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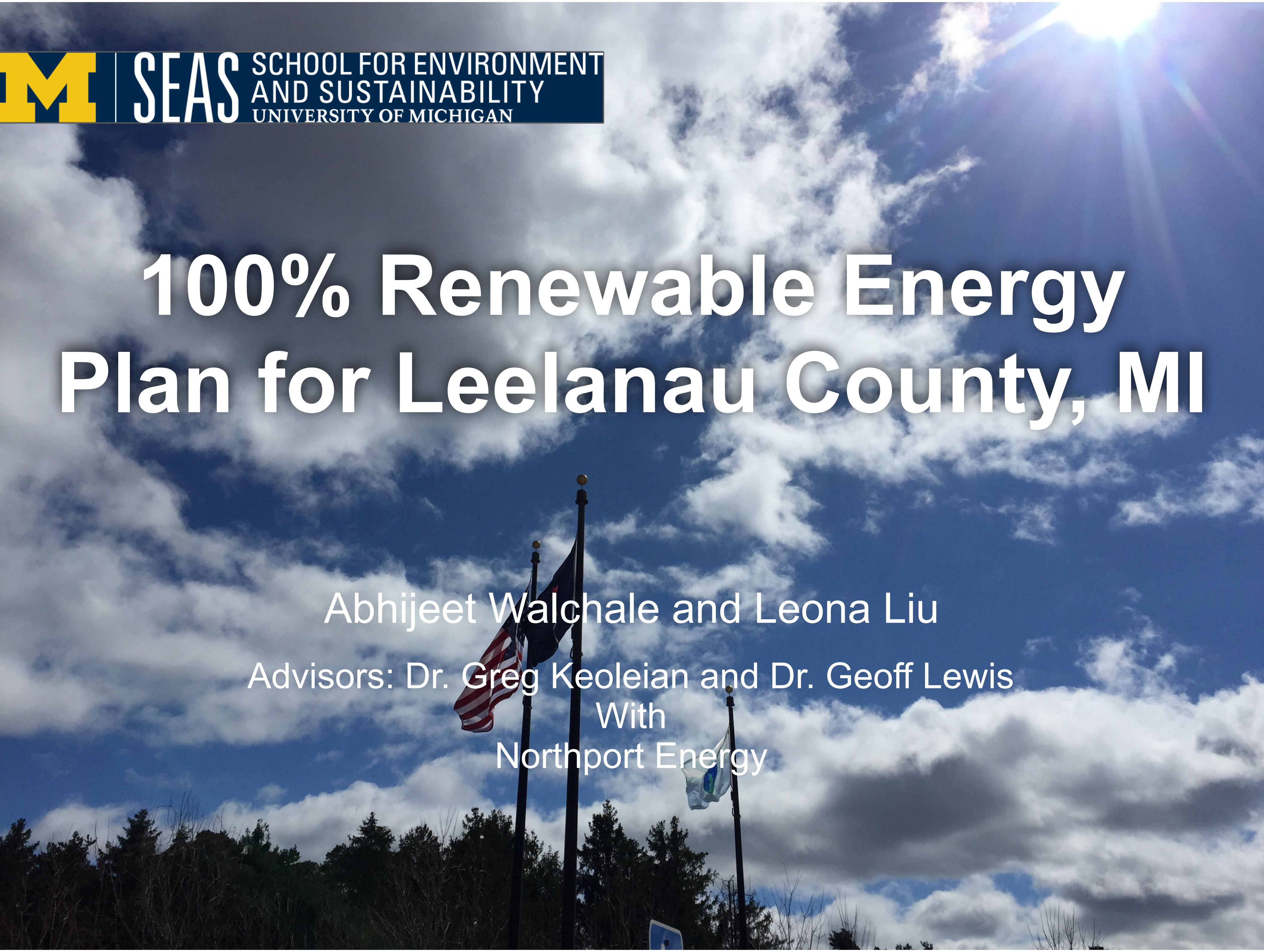

