



Energy Self-Reliant States Homegrown Renewable Power

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This report has been significantly updated and expanded. The new version is available at <http://bit.ly/energyselfreliantstates>

Executive Summary

How much energy could be generated by states tapping into internal renewable resources? To date, no study has addressed this question comprehensively. This report is a first attempt to do so.

The data in this report, while preliminary, suggest that at least half of the fifty states could meet all their internal energy needs from renewable energy generated inside their borders, and the vast majority could meet a significant percentage. And these estimates may well be conservative.

A national renewable energy policy should reflect the unique distribution of these energy sources. Wind and solar and, to a lesser extent, biomass, can be found in abundance in virtually all parts of the country. A federal policy that focuses on harnessing local renewable resources for local markets could dramatically expand the number of communities and states economically benefiting from the use of renewable fuels while minimizing the transportation-related environmental impact of moving energy products long distances.

Yet current federal energy policy is largely focused on harnessing renewable energy in a few states and transporting it hundreds or even thousands of miles to customers in other states.

The rationale for this reliance on long distribution lines is that while renewable energy is widely distributed, the resources and cost of harnessing them vary widely state-by-state.

That is true. Agricultural states in the heartland can grow biomass in larger quantities and at a lower cost than states on the coasts. A state like Nevada has significantly more annual solar energy than Oregon. North Dakota's high wind speeds translate into lower production costs.

However, while significant variations in renewable energy among states exist; in most cases, when transmission or transportation costs are taken into account, the net cost variations are quite modest. Homegrown energy is almost always cheaper than imports, especially when you factor in social, environmental and economic benefits.

Policies that encourage energy self-reliance at a state and even in many cases a local level could enable communities and regions to achieve economic and environmental goals simultaneously. It's a win-win situation.

Acknowledgments

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Since 1974, the Institute for Local Self-Reliance (ILSR) has worked with citizen groups, governments and private businesses to extract the maximum value from local resources.

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Introduction

Renewable energy is unique because it is available almost everywhere and in many cases, can most effectively be harnessed in distributed fashion. Nevertheless, federal policy unaccountably subsidizes and encourages the harnessing of renewable fuels in a few states and sending the energy long distances to customers in other states.

The rationale for this policy is that renewable energy should be harnessed for the least cost – where the wind blows most strongly and reliably, or the sun shines most often, or the soil is most productive.

If carried to its logical conclusion, this could result in a centralization of our power supply. Advocates of this policy, for example, note that sufficient solar radiation falls on just a section of Nevada to power the entire country. The two Dakotas have enough wind electricity potential to meet over 80% of U.S. annual electricity consumption. The agricultural heartland can grow crops less expensively, and in greater abundance, than coastal states.

This philosophy has led federal policy to focus on developing the means to transport electricity and transportation fuel generated from wind and sunlight and soil out of the middle and southwestern parts of the country to coastal markets. And this in turn leads to calls for a dramatic expansion of high voltage transmission grids and rail lines and terminals.

There is no question that the abundance and cost effectiveness of renewable energy does indeed vary from state to state. Nevada, for example, can produce solar electricity from photovoltaic panels for about 20 percent less than Iowa and about 35 percent less than Pittsburgh, PA.¹ Iowa has thirty times the biomass resource of Nevada and could produce biofuel more cheaply. A typical North Dakota commercial wind turbine could produce electricity at a cost close to 30 percent less than an Ohio one. But in most cases, these significant variations result in modest variations in the cost of energy to the ultimate consumer because of the cost of transporting the energy.

For example, if Ohio's electricity came from North Dakota wind farms – 1,000 miles away – the cost of constructing new transmission lines to carry that power and the electricity losses during transmission would surpass the lower cost of production, resulting in an electricity cost 15 percent higher than local generation with minimal transmission upgrades.²

State based renewable energy strategies can strengthen local and regional economies. States have clearly indicated their desire that renewable energy be harnessed within their borders and in most cases consumed by in-state businesses and households. For example, Minnesota enacted a Community-Based Energy Development statute that helps secure more locally owned wind power, and an ethanol producer payment that supports small-scale ethanol plants. Missouri has an incentive for locally owned biodiesel refineries and also provides a producer incentive for ethanol, but only if it is made from in-state agricultural products.³ Louisiana recently passed a biofuel law that prioritizes in-state production of “advanced biofuel” from Louisiana-grown feedstocks.⁴ Delaware requires its major utility to request proposals for new in-state generation.⁵

A handful of states do focus on renewable energy exports largely because their renewable energy production currently exceeds in-state demand. But in-state markets could expand as the country moves to higher proportions of renewable energy. For example, Minnesota exports almost two thirds of its in-state ethanol production. Much of it goes some 2,000 miles to California. This is because of a federally imposed 10 percent limit on the amount of ethanol Minnesota vehicles can use. If this limit were raised to 30 percent, all Minnesota ethanol could be consumed within the state. This would be attractive to Minnesota biorefineries because they could avoid the cost of transporting their product long distances. It would also be attractive to consumers, who would be less reliant on the vagaries of the international oil market.⁶

How much energy could be generated by states tapping into their own renewable resources? In this report we examine the potential for renewable electricity and transportation fuel. The report does not include the third leg of U.S. energy consumption – building heating. Thus, about 30 percent of a state's energy use is not considered in this analysis.⁷

The data is preliminary and we hope others can refine and expand on it. But the data we have suggests an important conclusion: the majority of states could satisfy a significant amount of their internal electricity and transportation fuel needs from local resources and by tapping their human ingenuity. Indeed, as the report discusses, we believe current data may considerably understate the potential.

