The Beacon Hill Institute

The Economic Impact of Arizona's Renewable Energy Standard and Tariff

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Executive Summary

In 2006, the Arizona Corporation Commission adopted a Renewable Energy Standard and Tariff (REST) rule. The rule requires Arizona's regulated electric utilities to produce 15 percent or more of their energy from specific renewable sources by 2025.

The Beacon Hill Institute has applied its STAMP® (State Tax Analysis Modeling Program) to estimate the economic effects of these REST 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 Arizona's REST 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 REST rule will raise the cost of electricity by $389 million for the state's electricity consumers in 2025, within a range of $239 million and $626 million
- The REST mandate will cost Arizona's electricity consumers $1.383 billion from 2013 to 2025, within a range of $857 million and $2.221 billion
- Arizona's electricity prices will rise by 6 percent by 2025, within a range of 3.7 percent and 9.7 percent

These increased energy prices will hurt Arizona's households and businesses and, in turn, inflict harm on the state economy. In 2025, the REST would:

- Lower employment by 2,500 jobs, within a range of 1,500 jobs and 4,100 jobs
- Reduce real disposable income by $334 million, within a range of $202 million and $543 million
- Decrease investment in the state by $38 million, within a range of $23 million and $61 million
- Increase the average household electricity bill by $128 per year; commercial businesses by an average of $686 per year; and industrial businesses by an average of $28,600 per year

Introduction

After a three-year review the Arizona Corporation Commission adopted the Arizona Renewable Energy Standard and Tariff (REST) in November 2006. The rule requires that all regulated electric utilities to generate 15 percent of their retail electricity sales from eligible renewable energy sources by 2025. The rule initially set the mandate at 1.25 percent in 2006, with one-half percentage point increases in each year, making the 2015 requirement 5 percent. In the years 2016 through 2025, the REST mandate increases by one percentage point each year. [1]

Utilities are required to file with the commission annual compliance reports, implementation plans, and notices of non-compliance. The commission may assess penalties for non-compliance with the REST, subject to a review process. The commission may also waive compliance with any provision of the rules for "good cause," but the rule fails to define what constitutes "good cause." [2]

The REST allows utilities to use solar, wind, biomass, biogas, geothermal and other similar technologies. The policy also allows new electricity generated by hydroelectric power facilities built before 1997 provided the additional electricity results from increased capacity due to technological and operational efficiencies. The policy also allows for new hydroelectric facilities used to regulate the output of other eligible, intermittent renewable resources (wind and solar), or new facilities with a capacity of less than 11 megawatts (MWs) that does not require new damming of a river. The rules allow for new and emerging technologies to be added as they become feasible.[3]

The REST requires a growing percentage of the total resource portfolio to come from distributed generation – such as a large solar installation on the roof of a shopping mall, or solar panels at a residential building. Fifty-percent of the distributed renewable energy requirement must come from residential sources and the remaining fifty-percent from nonresidential, non-utility sources. The distributed energy requirement started at 5 percent of

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[1] The Arizona Corporation Commission, Utilities Division, Renewable Energy Standard and Tariff, Internet http://www.azcc.gov/divisions/utilities/electric/environmental.asp, (accessed January 2013)
[2] Arizona Administrative Code, Title 14. Public Service Corporations; Corporations and Associations; Securities Regulation, Chapter 2. Corporation Commission Fixed Utilities, Article 18, Renewable Energy Standard and Tariff, R14-2-1802. Eligible Renewable Energy Resources, http://www.azsos.gov/public_services/Title_14/14-02.htm#ARTICLE_18, (accessed January 2013)
[3] Ibid, R14-2-1816. Waiver from the Provisions of this Article.

the total renewable generation in 2007 and peaked at 30 percent of the total renewable generation after 2011. The rules include funding for utility customers to build distributed renewable energy resources and net metering that allow these projects to provide energy to the electricity grid.[4]

