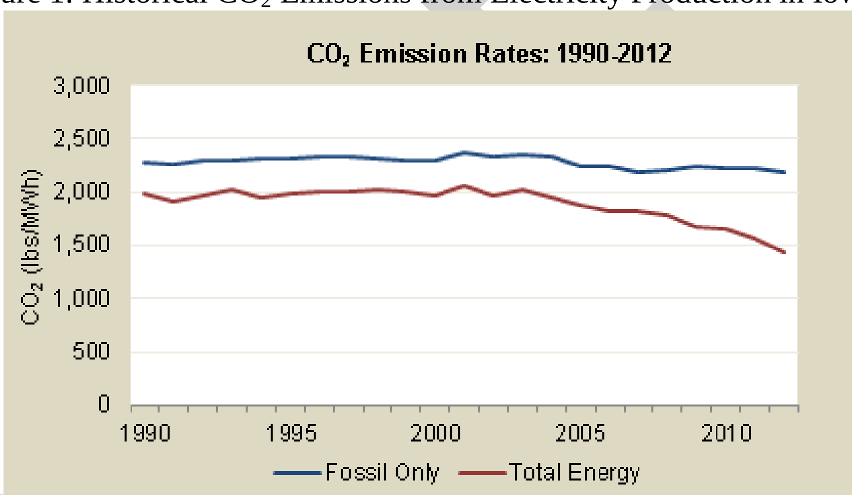

Figure 2: Historical CO_2 Emission Rates from Electricity Production in Iowa

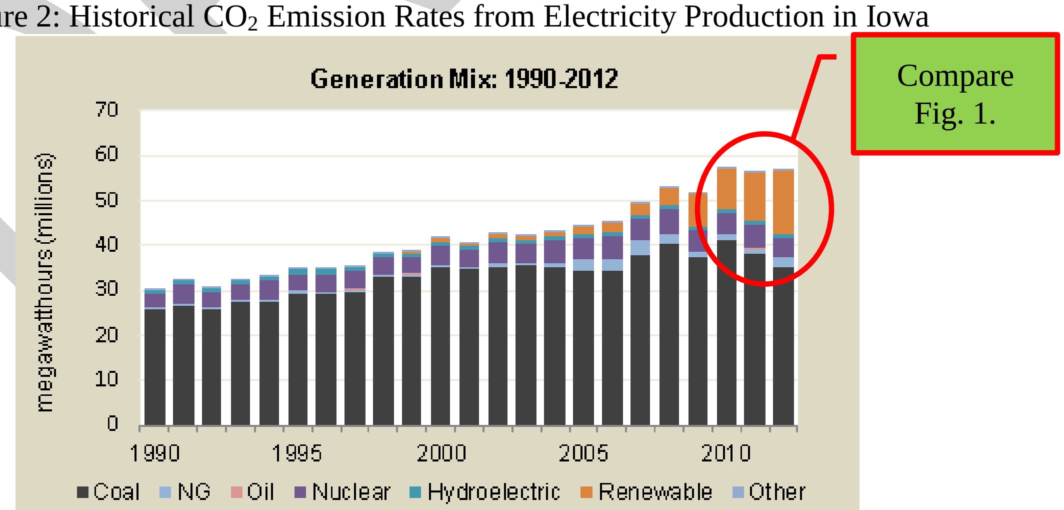

Figure 3: Historical Electricity Generation Mix in Iowa

Of particular interest is the corollation especially observable in the 2010 – 2012 years, between the CO_2

emissions (Figure 1), the reduction of coal in the energy mix (Figure 3), and the addition of wind (also Figure 3). The chart below (Figure 4) illustrates this more vividly, where 2010 is taken as baseline so that the changes are clearer.

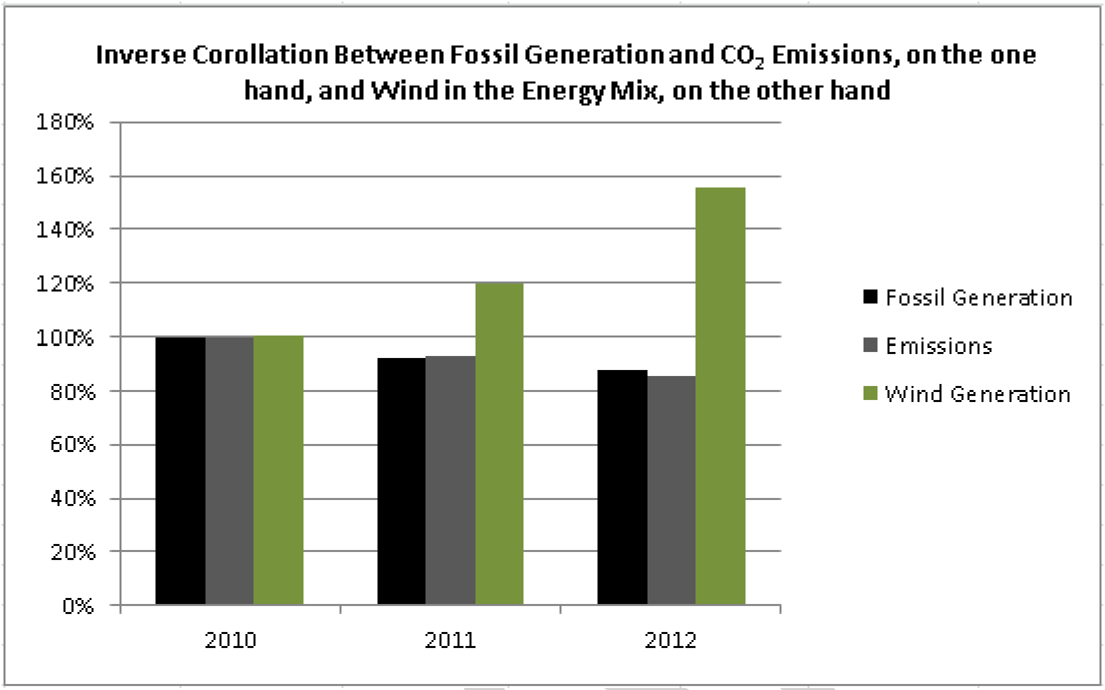

Figure 4: Corollations between Wind, Fossil Generation, and CO_2 Emissions

III. Wind Generation in Iowa

In 2003 Iowa had about 580 MW of wind capacity installed. By the end of 2014 Iowa's installed capacity was 5,688 MW. The National Renewable Energy Laboratory (NREL) estimates Iowa's total potential wind capacity at about 570,000 MW, more than 100 times the 2014 total, so there is no physical limit in the foreseeable future on the power Iowa wind could provide. The pie chart below, Figure 5, illustrates the extent to which Iowa's wind potential has been developed, with the small blue wedge representing Iowa's currently installed capacity.

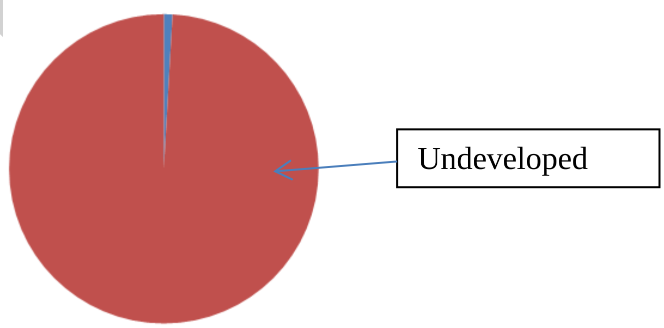

Figure 5: Portion of Iowa's Wind Potential that has been Developed (Blue Wedge)

The Iowa Wind Energy Association (IWEA) has set a goal for Iowa of 20,000 MW by 2030, a goal which is close to the estimate used in the Department of Energy's "20% Wind Energy by 2030" report, published in 2008.[ii] That would represent about 3½% of Iowa's potential. In the second week of March, 2015, the DOE released its new Wind Vision report, which updates the 2008 report. In the Wind Vision report, the DOE envisages Iowa's total installed wind capacity by 2030 at 27,000 MW, a 35% increase over IWEA's previously stated goal.[iii] Thus, the Wind Vision scenario for Iowa has Iowa's average growth in wind capacity from 2016 to 2030 at over 1,450 MW annually, significantly more optimistic than the moderate scenario analyzed here.

Figure 6 shows the growth in Iowa's installed capacity from 2003 to 2013, with projections for 2014 and 2015 based on installations ongoing and committed. The darker parts of the bars indicate the amount added (or committed, in the case of 2015) that year.