A Note on Methodology

This report examines the potential for states to increase their generation of electricity from wind and rooftop solar photovoltaics (PV) and their production of cellulosic biofuels (primarily ethanol). In the case of wind and solar, the study likely underestimates the full potential of state generation, an issue explored further in the respective sections.

Wind

The wind power data in this report is derived from the 1991 Pacific Northwest Laboratory (PNL) study, *An Assessment of the Available Wind Land Area and Wind Energy Potential in the Contiguous United States*.⁸ This study surveyed the available wind data measured at 30 meters (and extrapolated the data to 50 meters) in each of the lower 48 states. Land was excluded from wind energy development based on environmental limitations (park designations, etc) and various land uses (urban areas, wetlands, etc).

ILSR's analysis used the "moderate" land exclusion estimates and also updated the 1991 study. Wind power density was estimated by extrapolation to 80 meters using the 1/7th power law. Power losses were reduced from 25% to 15%.⁹

We believe the resulting ILSR estimate may well considerably underestimate wind power potential for at least two reasons.

First, states that were considered to have no economical wind speeds in the PNL study are recorded as having none in this report. But this significantly understates the current reality of the wind industry. For the 1991 report, a minimum economical wind speed was assumed to be Class 3 at 30 meters. If a state had no wind of this quality, it was shown to have zero wind resource (and is displayed in **Figure 3** with a zero). But modern turbines are more than twice the height (80 meters) of the original measurements and thus many considered to have "no wind resource" in the PNL report may in fact have considerable wind potential.

Consider, for example, the impact of new data on the potential for wind energy in Indiana. In the original study, no part of the state was considered suitable for wind development. However, an updated wind speed map from the National Renewable Energy Laboratory (**Figure 1**) shows a significant amount of land – over 2,000 square kilometers – with a good wind resource (Class 3) at 50 meters. This could provide as much as 25 billion kilowatt-hours of electricity, 23 percent of the state's total sales.

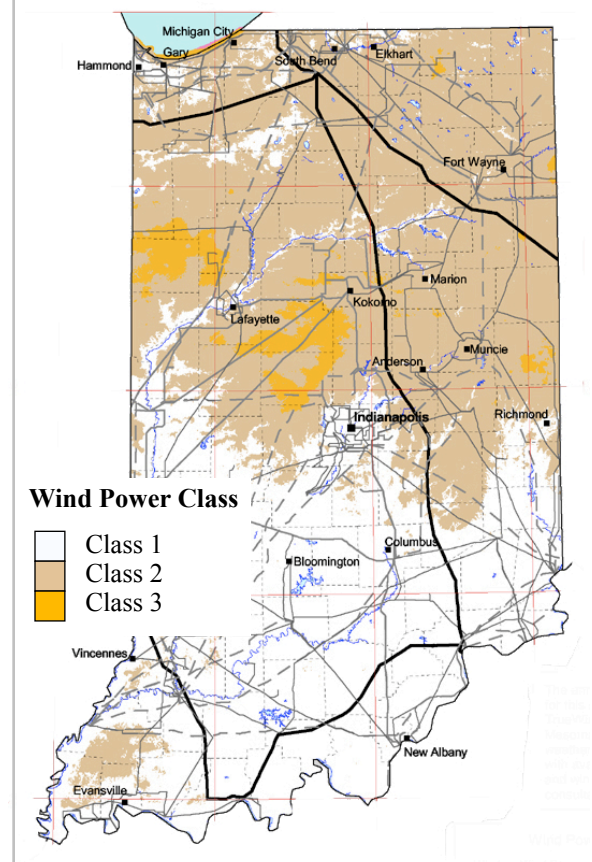
Indeed, **Figure 1** is itself an underestimate, because modern wind turbines are typically 80 meters or taller at

the turbine hub. Taller turbines would intersect an even better wind resource.

A second underestimate contained in our analysis is the exclusion of offshore wind. This can be substantial, particularly with states on the Eastern Seaboard that are already developing their offshore wind potential.¹⁰ By one estimate, coastal wind resources off of Delaware, for example, are sufficient to provide four times the state's average electricity consumption.¹¹ Moreover, "coastal region running from Massachusetts to North Carolina contain[s] up to 330,000 megawatts of average electrical capacity...larger, in terms of energy equivalence, than the entire mid-Atlantic coast's total energy demand — not just for electricity but for heating, for gasoline, for diesel and for natural gas."

