



MN **SOLAR** PATHWAYS

illuminating pathways to 10% solar

Additional Capacity, Curtailment and Synthetic Natural Gas: A recipe for a high renewables Minnesota?

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MN Solar Pathways is a 3-year award from US DOE



Core Team



Technical Committee



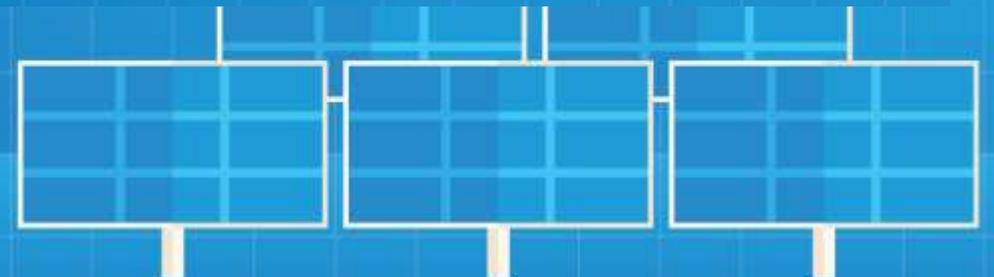
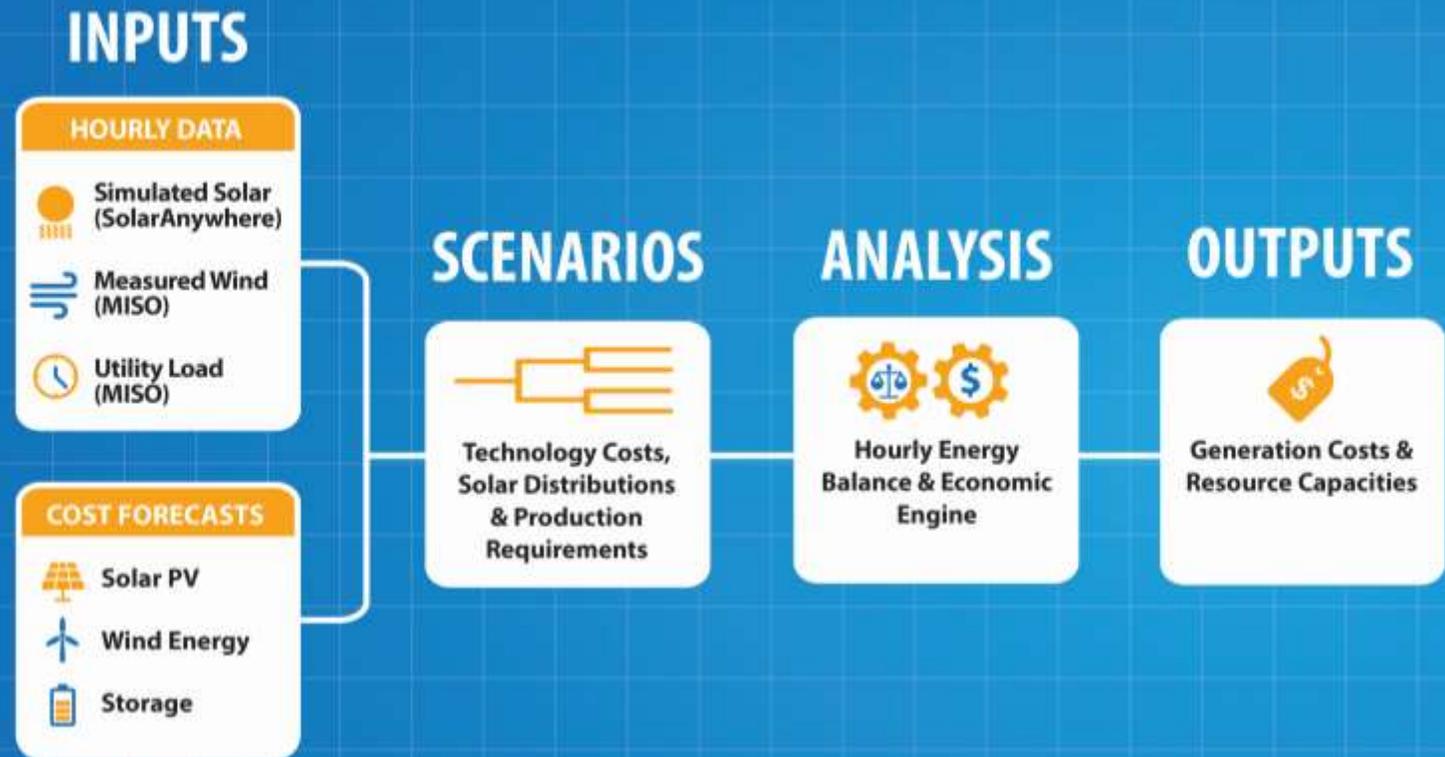
Technical Analysis





