Collaborating to find least-risk, best-value strategies for Minnesota to achieve its solar energy goals

Association of Energy Services Professionals
November 13, 2019
MN Solar Pathways is a 3-year award from US DOE.
10% Solar by 2030

**216B.1691 Renewable Energy Objectives.**

Subd. 2f. (c) It is an energy **goal** of the state of Minnesota that, by 2030, ten percent of the retail electric sales in Minnesota be generated by solar energy.

10% Solar is approximately 6 Gigawatts of solar capacity by 2030
Project Timeline

- **2017**
  - **Interconnection Work | YR 1**
    - Examine current interconnection processes at utilities across the State of Minnesota

- **2018**
  - **Enhanced Hosting Capacity | YR 1-2**
    - Quantify how new technologies can impact the grid’s ability to host solar energy
  - **Solar Potential Analysis | YR 1-2**
    - Estimate the generation cost to achieve 10% solar by 2025 and 70% solar and wind by 2050

- **2019**
  - **Solar Deployment Strategy | YR 2-3**
    - Calculate the economic impacts and market incentives created by different solar portfolios

- **2020**
  - **Interconnection Work | YR 1**
    - Examine current interconnection processes at utilities across the State of Minnesota

MN Solar Pathways
Interconnection Streamlining
If you remember nothing else:

Transparency and Automation
Drivers - Increased Pressure

• Emerging Challenges:
  • Growing connection queues
  • Pressure to improve procedural consistency, transparency, and automation
  • Inconsistent technical screens to address reliability concerns caused by DER
Data Gathering

Most information was derived from detailed in-person interviews

Geographically-dispersed group included:

• three investor-owned utilities (IOUs),
• two cooperative utilities (co-ops)
• one municipal utility
Evaluation - Functional Elements

1. The ability to respond to interconnection applicants in a consistent and timely manner.
2. Interconnection application process transparency.
3. Support for application status tracking.
4. Sharing of non-identifying information via a regularly maintained public queue.
5. The ability for utility customers to apply for interconnection online.
6. Automated management of the application approval process.
7. Identified opportunities for increasing the automation of technical screens.
MN Solar Pathways

- **Stretch Goals**
  - Online Application Portal
  - Online Hosting Capacity Maps
  - Automated Document Generation

- **Moderate Intensity**
  - Queue Position Status Availability
  - Online Payment
  - Publicly-Available Educational/Training Classes

- **Low Hanging Fruit**
  - Informative & Easily Navigable DG Website
  - Single Point-of-Contact for Applicants
  - Customer Application Checklist

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Enhanced Hosting Capacity Analysis
Hosting Capacity

“The amount of DER that can be accommodated without adversely impacting quality or reliability under existing control configurations and without requiring infrastructure upgrades”
**Constraints**

1. Thermal Overload
2. Voltage (Over and Deviation)
3. Rapid voltage change

**Potential Solutions**

Advanced Technologies

- Smart inverters (distributed and centrally-coordinated control)
- Energy storage
- Thermal load shifting
- Curtailment
- Combined control of the above four technologies
### Results Summary

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Conclusion

• It Depends!
  • Smart Inverters
    • Successful on some feeders for voltage control, but limited effectiveness in rapid voltage change
  • Curtailment
    • Requires coordination of utility, developer and technology provider, but economics may pencil out (more on that later)
  • Thermal Load shifting
    • Limited benefit, particularly in low population density areas
  • Storage
    • Provided most flexibility, but 0% curtailment means uneconomic batteries
Solar Potential Analysis
Solar Potential Analysis

The Solar Potential Analysis estimates the generation cost to achieve 10% solar by 2025 and 70% solar and wind by 2050 in MN*.