ILSR's calculations does not assess the impact of wind (or solar) intermittency. However, when states are developing their wind power potential over a large area, as this report examines, the intermittency issues of wind power are mitigated to some extent by the geographic diversity of wind speeds. Furthermore, natural gas fired backup power plants could make a significant part of the

Figure 1 - Indiana Wind Power Class at 50 meters (NREL)



wind power “firm.”¹² Finally, rapid advances are occurring in battery storage which, if massively deployed, could ameliorate the intermittency impact. (See below for discussion of electrified vehicles.)

Solar

The solar power data comes from a national estimate of rooftop solar PV potential in 2015 by Navigant Consulting.¹³ That report estimated total roof space available on residential and commercial buildings, taking into account shading, orientation, and structural adequacy. The report concluded that only 25 percent of residential rooftop space and 60 percent of commercial rooftop area are available for rooftop solar arrays.

For the solar modules, Navigant assumed a current efficiency of 13.5 percent, rising to 18.5 percent by 2015. The figures used in this report are the 2015 estimates, even though the Navigant data may be an overestimate of rooftop potential because the overall module efficiency of PVs is likely to be less than the 18.5 percent assumed in the report.

However, this overestimate of rooftop potential is dwarfed by the exclusion of many other sources of

solar electricity. For example, the report does not include installation options such as parking lot canopies or building facades. These could generate several times more electricity than rooftop arrays. The state of California, for example, did a solar resource assessment and found that while its rooftop potential was close to 38,000 megawatts (MW), its total PV potential was over 16 million MW – 400 times greater.¹⁴ And the California estimate still contained many land use and practical exclusions.¹⁵

The data also excludes the vast potential for in-state concentrating solar power (CSP), such as parabolic trough or power tower plants. The previously mentioned California study found a technical potential of 1,000 gigawatts (GW) of concentrating solar power in California. A study for the Western Governors’ Association identified over 200 GW of prime CSP potential within their states,¹⁶ enough to provide 1/6th of U.S. power needs, as well as several thousand GW of technically feasible development.¹⁷

Finally, this report does not examine other solar technologies that could displace electricity, for example, solar water heating or a greater use of natural light – day-lighting – in buildings.



Biomass

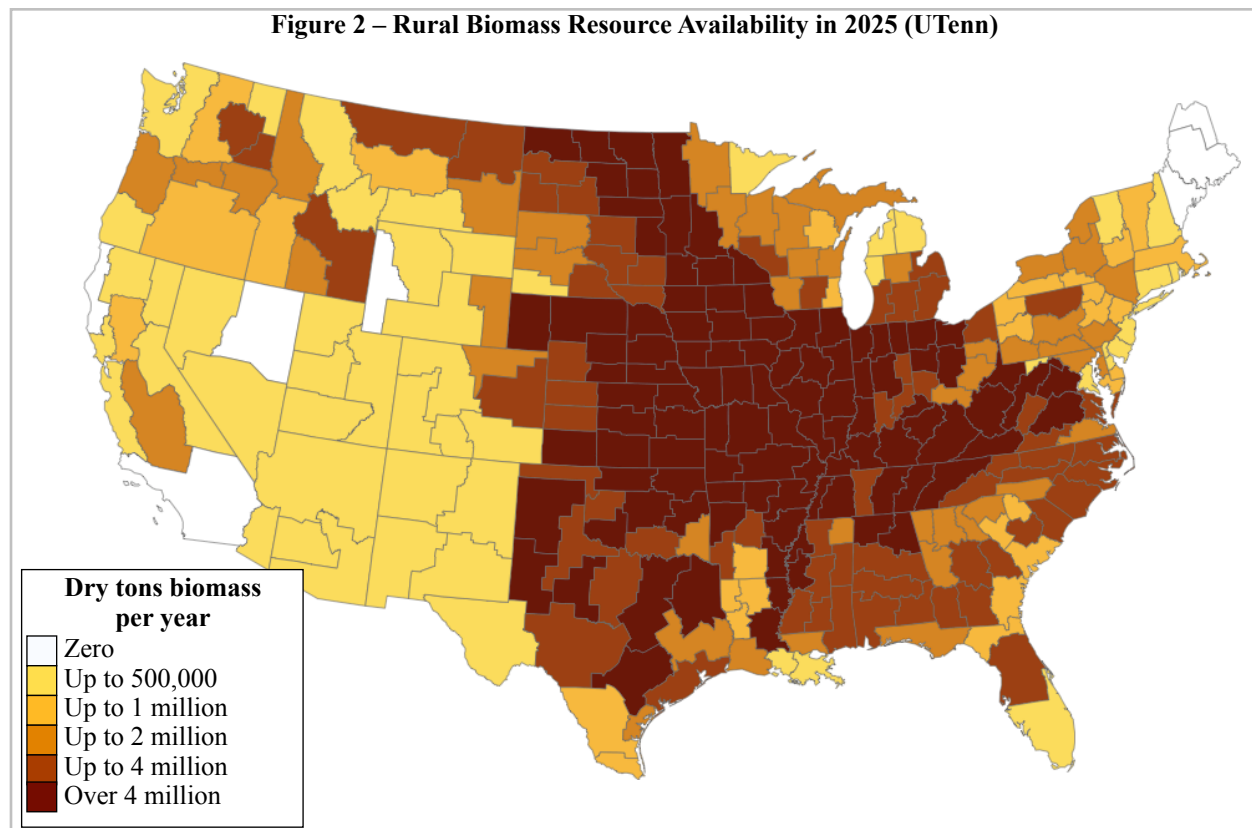
The biomass data relies on a University of Tennessee (UTenn) study examining the potential of achieving 25% of all primary energy from renewable sources by 2025.¹⁸ The data examined the potential land available for energy crops as well as the potential for agricultural residue and wood waste. Estimates for each state's biomass resource in the study, and in our report are based on the low end of each region's 2025 "all energy" biomass potential. This data is pictured in **Figure 2**.