Utilities must obtain Renewable Energy Credits (RECs) for each kilowatt-hour (kWh) of electricity generated by renewable sources. For distributed renewable energy heating and cooling resources, one REC is issued for each 3,415 British Thermal Units (BTU) of heat produced by the resource. RECs can be acquired as long as the transaction is documented and the utility can demonstrate the renewable electricity was delivered to their customers. The RECs are also bankable for use in future years.[5]

The REST rule also applies several extra credit multipliers for electricity produced from: (1) "early installation" of renewable facilities built between 2001 and 2003; (2) a 0.5 multiplier for facilities built in Arizona prior to January 1, 2006; (3) 0.5 for facilities built in Arizona prior to January 1, 2006 and contain components manufactured in Arizona; (4) 0.5 for distributed solar electric generator facilities built in Arizona prior to January 1, 2006 that satisfy two conditions related to location and participation in green pricing – net metering or solar leasing programs. The multipliers are additive, except that the maximum combined Extra Credit Multiplier cannot exceed 2.[6]

REST also provides for a credit that applies to utilities that own or make a significant investment in a solar manufacturing located in Arizona. The credits are equal to the nameplate capacity of solar electric generators produced and sold in a calendar year multiplied by 2,190 hours, which approximates a 25 percent capacity factor. The extra credit multipliers cannot be combined with this manufacturing credit.[7]

REST outlines a "tariff" to allow utilities "for recovering the reasonable and prudent costs of complying" with the rules. Utilities must file an annual report for a tariff application that includes data to support the level of costs designed to recover only the costs in excess of the market cost of comparable conventional generation. The rule also sets out a process for utilities

[4] Ibid, subsection B.
[5] Ibid, R14-2-1803. Renewable Energy Credits.
[6] Ibid, R14-2-1806. Extra Credit Multipliers.
[7] Ibid, R14-2-1806. Extra Credit Multipliers.

to adjust the tariff to reflect changes in costs and provides a monthly "sample tariff" as a guide. The sample tariff is $1.05 per service for residential customers; $39.00 for non-residential customers; and $117.00 for non-residential customers whose metered demand is 3,000 kW or more for three consecutive months.[8]

The utility compliance reports provide cost estimates of the REST through 2011. Since 2007 the largest utilities, Arizona Public Service Company and Tucson Electric Power Company, have collected about $469 million from their customers under REST.[9] Some of these funds were not spent and were carried into 2012. The cost should only increase in the future as the REST requirements increase and the lowest cost and most efficient projects are funded first and the higher cost projects are delayed into the future.

In this paper the Beacon Hill Institute at Suffolk University (BHI) estimates the costs of Arizona's REST 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 REST mandate.[10]

Since renewable energy generally costs more than conventional energy, many have voiced concerns about these higher electric rates. A wide variety of cost estimates exist for renewable electricity sources. 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. The EIA cost estimates include the Federal Renewable Electricity Production Tax Credit and "a 3-percentage point increase in the cost of capital is added when evaluating investments in greenhouse gas (GHG) intensive technologies like coal-fired power and coal-to-liquids (CTL) plants without carbon control and sequestration (CCS)." The EIA

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[8] Ibid, R14-2-1808.

[9] The Arizona Corporation Commission, Utilities Division, Renewable Energy Standard and Tariff, Internet http://www.azcc.gov/divisions/utilities/electric/environmental.asp,(Accessed January 2013)

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

admits that the "adjustment is somewhat arbitrary" and is similar to that of an emissions fee of $15 per metric ton of carbon dioxide (CO_2).[11]

None of the assumptions used by EIA or others are certain or likely to be in place in 2025, when the REST mandate peaks. The production tax credit is controversial and was only extended for only one year as part of the so called "Fiscal Cliff" resolution. Congress has not enacted any GHG legislation, and in its current form, is unlikely to in the future.

