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Wisconsin Opportunity in Domestic Energy Production: The Economic and Health Benefits of 100% In-State Energy Production

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February 4, 2019

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Summary

Wisconsin has a current (2016) **energy spending deficit of $14.4 billion** ($14.4 billion in expenditures leaves the state). With no substantial in-state fossil fuel resources, reliance on fossil fuels is hurting the Wisconsin economy. Transitioning to in-state energy resources would bring dollars and jobs back to the state of Wisconsin. Current primary energy consumption is 522 Terawatt-hours (TWh; 1781.1 trillion BTU – an energy unit conversion chart is provided at the end of the report) annually, and end-use energy is 377.8 TWh (1288.9 trillion BTU). In transitioning to an entirely electric economy, Wisconsin's consumption would decrease to an estimated 265.8 TWh (906.8 trillion BTU) primary energy or 223.0 TWh (760.8 trillion BTU) end-use energy annually. The decrease is from avoided conversion losses and the higher efficiency of electric equipment, primarily for vehicles and heating. 100% in-state production would directly **create an estimated 162,100 net jobs** (a 110% increase over the current 147,900 energy jobs in Wisconsin)**.** Electricity prices are expected to remain comparable to current prices with an estimated increase of 10% per unit of energy (~$0.010/kWh). However, with increased investment in energy efficiency, we calculate a decrease in annual energy expenditures from $19.1 billion to $18.6 billion (a 3% decrease). The additional in-state spending ($14.4 billion - $0.5 billion) directly **increases state GDP by $13.9 billion,** or nearly 5%. In-state energy is estimated to **increase gross tax revenue on wholesale expenditures by $110.5 million plus $457.9 million in added income tax** from new jobs. The additional tax revenue could be used to offset added costs for the most difficult sectors to transition to in-state energy resources. Social and environmental benefits include reductions in **carbon dioxide (CO_2) emissions valued at $4.6 billion** and **air pollution exposure valued at $21.1 billion** in avoided human health damages. Therefore, for every MWh converted to in-state sources or saved through energy efficiency (167.2 TWh total would need to be met by new in-state sources), the emissions benefits would total $154 and $3.40 in tax revenue would be generated. In addition, one job is created for about every GWh converted. Unquantified impacts include impacts to water use, negotiation power, price stability, resiliency and grid performance, exports, improved urban design, comfort, land-use, and non-air-pollution-related health impacts. Many of these impacts would be overwhelmingly positive for Wisconsin. **The economic, social, and political benefits of in-state energy production support the implementation of policy to drive such a transition.**

The Current State of Wisconsin Energy Production, Use, and Expenditures

Wisconsin currently uses 1288.9 trillion BTU end-use energy (1781.1 trillion BTU primary energy) annually based on 2016 data from the U.S. Energy Information Administration's (EIA) State Energy Data System (SEDS) [1]. Current annual electricity demand (2016) totals 69.7 TWh (237.8 trillion BTU). The most recently published data from the Wisconsin Public Service Commission (PSC) shows end-use energy consumption as 1114.7 trillion BTU, resource energy consumption as 1571.4 trillion BTU and electricity consumption as 234.9 trillion BTU in 2012 [2]. Data is taken from the PSC's Office of Energy Innovation book of Wisconsin Energy Statistics (WES). The last version (the 2013 WES) was published with data through 2012 and the next version will be published soon with data through 2015. Some data through 2015 was obtained directly for the purposes of this report. In 2015, end-use consumption was 1149.6 trillion BTU (1300.9 trillion BTU according to EIA), primary consumption was 1599.1 trillion BTU (1797.8 trillion BTU according to EIA), and electricity consumption was 234.5 trillion BTU. In this analysis, we use 2016 data from the EIA as the most recent available statistics and utilize WES data to contextualize EIA data, or when otherwise necessary. Energy imported from outside Wisconsin includes 357.3 trillion BTU of coal, 499.6 trillion BTU of natural gas, 527.0 trillion BTU of petroleum, and 110.1 trillion BTU net inflow of electricity.

The WES shows $15.7 billion in energy expenditures in 2012 left the state of Wisconsin [2]. This comprises 68.1% of Wisconsin's $23.1 billion in energy expenditures. In 2016, EIA data shows Wisconsin's energy expenditures as $19.1 billion [1]. In 2012, expenditures were $24.1 billion. From 2014 to 2015, expenditures dramatically decreased, in large part due to a drop in the price of oil and to a lesser extent natural gas, paired with decreases in natural gas use. WES data obtained for 2015 lists expenditures as $19.0 billion ($20.7 billion according to EIA). Using ratios for expenditures leaving the state of Wisconsin following WES 2013 methods and results (95% of coal spending out-of-state, 85% of natural gas, and 85% of petroleum), we estimate 2016 expenditures leaving the state based on EIA data as $14.4 billion. Therefore, Wisconsin's current energy spending deficit is $14.4 billion.