The Tennessee study concluded there would be a significant diversion of pasture land to energy crops to make way for biomass development. Also, it projected annual yield increases ranging from 1.5 to 5 percent for switchgrass – their expected primary dedicated energy crop – depending on the region of the country. The Tennessee estimates may be conservative. Several

state biomass studies have identified resources significantly higher than that of the Tennessee. For example, a Washington state study¹⁹ and a South Carolina state study²⁰ both found nearly twice the biomass resource of the UTenn study. A California state assessment of biomass resources found quadruple the biomass resource.²¹

Moreover, while the U of Tennessee used switchgrass as its energy crop, a recent three year study in Illinois concluded that miscanthus grass has a yield 2.5 times greater than switchgrass and could have a dramatic impact on the study's estimates.²²

The biofuels projections for each state in **Figure 6** assume a production of 100 gallons of ethanol from a dry ton of cellulosic feedstock. Current production is about 70 gallons a ton.



Solar Power

By simply relying on rooftop solar photovoltaic (PV) panels, many states could satisfy a substantial portion of their electricity needs.

One state, California, could meet at least half its electricity demand solely with rooftop solar (and sufficient electricity storage). A majority of states could generate more than a quarter of their electricity from rooftop solar power.

Figure 4 illustrates the percent of each state's 2007 electricity sales that could be met by rooftop solar PV.²⁵

