State of Renewables

US and state-level renewable energy adoption rates: 2008-2013

Elena M. Krieger, PhD
Physicians, Scientists & Engineers for Healthy Energy
January 2014

1 Introduction

While the United States power sector is strongly dominated by conventional fossil and nuclear power plants, the contribution from renewable resources is growing and the energy mix varies greatly by state. Here we evaluate electricity generation from utility-scale renewables (i.e. power from wind, water, solar, geothermal and biomass resources) in the United States on the national level as well as in five states: California, New York, Texas, Minnesota, and Indiana. To date, renewables make up only a small percentage of total power generation in most states, with the exception of large hydroelectric power. A number of states, however, have incorporated renewable energy at much faster rates than the national average, and these examples may offer insight into approaches to increase renewables generation in other regions.

Renewable portfolio standards (RPS) and strategies to increase renewable energy market penetration vary greatly by state. For example, California has high renewable energy targets, along with parallel programs for efficiency, storage, demand response, and distributed generation, which are not covered by its RPS. States such as Wyoming, however, have no renewable energy targets at all. Most state RPS targets are set as a percentage of total electricity generation, although Texas has instead set goals for total installed electricity generation capacity. Timelines and strategies are state-dependent. Minnesota has different targets for each utility. New York, Indiana, and Minnesota all define very different suites of technologies under each RPS. California has some of the most aggressive RPS targets, while Indiana's are lower than most and voluntary.

The data presented here reflect annual variations in electricity demand, and can highlight both challenges to integrating renewable resources and strategies for overcoming these hurdles. For example, hydroelectric and wind power are frequently at peak generating capacity in fall and spring, while demand peaks in winter and summer. Higher rates of solar power generation may help smooth this annual variability because solar peaks in the summer.[1] It is important to note that these data do not capture daily or

[1] For a formal analysis of coupling renewable resources to reduce variation, see [1].

hourly variability: increasing rates of solar generation might help mitigate the annual variation introduced by wind and hydroelectric power, but additional measures will be needed to account for the daily variation in these resources. Solar tends to peak in the middle of the day, for example, and wind is often more powerful in the evening. Energy storage and demand response may play an important role in managing these daily variations. However, these technologies play less of a role on the long time scales illustrated here, and so will not be discussed in depth.

The plots below show the status of renewable energy integration in the United States as of late 2013. By looking at generation over the past six years, we can see how rapidly electricity generation from renewables has grown in each of our focus states within the context of each RPS. The impact of annual variations – and benefits from resource coupling – can be visualized for each state. The data also reflect the influence of RPS targets, although we must note that many states import or export electricity, have provisions for renewable energy credits, or set other conditions in their RPS such that state-level generation alone cannot be used to evaluate whether each standard is being met. Nevertheless, the rapid integration of renewables in some regions suggests strategy in some states could be used to accelerate adoption in others. We first show data averaged across the United States, and then look at individual states.

2 Data Sources

Unless otherwise indicated, all data analyzed in this whitepaper are sourced from the Energy Information Association's compiled Electric Power Monthly [2], using electric power industry generation totals from January 2008 through October 2013. Information regarding state renewable portfolio standards is compiled from the Database of State Incentives for Renewables & Efficiency [3]. Generation from distributed resources, such as rooftop solar, is difficult to measure accurately and typically does not count towards RPS targets, so we have not included it in this analysis. As a result, total electricity generated from renewables in each state is likely higher than shown in the plots below, which only include utility-scale generation. We also do not differentiate between small and large hydropower generation, although these technologies are frequently assessed separately for state RPS targets. Finally, while we present information on both RPS targets and in-state electricity generation, we emphasize that these results are not always directly comparable due to different definitions of eligible renewable technologies, import and export of electricity, the use of renewable energy credits, and other state-level energy policies. The states selected for analysis – New York, California, Texas, Minnesota, and Indiana – were chosen for their regional distribution and wide range of energy resources and policies.

3 United States

Electricity generation by source in the United States for 2008-2013 is shown in Figure 1. Generation peaks each year in August every year driven predominately by air

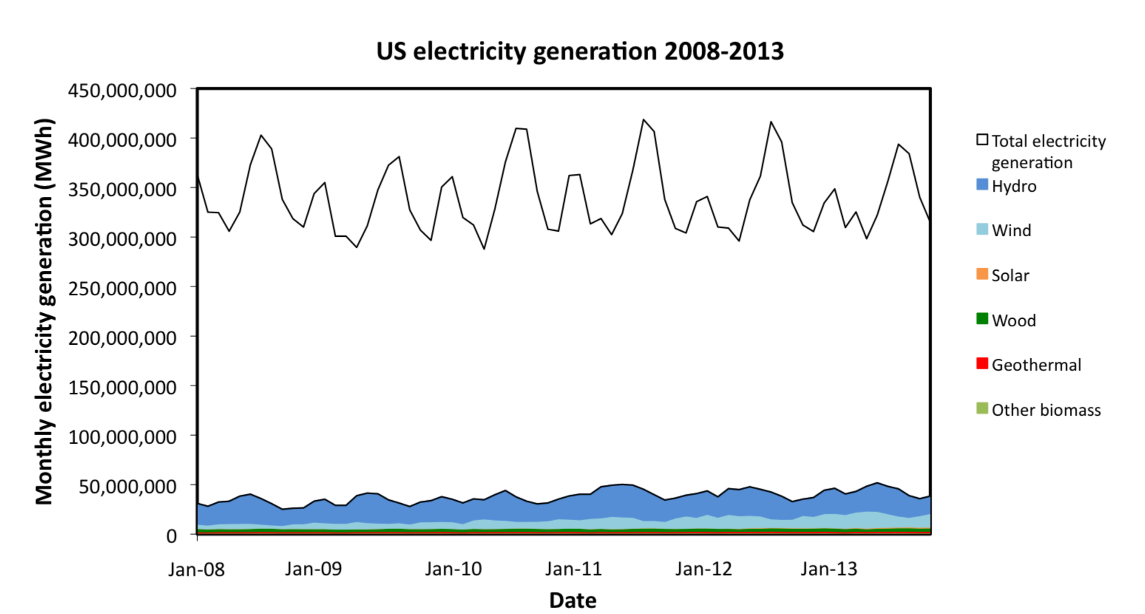

Figure 1: Electricity generation in the United States by source, 2008-2013. Generation from each renewable resource is shown as a cumulative area plot and the total electricity generation from all sources is given as line plot for reference. The region between renewables generation and total generation is made up primarily of electricity from coal, natural gas, and nuclear power plants.

conditioner usage. A secondary maximum occurs in the winter due to increased space heating and lighting demands. Generation is at its lowest in the months of April and October. By enlarging renewable generation in Figure 2 we can see that generation from the two largest renewable sources, hydroelectric and wind, is poorly aligned with these annual peaks. Hydroelectric generation tends to peak in the late spring when snow melt is at its highest, and wind often peaks in the winter and spring, although output from both varies greatly by region. Solar peaks in the summer along with demand, but installed capacity is too low to make a large impact when averaged across the United States. As noted above, only utility-scale capacity is represented here; generation from distributed solar on a residential and commercial scale is difficult to track because much of it occurs "behind the meter" – independent of the main grid's transmission and distribution system – and is not typically measured directly. Accounting for distributed installations (i.e. residential solar panels) may double capacity [4], but even taking estimate distributed generation into account the total generation is still very low.