In-State Energy Demand Projections

The following will assess the feasibility of achieving 100% of energy demands through in-state production. First, demand must be projected using only sources that are available in Wisconsin. For the purposes of this study we assume this means all energy is consumed as electricity unless production already exists in the state (i.e. ethanol). In aggregate, entirely in-state demand would total 906.8 trillion BTU primary energy (not including energy efficiency) or 760.8 trillion BTU end-use energy. This is calculated by summing the demand by sector calculated in the section below and then reincorporating current non-electric end-use energy provided by in-state energy sources in Wisconsin. These are added in directly as a conservative accounting of lost electrification benefits. Avoided conversion losses and more efficient equipment (especially vehicles and heating equipment) account for an avoided 874.3 trillion BTU demand (or 49.1%). In reality, many small demand sectors would likely be difficult to transition to electricity, and other energy carriers (i.e. biofuels or hydrogen) might be more practical for many applications, but in this analysis new in-state production and demand is assumed to be electric as a simplification. This analysis also assumes demand for energy services remains constant based on current levels.

Transportation Demand

We estimate transportation demand assuming current levels of transport are met using only in-state sources. Transportation demand in Wisconsin currently totals 434.9 trillion BTU (22.6 trillion BTU supplied by ethanol, and the rest is 99% petroleum) [1]. 96% of total consumption in the transportation sector is provided by distillate fuel oil (i.e. diesel) or motor gasoline (417.6 trillion BTU). Therefore, this analysis assumes comparing an average electric vehicle efficiency to that of an average gasoline vehicle is appropriate to estimate projected transportation demand. Using an assumed vehicle efficiency of 100 MPGe for the average electric vehicle, or roughly 34kWh/100 miles, and 20mpg for gasoline vehicles, electric vehicles are then exactly five times as efficient as gasoline vehicles. Therefore, future transportation demand is 20% of current demand, with the exception of 22.6 trillion BTU of ethanol currently produced in Wisconsin. Transportation demand is thus projected to be 82.5 trillion BTU of electricity or 105.1 trillion BTU total.

Residential and Commercial Demand

Residential energy demand is currently 401.3 trillion BTU in primary energy [1]. 157.8 trillion BTU come from direct use of natural gas (83%) and petroleum (17%). End-use demand totals 247.4 trillion BTU. Commercial demand is currently 360.4 trillion BTU with 106.7 trillion BTU from direct use of coal (0.5%), natural gas (87%), and petroleum (12.5%). End-use demand totals 191.8 trillion BTU. Using an electric heat pump with EER of 11 compared to an 80% efficient gas furnace we approximate that electric equipment is four times as efficient as previous equipment. Since a large portion of residential and commercial energy use is for space heating, we assume that all direct fossil-fuel use in the residential and commercial energy sector is replaced by electricity at a 4:1 efficiency gain. This may slightly underestimate future demand as not all electric equipment would be four times as efficient but other upgrades are likely outside of heating as well. Future electricity demand to replace direct fossil fuel use is thus projected to be 39.5 trillion BTU in the residential sector and 26.7 trillion BTU in the commercial sector. Residential end-use energy demand then totals 129.1 trillion BTU and commercial demand totals 111.8 trillion BTU.

Industry Demand

Industry demand currently totals 584.5 trillion BTU in primary energy [1]. 245.8 trillion BTU is direct use of fossil fuels (7.6% coal, 60.9% natural gas, and 31.4% petroleum). End-use demand totals 414.8 trillion BTU. Due to the varied and industry-specific uses of these fuels, this analysis assumes that electricity provides 1:1 equivalent energy resource to replace the out-of-state resources. In reality, this sector will probably be the most difficult to transition away from out-of-state resources and demand profiles are likely uncertain. Therefore, total end-use industrial energy demand is estimated to remain 414.8 trillion BTU.

In-State Energy Production Potential

Wisconsin has several in-state resources that can supply reliable and affordable energy. This section is meant to illustrate one possible way these resources could meet the needs of the state given estimates of the resource available and potential costs of producing energy taken from the National Renewable Energy Laboratory (NREL). The projected mix is not prescriptive and is solely meant to show feasibility of a 100% in-state energy scenario. In NREL analysis, not all technologies have an estimate of economical resource and values are highly dependent on assumptions regarding valuation of damages and future technology costs. Therefore, the illustration here is not an estimate or a prediction, but rather one possible mix of in-state generation that allows us to calculate the benefits of this transition based on realistic representation of in-state resources.

An estimate of technical resource potential is provided for each energy production technology listed in Table 1 and totals 21700 trillion BTU (28 times projected demand) [3]. Also listed in Table 1 are economic resource potential when available and proposed production in the illustrative case used here. Estimates show up to 43% of projected demand can be met by resources already in production or economical according to NREL [4]. For all benefit calculations that follow in this analysis the illustrative scenario described in Figure 1 and Table 1 is used. The projected energy mix first includes all resources in production or currently economical then adds in available technical resource based on providing a range of technologies given costs listed in NREL's analysis. Detailed data is provided by technology in the following sections. Technical and economic potential are from the National Renewable Energy Laboratory's (NREL) resource analysis when available [3,4]. NREL's economic potential study includes multiple scenarios. Here we choose Primary Case 3a which includes a decreasing value of intermittent resources and an estimate of the social cost of carbon to determine economical resource.