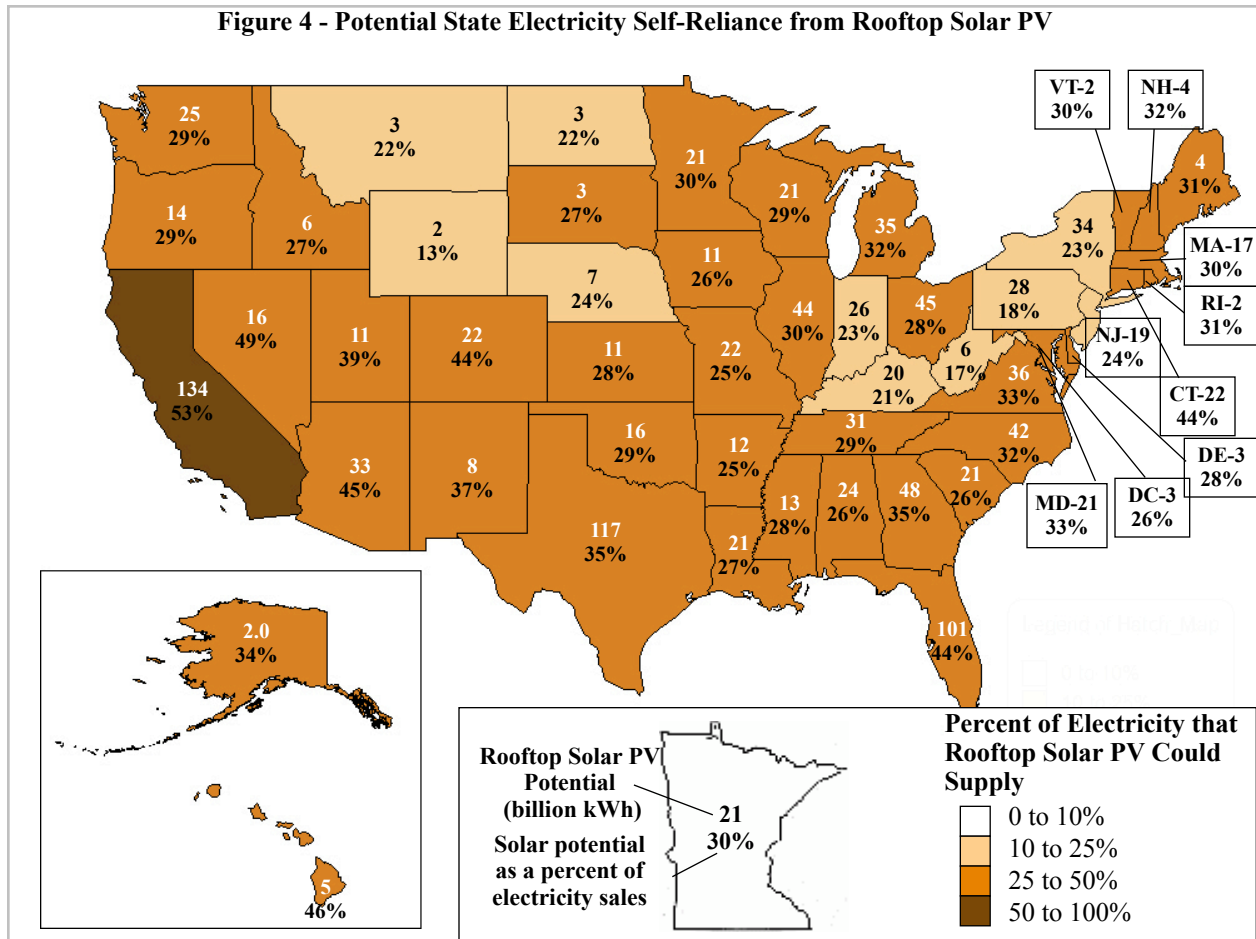
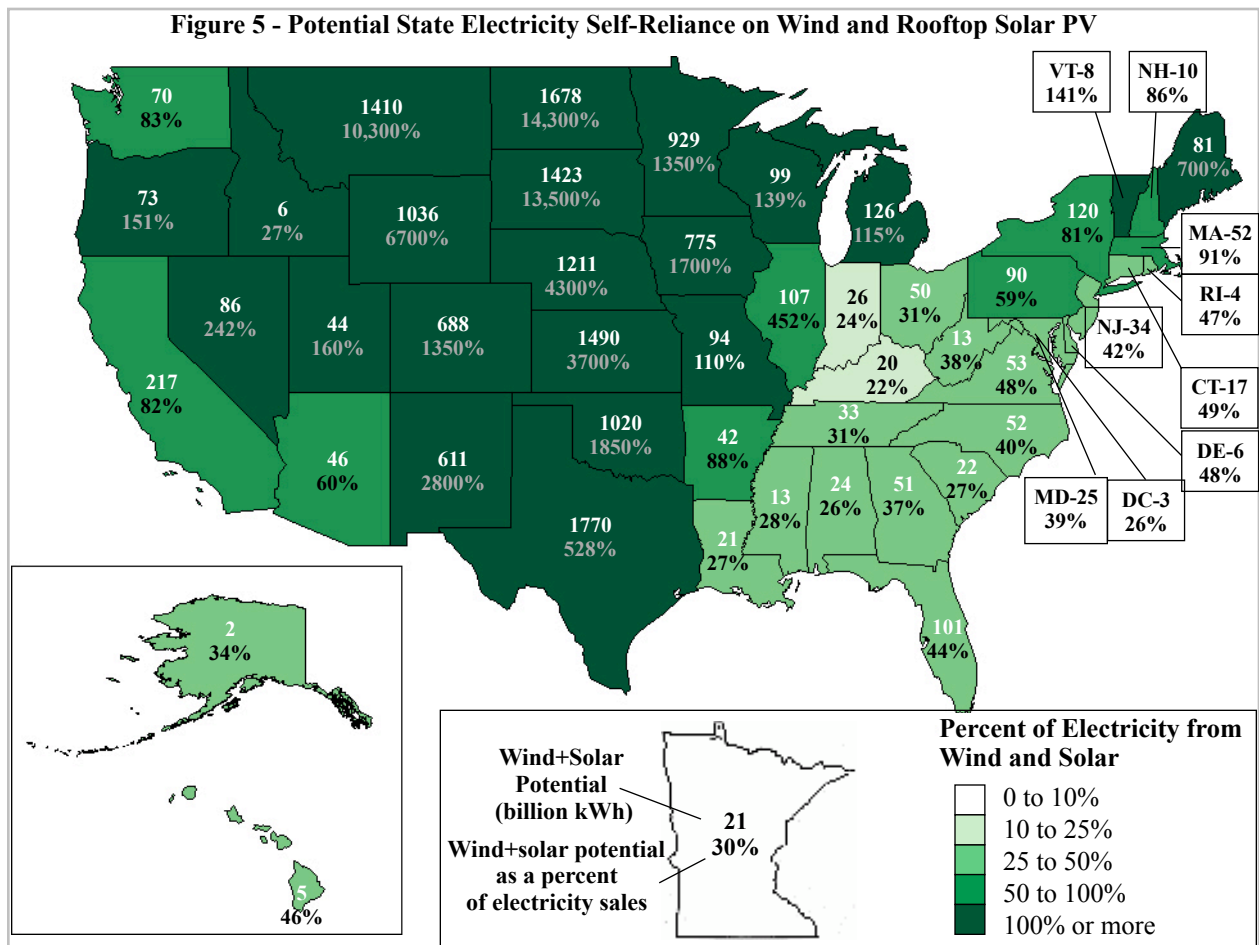