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*



Generation costs only
Based upon installed costs



No transmission or distribution costs
Does not address rate structures

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

Key Model Components

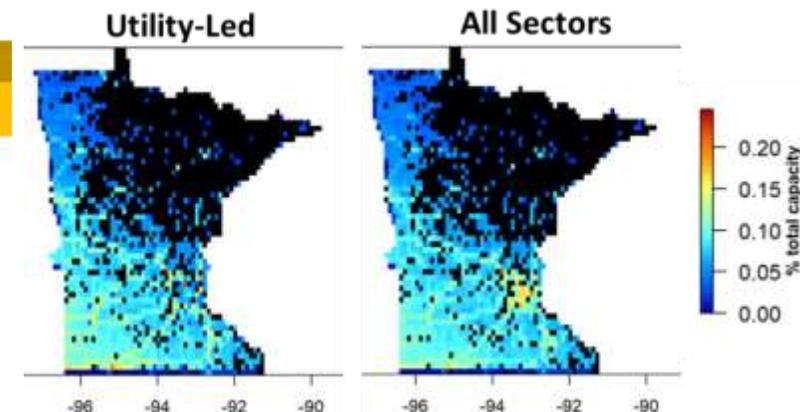
- Electrification
 - 75% residential heating & DHW
 - 95% light vehicle
- Meets hourly load
 - Fully-dispatchable
- Geographic diversity
 - Wind / Solar distributed throughout the state



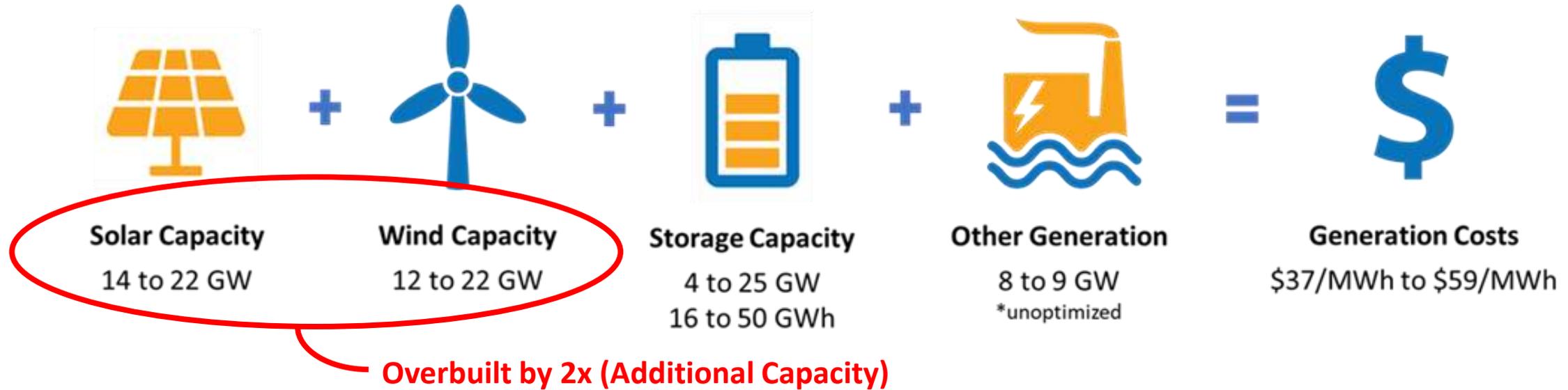
Dispatchability of SPA Production Requirements