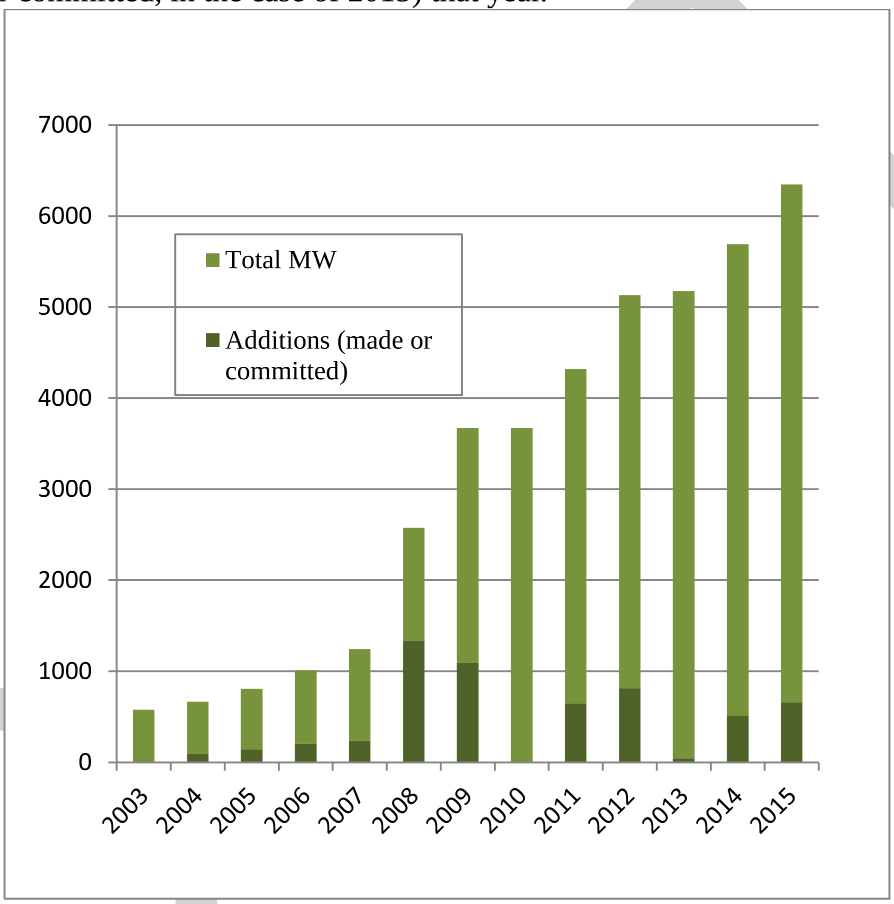

Figure 6: History and Near Future of Iowa Wind Installation

In 2014 installation of 511 MW was underway with 667 MW more planned by MidAmerican in 2015. MidAmerican's additions will bring Iowa's total installed capacity to at least 6,355 MW by 2016.

In terms of the electricity produced by Iowa's wind farms over this period, 2003 saw about one million MWh (1,000 GWh) of wind energy produced, whereas in 2013 production was more than 15.7 million MWh.[iv] MidAmerican, at the 2014 Iowa Wind Energy Association meeting, estimated that its new facilities will have an average capacity factor of about 40%. Using that value, the estimated generation coming from the addition of 1,178 MW of wind power will be about 4.1 million MWh. This would bring Iowa's total annual wind generation to nearly 20 million MWh annually starting in 2016.

At the time of this writing, (early 2015) the authors are not aware of any other wind projects being committed in Iowa. Assuming that the current and projected build-out comes online at a constant rate, an estimate of the generation for 2014 and 2015 can be derived. The result is displayed in the Figure 7, with the estimates for 2014 and 2015 in gray.[v] (The 2014 data through November is available at the time of this writing, and totals 14.8 million MWh.)

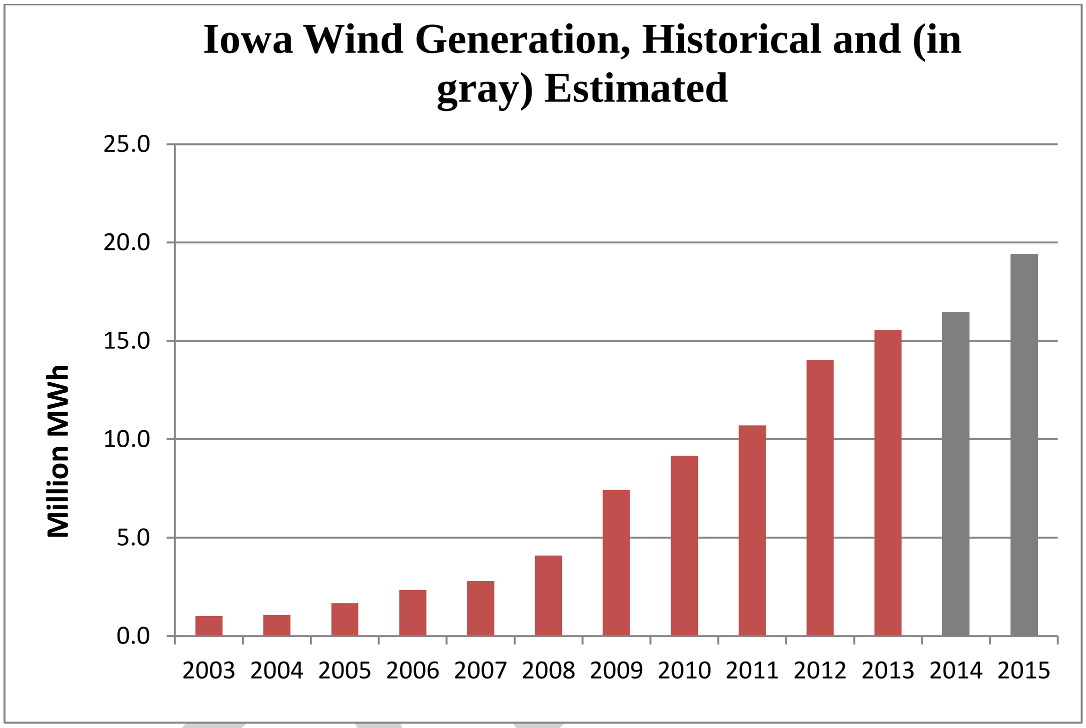

Figure 7: Historical and Estimated Wind Energy Production 2003-2015

IV. Wind Deployment Scenarios

In its 111(d) proposal the EPA used 2012 baseline data and proposed a 2030 goal as follows:

Baseline 2012			2030 Goal			
TWh	Metric Tons	#/MWh	#/MWh	%	#/MWh	Metric Tons
Energy Produced	Total CO_2 emitted	Emission rate	Emission rate	Rate Reduction	Rate Reduction	CO_2 Reduction
49	35,000,000	1,552	1,301	16%	251	5,660,438

Figure 8: Values of EPA Baseline and 2030 Goal for Iowa

(Note that the total metric tons CO_2 reduction value assumes that total electricity production remains flat.)

In setting its goal for Iowa the EPA made its calculation based on an assumption of no additional wind power being added after 2012. The explanation for this surprising assumption has to do with the fact that Iowa has been such a leader in wind development. Be that as it may, the EPA was wise enough to suggest that multi-state regions come together to meet their emission goals, so that clean energy from one state exported to another can count toward meeting goals. The most economical way for the U.S. to reduce carbon emissions is to build renewable energy facilities where they are most efficient taking all costs including transmission into account. At sufficient distance the extra cost of transmission can make a new wind facility in a windy but remote location a more costly choice than adding wind or other renewable generation closer to load. But enough transmission capacity exists and can be built economically to support the building of a great deal of new wind generation in Iowa for export to other states at low cost. This issue will be addressed in much more detail in a later section.

Figure 9 reproduces the information in Figure 8, and adds the values for Illinois, Indiana, Michigan, Missouri, Ohio, and Wisconsin, other Midwest states whose wind resources are of less high quality than Iowa’s. Of special note is Illinois, which produced more than twice the amount of electricity as Iowa in 2012, emitted almost 2 ½ times as much CO_2 with a 22% higher emissions rate, and whose EPA goal is a rate reduction from baseline of over double that for Iowa. In terms of absolute quantity of CO_2 reduction, the EPA’s goal for Illinois is five times its goal for Iowa. Note also that all of the other states in Figure 9 are given goals much more ambitious than was given to Iowa.

EPA Calculations of State Emissions in 2012 and Goals for 2030 under 111d Proposal, Selected States							
	Baseline 2012			2030 Goal			
	TWh	Metric tons	#/MWh	#/MWh	%	#/MWh	Metric Tons
State	Energy Produced	Total CO_2 emitted	Emission rate	Emission rate	Rate Reduction	Rate Reduction	CO_2 Reduction (Assuming Constant Energy Production)
IA	49	35,000,000	1,552	1,301	16%	251	5,660,438
IL	101	87,000,000	1,895	1,271	33%	624	28,648,021
IN	105	92,000,000	1,923	1,531	20%	392	18,754,030
MI	82	63,000,000	1,696	1,161	32%	535	19,873,231
MO	80	71,000,000	1,963	1,544	21%	419	15,154,865
OH	111	93,000,000	1,850	1,338	28%	512	25,738,378
WI	46	38,000,000	1,827	1,203	34%	624	12,978,654
Total	574	479,000,000					126,807,617

Figure 9: EPA Baseline and Proposed 2030 Goals for Iowa and Less Windy Midwest States

How close is Iowa to meeting the 111(d) goal just from wind deployments currently in existence and committed after 2012? Given Iowa’s vast untapped wind resource and its demonstrated history of adding wind capacity, what are some reasonable scenarios for future wind development and their impact on CO_2 reduction?