One could justify the higher electricity costs if the environmental benefits – in terms of reduced GHG 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.[12] Thus, there appear to be few, if any, benefits to implementing REST policies based on heavy uses of wind.

Governments enact REST-type policies because most sources of renewable electricity generation are less efficient and thus more costly than conventional sources of generation. The REST policy forces utilities to buy electricity from renewable sources and thus guarantees 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 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.

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[11] http://www.eia.gov/forecasts/aeo/electricity_generation.cfm

[12] 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.

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 Arizona's REST. Each estimate represents the change that will take place in the indicated variable against the counterfactual assumption that the REST mandate would not be implemented. The appendix contains details of our methodology. Table 1 displays the cost estimates and economic impact of the 15 percent REST mandate in 2025, compared to a baseline of no REST policy.

Table 1: The Cost of the 15 percent REST Mandate on Arizona (2013 $)

Costs Estimates	Low	Medium	High
Total Net Cost 2025 ($ million)	239	389	626
Total Net Cost 2013-2025 ($ million)	857	1,383	2,221
Electricity Price Increase in 2025 (cents per kWh)	0.42	0.68	1.09
Percentage Increase	3.7	6.0	9.7
Economic Indicators			
Total Employment (jobs)	(1,500)	(2,500)	(4,100)
Investment ($ million)	(23)	(38)	(61)
Real Disposable Income ($ million)	(202)	(334)	(543)

The current REST will impose costs of $389 million by 2025, within a range of $239 million and $626 million. As a result, the REST mandate would increase expected electricity prices by 0.68 cents per kilowatt hour (kWh) or by 6.0 percent, within a range of 0.42 cents per kWh, or by 3.7 percent, and 1.09 cents per kWh, or by 9.7 percent.

The STAMP model simulation indicates that, upon full implementation, the REST law will harm Arizona'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 2025 the Arizona economy will shed 2,500 jobs, within a range of 1,500 and 4,100 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 2025, real disposable income will fall by an average of $334 million,

between $202 million and $543 million under the low and high cost scenarios respectively. Furthermore, net investment will fall by $38 million, within a range of $21 million and $61 million.

Table 2 shows how the REST mandate will affect the average annual electricity bills of households and businesses in Arizona. In 2025, the 15 percent REST will cost families an average of $130 per year; commercial businesses $690 per year; and industrial businesses $29,290 per year. An average household would spend $850 more between 2013 and 2025; a commercial ratepayer $4,580 more; and an industrial ratepayer would pay $218,290 more.

Table 2: Annual Effects of REST on Electricity Ratepayers (2013 $)

	Low	Medium	High
Cost in 2025			
Residential Ratepayer ($)	80	130	210
Commercial Ratepayer ($)	420	690	1,100
Industrial Ratepayer ($)	17,600	28,600	46,000
Total over period (2013-2025)			
Residential Ratepayer ($)	520	850	1,370
Commercial Ratepayer ($)	2,810	4,580	7,380
Industrial Ratepayer ($)	134,130	218,290	351,650

Emissions: Life Cycle Analysis

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

The burning of fossil fuels to generate electricity produces emissions 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 (MSW) 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."[13]

> "Wind turbines harness air currents and convert them to emissions-free power."[14]
> ~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."[15]
> ~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), but excluding the whole manufacturing phase (from the extraction to the 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 displays LCA results for conventional and nonconventional sources.

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

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

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

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.

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 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 dies down, 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. As a result, according to a recent study, wind power could actually increase pollution and greenhouse gas

emissions in areas that generate a significant portion of their electricity from coal.[16] The current LCA literature ignores this important portion of the analysis, which provides a distorted assessment of wind and solar power.

Nevertheless, even incorporating renewable sources does, in and of themselves, produce much less emissions than conventional sources, displacing only a small amount of emissions from conventional sources. Indeed, this amount is multiplied, due to lower capacity ratings of many green energy sources and required backup generation.

