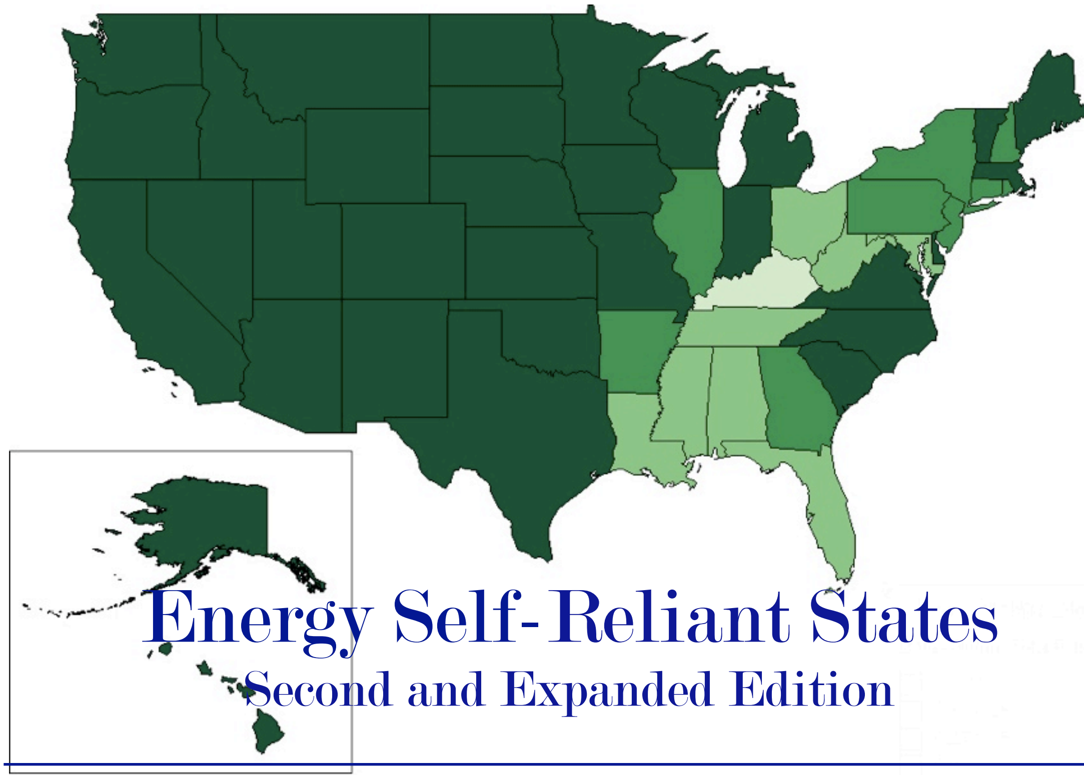

Energy Self-Reliant States

Second and Expanded Edition

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with new wind potential estimates from the National Renewable Energy Lab

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All shortcomings, of course, are the responsibility of the authors.

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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.

A program of ILSR, the New Rules Project helps policy makers to design rules as if community matters.

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Executive Summary

In 2009, the nation is involved in a vigorous and far reaching debate about the scale of future energy systems. As we shift from fossil fuels to renewable energy a new question looms before us. Will we embrace a centralized renewable energy future characterized by greater federal involvement in planning, or will we meet local and state needs with local and state-based strategies?

The ubiquitous nature of renewable energy argues for a decentralist energy approach. This ILSR report offers data that supports that argument. *Energy Self-Reliant States* examines the renewable electricity potential for each state. The estimates do not represent the technical potential but rather the commercial potential.

The conclusion is both surprising and welcome. All 36 states with either renewable energy goals or renewable energy mandates could meet them by relying on in-state renewable fuels. Sixty-four percent could be self-sufficient in electricity from in-state renewables; another 14 percent could generate 75 percent of their electricity from homegrown fuels.

Indeed, the nation may be able to achieve a significant degree of energy independence by harnessing the most decentralized of all renewable resources: solar energy. More than 40 states plus the District of Columbia could generate 25 percent of their electricity just with rooftop PV.

In fact, these data may be conservative. The report does not, for example, estimate the potential for ground photovoltaic arrays – although it does estimate the amount of land needed in each state to be self-sufficient relying on solar – even though common sense suggests that this should dwarf the rooftop potential.

Even as FERC and Congress and environmental groups, spurred by independent renewable power producers (some of the biggest of whom are subsidiaries of regulated utilities) rush to pre-empt state authority and accelerate the construction of a new $100-200 billion interregional transmission network, the case for state-focused planning has never been stronger.

For it is at the state, not the federal level, that comprehensive, least cost energy planning is used. It is at the state – not the federal or multi-state regional level – that efficiency, demand reduction, distributed generation and other commercially available strategies are often evaluated together.

It is at the local level that new technologies like smart grids, electric vehicles, distributed storage, and rooftop solar will have their major impact. The integration of millions of electric vehicles into the grid, for example, will change the context for energy planning by creating, for the first time, abundant storage for electricity.

It is at the state and local level that the most important new energy developments are taking place. Efficiency Vermont has empirically proven that an aggressive electric conservation program can reduce current consumption even with economic and population growth. Cities like Berkeley already are mapping their rooftop solar potential, installing charging stations for electric vehicles, and directly financing efficiency and renewable energy in households and businesses.

Perhaps the most important reason to make states the principal actors in energy planning is that their collective economic self-interest is consistent with the national interest Every state could create thousands of new jobs and hundreds of millions, perhaps billions, of dollars in economic development, through a vigorous strategy of energy efficiency and renewable energy.

Those promoting a new inter-regional transmission network argue that even if renewable energy is to be found everywhere, states with more reliable and higher speed winds or with more abundant sunshine can generate electricity cheaper.

That is undeniable. Nevada can produce solar electricity from photovoltaic panels at a price about 20 percent less than Iowa and about 35 percent less than Pennsylvania.[1] A typical North Dakota commercial wind turbine can produce electricity at a cost about 30 percent less than one in Ohio.

But in most cases these significant variations result in modest variations in the retail cost of energy when the cost of transporting the energy is taken into account.[2]

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 could result in an electricity cost to the customer that is about the same, or higher, than local generation with minimal transmission upgrades.

Thus centralized renewable energy might not be in the nation's economic interest, even when the cost-benefit analysis focuses solely on the impact on the retail price. But if we were to use a more expansive definition of economic interest, that is, the impact of renewable energy development on local and state jobs and economies, state-based energy self-reliance strategies can be clear economic winners.

States have clearly indicated their desire to harness renewable energy within their borders. For example, Ohio requires half of its renewable energy mandate to be met with in-state production. Colorado and Missouri each have a 1.25 multiplier for in-state resources used to meet their renewable energy requirements. Minnesota's Community-Based Energy Development statute encourages more locally owned wind power. Washington state offers solar incentive payments based on the portion of the panels made in the state, as well as reserving incentives for community solar.[3]

The data in this report argue that a new extra high voltage inter-regional transmission network may not be needed to improve network reliability, relieve congestion and expand renewable energy. The focus should be on upgrading the transmission, subtransmission and distribution systems inside states.

This report reveals that many states have sufficient renewable energy to generate 100 percent of their electricity. Clearly this is a theoretical statement in the sense that it is very long term and to achieve high penetration rates of variable renewable energy will require significant developments in storage technology as well as significant investments in upgrading distribution and transmission networks to allow for massive amounts of dispersed generation.

Yet even if there is much to do before very high proportions of our electricity system can be generated by renewable energy, these data do suggest that for the foreseeable future states can and should harness homegrown renewable fuels to meet in-state demand. No state has yet exceeded 10 percent renewable electricity (excluding large scale hydro) and as this report shows, all states with renewable energy mandates, no matter how high, could satisfy them by relying solely on in-state energy sources.

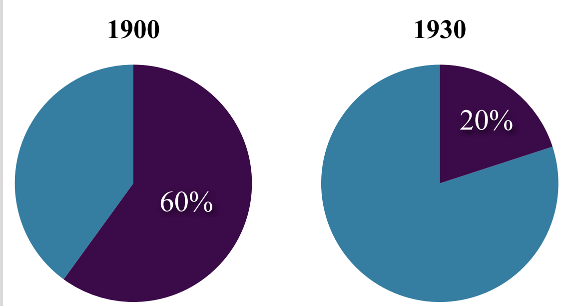
The power of states to control their renewable energy future hangs in the balance. Others have documented how states have used their authority to improve the prospects for renewable energy, from policies favoring domestic generation to smart grids and conservation programs. This report provides compelling evidence that if states retain their authority, energy self-reliance is within their grasp.

A (Very) Brief History of the U.S. Electricity System

To understand where we are and the choices before us, we need to know where we've been and how we got here. The battle over inter-regional transmission lines is the culmination of dramatic changes in the electricity system that began in the 1970s. To understand these changes, and the current debate, we must go back a little more than a century to the beginnings of the electricity era. In the beginning, before there were giant utilities, state and federal regulatory agencies and regional transmission lines, companies didn't sell electricity.[4] They sold power plants. In the spring of 1883, the Edison Electric Illuminating Company had 334 operating generators in cotton mills, grain elevators, manufacturing plants, newspapers and theaters. When central power plants did emerge, they were neighborhood affairs. Edison's Pearl Street Station in lower Manhattan served 59 customers with a 72 kilowatt demand.

But the economies of scale of fossil fueled power plants and larger grid systems became increasingly evident. Bigger plants operating at higher pressures and temperatures could produce more kilowatt-hours (kWh) per unit of fuel burned. The more customers connected to a grid, the fewer power plants needed to reliably provide them with electricity on demand. Metropolitan and then regional utilities arose.

Figure 1 – The Percent of Electricity Generated On-Site Fell Quickly in the Early 20th Century



In 1900, 60 percent of electricity was generated on-site, but as early as 1908 one observer noted that "although isolated plants are still numerous in Chicago, they were never so hard pressed by central service as now." The die was cast. From 1919 to 1927 some 52,000 small steam engines and another 18,000 internal combustion engines were scrapped. By 1930 only 20 percent of electricity was generated on-site.

In the first quarter of the 20th century the political question was who would own and control the new utilities. Eventually a compromise was reached. State regulatory commissions would oversee vertically integrated monopolies that owned the power plant, the transmission and distribution lines and sold directly to the customer. (Municipally owned, self-regulating utilities also proliferated, and in the 1930s, spurred on by federal intervention, rural electric cooperatives also spread).

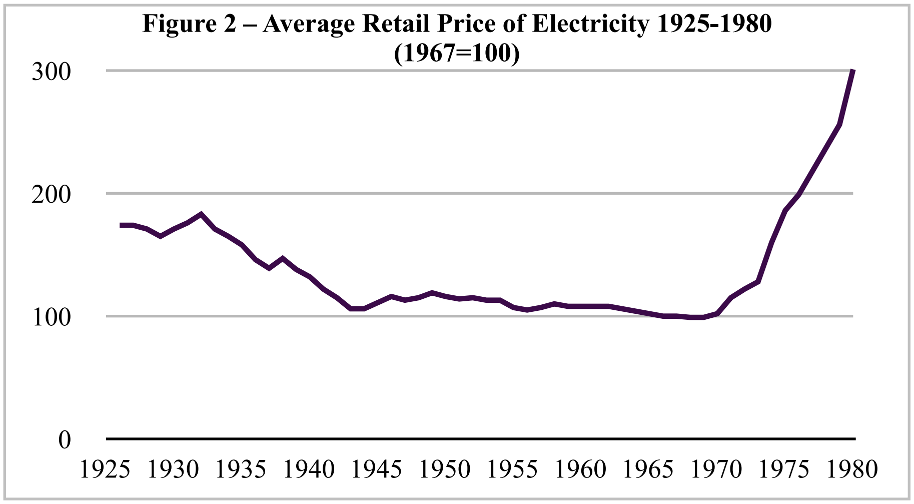
State regulatory agencies guaranteed utilities a profit sufficiently high to attract investors, but no higher. In return utilities had a legal obligation to serve all customers and to maintain a high level of reliability and performance.

It was a tidy system that worked reasonably well for about 70 years. Regulatory commissioners had an easy job: deciding how fast rates would drop. By 1965, the average price of electricity had declined to 1.5 cents per kWh, down from more than 30 cents in 1910.

The System Staggers

In the 1970s, the context for energy planning changed dramatically. The ten fold increase in the price of oil destabilized the economy, generating high inflation and even higher borrowing costs. The price of new power plants rose sharply. For the first time in two generations, the price of electricity rose.

The bigger-is-better principle that began in the early 1900s reached its peak in the 1970s when utilities, urged on by the federal government aggressively embraced huge nuclear power installations that individually could serve as many as 4 million households. By 1980 some utilities were investing more than their stockholders' equity in new power plants. They were, in short, betting the farm that demand would continue to double every ten years.



They lost the bet.

Demand leveled off and, in the early 1980s, fell for the first time since the Depression. Surplus electrical generating capacity reached 39 percent. Several utilities declared bankruptcy. A 1984 cover story by Business Week asked, "Are Utilities Obsolete?"

The economic and financial instability of the late 1970s and early 1980s spurred actions at both the state and federal level. At the state level, regulatory agencies shook off their passivity and embarked on a more aggressive, hands-on approach. From 1985 to 1991 regulatory commissions disallowed $14 billion in nuclear investments, blaming utility management for making poor decisions and forcing shareholders to bear the loss.

Prodded by environmental activists, state regulatory commissions began to develop new decision making rules and tools. A utility that wanted to build a new power plant or a new transmission line had first to prove a need. And it had to evaluate whether alternatives like improved efficiency or smaller power plants located nearer the final customer could meet that need more effectively. By the early 1990s, a number of states began to account for the environmental damage of power plants in this new least-cost planning process. By the mid 1990s, some states were giving a priority to renewable energy. In 1993, California issued the first request for bids restricted only to clean power. The response was overwhelming. Other states began to enact renewable energy mandates.

By the mid 1990s, the economy and the price of energy had stabilized. The country had soaked up the electricity surplus of the early 1980s. States had put in place a more sophisticated and proactive planning process.

But the instability of the 1970s had also led to aggressive federal actions that initially reinforced state regulatory responses but eventually threatened to overwhelm them.