Figure 3 shows US generation from various renewable energy sources as a fraction of total generation. On a national level, only hydroelectric and wind power make a significant contribution to total generation, although in individual states other renewable sources contribute a greater fraction of electricity generation. The fraction of generation from wind nearly tripled between October 2008 and October 2013, from 1.5% to 4.3%. The fraction of electricity generated by utlity-scale solar increased by a factor of 15 over the same five-year span, but in October 2013 still only accounted for 0.3% of total generation.

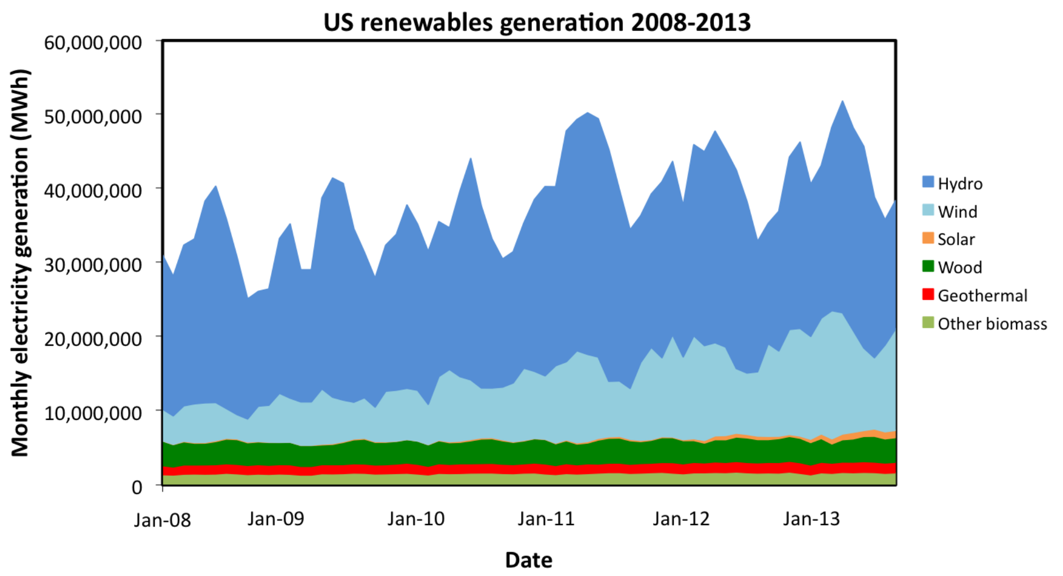

Figure 2: Renewable electricity generation in the United States by source, 2008-2013.

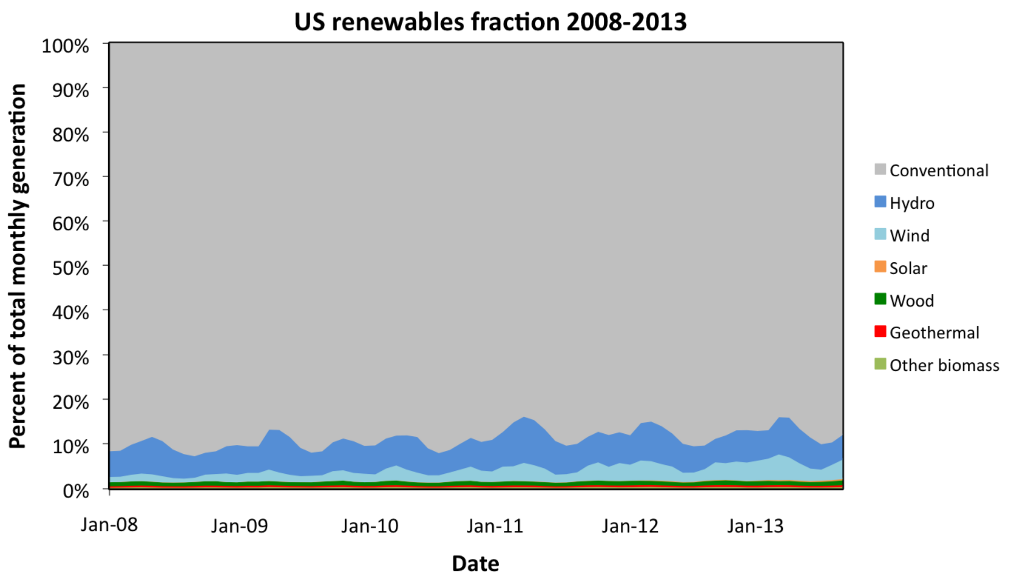

Figure 3: Fraction of electricity derived from renewables in the United States, 2008-2013.

The United States does not have a nationwide renewable portfolio standard; instead, each state defines its own energy goals independently. Strong RPS targets have been achieved in many states, and not at overwhelming costs. Existing RPS targets for California, Indiana, New York, and Minnesota are shown in Figure 4, excluding Texas, which has targets for installed capacity (MW), not percent of total generation. Each of these targets is uniquely defined. New York includes large hydropower. Minnesota has different targets for different blocs of utilities. Texas has capacity targets, as mentioned. Indiana's targets are voluntary and include technologies such as nuclear and "clean coal," which do not have RPS eligibility in most states. In the following sections, we will look at more detailed renewable generation data in each of these states.

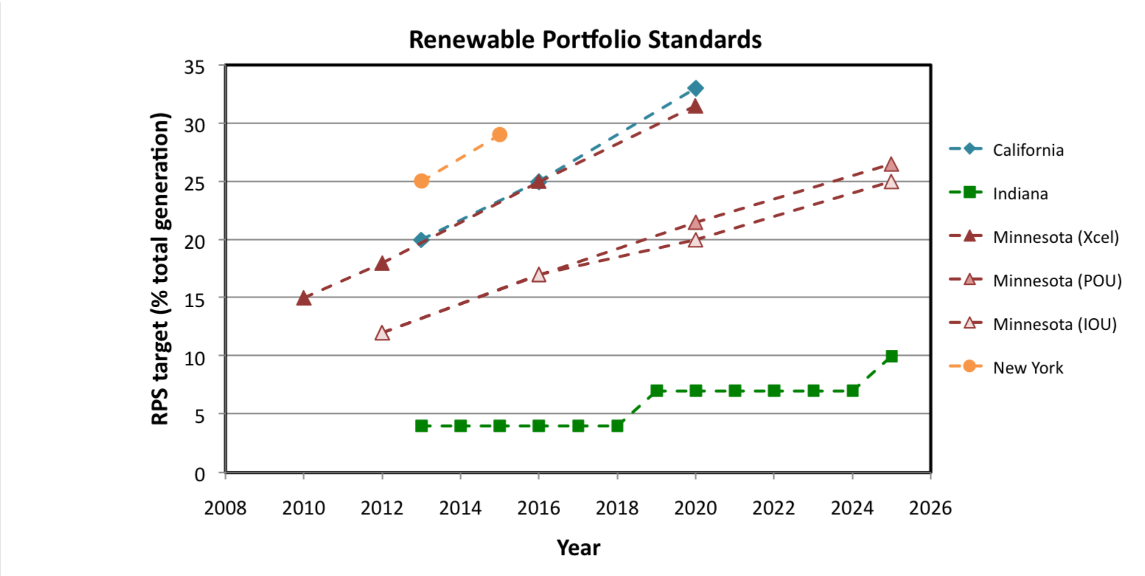

Figure 4: Renewable portfolio standards and clean energy targets for California, Minnesota, New York and Indiana. Minnesota has different targets for the utility Xcel, publicly-owned utilities (POUs), and investor-owned utilities (IOUs). Eligible technologies vary by state: New York includes large hydroelectric power, unlike California and Minnesota, and Indiana includes nuclear and natural gas switching from coal. Texas is not included because its targets are set as capacity requirements, not generation requirements.