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 REST dictates in Arizona, BHI compared the total emissions impact according to our projections using a life cycle analysis for the various energy sources. Table 4 on the following page displays the results.

[16] See "How Less Became More: Wind, Power and Unintended Consequences in the Colorado Energy Market," Bentek Energy, LLC. (Evergreen Colorado: May, 2010).

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

Emission Gas	2025	Total 2013-2025
No Capacity Factor Differences		
Carbon Dioxide	-6,510	-23,020
Sulfur Oxide	-10	-30
Nitrogen Oxide	-30	-110
Capacity Factor Differences		
Carbon Dioxide	-2,060	-7,280
Sulfur Oxide	3	11
Nitrogen Oxide	-8	-27

The REST mandates reduce emissions of CO_2 by 2,060 million metric tons in 2025, with a total reduction of 7,280 million tons between 2013 and 2025. If no backup 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 Arizona's reliance on wind power to cover much of the REST. Sulfur dioxide emissions show a slight increase compared to the baseline. Arizona 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 away from gas towards biomass.

Conclusion

Former Arizona Corporation Commissioner Barry Wong wrote in the press release announcing the approval of the REST rules:

> "This is a quantum, but prudent, leap in public policy and puts Arizona squarely in the national spotlight. I believe we will one day look back on this action as the vote that created the T-Gen [Genome Technology] of the energy industry – fueling economic development, technical innovation and a new wave of entrepreneurship here in Arizona."[17]

[17]Public Information Office, Arizona Corporation Commission, "Commissioners Approve Rules requiring 15 Percent of Energy from Renewables by 2025," http://www.azcc.gov/divisions/utilities/electric/environmental.asp (November 1, 2006).

Commissioner Wong was correct that the law has fueled economic development and entrepreneurship in Arizona. However, these entrepreneurs do not seek to provide innovative products that customers demand. Rather government incentivizes behavior that tilts public policy in their favor by mandating costlier and inefficient electricity production.

While REST generates economic benefits for a small group of favored industries, all of Arizona's electricity customers pay higher rates, diverting resources away from household spending and savings and business investment. As a result, Arizona residents will have fewer 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 Arizona to locations with lower electricity prices. Therefore, the REST Arizona 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 REST-type policies to prop up the price of renewable electricity generation. They begin with two disadvantages: renewables are less efficient and more costly than conventional sources of generation. Renewables suffer weak demand in the open market place. REST policies force utilities to buy electricity from renewable sources. These policies guarantee a market for the renewable sources. The higher costs are passed to electricity consumers, including residential, commercial and industrial customers.

The U.S. Department of Energy's Energy Information Administration estimates the "levelized energy cost" (LEC) — or financial breakeven cost per MWh — to produce new electricity in its Annual Energy Outlook.[18] 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 2017. 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, geothermal 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 2017 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 projections that the LEC for all four electricity sources (coal, gas, nuclear and wind) will fall significantly from 2017 to 2025. 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 2017 to 2020. The biomass LEC drops by 23.7 percent and solar by 15 percent over the period. These compare modest cost increases of 13.2 percent for coal and 1.4 percent for gas, and a drop of 8.9 percent for nuclear over the same period. EIA does

[18] "Levelized Cost of New Generation Resources in the Annual Energy Outlook 2012," (U.S. Energy Information Administration, 2011), http://goo.gl/DG6Qk (accessed Oct. 2, 2012).

provide overnight capital costs for renewable technologies under a "high cost" scenario. However, for each renewable technology the EIA "high cost" scenario projects capital costs to drop between 2015 and 2035.

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 33 percent capacity factor for wind power, which, as we will see below, appears to be at the high end of any range of estimates.