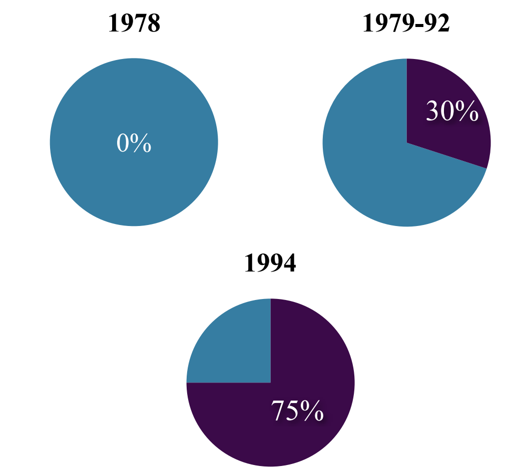
Congress responded to the twin oil shocks of the 1970s by encouraging more efficient electricity generation and renewable electricity. To achieve this goal Congress abolished the 60 year old monopoly utilities had over electricity generation. The 1978 Public Utilities Regulatory Policy Act (PURPA) prohibited utilities from obstructing onsite power generation and required them to purchase power from independent power producers (IPPs) if the producer used renewable energy or captured a significant portion of the waste heat generated by a fossil fueled power plant. Interestingly, PURPA in its original form encouraged dispersed and decentralized electricity by applying only to relatively small power plants (under 80 MW).

By 1982, over 500 applications had been submitted to the Federal Energy Regulatory Commission (FERC) for qualifying PURPA status. The independent power industry was born.

Then, coincidentally but providentially for the independent power industry, the price of natural gas plummeted, making their new high efficiency natural gas plants increasingly competitive. In reaction to the multi-billion dollar cost overruns at nuclear plants, state regulators began to require utilities to conduct competitive bidding for new capacity. At the same time, the increased scrutiny of state regulatory agencies of utility investments introduced an element of uncertainty about future profits.

These two rule changes encouraged utilities to reduce their own power plant investments and instead purchase power from IPPs. A growing number of IPPs were subsidiaries or joint partners of utilities.

Figure 3 – The Percent of New Capacity from Independent Power Producers Rose Dramatically



From 1979 to 1992, independent producers built 30 percent of all new electrical capacity.

The independent power industry began to assert its new political clout in a way that increasingly changed the very structure and mission of the US electrical system. The original PURPA enabled IPPs under a certain size to sell electricity to their nearby utility.

IPPs wanted a much larger market for their product. In 1992, after intensive lobbying led by Enron, the leader of the pack of new IPPs, Congress added a new category of non-utility generator, Electric Wholesale Generator, that enabled larger producers to qualify for federal regulatory benefits. Congress also deregulated the wholesale electricity market.

By 1994, IPPs accounted for almost three quarters of new capacity.

With the deregulation of the wholesale electricity market, Congress gave independent producers access to the nation's high voltage transmission lines on an equal basis with existing utilities. This created a problem because the transmission system was built to transmit electricity from a utility-owned power plant to a utility customer usually within the same area. Suddenly Congress made the transmission system a common carrier. Then and now, advocates of the transmission system as a common carrier use the metaphor of the interstate highway system. It is a misleading and inaccurate analogy.

Vehicles travel directly from point A to point B. Electricity travels along the path of least resistance. The owner of a power plant in Montana might sell power to the owner of an office building in Seattle, but the electricity generated in Montana may travel to Los Angeles. A power transfer from Indiana to New Jersey could produce electricity flows over the lines of more than 20 different utilities with less than half of the transferred power traveling a relatively direct route.

Thus, unlike managers of an interstate highway system, the managers of a national transmission system can only know how much capacity they may have on any one of their "highways" when they know how much electricity is flowing on all of their roads. This imposed real costs on utilities. In the late 1990s, the Philadelphia Electricity Company (PECO) warned FERC, "What used to be at times a severe, localized problem for certain transmission providers – parallel path flows – has now been turned into a severe, regionalized problem, which in the worst of times, may impact almost half the United States."

The challenge of tracking these loop flows of electricity was compounded by the reluctance of private developers to disclose plans for future power plants, and the impact of this reluctance itself was multiplied by the rise of a new entity in the electricity market: electricity marketers. In 1986, FERC approved the nation's first power marketer. By early 1997 there were 284; by October 2000, over 450.

Traditionally, the relationship between buyers and sellers of electricity was almost familial. The new electricity market would be far less collegial. "Watching electric companies deal with one another used to be about as exciting as watching cows graze," Allan Sloan of the Washington Post observed in the late 1990s. "The herd members were ultra-polite. They traded power back and forth, but no one gouged, because the guy you gouged today might be in a position to gouge you tomorrow. But since deregulation began in the electric biz a few years ago, a whole new bestiary has emerged. Bye bye cows. Hello, independent electricity traders; sharp-toothed velociraptors willing to bite, slash and maim to make a buck."

The old system of cost-based rates and collegial trading and all-the-eggs-in-one-basket state energy planning was replaced with market-based rates and cut throat trading. The cost of service based system was established in part because electricity is not like other commodities. It cannot be stored. There are no alternatives. It is often used in a situation where price doesn't change behavior (in economic parlance, the demand for electricity is very inelastic).

Thus there is significant potential for manipulation leading to excessive prices and profits. This potential was starkly demonstrated in the summer of 2000 in California which had along with almost half the states deregulated its retail as well as wholesale market, allowing IPPs to sell directly to the final customer. Spot prices soared to 15 times their historical average. Californians experienced rolling blackouts. The state incurred billion of dollars of debt that in 2009 continues to haunt that state.

Transmission is the Solution: But What Was the Question?

The electricity system stumbled into the 21st century. The newly deregulated wholesale and retail markets were causing substantial problems but policymakers lacked the will or perhaps the inclination to move back toward a cost-based, coherent regulatory system. Increasingly, utilities and independent power producers and FERC saw expanded transmission capacity as the solution. IPPs lobbied for more transmission capacity to increase their sales to distant markets while utilities saw it as a way to minimize the problem of loop flows and improve reliability.

But to get the new interregional transmission lines would require federal intervention. The Energy Policy Act of 2005 marked a major step forward in the federalization of electricity planning. For the first time, Congress enabled the federal government to approve the siting and location of new electric transmission projects. The new law required the Department of Energy (DOE) to designate selected geographic areas as "National Interest Electric Transmission Corridors." Applicants for electricity transmission projects proposed within these "corridors" could request FERC to exercise federal siting authority if state regulators had not acted within 12 months.

FERC asserted its right to impose a transmission line even if a state rejected the application with a year. In February 2009 a federal appeals court denied FERC's interpretation. The case is on appeal and Congress is debating whether to explicitly grant FERC that authority over all or parts of the country.

This marked a profound change from traditional electricity planning. The Department of Energy could now issue the equivalent of the "certificate of need" that, at the state level, would set in motion a serious examination of alternatives. The federal government, and the new regional transmission operators (RTOs) insisted they were not required to and would not examine alternatives.

In 2007, when the DOE identified an area stretching from Albany, NY to northern Virginia, including all of New Jersey and parts of Ohio and West Virginia, as a "critical congestion area" the affected states appealed. They argued that DOE was required to study non-transmission means to reduce congestion.

DOE demurred. "The Department believes that expanding its role to include analyzing and making findings on competing remedies for congestion could supplant, duplicate or conflict with the traditional roles of States and other entities."

In other words, **DOE declared it has the right to supplant the traditional roles of states by imposing a high voltage transmission line but does not have the right nor is it obligated to evaluate whether that transmission line is needed because such an evaluation would invade the traditional role of states!**

Renewables: A New and Still Inadequate Rationale for Transmission Lines

Recently a new rationale for extra high voltage transmission lines has emerged. For 15 years the driving force behind the initiative for new lines has been independent owners of fossil fueled power plants. But in the last two years a new national extra high voltage transmission network is increasingly justified as necessary to expand our production of renewable electricity.

The result is that by 2008, an unprecedented coalition had emerged to lobby for these lines. The coalition ranged from the liberal Center for American Progress to the conservative Manhattan Institute, from arch-Republicans like T. Boone Pickens to Democrats like Al Gore, from the Natural Resources Defense Council to the Coal Association.

Although the justification has changed, many of the routes of proposed transmission lines have not. One reason is that by a geological and meteorological accident, the states with the most wind or the most solar energy also are home to significant coal deposits.

Critics note that because of the nature of electricity, new lines from coal country may well primarily carry coal-fired electricity even if the line reaches into an area with wind farms. They also point out that even when developers justify new transmission as a way to move renewable energy they are unwilling to guarantee that a majority of the electricity these lines carry will be renewable and to date neither FERC nor state commissions have conditioned approval of a new transmission line on its serving primarily as a renewable electricity carrier.

The introduction of renewables into the transmission planning debate changes the nature of the debate in a number of ways Transmission lines have traditionally been justified as ways to lower the cost of energy, reduce congestion and increase reliability. But renewables won't lower energy prices, unless a stiff carbon tax is imposed that raises the price of coal-fired electricity dramatically, a very unlikely political development, at least in the short term. And if such a carbon fee were put in place, it might lead to the closure of older coal fired power plants and the introduction of more dispersed natural gas plants, freeing up transmission capacity for renewables. Moreover the variability of solar and wind energy makes it hard to justify them as ways to increase electric grid reliability.

Congress has given FERC an array of new tools to accelerate interstate and interregional transmission line construction. Mentioned above is the ability to pre-empt state decision making. Another is to give transmission companies a significantly higher rate of return than they would otherwise have received under a regulated system. A third is the ability to impose the costs of transmission lines on all customers in the states crossed by the transmission lines.

This last proposal has raised considerable opposition in the states. Traditionally those who pay for new transmission lines are those who will benefit from them. But now those who propose transmission lines aren't seriously arguing that the communities across whose territory these lines cross will directly economically benefit from them. Instead the benefits are seen as more psychological: pride in knowing the nation is generating significant amounts of electricity from low carbon and renewable resources.

However, this argument runs up against the desire of many importing states to first harness their homegrown renewable energy before depending on imports. The cost allocation issue led the Governors of ten East Coast states, in May 2009, to write to senior members of Congress to protest that requiring their residents and businesses to pay billions of dollars for new transmission lines that would import electricity from the upper Midwest into their region “could jeopardize our states’ efforts to develop wind resources….”. They added, “it is well accepted that local generation is more responsive and effective in solving reliability issues than long distance energy inputs.”

In an Op Ed in the New York Times, Ian Bowles, Massachusetts Secretary of Energy and Environmental Affairs explained, “lawmakers should resist calls to add an extensive and costly new transmission system that would carry electricity from remote areas like Texas, the Great Plains and Eastern Canada to places with high energy demands like Boston, Chicago and New York… Renewable energy resources are found all across the country; they don’t need to be harnessed from just one place.”

The desire of North Dakota and Oklahoma to export their electricity is understandable, but should Illinois have to pay for transmission lines that would enable them to buy imported renewable electricity when they can generate all their electricity from in-state wind and solar? Or to reverse the equation, should North Dakotans pay for a line that transmits offshore wind energy from Delaware?

We don’t need to pit one state against another as we pursue a sustainable energy future. As this report shows, there is more than enough renewable energy at competitive prices to go around. For the foreseeable future we should focus on sharing the economic benefits of renewable energy as widely as possible. State and local energy independence is the path we should pursue.

A Note on Methodology

The data in this report show that many states have sufficient renewable energy to generate 100 percent of their electricity. As noted above, no state has yet exceeded 10 percent renewable electricity (excluding large scale hydro). To achieve the levels required in current renewable energy mandates (e.g. 25 percent) may require a major upgrading of in-state distribution and transmission networks. Very high penetration rates will require new developments in electricity storage.

Nevertheless, it is important to note that the estimates for renewable energy production in this report do not represent their technical potential, which would be much greater, but rather their commercial potential. Thus, for wind we estimate the production from wind speeds currently harnessed for commercial generation. For geothermal we use only those sources over a high temperature level. The data also takes into account environmental considerations. As a result, for wind and small scale hydro we use estimates that exclude many sites for environmental purposes.

A detailed discussion of the methodology used to develop the estimates for each resource (each map) can be found in the **Appendix**.

The maps show the percentage of 2007 electricity consumption that could be met by renewable energy. We have not tried to forecast future electricity demand. Forecasts have been reduced dramatically in the last four years and studies indicate that we could have a flat or even negative growth if we adopted aggressive efficiency measures.

A wild card in estimating future electricity demand is the electrification of our transportation system. The electrification goal is embraced by virtually all policy makers. If 75 percent of our gasoline were replaced by electricity it would increase electricity consumption by about 20 percent. On the other hand, it would also establish a system of widely distributed and abundant storage that would change the very underpinnings and assumptions of an electricity system designed without storage in mind. Thus electric vehicles will both increase electricity consumption and make it possible for variable renewable electricity sources to comprise a much higher percentage of our overall electricity.

Some renewable fuels, like sunlight and wind, are variable. Thus the estimates, especially for wind, assume a significant level of storage or on-demand distributed generation. However, some renewable resources like geothermal are not variable and could be used for baseload generation.

The reader will note that biomass is not included in the renewable energy sources evaluated. A word of explanation is in order. Unlike sunlight and wind, which can be harnessed only to produce some form of energy (mechanical, electrical, thermal), biomass has many uses. The highest use is for nutrition, then materials and chemicals, and finally energy. But in the energy hierarchy, electricity generation is at the bottom. Biomass can be an efficient and significant provider of heat, and in the process electricity might be generated. But this report does not examine sources of heat, and the amount of electricity generated as a byproduct of heat production would be modest.

Renewable Electricity Potential

Each of the following sections examine the potential electricity that could be generated by each state from a single renewable resource. The last section combines the data into a single map.

Onshore Wind Power

Credit: Energy Northwest

ILSR's analysis reveals an impressive potential for electricity self-reliance from wind alone. As many as 22 states could match their entire electricity sales with onshore wind power based on updated National Renewal Energy Laboratory (NREL) figures; 28 could meet at least half (if sufficient storage were provided).[5] **Figure 4** shows the level of self-sufficiency of each state based on its wind potential and its 2007 electricity sales, from the original report.[6]

As we can see, much of the West and Midwest can be entirely self-sufficient by harnessing in-state wind power. The Southeast has the fewest commercially viable onshore wind resources. The next two figures illustrate the changes in wind potential shown in the new data.