100% Renewable Energy Plan for Leelanau County, MI

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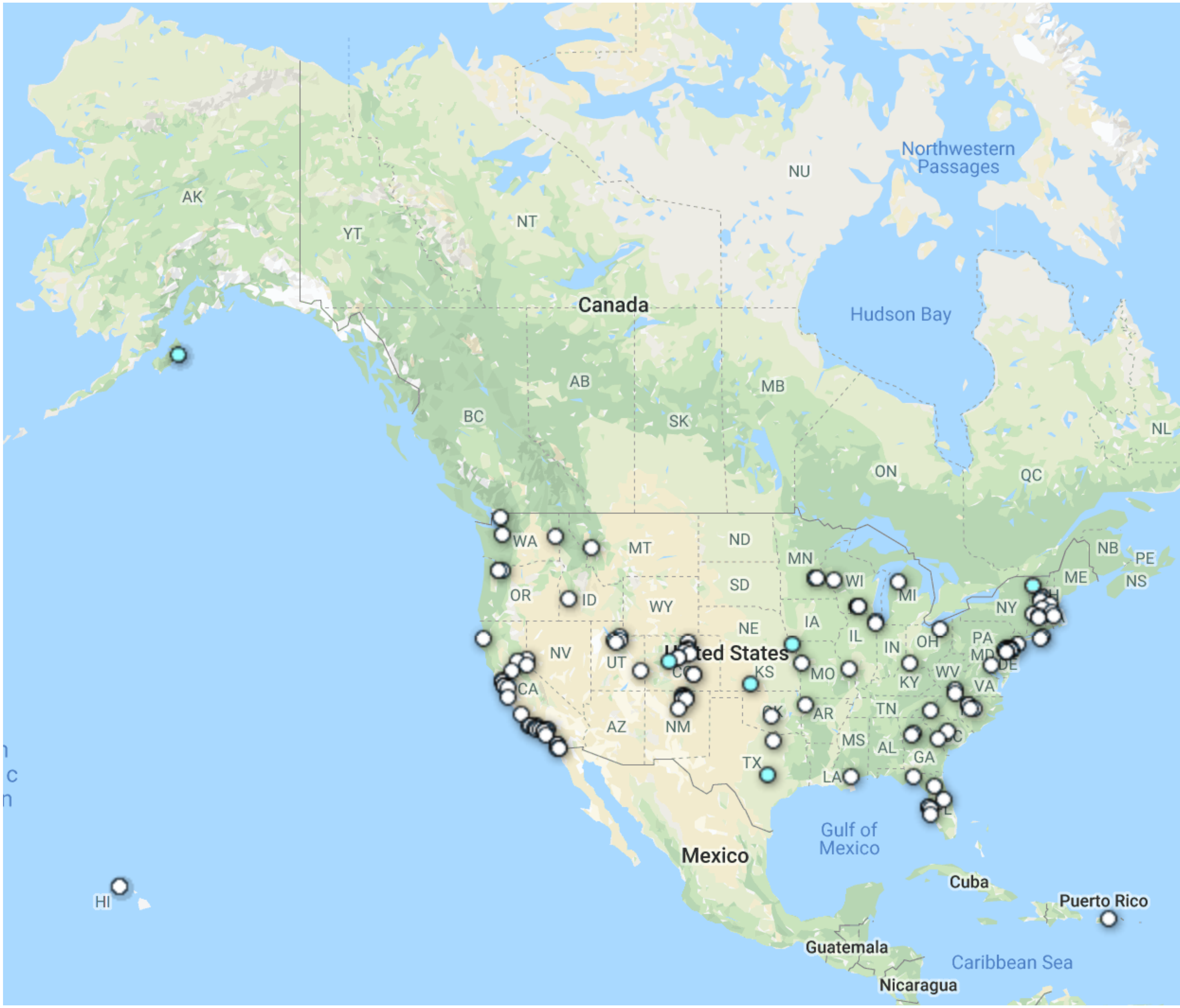
Advisors: Dr. Greg Keoleian and Dr. Geoff Lewis
With
Northport Energy

NORTHPORT ENERGY

Summary of 2015 Leelanau Township Renewable Energy Study

- Community members are generally open to the idea of increasing renewable energy in Northport and Leelanau Township.
- The gains from energy-efficiency measures will likely be modest in the overall scheme of moving to 100% renewable energy, but can help to put energy use on a downward trend.
- Leelanau Township has sufficient wind and solar energy to supply the totality of its electricity consumption. The 100% goal could be met by deploying several large scale systems.
- Developed three scenarios to achieve 100% renewable energy and assessed their average costs. In rapid scenario, where the goal will be achieved by 2030, the cost per megawatt hour is the lowest, at $146.93.