The authors evaluated four scenarios: First, how much wind capacity in addition to what is currently in existence and what is currently committed would be needed for Iowa to meet the 16% CO_2 reduction goal from wind alone? As already discussed MidAmerican has made significant commitments to developing wind in Iowa with installations ongoing and planned through 2015. For the second scenario, a 30% CO_2-emissions-reduction target, more in line with other Midwestern states, is envisaged and evaluated for being met by wind. Third, since the EPA’s target for achieving its goal is 2030, a scenario in which Iowa adds an average of 500 MW annually to 2030 was considered as a conservative option. This option is conservative in that it is lower than the average annual amount of wind generation added since 2008. Fourth, a moderate scenario in which Iowa adds an average of 1000 MW annually to 2030 was assessed. In this scenario the authors also modelled a modest increase in capacity factor over time to account for improvements in technology. As mentioned above, this scenario is very close to the goal that the Iowa Wind Energy Association has called for, and is also in line with the DOE report on 20% wind by 2030.

To arrive at the estimates of CO_2 reduction for the scenarios, it is necessary to estimate the amount of CO_2 reduction achieved by the production of electricity from wind. The calculations and reasoning the authors used to arrive at the estimate are given in the Methodology section below, section VII. The methodology used arrived at a CO_2 emission reduction rate value of 1,533 lbs/MWh, which is a midpoint in an uncertainty range between a lower bound of 1,190 lbs/MWh and an upper bound of 1,875 lbs/MWh. As explained in the methodology section, the authors believe this to be a very conservative estimate.

Scenario 1: Meeting a 16% emissions-reduction goal.

Assuming a 40% capacity factor on new wind generation installed in 2014 and 2015 the following chart illustrates the extent to which Iowa's progress toward the current EPA 111(d) goal for 2030 is already achieved just on the basis of wind developments already undertaken. **In effect Iowa likely already has achieved, just from the wind development currently existing and committed, at least 52% of the 2030 goal the EPA has proposed. The conservative estimates used indicate that by 2016 Iowa's CO_2 rate will be no more than 1,450 lbs/MWh and likely closer to 1,400 lbs/MWh, with a midpoint estimate of 1,421 lbs/MWh. See Figure 10.**

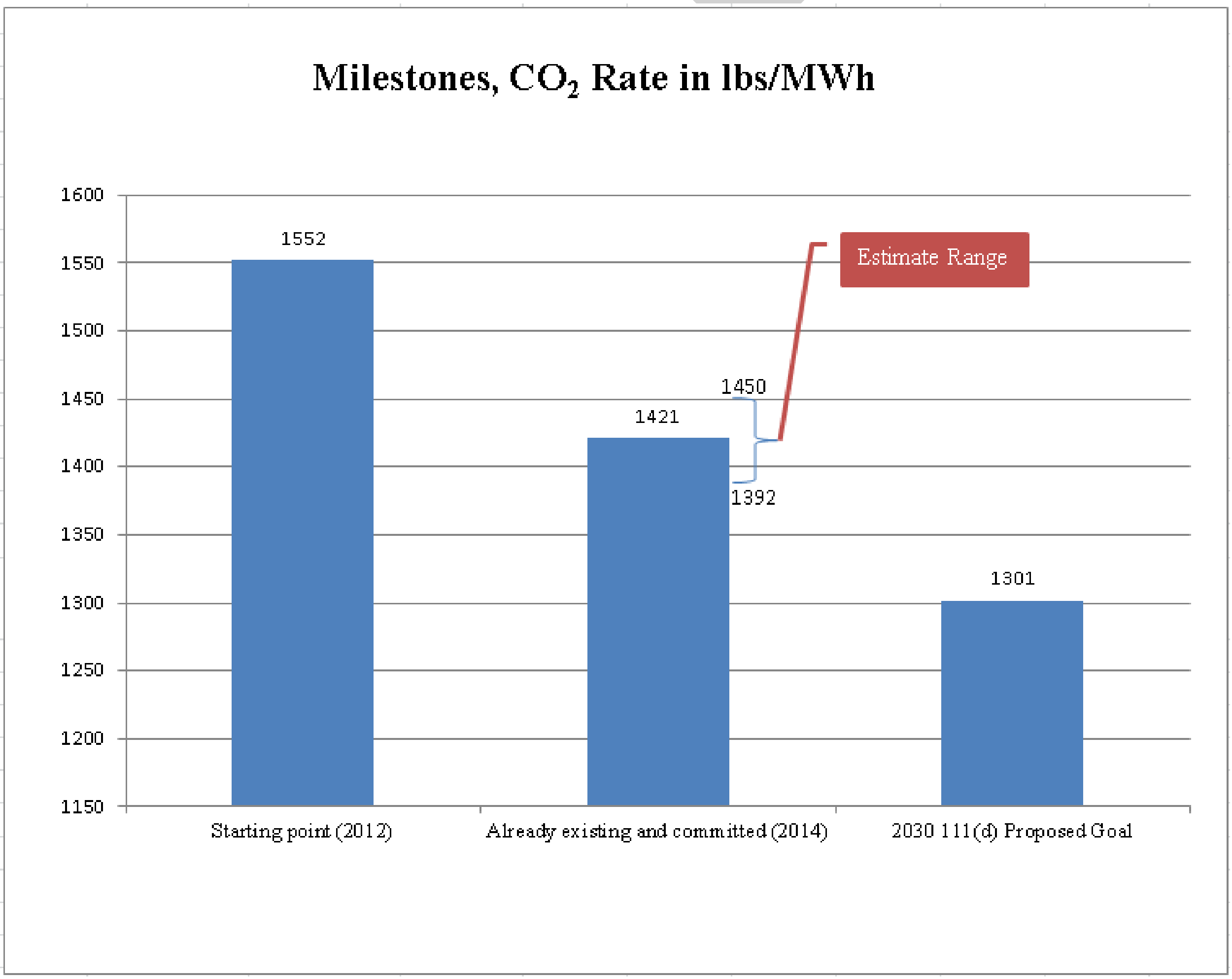

Figure 10: Progress toward 2030 Goal Already Made from Wind

Thus, from 2016 to 2030, a reduction of an additional 120lbs/MWh is all that would be needed. To achieve this from wind alone would require only approximately 1,112 MW, or an average of about 74 MW annually. (Using the estimates here, about 2,300 MW of wind should be sufficient to meet the 2030 goal against the 2012 baseline. Since Iowa will have installed 1,212 MW of that by 2016, only a very small amount would remain from 2016 to 2030.)

Iowa leads the nation in the percentage of its electricity generated from wind. In 2014 that figure was over 28%. If Iowa just meets the 16% carbon-reduction goal of this scenario, Iowa's percentage of generation from wind will be 35%.

Scenario 2: Wind development to reduce CO_2 emissions by 30% from 2012 levels by 2030.

As shown in Figures 8 and 9, a 16% reduction in CO_2 equates to about 5.7 million metric tons. A 30% reduction means a reduction of 10.5 million metric tons, to a rate of 1,086 lbs/MWh. Using the same estimates for capacity factor and emission-reduction rate as above, along with the assumption of no increase in total generation, **the midpoint estimate of the amount of wind that would need to be built to reach such a goal is a total of 3,098 MW from 2016 to 2030, or about 207 MW annually.** The estimate range is from 2,312 MW to 4,340 MW, or 154 to 289 MW added annually.

In this scenario Iowa would be generating 45% of its electricity from wind.

Scenarios 3 and 4: Continued wind development at conservative and moderate rates.

Figure 11 is a chart of the wind capacity additions since 2004 by year in Iowa including those currently being constructed and committed for 2014 and 2015. As the chart and trend line show, developers have been adding on average slightly more than 500 MW of additional capacity annually over the last decade. Also there is manufacturing and construction capability to add much more than that.

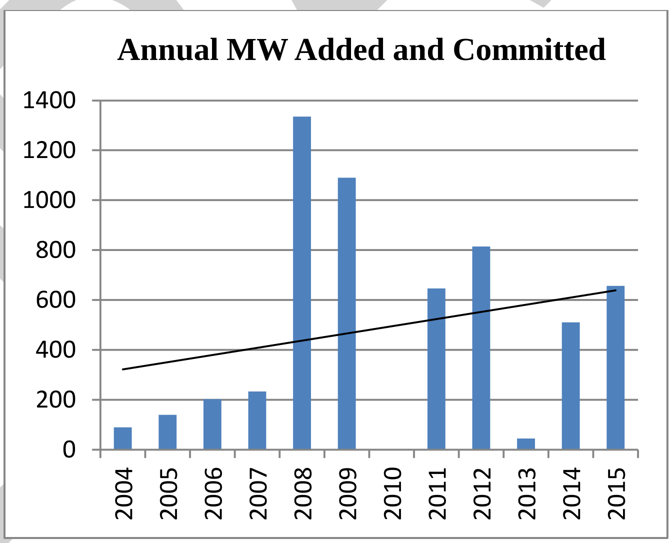

Figure 11: Annual Wind Capacity Additions

The constraints on Iowa's ability to easily add wind power have mostly to do with transmission. Over a time frame of 15 years (2016-2030) quite a lot of transmission capacity can be built. The authors therefore considered a scenario where Iowa, on average, adds 500 MW of wind annually as a conservative goal. This is a rate of installation lower than the average since 2008. Call this the 'conservative' scenario. For a moderate build-out scenario the authors took a page from the Iowa Wind Energy Association (IWEA), which has called for Iowa to have 20,000 MW of wind by 2030. Thus for the moderate scenario, imagine that an average of 1,000 MW of wind would be added annually to 2030.

