The Beacon Hill Institute

The Economic Impact of Missouri's Renewable Energy Standard

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Executive Summary

In November 2008 residents of Missouri voted in favor of a ballot initiative that eliminated the state's voluntary renewable energy standards and replaced it with a formal, mandatory Renewable Energy Standard (RES). This law requires that Missouri produce 15 percent or more of its energy by 2021 from specific renewable energies, with an explicit carve-out to encourage solar energy. Typically this type of law applies to all major energy sources in a state, but the Missouri RES only applies to investor-owned utilities, or about 65 percent of electricity sales.

The Beacon Hill Institute has applied its STAMP® (State Tax Analysis Modeling Program) to estimate the economic effects of these RES mandates. The U.S. Energy Information Administration (EIA), a division of the Department of Energy, provides optimistic estimates of renewable electricity costs and capacity factors. This study bases our estimates on EIA projections, but we also provide three estimates of the cost of Missouri's RES mandates — low, medium and high — using different cost and capacity factor estimates for electricity-generating technologies from the academic literature. Our major findings show:

- The current RES law will raise the cost of electricity by $1.41 billion for the state's electricity consumers in 2021, within a range of $510 million and $2.195 billion; and
- Missouri's electricity prices will rise by 14.8 percent by 2021, due to the RES law.

These increased energy prices will hurt Missouri's households and businesses and, in turn, inflict significant harm on the state economy. In 2021, the RES would:

- Lower employment by an expected 6,065 jobs, within a range of 2,185 jobs and 9,450 jobs
- Reduce real disposable income by $675 million, within a range of $245 million and $1.055 billion
- Decrease investment by $75 million, within a range of $27 million and $116 million
- Increase the average household electricity bill by $195 per year; commercial businesses by an average of $1,195 per year; and industrial businesses by an average of $27,425 per year.

Introduction

Missouri has few fuel resources; therefore most of its resources must be obtained from out of state. This, combined with large windy and fertile flatlands has motivated the state government to respond with public policy initiatives designed to promote the use of alternative energy sources.

Implemented in November 2008, the Missouri Green Power Initiative Statute 393, which instituted the state's Renewable Energy Standard (RES), was certified by the Secretary of State soon afterward.[1] This bill required all electric utilities' renewable energy sources to make up at least two percent of retail electricity sales generated for the years 2011 through 2013; no less than five percent for the years 2014 through 2017; no less than 10 percent for the years 2018 through 2020; and at least 15 percent renewable production each year for 2021 and after. Additionally, the law requires that two percent of the 15-percent mandate (.3 percent overall) to come from solar power.

An expanded list of eligible renewables was included in a July 2010 revision to the law. This list includes wind, solar (both thermal and photovoltaic), dedicated crops, numerous biomass types, wood waste and fuel cells – as long as all mentioned come into effect after November 4th, 2008.[2] Hydroelectric power, one of the most common and inexpensive forms of renewable energy, only counts if it has a nameplate rating less than 10 MW. Besides the exclusion of large hydropower, nuclear energy is not included.

Specifics of the law were released in 2010 by the Secretary of State and the Missouri Public Service Commission (MPSC), two of the overseers of the implementation of the RES. The law assigns bonus credits for electricity generation inside the state. Renewable power generation within Missouri counts for 1.25 total megawatt hours (MWhs) of production toward the RES: one for the actual production, and an additional twenty-five hundredth of a credit for the in-state production. The law also states that solar renewable credits (S-REC) are applicable as REC.

The Act also contains measures to theoretically limit the impact of retail rate increases to customers. This means that electricity providers are not required to comply fully with the law,

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[1] Missouri Statutes, Chapter 393. Sections 1020 to 1040.
http://www.moga.mo.gov/statutes/chapters/chap393.htm.

[2] Missouri Senate Bill No. 795. http://www.senate.mo.gov/10info/pdf-bill/tat/SB795.pdf.

if, as determined by the MPSC, the average retail price would be affected by more than 1 percent due to the RES law. However, the MPSC should determine this rate increase "by estimating and comparing the electric utility's cost of compliance with least-cost renewable generation and the cost of continuing to generate or purchase from entirely nonrenewable sources." Additionally, "future environmental regulatory risk including that of greenhouse gas regulation should be taken into account."[3]

So, according to the language of the law, the MPSC is required to assure that utilities attain the RES, and has the sole authority to determine if the cost impacts will be greater than one percent. While making this determination they must estimate the cost of compliance (including the possible cost of non-built renewable energy), the least cost energy source (of a theoretical power plant) as well as the theoretical purchase contracts. On top of this they need to determine the cost of future regulatory policy in the U.S. If MPSC analysts are able to do all of this accurately, frankly their talents are being wasted. We assume, based on what has been seen in other states with similar caps, that the MPSC will err on the side of enforcing the cap. Additionally, this will allow the model to calculate the entire cost of the RES bill, as approved and passed by lawmakers.

Another component of the Act – the banking of unused Renewable Energy Credits (RECs) – could help defray costs. By producing more green energy than required by the Act, energy suppliers could bank credits to reduce future requirements. However the EIA projections made prior to the law show a baseline scenario in which renewable electricity generations will fall below REP minimums. Therefore we think it is unlikely that producers will supply excess renewable energy to trigger banking. All green energy produced will go towards the requirement that year; not banked for future consumption. For this reason, we assume that they will have no effect on overall price of production.

Despite the lengths to which the law goes to support favored renewable energy production, the law only applies to investor-owned utilities, exempting both municipal utilities and electric cooperatives which most other state RESs cover. By exempting these utilities, the law, in effect, only covers about 65 percent of energy produced in the state, reducing the potential effects on the state economy.

[3] Missouri Register. August 16, 2010. Vol. 35, No. 16, Page 1190. https://www.efis.psc.mo.gov/mpsc/commoncomponents/viewdocument.asp?DocId=935517878.

Since renewable energy generally costs more than conventional energy, many have voiced concerns about higher electric rates. A wide variety of cost estimates exist for renewable electricity sources, and the EIA provides estimates for the cost of conventional and renewable electricity generating technologies. However, the EIA's assumptions are optimistic about the capacity of renewable electricity to generate cost-efficient and reliable energy.

A review of the literature shows that in most cases the EIA's projected costs can be found at the low end of the range of estimates, with the EIA's capacity factor for wind at the high end of the range. The EIA does not take into account the actual experience of existing renewable electricity power plants. Therefore we provide three estimates of the cost of Missouri's RES mandate: low, medium and high, using different cost and capacity factor estimates for electricity-generating technologies from the academic literature.