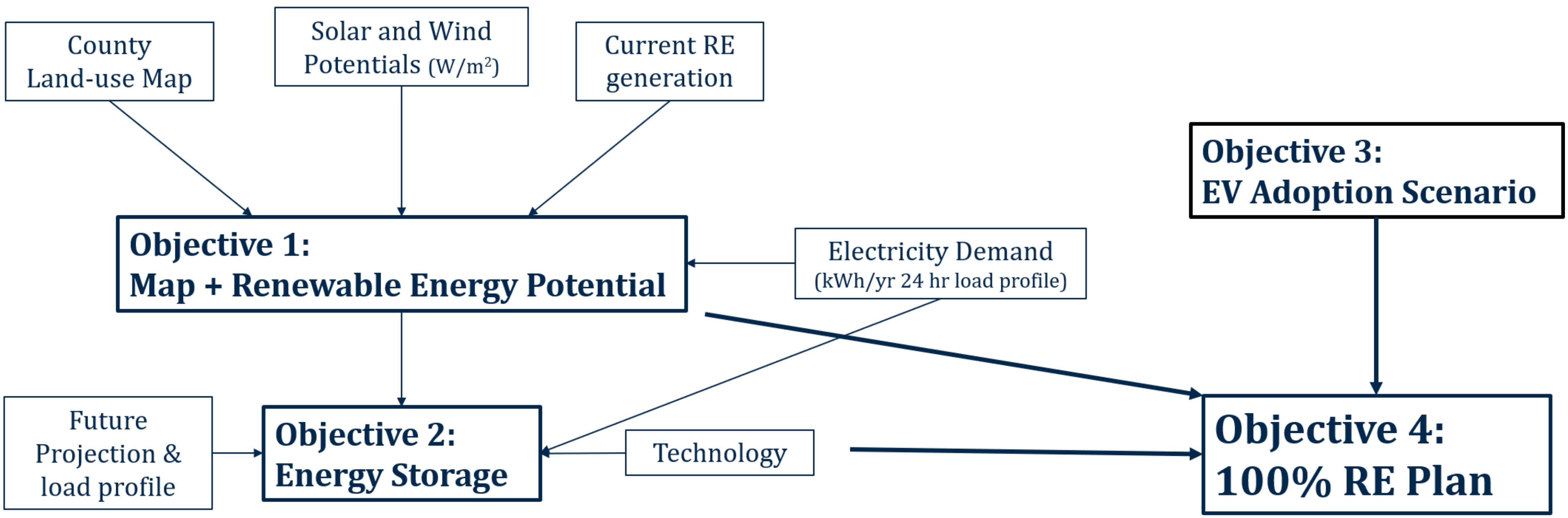
Over 100 Communities have 100% RE Commitments



Objectives

- Predict the Leelanau County electricity demand by 2040
- Identify the renewable energy opportunities to meet the predicted demand
- Assess the impact of Battery storage and electric vehicles in the county
- Compare the financial investment and benefits of building all this solar, wind energy