Figure 4 - Potential State Electricity Self-Sufficiency Using Onshore Wind Power

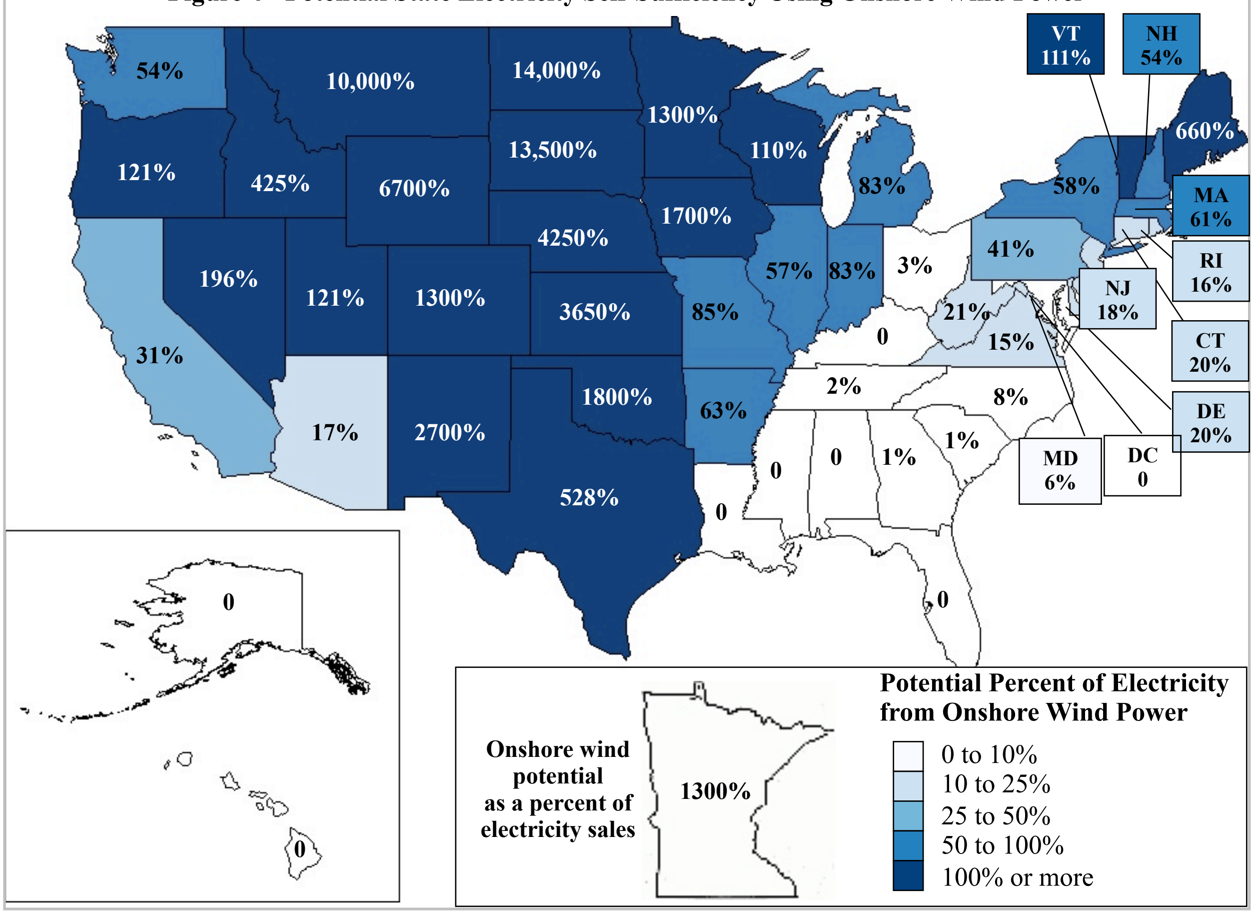


Figure 4a - Change in Potential State Electricity Self-Sufficiency Using Onshore Wind Power

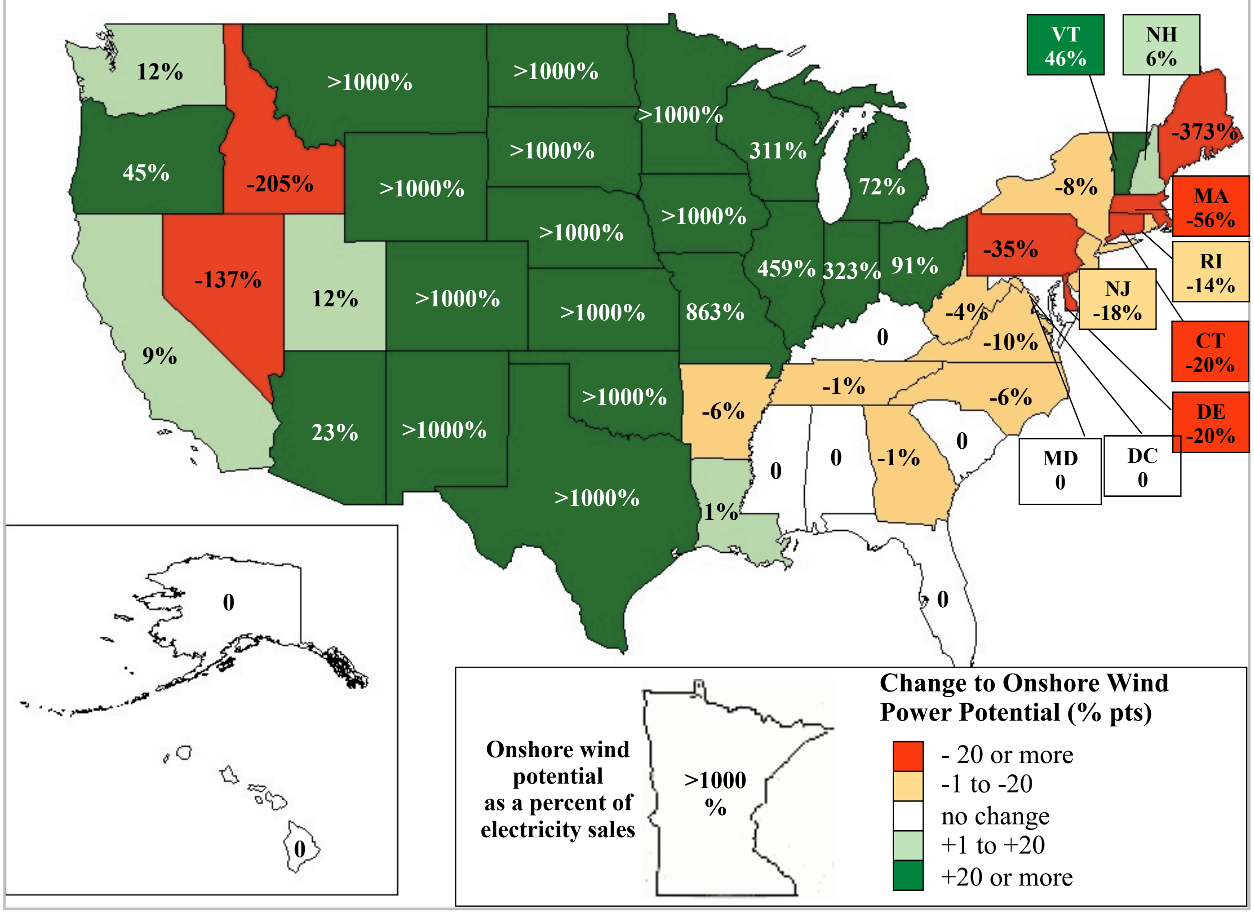
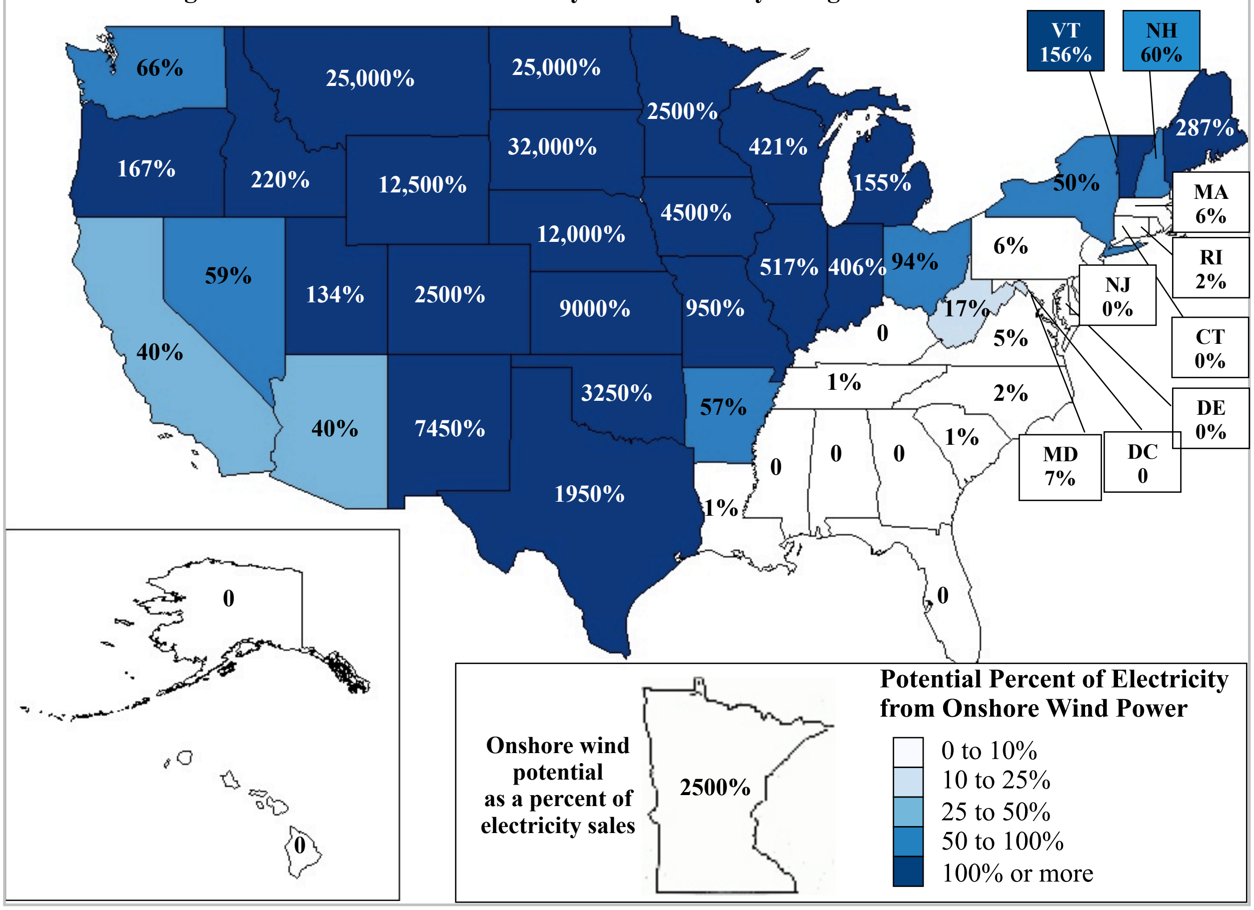


Figure 4a maps the change in wind potential from the old data to the new NREL data. The new data creates some big winners and losers, with the Midwest seeing a huge boost in estimated potential and the Eastern seaboard losing most of its estimated onshore potential. Idaho and Nevada are Western outliers, seeing a significant drop in their potential as a percent of their electricity consumption.

Figure 4b illustrates the new wind potential data released by NREL in early 2010. The impact is primarily felt along the Eastern Seaboard, where few states show any significant onshore wind potential. Outside the East, Nevada is the biggest loser as its wind potential drops from near 200% to around 60% of electricity sales.

Figure 4b - Potential State Electricity Self-Sufficiency Using Onshore Wind Power

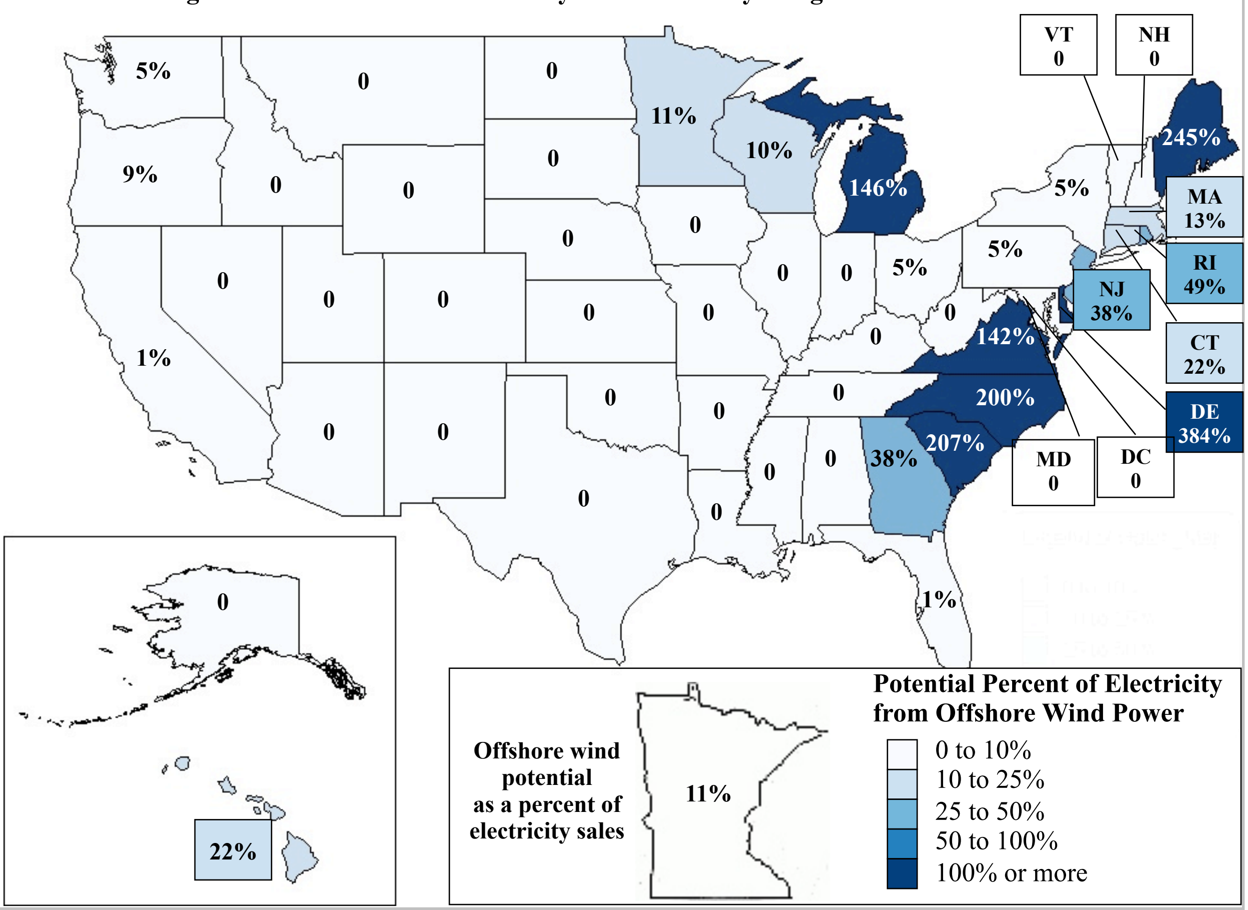


Offshore Wind Power

Figure 5 estimates offshore wind potential for states where reasonable data is available. In particular, there's a clear potential for offshore wind development along the Eastern Seaboard and in the Great Lakes.

Offshore wind may help states meet their renewable energy targets, but in the quantities required, it will also require substantial transmission investment. Offshore wind energy, as we discuss later in the report, will also be considerably more expensive than onshore wind energy.