Additional assumptions: Although wind turbine technology has been improving dramatically in recent years leading to large increases in capacity factors, the authors continued to assume an average of 40% capacity factor throughout the period to 2030 for the conservative scenario. For the moderate scenario, however, the authors have factored in an increase in capacity factor over time amounting to one percent per year. Thus, for example, in year two a capacity factor of 40.4% is used and by the end of the 15-year period the average capacity factor is assumed to be 46%.

As would be expected, the conservative and moderate build-out scenarios result in Iowa far exceeding the goals set in the initial EPA 111(d) proposal for 2030, enabling Iowa's wind to contribute quite significantly to regional CO_2 reduction goals. Figure 12, below, depicts the extent to which CO_2 emission rates could be expected to fall in each scenario with comparison to Iowa's current EPA goal. As the Figure shows, in the conservative scenario, just from the addition of wind, Iowa's emission rate would likely be 611 lbs/MWh or less, with a range from 401 to 821 lbs/MWh. In the moderate scenario, from the addition of wind alone, Iowa's emission rate would likely turn negative, to be less than -318 lbs/MWh, with a range from -735 to +100 lbs/MWh. Clearly, in the moderate scenario Iowa must export a significant amount of its electrical production. Practically speaking, Iowa would be exporting much of its production in the conservative scenario, and in fact, Iowa currently exports some of its wind energy.

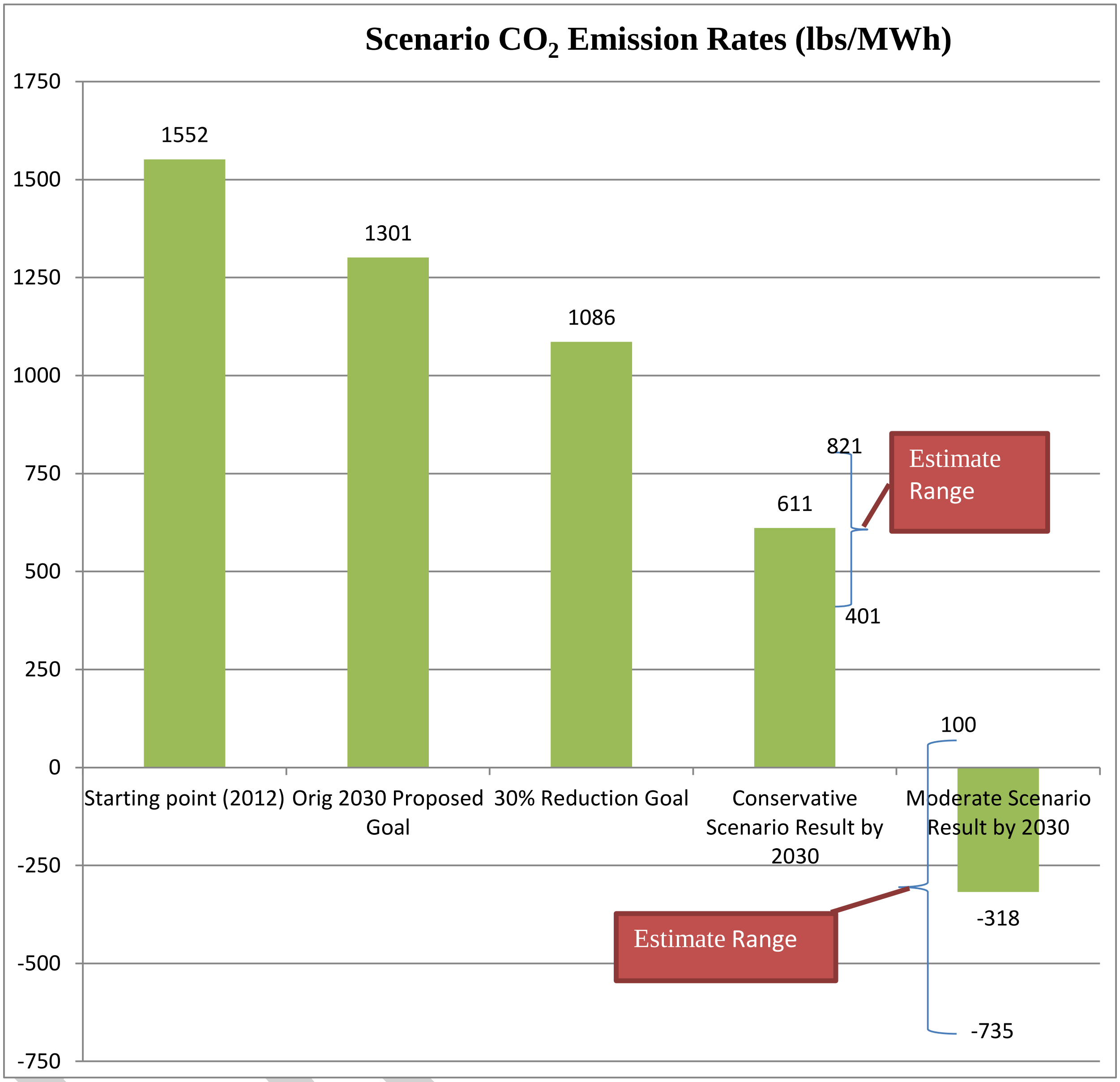

Figure 12: Projected CO_2 Emission Rates in 2030 for the Two Scenarios

It is instructive to look at these results in terms simply of the quantity of CO_2 that is reduced. The original EPA goal for Iowa, assuming electricity production is unchanged, asks for a reduction of less than 5.7 million metric tons of CO_2 annually by 2030. In the conservative scenario developed here, Iowa would be reducing its CO_2 by more than 21 million metric tons annually, and in the moderate scenario the reduction would likely be more than 42 million metric tons annually, with a potential at the high end of the estimate range, of being greater than 50 million metric tons. If the EPA goal for Iowa is not increased, Iowa would likely be capable of contributing more than 15 million metric tons of CO_2 reduction to the region in the conservative scenario, and should be able to contribute more than 36 million metric tons (possibly as much as 45 million metric tons) in the moderate scenario. (Without the moderate scenario's assumption of increasing capacity factors, the median estimated contribution would simply be double that of the conservative scenario, or 30 million metric tons.) All this, of course, is just from wind development. If Iowa makes advances in energy efficiency and other carbon reduction measures, then of course even more would be available.

Impact of Mid-2015 Announced Wind Additions

Within just a few days of the release of the original version of this report, Mid-American and Alliant Energy announced additions of wind generation to be made over the next few years. Mid-American announced the addition of 552 MW and Alliant 200 MW, for a total of 752 MW. Since the original estimate for achieving the scenario 1 goal required 1,112 additional MW, if this announced 752 MW is built, then only 360 MW would remain to meet that goal. If built by 2018 then an average of just 28 MW annually thereafter would suffice to meet the goal. However, such small values suggest a level of precision that this analysis does not support. The authors' methodology supports the view that an additional 752 MW will most likely result in Iowa meeting at least 84% of that 2030 goal, with the midpoint estimate of its emissions rate at 1341 lbs/MWh. But, given the very conservative estimation methods used, and the size of the estimate range, there is a high likelihood that this 752 MW of additional wind would be sufficient for Iowa to meet the original target of 1301 lbs/MWh.

Impact for Other States in the Region

Look again at Figure 9, reproduced here as Figure 13, focusing on the goals for the quantity of CO_2 reduction with the values for the quantity of CO_2 reduction in the scenarios just developed in mind. Notice that the quantity of CO_2 reduction entailed by the EPA goals for Iowa's immediate neighbors, Illinois, Missouri, and Wisconsin, is about 57 million metric tons, well over the amount Iowa is estimated to be able to contribute in the moderate scenario.

EPA Calculations of State Emissions in 2012 and Goals for 2030 under 111d Proposal, Selected States

	Baseline 2012			2030 Goal			
	TWh	Metric Tons	#/MWh	#/MWh	%	#/MWh	Metric Tons
State	Energy Produced	Total CO_2 emitted	Emission rate	Emission rate	Rate Reduction	Rate Reduction	CO_2 Reduction
IA	49	35,000,000	1,552	1,301	16%	251	5,660,438
IL	101	87,000,000	1,895	1,271	33%	624	28,648,021
IN	105	92,000,000	1,923	1,531	20%	392	18,754,030
MI	82	63,000,000	1,696	1,161	32%	535	19,873,231
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OH	111	93,000,000	1,850	1,338	28%	512	25,738,378
WI	46	38,000,000	1,827	1,203	34%	624	12,978,654
Total	574	479,000,000					126,807,617

Figure 13: Reproduction of Figure 9, EPA Goals for 2030, Selected States

Figure 14 illustrates the authors' best estimates for the capacity factor of new wind generation in each state. The installed capacity and wind potential is also listed.