4 California

Figure 5 shows cumulative renewable and total electricity generated in California from 2008-2013. Generation peaks in August, but due to the mild climate does not have the significant winter peak characteristic of colder regions. Renewables generation can be seen in more detail in Figure 6. Hydroelectric and wind generation both peak in late spring and early summer, but decline in August. California is the only state to have a significant contribution from geothermal, accounting for 6.3% of total generation over the years selected. Generation rates from geothermal remain relatively constant during the course of the year. Monthly utility-scale solar generation increased by a factor of five from October 2011 to October 2013, accounting for 2.5% of October 2013 generation. It is likely that total solar generation is close to double the amount shown here due to the contribution from distributed installations [5], but only utility-scale sources are eligible under the RPS targets [3]. The California RPS target includes small hydroelectric but not large hydroelectric generation. These two are not differentiated in Figures 5, 6 and 7.

The California RPS targets require that 20% of retail electricity sales must be generated from renewables by Dec. 31, 2013, 25% by Dec. 31, 2016, and 33% by 2020. If the target is not reached by a utility, it can purchase renewable energy credits to make

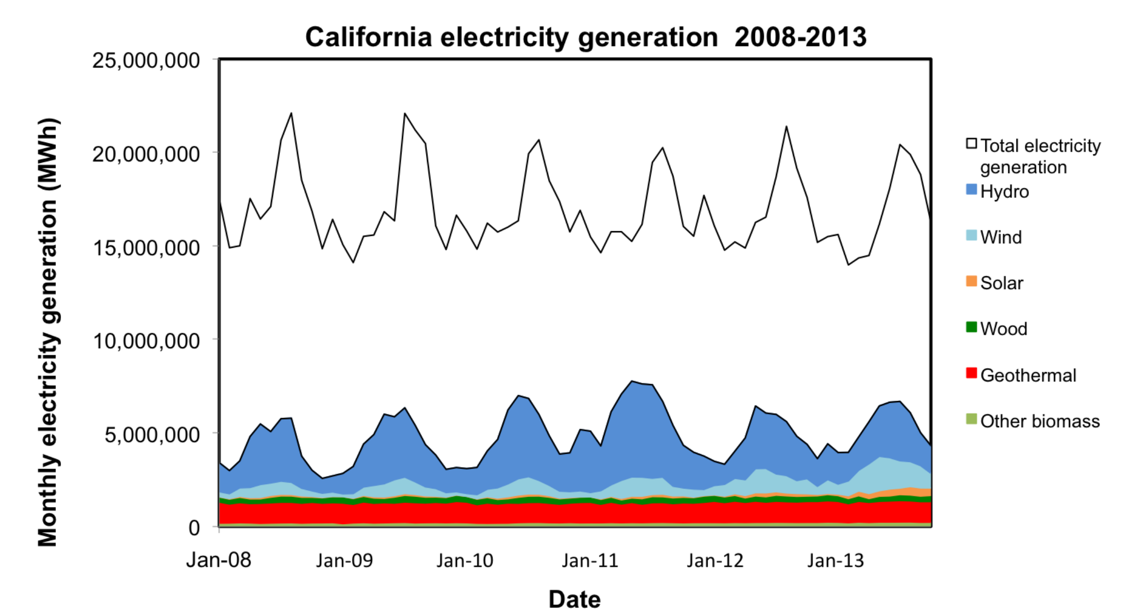

Figure 5: Electricity generation in California by source, 2008-2013.

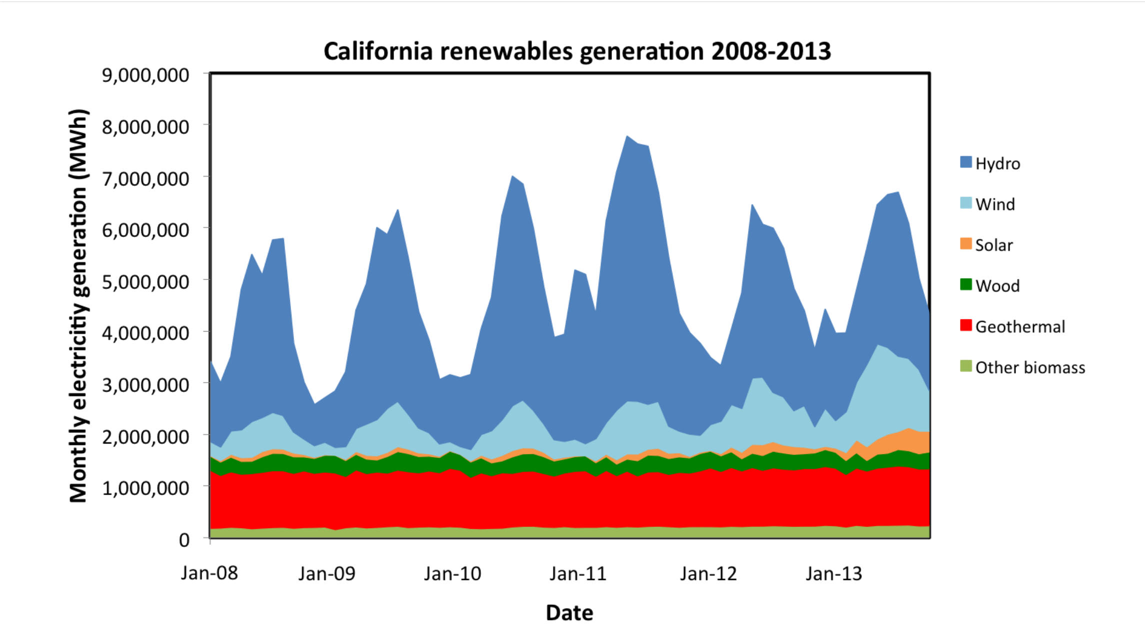

Figure 6: Renewable electricity generation in California by source, 2008-2013.

up the rest. It is worth noting that the total in-state generation shown here does not supply all retail sales in California, where nearly a quarter of electricity is imported. Using in-state generation as a proxy, California is approximately on track to meet its RPS targets (Figure 7), but reaching 33% of generation might become increasingly challenging. Not only does offsetting variability become increasingly difficult as the penetration of renewable sources increases, but the proportion of renewables from each resource is likely to change if geothermal generation continues to stay constant while wind and solar increase. California is introducing additional strategies to tackle the challenges introduced by intermittency, including a 2020 target of 1.3 GW of en-

