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Renewable Minnesota

A technical and economic analysis of a 100% renewable energy-based electricity system for Minnesota

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- Arjun Makhijani, Christina Mills, and M.V. Ramana

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This report is available online at http://www.ieer.org/reports/renewableminnesota.pdf

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Executive Summary

The electric energy sector in Minnesota, and more generally the United States, is in a state of transition, with considerable uncertainty regarding the future costs of carbon-dioxide (CO_2) and other greenhouse gas emissions. Utilities must also comply with more stringent clean air requirements, which particularly affect coal-fired power plants, many of which utilities may opt to shut down. Additionally, there is a growing momentum for utilities to protect themselves and their ratepayers against volatile fossil fuel markets. For some, nuclear power seemed to be the answer to these questions, despite its costs and risks.

At the same time, the pace and scale of renewable energy development has been rapid. The United States has an installed capacity of wind energy approaching 47,000 megawatts (MW) and installed grid-connected solar electric capacity of 3,100 MW. [1] Solar installations have increasingly become large-scale, with growing numbers of photovoltaic (PV) and concentrating solar power (CSP) projects having capacities in the tens or hundreds of megawatts per installation. At the same time, the number of residential solar projects has also continued to increase.

This momentum has also led to improving the cost-effectiveness of renewable energy generation. For instance, in the Dakotas and Wyoming, where wind energy capacity factors are on the order of 40 percent, the costs of wind-generated electricity are comparable to new coal or natural gas combined cycle power plants without including subsidies or a price on carbon. Wind-generated electricity is also less expensive than nuclear and remains lower than nuclear even when storage costs are added.[2]

Renewable energy resources are plentiful across the country. Studies of the Midwest and the footprint of the regional transmission organization, the Midwest Independent Transmission System Operator (MISO), have routinely shown the high wind energy potential in the central corridor of the United States, including Minnesota. The state is endowed with ample wind and solar energy resources, and over the years has developed a strong public policy foundation to support development of these resources. This study examines how Minnesota might take advantage of these resources to design a renewable energy-based electricity system.

[1] AWEA 2012 and SEIA and GTM Research 2011 p. 3

[2] All cost estimates in this study are market-based estimates to the extent possible. Specifically, subsidies such as investment tax credits, production tax credits, federal loan guarantees, and interest-free financing by ratepayers are not included in any of the cost estimates.

Our overall goal is to examine whether a fully renewable energy-based electricity system is technically and economically feasible for the state of Minnesota. In 2007 the state articulated a goal of significantly reducing the greenhouse gas emissions from all sectors. Since 1970 the electricity sector has been a leading source of emissions, and has been the only sector to continually increase its emissions over the past 40 years. Clearly a dramatic reduction in electricity sector emissions will be critical in achieving any significant reduction in greenhouse gas emissions overall.

Pioneering a renewable grid: dealing with the "relational system peak"

A principal insight that emerges from this study is that the conventional notion of a "peak load" needs to be replaced in designing an electricity system with a high proportion of solar and wind energy. At present the system peak is determined entirely by consumers – it is the time of highest simultaneous load on the system. In a renewable energy system with storage, depending on how it is configured, it is entirely possible that there may be plentiful electricity generated at such times. The crunch time may be during periods when the wind and solar supply are low *relative* to demand. So it is possible for a system "peak" – i.e., maximum use of generation from stored energy – to occur when demand is not at its highest. Indeed, this will often be the case. We have called this phenomenon the "relational system peak." The electricity system of the future, if it is to have a large fraction of solar and wind energy, will need to optimize these renewable energy investments with investments in specific technologies such as combined heat and power (which increases both generation and efficiency), making use more efficient at critical times of the year, and demand dispatch to reduce the relational system peak. Instead of the peak load that drives marginal investments in generation as at present, dealing with the relational system peak will require comprehensive consideration of investments throughout the system – generation, demand, and storage (though not necessarily by utilities in all cases).

We used historical data on electricity supply and demand from Xcel Energy, which is the state's largest electricity provider and is a good representative of these parameters for the state as a whole, and the best available industry data on the various energy technologies. This approach allowed for a methodology that limited the potential for error that can be expected from a more complex and resource intensive forecast model, while also providing a reasonable analysis of the feasibility of a fully renewable electricity system. Using the same criteria for reliability that apply today, we found that it is technically and economically feasible to meet the entire 2007 electricity demand of Xcel Energy using only renewable energy generation combined with storage technology and energy efficiency improvements. We assume that the composition of renewable energy generation is a mix of commercial-scale wind energy and rooftop solar PV, due to economies of scale and the most likely application of each technology in Minnesota. Further, Minnesota's renewable energy resources are large enough to accommodate any foreseeable growth in electricity demand in the next four decades and beyond. Hence, we were able to start with the analysis of the 2007 Xcel data and extend it to the whole state when assessing cost and jobs implications.

