Grid Integration of Wind & Solar

Challenges, Progress, Future Developments

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April 16, 2016
University of Minnesota Workshop

This presentation represents the views of Commissioner Schuerger and not necessarily those of the Minnesota Public Utilities Commission as a whole.

Outline

- Challenges; Successes
- Wind Integration in the Midwest
- MN Renewable Energy Integration & Transmission Study
- Balancing the Grid; Distributed Resources
- Summary - The Future Electric Grid

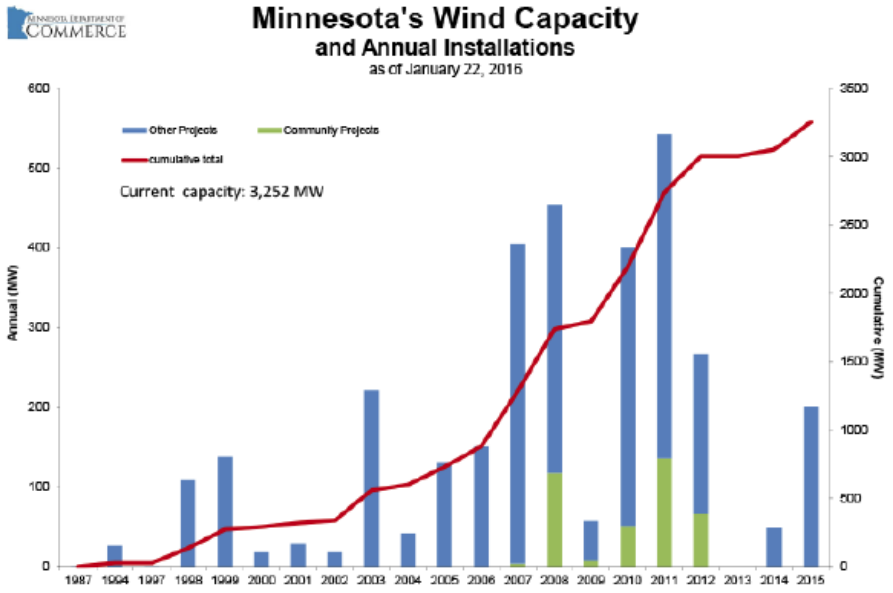
Minnesota Studies, Additional Reading, Biography

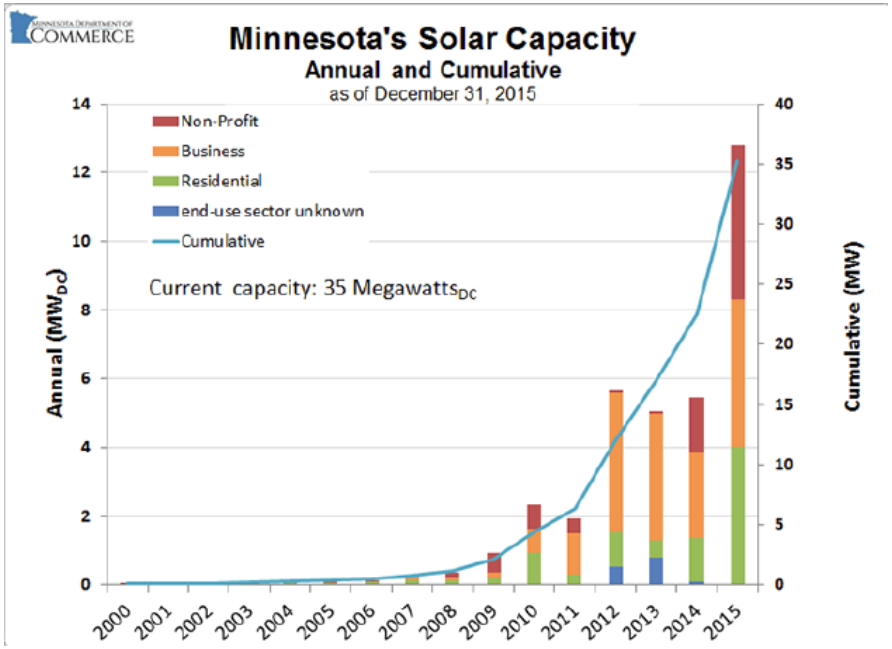
Challenges

- **Reliable power system operation requires balance between load and generation**
- Physical power systems and competitive wholesale markets were designed around the operation of traditional forms of generation
- **Power system operators are constantly faced with variability and uncertainty**
  - Wind and solar generation adds to the variability and uncertainty of power system
  - **In real time operations, the system must respond to the *net load* including both expected and unexpected variations**