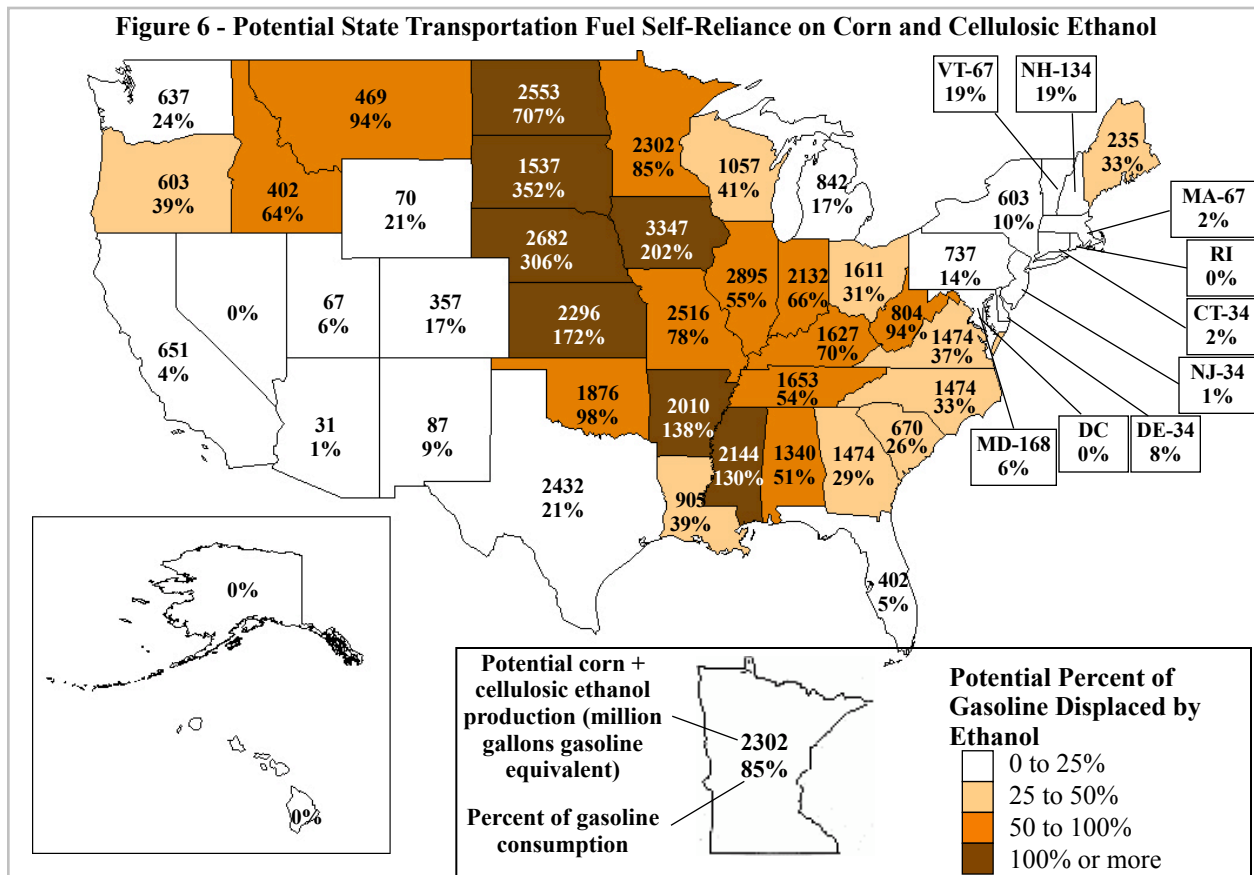


Figure 5 - Potential State Electricity Self-Reliance on Wind and Rooftop Solar PV



Combined Wind and Solar

Combining the solar rooftop PV resource potential with the previously mapped wind resources would allow 21 U.S. states to fully satisfy their electricity needs with renewable electricity (**Figure 5**); 30 states could generate at least half their electricity just from wind and solar rooftop generators.