Figure 5 - Potential State Electricity Self-Sufficiency using Offshore Wind Power



Solar Power

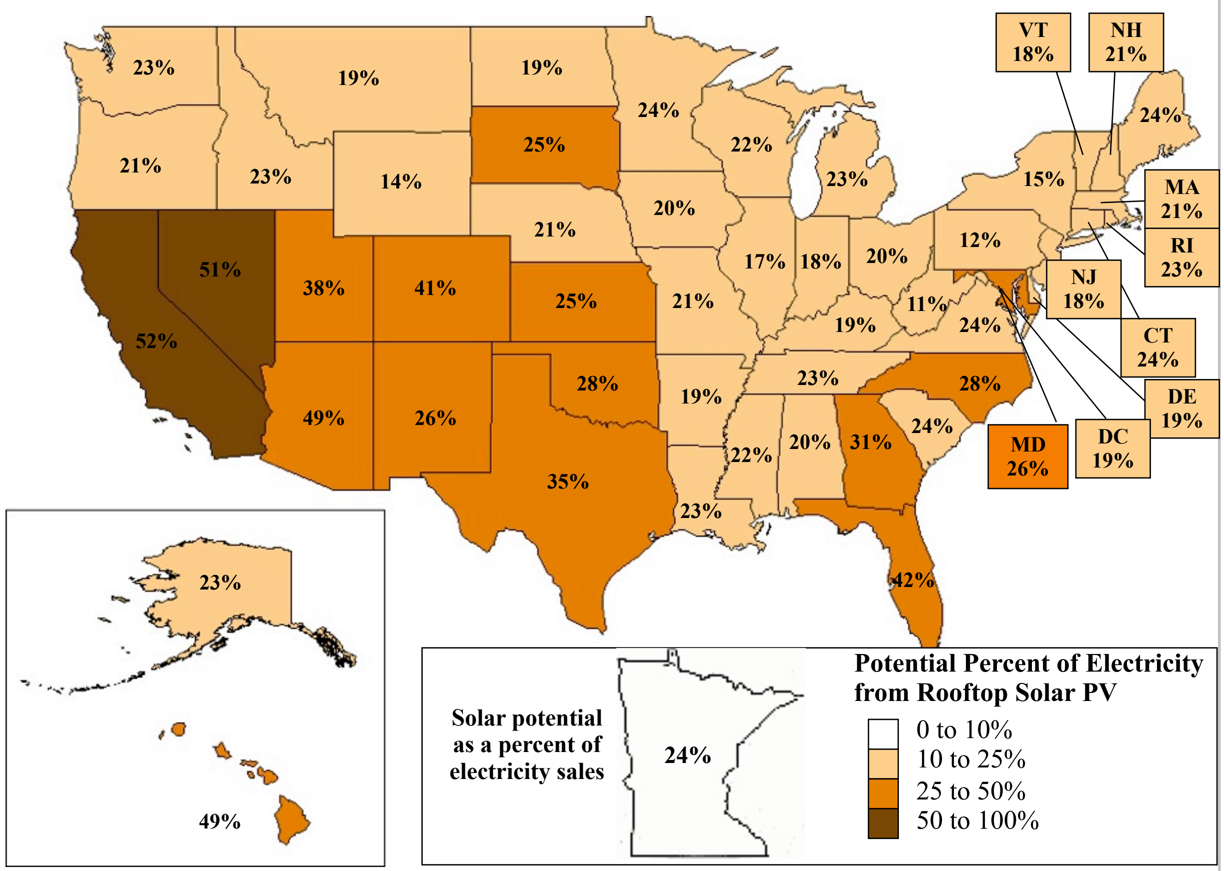
Unlike most other renewable energy resources, sunlight falls in significant quantities in every state. By simply relying on rooftop solar PV panels, many states could satisfy a substantial portion of their electricity needs. **Figure 6** illustrates the percent of each state's 2007 electricity sales that could be met by rooftop solar photovoltaics (PV).[7]

Credit: groSolar

Two states, California and Nevada, could generate at least half their annual electricity solely with rooftop solar (and sufficient electricity storage). Many states could generate around a quarter of their electricity from rooftop solar power.

As we would expect, the southern half of the US can generate more solar electricity, on average, than the northern tier. But it is interesting that Minnesota, Wisconsin and Michigan can generate as much as Louisiana, Alabama and Mississippi.

Figure 6 - Potential State Electricity Self-Sufficiency using Rooftop Solar PV



Since **Figure 6** only looks at rooftop solar it significantly understates the potential for solar self-sufficiency. For example, it does not include options such as parking lot canopies. The U.S. has as much as 949 square miles of parking lots, just counting non-residential, surface lots. If half of these are suitable for solar PV canopies, it could generate 6% of total U.S. electricity.[8]

Credit: Envision Solar

Including ground mounted PVs or concentrated solar power installations could multiply the level of generation many times over. The state of California's solar resource assessment found that while its rooftop potential was close to 38,000 megawatts (MW), its total PV potential was over 16,000,000 MW – 400 times greater.[9] The California estimate excluded a great deal of land for environmental and practical considerations.[10] Our map also excludes the vast potential for in-state concentrating solar power (CSP), such as parabolic trough or power tower generating plants. The California study found a technical potential of 1,000 gigawatts (GW) of concentrating solar power in California.

Highway right-of-way also represents another significant portion of land that could accept solar PV. On either side of 4 million miles of roads, the U.S. has approximately 60 million acres (90,000 square miles) of right of way.[11] If 10 percent the right of way could be used, over 2 million MW of roadside solar PV could provide close to 100 percent of the electricity consumption in the country. In California, solar PV on a quarter of the 230,000 acres of right of way could supply 27% of state consumption.

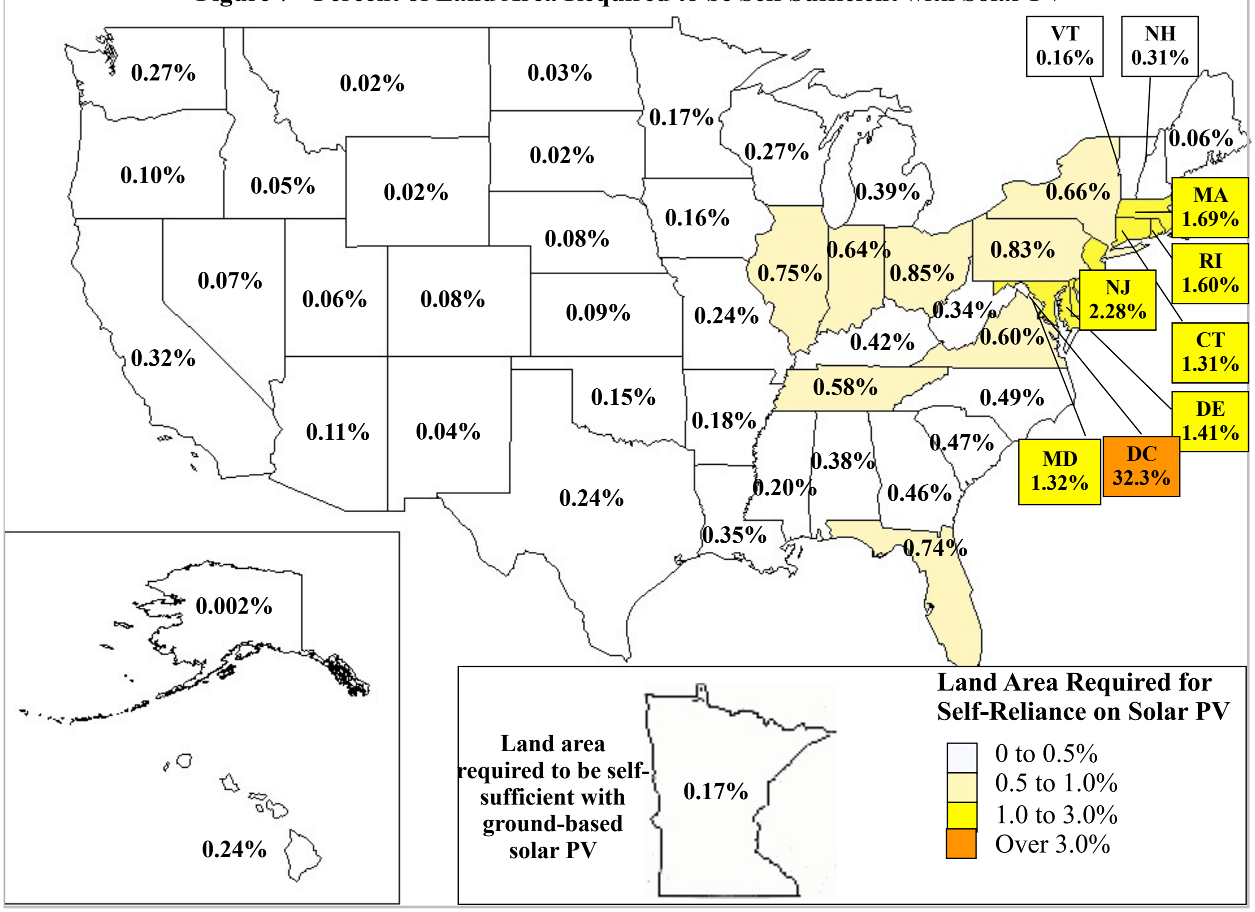
Another way to approach the issue of a state's solar energy capacity is to estimate the percentage of the state's land area needed to generate all of its electricity. Surprisingly, the number is very, very low.

Figure 7 estimates the percentage of each state's land area that would have to be covered with ground-mounted solar PV to achieve electricity self-sufficiency. (Rooftop potential was not included in this estimate except for the one place it makes a significant difference – DC).

Credit: Currin Corporation

In California, to achieve self-sufficiency solely from solar PV would require a land area equal to about half of Orange County. In New York state the area required is about three-quarters the size of New York City.

Figure 7 - Percent of Land Area Required to be Self Sufficient with Solar PV



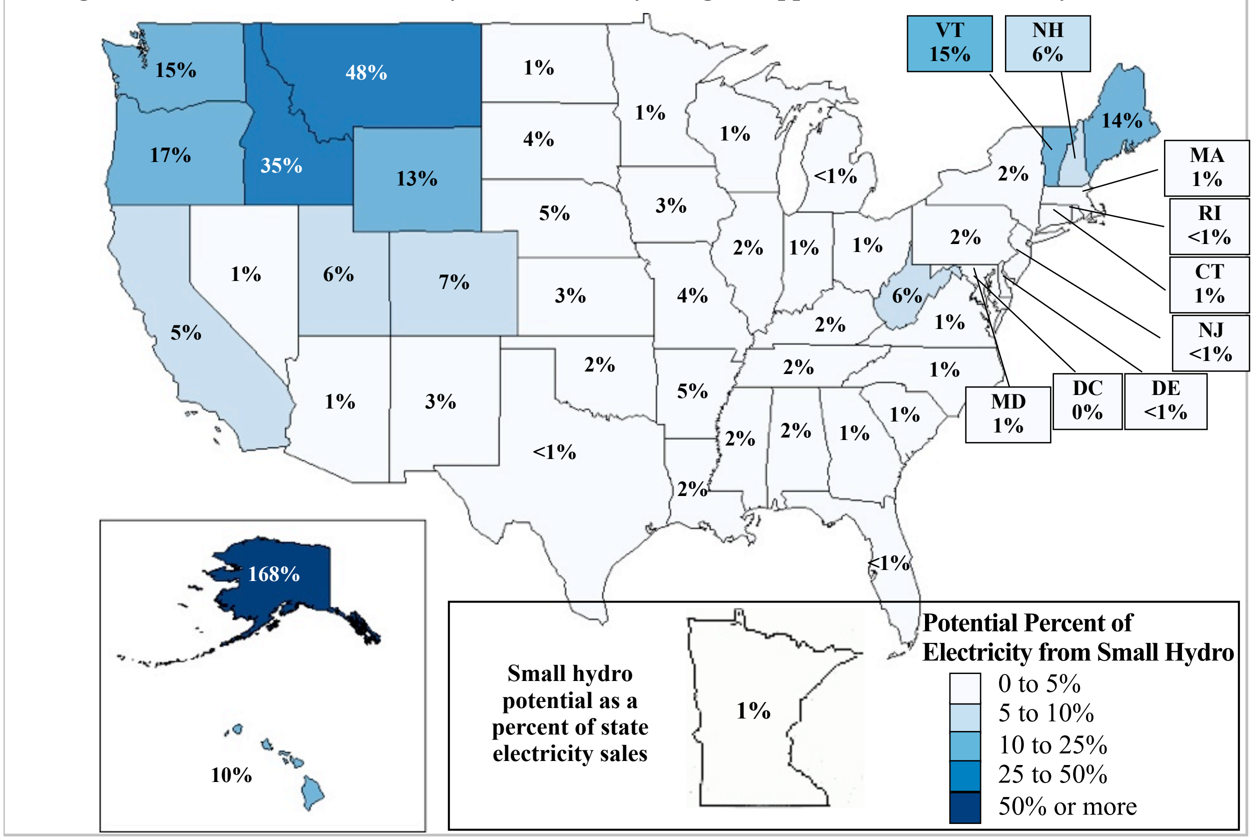
Small Hydro Power

Figure 8 estimates the untapped potential of small hydropower. As the map reveals, most states have few opportunities to tap additional small hydro, but there's a concentration in the Northwest and Northeast where substantial electricity potential is available.

The estimates include substantial environmental exclusions, discussed in greater detail in the **Appendix**.