Successes to Date

Regional wind generation, and now regional solar generation, are growing rapidly





Growth due to:

- **Significantly improved technology** (power electronics, controls, physical attributes, etc);
- **Plummeting costs *and* increasing value** (energy, capacity, grid services, operational security, etc); and
- **Vast advancements in understanding how to plan and operate power systems with high levels of variable renewables**

Wind Integration into the Midwest Regional Grid

2000s: Work on grid integration of large amounts of wind generation in Minnesota and the upper Midwest began:

- **Initial work focused on interconnection** of individual wind plants (performance, technology) to the existing grid (rules/standards, topology, operational practices);
- Several MN integration and MISO transmission studies facilitated significant learning on all sides of the challenge; ***Higher penetrations required a forward looking systems approach & regional consensus on planning scenarios***.

Today: Regional grid operator (MISO) & MN utilities are successfully integrating large amounts of wind generation into the regional grid:

- **The regional grid is operated and planned differently** (wind forecasting in unit commitment, dispatch, regional MVP transmission lines); **new approaches/tools; improved market rules**;
- Wind generators are able to and are required to perform much better (Low Voltage Ride Through, reactive power, dispatched);
- **Reliability is high, impacts are low, costs are low**.

Next decade: Ongoing regional work; And, **much more local distribution work**.

Minnesota Renewable Energy Integration and Transmission Study (MRITS 2014)

- **Engineering study of increasing Minnesota wind and solar generation to 40% by 2030**, and to higher proportions thereafter, **while maintaining system reliability**;
- Completed **by the Minnesota utilities** and transmission companies, in coordination with the regional grid operator (MISO); **with independent, expert technical review** throughout the study by a committee appointed and led by the MN Department of Commerce
- Study incorporates three core and interrelated analyses:

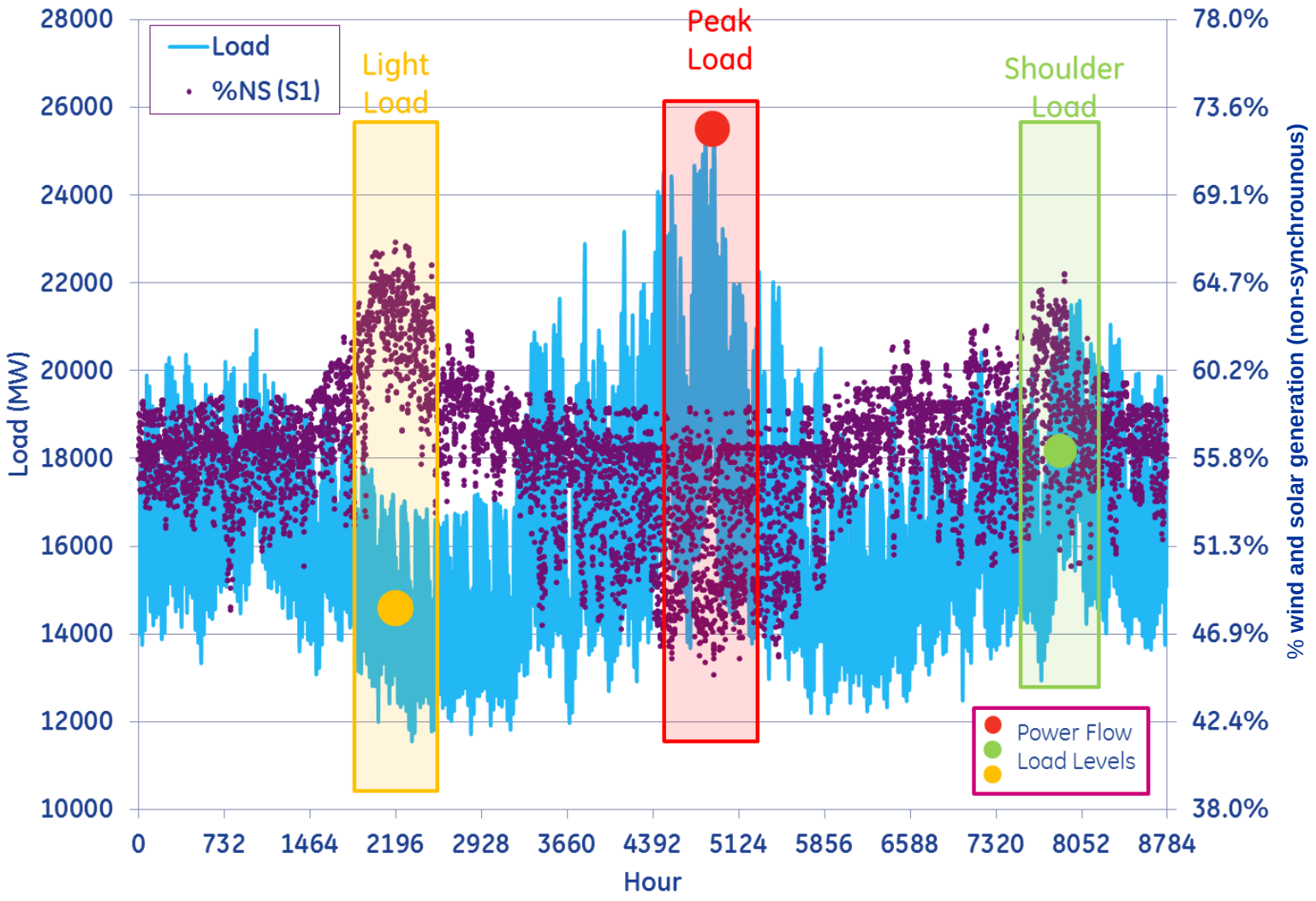
  1) ***Power flow analysis*** – development of a conceptual transmission plan, which includes transmission necessary for generation interconnection and delivery and for access to regional geographic diversity and regional supply and system flexibility;

  2) ***Production simulation analysis*** – evaluation of **hour by hour operational performance** of the power system for an entire year (sufficient reserves, load served, wind / solar curtailments, ramp range and rate, and thermal cycling); and

  3) ***Dynamics analysis*** – evaluation of **transient stability** (ability of the regional power system to return to steady state following some type of disturbance) and **system strength** (ability of an ac transmission system to support stable operation of large amounts of inverter-based generation).

MRITS Study Operational Performance Analysis – Identification of Challenging Hours