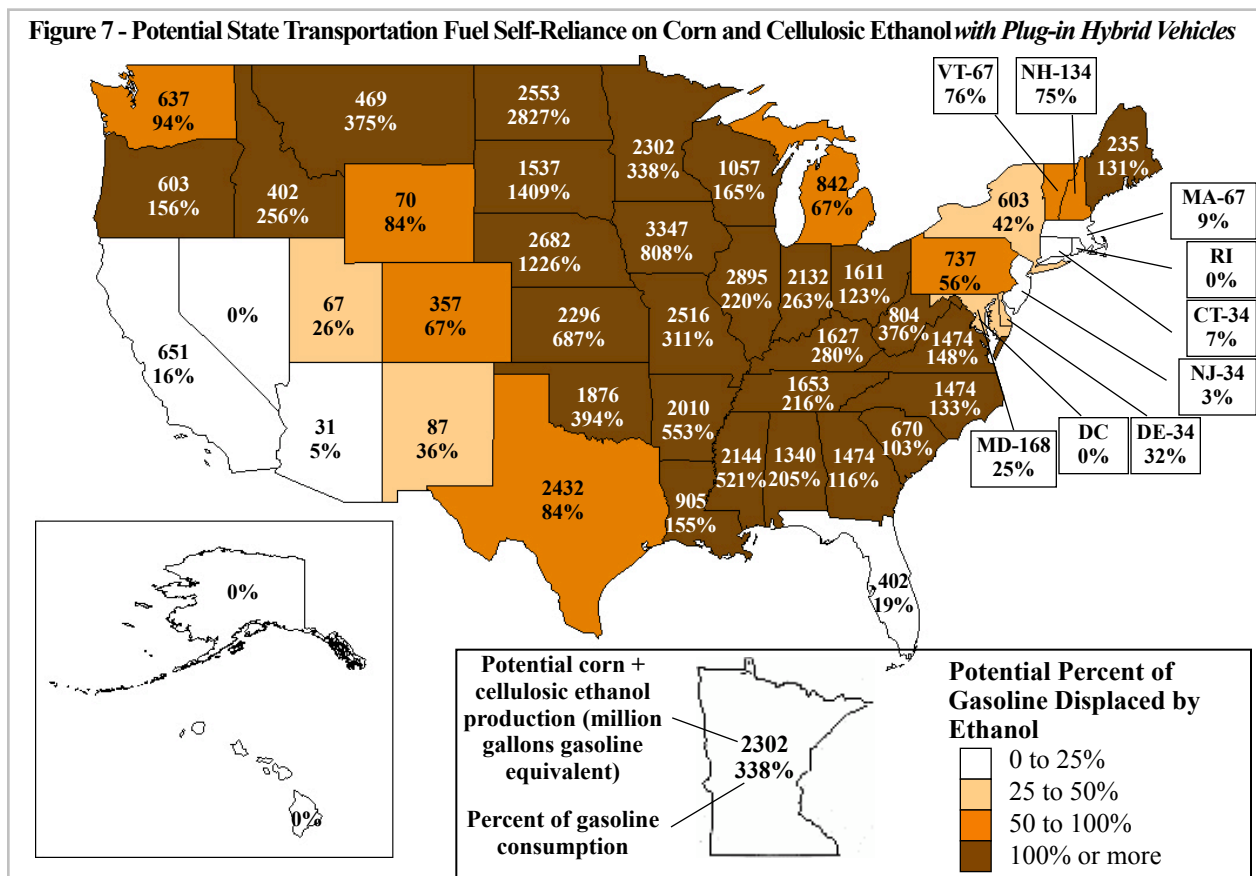
Renewable Fuel Potential

Transportation fuel self-reliance is a greater challenge than renewable electricity self-reliance. Many states lack the agricultural land to grow crops like corn and soybeans that provide the foundation for current ethanol and biodiesel production.

But the nation is moving from the corn ethanol era to the cellulosic, and non-food crop, era. The 2007 Energy Act requires 36 billion gallons of biofuels by 2022, and more than 75 percent of the new production after 2008 will consist of what is called “advanced biofuels.” Cellulosic feedstocks, unlike conventional crops, will be grown to maximize overall mass and can be grown over a much wider area, giving more states the ability to nurture a homegrown biofuels industry. **Figure 2** shows how much biomass could be cultivated by 2025.²⁶ The biomass resources on this map include crop residues (e.g. corn leaves and stalks – “stover”), dedicated energy crops (switchgrass), forest residues, and mill wastes.

Assuming states convert all of their non-food biomass into biofuel and continue to produce corn ethanol at current levels, at least seven states could produce as much or more ethanol than their current demand for gasoline, on an energy equivalent basis (**Figure 6**). A further 11 states could meet at least half their current demand, and over half of all states could meet at least a quarter of their gasoline demand with cellulosic ethanol.

Cellulose can be converted into a product that can be upgraded to diesel, and of course, biodiesel substitutes for diesel. We did not examine the potential for diesel substitution. Gasoline accounts for about 80 percent of vehicle fuel use, so one can change the estimates used here accordingly to arrive at a percentage of total transportation fuel capable of being displaced with biofuels.



Marrying Electricity and Transportation

So far in this report, we have assumed that the electric sector and the transportation sector do not overlap. However, there is growing interest in electric hybrid and all-electric vehicles in the United States by major car companies and federal and state policy makers.

ILSR has elaborated the argument for electrified vehicles elsewhere.²⁷ In brief, electric vehicles are more efficient than gasoline powered vehicles. Electricity is a virtually oil free transportation fuel. And the battery storage of electrified vehicles can help overcome the Achilles heel of renewable electricity generation – intermittency.

For the foreseeable future, electric vehicles will largely be sold with a liquid fuel backup engine, but drivers with the capability of using electricity will try to maximize its use because the fuel cost of driving on electricity is about 3 cents per mile while the fuel cost of driving on gasoline is about 15 cents per mile.

Urban drivers will use electricity to power a much greater percentage of their vehicle's miles than would rural motorists. Overall, we might assume that with a 40 mile electric only driving range, electricity would account for 75 percent of all miles driven.