State	Est. Mean Cap Factor	Mid-2014 MW Installed	MW Potential
IA	0.4	5,177	571,000
IL	0.32	3,568	250,000
IN	0.28	1,544	148,000
MI	0.27	1,350	59,000
MO	0.32	459	274,000
OH	0.26	435	55,000
WI	0.3	648	104,000

Figure 14: Mid-2014 Installed Capacity, Estimated Capacity Factors and Potential in Selected States

Clearly no state is close to exploiting the potential of its wind resource. It is natural to ask, as with Iowa, how much wind development would be needed in each state for it to meet its EPA 2030 goal from its in-state wind alone. Figure 15 summarizes the answer, based on the same methods used for estimating Iowa's capability. As above, the range is based on the estimate range for the amount of CO_2 reduction wind power achieves.

State	High End of Range	Midpoint	Low End of Range
IA	2,993	2,324	1,900
IL	18,933	14,702	12,017
IN	14,165	10,999	8,991
MI	15,566	12,087	9,880
MO	10,016	7,777	6,357
OH	20,936	16,257	13,289
WI	9,149	7,105	5,807

Figure 15: Estimated Additional Wind Capacity in MW Needed to Meet State EPA Goals from In-state Wind Alone in Selected States

Comparing even the low ends of the ranges here with the MW installed at midway through 2014 in Figure 14, the increases in wind installation required in all of the states except for Iowa would be substantial, ranging from a multiple of nearly 3.4 for Illinois, to a multiple greater than 30 for Ohio. See Figure 16.

IA	0.37
IL	3.37
IN	5.82
MI	7.32
MO	13.85
OH	30.55
WI	8.96

Figure 16: Minimal Factor Increase in Wind Capacity Installation for Selected States to Meet Their 111(d) Goals from In-state Wind Alone

The authors select these states because, as mentioned above, their wind resources are not of as high a quality as Iowa's. Capacity factor is, in effect, a measure of the quality of the wind resource, and directly and strongly affects the economics of a wind project

These states can easily utilize all the wind-generated electricity Iowa could provide by 2030. Because of their lower capacity factors, *other things equal*, wind would not be as cost effective in these states as in Iowa. However, other things are never equal. These states have much larger population centers with much larger electricity demands, and their transmission infrastructure tends to be more built out. Their wholesale and retail electricity costs are different, typically higher than Iowa's. Their state renewable energy policies are different. The economics of a wind farm at a particular location is very much a function of that location, and so profitable cost-effective wind development is to be expected in these states as well. Looking again at Figures 16 and 14, especially Illinois and Indiana appear to have good prospects for adding enough wind energy to meet a high portion of their EPA goals.

While it would most likely not be feasible for all of these other states to exploit their wind resource to meet their entire emission-reduction goal, as set above, it would be feasible for most of them to use it to meet a significant portion of that goal. (For Missouri, because neighboring Kansas has an excellent wind resource, and Ohio, because it mostly lacks a high quality wind resource, it might be better to rely much more on imports.) Using the same figure (1,533 lbs/MWh) that was used in the Iowa estimates for the emissions reduction rate for wind, Figure 17 shows how much wind capacity would need to be installed in each of these states for them to meet 10%, 25%, 50%, and 75% of their goals from in-state wind, along with the CO_2 shortfall (in metric tons) that would result.

	To Meet 10% of Goal		To Meet 25% of Goal		To Meet 50% of Goal		To Meet 75% of Goal	
State	MW Additions	Met T CO_2 Shortfall	MW Additions	Met T CO_2 Shortfall	MW Additions	Met T CO_2 Shortfall	MW Additions	Met T CO_2 Shortfall
IL	1,470	25,783,219	3,675	21,486,016	7,351	14,324,011	11,026	7,162,005
IN	1,100	16,878,627	2,750	14,065,523	5,500	9,377,015	8,249	4,688,508
MI	1,209	17,885,908	3,022	14,904,923	6,044	9,936,616	9,066	4,968,308
MO	778	13,639,379	1,944	11,366,149	3,889	7,577,433	5,833	3,788,716
OH	1,626	23,164,541	4,064	19,303,784	8,128	12,869,189	12,193	6,434,595
WI	710	11,680,788	1,776	9,733,990	3,552	6,489,327	5,328	3,244,663
Totals	6,893	109,032,461	17,232	90,860,384	34,464	60,573,590	51,696	30,286,795

Figure 17: Capacity of Wind Installation in Selected States that could be expected to Meet 10%, 25%, 50% and 75% of the Stated EPA CO_2 Emission Reductions by 2030, with Remaining CO_2 Shortfall

As pointed out above, given the initial EPA goal for Iowa, and the conservative scenario, Iowa would most likely be able to contribute at least 15,000,000 metric tons of CO_2 reduction to the region, and in the moderate scenario at least 36,000,000. Another way to look at this would be that if Illinois, Indiana, Missouri and Wisconsin met 50% of their own CO_2 reduction goals, then Iowa wind could provide most if not all of the balance of the reductions needed under the moderate scenario. (The shortfall for Illinois, Indiana, Missouri and Wisconsin after meeting 50% of their goals comes to about 37.8 million metric tons. If a "modified" moderate scenario is envisaged, without the assumption of increasing capacity factors, then, as noted above, 30 million metric tons of CO_2 reduction would be "available", which would supply about 40% of the combined goals for the states of Illinois, Indiana, Missouri, and Wisconsin.)

V. Costs

The cost of wind power has been declining in recent years, helping explain why companies like MidAmerican are investing billions of dollars to add to their fleet. The technology continues to improve as well. The industry may have hit the tipping point where competition, efficiencies and innovation will continue to drive the cost lower into the future.

A number of studies have tried to estimate future costs of wind energy production. The following chart (Figure 18) is from an NREL conference paper in 2012, "The Past and Future Cost of Wind Energy"[vi], and summarizes the studies that had been undertaken to that time. The range of estimates is wide (one study estimated no cost reduction), but as the authors note, the range is narrowed significantly by looking at the estimates from the 20th to 80th percentiles. Among those studies the estimates vary from projecting cost reductions of roughly 20% to 30% in levelized cost of wind energy to 2030.

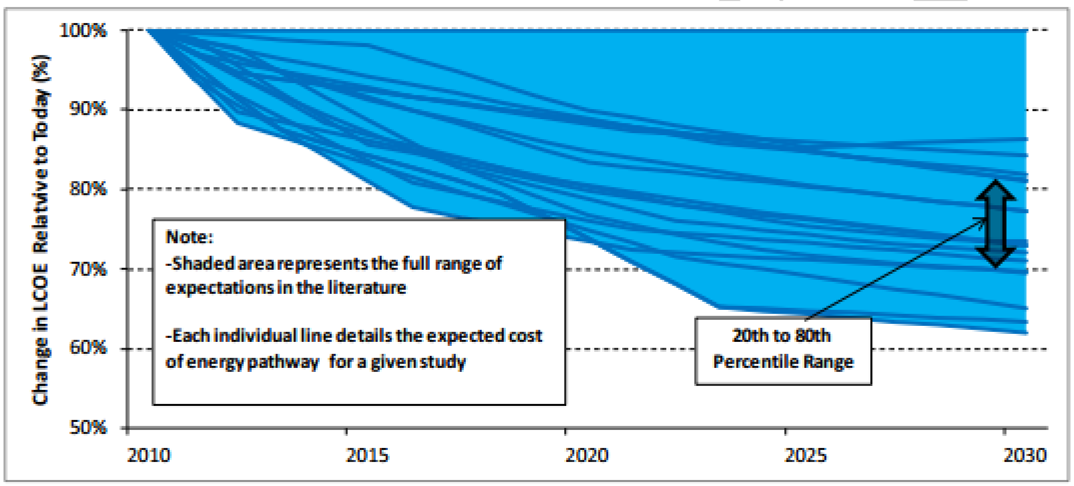

Figure 18: Estimated Range of Future Levelized Cost of Energy (LCOE) across 18 scenarios.

The Lawrence Berkley National Laboratory (LBNL) publishes a yearly report on the wind industry and some of the highlights from the 2013 report are the following[vii]:

- *Turbine prices in recent transactions have been in the $900-$1300/kW range after hitting about $1500/kW by the end of 2008.*
- *Installed costs were roughly $1630/kW in 2013, "down more than $300/kW from the reported average cost in 2012." Iowa's costs are among the lowest.*
- *Wind power pricing fell to an average levelized price of $25/MWh nationwide in 2013, a new low.*
- *"[W]ind energy integration costs are almost always below $12/MWh—and often below $5/MWh—for wind power capacity penetrations of up to or even exceeding 40% of the peak load…."*

Studies comparing the costs of different forms of energy production also exist. One of the most recent was done by Lazard published in September 2014. The following chart, Figure 19, is from their report on the levelized cost of energy, version 8.[viii] As the figure shows, the unsubsidized cost of wind generation was found to be from \$37-\$81 per MWh. This is in line with the average \$25/MWh levelized price found by LBNL, as that is not an unsubsidized rate.