Study Objectives

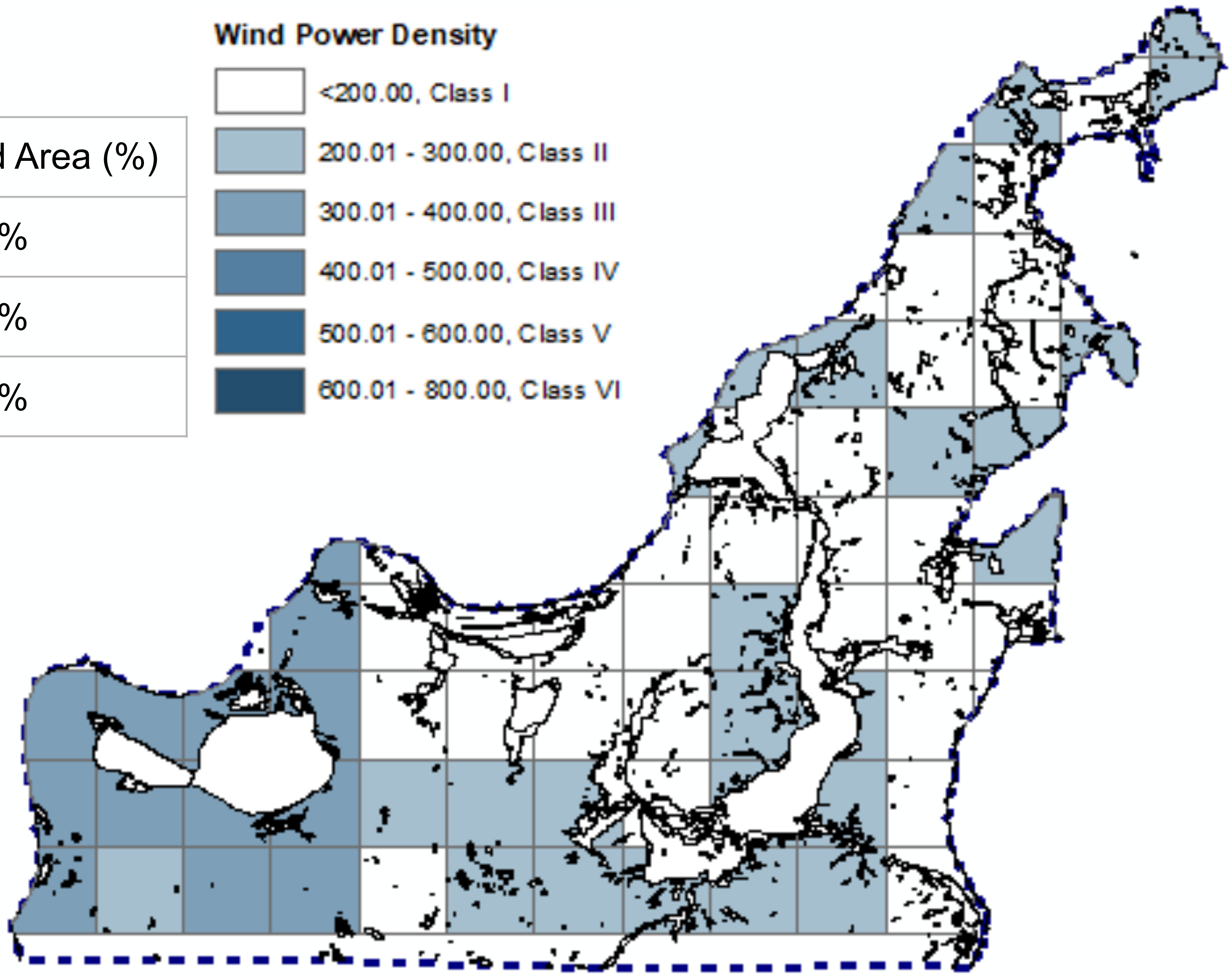


Where is the resource located?

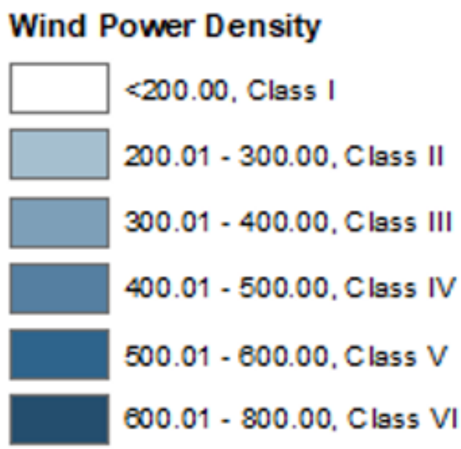
Objective 1: Map + Renewable Energy Potential