One could justify the higher electricity costs if the environmental benefits – in terms of reduced greenhouse gases (whether they are a harm or benefit is hotly disputed) and other emissions – outweighed the costs. However, it is unclear that the use of renewable energy resources – especially wind and solar – significantly reduces GHG emissions. Due to their intermittency, wind and solar require significant backup power sources that are cycled up and down to accommodate the variability in the production of wind and solar power. A recent study found that wind power actually increases pollution and greenhouse gas emissions.[4] Thus, there appear to be few, if any, benefits to implementing RES policies based on heavy uses of wind.

Governments enact RES policies because most sources of renewable electricity generation are less efficient and thus more costly than conventional sources of generation. RES policies force utilities to buy electricity from renewable sources, and thus guarantee a market for them. These higher costs are passed on to electricity consumers, including residential, commercial and industrial customers.

Increases in electricity costs are known to have a profound negative effect on the economy – not unlike taxes – as prosperity and economic growth are dependent upon access to reliable and affordable energy. Since electricity is an essential commodity, consumers will have limited opportunity to avoid these costs. For the poorest members of society, these energy taxes will compete directly with essential purchases in the household budget, such as food, transportation and shelter.

[4] See "How Less Became More: Wind, Power and Unintended Consequences in the Colorado Energy Market," http://goo.gl/kr6qN, Bentek Energy, LLC. Evergreen Colorado: May 2010.

In this paper the Beacon Hill Institute at Suffolk University (BHI) estimates the costs of this Act and its impact on the state's economy. To that end, BHI applied its STAMP® (State Tax Analysis Modeling Program) to estimate the economic effects of the state RES mandate.[5]

[5] Detailed information about the STAMP® model can at http://www.beaconhill.org/STAMP_Web_Brochure/STAMP_HowSTAMPworks.html.

Estimates and Results

In light of the wide divergence in the costs and capacity factor estimates available for the different electricity generation technologies, we provide three estimates of the effects of Missouri's RES mandate using low, medium and high cost estimates of both renewable and conventional generation technologies. Each estimate represents the change that will take place in the indicated variable against the counterfactual assumption that the RES mandate would not be implemented. The forthcoming Appendix contains details of our methodology. Table 1 displays the cost estimates and economic impact of the 15 percent RES mandate in 2021, compared to a baseline of no RES policy.

Table 1: The Cost of the 15 Percent RES Mandate on Missouri (2012 $)

Costs Estimates	**Low**	**Medium**	**High**
Total net cost in 2021 ($m)	510	1,410	2,195
Total net cost 2013-2021 ($m)	2,060	4,470	6,875
State as a Whole			
Electricity price increase in 2021 (cents per kWh)	0.46	1.27	1.97
Percentage increase	5.3	14.8	23.0
Investor-Owned Utility Customers			
Electricity price increase in 2021 (cents per kWh)	0.69	1.91	2.97
Percentage increase	8.0	22.2	34.7
Economic Results (2021)			
Total Employment	(2,185)	(6,065)	(9,450)
Investment ($m)	(27)	(75)	(116)
Real Disposable Income ($m)	(245)	(475)	(1,055)

The current RES will impose costs of $1.41 billion by 2021, within a range of $510 million and $2.195 billion. As a result, the RES mandate would increase average electricity prices by 1.27 cents per kilowatt-hour (kWh) or by 14.8 percent, within a range of 0.46 cents per kWh, or by 5.3 percent, and 1.97 cents per kWh, or by 23 percent. These numbers are averages for the state as a whole, but the RES law only imposes itself upon investor-owned utilities, which cover approximately 65 percent of retail sales. If you received your energy from an investor-owned utility, the price increase you could expect would be 1.91 cents per kWh, or 22.2 percent.

The STAMP model simulation indicates that, upon full implementation, the RES law will harm Missouri's economy. The state's ratepayers will face higher electricity prices that will increase their cost of living, which will in turn put downward pressure on households' disposable income. By 2021 the Missouri economy will shed 6,065 jobs, within a range of 2,185 and 9,450 jobs.

The job losses and price increases will reduce real incomes as firms, households and governments spend more of their budgets on electricity and less on other items, such as home goods and services. In 2021, real disposable income will fall by an expected $675 million, between $245 million and $1.055 billion under the low and high cost scenarios respectively. Furthermore, net investment will fall by $75 million, within a range of $27 million and $116 million.

Table 2 shows how the two different RES mandates affect the average annual electricity bills of households and businesses in Missouri. In 2021, the 15 percent RES will cost families an expected $195 per year; commercial businesses $1,195 per year; and industrial businesses $27,425 per year. An average household would spend $635 more between 2013 and 2021; a commercial ratepayer $3,880 more; and an industrial ratepayer would pay $89,155 more.

Table 2: Annual Effects of RES on Electricity Ratepayers (2012 $)

	Low	Medium	High
Cost in 2021			
Residential Ratepayer ($)	70	195	305
Commercial Ratepayer ($)	430	1,195	1,860
Industrial Ratepayer ($)	9,890	27,425	42,735
Total over period (2013-2021)			
Residential Ratepayer ($)	295	635	975
Commercial Ratepayer ($)	1,800	3,880	5,965
Industrial Ratepayer ($)	41,405	89,155	137,120

Again, the above numbers are averages across all residents in Missouri, while the costs will be limited to just those that have electricity supplied by investor-owned utilities. Those residents and businesses will pay an expected $250 per year in 2021; commercial businesses $1,520 per year; and industrial businesses $34,980 per year. An average household would spend $815 more between 2013 and 2021; a commercial ratepayer $4,985 more; and an industrial ratepayer would pay $114,580 more.

Emissions: Life Cycle Analysis

One could justify the higher electricity costs if the environmental benefits – in terms of reduced emissions – outweighed the costs. Up to this point we calculated the costs and economic effects of requiring more renewable energy in the state of Missouri. The following section conducts a Life Cycle Analysis (LCA) of renewable energy and the total effect that the state RES law is likely to have on Missouri's emissions.

The burning of fossil fuels to generate electricity produces emission of gases as waste such as Carbon Dioxide (CO_2), Sulfur Oxides (SO_x) and Nitrogen Oxides (NO_x). These emissions are found to negatively affect human respiratory health and the environment (SO_x and NO_x) or are said to contribute to global warming.