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 - 2017	0.85	64.9	4.0	27.5	1.2	97.7
2020		71.3	6.7	28.2	1.2	107.3
Gas - 2017	0.87	17.5	1.9	45.6	1.2	66.1
2020		16.9	1.92	47.0	1.2	67.0
Advanced Nuclear -2017	0.90	90.1	11.1	11.7	1.0	113.9
2020		79.5	11.6	11.9	1.1	103.7
Geothermal - 2017	0.91	75.1	11.9	9.6	1.5	98.2
2020						87.0*
Onshore Wind – 2017	0.33	82.5	9.8	0	3.5	96.0
2020		80.3	9.8	0	3.8	93.9
Solar PV - 2017	0.25	140.7	7.7	0	4.3	152.7
2020						129.8*
Biomass -2017	0.83	56.0	13.8	44.3	1.3	115.4
2020						88.0*
Hydro -2017	0.53	76.9	4.0	6.0	2.1	88.9
2020						69.0*

* 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/irl69 (accessed Sept. 18, 2012).

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.[19] 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.

Wind, solar and biomass are the largest renewable power sources and are the most likely to satisfy future REST 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, solar and biomass in different ways as the REST mandates ratchet up over the next decade.

Wind, solar and biomass resources face land use issues. Conventional energy plants can be built within a space of several acres, but wind and solar power plants with the same nameplate capacity (not actual capacity) would require many square miles of land While solar power suffers from similar land needs, it can be more easily adapted to suburban and urban areas in a small scale, such as building rooftops. Nevertheless, industrial scale solar plants still require much larger landmass than conventional plants.

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).[20]

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[19] 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://goo.gl/24r2u.

[20] "Evidence to the House of Lords Economic Affairs Committee Inquiry into 'The Economics of Renewable Energy'," Memorandum by Dr. Phillip Bratby, May 15, 2008. http://goo.gl/oyh1Y (accessed Oct. 2, 2012).

Solar also suffers from larger land use issues. Solana Generating Station, the largest solar plant in the United States near Gila Bend, Arizona will have a total capacity of 270 megawatts (MW) and will cover an area of 1,900 acres or 7.7 square kilometers.[21]

The need for large areas of land to site wind and solar 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.

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 and 25 percent for solar p.v. and 20 percent for solar thermal. This figure is inconsistent with estimates from other studies.[22] According to the EIA's own reporting from 137 current wind power plants in 2003, the average capacity factor was 26.9 percent.[23] In addition, a recent analysis of wind capacity factors around the world finds an actual average capacity factor of 21 percent.[24] Estimates find solar p.v. capacity factor of 19 percent .[25]

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 dispatchable and 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.

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[21] National Renewable Energy Laboratory, Concentrating Solar Power Projects, Internet, http://www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=23,

[22] Nicolas Boccard, "Capacity Factors for Wind Power: Realized Values vs. Estimates," *Energy Policy* 37, no. 7 (July 2009): 2680. http://goo.gl/oyh1Y.

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

[24] Boccard.

[25] Laumer, John (June 2008). "Solar Versus Wind Power: Which Has The Most Stable Power Output?". *Treehugger*. Retrieved 2008-10-16.

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. According to the National Renewable Energy Laboratory, 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."[26] 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 REST mandates and a 20 percent federal REST in 2025.[27] 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.[28] 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

To calculate the cost of renewable energy under the RES, BHI used data from the Energy Information Administration (EIA), a division of the U.S. Department of Energy, to determine the percent increase in utility costs that Arizona residents and businesses would experience. This calculated percent change was then applied to calculated elasticities, as described in the STAMP modeling section.

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[26] "Biomass Energy Basics," (National Renewable Energy Laboratory), http://www.nrel.gov/learning/re_biomass.html.
[27] Hewson, 61.
[28] Heather Stewart, "High costs of basics fuels global food fights," *The Observer*, February 17, 2007, http://goo.gl/7tL9a (accessed Oct. 2, 2012); See also Celia W. Dugger, "As Prices Soar, U.S. Food Aid Buys Less," *New York Times*, Sept. 29, 2007, 2007, http://goo.gl/SYFCA.