Implications

The potential is clear – most states can be energy independent by relying on their homegrown, renewable resources. At least twenty-one could satisfy 100 percent of their electricity needs from in-state renewable energy. At least seventeen could satisfy 50 percent of their gasoline demand with domestic biofuels. If electricity becomes a major transportation fuel, twenty-seven states could meet their entire demand for automobile fuel with renewable biofuel.

This report's estimates may be considered very conservative, since it does not consider non-rooftop solar or offshore wind. Moreover, it doesn't examine other potentially significant renewable electricity sources. The U.S. Geological Survey, for example, issued a recent report that found Alaska, Hawaii, and 11 western states could generate more electricity from in-state, high temperature geothermal than they use.²⁹ Low-temperature geothermal – a significant potential source of building climate control available everywhere, which could lead to a reduction in electricity use for air conditioning, for example – has scarcely been tapped. Micro-hydro can also contribute significant additional amounts of electricity.³⁰

In other words, by tapping into human ingenuity, states and many countries can approach energy self-sufficiency. As noted in the beginning of this report, states have been the driving force behind renewable energy developments, largely because they correctly view these as economic development initiatives. In the next 20 years, the United

The widespread introduction of electrified vehicles would affect this report's conclusions regarding electricity and transportation fuels in two respects.

First, the amount of electricity needed by each state would rise by 10-25 percent, but this would not significantly change our maps.²⁸ As noted above, state capacity for electricity self-reliance is widespread, and the built-in underestimates mean that the increased need for electricity is likely accounted for by undercounting native resources.

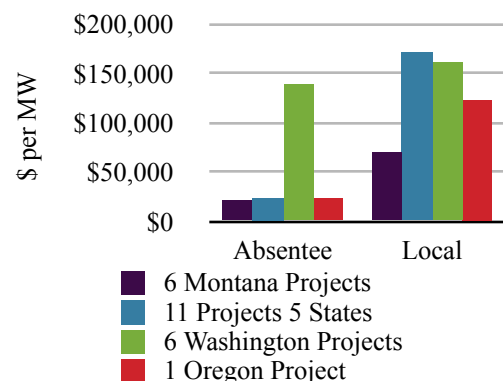
Second, since the backup engine will power only 25 percent or so of the vehicle's driving, the amount of biomass and biofuel needed drops dramatically, leading to a significant redrawing of the state-by-state map.

Figure 7 shows the redrawn map of state biofuel production potential, based on the full adoption of plug-in hybrid vehicles and 75 percent of car miles powered by electricity. Twenty-seven states could now be self-reliant in vehicle fuel, producing enough biomass-derived biofuel to supply a fleet of plug-in hybrid vehicles.

States may invest up to \$1 trillion in new renewable energy projects. To date, the federal government is providing incentives that favor large scale and centralized renewable energy projects and that demand long distance transportation of the energy product. But in most cases, the implementation of these projects will be dependent on state acquiescence.

As the data in this report suggests, states would do well to look inward for their energy security. This strategy can yield profound economic and social benefits. Widely dispersed energy production can be the basis for a resilient energy system where a branch falling on an electric line in

Figure 8 – Economic Impact of Absentee and Local Ownership of Wind



Ohio does not result in a 12-state blackout as happened in 2003, and where Georgia motorists do not have to wait for hours in line to get gasoline because a hurricane in the Gulf of Mexico disrupted a major oil pipeline.

The principle of decentralization that argues for states to pursue a policy of domestic energy self-reliance also applies to in-state energy policy. Large states should look to distribute energy production facilities as widely as possible.

Some might argue that bigger is better within a state. Previous reports by ILSR have examined the economies of scale of renewable energy production and found that they are modest and largely or totally disappear when one takes into account the cost of transporting the energy product long distances to the final customer.³¹

Renewable energy should be used as close as possible to where it is generated. Small scale, distributed energy facilities also lend themselves to local ownership. As other reports by ILSR have concluded, the economic benefit to a community and a state is much higher when there is local ownership than when facilities are owned by absentees (**Figure 8**).³²

Local ownership has another benefit. It confers a greater sense of responsibility and self-reliance on the project

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Page 4: Ascension Technology, Inc., NREL PIX

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owners than a similar project where local residents are just observers.³³

Looking inward for our energy solutions may require different federal and state energy policies. For example, currently much of the focus is on building more high voltage transmission lines to enable the export of renewable electricity from a handful of states. A better strategy, at least for the next decade, would be to focus on using existing transmission and subtransmission and distribution lines more efficiently so that additional distributed electricity can be built without the need for substantial investments in new lines.

Similarly, much focus currently is put on beefing up the railroad infrastructure to accommodate the increased production of ethanol from a handful of states. A better strategy would be to raise the percentage of biofuels vehicles are allowed to use, thereby creating in-state markets for those states currently in surplus in biofuels production, and to encourage the development of thousands of smaller biorefineries located in a majority of America's rural counties.

The data are clear. Most states have substantial renewable energy resources. Many states can be self-sufficient on renewable energy. All states could benefit from policies that encourage local ownership and control of renewable energy development.

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