Many proponents of renewable energy (such as wind power, solar power and municipal solid waste) justify the higher electricity prices, and the negative economic effects that follow, based on the claim that these sources produce no emissions (see examples below). But this is misleading. The fuel that powers these services, such as the sun and wind, create no emissions. However, the process of construction, operation and decommissioning of renewable power plants does create emissions. This begs the question:

Is renewable energy production as environmentally friendly as some proponents claim?

> "Harnessing the wind is one of the cleanest, most sustainable ways to generate electricity. Wind power produces no toxic emissions and none of the heat trapping emissions that contribute to global warming."[6]
>
> "Wind turbines harness air currents and convert them to emissions-free power."[7]
>
> ~Union of Concerned Scientists
>
> "As far as pollution…Zip, Zilch, Nada… etc. Carbon dioxide pollution isn't in the vocabulary of solar energy. No emissions, greenhouse gases, etc."[8]
>
> ~Let's Be Grid Free. Solar Energy Facts

The affirmative argument is usually based on the environmental effects of the operational phase of the renewable source (that will produce electricity with no consumption of fossil fuel and no emissions) excluding the whole manufacturing phase (from the extraction to the

[6] How Wind Energy Works. Union of Concerned Scientists. http://www.ucsusa.org/clean_energy/our-energy-choices/renewable-energy/how-wind-energy-works.html.
[7] Our Energy Choices: Renewable Energy. Union of Concerned Scientists. http://www.ucsusa.org/clean_energy/our-energy-choices/renewable-energy/.
[8] Solar Energy Facts. Let's Be Grid Free. http://www.letsbegridfree.com/solar-energy-facts/.

erection of the turbine or solar panel, including the production processes and all the transportation needs) and the decommission phase. LCA offers a framework to provide a more complete answer the question.

LCA is a "cradle-to-grave" approach for assessing industrial systems. LCA begins with the gathering of raw materials from the earth to create the product and ends at the point when all materials are returned to the earth. By including the impacts throughout the product life cycle, LCA provides a comprehensive view of the environmental aspects of the product or process and a more accurate picture of the true environmental trade-offs in product and process selection. Table 3 on Page 10 displays LCA results for conventional and renewable sources.

Coal and gas produce significantly more emissions of all three gases than all the other technologies. Nuclear and wind produces the least emissions of the nonconventional types, with solar and biomass significantly higher due to construction and decommission for solar and production and operations for biomass. However, the construction and decommission phases of wind and solar produce non-trivial levels of emissions, with solar several factors higher than the others. Nevertheless, LCA analysis shows that wind, nuclear, solar and biomass produce significantly less emissions than coal and gas.

Table 3: Emissions by Source of Electricity Generation (Grams/kWh)[9]

Phase	Emission	Coal	Gas	Wind	Nuclear	Solar	Biomass
Construction and Decommission	CO_2	2.59	2.20	6.84	2.65	31.14	0.61
	NO_x	0.01	0.01	0.06	0.00	0.12	0.00
	SO_x	0.06	0.05	0.02	0.00	0.14	0.00
Production and Operation	CO_2	1,022.00	437.80	0.39	1.84	0.27	58.60
	NO_x	3.35	0.56	0.00	0.00	0.02	5.34
	SO_x	6.70	0.27	0.00	0.01	0.00	2.40
Total	CO_2	1,024.59	440.00	7.23	4.49	31.42	59.21
	SO_x	3.36	0.57	0.06	0.01	0.14	5.34
	NO_x	6.76	0.32	0.02	0.01	0.14	2.40

However, this LCA analysis is incomplete. The analysis shows that wind and solar technologies derive benefits from their ability to produce electricity with no consumption of fossil fuels and subsequent pollution without adequately addressing the intermittency of these

[9] U.S. Department of Energy, Energy Information Administration, *2016 Levelized Cost of New Generation Resources from the Annual Energy Outlook 2011* (2008/$MWh), http://www.eia.doe.gov/oiaf/aeo/electricity_generation.html, (accessed February, 2012).

technologies. These intermittent technologies cannot be dispatched at will and, as a result, require reliable back-up generation running —idling per se —in order to keep the voltage of the electricity grid in equilibrium. For example, if the wind wanes, or blows too hard (which trips a shutdown mechanism in commercial windmills), another power source must be ramped up (or cycled) instantaneously. Therefore new wind and solar generation plants do not replace any dispatchable generation sources.

This cycling of coal and (to a much lesser extent) gas plants causes them to run inefficiently and produce more emissions than if the intermittent technologies were not present. A recent study found that wind power could actually increase pollution and greenhouse gas emissions in areas that generate a significant portion of their electricity from coal.[10] The current LCA literature ignores this important portion of the analysis, which provides a distorted assessment of wind and solar power.

Even the incorporation of renewable sources does, by themselves, produce much fewer emissions than conventional sources, they displace only a small amount of emissions from conventional sources.

To better judge the actual total benefit derived from switching from the current energy source portfolio to one that involves more renewable energy, as the RES dictates in Missouri, BHI compared the total emissions impact according to our projections using a life cycle analysis for the various energy sources. Table 4 displays the results.

Table 4: Change in Emissions Due to the Missouri RES Mandates ('000 metric tons)

Emission Gas	2021	Total 2013-2021
No Capacity Factor Differences		
Carbon Dioxide	(7,270)	(21,795)
Sulfur Oxide	(21)	(64)
Nitrogen Oxide	(47)	(140)
Capacity Factor Differences		
Carbon Dioxide	(1,340)	(7,200)
Sulfur Oxide	(3)	(17)
Nitrogen Oxide	(8)	(45)

10 See "How Less Became More: Wind, Power and Unintended Consequences in the Colorado Energy Market," http://goo.gl/kr6qN, Bentek Energy, LLC. Evergreen Colorado: May 2010.

The RES mandates reduce emissions of CO_2 by 1.3 million metric tons in 2021, with a total reduction of 7.2 million tons between 2013 and 2021. If no back up capacity was required due to the intermittency issues of renewables, then the reduction would be more than seven times as much, due mainly to our projection of Missouri's reliance on wind power to cover much of the RES. Sulfur dioxide emissions show only a slight decrease compared to a baseline. Missouri currently has a relatively high use of coal and low usage of biomass for energy production, leading to this modest decrease. In other states we have seen an actual increase in SO_x as they switch from gas towards biomass.