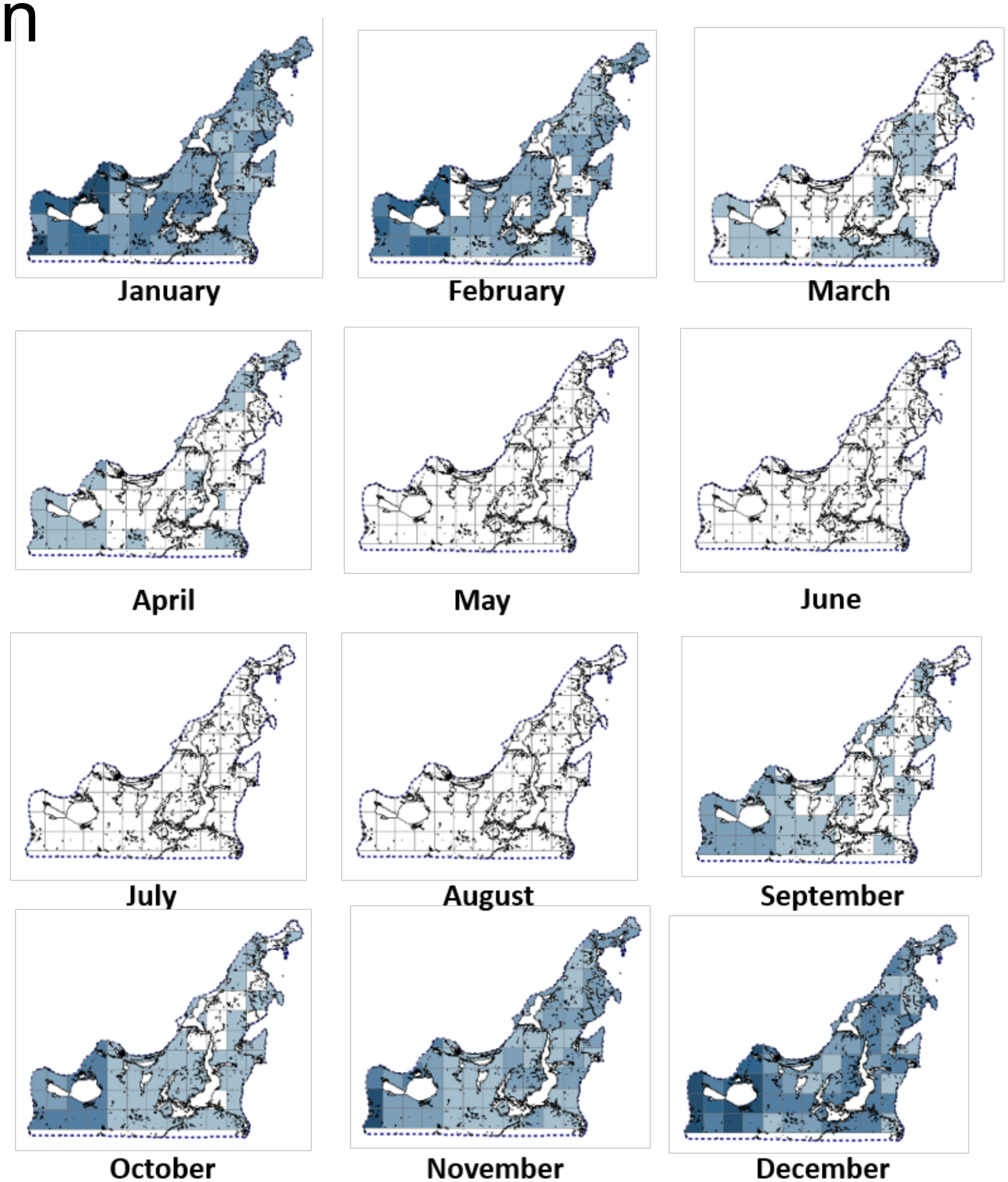
Wind Power Density Overview

Wind Power Class	Land Area (%)
1	47.1%
2	34.7%
3	18.2%



WPD Seasonal Variation