This study is a first step. We did not attempt to model an intelligent electricity grid in which large numbers of distributed generation sources and storage types, and smart appliances are managed as an integral part of a larger grid operation, due to the difficulties in estimating the costs and shape of such a system. Neither the data nor the system integration modeling capabilities are publicly available today at a level of detail needed for a reliable technical analysis, much less a cost analysis. Yet the need for such a design tool emerges very clearly from our analysis.

The storage technology that we assume for our analysis is compressed air energy storage (CAES), which has been used commercially for decades with coal-fired power plants in two locations: Germany and Alabama. Compressed natural gas storage in caverns and aquifers is also a standard technology. CAES is only one option for commercial scale storage technology, and because it has a proven track record, we have used it as the placeholder technology for the storage capacity needed. Minnesota does have geology that may be suitable for CAES at many locations; however, in-depth investigations are needed to identify potential sites. A single storage technology allows a straightforward determination of technical feasibility as well as cost. In practice a mix of storage technologies as well as demand dispatch, which shapes the part of load curve in relation to the available supply and storage, would be used.

The notion that solar and wind energy cannot be the mainstay of an electricity generation system because they are intermittent is incorrect. This study shows that they can be dispatched reliably – when there is storage. In our analysis we maintain the usual reliability criterion – 12 percent reserve margin over demand – for every hour of the year. And such a system does not have to be prohibitively costly. As it turns out, a 100 percent renewable energy-based electricity system for Minnesota increases rates by a mere 1-2 cents per kilowatt hour when sufficient reasonable and economical investments are made in energy efficiency.

While one reason to pursue renewable energy in the electricity sector is to provide a hedge against volatile fossil fuel prices and to provide a lower financial risk for investors, another reason is that renewable energy-based electricity provides a better product to society. The electrons speeding through the wires of the grid are the same, but the social, health, and safety consequences are far different. People will literally breathe easier, water use will be lower, and the risks related to CO_2 emissions will be nearly eliminated from the electricity sector. We do not examine the net jobs impact, but do discuss the broader overall jobs potential from renewable energy development in Minnesota.

Main Findings

- **A renewable energy-based electricity sector is technically feasible**, using available and proven technologies. If this is supplemented with an intelligent grid with two-way communication and more efficient use and integration of distributed generation and storage resources, this can help reduce the costs of implementing a renewable energy-based electricity sector.
- **There are ample renewable resources in Minnesota**. There is more than enough wind and solar energy potential to meet the entire 2007 demand of Xcel Energy's customers every hour and to accommodate growth in the foreseeable future. These technologies are already commercially available. While we have not examined the subject in detail here, there is evidence that the requisite amount of utility-scale storage technology can also be installed within the state.
- **An efficient, renewable electricity system can be achieved at an overall cost comparable to the present total cost.** The added costs of renewable energy generation, as compared to the current generation from mature and fully-depreciated fossil fuel and nuclear generation facilities, can be offset by increasing the energy efficiency of household and building appliances. The net costs of electricity services – lighting, cooling, running appliances, etc., would be the same as today, but partitioned between generation, storage, efficiency, transmission and distribution.
- **Energy efficiency lowers the effective cost of electricity services and electricity bills.** There are ample opportunities for reducing electricity use while maintaining the same level of services such as lighting and cooling and running computers. For instance, a more efficient refrigerator or air conditioner would provide the same level of cooling, but would use less electricity to do so. But the investment in the refrigerator would be a little more compared to an average model. Appliance and building energy standards, supplemented by utility programs, are an effective way to have high penetration of energy efficiency measures and achieve cost savings.

Recommendations

In order for Minnesota to achieve any significant reduction in greenhouse gas emissions, dramatic changes to the electricity sector are necessary. We have identified a number of steps that can help position Minnesota to utilize its available renewable energy resources, as well as create a more informed technical and cost framework for transitioning to a renewable energy-based electricity sector:

- Initiate a detailed, state-wide energy efficiency study, including the technical and economic aspects and the effect of efficiency and demand dispatch investments on the electricity demand pattern and on relational system peaks.
- Require utilities to include increased renewable energy and storage in their Integrated Resource Plans by modeling what it would take to meet their projected demand with only renewable energy resources and the steps, time, and investment it would take to accomplish that goal..
- Initiate a study that would address how demand dispatch, storage, specific efficiency measures, and combined heat and power could be combined to reduce the costs of a fully renewable electricity system.
- Initiate a detailed exploration of the feasibility of CAES and other utility-scale storage options in Minnesota.
- Further refine the findings in this report by developing an optimized framework for reducing the relational system peak.
- Conduct similar studies at the regional level in cooperation with other states in the Midwest.
- Adopt a state-wide goal for achieving a 100 percent renewable energy standard, with achievable benchmarks and milestones and a periodic review of progress every few years.