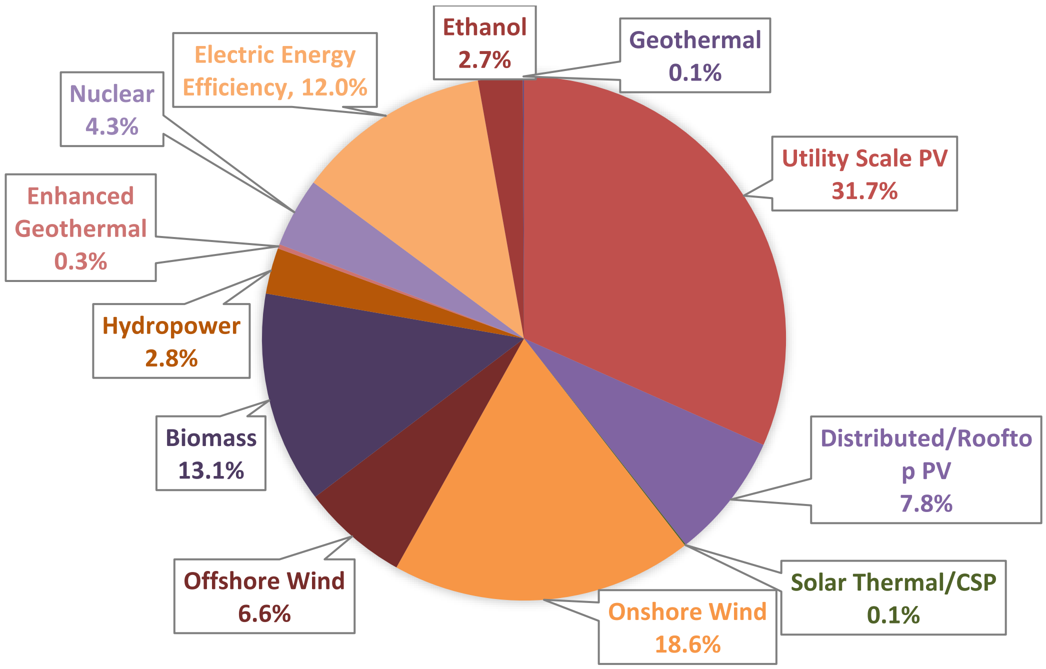

Figure 1: The proposed fuel mix for a 100% in-state energy scenario.

Solar Energy

Solar energy potential is assessed in three categories: utility-scale photovoltaics (PV), distributed/rooftop PV, and solar thermal (including concentrating solar power - CSP).

1. *Utility-Scale Photovoltaics (UPV)*

Utility-scale PV has an extremely large technical potential of 17400 trillion BTU (22 times total projected demand) divided between urban (1%) and rural (99%) land [3]. However, according to NREL's study, none of this would be economical and the net loss of developments would on average be greater than $0.025/kWh [4]. This is at odds with reality as there are several utility-scale solar projects in the queue for Wisconsin (including a potential 300MW project). The discrepancy is likely due in part to dramatic decreases in costs between the completion of NREL analysis and present day. Since there is such a large UPV resource in Wisconsin, we assume UPV would provide 1.5% of total potential (260.9 trillion BTU), or 31.7% of projected demand covering ~1,000 square kilometers [i]. To account for any cost discrepancies, we include a 10% increase in electricity costs across the board in quantification of impacts. Although given the rapid decrease in solar costs, UPV may end up offering cost savings compared to current options. Competing land uses are not assessed in this analysis.

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[i] 1.5% of demand is chosen so that solar will provide approximately one third of energy demand in the illustrative in-state energy scenario.

2. Distributed/Rooftop Photovoltaics (DPV)

Distributed PV has technical potential of 63.9 trillion BTU in Wisconsin (taken as the average of estimates from NREL and Project Sunroof, a Google tool to estimate solar savings) [3,5]. NREL estimates the economic potential as nearly half of the technical potential (27.6 trillion BTU) [4]. Estimates also show uneconomic potential has a net loss of no more than $0.002/kWh. Therefore, we assume all technical potential is developed for a total of 63.9 trillion BTU (7.8% of projected demand).

3. Solar Thermal and Concentrating Solar Power

NREL assesses Wisconsin as having no technical potential for CSP [3]. However, solar thermal is a category including CSP as well as solar hot water heaters, and other small projects. EIA lists current, non-electric solar production as 0.6 trillion BTU in Wisconsin [1]. Therefore, this analysis assumes solar thermal remains constant at 0.6 trillion BTU.

Wind Power

Wind power is divided into two categories: onshore and offshore. Combined, wind provides approximately 1/4 of projected demand.