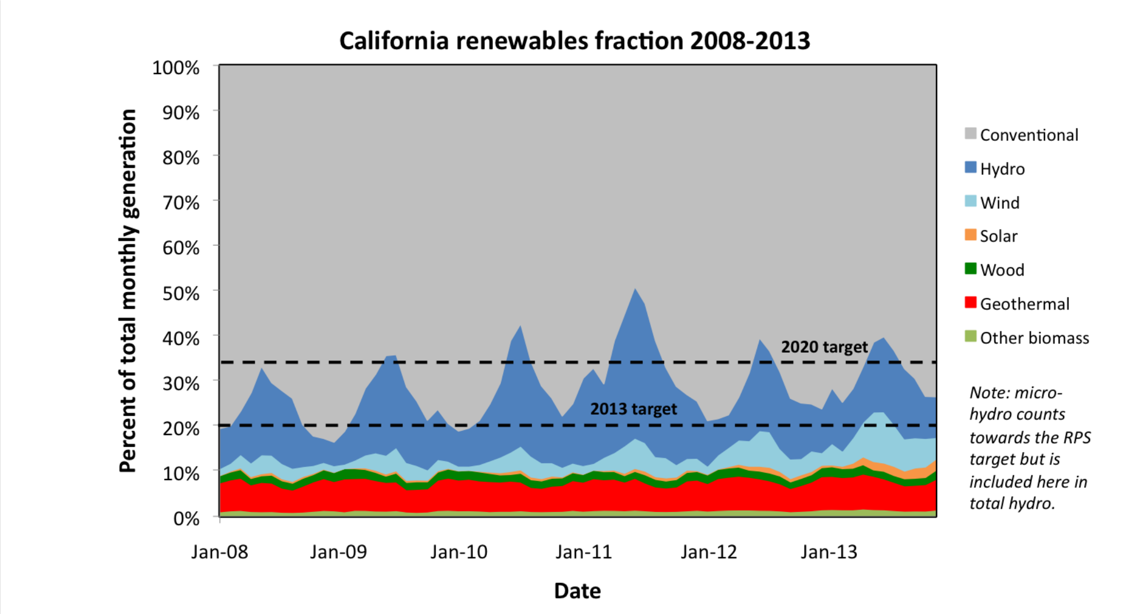

Figure 7: Fraction of in-state electricity generation derived from renewables in California, 2008-2013. The RPS targets for retail electricity sales in 2013 and 2020, which do not include hydroelectric generation, are 20% and 33%, respectively.

ergy storage procurement, as well as demand response programs. Although rainfall and snowfall have been erratic in recent years, the high level of in-state hydroelectric capacity may also help mitigate variability from wind and solar.

5 New York State

Electricity generation in New York state for 2008-2013, presented in Figure 8, reflects a large and steady contribution from hydroelectric power. A closer look at at renewables generation in Figure 9 shows growing wind capacity and a constant low contribution from wood and biomass, but negligible contributions from utilty-scale solar.

New York's renewable energy targets are shown in Figure 10. By 2015, New York aims for 29% of consumption to be supplied from utility-scale or distributed renewables; voluntary green power markets where customers opt to purchase renewable energy are projected to offset another 1% of conventional generation. Over two thirds of the RPS target is expected to be met by existing (mostly hydroelectric) facilities. Only about 8% of additional renewable generation (just over 0.5% of total sales) is expected to be from distributed, non-utility resources [3]. Although renewables capacity is increasing and monthly generation occasionally reaches New York's 2015 RPS target, New York must accelerate installations to reach this target for total annual electricity generation. As wind and solar increase, the state's large hydroelectric capacity will help smooth high levels of these more variable renewable resources coming online. New York's hydroelectric generation also shows less annual variation than other regions.

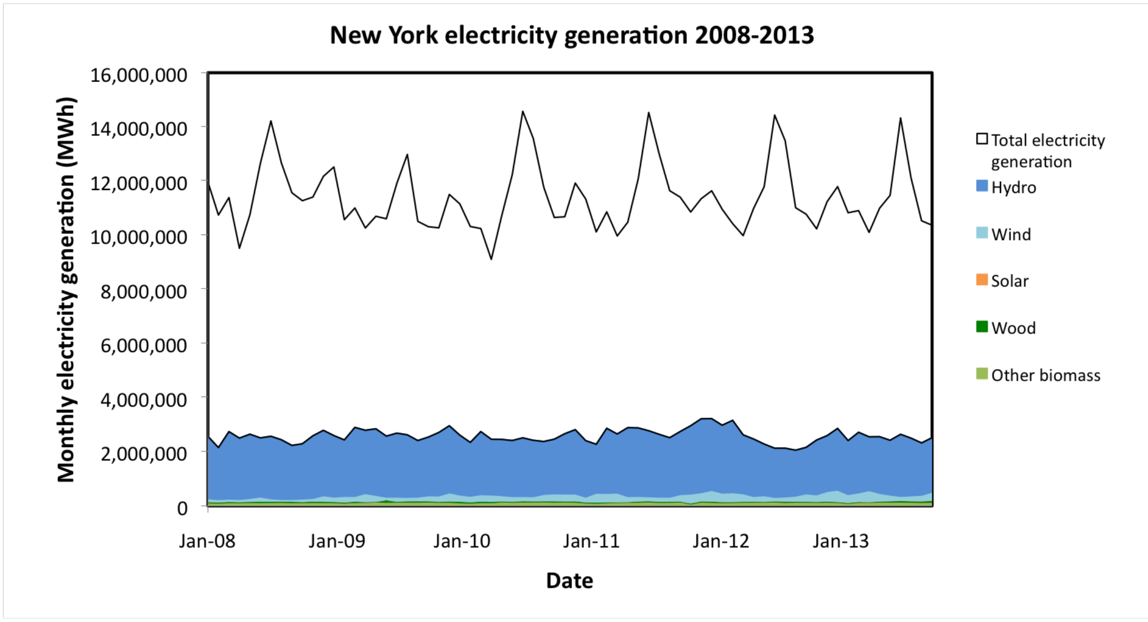

Figure 8: Electricity generation in New York by source, 2008-2013.

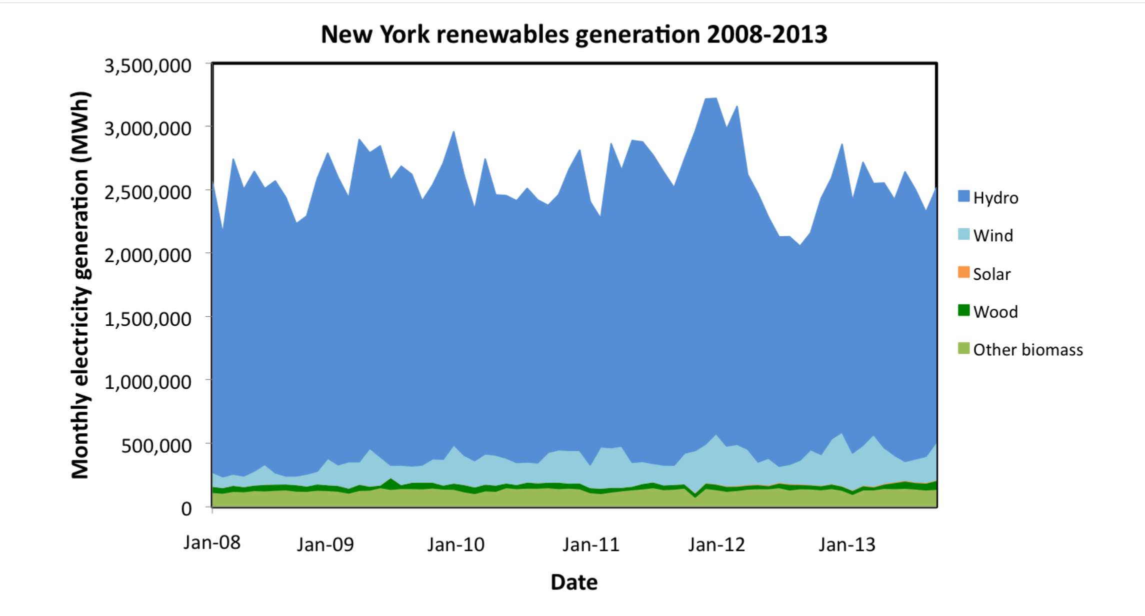

Figure 9: Renewable electricity generation in New York by source, 2008-2013.