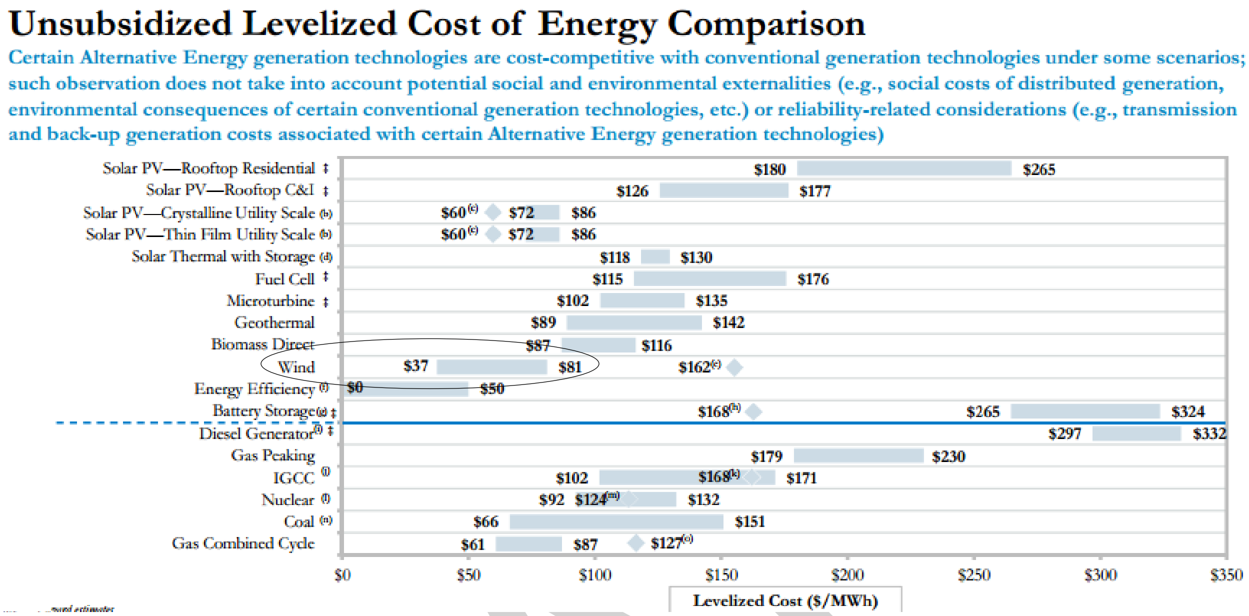

Figure 19: From Lazard's Levelized Cost of Energy Analysis

The authors have assumed that the delivered cost for new wind generation in Iowa is around \$25 to \$30 per MWh with a federal production tax credit (PTC) of \$23 per MWh. Without the PTC, the levelized cost might only go up about \$15 per MWh since the PTC is only available for 10 years and using the PTC often results in less cost efficient financial structures for wind projects. .

The last two bullet points from the LBNL report can be used to estimate the cost per unit of CO_2 reduction from wind. Iowa's wind penetration is about 28%, but the grid doesn't stop at the border. Some of Iowa's production is exported to neighboring states, especially Illinois, where the wind penetration is about 5%[ix], and where the electricity load and production dwarf Iowa's. The delivered cost of additional wind power would likely go up with any major expansion in Iowa due to additional cost of transmission system investments and wind integration costs, although these costs could be mitigated by cost reductions from turbines and O&M as estimated above and illustrated in Figure 18.

Transmission Costs

All of the wind power added to date in Iowa has required some modest investment in the transmission system. Most of these investments have been to increase the capacity of existing lines and substations. Such incremental investments are relatively economical per kW of added wind generation capacity compared to the construction cost of a new 345 kV line. Transmission and generation planners have been very successful in finding the most economical transmission investments per kWh of added wind generation. For example, although the southeastern half of Iowa has the potential for more economical transmission capacity improvements per kW, the area is less windy which results in higher cost per kWh at the wind turbine bus. This combination of less expensive transmission improvements and higher wind generation costs has not been the most economical combination yet as there are no wind farms in this area. Balancing this tradeoff between low transmission costs and higher wind generation costs will continue as the best sites are built out. As a result, the delivered cost, which includes transmission costs, of each new wind generation project faces upward pressure over time as more wind generation is added. Despite this upward transmission cost pressure better wind turbine technology has generally been lowering the overall delivered cost of wind generation.

Figure 20 shows the location of the utility-scale wind generation in and around Iowa. Essentially all of Iowa’s wind generation is in the northwest half of Iowa where it is the windiest and where the existing transmission grid could be economically upgraded to accommodate the new wind generation.

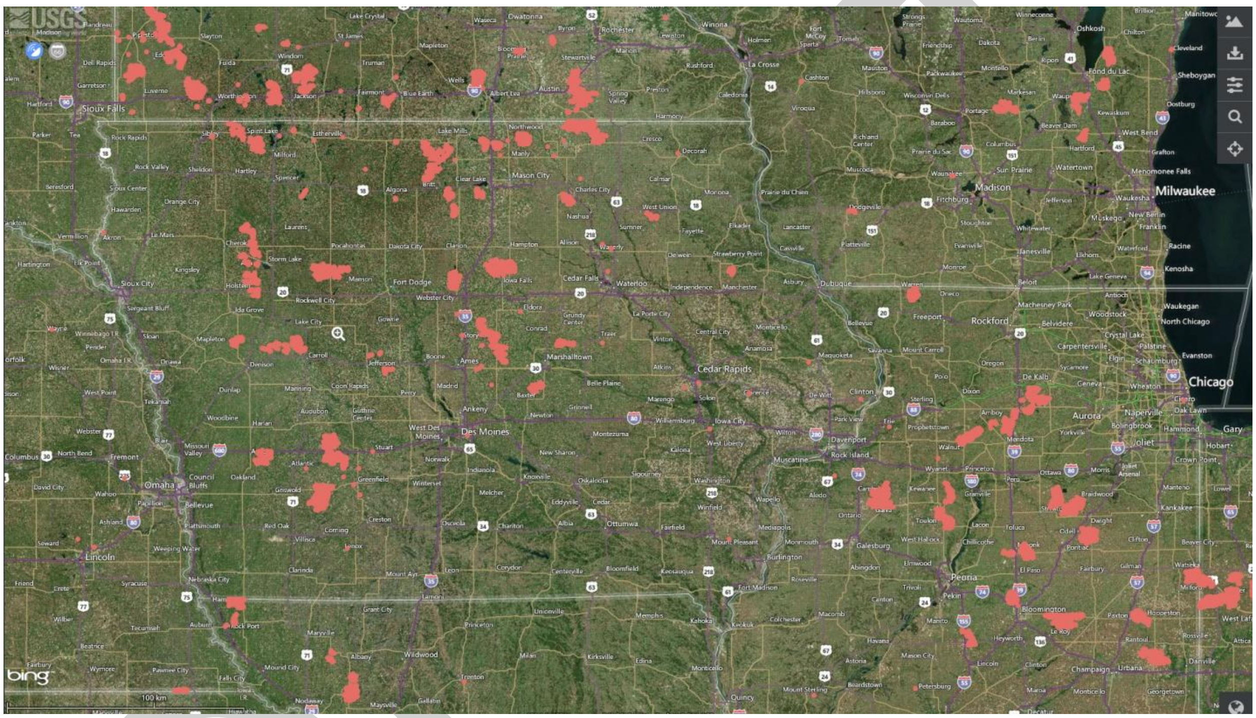

Figure 20: Utility Scale Wind Generation In and Around Iowa

The conservative and moderate wind generation expansion scenarios will require increasing transmission investments which will generally raise the delivered cost of new wind generation in Iowa over time compared to what it would be if all else could be held constant.

The proposed Rock Island Clean Line transmission project is a 500-mile high-voltage direct current (HVDC) line and system specifically intended to increase the export of up to 3,500 MW of wind power from the northwest Iowa region to Illinois. This $2.0 billion project might represent the upper bound of transmission cost for wind power since it is specifically for wind power. This type of project could be replicated for transmitting power from windy areas to less windy areas. The authors estimate that the delivered cost of wind power to Illinois would be about $40 per MWh. This $40 cost includes the all-in cost of wind power and the transmission system, based on the continuation of the PTC. With another $5 per MWh for integration costs, the authors believe that the cost of additional wind power in Iowa is lower than this at this time but that the cost will generally increase over time with $45 per MWh representing an upper cost benchmark for Iowa wind power with the PTC.