1. Onshore Wind

Domestic onshore wind potential from NREL is 871 trillion BTU [3]. Current wind production is 14 trillion BTU (1.6% of the potential) [1]. Economic potential is assessed as 33.8 trillion BTU, or 3.9% of technical potential [4]. In this analysis, onshore wind is assumed to provide all remaining energy necessary after assessing other technologies. This totals 17.6% of total technical potential. All non-economic wind is within $0/kWh to $0.025/kWh loss according to NREL and prices are not expected to be largely impacted. At this rate, onshore wind supplies 153.4 trillion BTU, or 18.6% of total demand.

2. Offshore Wind

The technical potential for offshore wind is 1084 trillion BTU [3]. Unfortunately, NREL does not assess the economic potential of offshore wind. Therefore, we assess the expected contribution of offshore wind using onshore wind characteristics as a guide and assume just 5% of technical potential (54.2 trillion BTU) is developed totaling 6.6% of projected demand. This assumption relies on overcoming technical hurdles in producing offshore wind in the Great Lakes, but ensures offshore wind is not ignored in the illustrative example of in-state energy production.

Biomass and Biofuels

Biomass potential is assessed by NREL as both solid and gaseous biopower potential based on crop, forest, and mill residues, urban wood waste, and methane emissions from manure, wastewater treatment and landfills [3]. Therefore, this estimate does not include biofuels and the production of fuels or power from energy crops directly. Technical potential is 45.4 trillion BTU, but production according to EIA is already 117.3 trillion BTU primary energy (107.8 trillion BTU end-use) because this number also includes wood-based and non-power energy from biomass [1]. We assume biomass is consumed at its current rate since it is already in-state energy. At this rate, biomass provides 13.1% of projected demand. The technical potentials of biofuels like ethanol and biodiesel production are not assessed in NREL's study since it is limited to the power sector. Ethanol and biodiesel would offer an alternative to electrifying equipment, especially in the transportation sector. Here we assume no production of biofuels beyond the 22.6 trillion BTU of ethanol currently consumed (2.7% of projected total demand). However, expanding biomass production could offer a more cost-effective and achievable alternative to electricity for difficult-to-transition sectors than given in the illustrative scenario here.

Hydropower

NREL assesses the technical potential of hydropower as 7.8 trillion BTU, however current consumption from EIA is 25.8 trillion BTU [1,3]. Therefore, we assume hydropower production remains constant and provides 3.3% of projected demand.

Geothermal

Geothermal energy is divided into three categories: geothermal hydrothermal power, enhanced geothermal systems (EGS), and geothermal energy as defined by EIA [6]. According to EIA, geothermal currently provides 0.6 trillion BTU of energy, but this is consumed as direct energy or as part of a ground-source heat pump system, not in power production like geothermal hydrothermal or EGS [1]. The potential of geothermal hydrothermal is zero in Wisconsin, as the state lacks easily accessible geothermal resources [3]. However, EGS has a large potential in Wisconsin, 2200 trillion BTU. Unfortunately, NREL does not assess the economic potential of EGS, but it is a safe assumption that EGS is not economical in Wisconsin currently. For the purposes of this study, we assume as very small proportion of EGS technical potential (0.1%) is developed, possibly as a trial or case study. Therefore, EGS provides 2.2 trillion BTU (0.3% of total demand) and geothermal as defined by EIA remains constant and provides 0.6 trillion BTU (0.1% of total demand).

Nuclear

In this study, though nuclear is not technically an in-state resource, it is assumed as such because the fuel itself is only a small part of nuclear power production. In addition, as a large source of baseload power, continuing nuclear production may aid grid integration of other intermittent resources. Current nuclear power production is 106.2 trillion BTU primary energy (estimated 35.4 trillion BTU end-use), and we assume this remains the case in the in-state scenario, and thus nuclear provides 4.3% of projected demand [1].

Energy Efficiency

Energy efficiency is not assessed in demand projections. Rather it is included here as a potential technology to meet said demand. The Wisconsin Focus on Energy Potential study is used to assess energy efficiency [7]. The report finds the maximum achievable potential of energy efficiency in the electric sector is 1.29% annually where 100% of the incremental cost of an efficiency measure is paid through an efficiency program. Therefore, we assume energy efficiency reduces electricity demand 1.29% annually. To this point in the report, the time required to produce the estimated energy is ignored as we are interested in the benefits of an illustrative 100% in-state energy scenario regardless of when it is achieved. However, energy efficiency is presented as a percentage per year and the time dimension cannot be ignored. In the Focus on Energy report, 2030 is the base year and savings are reported over 12 years. Therefore, we assume 1.29% savings annually for 12 years totaling 99.2 trillion BTU. Overall, energy efficiency thus accounts for 12.0% of projected demand. The cost of this is not assessed by this report and would be borne by the energy efficiency program, but the direct energy savings of a 99.2 trillion BTU reduction in electricity demand would total $3.1 billion using 2016 prices. In addition, energy efficiency investments are often cost-saving and energy efficiency is likely one of the cheapest and fastest options for transitioning to in-state energy. Natural gas efficiency is also assessed in the Focus on Energy study, but as natural gas demand becomes zero in Wisconsin, this efficiency becomes irrelevant.