Sector	Scenario	
	Utility-Led	All Sectors
Residential	5%	15%
Commercial	5%	25%
Community	20%	25%
Utility	70%	30%



70% Solar and Wind by 2050:



- Economic curtailment of surplus renewables is cheaper than long-term battery storage
- Doubling renewable capacity reduces storage requirements by 6x

~~70% Solar and Wind by 2050:~~
63% to 67%



Solar Capacity
14 to 22 GW



Wind Capacity
12 to 22 GW



Storage Capacity
4 to 25 GW
16 to 50 GWh



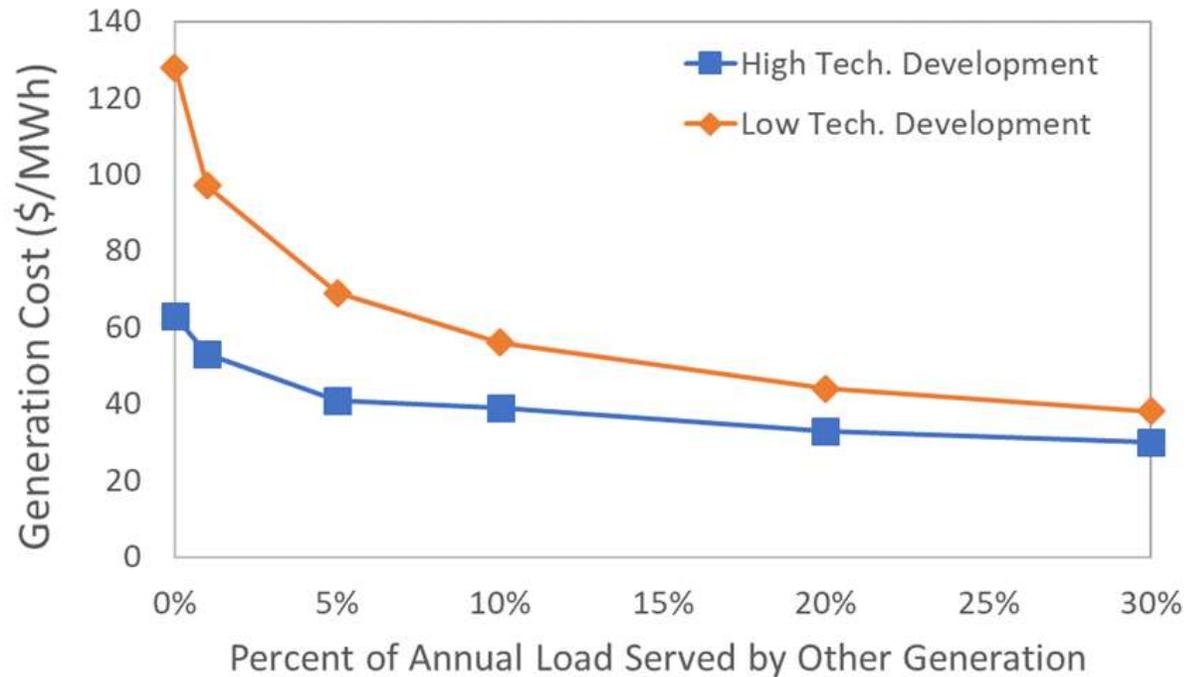
Other Generation
8 to 9 GW
*unoptimized



Generation Costs
\$37/MWh to \$59/MWh

- The incremental cost of the last 10% of renewable kWhs are equal to the first 90%
- Using other generation resources during brief periods of low-solar and low-wind production cuts net generation cost by nearly half