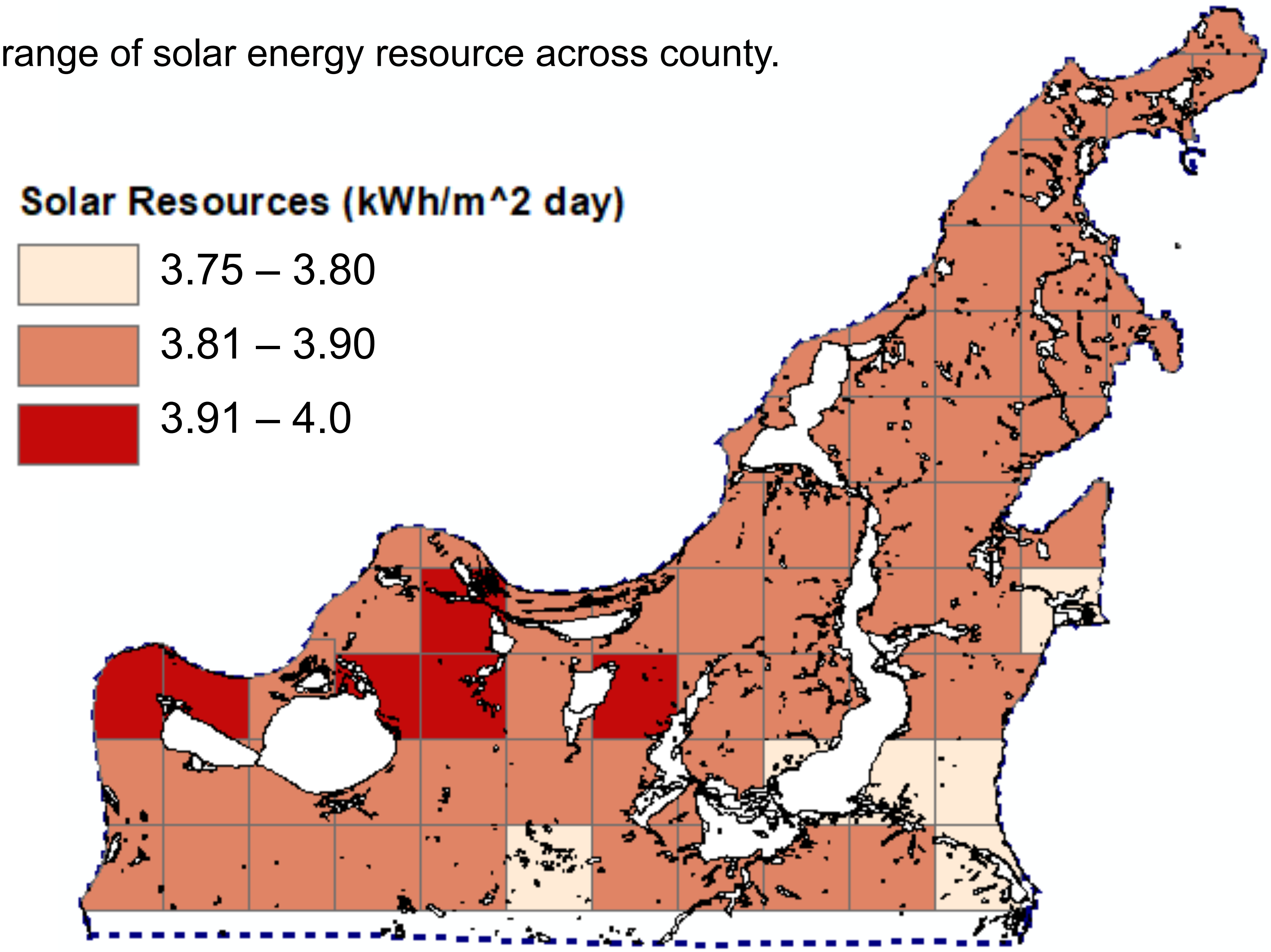


Abundant in winter (November to February)

Too low to be economically viable in summer (May to August)