Conclusion

Under the Objective of Statute 393, describing the RES, it states:

> "the policy of this state to encourage electrical corporations to develop and administer energy efficiency initiatives that reduce the annual growth in energy consumption and the need to build additional electric generation capacity."[11]

Leaving aside the fact that encouraging utilities to reduce energy consumption is like asking the Coca-Cola Company to reduce consumption of Coke, the only true way to reduce consumption of a normal good is higher costs. The RES policy put in place certainly succeeds in that area, raising utility rates by close to 20 percent by the time the full policy is in effect. The policy does indeed encourage (specific) utilities to build additional capacity, but only those favored by the authors of the policy. Furthermore, as basic economics states, increasing supply puts downward pressure on prices, leading to increased consumption. In the case of the RES, this downward pressure is offset by the less efficient energy sources that the RES itself dictates.

The law goes even further in its efforts to encourage inefficient energy. By offering incentives to create the renewable energy in state, the measure tries to promote in-state jobs at the expense of higher prices, but they commit the broken window fallacy. By requiring utilities to forego lower-cost sources of conventional energy, and instead use high-cost "green energy," supporters of the Act might be able to point to individual investment projects and jobs as positive. However, the important consideration should be the net economic effects of the

[11] Missouri Revised Statutes. Chapter 393: Gas, Electric, Water, Heating and Sewer Companies. 393.1040. http://www.moga.mo.gov/statutes/chapters/chap393.htm.

mandate. The lost jobs that will be lost due to higher energy costs are not as easy to identify, but they are just as important.

While Statute 393 might generate small economic benefits, Missouri electricity ratepayers will pay higher rates, face reduced employment opportunities, and watch investment flee to other states with more favorable business climates.

Firms with high electricity usage will likely move their production, and emissions, out of Missouri to locations with lower electricity prices. Therefore the Missouri policy will not reduce global emissions, but rather send jobs and capital investment outside the state.

Appendix

Electricity Generation Costs

As noted above, governments enact RES policies because most sources of renewable electricity generation are less efficient and thus more costly than conventional sources of generation. RES policies force utilities to buy electricity from renewable sources and thus guarantee a market for the renewable sources. These higher costs are passed to electricity consumers, including residential, commercial and industrial customers.

The U.S. Department of Energy's Energy Information Administration (EIA) estimates the Levelized Energy Cost (LEC), or financial breakeven cost per MWh, to produce new electricity in its *Annual Energy Outlook*.[12] The EIA provides LEC estimates for conventional and renewable electricity technologies (coal, nuclear geothermal, landfill gas, solar photovoltaic, wind and biomass) assuming the new sources enter service in 2016. The EIA also provides LEC estimates for conventional coal, combined cycle gas, advanced nuclear and onshore wind only, assuming the sources enter service in 2020 and 2035.

While the EIA does not provide LEC for hydroelectric, solar photovoltaic and biomass for 2020 and 2035, it does project overnight capital costs for 2015, 2025 and 2035. We can estimate the LEC for these technologies and years using the percent change in capital costs to inflate the 2016 LECs. In its *Annual Energy Outlook*, the EIA incorporates many assumptions about the future price of capital, materials, fossil fuels, maintenance and capacity factor into their forecast. Table 5 on the following page shows the EIA projects that the LEC for all four electricity sources (coal, gas, nuclear and wind) will fall significantly from 2016 to 2035. The fall in capital costs drives the drop in total system LEC over the period.

Using the EIA change in overnight capital costs for solar and biomass produces reductions in LECs similar to wind from 2016 to 2035. The biomass LEC drops by 38.7 percent and solar by 53.5 percent over the period. These compare to much more modest cost reductions of 5.2 percent for coal, an increase of 14.2 percent for gas, and a drop of 22.1 percent for nuclear over the same period. EIA does provide overnight capital costs for renewable technologies under a

[12] See Footnote #9.

“high cost” scenario. However, for each renewable technology the EIA “high cost” scenario projects capital costs to drop between 2015 and 2035.

Table 5: Levelized Cost of Electricity from Conventional and Renewable Sources (2009 $)

Plant Type	Capacity Factor	Levelized Capital Costs	Fixed O&M	Variable O&M (with fuel)	Transmission Investment	Total Levelized Cost
Coal - 2016	0.85	65.3	3.9	24.3	1.2	94.8
2020		75.84	7.9	25.1	1.2	110.0
2035		55.4	7.9	25.4	1.19	89.8
Gas - 2016	0.87	17.5	1.9	45.6	1.2	66.1
2020		18.4	1.89	46.7	1.2	68.2
2035		13.5	1.89	59.0	1.2	75.5
Advanced Nuclear -2016	0.9	90.1	11.1	11.7	1	113.9
2020		89.1	11.1	12.3	1	113.5
2035		62.3	11.1	14.3	1	88.7
Onshore Wind - 2016	0.344	83.9	9.6	0	3.5	97.0
2020		86.4	9.5	0	3.4	99.2
2035		71.4	9.9	0	3.6	84.9
Solar PV - 2016	0.217	194.6	12.1	0	4	210.7
2025						142.0*
2035						98.0*
Biomass -2016	0.83	55.3	13.7	42.3	1.3	112.5
2025						88.0*
2035						69.0*
Hydro -2016	0.514	74.5	3.8	6.3	1.9	86.4
2025						69.0*
2035						55.0*

* Authors' projections based on linear changes in EIA estimates for overnight capital costs during these time periods. For overnight capital costs, see "Assumptions to the Annual Energy Outlook 2011," (U.S. Energy Information Administration, 2011), 168, http://goo.gl/irI69.

Table 5 also displays capacity factors for each technology. The capacity factor measures the ratio of electrical energy produced by a generating unit over a period of time to the electrical energy that could have been produced at 100 percent operation during the same period. In this case, the capacity factor measures the potential productivity of the generating technology. Solar, wind and hydroelectricity have the lowest capacity factors due to the intermittent nature of their power sources. EIA projects a 34.4 percent capacity factor for wind power, which, as we will see below, appears to be at the high end of any range of estimates.

Estimating a capacity factor for wind power is particularly challenging. Wind is not only intermittent but its variation is unpredictable, making it impossible to dispatch to the grid with any certainty. This unique aspect of wind power argues for a capacity factor rating of close to zero. Nevertheless, wind capacity factors have been estimated to be between 20 percent and 40 percent.[13] The other variables that affect the capacity factor of wind are the quality and consistency of the wind and the size and technology of the wind turbines deployed. As the U.S. and other countries add more wind power over time, presumably the wind turbine technology will improve, but the new locations for power plants will likely have less productive wind resources.

The EIA estimates of LEC and capacity factors paint a particularly rosy view of the future cost of renewable electricity generation, particularly wind. Other forecasters and the experience of current renewable energy projects portray a less sanguine outlook.