Credit: Duane Hippe

Figure 8 - Potential State Electricity Self-Sufficiency using Untapped Small and Micro Hydro Power

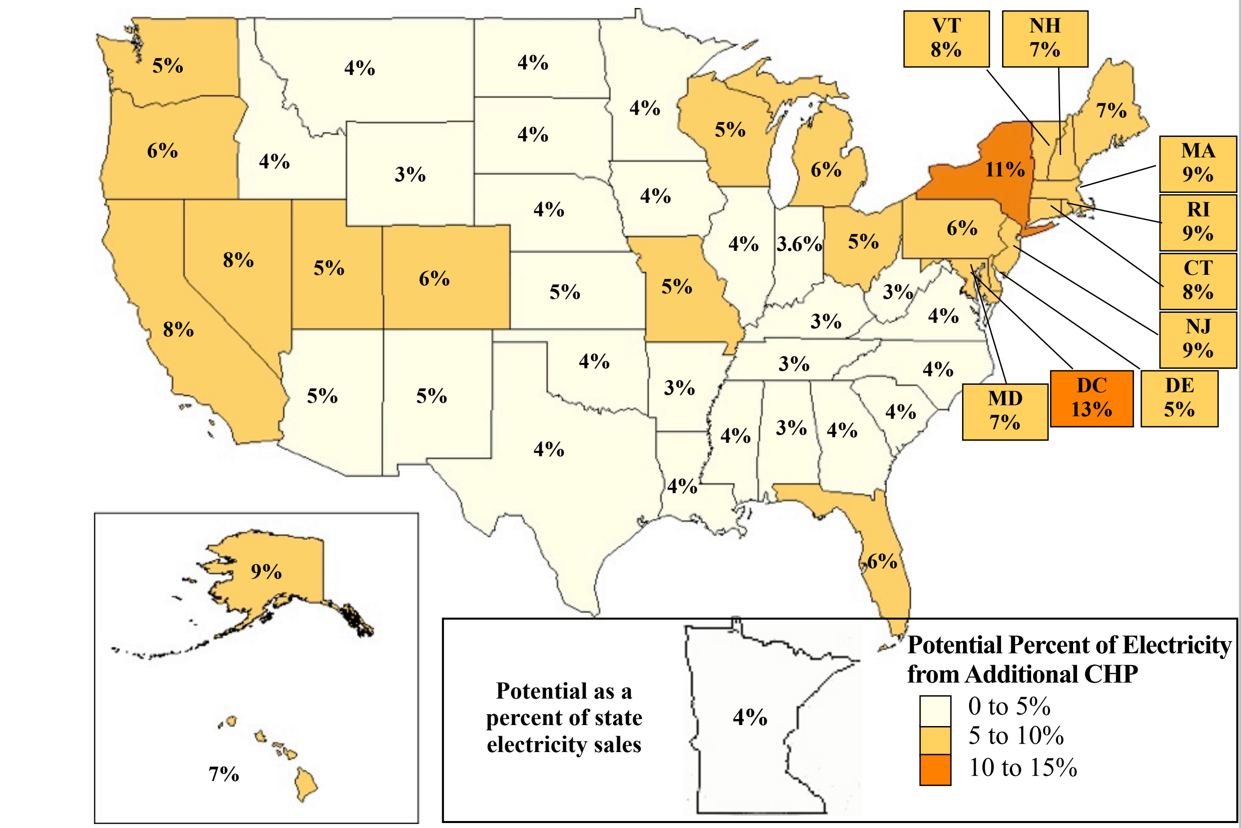


Combined Heat and Power

Combined-heat-and-power (CHP) systems harness waste heat to generate electricity. CHP systems can convert 60 percent or more of the renewable or fossil fuel into usable energy, electricity and heat.

Figure 9 shows the electricity generation potential of installing additional combined-heat-and-power systems across the United States. The overall percentage is modest and varies surprisingly little from state to state. However, commercial building and industrial CHP are renewable energy investments that usually have the shortest payback of all renewable energy technologies.[12]

Figure 9 - Potential State Electricity Self-Sufficiency using Untapped Combined Heat and Power



Conventional Geothermal

Conventional geothermal uses steam heat close to the Earth's surface to generate electricity. Geothermal can provide round-the-clock energy for electricity and building heat.

Figure 10 shows the potential power generation from conventional geothermal sources. These are concentrated in the western third of the country and can generate significant quantities of electricity.[13] Nine states could produce at least 10 percent of their domestic electricity consumption from conventional geothermal. Nevada could satisfy 40 percent of its electricity needs.

One important aspect of geothermal is that it can be used as a baseload power plant with predictable and steady output year round.

Credit: Joel Renner

Figure 10 - Potential State Electricity Self-Sufficiency using Conventional Geothermal Power

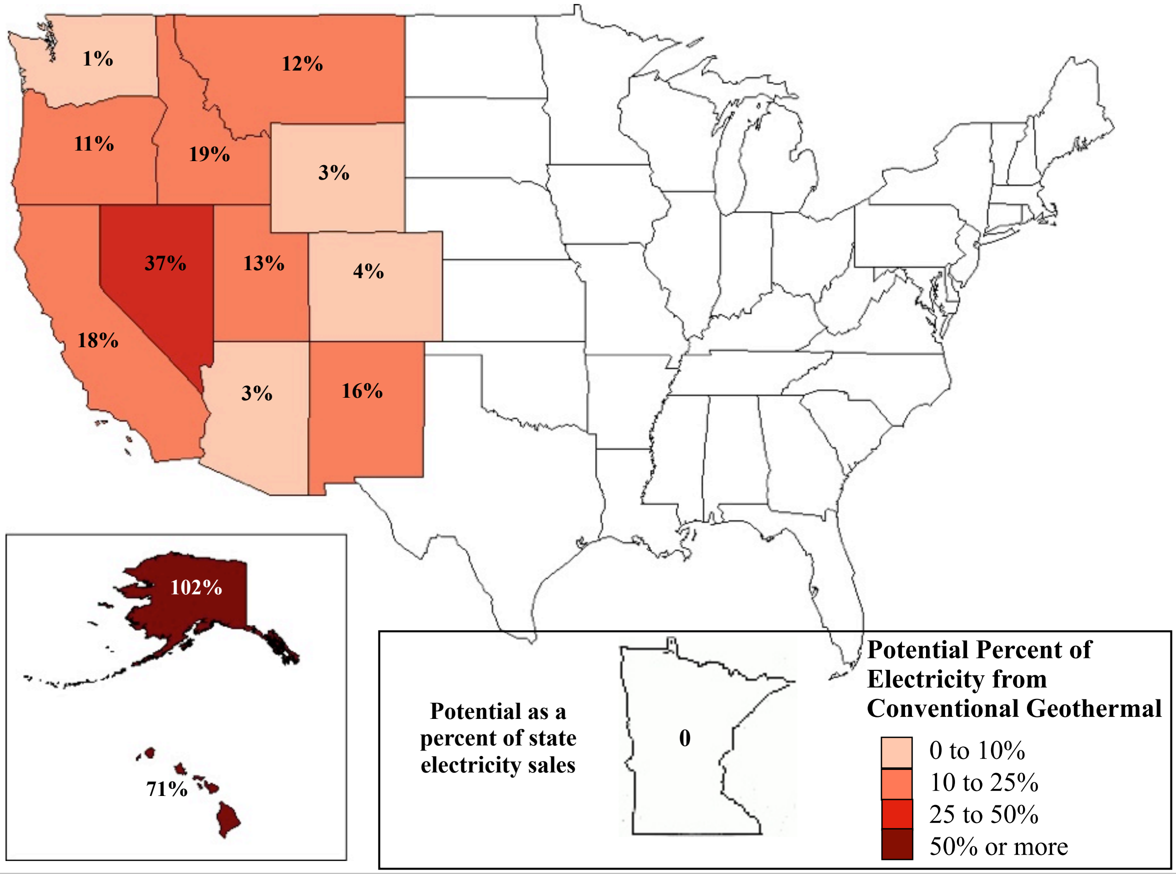
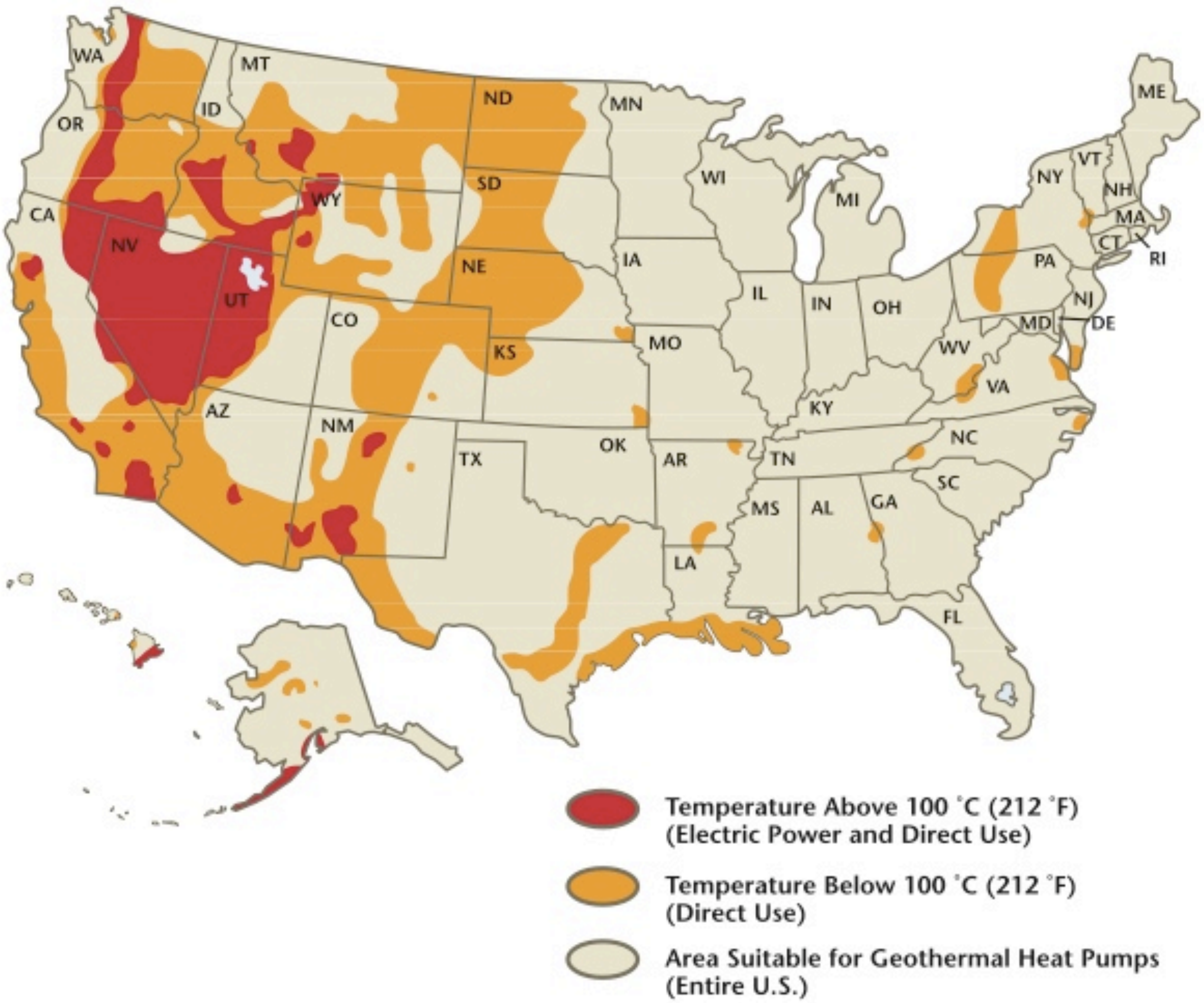


Figure 11 examines geothermal potential from another perspective. It shows the subsurface temperature levels in different parts of the country. Again, it shows an abundance of conventional geothermal resources in the Western states, and no high temperature resources east of New Mexico.[14]

Figure 11 – U.S. Geothermal Resource by Temperature (NREL)



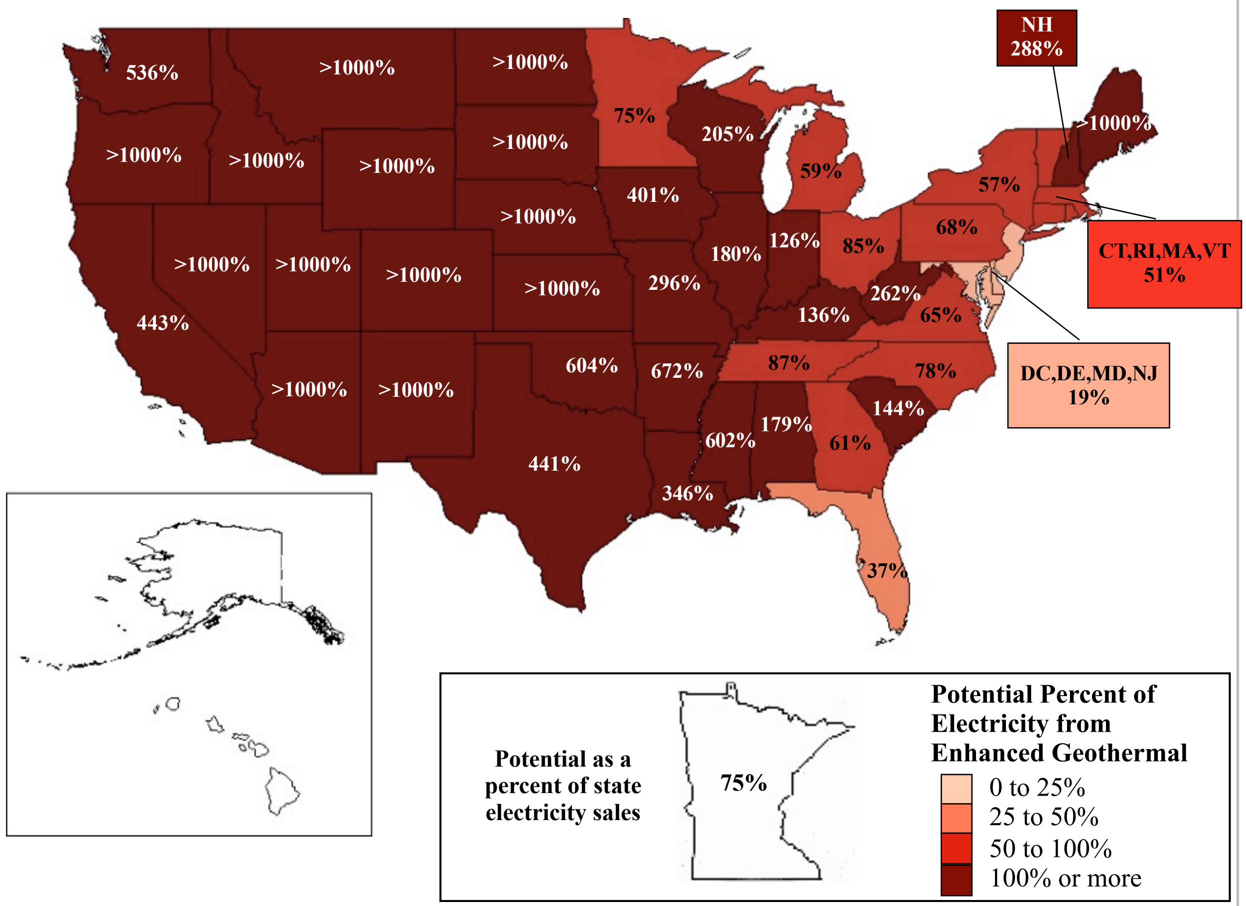
This map reveals another important fact. The entire country is suitable for installing geothermal heat pumps. Indeed, the geothermal heat industry is expanding rapidly. In 2008 some 60,000 systems were installed. With the expansion of the renewable energy tax credit to geothermal, these systems have relatively short payback periods and can reduce household space conditioning energy consumption by 30-50 percent. Geothermal will modestly increase electricity consumption as it eliminates natural gas or oil use for heating but can reduce electricity consumption if it also generates cooling.