Discussion

Wisconsin has no fossil fuel resource, so in this scenario, coal, natural gas, and petroleum consumption are zero, a reduction of 357.3 (coal), 499.6 (natural gas), and 527 (petroleum) trillion BTU each. The spatial distribution of energy systems transitions within Wisconsin are beyond the scope of this analysis but would be expected to have a positive impact across the state as the largest resources (solar, wind, biomass) are all available statewide at varying degrees of cost-effectiveness. Other technologies that are not explicitly assessed but will be important include storage technologies and transmission and distribution. Both are considered in part due to the decreasing value of renewables in the NREL scenario chosen for economic potential analysis and the consideration of necessary transmission and distribution infrastructure in that study. Emerging energy technologies such as wave, tidal, and others may also play a role in in-state energy production, but at this time are not considered as viable options. Non-electric energy carriers would be important to consider as alternatives to electricity. For example, biofuels could provide a substantial portion of Wisconsin's energy demand and hydrogen could be a more viable option for transitioning some industries away from out-of-state resources. Hydrogen production potential in Wisconsin from existing power sources is summarized by NREL in the Hydrogen Demand and Resource Analysis (HYDRA) tool (https://maps.nrel.gov/hydra/). Modal and behavior shifts could also be considered in this transition to in-state resources but are currently not assessed. A large-scale transition to in-state resources would necessitate large changes which could include design and process changes that would impact human activity.

Feasibility and cost of a transition to fully in-state sources of energy would be largely impacted by several variables not considered in detail in this analysis. Grid operation and reliability when energy is supplied by a large percentage of intermittent and non-dispatchable resources would need to be thoroughly analyzed as production of these resources grows. However, this is not expected to be prohibitive, but rather may increase costs. Buying and selling electricity across state lines would aid integration and can be assumed to result as cost-neutral. In addition, the cost dynamics of new equipment and energy sources are not considered here. Many in-state energy resources rely on technologies with high-capital costs which could pose a challenge to transition efforts. Sunk costs on existing assets would also have a large impact on costs. End-use infrastructure reliant on fossil fuels would also likely be slow and potentially difficult to transition to electricity (for example, HVAC systems in buildings, gasoline vehicles, and industrial processes). Competing land-uses would also impact future in-state energy production but is beyond the scope of this assessment.

Quantification of Economic, Social, and Environmental Impacts

Direct Cost, Tax, and Deficit Impacts

The Wisconsin energy deficit is estimated as $14.4 billion as discussed previously in "The Current State of Wisconsin Energy Production, Use and Expenditures." To estimate the cost of the new in-state energy system, we apply an electricity cost of $0.1175/kWh (a 10% increase above 2016 electricity prices) [1]. 10% is chosen as a rough estimate based on the percentage of economic production and the levelized-cost of electricity of uneconomic proposed production. Non-electric sources of energy are assumed to have the same cost. Total cost is then calculated as $18.6 billion, a decrease of $0.5 billion from the current annual expenditures of $19.1 billion. Therefore, $13.9 billion in expenditures would newly flow to the state. Expenditure estimates are shown in Table 1.

The gross tax rate of Wisconsin wholesale electric revenues is 1.59% based on special state taxes for utilities [8]. Assuming retail electricity prices are twice that of wholesale prices, and all additional expenditures were not previously taxed, on an additional $13.9 billion in-state retail expenditures, additional state utility taxes would total $110.5 million annually. In addition, assuming an increase of 162,100 jobs (see next section), an average salary of $50,000/year and an effective state tax rate of 5.65% for single taxpayers (https://www.revenue.wi.gov/Pages/FAQS/pcs-taxrates.aspx), income taxes would total an additional $457.9 million. In the short-term, this additional $568.4 million in tax revenue could go to support transition policies in industries where in-state energy resources are less cost-effective and cover energy efficiency incentive costs. Or state revenues could provide financing structures to encourage investment as many in-state resources have low operating costs, but high capital costs. This estimate does not include the additional taxes from new infrastructure or impacts from changes to non-energy sectors and is a simplified estimate.

Employment

Jobs created through domestic energy production are estimated using two different techniques. Employment numbers per energy produced by each technology as defined in Wei et al. (2010) [9]. The values are provided in Table 2. Using these values alone, the original number of job-years in Wisconsin totals 62,000, however this does not match employment numbers of 147,900 energy jobs from the U.S. Energy and Employment Report (USEER) [10]. Under the proposed scenario, jobs total 100,000 for an increase of 38,000 jobs (+61%). Since this analysis is sensitive to the technologies chosen to meet projected demand, we also assess the impact if the least and most employment-dense technologies are used, and find a minimum job change of -23,500 job-years (-38%) and a maximum of 135,300 (+218%). However, the USEER reports energy jobs by state and assesses jobs differently. The results are quite different, showing 147,900 total jobs (including transmission, distribution, storage (TDS), and motor vehicle jobs). If TDS, motor vehicle, and efficiency jobs are removed, Wisconsin only has 18,600 jobs which is lower than the Wei et al., (2010)-based estimates. In addition, the energy efficiency jobs are drastically different with 62,300 currently in Wisconsin, but only an estimated 650 using Wei et al., (2010) rates.