Today wind and biomass are the largest renewable power sources and are the most likely to satisfy future RES mandates. The most prominent issues that will affect the future availability and cost of renewable electricity resources are diminishing marginal returns and competition for scarce resources. These issues will affect wind and biomass in different ways as state RES mandates ratchet up over the next decade.

Both wind and biomass resources face land use issues. Conventional energy plants can be built within a space of several acres, but a wind power plant with the same nameplate capacity (not actual capacity) would require many square miles of land. According to one study, wind power would require 7,579 miles of mountain ridgeline to satisfy current state RES mandates and a 20 percent federal mandate by 2025.[14] Mountain ridgelines produce the most promising locations for electric wind production in the eastern and far western United States.

After taking into account capacity factors, a wind power plant would need a land mass of 20 by 25 kilometers to produce the same energy as a nuclear power plant that can be situated on 500 square meters (one-quarter square kilometer).[15]

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[13] Renewable Energy Research Laboratory, University of Massachusetts at Amherst, “Wind Power, Capacity Factor and Intermittency: What Happens When the Wind Doesn’t Blow?” Community Wind Power Fact Sheet #2a, http://www.ceere.org/rerl/about_wind/RERL_Fact_Sheet_2a_Capacity_Factor.pdf.

[14] Tom Hewson and Dave Pressman, “Renewable Overload: Waxman-Markey RES Creates Land-use Dilemmas,” *Public Utilities Fortnightly* 61 (August 1, 2009).

[15] “Evidence to the House of Lords Economic Affairs Committee Inquiry into ‘The Economics of Renewable Energy’,” Memorandum by Dr. Phillip Bratby, May 15, 2008.

The need for large areas of land to site wind power plants will require the purchase of vast areas of land by private wind developers and/or allowing wind production on public lands. In either case land acquisition/rent or public permitting processes will likely increase costs as wind power plants are built. Offshore wind is vastly more expensive than onshore wind power and suffers from the same type of permitting process faced by onshore wind power plants, as seen in the 10-year permitting process for the planned Cape Wind project off the coast of Massachusetts.

Missouri is better positioned to harness wind power better than 75 percent of states in the nation, as it "tripled its installation over 2009 and 2010."[16] The majority of this growth took place in the northwest of the state, where conditions are similar to the relatively optimal Great Plains.

The swift expansion of wind power will also suffer from diminishing marginal returns as new wind capacity will be located in areas with lower and less consistent wind speeds. As a result, fewer megawatt hours of power will be produced from newly built wind projects. The new wind capacity will be developed in increasingly remote areas that will require larger investments in transmission and distribution, which will drive costs even higher.

The EIA estimates of the average capacity factor used for onshore wind power plants, at 34.4 percent, appears to be at the higher end of the estimates for current wind projects. This figure is inconsistent with estimates from other studies.[17] According to the EIA's own reporting from 137 current wind power plants in 2003, the average capacity factor was 26.9 percent.[18] In addition, a recent analysis of wind capacity factors around the world finds an actual average capacity factor of 21 percent.[19] Other estimates find capacity factors in the mid-teens and as low as 13 percent.[20]

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[16] *American Wind Energy Association*, Wind Energy Facts: Missouri, http://www.awea.org/learnabout/publications/factsheets/upload/2Q-12-Missouri.pdf, (accessed August, 2012).

[17] Nicolas Boccard, "Capacity Factors for Wind Power: Realized Values vs. Estimates," *Energy Policy* 37, no. 7 (July 2009): 2680.

[18] Cited by Tom Hewson, Energy Venture Analysis, "Testimony for East Haven Windfarm," January 1, 2005, http://www.windaction.org/documents/720 (accessed December 2011).

[19] Boccard.

[20] See "The Capacity Factor of Wind, Lightbucket," http://lightbucket.wordpress.com/2008/03/13/the-capacity-factor-of-wind-power/, (accessed December 2011) and National Wind Watch, FAQ, http://www.wind-watch.org/faq-output.php (accessed December 2011).

Biomass is a more promising renewable power source. Biomass combines low incremental costs relative to other renewable technologies and reliability. Biomass is not intermittent and therefore it is distributable with a capacity factor that is competitive with conventional energy sources. Moreover, biomass plants can be located close to urban areas with high electricity demand. But biomass electricity suffers from land use issues even more so than wind.

The expansion of biomass power plants will require huge additional sources of fuel. Wood and wood waste comprise the largest source of biomass energy today. Other sources of biomass include food crops, grassy and woody plants, residues from agriculture or forestry, oil-rich algae, and the organic component of municipal and industrial wastes.[21] Biomass power plants will compete directly with other sectors (construction, paper, furniture) of the economy for wood and food products and arable land.

One study estimates that 66 million acres of land would be required to provide enough fuel to satisfy the current state RES mandates and a 20 percent federal RES in 2025.[22] When the clearing of new farm and forestlands are figured into the GHG production of biomass, it is likely that biomass increases GHG emissions.

The competition for farm and forestry resources would not only cause biomass fuel prices to skyrocket, but also cause the prices of domestically-produced food, lumber, furniture and other products to rise. The recent experience of ethanol and its role in surging corn prices can be casually linked to the recent food riots in Mexico, and also to the struggle facing international aid organizations that address hunger in places such as the Darfur region of Sudan.[23] These two examples serve as reminders of the unintended consequences of government mandates for biofuels. The lesson is clear: biofuels compete with food production and other basic products, and distort the market.

Calculation of the Net Cost of New Renewable Electricity

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[21] Biomass Energy Basics, National Renewable Energy Laboratory, Biomass Basics, http://www.nrel.gov/learning/re_biomass.html (accessed December, 2010).

[22] Tom Hewson and Dave Pressman, "Renewable Overload: Waxman-Markey RES Creates Land-use Dilemmas," *Public Utilities Fortnightly* 61 (August 1, 2009).

[23] Heather Stewart, "High costs of basics fuels global food fights," *The Observer*, Febr. 17 2007, 2007, http://goo.gl/7tL9a and Celia W. Dugger, "As Prices Soar, U.S. Food Aid Buys Less," *New York Times,* Sept. 29, 2007, 2007, http://goo.gl/SYFCA.

To calculate the cost of renewable energy under the RES, BHI used data from the EIA to determine the percent increase in utility costs that Missouri residents and businesses would experience. This calculated percent change was then applied to calculated elasticities, as described in the STAMP modeling section.