**Inputs**

- **Hourly Data**
  - Simulated Solar (SolarAnywhere)
  - Measured Wind (MISO)
  - Utility Load (MISO)

- **Price Forecasts**
  - Solar PV
  - Wind Energy
  - Storage

**Scenarios**

- High & Low Development Production Profiles
- Utility-Led & All Sectors
- 2025 & 2050 Timeframes

**Analysis**

- Storage Dispatch
- Load Shifting
- Curtailment

**Outputs**

- Lowest Levelized Cost of Electricity (LCOE) and associated resource requirements*

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* The SPA is a production cost model for solar and wind only, and is specific to MN (does not include integration with MISO).

- Generation costs only
- Based upon installed costs

- No transmission or distribution costs
- Does not address rate structures
SPA Key Findings
SPA Key Finding #1

Solar and wind energy can economically serve 10% of Minnesota’s electrical load by 2025 and 70% by 2050.
SPA Key Finding #2

*Additional Capacity* coupled with appropriate dispatch (energy curtailment) is considerably less expensive than, and a viable alternative to, long-term or seasonal storage in a high renewables future.

*Additional Capacity* is solar and wind capacity over and above that needed to meet annual energy needs but still beneficial for improving the economic dispatchability of the solar/wind fleet.
SPA Key Finding #2 (continued)

MN Load
Solar Production

0% Additional Capacity

11% Additional Capacity

100% Additional Capacity
0% Capacity Overbuilding, 0% Curtailment

Zero overbuilding of solar capacity means seasonally shifting large amounts of energy.

Seasonal overproduction

Seasonal underproduction

*Note, this figure shows daily (not hourly) energy production
43% Capacity Overbuilding, 30% Curtailment

Seasonal energy shifting is required even at 30% curtailment

Roughly 3 months of underproduction
100% Capacity Overbuilding, 50% Curtailment

Around 50% curtailment, storage needs are determined by multi-day periods of low production.

Multi-day variability of solar production determines storage requirements as opposed to months.
Headlines

The Interchange by Greentech Media – Solar and Wind Curtailment: A Liability or Asset for Decarbonizing the Grid?

The Conversation – A radical idea to get a high-renewable electric grid: Build way more solar and wind than needed

Utility Dive – Minnesota study finds it cheaper to curtail solar than to add storage
Key Model Components

- Electrification
  - 75% residential heating & DHW
  - 95% light vehicle
- Meets hourly load
  - Fully-dispatchable
- Geographic diversity
  - Wind / Solar distributed throughout the state
70% Solar and Wind by 2050:

- **Solar Capacity**: 14 to 22 GW
- **Wind Capacity**: 12 to 22 GW
- **Storage Capacity**: 4 to 25 GW, 16 to 50 GWh
- **Other Generation**: 8 to 9 GW *unoptimized

Generation Costs:
- $37/MWh to $59/MWh

- Economic curtailment of surplus renewables is cheaper than long-term battery storage

Overbuilt by 2x (Additional Capacity)
SPA Key Finding #3

Flexible *Other Generation* resources used in limited amounts support a high renewables future.

*Other Generation resources* are non-solar and non-wind resources in Minnesota that meet a portion of the Hourly Production Requirements during brief periods of low-solar and wind resources.
Additional Capacity Decreases Storage Needs

- Doubling renewable capacity reduces storage requirements by 6x
Challenges of Economic Curtailment

• Who curtails what now?
  • 30% to 70% of solar is behind the meter
  • Curtailment may disproportionately fall on large (utility scale) systems

• How to transition from current energy market to one that supports additional capacity and economic curtailment?
  • Lowest system costs are not an incentive for individual systems
  • Uncertainty on future curtailment is large risk
Opportunities

• 40,000 GWh (~60% of current electricity)
  • Free?