The Midcontinent Independent System Operator (MISO) has identified several Multi-Value Transmission Projects (MVPs) that reduce the overall cost of power to the MISO region by allowing more wind generation to be added to the grid. These MVP projects and future projects will allow some growth of wind power in Iowa. The cost of these MVP projects will be spread over the entire MISO footprint since the projects are expected to reduce the overall cost of power to consumers in MISO. As a result, this additional wind power in Iowa will not significantly increase the cost of transmission delivery that Iowans pay.

To summarize: Based on the authors' assessment, new wind generation currently costs about $30 per MWh and the cost will generally increase over time to a value of about $45 per MWh due to higher transmission and integration costs. These costs are based on the continuation of the federal PTC.

Cost of CO_2 Reduction

The average cost of power in the MISO market in Iowa is in the range of $30 per MWh. On windy days, the cost would typically be a little less due to supply and demand pressures. This market price of power does not specifically include any costs for CO_2 emissions. With the current cost of new wind power being about $30 per MWh the market price for conventional power is about equal to the cost of new wind generation. When considering the integration costs of wind power and the slightly lower costs of market power during high wind periods, new wind generation might have a current cost premium of $5 per MWh. This cost premium will likely go up under the conservative or moderate expansion scenarios. If this $5 per MWh premium is considered a cost of reducing CO_2, then the current cost of CO_2 reductions from wind is about $7 per metric ton ($5 divided by 1,533 lbs. of CO_2 per MWh divided by 2,200 pounds per metric ton).

The cost premium in the future will depend upon the market price for power which depends on the cost of natural gas to some extent. Even if the delivered cost of wind power goes up to $45 per MWh with a moderate expansion of wind power in Iowa, the price premium may not go up by the same $15 per MWh increase in wind power costs because market prices will rise over time due to higher fuel and environmental compliance costs. Furthermore, utility scale energy storage will very likely be added to the grid to reduce the cost of integrating wind and solar generation. Therefore the cost premium for wind power might only be $10 per MWh. Once again, considering that premium a cost of reducing CO_2 would imply that the cost of CO_2 reductions from wind would be about $15 per metric ton of CO_2.

VI. Economic Impacts

Like any major capital improvement project, there are economic benefits in the form of direct and induced economic activity. There are construction jobs and the induced economic benefits to the local economy from that activity. Iowa has factories that produce major wind turbine components, and if any wind turbines are ordered from those factories, the companies and the state of Iowa will benefit. Land owners receive substantial annual lease payments for hosting turbines. Local governments receive increased tax revenues that continue for many years, lowering the tax rates for local taxpayers.

The Iowa Wind Energy Association (IWEA) provides a number of highlights about wind energy's economic benefits to the state, among which are the following:

- Dickenson County will enjoy a nearly $81 million increase in its tax base when the latest 97 turbines are fully assessed.

- Pocahontas County will have an increase of $189 million in its tax base when the 216 turbines installed there are fully assessed. The county has received more than $3 million in tax revenue from the turbines in the last three years, and some residents have seen their tax bills decrease.
- Iowa's wind energy industry in the past supported 6,000 to 7,000 jobs directly.
- Landowners receive more than $16 million annually in lease payments.
- Total increased assessed value of property for the turbines existing in the state through 2013, when fully realized, is estimated to be $2.6 billion.
- Capital investment from wind development in Iowa will total more than $10 billion by the end of 2015.

MidAmerican, in its initial announcement of an additional 1,050 MW of new wind generation in Iowa by the end of 2015, estimated that the expansion would provide "more than $360 million in additional property tax revenues over the next 30 years" and that landowner payments would total $3.2 million annually.

Retail Electric Rate Impact

A number of studies and the actions of several large utilities have shown that wind can stabilize and potentially lower electricity rates over time. MidAmerican's multibillion-dollar investment in wind in Iowa would not be occurring if MidAmerican did not see the investment as good for its customers. Xcel Energy has also made substantial investments in wind energy, because it believes wind is the lowest cost electricity over the long term. Also refer again to Figure 18 above, where, in comparing the popular forms of energy generation, Lazard reports that wind has the lowest levelized cost, and of all the forms of CO_2-reduction technologies it considers, only energy efficiency is lower cost.

In MidAmerican's 2013 announcement of its large expansion in Iowa, it said that the expansion "will help reduce future rates to our customers by as much as $10 million per year".[x] Xcel has echoed this point repeatedly as its subsidiaries have negotiated purchase of large amounts of wind power. For example, subsidiary Northern States Power (NSP), later in 2013, signed up 600 MW of new wind power from projects in Minnesota and North Dakota. Of this purchase Dave Sparby, President and CEO of NSP-Minnesota said, "These projects will lower our customers' bills, offer protection from rising fuel costs, and provide significant environmental benefits."[xi]

Wind power may not always reduce power costs for all utilities. It is difficult to determine what the real impact is on today's electric rates since there are so many factors at play. Especially relevant is the cost of the externalities that are not currently reflected in the bills ratepayers see. If some of those costs begin to show up, such as through a carbon tax, electric rates for coal burners could go up significantly. As climate issues multiply, the likelihood of such a change in policy increases. In such an event as that, wind power's effect on future electric rates would likely be very favorable. Even without it, wind power's effect on future electric rates will not likely cause significant increases.

VII. Methodology

This study draws together results of previous work from a variety of readily available and reliable sources to look at the role Iowa's wind resource could play in economically reducing carbon pollution. In looking at how wind power can reduce CO_2, the number that is most important is the estimate of the amount of CO_2 reduced by a given unit of wind power, the CO_2 reduction rate. Until fairly recently little publically available information on wind power's CO_2 reduction rate existed, and there is still uncertainty associated with precise values. To some extent the rate is a moving target as the fleet of generators changes.

Since it emits no CO_2, it is clear that adding wind to a power portfolio that includes fossil fuel generation reduces the CO_2 emission rate. The extent of the reduction depends on the amount and type of fossil fuel generation that is displaced. In the best case the reduction would be one for one, i.e., every MWh of wind generated electricity eliminates a MWh of fossil generation. The type of generation that emits the most CO_2 is coal. So, it is when displacing coal-fired generation that wind has the most effect in reducing CO_2. Adding wind to a power portfolio consisting mostly of coal will have a larger effect than adding wind to a portfolio consisting mostly of other energy sources..

Figure 24 shows the historical CO_2 emission rates for the fossil sources in Iowa, as well as the historical CO_2 emission rate for all sources, including renewables, combined.[xii]

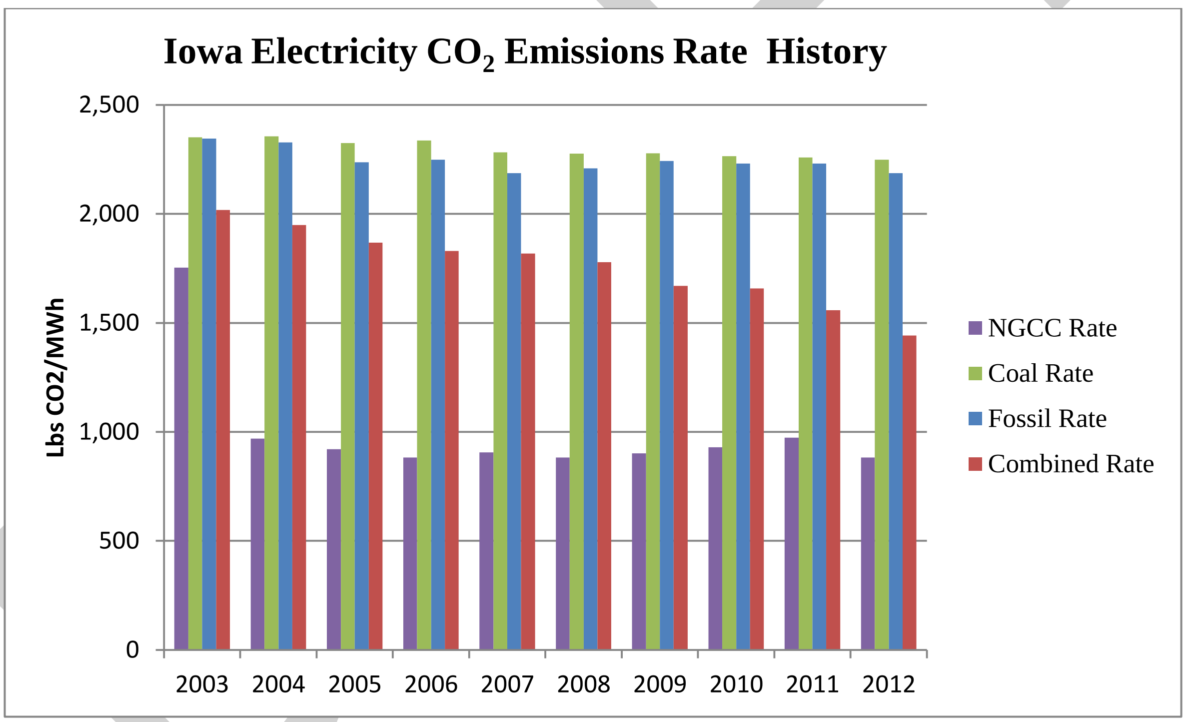

Figure 24: Past CO_2 Emission Rates for Fossil Sources and for All Sources Combined

Energy markets are complex, and it is not possible for coal production to throttle back and forth very efficiently in response to renewable generation. There is no obvious precise answer to the amount of CO_2 reduction that can be expected from adding wind. However, based on studies and modeling already performed, it is possible to make some reasonable estimates.