We collected historical data on the retail electricity sales by sector from 1990 to 2010 and projected its growth through 2025 using its historical compound annual growth rate (see Table 6).[24] To these totals, we applied the percentage of renewable sales prescribed by the Missouri RES. By 2021, renewable energy sources must account for 15 percent of total electricity sales in Missouri.

Next we projected the growth in renewable sources that would have taken place absent the RES. We used an average of the EIA's projection of renewable energy sources by fuel for the SERC Reliability Corporation/Gateway and the Southwest Power Pool/North areas through 2025 as a proxy to grow renewable sources for Missouri. We used the growth rate of these projections to estimate Missouri's renewable generation through 2025 absent the RES.[25]

We subtracted our baseline projection of renewable sales from the RES-mandated quantity of sales for each year from 2013 to 2021, to obtain our estimate of the annual increase in renewable sales induced by the RES in MWhs. The RES mandate exceeds our projected renewables in all years (2013 to 2021). This difference also represents the maximum number of MWhs of electricity from conventional sources that are avoided, or not generated, through the RES mandate. We will revisit this shortly. Table 6 contains the results.

[24] U.S. Energy Information Administration, "Electric Power Monthly: Table 8. Retail Sales, Revenue, and Average Retail Price by Sector, 1990 through 2010," (2012), http://www.eia.gov/electricity/state/missouri/xls/sept08mo.xls. The historical compound growth rate was calculated independently for each sector — residential, commercial and industrial as well as transportation — using the years for which data were available. These independent rates were then used to project sales for each sector in subsequent years, with the projected total annual retail sales calculated as the sum of the projected annual sector sales.

[25] U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2010,* "Table 99: Renewable Electricity Generation by Fuel," http://www.eia.doe.gov/oiaf/archive/aeo10/aeoref_tab.html (accessed December 2010).

Table 6: Projected Electricity Sales, Renewable Sales and 15 Percent RES Requirement

Year	Projected Electricity Sales MWhs (000s)	Projected Renewable MWhs (000s)	RES Requirement MWhs (000s)	Difference MWhs (000s)
2013	61,316	2,062	1,226.32	(836)
2014	62,767	2,088	3,138.34	1,050
2015	64,252	2,115	3,212.60	1,097
2016	65,772	2,143	3,288.62	1,146
2017	67,329	2,178	3,366.44	1,188
2018	68,922	2,214	6,892.19	4,678
2019	70,553	2,247	7,055.28	4,808
2020	72,222	2,279	7,222.23	4,943
2021	73,931	2,318	11,089.69	8,772
Total	**607,064**	**19,645**	**46,492**	**26,847**

To estimate the cost of producing the additional extra renewable energy under an RES against the baseline, we used estimates of the LEC, or financial breakeven cost per MWh, to produce the electricity.[26] However as outlined in the "electricity generation cost" section above, the EIA numbers provide a rather optimistic picture of the cost and generating capacity of renewable electricity, particularly for wind power. A literature review provided alternative LEC estimates that were generally higher and capacity factors that were lower for renewable generation technologies than the EIA estimates.[27] We used these alternative figures to calculate

[26] U.S. Department of Energy, Energy Information Administration, *2016 Levelized Cost of New Generation Resources from the Annual Energy Outlook 2011* (2009/$MWh), http://www.eia.doe.gov/oiaf/aeo/electricity_generation.html (accessed February 2012).

[27] For coal, gas and nuclear generation we used the production cost estimates from the International Energy Agencies, Energy Technology Analysis Programs, "Technology Brief E01: Cola Fired Power, E02: Gas Fired Power, E03: Nuclear Power and E05: Biomass for Heat and Power," (April 2010 http://www.iea-etsap.org/web/Supply.asp (accessed February 2012). To the production costs we added transmission costs from the EIA using the ratio of transmissions costs to total LEC costs. For wind power we used the IEA estimate for levelized capital costs and variable and fixed O & M costs. For transmission cost we used the estimated costs from several research studies that ranged from a low of $7.88 per kWh to a high of $146.77 per kWh, with an average of $60.32 per MWh. The sources are as follows:
Andrew Mills, Ryan Wiser, and Kevin Porter, "The Cost of Transmission for Wind Energy: A Review of Transmission Planning Studies," Ernest Orlando Lawrence Berkeley National Laboratory, http://eetd.lbl.gov/EA/EMP (accessed December 2011); Competitive Renewable Energy Zones (CREZ) Transmission Optimization Study, The Electric Reliability Council of Texas, April 2, 2008 http://www.ercot.com/news/presentations/2006/ATTCH_A_CREZ_Analysis_Report.pdf (accessed December 2010); Sally Maki and Ryan Pletka, Black & Veatch, California's Transmission Future, August 25, 2010,

our "high" LEC estimates and the EIA figures to calculate our "low" cost estimates and the average of the two to calculate our "medium" cost estimates. Table 7 displays the LEC and capacity factors for each generation technology.

Table 7: LEC and Capacity Factors for Electricity Generation Technologies

	Capacity Factor	Total Production Cost (2009 $/MWh) 2010	2020	2025
Coal				
Low	.740	67.41	64.82	63.53
Average	.795	81.11	87.43	81.72
High	.850	94.80	110.03	99.91
Gas				
Low	.850	66.10	68.17	71.84
Average	.860	70.98	70.71	72.54
High	.870	75.86	73.25	73.25
Nuclear				
Low	.900	76.94	59.20	49.33
Average	.900	95.42	86.36	75.22
High	.900	113.90	113.52	101.12
Biomass				
Low	.680	112.50	100.07	87.63
Average	.755	112.50	101.80	93.00
High	.830	113.90	103.54	98.36
Wind				
Low	.155	148.78	96.10	87.50
Average	.269	218.23	182.82	169.45
High	.344	287.67	269.54	251.40

We used the 2016 LEC for the years 2010 through 2018 to calculate the cost of the new renewable electricity and avoided conventional electricity, assuming that before 2016 LEC underestimates the actual costs for those years and for 2017 and 2018, the 2016 LEC slightly overestimates the actual costs. We assumed that the differences will, on balance, offset each other. For 2019 and 2020 we used the 2020 LEC. The assumption is that LEC will decline over time due to technological improvements over time.

We use the EIA's reference case scenario for all technologies. We adjusted the 2016 LECs to 2025 by using the percentage change in the capital costs from 2015 to 2025, since capital costs often represent the largest component of the cost structure for most technologies. For the

http://www.renewableenergyworld.com/rea/news/article/2010/08/californias-transmission-future (accessed December 2011).

technologies that the EIA does not forecast LECs in 2020, we used the average of the 2016 and 2025 LEC calculations, assuming a linear change over the period.