6 Texas

Most of Texas is connected by its own independent electric grid, and the state produces more electricity than any other state in the US. Annual generation is shown in Figure 11. Although Texas has little utility-scale solar capacity, the state has the highest installed wind capacity in the United States, and wind strongly dominates its renewables mix (Figure 12). Renewable generation as a fraction of the total, shown in Figure 13, reaches more than 10% in the spring.

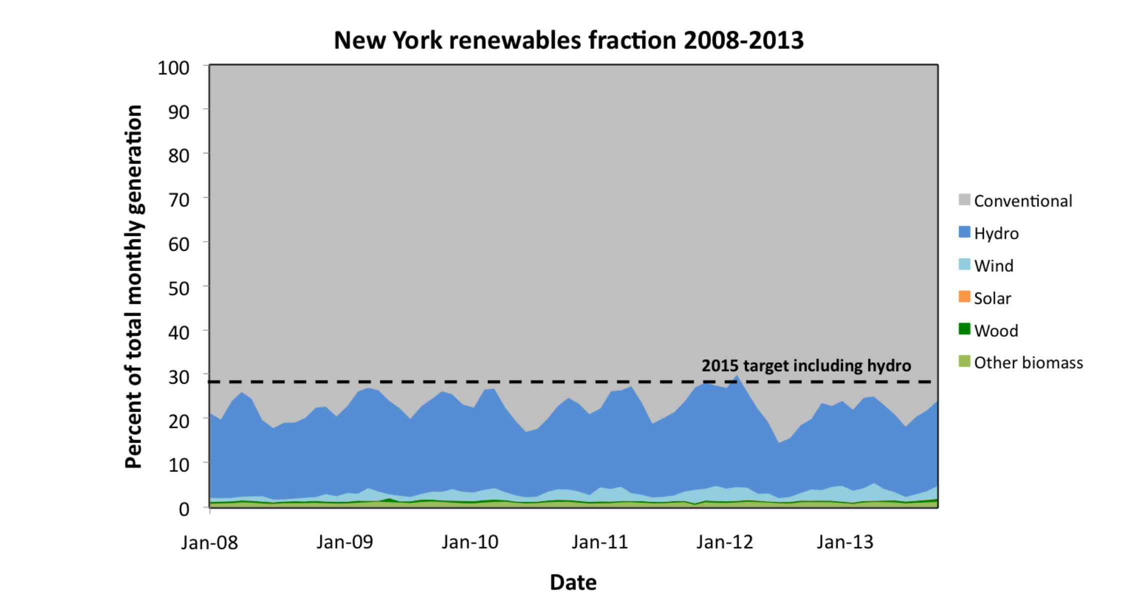

Figure 10: Fraction of electricity derived from renewables in New York, 2008-2013. The state RPS target is 30% by 2015, including hydroelectric power.

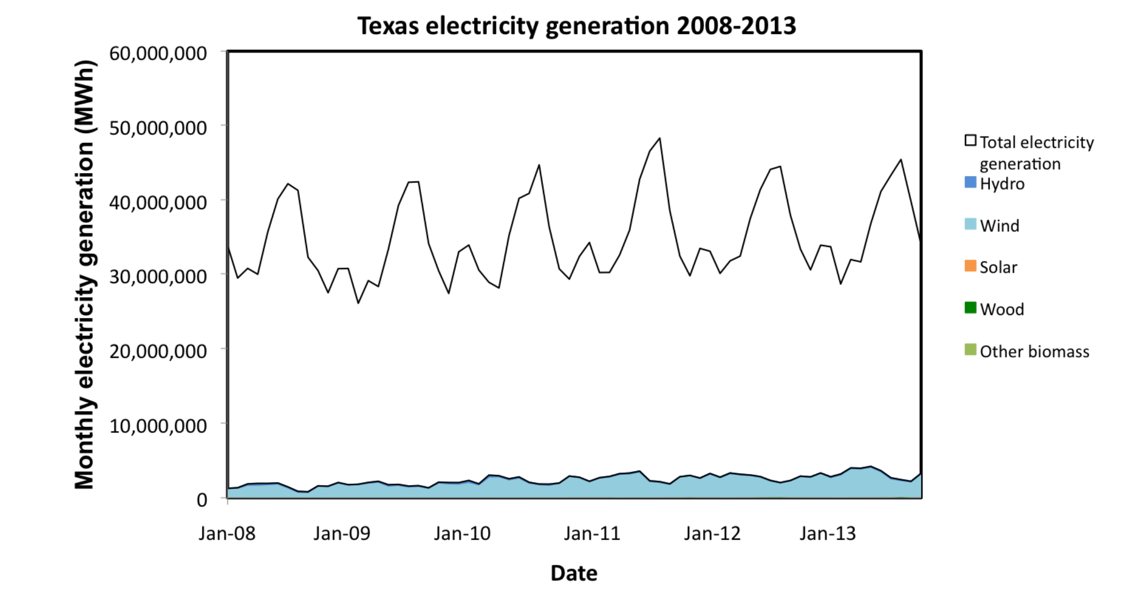

Figure 11: Electricity generation in Texas by source, 2008-2013.

Texas set its renewable energy targets as an installed capacity of 5,880 MW by 2015 and 10,000 MW by 2025, deviating from the standard approach of setting generation targets in terms of percent of total generation. As of 2013, installation has far surpassed both targets at over 12,000 MW [6]. Total summer capacity in Texas in 2010 was 108,258 MW. Wind generation in Texas is lowest in August, when demand reaches its peak, suggesting a role for increasing solar generation as wind penetration increases. As described earlier, solar and wind tend to peak at different times of the day, so even if resource coupling reduces annual variation, some type of short-term energy storage may also be important for smoothing daily variation in renewable