Because of its indirect impacts on electricity, we have not included low temperature geothermal in our analysis.

Enhanced Geothermal

Figure 12 examines the potential for states to produce electricity from enhanced geothermal resources. We offer this map for informational purposes only. We do not use this data in our combined map because enhanced geothermal is an immature renewable energy technology and is not yet commercially viable. Enhanced geothermal accesses hot rocks at a depth of 3-10 kilometers and injects water to produce steam. Hardly any enhanced geothermal power has been tapped to date, but Massachusetts Institute of Technology (MIT) researchers believe at least 100 GW of enhanced geothermal could be built by 2050.[15]

Figure 12 - Potential State Electricity Self-Sufficiency using Enhanced Geothermal Power



Combined Renewable Resources

Figure 13a illustrates the portion of state electricity that can be generated in-state from all renewable resources examined in this report, excepting enhanced geothermal.

As the map shows, about a dozen states have renewable energy capacities far exceeding their internal needs. This has encouraged the current federal emphasis on extra high voltage transmission lines.

However, the map also reveals that over 60 percent of all U.S. states (32) can be self-sufficient in electricity if they relied on native renewable energy resource. A further nine (9) can generate at least half of their electricity from domestic renewables.

It is unlikely these states will want to rely on imports if they have so much domestic potential.

The Southern states from Kentucky to Louisiana appear to have the least potential for renewable energy self-reliance. However, even these states could meet 25 percent or more of their electricity needs from in-state renewable resources.

Figure 13a - Potential State Electricity Self-Sufficiency using Combined Renewable Resources

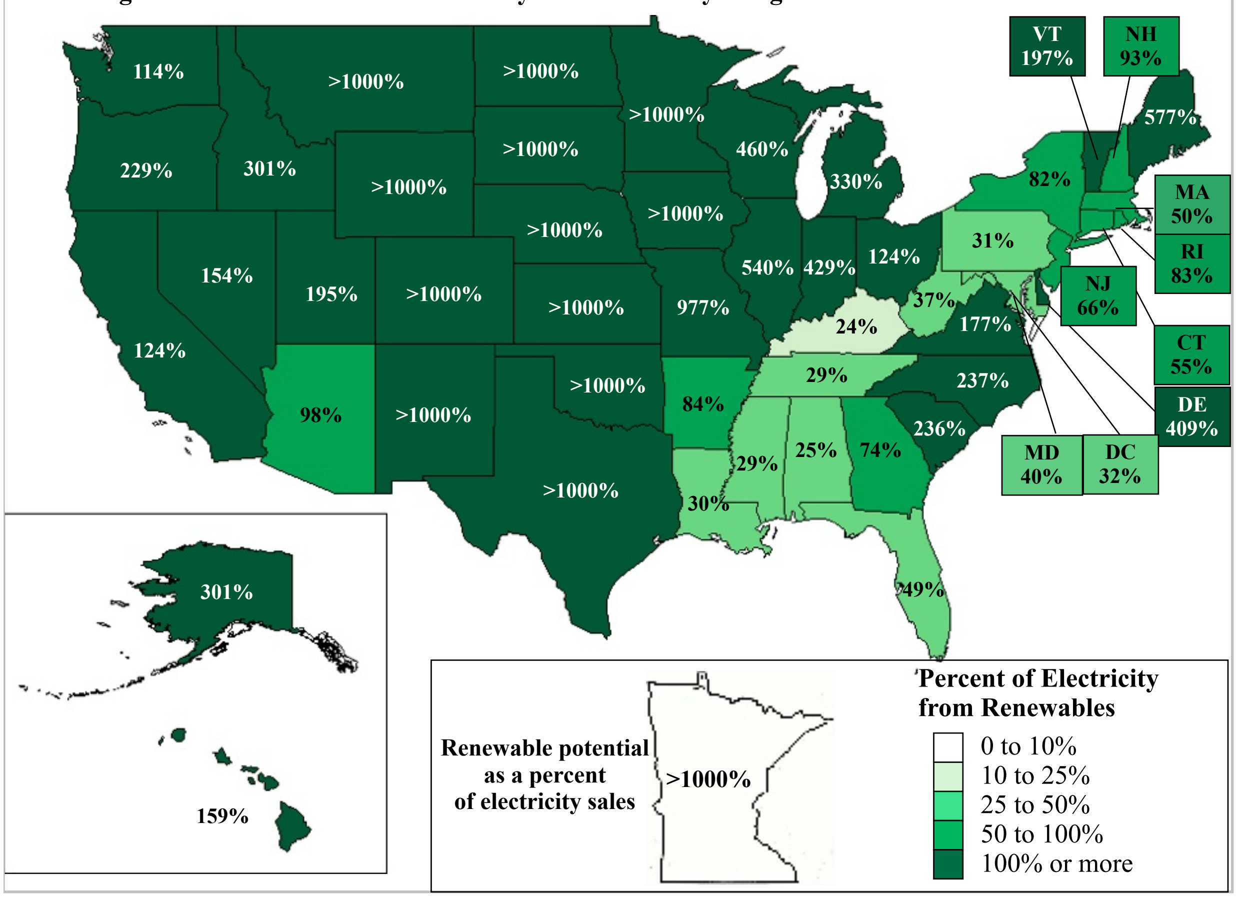
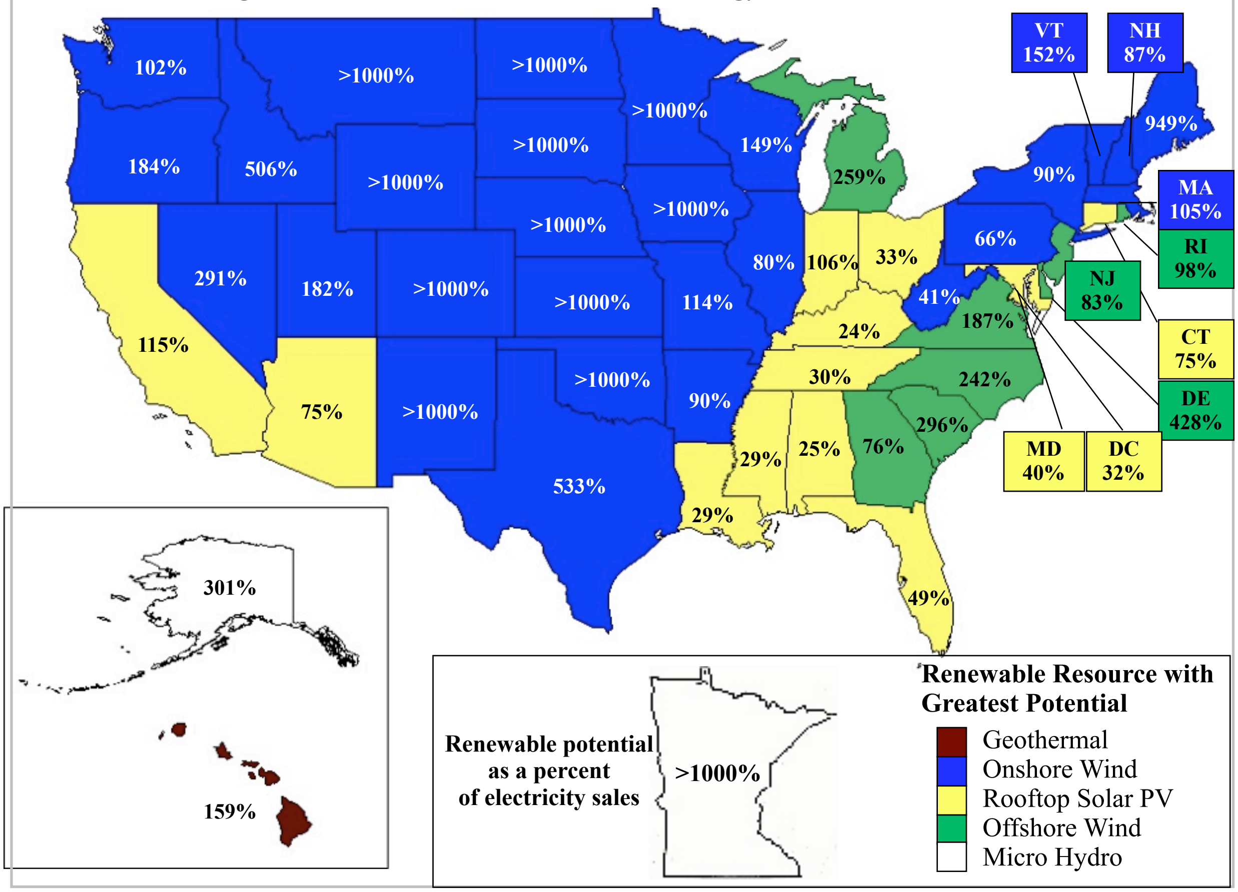


Figure 13b presents the same data as the prior map, but from a different perspective. While retaining the overall self-sufficiency percentages from **Figure 13a** it color codes states based on their most abundant renewable energy source. Onshore wind dominates the Northwest, Midwest and New England, solar PV the inland Southeast and Southwest, and offshore wind the mid-Atlantic states.

Figure 13b - Most Abundant Renewable Energy Resource in Each State



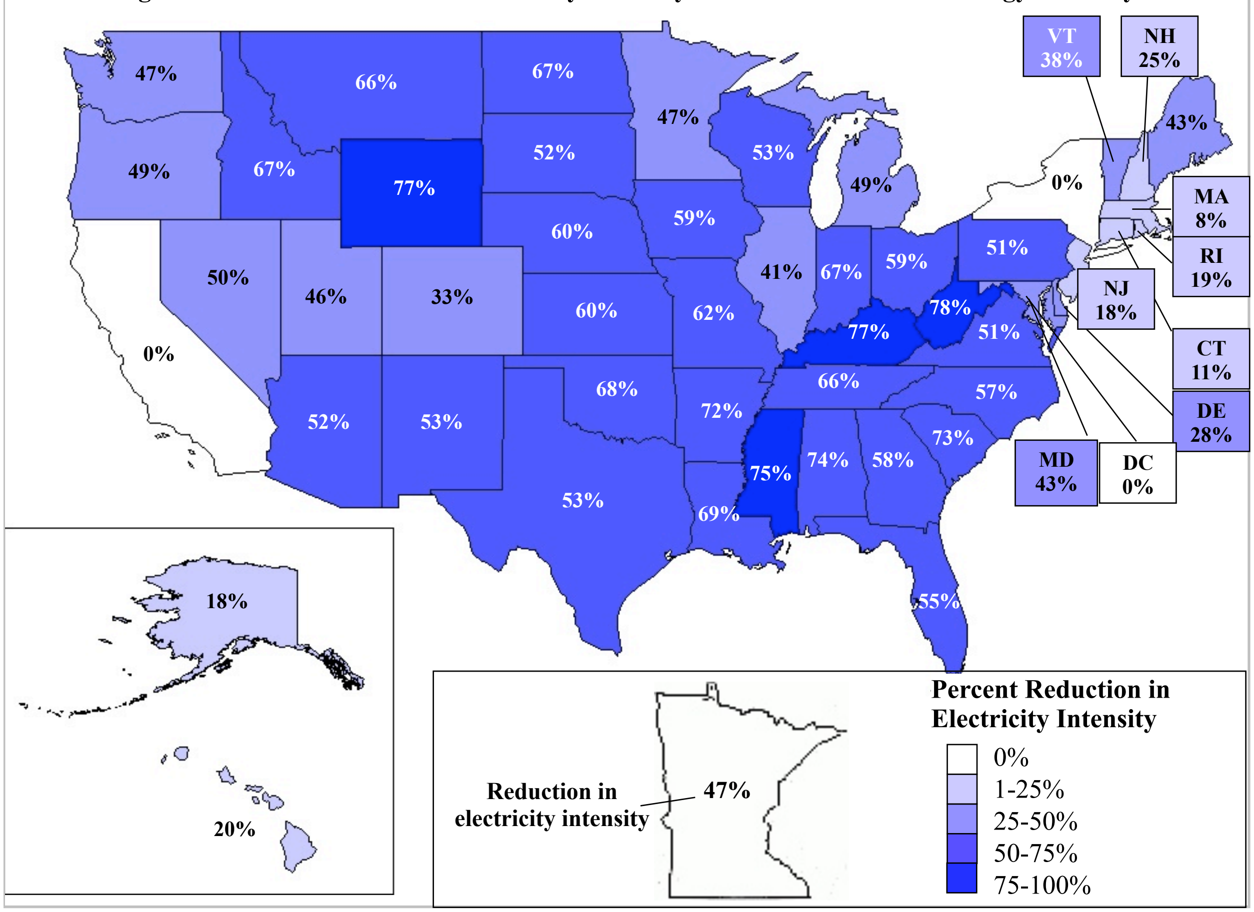
Taking Account of Energy Efficiency

As we have seen, an enormous amount of renewable energy is available in each state, enough to make most states self-sufficient. However, the level of self-reliance will also depend on how much states improve the efficiency of their energy use. In our maps, we assumed stable electricity consumption, despite expanding economies and populations. Conceivably, a very aggressive efficiency program by states could reduce absolute consumption.

As a thought exercise, we estimated the reduction in a state's electricity intensity (as measured by its electricity use per dollar of state GDP, per capita) that would occur if it were to match that of California, the acknowledged leader in energy efficiency (NY and DC also have high efficiencies, probably because of the high densities of New York City and DC). **Figure 14** shows the data.

A reduction in electricity intensity does not in the long run translate into an absolute reduction in consumption. But as this map shows, most states could achieve absolute reductions in the short term if they approached the electricity efficiency of California.

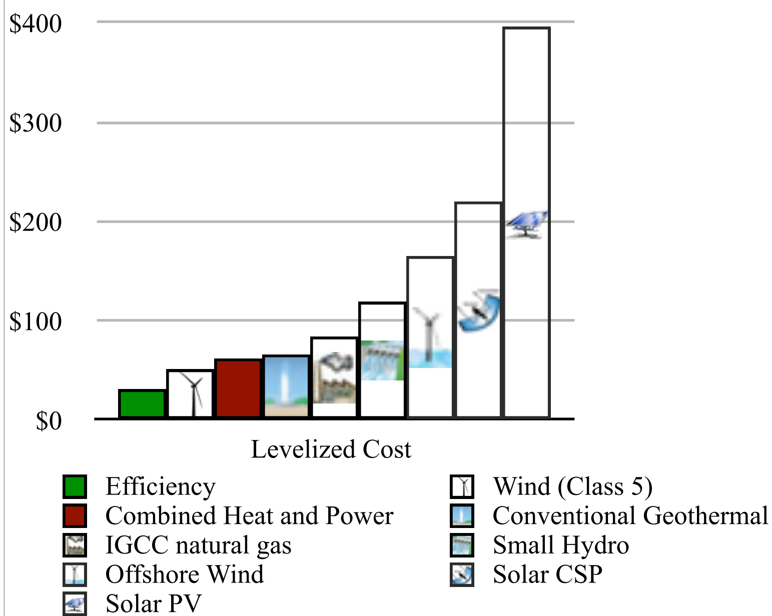
Figure 14 - Reduction in State Electricity Intensity to Match California's Energy Intensity



Economics of Renewable Energy

The economics of the various renewable energy technologies varies significantly. **Figure 15** summarizes the latest cost information available for the various technologies. Most of the data is from the California Energy Commission.[16] A cautionary note might be in order here. These numbers should be considered very approximate. The comparative costs may be more revealing than the cost estimate for a specific technology.