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).[29] To these totals, we applied the percentage of renewable sales prescribed by the Arizona REST. By 2025, renewable energy sources must account for 15 percent of total electricity sales in Arizona.

Next we projected the growth in renewable sources that would have taken place absent REST. 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 Arizona. We used the growth rate of these projections to estimate Arizona's renewable generation through 2025 absent the REST. In addition, we projected growth in the "Green Choice" program of Arizona Public Service Company, which offers customers the option to pay higher rates for renewable energy.[30] The combination of these two numbers provides us with our baseline percentage of total electricity sales from renewables between 2013 and 2025, 0.39 percent and 0.86 percent respectively.

We subtracted our baseline projection of renewable sales from the REST-mandated quantity of sales for each year from 2013 to 2025, to obtain our estimate of the annual increase in renewable sales induced by the REST in megawatt-hours. The REST mandate exceeds our projected renewables in all years (2013 to 2025).

Next we used generation and costs information from the utilities REST compliance reports from 2007- 2011 to build a picture of how the utilities are complying with REST. For the years 2012 – 2025, we assumed the future mix of renewable resources would resemble the current 2011 mix. The major utilities, Arizona Service Company and Tucson Electric Power Company, were exceeding the modest REST mandates in each compliance year and thus were able to build banks of 654,000 MWhs of RECs in 2011. We assume that the utilities continue to add to

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[29] "Electric Power Monthly: Table 8. Retail Sales, Revenue, and Average Retail Price by Sector, 1990 Through 2012," (U.S. Energy Information Administration, 2012), http://www.eia.gov/electricity/state/missouri/xls/sept08mo.xls. The historical compound growth rate was calculated independently for each sector — residential, commercial, industrial and transportation — using the years for which data was 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. The result is a growth rate of 2.85% compared to a 3.0% projection by the Arizona Public Service Company. See: http://www.aps.com/_files/various/ResourceAlt/2012ResourcePlan.pdf.

[30] U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2012*, "Table 99: Renewable Electricity Generation by Fuel."

their bank, reaching a maximum of 1,159,000 MWh of RECs in 2015, when the REST mandate begins to increase by 1 percent per year. Then we assume the utilities begin to draw dawn their REC banks until it is empty in 2023. Table 6 contains the results.

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

Year	Projected Electricity Sales MWhs (000s)	Projected Renewable MWhs (000s)	REST Requirement MWhs (000s)	Difference MWhs (000s)
2013	41,489	162	1,660	1,497
2014	42,632	178	1,918	1,740
2015	43,806	195	2,190	1,995
2016	45,012	214	2,701	2,486
2017	46,252	235	3,238	3,002
2018	47,525	258	3,802	3,544
2019	48,834	284	4,395	4,112
2020	50,179	311	5,018	4,707
2021	51,561	341	5,672	5,330
2022	52,981	375	6,358	5,983
2023	54,440	411	7,077	6,666
2024	55,939	451	7,831	7,380
2025	57,479	495	8,622	8,127
Total	**417,288**	**2,180**	**30,593**	**28,413**

To estimate the cost of producing the additional extra renewable energy under an REST against the baseline, we used estimates of the LEC, or financial breakeven cost per MWh, to produce the electricity.[31] 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

[31] U.S. Department of Energy, Energy Information Administration, *2017 Levelized Cost of New Generation Resources from the Annual Energy Outlook 2012* (2009/$MWh), http://www.eia.doe.gov/oiaf/aeo/electricity_generation.html.

generation technologies than the EIA estimates.[32] We used these alternative figures to calculate 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 below 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 (2012 $/MWh) 2010	2020	2025
Coal				
Low	.740	67	65	64
Medium	.795	83	86	79
High	.850	98	107	95
Gas				
Low	.850	63	67	73
Medium	.860	65	70	75
High	.870	66	73	78
Nuclear				
Low	.900	77	59	63
Medium	.900	98	85	81
High	.900	114	104	98
Biomass				
Low	.680	111	87	83
Medium	.755	112	95	93
High	.830	114	104	98
Wind				
Low	.155	96	94	83
Medium	.269	111	109	102
High	.355	173	169	165
Solar p.v.				
Medium	.269	119	89	89
Solar thermal				
Medium	.200	176	132	132