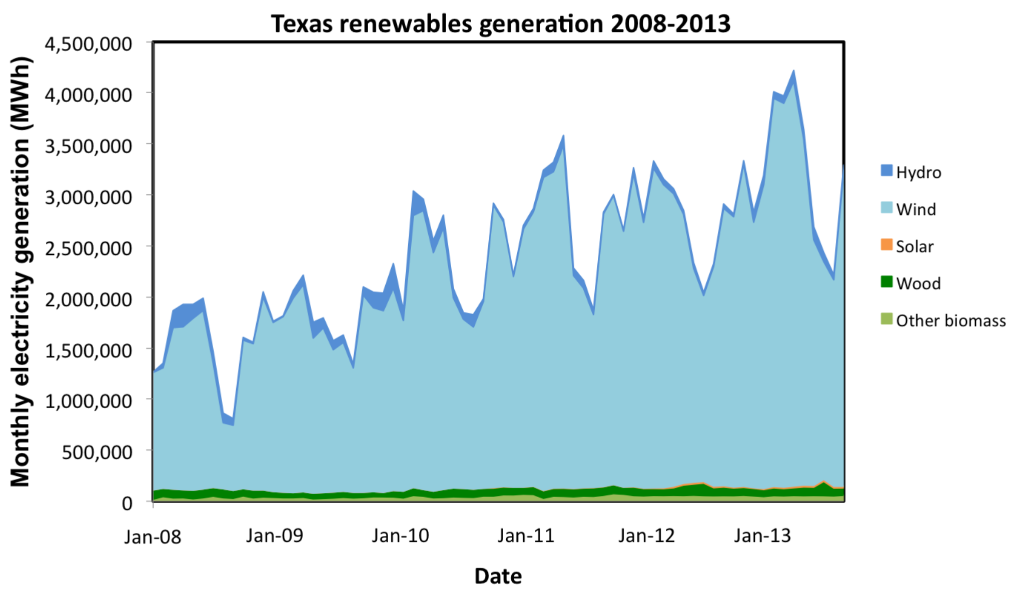

Figure 12: Renewable electricity generation in Texas by source, 2008-2013.

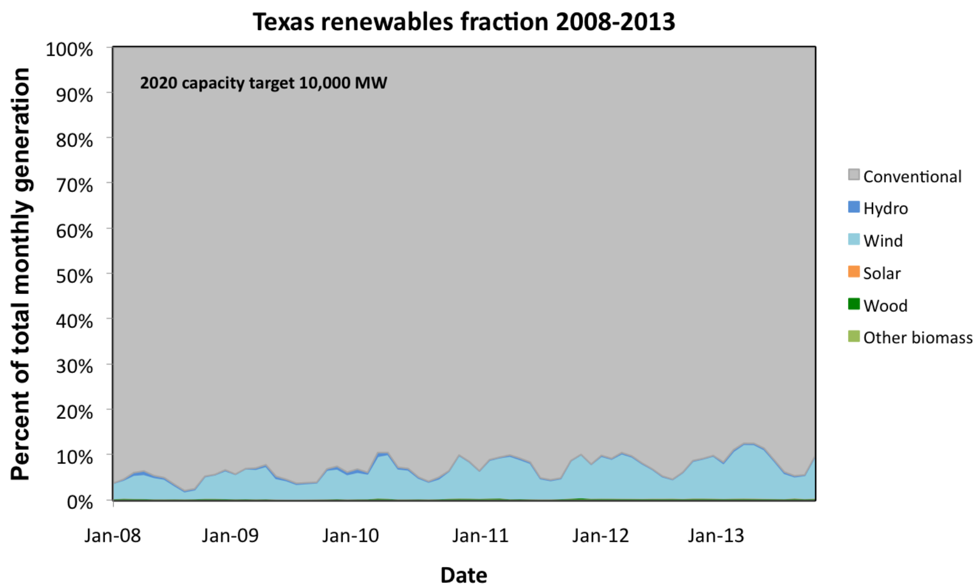

Figure 13: Fraction of electricity derived from renewables in Texas, 2008-2013. The RPS target is a capacity target of 10,000 MW by 2025.

generation. Energy efficiency and demand response measures may also play a role in reducing the summer peak.

7 Minnesota

Electricity generation in Minnesota peaks in the winter and summer, while in-state renewables generation is greatest in spring and fall (Figure 14). Renewable generation is dominated by wind, with some contribution from wood, biomass, and hydroelectric power (Figure 15).[2]

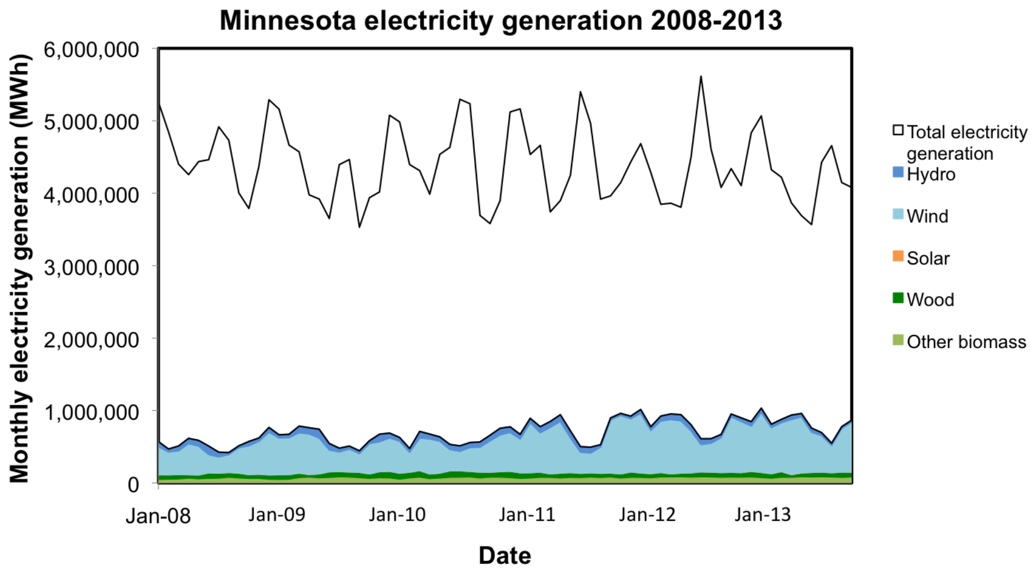

Figure 14: Electricity generation in Minnesota by source, 2008-2013.

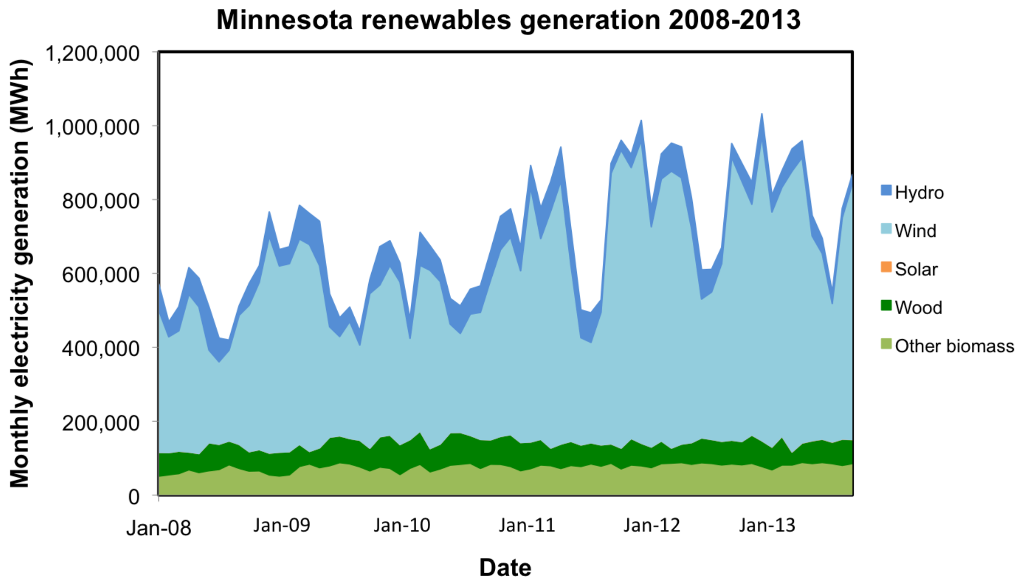

Figure 15: Renewable electricity generation in Minnesota by source, 2008-2013.