NREL has done a study for the western U.S. and found that wind and solar generation reduced CO_2 emissions 1,190 lbs/MWh.[xiii] The energy mix in this region of the country is about 30% coal, 30% natural gas, 22% hydro, and 10% nuclear, with renewables comprising most of the rest[xiv]. NREL's study found that whether natural gas or coal was displaced depended strongly on the relative price of the two. In scenarios of cheap natural gas ($3.50/MBTU), primarily coal was found to be displaced. In those scenarios the reduction in CO_2 emissions was found to be about 80% greater than in scenarios where natural gas was relatively expensive.[xv] NREL's base assumptions for the study were a relatively high price for natural gas. Thus it found that mostly natural gas was displaced, and the 1,190 lbs/MWh number was the result.

For Iowa, in 2012, coal was about 62% of the mix, and natural gas only 2.6% of the mix. In 2010 coal accounted for more than 70% of the mix in Iowa, according to the EPA. The most recent EIA data for 2013 puts coal at 59% of the mix. The EIA figure for Illinois and other selected Midwestern states for 2012 and 2013 are given in the table below, Figure 25.

	% of Total Electricity Generation from Coal	
State	2012	2013
IA	62%	59%
IL	41%	43%
IN	81%	84%
MI	49%	53%
MO	79%	83%
OH	66%	69%
WI	51%	62%

Figure 25: Portion of Electricity Generation from Coal for Selected States, 2012 and 2013[xvi]

Iowa's reliance on coal, as with most of the Midwest, is thus double that of the West and the use of natural gas in Iowa is only a tenth as much. As a result, wind in Iowa is much more likely to displace coal and so have a much larger CO_2 reduction rate. It therefore seems reasonable to view the 1,190 lbs/MWh value for the CO_2 reduction rate for the western U.S. as a lower boundary for what could be expected in Iowa, and in fact a lower boundary could thus be reasonably put quite a bit higher. To stay on the conservative side, the authors have used the 1,190 value as a lower bound.

The EPA has developed a tool called AVERT (AVoided Emissions and geneRation Tool), launched in February 2014, which contains a database of all of the generators in the U.S. and is intended to estimate the emissions benefits from energy efficiency and renewable energy programs.[xvii] AVERT uses historical data from 2007-2013. It represents the dynamics of electricity dispatch based on historical patterns. The tool divides the U.S. into regions as shown in Figure 26.

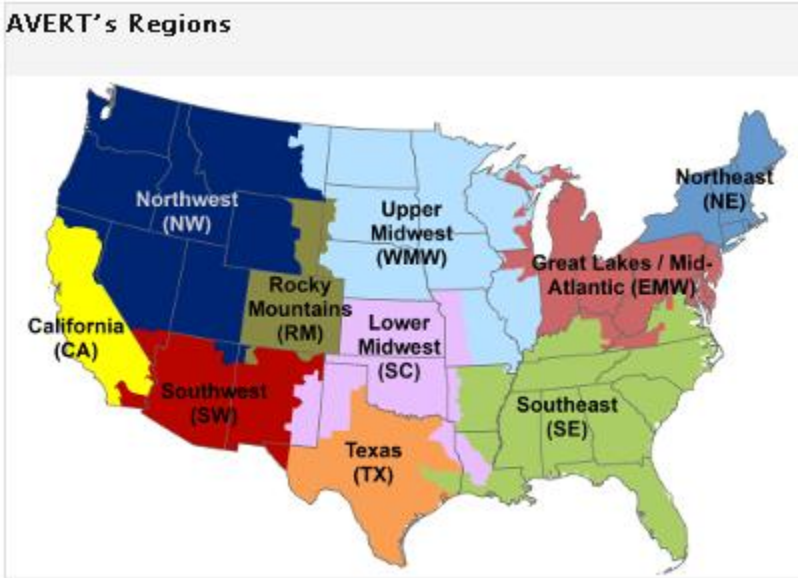

Figure 26: AVERT Regions

Iowa is entirely in the upper Midwest region.

The following is from the AVERT website explaining how AVERT works.

1. AVERT's Statistical Module uses hourly "prepackaged" data from EPA's Air Markets Program Data (AMPD) to perform statistical analysis on actual behavior of past generation, heat input, SO_2, NO_x, and CO_2 emissions data given various regional demand levels. (AVERT's Statistical Module can also analyze user-modified data created in the AVERT's Excel-based Future-Year Scenario Template). AVERT's Statistical Module produces regional data files that are input files used in the AVERT's Excel-based Main Module.
2. AVERT's Main Module prompts users to select one of 10 AVERT Regional Data Files and enter EE/RE impacts (MWhs or MW) from a selection of options.
3. The AVERT Main Module performs the emissions displacement calculations based on the hourly electric generating unit information in the regional data files and the EE/RE impacts entered into the tool.

The authors used the AVERT tool to generate additional estimates of the CO_2 emissions reductions that might be attributable to wind generation in Iowa. The tool takes as input a value, in MW, of the type of renewable capacity to be added to a region. Since some Iowa wind power is exported to the east and could also go south, scenarios were run not only for the Upper Midwest region, but also for the Great Lakes/Mid-Atlantic region, and the Southeast region. Scenarios of an addition of 5,000 to 15,000 MW of wind were run for the Upper Midwest region, and of 15,000 MW for the Great Lakes/Mid-Atlantic and Southeast regions. The results are presented in the following table (Figure 27).

Region	Scenario (MW of Wind Added)	CO_2 Emissions Reduction Rate (lbs/MWh)
Upper Midwest	5,000	1,822
	10,000	1,848
	15,000	1,875
Great Lakes/Mid-Atlantic	15,000	1,553
Southeast	15,000	1,365

Figure 27: Results of AVERT Modelling Scenarios

The midpoint between the lower boundary (from NREL, for the West) and the maximum rate here is **1,533** lbs/MWh, and seems a reasonable and conservative estimate for the CO_2 emissions impact that wind in Iowa would have. Expecting the correct value to be between 1,190 and 1,875 implies a range of 22% (343 lbs/MWh) from the median. For simplicity, in this study, where a range of values is not given, the authors use the value of 1,533 lbs/MWh as the CO_2 reduction rate for wind in Iowa and the Midwest.

VIII. Observations and Summary

Despite the quantitative uncertainties, Iowa's wind energy is a powerful force for reducing CO_2 emissions. Given this potential, the EPA's 111(d) target for Iowa is not at all ambitious, as, just from its wind development alone, Iowa already is likely more than half of the way to the 2030 target. Based on the very competitive cost of wind power, the cost for Iowa to comply with the 111(d) requirement, if it uses only wind power to do so, will be very modest. Furthermore, a moderate expansion of wind power in Iowa for helping other states meet compliance could be cost competitive and would likely have nominal cost impacts on Iowans since the added costs for the wind power and integration will be largely paid by the customers using the power. The work described in the DOE's recent Wind Vision report makes a case that a significantly larger deployment of wind capacity, averaging 1,450 MW annually, would be feasible.

Given the local economic and the wider environmental impacts, the continued expansion of wind power on a large scale in Iowa appears to be extremely beneficial, to the state, the region, and the planet.

[i] Data is from the U.S. Energy Information Administration (EIA). Source: NRDC Emissions Data Tool

[ii] While a specific number is not found in the report itself, a value greater than 10,000 MW is shown in the projection map for Iowa for 2024. http://www.nrel.gov/docs/fy08osti/41869.pdf p. 157. The value "close to 20,000 MW" is confirmed from conversation with writers of the report.

[iii] http://www.energy.gov/windvision

[iv] http://www.eia.gov/electricity/data/browser/

[v] IBID.
[vi] http://www.nrel.gov/docs/fy12osti/54526.pdf

[vii] http://energy.gov/sites/prod/files/2014/08/f18/2013%20Wind%20Technologies%20Market%20Report_1.pdf
[viii] www.lazard.com/PDF/Levelized_Cost_of_Energy_-_Version_8.0.pdf
[ix]http://www2.illinois.gov/xxipa/Documents/IPA-2014-Renewables-Report-3-31-14-final.pdf
[x] IBID.
[xi] http://www.aweablog.org/blog/post/4000-mw-and-counting-xcel-energy-punctuates-busy-first-half-of-2013-for-rfps-contracts
[xii] Data from the EIA.
[xiii] http://www.nrel.gov/electricity/transmission/western_wind.html
[xiv] 2010 data from EPA eGRID http://www.epa.gov/cleanenergy/documents/egridzips/eGRID_9th_edition_V1-0_year_2010_Summary_Tables.pdf

[xv] http://www.nrel.gov/docs/fy10osti/47781.pdf
[xvi] http://www.eia.gov/electricity/data/browser/
[xvii] http://epa.gov/avert/