Chronological Load and % Wind & Solar Generation



MRITS Study Key Findings

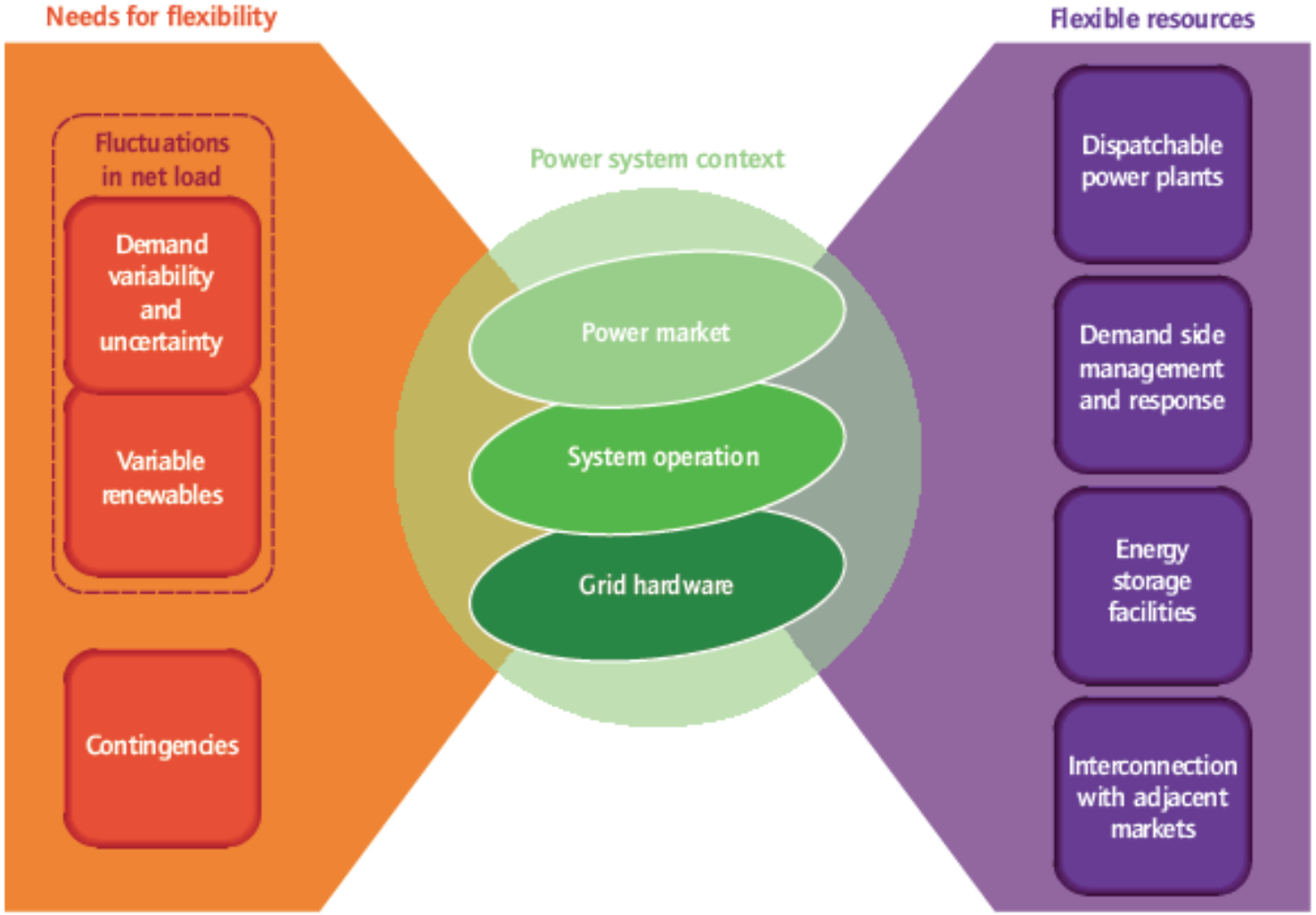
- **The power system can be successfully operated for all hours of the year with wind and solar resources increased to 40% for Minnesota** (and with current renewable energy standards fully implemented in other Midwest states); Requires some upgrades to existing transmission lines.

  There are no fundamental system-wide dynamic stability or voltage regulation issues introduced with wind and solar resources increased to 40% for Minnesota.

- The system can be successfully operated for all hours of the year with wind and solar resources increased to 50% for Minnesota (and with current renewable energy standards in other Midwest states increased by 10%); Requires significant upgrades and expansions to the transmission system.