[2] The original EIA dataset contains a small contribution from geothermal for the year 2011, but this generation is absent from other datasets and so is not included here.

Minnesota has structured its RPS targets such that they vary by utility. The largest utility, Xcel, has the highest of these targets: 25% by 2016 and 31.5% by 2020 with specific wind and solar goals. Other public utilities are required to reach 17% by 2016 and 21.5% by 2020, and non-public utilities 17% by 2016 and 20% by 2020. Renewable energy credits can be used towards compliance. Targets and total state generation are shown in Figure 16.

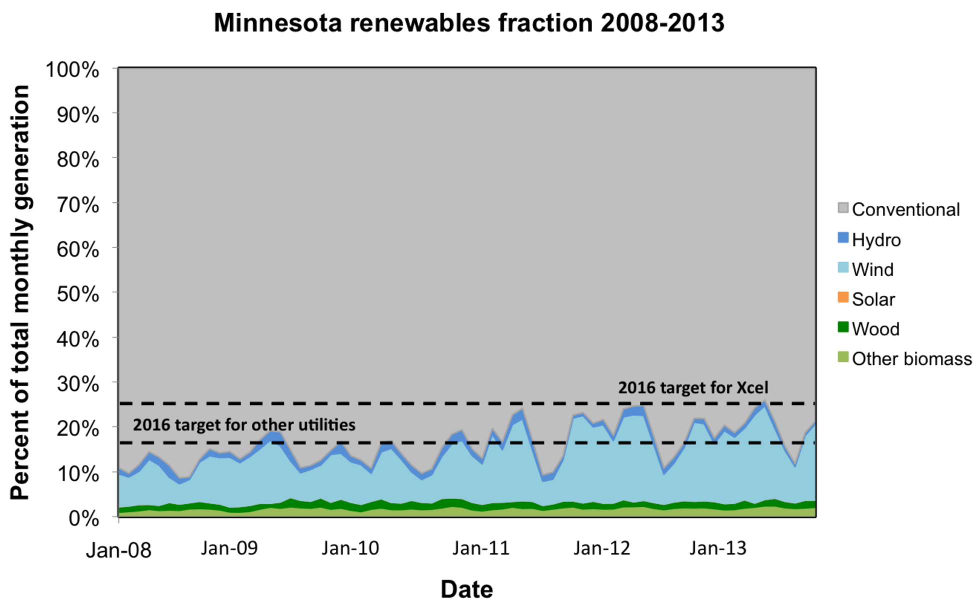

Figure 16: Fraction of electricity derived from renewables in Minnesota, 2008-2013. Minnesota's RPS targets vary by utility.

Minnesota has been adding wind capacity, but has even larger wind resources available. The National Renewable Energy Laboratory (NREL) predicts that Minnesota could generate 1,679,000 GWh per year from wind turbines running at greater than 30% capacity [7]. For context, Minnesota generation is currently 52,560 GWh annually from all sources [2].

8 Indiana

Indiana relies almost entirely on conventional electricity generation, primarily powered by coal (Figure 17). Indiana's first wind farm was brought online in mid-2008, and generation has grown since then (Figure 18). Biomass and hydroelectric power each provide less than 0.5% of generation, but the contribution from solar is negligible. Renewables generation as a fraction of the total is shown in Figure 19.

Indiana has set a voluntary target for utilities of 10% "renewables" by 2025 with intermediary targets of 4% for 2013-2018 and 7% for 2013-2018. The requirement for "renewables" is very broad, however, and includes up to 30% contribution from nuclear, clean coal, natural gas displacing coal, and other sources not typically categorized as renewables. Indiana is not without renewable energy resources, however.

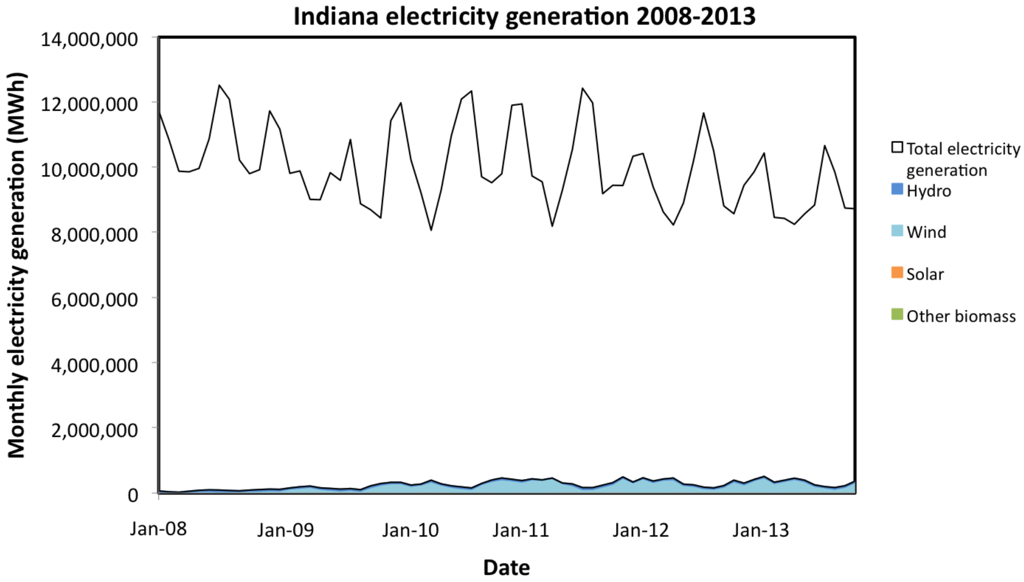

Figure 17: Electricity generation in Indiana by source, 2008-2013.

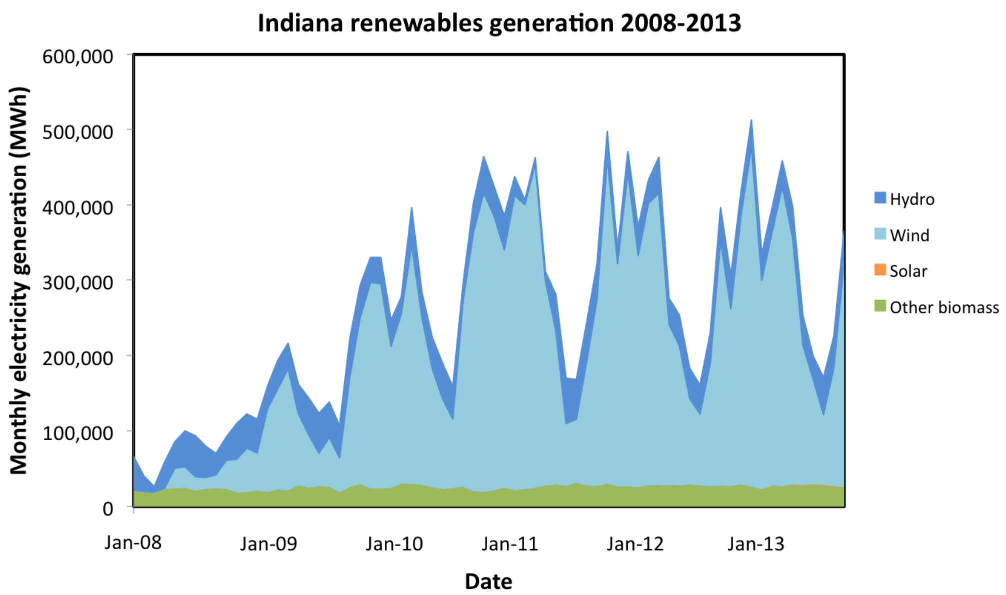

Figure 18: Renewable electricity generation in Indiana by source, 2008-2013.