[32] 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. 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 $3.8 per kWh to a high of $79 per kWh, with an average of $15 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; 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; Sally Maki and Ryan Pletka, Black & Veatch, California's Transmission Future, August 25, 2010, http://www.renewableenergyworld.com/rea/news/article/2010/08/californias-transmission-future.

We adjusted the LECs for solar p.v. and solar thermal down to the EIA regional minimum to reflect the fact that Arizona likely has a cost advantage in solar energy over other U.S. regions. We then reduced the LEC for biomass until our estimated gross total costs for the year 2011 matched that of the compliance reports for all utilities. This averages $112.38 per MWh across all renewable technologies for 2011.

We use the EIA's reference case scenario for all technologies. We adjusted the 2017 LECs to 2025 by using the percentage change in the capital costs from 2017 to 2025, since capital costs often represent the largest component of the cost structure for most technologies. For the 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 2020, 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 technology, we assume no hydroelectric or nuclear sources are displaced since most were built decades ago with large sunk costs and offer relatively cheap and clean electricity today.

To determine the impact of the REST standard in a given year, we calculated the amount of renewable energy the REST 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 REST policy. We then determined which renewable energy source(s) would be used to meet the renewable energy sales attributable to the REST 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.[33]

Tables 8, 9 and 10 on the following pages display the results of our medium-, low- and high-cost calculations for the 15 percent REST respectively. We converted the aggregate cost of the REST into a cost per-kWh by dividing the cost by the estimated total number of kWh sold for that year. We converted the aggregate cost of the REST into a cost per-kWh by dividing the cost by the estimated total number of kWh sold for that year. For example, for 2025 under the medium cost scenario above, we divided $389.316 million into 57,479 billion kWhs for a cost of 0.68 cents per kWh.

Table 8: Medium Cost Case of 15 Percent REST Mandate from 2013 to 2025

Year	Gross Cost (2010 $000s)	Less Conventional (2010 $000s)	Total (2010 $000s)
2013	206,230	124,297	81,933
2014	236,586	140,429	96,158
2015	268,455	158,304	110,151
2016	296,673	176,104	120,569
2017	358,432	214,389	144,043
2018	423,363	255,737	167,627
2019	491,593	296,444	195,149
2020	563,255	344,139	219,116
2021	638,483	389,823	248,660
2022	717,421	439,204	278,217
2023	800,215	489,579	310,637
2024	906,486	555,393	351,093
2025	997,988	608,672	389,316
Total	**3,483,071**	**2,099,666**	**1,383,405**

[33] For example, if the REST 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 foregone 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 6): 0.269/0.86 * 100 MWh of natural gas = 31.3 MWh of natural gas energy production.

Table 9: Low Cost Case of 15 Percent REST Mandate from 2013 to 2025

Year	Gross Cost (2010 $000s)	Less Conventional (2010 $000s)	Total (2010 $000s)
2013	190,556	141,219	49,337
2014	218,602	157,878	60,724
2015	248,045	177,032	71,013
2016	274,118	197,598	76,520
2017	331,172	240,506	90,665
2018	391,156	287,576	103,581
2019	454,189	332,306	121,883
2020	520,392	387,959	132,433
2021	589,891	438,790	151,102
2022	662,818	494,700	168,119
2023	739,308	550,940	188,368
2024	837,484	624,848	212,636
2025	922,020	683,004	239,017
Total	**3,218,122**	**2,360,863**	**857,258**