Grid Balancing and Flexibility

Numerous peer reviewed studies have shown that integrating large amounts of wind and solar generation into the regional grid is effectively a balancing challenge (Tens of minutes to hours)



Source: *Harnessing Variable Renewables. IEA.*

Distributed Energy Resources

Supply and demand side resources that can be used throughout an electric distribution system to meet energy and reliability needs of customers; can be installed on either the customer or the utility side of the electric meter

- Include ***Efficiency*** (End use efficiency),
- ***Distributed Generation*** (Solar PV, Combined heat and power, Small wind),
- ***Distributed Flexibility and Storage*** (Demand response, Electric vehicles, Thermal storage, Battery storage), and
- ***Distributed Intelligence*** (Information and control technologies that support system integration)

Summary - The Future Electric Grid

- Today's electric grid is reliable, affordable, increasingly clean;
- **Large amounts of wind and solar generation are being successfully integrated into the regional grid now – much more over next decade;**
- **The grid is at a time of significant change,** drivers include:
  - **Evolving public policy**, new environmental regulations, de-carbonization;
  - **Changing consumer demands**, increasingly engaged customers;
  - **New distributed technologies**, both supply and demand side resources;
- **Tomorrow's grid will optimize and extract value throughout the grid**
  - will be more distributed and flexible;
  - will operate resiliently against natural disaster and attacks;
  - will be cleaner, reliable, and affordable;
- The **regional transmission grid and markets will continue to be vital**;
- The **local electric distribution systems will need updated planning** to support a reliable, efficient, robust grid in a changing (and uncertain) future.

Thank you!

- *Discussion and Questions*

Minnesota Studies

Minnesota Renewable Energy Integration and Transmission Study (MRITS)

"Minnesota Renewable Energy Integration and Transmission Study – Final Report." October 2014.

MRITS – presentation slides. November 2014 Webinar; January 2015 PUC Planning Meeting.

http://mn.gov/commerce/industries/energy/distributed-energy/mrits.jsp

Dispersed Renewable Generation Studies – MN Transmission Owners

"Dispersed Renewable Generation Study – Phase II." Prepared for the Minnesota Department of Commerce Office of Energy Security, September 2009.
https://www.cards.commerce.state.mn.us/CARDS/security/search.do?method=showPoup&documentId={EBF556A0-8947-465E-B361-1A3ACF7E6FEE}&documentTitle=35425&documentType=6

Dispersed Renewable Generation Study Phase II Presentation, September 2009.

"Dispersed Renewable Generation Study – Phase I." Prepared for the MN Department of Commerce OES, June 2008.

Dispersed Renewable Generation Study Phase I Presentation, June 2008.
http://uvig.org/resources/#!/3700/u-s-regional-and-state-studies

Minnesota Wind Integration Study – EnerNex and WindLogics

"Final Report – 2006 Minnesota Wind Integration Study, Volume I." Prepared for the MPUC, Nov 2006.
http://uvig.org/wp-content/uploads/2013/01/windrpt_vol-1.pdf

"Final Report – 2006 Minnesota Wind Integration Study, Volume II – Characterizing the Minnesota Wind Resource." Prepared for the Minnesota Public Utilities Commission, November 2006.
http://uvig.org/wp-content/uploads/2013/01/windrpt_vol-1.pdf

Wind Integration Study Presentation, December 2006.
http://uvig.org/wp-content/uploads/2013/01/windpresent.pdf

Xcel Wind Integration Study – EnerNex and WindLogics

"Xcel Energy and the MN Department of Commerce Wind Integration Study – Final Report." Sept 2004.
Wind Integration Study Presentation, September 2004.
http://uvig.org/resources/#!/3700/u-s-regional-and-state-studies

Additional Reading

Ackerman, Thomas. *Wind Power in Power Systems.* New York: John Wiley & Sons. Second Edition. 2012.

Barbose and Darghouth. *Tracking the Sun VIII: The Installed Price of Residential and Non-Residential Photovoltaic Systems in the United States.* Lawrence Berkeley National Laboratory, August 2015. http://energy.gov/eere/sunshot/downloads/tracking-sun-viii-installed-price-residential-and-non-residential

DeMeo, Jordan, Kalich, King, Milligan, Murley, Oakleaf, and Schuerger. *Accommodating Wind's Natural Behavior: Advances in Insights and Methods for Wind Plant Integration.* IEEE Power & Energy Magazine, Nov/Dec 2007.