Figure 15 – Levelized Cost of Energy Generation ($ per Megawatt-hour)



Technology	Levelized Cost ($/MWh)
Efficiency	$31
Onshore Wind (Class 5, $2/W)	$38-87 ($51)
Combined Heat and Power	$64
Conventional Geothermal	$66
IGCC natural gas ($4/mmbtu)	$84
Small Hydro	$119
Offshore Wind	$165
Concentrating Solar (trough)	$220
Solar PV ($9/W installed)	$396

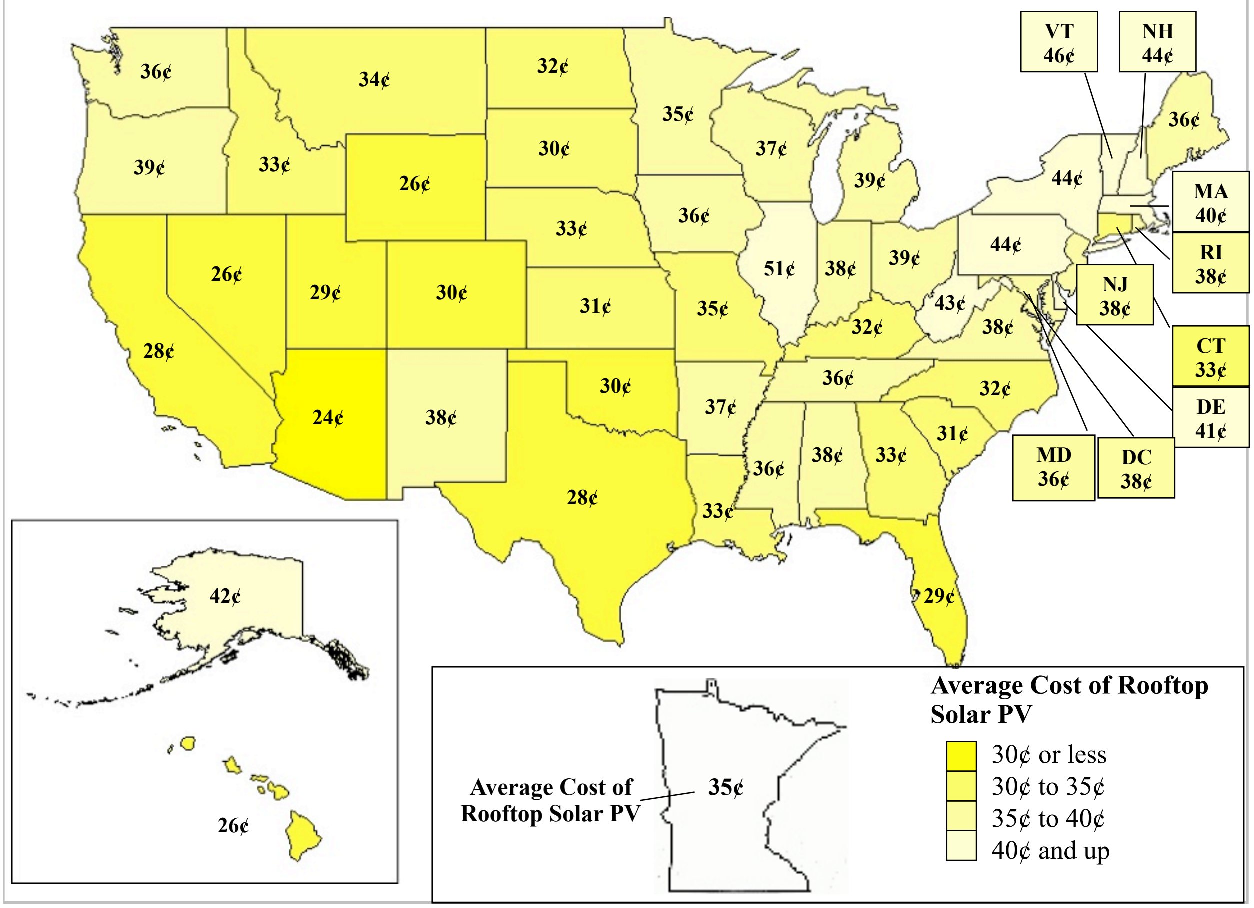
As is clear from the table, efficiency, CHP, geothermal and onshore higher speed wind power are already cheaper than one of the most efficient fossil fuel generating plants. The remaining technologies are not as cheap, but they use free, renewable fuel that does not share the price volatility of natural gas.

The data also illustrate that offshore wind is not cost competitive with its onshore cousin, probably even when the latter is sent long distances over transmission lines. However, several states have shown a clear interest in developing offshore wind as part of an economic development strategy which may occur in states with high electricity prices.

Solar PV shows up as a clear outlier, but the cost of generation must be taken in context. The data does not take into account avoided transmission and distribution costs nor the tendency for solar to maximize generation at peak air conditioning hours which in many states means the hours of highest cost electricity.

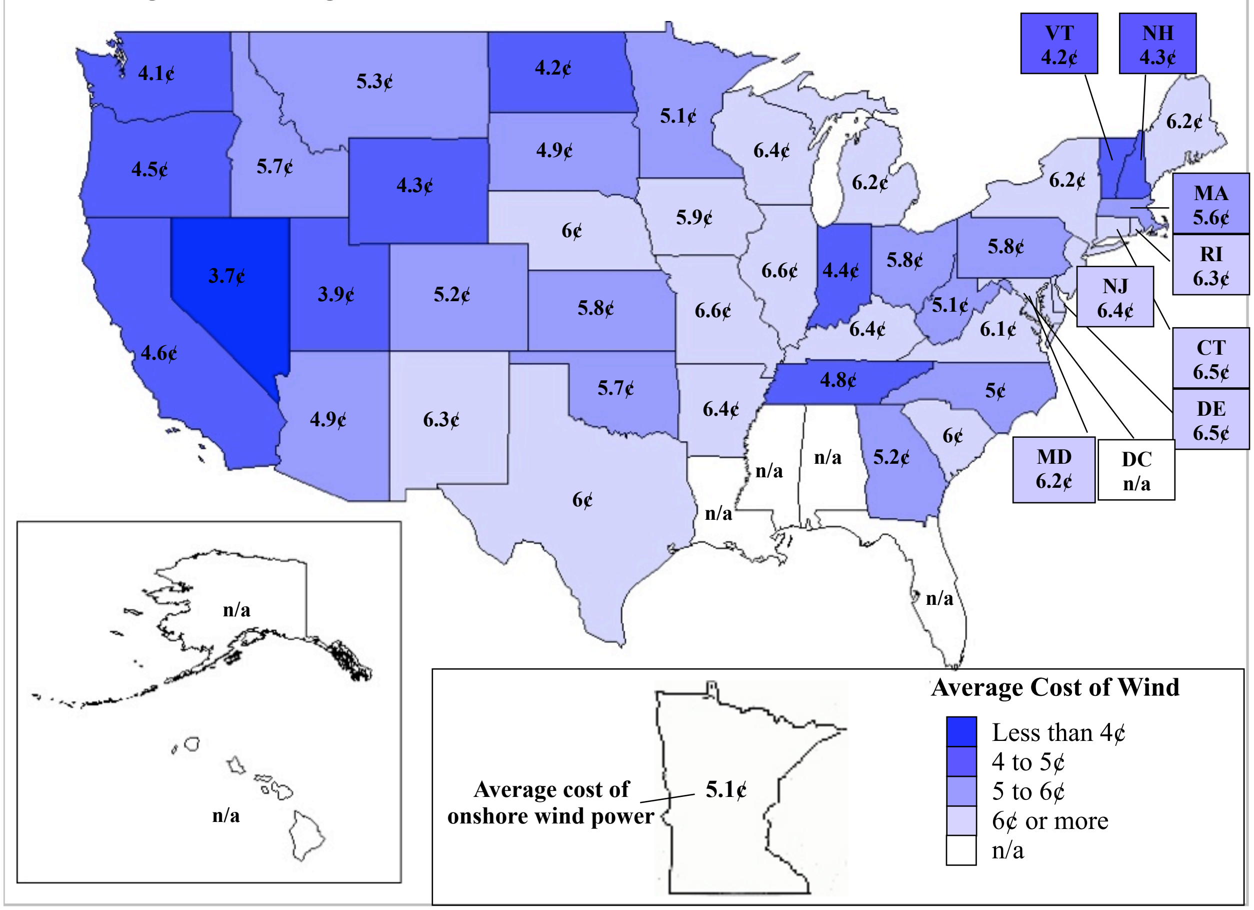
The following two maps (**Figures 16 and 17**) illustrate the cost of generation from solar PV and wind across various states.

Figure 16 - Average Cost to Maximize Rooftop Solar PV (with federal tax incentives)



The differences in prices for solar PV reflect the difference in solar insolation across the different states. As one might expect, prices for solar are significantly lower in the sunny Southwest than in the rest of the country.

Figure 17 – Average Cost to Maximize Onshore Wind Power (with federal tax incentives)



The price differences for wind seem counterintuitive at first glance, but it's due to the methodology of the map. In the 1991 wind potential study, for example, Indiana and Vermont were found to have a very small amount of wind power but at higher wind speeds. Thus, their average cost to maximize wind potential is very low. In general, however, higher wind speeds on the Great Plains are reflected in lower average cost of wind power than in the rest of the country.

A First Glance at the Cost of Energy Self-Reliance

The availability of state specific cost data for wind and rooftop solar, combined with reasonable estimates of the cost of generation for other renewable energy technologies makes it possible to offer a very rough estimate of the cost of achieving electricity self-reliance.

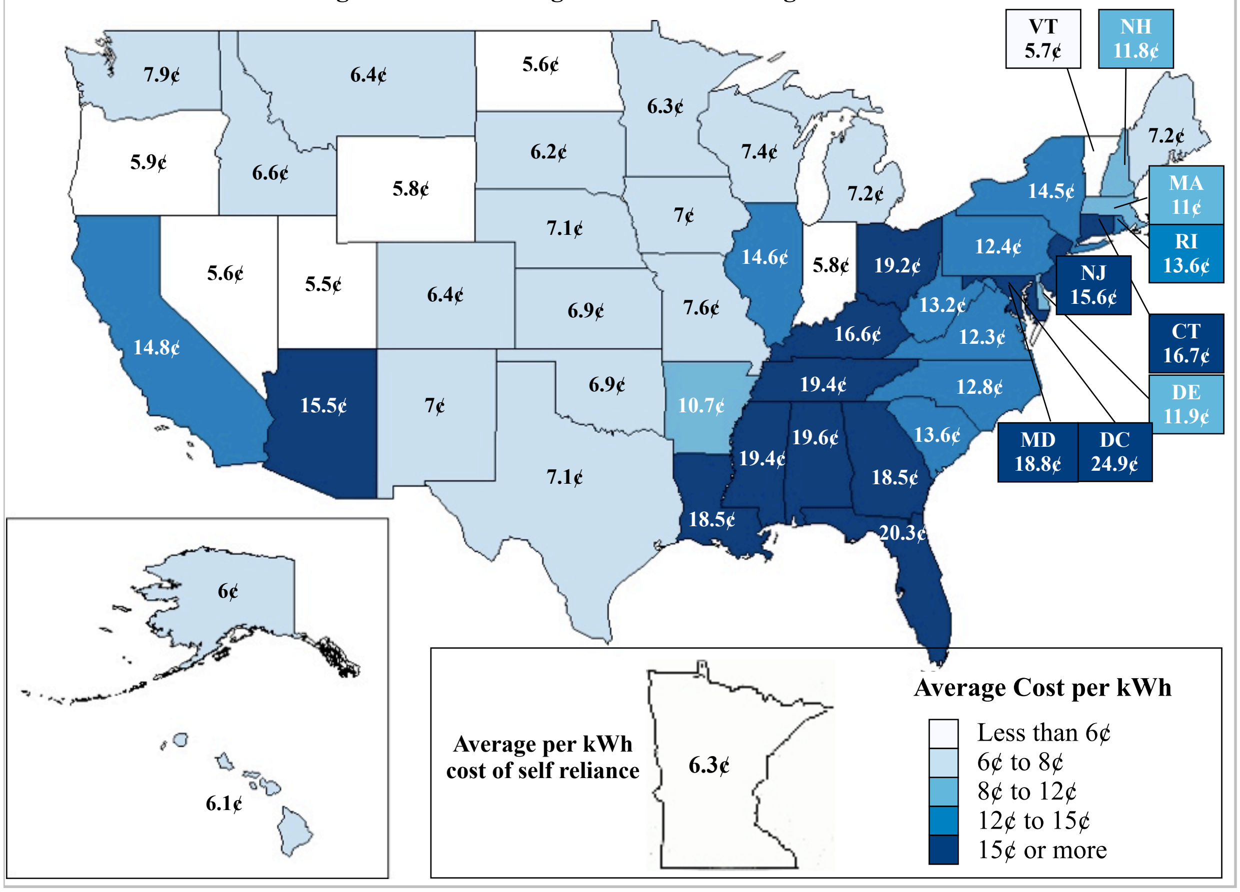
We assume states will pursue a lowest cost strategy for self-reliance, beginning with energy efficiency and conservation and then developing renewable energy sources in order of cost, least to greatest.

Figure 18 attempts to provide a very rough estimate of this cost, but there are several caveats:

- Absolute reductions in energy demand are rare (barring a recession) so the assumption that states can reduce electricity demand by 20 percent with efficiency is an aggressive one. Note: This does not include California, New York, or DC, which **Figure 14** shows to be leaders in energy intensity.
- States do not always pursue new generation based on a least cost formula, but may diversify their supply for reliability or grid stability.
- The prices reflect federal incentives and thus may not reflect the cost to ratepayers in the future.

The prices include capital and financing, operations and maintenance, and fuel costs as well as federal tax credits. The costs are levelized and do not factor in profit margins. The prices should be considered comparable to wholesale electricity prices.