NREL has estimated that that wind turbines running at 30% or greater capacity factor at or above a height of 80m could generate 443,912 GWh per year – more than four times the estimated potential for all of California [7] and also about four times Indiana's total generation in the last year. From November 2012 to October 2013 Indiana generated 110,333 GWh from all resources, but only 3,243 GWh from wind.

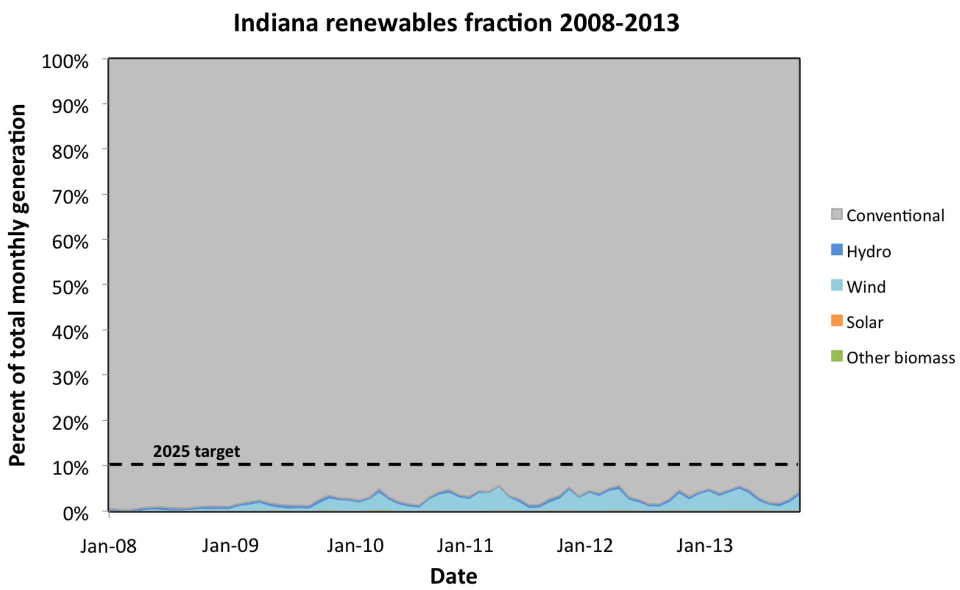

Figure 19: Fraction of electricity derived from renewables in Indiana, 2008-2013. Indiana's RPS target is 10% by 2025, with a broad definition of renewables including nuclear power.

9 Discussion

The electricity generation data presented above highlights the need for very different renewable energy strategies in each state, based not only on the potential resource base but also on existing generation and demand cycles. Wintertime peaks in generation are low in warm states like Texas and California, but in Minnesota are nearly as high as the summer peaks. Hydroelectric power shows much greater annual variation in California, where melting snowpacks recharge the reservoirs every spring, than in New York. Variation in annual generation from wind is also region-dependent. Much as generation resources in the power sector today vary greatly by state, the transition from conventional to renewable energy sources will look very different in New York than it will in Indiana or California.

Despite their many differences, renewable transitions in one state can provide examples and lessons for others to follow. Indiana could follow the lead of Minnesota, for example, and ramp up wind generation. Electricity prices in Minnesota were less than a cent higher than in Indiana as of October 2013 [8], in spite of its much higher fraction of electricity from renewables (Figure 16 and Figure 19). California and other southwestern states have demonstrated that while countrywide adoption of solar is slow, much faster rates are feasible. Texas easily passed its renewable capacity targets with wind, but could greatly strengthen its targets for solar and may benefit from doing so during the hot summer months when electricity demand peaks. While the mix of guidelines across states may be difficult to navigate, they also offer a variety of potential policy models for other states to follow. If Indiana were to ramp up its targets, it could set a capacity requirement like Texas or goals for specific utilities like Minnesota if statewide generation goals are difficult to pass in the legislature.

Increasing the geographic scope and the pace of renewable energy deployment faces different challenges in each state. California, for example, has generated more than 20% of electricity from non-hydroelectric renewables during some months. At these high penetration rates, intermittency becomes an increasingly important consideration. Intermittency is less pressing in places like Indiana, which installed its first wind farm in 2008 and has only a small total contribution from renewables in its power mix. Even if the addition of renewable power may be technologically straightforward, RPS targets may be difficult to enact due to political reasons in many states. In California, there is a lot of political will behind the advancement of renewable energy, and the installed capacity of these technologies has grown rapidly. Subsequently, the state is now facing novel technical hurdles for optimizing the integration of intermittent renewable resources, demand response, efficiency, storage and improved transmission in such a way that its 33% renewable energy targets can be met by 2020. The strategies that California and other states test as they ramp up their renewables capacity can be used as an example for states that are earlier in their transition. The rest of the country may benefit greatly from technical- and knowledge-transfer from first adopters, accelerating the integration of renewable energy into the power sector.

References

[1] M. Z. Jacobson and M. A. Delucchi, "Providing all global energy with wind, water, and solar power, Part I: Technologies, energy resources, quantities and areas of infrastructure, and materials," *Energy Policy*, vol. 39, no. 3, pp. 1154–1169, 2011.

[2] Energy Information Association, "Electric power monthly." www.eia.gov/electricity/data/state/generation_monthly.xls, [Accessed: 12/23/13], October 2013.

[3] DSIRE, "Database of states incentives for renewables and efficiency." www.dsire.org [Accessed: 12/23/13], December 2013.

[4] Larry Sherwood, "U.S. solar market trends 2012." Interstate Renewable Energy Council, July 2013.

[5] Go Solar California, "Program totals by administrator." www.californiasolarstatistics.ca.gov [Accessed: 12/23/13], December 2013.

[6] American Wind Energy Association, "State wind energy statistics: Wind." www.awea.org/Resources/state.aspx?ItemNumber=5183 [Accessed: 12/23/13], June 2013.

[7] National Renewable Energy Laboratory, "Estimates of windy land area and wind energy potential, by state." www.windpoweringamerica.gov/pdfs/wind_maps/wind_potential_80m_30percent.pdf [Accessed: 12/23/13], April 2011.

[8] Energy Information Association, “Electric power monthly with data for October 2013.” www.eia.gov/electricity/monthly/pdf/epm.pdf [Accessed 12/30/13], December 2013.