De Martini and Kristov. *Distribution Systems in A High Distributed Energy Resource Future: Planning, Market Design, Operation, and Oversight.* Oct 2015. https://emp.lbl.gov/sites/all/files/FEUR_2%20distribution%20systems%2020151023.pdf

Milligan, Frew, Kirby, Schuerger, Clark, Lew, Denholm, Zavadil, O'Malley, and Tsuchida. *Alternatives No More: Wind and Solar Power are Mainstays of a Clean, Reliable, Affordable Grid.* IEEE Power & Energy Magazine, Nov/ Dec 2015.

Milligan, Porter, DeMeo, Denholm, Holttinen, Kirby, Miller, Mills, O'Malley, Schuerger, and Soder. *Wind Power Myths Debunked: Common Questions and Misconceptions.* IEEE Power & Energy Magazine, Nov/Dec 2009.

MN Dept of Commerce. *Minnesota Renewables Update.* February 2016. http://mn.gov/commerce/assets/MinnesotaElectricityRenewable_tcm17-156466.pdf

MN PUC. *Staff Report on Grid Modernization.* March 2016. Docket CI-15-556, http://mn.gov/puc/.

Schuerger, Johal, Roose, Matsuura, and Piwko. *Catching Some Rays: Variable Generation Integration on the Island of Oahu.* IEEE Power & Energy Magazine, Nov/Dec 2013.

Smith, Parsons, Acker, Milligan, Zavadil, Schuerger, and DeMeo. *Best Practices in Grid Integration of Variable Wind Power: Summary of Recent US Case Study Results and Mitigation Measures.* EWEC 2007, Milan, Italy. May 2007.

Wiser, R., Bolinger, M. *2014 Wind Technologies Market Report*. Lawrence Berkeley National Laboratory, August 2015. https://emp.lbl.gov/publications/2014-wind-technologies-market-0

International Energy Agency. *Expert Group Report on Recommended Practices for Wind Integration Studies*. Sept 2013. http://www.ieawind.org/index_page_postings/100313/RP%2016%20Wind%20Integration%20Studies_Approved%20091213.pdf

Utility Variable Generation Integration Group. http://uvig.org/newsroom/

National Renewable Energy Laboratory Grid Integration

- Integration of Large-Scale Renewable Energy into the Transmission System. http://www.nrel.gov/electricity/transmission/
- Distributed Grid Integration of Increasingly Large Amounts of Renewable Energy. http://www.nrel.gov/electricity/distribution/

Biography

Matt Schuerger was appointed to the Minnesota Public Utilities Commission by Governor Mark Dayton, effective February 1, 2016. His term will expire January 3, 2022.

Matt has over thirty years of experience in the energy industry as a senior manager and professional engineer including work with power system planning, energy markets, grid modernization, distributed energy resources, grid integration of renewable energy, energy policy, strategic planning, and business development. From 2001 until he was named to the Commission, he was the president of an engineering and management consulting firm. Prior to that, Matt was the Executive Vice President of District Energy St. Paul Inc., a privately held provider of district heating, district cooling, and cogenerated electricity.

Renewable energy integration projects include work as a consultant for the Minnesota Department of Commerce on the 2013/2014 Minnesota Renewable Energy Integration and Transmission Study and on the 2013/2014 Minnesota Value of Solar Methodology development; for DOE's National Renewable Energy Laboratory on the 2012 Hawaii Solar Integration Study, the 2011 Maui Smart Grid Demonstration Project, the 2010 Oahu Wind Integration and Transmission Study, and the 2009 Eastern interconnection Wind Integration and Transmission Study; for the Minnesota Department of Commerce on the 2008 and 2009 Minnesota Dispersed Renewable Generation Studies; for the Minnesota Public Utilities Commission on the 2006 Minnesota Wind Integration Study; and for the Minnesota Department of Commerce on the 2004 Xcel Wind Integration Study.

Matt is a licensed professional engineer and has a M.S. in electrical engineering from the University of Minnesota, an MBA from the University of St. Thomas, and a B.S. in mechanical engineering from Purdue University.