Therefore, we use the USEER-reported employment numbers to estimate employment in the projected case when available and appropriate as given in Table 2. We assume motor vehicle jobs remain unchanged at 47,600 and electricity jobs classified as "other" are eliminated. We also assume transmission, distribution, and storage jobs scale based on electricity demand increasing from 19,400 to 51,600. For solar and geothermal, we continue to use the Wei et al., (2010) job rate as current solar energy production is too low to be indicative of job numbers and geothermal is not listed explicitly in job data. Energy efficiency jobs are based on a change from business-as-usual savings of 0.80% to maximum achievable savings of 1.29% based on Focus on Energy results, but not scaled by any changes in demand as energy services are assumed to remain constant. Jobs in energy efficiency thus increase from 62,300 to 100,500. Overall, jobs increase from 147,900 to 310,000 using this method. An increase of 162,100 jobs (110% increase). We consider this estimate the better job quantification as it relies on Wisconsin employment data and is more recent than the Wei et al., (2010) study. However, the Wei et al., (2010)-based estimates are used for context and provide a minimum and maximum estimate of -38% to +218%. When applied to USEER-based estimates, this provides a range of -56,200 to +322,400 net jobs.

Social Value of Carbon Mitigation

The social cost of carbon (SCC) is a metric used to quantify the benefits or damages of CO_2 emissions. An Interagency Working Group of the U.S. government released SCC estimates for regulatory impact assessment purposes [11]. The central estimate for the year 2020 of \$42/ton of CO_2 emissions avoided is used here. Wisconsin's annual CO_2 emissions are reported by the EIA by fuel and emissions from out-of-state sources are completely removed, totaling 95.6 million metric tonnes of CO_2 avoided [12]. This totals a benefit of \$4.0 billion in 2007 dollars used for SCC estimates. In 2016 dollars, the benefit is \$4.6 billion. In addition, benefits to reductions in non-carbon greenhouse gases would also accrue from 100% domestic energy production but are not quantified here.

Air Pollution Benefits

In addition to avoided greenhouse gas emissions, health-damaging pollutant emissions are reduced through a switch to local, low-emission sources of energy. Here we directly consider the health benefits of avoided emissions of fine particulate matter ($PM_{2.5}$) and $PM_{2.5}$ precursors using benefit per ton estimates for the year 2020 using a 3% interest rate from the U.S. Environmental Protection Agency (EPA) by emission sector and emissions estimates from the EPA's air trends state database [13–15]. These benefits consider the health benefits of air quality reductions in $PM_{2.5}$ directly emitted, and $PM_{2.5}$ chemically formed from emissions of nitrogen oxides (NO_X) and sulfur dioxide (SO_2) based on epidemiologically-derived exposure-response functions that link exposure to $PM_{2.5}$ to associated adverse health outcomes. For mortality and non-fatal heart attacks, the average of study estimates reported in benefit per ton estimates are used to quantify impacts in this report. The air quality reductions considered occur from emissions reductions in Wisconsin, but exposure will decrease across a much larger area.

Monetized health benefits are listed in detail in Table 2 of EPA's 2018 technical support document[15] and regulatory impact analysis[16] and include adult premature mortality, respiratory emergency room visits, acute bronchitis (ages 8-12), lower respiratory symptoms (ages 7-14), upper respiratory symptoms (asthmatics ages 9-11), minor restricted-activity days (ages 18-65), lost work days (ages 18-65), asthma exacerbation (ages 6-18), cardiovascular hospital admissions, respiratory hospital admissions, and non-fatal heart attack. The impacts of 100% in-state energy are quantified in Table 3. However, avoided mortality benefits are by far the largest fraction of monetized benefits, over 98%. Economic valuation is based on a combination of willingness-to-pay and value-of-statistical-life and values are summarized in Table 5-9 of EPA's 2013 regulatory impact analysis [16].

Overall, 55.5 thousand tons (92.5%) of SO_2, 189.8 tons (95%) of NO_X, and 28.8 tons (28.5%) of primary $PM_{2.5}$ are estimated to be avoided by using 100% in-state energy sources. Using benefit-per-ton estimates based on sectors this has a total value of $18.2 billion. This assumes emissions from current biomass and ethanol use are negligible and may therefore slightly overestimate benefits. Health highlights include an annually avoided 1,910 premature deaths, 148,000 work-loss days, 34,400 asthma cases, 50,000 cases of lower or upper respiratory symptoms, 873,000 minor restricted activity days and 650 non-fatal heart attacks. Additionally, in Wisconsin several counties have difficulty attaining ozone (O_3) standards which also have significant health impacts. Based on the 2017 global burden of disease estimates of disability-adjusted-life-years lost from $PM_{2.5}$ exposure (34,200) and O_3 exposure (5,500) in Wisconsin, calculated using the GBD Compare Tool [17,18], we assume that health benefits from O_3 reduction will be 16% of the $PM_{2.5}$ benefits based on the current ratio of exposure impacts. This is a rough, illustrative approximation as O_3 chemistry is significantly different than $PM_{2.5}$ and depends on different precursor emissions. Ozone benefits therefore total an estimated $2.9 billion. Including O_3 benefits increases the value of avoided air pollution to a total of $21.1 billion annually.