Once we computed new LECs for the years 2020 and 2025, we applied these figures to the renewable energy estimates for the remainder of the period.

For conventional electricity, we assumed that the technologies are avoided based on their costs, with the highest cost combustion turbine avoided first. For coal and gas, we assumed they are avoided based on their estimated proportion of total electric sales for each year. Although hydroelectric and nuclear are not the cheapest technologies, we assume no hydroelectric or nuclear sources are displaced since most were built decades ago and offer relatively cheap and clean electricity today.

To determine the impact of the RES standard in a given year, we calculated the amount of renewable energy the RES would require that year and compared it to our renewable energy baseline sales for that year; the difference represents the renewable sales attributable to the RES policy. We then determined which renewable energy source(s) would be used to meet the renewable energy sales attributable to the RES and calculated the additional renewable energy costs by using the LEC(s) for the relevant energy source(s).

The increased total costs in renewable energy lead to decreased total costs in conventional energy, since less conventional energy would be needed and sold. The decrease in conventional energy production is not as large as the increase in renewable energy production, however. Wind power and solar power in particular are intermittent (as reflected in their relatively low capacity factors), and it would still be necessary to keep backup conventional energy sources online and ready to meet any sudden electrical demands that renewable sources could not instantly provide. To estimate the share of conventional energy that would still be running as backup, we used a ratio of the renewable energy capacity factor to the conventional energy capacity factor.[28]

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[28] For example, if the RES will require 100 MWh more wind than would otherwise be produced, then that 100 MWh of wind will produced at the LEC for wind. Ideally, then 100 MWh of natural gas-based energy would no longer be needed, and the forgone costs would be computed at the LEC for natural gas. Since wind would require a backup, however, we would estimate the amount of natural gas energy production needed on standby by employing a ratio of the capacity factors of the two energy sources (using, for example, the mid-range estimates from Table 7): 0.269/0.86 * 100 MWh of natural gas = 31.3 MWh of natural gas energy production.

Tables 8, 9 and 10 on the following pages display the results of our Medium, Low and High Cost calculations for the 15 percent RES respectively. We converted the aggregate cost of the RES into a cost per-kWh by dividing the cost by the estimated total number of kWh sold for that year. For example, for 2021 under the medium cost scenario above, we divided $1.409 billion into 111.34 billion kWhs for a cost of 1.27 cents per kWh.

Table 8: Medium Cost Case of 15 Percent RES Mandate from 2013 to 2021

Year	Gross Cost (2010 $000s)	Less Conventional (2010 $000s)	Total (2010 $000s)
2013	(162,644)	(24,286)	(138,357)
2014	213,610	24,512	189,098
2015	223,119	25,712	197,407
2016	232,823	26,937	205,886
2017	241,364	28,032	213,331
2018	937,460	118,137	819,323
2019	896,278	120,851	775,428
2020	921,083	124,179	796,905
2021	1,632,168	222,770	1,409,398
Total	**5,135,262**	**666,842**	**4,468,420**

Table 9: Low Cost Case of 15 Percent RES Mandate from 2013 to 2021

Year	Gross Cost (2010 $000s)	Less Conventional (2010 $000s)	Total (2010 $000s)
2013	(118,891)	(39,357)	(79,534)
2014	165,220	39,460	125,760
2015	172,448	41,411	131,037
2016	179,826	43,399	136,427
2017	186,341	45,251	141,090
2018	711,980	190,724	521,256
2019	487,701	202,934	284,767
2020	501,209	208,500	292,709
2021	882,777	374,557	508,220
Total	**3,168,611**	**1,106,878**	**2,061,733**

Table 10: High Cost Case of a 15 percent RES Mandate from 2013 to 2021

Year	Gross Cost (2010 $000s)	Less Conventional (2010 $000s)	Total (2010 $000s)
2013	(234,772)	(10,691)	(224,081)
2014	293,384	10,887	282,497
2015	306,652	11,412	295,240
2016	320,192	11,949	308,242
2017	332,072	12,402	319,670
2018	1,309,175	52,257	1,256,918
2019	1,254,317	50,338	1,203,979
2020	1,289,023	51,730	1,237,293
2021	2,288,868	92,598	2,196,270
Total	**7,158,911**	**282,882**	**6,876,030**

Ratepayer Effects

To calculate the effect of the RES on electricity ratepayers we used EIA data on the average monthly electricity consumption by type of customer: residential, commercial and industrial.[29] The monthly figures were multiplied by 12 to compute an annual figure. We inflated the 2010 figures for each year using the average annual increase in electricity sales over the entire period.[30]

We calculated an annual per-kWh increase in electricity cost by dividing the total cost increase – calculated in the section above ─ by the total electricity sales for each year. We multiplied the per-kWh increase in electricity costs by the annual kWh consumption for each type of ratepayer for each year. For example, we expect the average residential ratepayer to consume 15,393 kWhs of electricity in 2021 and we expect the medium cost scenario to raise electricity costs by 1.27 cents per kWh in the same year. Therefore we expect residential ratepayers to pay an additional $195 in 2021.

[29] U.S. Department of Energy, Energy Information Administration, "Average electricity consumption per residence in MO in 2008," (January 2010) http://www.eia.gov/electricity/sales_revenue_price/index.cfm.
[30] U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2010*, "Table 8: Electricity Supply, Disposition, Prices, and Emissions," http://www.eia.doe.gov/oiaf/aeo/aeoref_tab.html.

Modeling the RES using STAMP

We simulated these changes in the STAMP model as a percentage price increase on electricity to measure the dynamic effects on the state economy. The model provides estimates of the proposals' impact on employment, wages and income. Each estimate represents the change that would take place in the indicated variable against a "baseline" assumption of the value that variable for a specified year in the absence of the RES policy.

Because the RES requires Missouri households and firms to use more expensive "green" power than they otherwise would have under a baseline scenario, the cost of goods and services will increase under the RES. These costs would typically manifest through higher utility bills for all sectors of the economy. For this reason we selected the sales tax as the most fitting way to assess the impact of the RES. Standard economic theory shows that a price increase of a good or service leads to a decrease in overall consumption, and consequently a decrease in the production of that good or service. As producer output falls, the decrease in production results in a lower demand for capital and labor.