Table 10: High Cost Case of a 15 Percent REST Mandate from 2013 to 2025

Year	Gross Cost (2010 $000s)	Less Conventional (2010 $000s)	Total (2010 $000s)
2013	243,529	109,425	134,104
2014	279,265	126,042	153,223
2015	316,791	143,448	173,343
2016	350,069	158,626	191,444
2017	422,619	193,188	229,431
2018	498,907	229,463	269,444
2019	579,086	267,502	311,583
2020	663,313	307,387	355,926
2021	751,751	349,164	402,588
2022	844,571	392,924	451,646
2023	941,946	438,711	503,235
2024	1,066,839	497,915	568,924
2025	1,174,506	548,261	626,245
Total	**4,105,329**	**1,884,243**	**2,221,085**

Ratepayer Effects

To calculate the effect of the REST on electricity ratepayers we used EIA data on the average monthly electricity consumption by type of customer: residential, commercial and industrial.[34] The monthly figures were multiplied by 12 to compute an annual figure. We inflated the 2011 figures for each year using the average annual increase in electricity sales over the entire period.[35]

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 17,489 kWhs of electricity in 2025 and we expect the medium cost scenario to raise electricity costs by 0.68 cents per kWh in the same year. Therefore we expect residential ratepayers to pay an additional $130 in 2025.[36]

Modeling the REST 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 REST policy.

Because the REST requires Arizona 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 REST. 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 REST. Standard economic theory shows that a price increase of a good or service leads to a decrease in overall consumption, and consequently a

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[34] U.S. Department of Energy, Energy Information Administration, "Average electricity consumption per residence in MT in 2008," (January 2010) http://www.eia.gov/electricity/sales_revenue_price/index.cfm.
[35] 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.
[36] We rounded the figure to the nearest $10s.

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 applied 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.[37]

In order to estimate the economic effects of a national REST 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), 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 REST policies. We used data from the EIA from the state electricity profiles, which contains historical data from 1990-2011 for retail sales by sector (residential, commercial, industrial, and transportation) in dollars and MWhs and average prices paid by each sector.[38] We inflated the sales data (dollars and MWhs) though 2020 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

[37] 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).
[38] Electric Power Monthly: Table 8. Retail Sales, Revenue, and Average Retail Price by Sector, 1990 Through 2011," (U.S. Energy Information Administration, 2012), http://www.eia.gov/electricity/state/missouri/xls/sept08mo.xls.

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 2025 for our medium cost case we divided our medium price of 11.20 cents per kWh by our estimated price increase of 0.68 cents per kWh for a price increase of 6.0 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 Arizona discussed above.

We applied the elasticities to percentage increase in electricity price and then applied the result to Arizona economic variables to determine the effect of the RES. These variables were gathered from the Bureau of Economic Analysis Regional and National Economic Accounts as well as the Bureau of Labor Statistics Current Employment Statistics.[39]

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.

[39] For employment, see the following: "State and Metro Area Employment, Hours, & Earnings," (U.S. Bureau of Labor Statistics, 2012), http://bls.gov/sae/ (accessed April 1, 2012). 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, 2012), http://www.bea.gov/itable/ (accessed April 1, 2012); "Gross Domestic Product by State," (U.S. Bureau of Economic Analysis, 2012), http://www.bea.gov/regional/ (accessed April 1, 2012). 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," (U.S. Bureau of Economic Analysis, 2012), http://www.bea.gov/regional/ (accessed April 1, 2012).

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.[40] 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.[41]

The LCA for wind power accounted for both onshore and off shore wind power, which has different values for manufacturing, dismantling, operation and transportation for each type.[42] Solar photovoltaic estimates were wide ranging, but a Science Direct paper supplied an in-depth, comprehensive review.[43] 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 energy.[44] There 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 Arizona energy system. The first calculation used the amount of renewable energy added per the Class I REST 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

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

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

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

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

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

results seen in Table 4. An identical calculated was done, but not accounting for capacity factors.

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