Other Impacts

Price volatility, conflict, and supply interruptions may all be minimized by using domestic sources of energy. In-state resources tend to be capital intensive but have few variable costs. However, reliability could be impacted by grid integration of large-scale intermittent and non-dispatchable resources. Wisconsin could be vulnerable to supply interruptions under circumstances of large scale in-state disasters or prolonged fluctuations in supply and demand. However, under times of peak supply and demand, the integration of the U.S. power system allows Wisconsin to purchase out-of-state electricity when required and sell excess electricity when available. Having in-state resources would also impact political will and could increase power in cross-state and international negotiations. Assessment of changes in land-use are beyond the scope of this analysis but could include both beneficial and negative impacts. Some shifts in energy use such as modal shifts in transportation and the redesign of communities and systems could cause external health and comfort benefits that are beyond the scope of analysis here. For example, efficient urban design that facilitates walking or biking short commutes has been shown to provide substantial health benefits. Other benefits might include improvements in indoor air quality, reductions in road accidents, and greater access to quality healthcare.

Conclusion

Producing Wisconsin's energy needs within the state has a myriad of economic and societal benefits. While Wisconsin does not possess traditionally valued fossil energy resources, the state is rich is alternative sources. In this analysis we use – and cite - a variety of reasonable assumptions and perform simplified analysis techniques to quantify the benefits of a complete transition to in-state energy sources for Wisconsin. These benefits include large energy savings from efficiency and electrification, job creation, elimination of the state's energy spending deficit, increased tax revenue, reduced air-pollution related health damages, and reduced climate change damages. The assumptions used here drive the analysis, and other analyses using different assumptions would find different quantitative results. However, the qualitative findings are clear. Transitioning Wisconsin to in-state energy resources would be an economic boon to the state and would substantially improve public health.

Table 1: Current Consumption, Potential, and Projected Production in the 100% in-state energy scenario.

Technology	2016 Primary Consumption (trillion BTU)	2016 Expenditure (million $, % leaving the state)	Technical Potential (trillion BTU)	Economic Potential (trillion BTU)	Projected Production (trillion BTU)	Projected Expenditures (million $)
Utility Scale PV	0	(electricity) [c]	17391.6 [h]	0	260.9	(electricity) [c]
Distributed PV	0.01	(electricity) [c]	63.9 [i]	27.6	63.9	(electricity) [c]
Solar Thermal	0.6	0 [d]	0 [j]	n/a [l]	0.6	0 [d]
Onshore Wind	14	(electricity) [c]	871.0	33.8	153.4	(electricity) [c]
Offshore Wind	0	(electricity) [c]	1084.2	n/a [l]	54.2	(electricity) [c]
Biomass	117.3	163.3	45.4 [k]	0	107.8	163.3
Ethanol	22.6	0.4 [e]	n/a [l]	n/a [l]	22.6	0.4 [e]
Hydropower	25.8	(electricity) [c]	7.8	4.4	23.4	(electricity) [c]
Geothermal Hydrothermal	0	(electricity) [c]	0	0	0	(electricity) [c]
Enhanced Geothermal	0	(electricity) [c]	2208.2	n/a [l]	2.2	(electricity) [c]
Geothermal (EIA)	0.6	0 [d]	n/a [l]	n/a [l]	0.6	0 [d]
Nuclear	106.2	(electricity, 75.4 in fuel costs) [c]	n/a [l]	n/a [l]	35.4	(electricity, 75.4 in fuel costs)
Energy Efficiency	n/a [a]	n/a	1.29% of electricity [m]	0.80% of electricity [m]	99.2	n/a [o]
Coal	357.3	819.9 (95%)	n/a [l]	n/a [l]	0	0
Natural Gas	499.6	2,625.9 (85%)	n/a [l]	n/a [l]	0	0
Petroleum	527	9,213.1 (85%)	n/a [l]	n/a [l]	0	0
Electricity Flow (into WI)	110.1	3,446.13 [f]	n/a	n/a	0	0
Electricity	237.9 [b]	7434 [g]	n/a	n/a	632.4 [q]	18,360 [p]
Electric Losses	492.2 [b]	n/a	n/a	n/a	63.2 [n,q]	n/a
TOTAL	**1781.1**	**19,124.4**	**21,683.4**	**74.1**	**824.0** [q]	**18,599**