BHI utilized its STAMP (State Tax Analysis Modeling Program) model to identify the economic effects and understand how they operate through a state's economy. STAMP is a five-year dynamic CGE (computable general equilibrium) model that has been programmed to simulate changes in taxes, costs (general and sector-specific) and other economic inputs. As such, it provides a mathematical description of the economic relationships among producers, households, governments and the rest of the world. It is general in the sense that it takes all the important markets, such as the capital and labor markets, and flows into account. It is an equilibrium model because it assumes that demand equals supply in every market (goods and services, labor and capital). This equilibrium is achieved by allowing prices to adjust within the model. It is computable because it can be used to generate numeric solutions to concrete policy and tax changes.[31]

In order to estimate the economic effects of a national RES we used a compilation of six STAMP models to garner the average effects across various state economies: New York, North Carolina, Washington, Kansas, Indiana and Pennsylvania. These models represent a wide variety in terms of geographic dispersion (northeast, southeast, midwest, the plains and west),

[31] For a clear introduction to CGE tax models, see John B. Shoven and John Whalley, "Applied General-Equilibrium Models of Taxation and International Trade: An Introduction and Survey," Journal of Economic Literature 22 (September, 1984): 1008. Shoven and Whalley have also written a useful book on the practice of CGE modeling entitled Applying General Equilibrium (Cambridge: Cambridge University Press, 1992).

economic structure (industrial, high-tech, service and agricultural), and electricity sector makeup.

First we computed the percentage change to electricity prices as a result of three different possible RES policies. We used data from the EIA from the state electricity profiles, which contains historical data from 1990-2008 for retail sales by sector (residential, commercial, industrial, and transportation) in dollars and MWhs and average prices paid by each sector.[32] We inflated the sales data (dollars and MWhs) though 2021 using the historical growth rates for each sector for each year. We then calculated a price for each sector by dividing the dollar value of the retails sales by kWhs. Then we calculated a weighted average kWh price for all sectors using MWhs of electricity sales for each sector as weights. To calculate the percentage electricity price increase we divided our estimated price increase by the weighted average price for each year. For example, in 2021 for our medium cost case we divided our average price of 8.57 cents per kWh by our estimated price increase of 1.27 cents per kWh for a price increase of 14.8 percent.

Table 11: Elasticities for the Economic Variables

Economic Variable	Elasticity
Employment	-0.022
Investment	-0.018
Disposable Income	-0.022

Using these three different utility price increases – 1 percent, 4.5 percent and 5.25 percent – we simulated each of the six STAMP models to determine what outcome these utility price increases would have on each of the six states' economy. We then averaged the percent changes together to determine what the average effect of the three utility increases. Table 11 displays these elasticities, which were then applied to the calculated percent change in electricity costs for the state of Missouri discussed above.

We applied the elasticities to percentage increase in electricity price and then applied the result to Missouri economic variables to determine the effect of the RES. These variables were

[32] U.S. Energy Information Administration, Electric Power Monthly: Table 8. Retail Sales, Revenue, and Average Retail Price by Sector, 1990 Through 2010," (2012), http://www.eia.gov/electricity/state/missouri/xls/sept08mo.xls.

gathered from the Bureau of Economic Analysis Regional and National Economic Accounts as well as the Bureau of Labor Statistics Current Employment Statistics.[33]

Life Cycle Analysis

For our LCA we used various studies to determine what the cradle-to-grave emissions per MWh was, taking into account construction, decommission, operation and maintenance.

For coal we reviewed three different system types: an 'average system' that accounts for emissions from typical coal fired generation in 1995; New Source Performance Standards based on requirements put into effect for all plants built after 1978; and Low Emission Boiler Systems, which are newer, more efficient coal plants.[34] The LCA calculations account for various inputs including, but not limited to, mining, transportation of minerals, power plant operation as well as decommissions and disposal of a plant. Natural gas plants LCAs were based on the LCA for Gas Combined Cycle Power Generation plants, a type of plant that is similar to the majority of the natural gas plants in the United States.[35]

The LCA for wind power accounted for both onshore and offshore wind power, which has different values for manufacturing, dismantling, operation and transportation for each type.[36] Solar photovoltaic estimates were wide ranging, but a *Science Direct* paper supplied an in-depth, comprehensive review.[37] It reviewed three different types of crystalline silicone modules as well as a CdTe thin film version and induced many different costs such as emissions from building the module and frame (for the crystalline silicone version) as well as operation and maintenance emissions. For biomass and wood waste LCA we used a report that looked at the production of energy using wood and biomass byproducts to produce

[33] For employment, see the following: U.S. Bureau of Labor Statistics, "State and Metro Area Employment, Hours, & Earnings," http://bls.gov/sae/. Private, government and total payroll employment figures for Michigan were used. For investment, see "National Income and Product Account Tables," U.S. Bureau of Economic Analysis, http://www.bea.gov/itable/; BEA, "Gross Domestic Product by State,", http://www.bea.gov/regional/. We took the state's share of national GDP as a proxy to estimate investment at the state level. For state disposable personal income, see "State Disposable Personal Income Summary," BEA, http://www.bea.gov/regional/.

[34] Pamela L Spath, Margaret K Mann, Dawn R Kerr, "Life Cycle Assessment of Coal-fired Power Production." National Renewable Energy Laboratory, June 1999.

[35] Pamela L Spath, Margaret M Mann. "Life Cycle Assessment of a Natural Gas Combined-Cycle Power Generation System." National Renewable Energy Laboratory. September 2000.

[36] ELSAM Engineering S/A "Life Cycle Assessment of Offshore and Onshore Sited Wind Farms.". October 2004.

[37] V M Fethankis, H C Kim. "Photovoltaics: Life Cycle Analysis." *Science Direct*. October 2009.

energy.[38] There are different types of delivery systems (lorry, train and barge) for the fuel, as well as construction, operation and decommissioning.

With total emissions per MWh calculated, we were able to use our in-house model to calculate the total emissions that would be added to and removed from the Missouri energy system. The first calculation used the amount of renewable energy added per the Class I RES law, as well as the amount of conventional power that would be removed, after accounting for capacity factor requirements to keep a constant amount of energy produced. Each MWh added was multiplied by its respective LCA emission, and then we subtracted the amount of conventional time LCA emissions. With a basic conversion from grams to metric tons, we had calculated the results seen in Table 4. An identical calculation was done, but not accounting for capacity factors.

[38] Christian Bauer. "Life Cycle Assessment of Fossil and Biomass Power Generation Chains." Paul Sherrer Institut. December 2008.

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