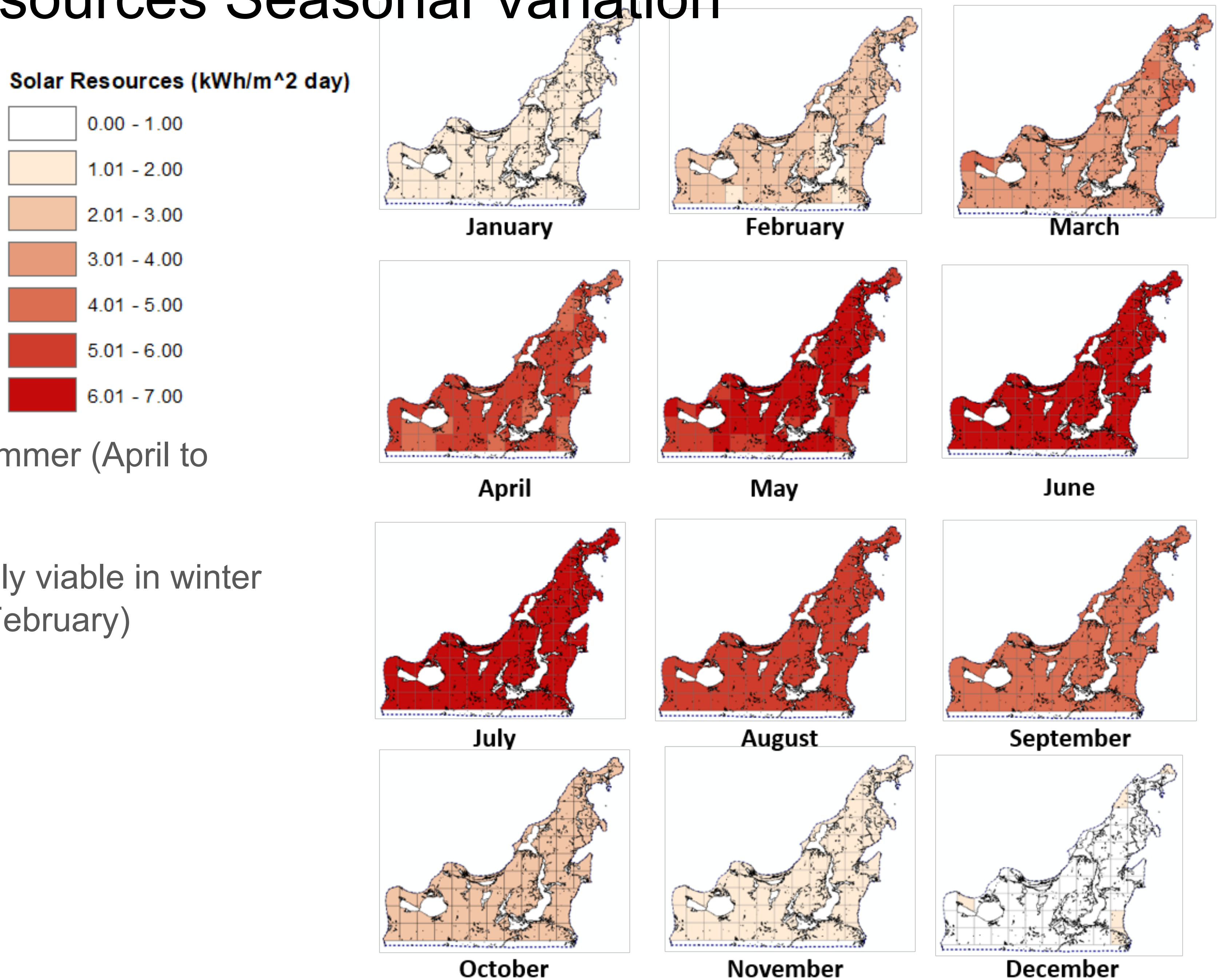
Solar Resources Overview

Overall a narrow range of solar energy resource across county.