Figure 18 - The Average Cost of Maximizing Self-Reliance



While the actual prices may not be precise, the relative cost of self-reliance is instructive. States in the West have lower costs because efficiency gains, conventional geothermal and onshore wind are largely sufficient to reach self-reliance. California, as the benchmark efficiency state, stands out because it is not granted any efficiency improvements and Arizona will depend a great deal on solar PV. In the Midwest, onshore wind keeps costs low. The Southeast relies on more expensive offshore wind to increase its self-reliance and the Northeast has to fall back on solar PV.

Notable outliers like Indiana, Vermont, and Maine have greater onshore wind resources than their neighbors, sufficient to reach self-sufficiency without resorting to higher cost renewables.

Intra State Transmission

The data in this report argue that a new extra high voltage inter-regional transmission network may not be needed to improve network reliability, relieve congestion and expand renewable energy. The focus should be on upgrading the transmission, subtransmission and distribution systems inside states. These investments should be designed to allow the integration of many variable and dispersed generators as well as growing amounts of distributed storage. New in-state transmission lines may well be needed but these will probably be lower voltage lines. In any event, they should be built only after maximizing energy efficiency and the use of existing transmission capacity.

Energy efficiency and demand reduction, as well as the use of distributed generation, can free up significant amounts of distribution and transmission capacity. Efficiency Vermont has empirically shown that efficiency investments can displace more than 100 percent of projected load growth (i.e. absolute load can decrease). Smart grid pilot studies find that 20 percent reductions in peak demand are achievable. The reductions can be even greater with judicious use of dispersed generation. Finally, backing out coal plants by substituting more dispersed natural gas plants could again free up transmission capacity.

Three studies by Minnesota utilities examined the capacity on existing transmission lines for interconnecting dispersed renewable generation. Even though the studies never used models based on maximizing dispersed generation, their data suggests that Minnesota could meet its 27.5 percent 2025 renewable portfolio standard by upgrading the existing transmission network. Two of the studies found that 1,200 MW of dispersed generators of 10-40 MW each could be added to the system for a cost about 90 percent less than the cost of building a conventional new power line needed to bring in the same capacity from out of state.[17]

Recently California established the Renewable Energy Transmission Initiative (RETI) to identify clusters of renewable energy to which it might need to build transmission lines. In its Phase I report issued in January 2009, RETI's research found that only about one-fifth of the electricity needed to meet its 33 percent renewable mandate could be imported less expensively than in-state renewable generation. If the state were to rely 100 percent on in-state renewables the average monthly electric bill for California businesses and households would increase by less than one-half of one percent.[18]

The RETI report came to another interesting conclusion. if the installed cost of photovoltaics were to decline significantly, a significant portion of the renewable mandate could be met with dispersed solar connected to low voltage transmission lines.

Cities

The finding of the RETI report on the potential for dispersed solar electric generation leads us to another point. This report provides data on the capacity for states to be energy self-reliant. States will play a key role in establishing policies that enable (or disable) homegrown energy generation. But much of the activity and innovation in renewable energy is coming at the local level. The decentralized nature of many of the new electricity technologies – smart grid, electric vehicles, rooftop solar, geothermal – would inevitably require local participation.

Photo Credit: Young Germany

A growing number of cities and counties have become aggressively involved in pursuing renewable energy and low carbon strategies. Several cities have issued bonds to finance renewable energy installations in households. In some cities, like San Francisco, a building owner can go online and fine out what the gross and useable square footage of his roof is for PV, what the electricity output would be and what the cost would be.[19]

A number of cities have studied their solar potential. Newark, Delaware, estimated it could satisfy 18 percent of its load with rooftop solar.[20] An earlier 1979 study by ILSR estimated that Washington, DC, could generate over 30 percent of its total energy from rooftop solar electric or solar thermal.[21] Our most recent data (see **Figure 7**) sets the electric-only percentage at 19.

A recent study of San Diego, CA concluded it had the technical potential (by 2020) within its region to produce more than 10 times its peak demand, using local solar, wind and local geothermal resources.[22]

Toward Energy Independent States and Cities

The potential is clear – most states can be energy independent by relying on homegrown, renewable resources. At least thirty-one could satisfy 100 percent of their electricity needs from in-state renewable energy (assuming sufficient distributed storage or distributed generation capable of generating on demand). At least 40 states could satisfy supply half their electricity with domestic renewable resources. Many cities can generate a significant amount of electricity from renewable resources found within their borders. And significant improvements in energy efficiency could significantly increase these numbers.

This report's estimates may be considered conservative, since additional technologies are available but are not considered (e.g. ground mounted PVs, concentrating solar power, and low temperature geothermal). The estimates of generation from the covered technologies relied on a conservative methodology (see **Appendix**). And no account was taken of improvements in the generation efficiency of renewable resources.

Achieving energy independence with homegrown renewable energy resources is well within the technical and financial capability of most states. While a reliance on solar PV might make it more economically challenging for some states, costs may come down as states focus first on less expensive options.
By tapping into human ingenuity, many states 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 States may invest up to $1 trillion in new renewable energy projects. All states can and should benefit from this investment.

There's a lot at stake, as characterized by Minnesota community wind developer Dan Juhl:

> *I live out on the Buffalo Ridge...I look out my window and I see hundreds of wind turbines. When I look at those turbines I'm happy and I'm sad... Most of those turbines are owned by our friends, the foreign multinationals. Out of two counties in Minnesota we export about 80 million dollars a year to France, Florida, Italy, Portugal, Spain. All of our energy future is going out the door when we could be turning that into something real for us.*

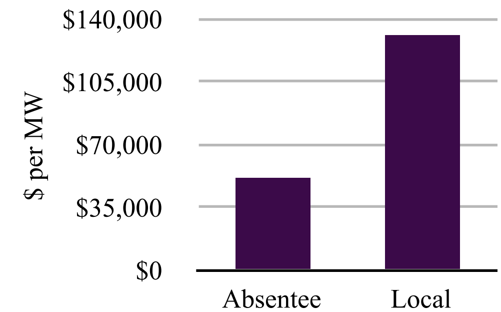
As the data in this report suggests, states would do well to look inward for their energy security. This strategy can yield profound economic and social benefits. Expanding wind power to 20% of generation in several Plains states will create nearly 158,000 jobs, with 20,000 jobs beyond the construction phase of the wind farms. Local economic benefits will total over $1.6 billion a year during the wind farms operations.[23] And widely dispersed energy production can be the basis for a resilient energy system where a branch falling on an electric line in Ohio does not result in a 12-state blackout as happened in the U.S. in 2003.

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, with a potential to increase economic benefits even further.

Some might argue that bigger is better within a state. But previous reports by ILSR have examined the economies of scale of renewable energy production and found them modest or even non-existent the cost of transporting the energy product long distances to the final customer is taken into account.[24]

Small scale, distributed energy facilities also lend themselves to local ownership, which – as reports by ILSR have concluded – significantly increases the economic benefit to a community and a state (**Figure 19**).[25]

Figure 19 – Locally Owned Wind Farms Have Higher Average Economic Impact



Local ownership has another benefit. It confers a greater sense of responsibility and self-reliance on the project owners than a similar project where local residents are just observers.[26]

Looking inward for our energy solutions requires 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 – is to maximize efficiency and conservation, to follow with maximizing use of the existing transmission, subtransmission, and distribution lines with distributed renewable energy generation, and finally to examine the need for substantial investments in new lines.

Credit: Ascension Technology, Inc.

Appendix - Methodology

The following sections explain the ILSR data presented in this report.

State Electricity Consumption

State electricity consumption data is for 2007. The data is from the Energy Information Administration.[27]

The increase in electricity consumption from electric cars was based on the following assumptions. Total vehicle miles traveled (VMT) were approximately 3 trillion in 2007. Cars account for 56.5 percent of VMT and are assumed to average 4 miles per kWh. 2 axle, 4 wheel trucks account for 35.4 percent of VMT and are assumed to average 2 miles per kWh. If 75 percent of VMT from these two sources switch from gasoline to electricity, it would increase electricity consumption by 19.2 percent (716 billion kWh).

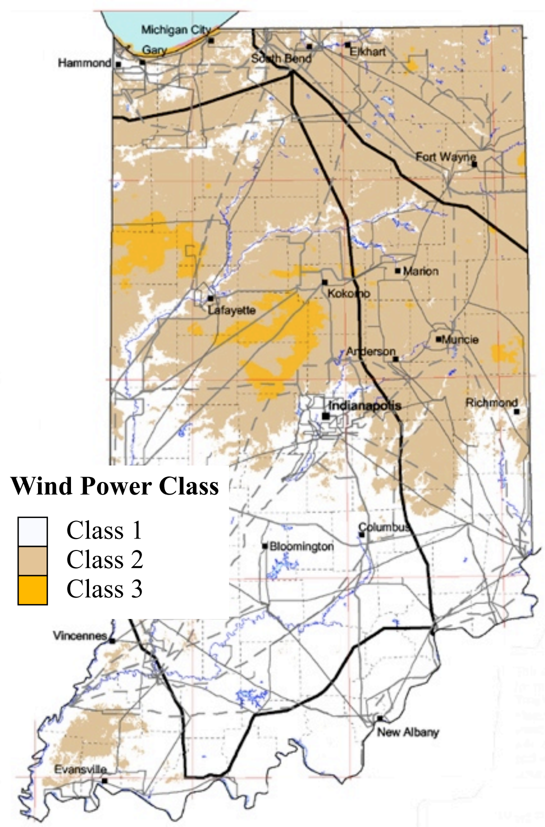
Storage

To achieve very high proportions of our electricity from variable renewable energy sources will require very significant amounts of storage and/or a restructuring of our electricity system to rely on more natural gas-fired distributed backup generators. The electricity storage sector has seen many technological and commercial developments. This report does not examine storage and its implications but in our analysis of variable renewable energy potential we assume sufficient storage is available.

Onshore Wind

The onshore 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*.[28] 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).

Figure 20 - Indiana Wind Power Class at 50 meters (NREL)



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%.[29]

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

The PNL study is the basis for estimating wind energy potential. But that 1991 report significantly understates the current reality of the wind industry. For the 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 4** with a zero). But modern turbines are more than twice the height (80 meters) of the original measurements and thus many states 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 1991 study, no part of the state was considered suitable for wind development. Ironically, the American Wind Energy Association shows that there are 530 MW of wind already installed and another 500 MW under construction. Furthermore, an updated wind speed map from the National Renewable Energy Laboratory (**Figure 20**) shows a significant amount of land – over 2,000 square kilometers – with a good wind resource (Class 3) at 50 meters. And preliminary estimates based on the updated map show a potential capacity of over 40,000 MW, capable of meeting 83 percent of the state's electricity needs at a 25% capacity factor.[30]

Indeed, **Figure 20** 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.

ILSR's calculations do 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 or renewable energy fired backup power plants could make a significant part of the wind power "firm."[31] Finally, rapid advances are occurring in battery storage which, if massively deployed, could ameliorate the intermittency impact.

Offshore Wind

Data on offshore wind resources are provided based on availability. The evaluation of potential is generally as conservative as the data allow, focusing on water depths less than 30 meters – depths already commercially developed – better wind resources (typically Class 5 or better), and excluding sea regions designated as protected or used for commercial shipping.

In some cases, estimates were only available for a collection of states, such as the estimate for New England (including ME, CT, MA, RI) and the Great Lakes (MN, WI, MI, OH, PA, NY). These estimates were split evenly among the states – an admittedly crude method – unless a state-specific estimate was also available (MI, ME, RI).[32]

Solar PV

The solar rooftop power data comes from a national estimate of rooftop solar PV potential in 2015 by Navigant Consulting.[33] That report estimated total roof space available on residential and commercial buildings, taking into account shading, orientation, and structural adequacy. The report assumed that only 25 percent of residential rooftop space and 60 percent of commercial rooftop area is 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. The calculation of total kWh potential adjusts for the stronger solar insolation in southern latitudes and the weaker solar insolation in northern states.

The calculations for the potential of solar PV in highway right-of-way are based on the following assumptions:

- At 12% efficiency, solar PV occupies 0.387 MW per acre.
- On 6 million acres – 10 percent of available right-of-way – 2 million MW of peak electricity would be available.
- At a 15% capacity factor, this produces some 3 million GWh per year, about equal to U.S. annual consumption of 3.72 million GWh.[34]

Small Hydro

The figures for additional small and micro hydro power are also conservative. They include only projects less than 30 MW that draw power from a parallel penstock with limited length, where the project is:[35]

- greater than 10 kW
- not in federally restricted area
- not in area with unfavorable zoning
- not near existing hydro plant
- within 1 mile of road
- within 1 mile of infrastructure or within typical distance

Combined-Heat-and-Power

The CHP data come from a 2000 report by Onsite Sycom and focus on opportunities in the commercial and industrial sectors.[36] In particular, the report looks for coincident thermal and electric loads, thermal loads using steam or hot water, an appropriate ratio of electric to thermal demand, and significant operating hours. The map data also assume a capacity factor (for electricity) of 30 percent and includes various fuel types and prime movers (e.g. combustion turbine).[37]

The data is verified as conservative by a 2008 report by the Oak Ridge National Laboratory.[38] In every case, the estimates from the 2000 report are below the low range estimate from the 2008 report.

Geothermal

The conventional geothermal estimates are based on data from the U.S. Geological Survey (USGS). The estimated potential is in the F95 range, meaning there's a 95 percent chance that the actual resources exceed these estimates. For electricity generation, a 95 percent capacity factor was used.

Unconventional geothermal potential was gathered from Google Earth, but based on the resource estimates in the 2006 MIT report on enhanced geothermal potential. Once again, the estimates are selected with a 95 percent probability that they are conservative, and with an assumption of just 2 percent resource recovery.[39]

Electricity Intensity

For this analysis, we used one broad-brush measure of electricity intensity: electricity use per dollar of state gross domestic product (GDP), per capita. The per capita GDP figures were taken from the U.S. Bureau of Economic Analysis, for 2007. Electricity sales figures came from the Energy Information Administration and are identical to the ones used throughout this report.

Since California is generally accepted as the leader in efficiency use of energy – their per capita energy use has not changed since the 1970s – each state's electricity intensity was benchmarked against that of California, a state that expends just 0.17 kWh per dollar of per capita GDP. The two states with better energy efficiency than California were assumed to make no improvements.

Thus, a state like Minnesota with an electricity intensity score of 0.32 kWh per $GDP per capita would reduce energy intensity by 47 percent, to 0.17 kWh per $GDP per capita.

Transmission

The transmission cost estimates are based on transmission line cost data from the Edison Foundation and American Electric Power.[40] The levelized cost per kWh was calculated by assuming that the 745 kilo-volt (kV) transmission line was maximized by serving a 5,000 MW wind farm, that the project was debt financed over 20 years at a 5% cost of capital and that the developer required a 12% return on equity. The wind farm was assumed to operate at a generous 40% capacity factor.

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