• Large amounts of excess capacity to provide grid services
  • Capacity, frequency, contingency, voltage control

• Hydrogen and synthetic natural gas from Power-to-Gas (P2G) process
  • Supply zero-emissions materials to hard to reach chemical industry
    • Fertilizer, pharmaceuticals, plastics, jet fuel, heavy industry
  • P2G to use existing infrastructure into flexible long term energy storage
    • Synthetic natural gas for back up electric load, remaining direct combustion natural gas loads
Curtailment Takeaways

• Incremental cost of the last renewable kWhs are very high

• Additional capacity with large amounts of economical curtailment is a viable least cost pathway

• Economic curtailment is an unrecognized opportunity and may be a pathway to decarbonization beyond the electric sector
SPA Key Finding #4

Storage is an important part of a high renewables future; it expands the dispatch capabilities of wind and solar assets.
SPA Key Finding #5

Shifting key flexible loads (like new electric vehicles) could decrease electricity generation costs 10-20%.

Shifting key flexible loads (like domestic hot water) could decrease electricity generation costs 10-20%.
Solar Deployment Strategies
Solar Deployment Strategy (SDS)

- Shaped by stakeholder engagement
- A replicable, living analysis to inform choices between deployment strategies
- A technical analysis rather than seeking to set policy
- Calculates the economic impacts and market incentives created by different solar portfolios and rate structures and the consequent ability of utilities, ratepayers, institutions, communities and the State to realize solar priorities or goals
SDS Will Provide

• An agreed upon framework for studying the effects of increasing solar adoption

• A way to explore the degree to which various parameters affect value proposition outcomes
Solar Deployment Strategy

The Solar Deployment Strategy will calculate the economic impacts and market incentives created by different solar portfolios and rate structures.
SDS Planning Tool Overview

Models future adoption of solar in a defined region

Forecasts “behavioral response” to cost-effectiveness

- Electric rates
- Compensation policies for excess solar
- Incentives

Uses machine-learning methods

- Logistic regression of predictor variables
- Training on historical data
Example Use Cases

Forecast response to changes in rates or incentives
Forecast response by low income customers to targeted incentive
Evaluate PV Demand Credit Rider
Calculate future carbon reduction
Determine additional utility-scale solar to meet 10% state goal
SDS Planning Tool Inputs

Hourly customer load profiles (8760 hours)
• User-defined profiles, or
• Utility-provided profiles by class (MSP project only, protected by trade secret)
• Selectable loads by class (from AEP Ohio rate classes)

Hourly solar production profiles (8760 hours)
• User-defined profiles, or
• Selectable profiles (any of five orientations, CPR simulated for Minnesota)

Electric rates
• User-defined rates, or
• Selectable Xcel Energy rates (6 rates included)

Other (solar costs, escalation, etc.)
Example Case Study (Preliminary)

Region: Xcel Energy Service Territory
Class: Residential
Test: *What is the carbon impact of a $1 per Watt incentive?*
Xcel Energy Residential Rooftop Adoption
Distributed solar capacity per year

MW Per Year

Installed Capacity

Installed Capacity, Cum.


0 1 2 3 4 5 10 15 20
MN Installed PV Costs: Historical and Projected
Simple Payback Predictors: Model Training
Xcel Energy, Residential

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2019 Energy Rate ($/kWh) 0.108 (Residential)
PV Annual Energy (kWh/kW) 1211 (SW-45)
Escalation - Electric Rates 2%
Adoption Forecast
Xcel Energy, Residential
Avoided CO$_2$ with $1$ per Watt Incentive

Xcel Energy, Residential, Amount over Baseline
Conclusions: SDS Planning Tool

• Can forecast solar outcomes in any defined region
  • State
  • Utility
  • City

• Detailed bill calculations based on hourly loads and solar generation

• Use cases include evaluation of rates, incentives, program design

• Need more experience before using for CSG
Case Studies

• Case Study 1
  • Utility service territories extrapolated to state

• Case Study 2
  • Customer solar adoption response to market signals/changes

• Case Study 3
  • Alternative non-utility incentive programs working in conjunction with a non-NEM rate design
  • Consideration of local climate action or renewable energy goals
Applications & Partnerships

• Clarifying and updating policy interpretation

• Alternative siting solutions

• Alternatives to traditional PPA structures
Thank You!
FIND OUT MORE AT
mnsolarpathways.org

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