[a] Energy efficiency is assumed to be at a current rate of 0.98% of demand (the BAU achievable estimate from Focus on Energy).
[b] This value is double-counted as it is end-use energy and already included in the primary energy numbers of each technology.
[c] This value is/would be counted as expenditures on electricity and is not broken out by the specific technology.
[d] Solar thermal and geothermal (as defined by EIA) are assumed to include negligible energy expenditures.
[e] Estimated based on gasoline costs.
[f] This value is double counted in the next row (electricity).
[g] $1207.2 million is double counted and already included in the costs of primary fuels.
[h] Split between urban (~1%) and rural (~99%)
[i] Average between NREL and Project Sunroof [3,5].
[j] Defined as the potential for concentrating solar power.
[k] Defined as discussed in biomass section of text. Waste-derived and residue power production only.
[l] Not included in potential study [4].
[m] Defined by Focus on Energy study as maximum achievable potential for electricity-based efficiency for technical potential, and business-as-usual is used for economic potential [7].
[n] Losses are defined as 10% of electricity demand for losses in transmission, distribution, and storage.
[o] Achieving the maximum achievable energy efficiency would require 100% incentives bearing an unquantified cost.
[p] Assuming the electricity retail price increases 10% to $0.1175/kWh.
[q] Electricity and electricity losses are double-counted for each specific technology. Total is end-use energy plus losses.

Table 2: Current and Projected Employment in the 100% in-state energy scenario.

Technology	Projected Production	Current Jobs	Job Rate (jobs/ trillion BTU)	Projected Jobs
Utility Scale PV	260.9	(DPV) [a]	255.0 [c]	66,518 [c]
Distributed PV	63.9	3,802	255.0 [c]	16,286 [c]
Solar Thermal	0.6	(DPV) [a]	67.4 [c]	40 [c]
Onshore Wind	153.4	1,549	49.8 [c] | 110.6 [d]	16,968 [d]
Offshore Wind	54.2	0	49.8 [c] | 110.6 [d,g]	5,998 [d,g]
Biomass	107.8	1,617 [b,e]	136.3 [c] | 13.8 [d,e]	1,617 [d,e]
Ethanol	22.6	1,495 [e]	136.3 [c] | 66.2 [d,e]	1,495 [d,e]
Hydropower	23.4	138 [e]	79.1 [c] | 5.4 [d,e]	138 [d,e]
Geothermal Hydrothermal	0	0	73.3 [c]	0 [c]
Enhanced Geothermal	2.2	0	73.3 [c]	162 [c]
Geothermal (EIA)	0.6	44 [c,e]	73.3 [c]	44 [c,e]
Nuclear	35.4	1,084	41.0 [c] | 10.2 [d,e]	1,084 [d,e]
Energy Efficiency	99.2	62,299	111.4 [c] | 63,570 per % savings [d,f]	100,457 [d,f]
Coal	0	2,730	32.2 [c] | 7.6 [d]	0
Natural Gas	0	1,379	32.2 [c] | 2.8 [d]	0
Petroleum	0	4,453	14.7 [c] | 8.4 [d]	0
Transmission, Distribution, Storage	n/a	19,423	81.6 [d,f]	51,631 [d,f]
Motor Vehicles	n/a	47,584 [e]	n/a	47,584 [e]
TOTAL	**824.0**	**147,895**	**n/a**	**310,000**

[a] All current solar jobs are listed as distributed PV.
[b] Includes all fuel jobs listed as “woody biomass” or “other fuels.”
[c] Job rate comes from Wei et al., (2010) [9].
[d] Job rate defined by current production and current jobs based on USEER and EIA [1,10].
[e] Jobs assumed to stay the same.
[f] Calculated based on electricity production. For energy efficiency, calculated by the change in electricity savings rates between business-as-usual and maximum achievable potential.
[g] Uses onshore wind values.

Table 3: Projected Health Savings in the 100% in-state energy scenario.

Emissions and Health Savings (# cases unless otherwise specified)	Directly Emitted $PM_{2.5}$ (cases)	SO_2 [a] (cases)	NO_X [a] (cases)	TOTAL
Health Savings (Billion $2015)	**11.5**	**4.2**	**2.4**	**18.2**
Emissions (thousand tonnes in 2017)	29	56	190	**274**
Adult Mortality	1,220	430	260	**1,910**
Respiratory ER Visits	420	140	80	**650**
Acute Bronchitis	1,010	340	220	**1,580**
Lower Respiratory Symptoms	13,000	4,400	2,800	**20,200**
Upper Respiratory Symptoms	18,700	6,400	4,100	**29,200**
Minor Restricted Activity Days	566,000	187,000	119,000	**873,000**
Work Loss Days	96,000	32,000	20,000	**148,000**
Asthma Exacerbation	22,100	7,500	4,700	**34,400**
Cardiovascular Hospital Admissions	190	70	40	**290**
Respiratory Hospital Admissions	180	70	40	**280**
Non-Fatal Heart Attacks	410	150	90	**650**
Estimated Ozone Savings (Billion $2015)	-	-	-	**2.9**

[a] Impacts from precursors SO_2 and NO_X are due to $PM_{2.5}$ exposure formed from emissions of SO_2 and NO_X.

Energy Conversion Chart:

1 trillion BTU = 293.07 GWh = 293×10^6 kWh
1 trillion BTU = 8.77 million gallons of gasoline
1 trillion BTU = 1.055 PJ = 1.055×10^{15} J
1 trillion BTU = 172 thousand barrels of oil equivalent
1 trillion BTU = 36,000 metric tonnes of coal = 39,683 short tons

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