Cost Effects of Using Other Generation During Periods of Low Renewables Production

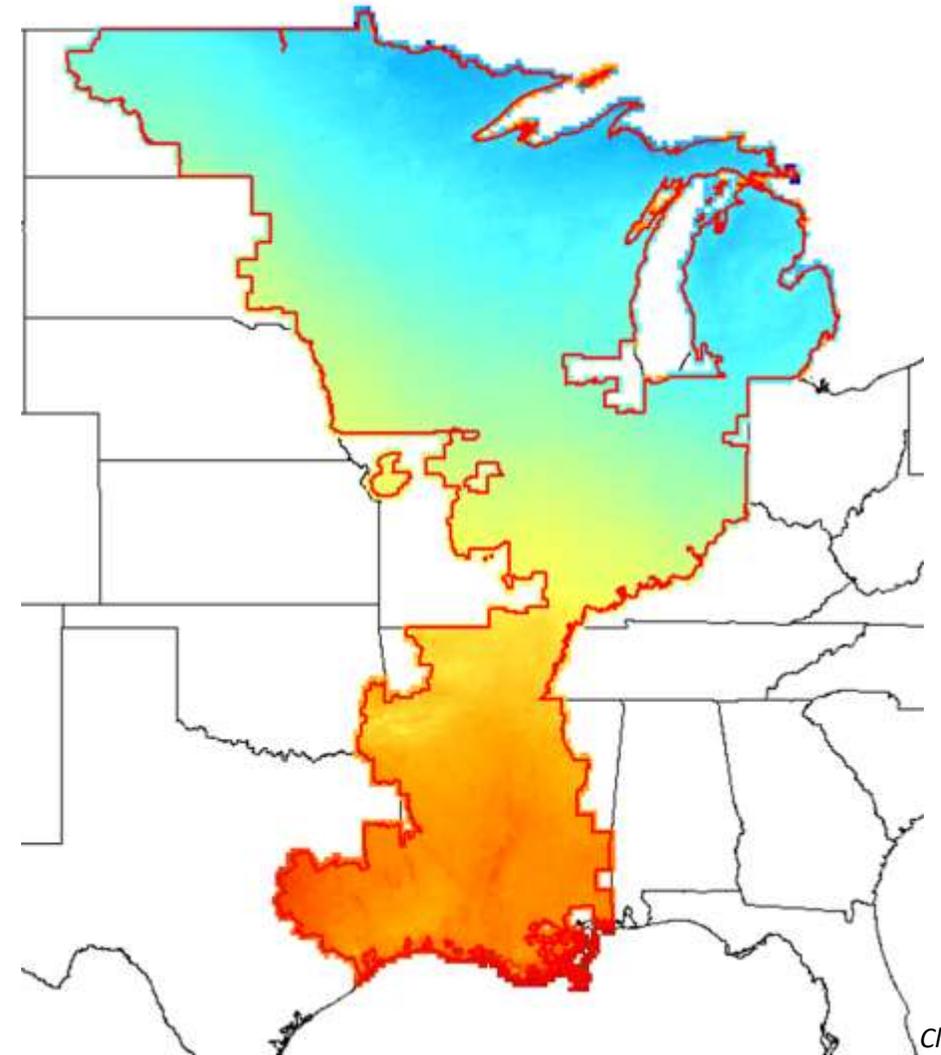


Challenges

- 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

Tools

- Solar Deployment Strategies Tool
 - Utilize Minnesota IOU data and other inputs to project future adoption rates, costs and benefits
- MISO wide Solar Potential Analysis



Clean Power
Research

Applications & Partnerships

- Clarifying and updating policy interpretation
- Alternative siting solutions
- Alternatives to traditional PPA structures



**GREAT PLAINS
INSTITUTE**

Better Energy.
Better World.

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

Conclusions

- 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



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Thank You!

FIND OUT MORE AT
<http://mnsolarpathways.org/>

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Additional Capacity Decreases Storage Needs