Objective 1: Map + Renewable Energy Potential

Solar Resources Seasonal Variation

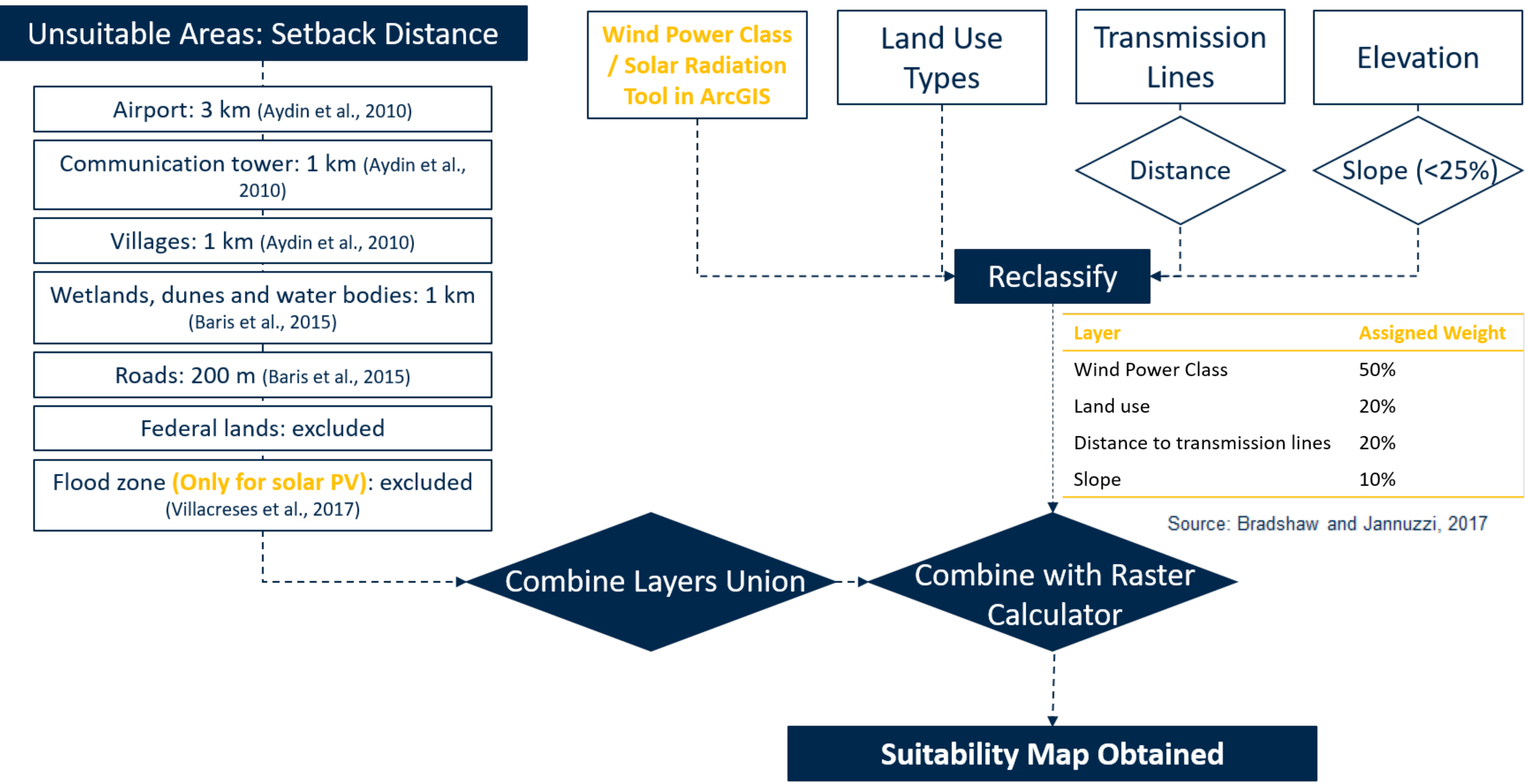


Abundant in summer (April to August)

Not economically viable in winter (November to February)

Is that area feasible to build on?

Identifying the potential available land areas



Layer	Assigned Weight
Wind Power Class	50%
Land use	20%
Distance to transmission lines	20%
Slope	10%

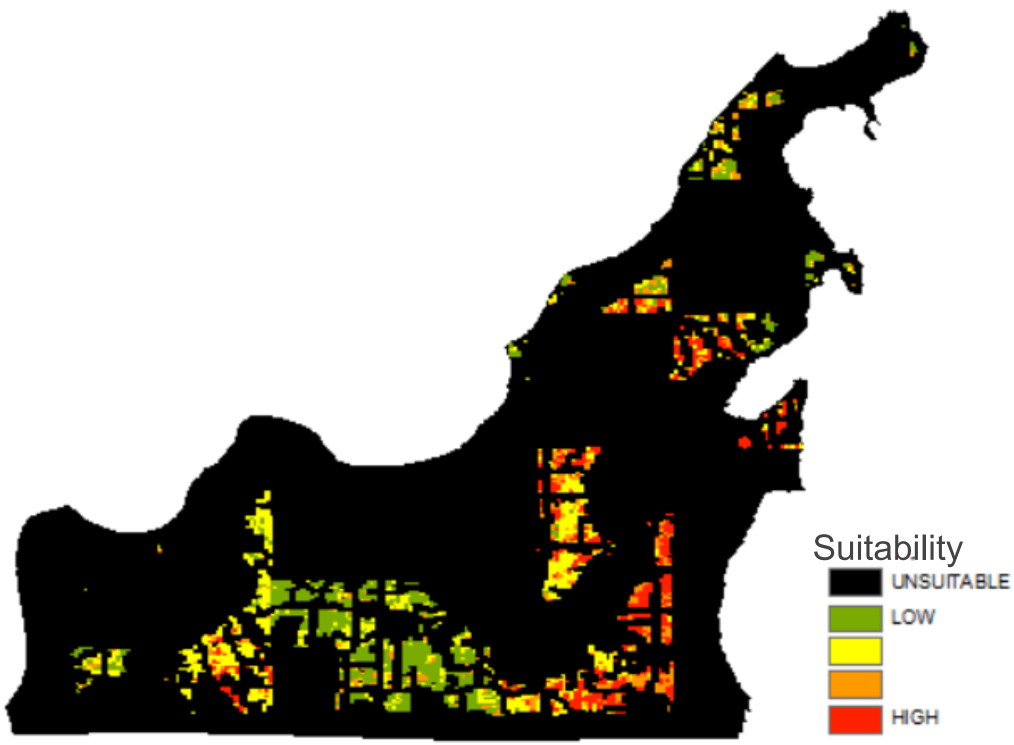
Source: Bradshaw and Jannuzzi, 2017

Criteria and Data Source for Wind Farm Suitability Modeling

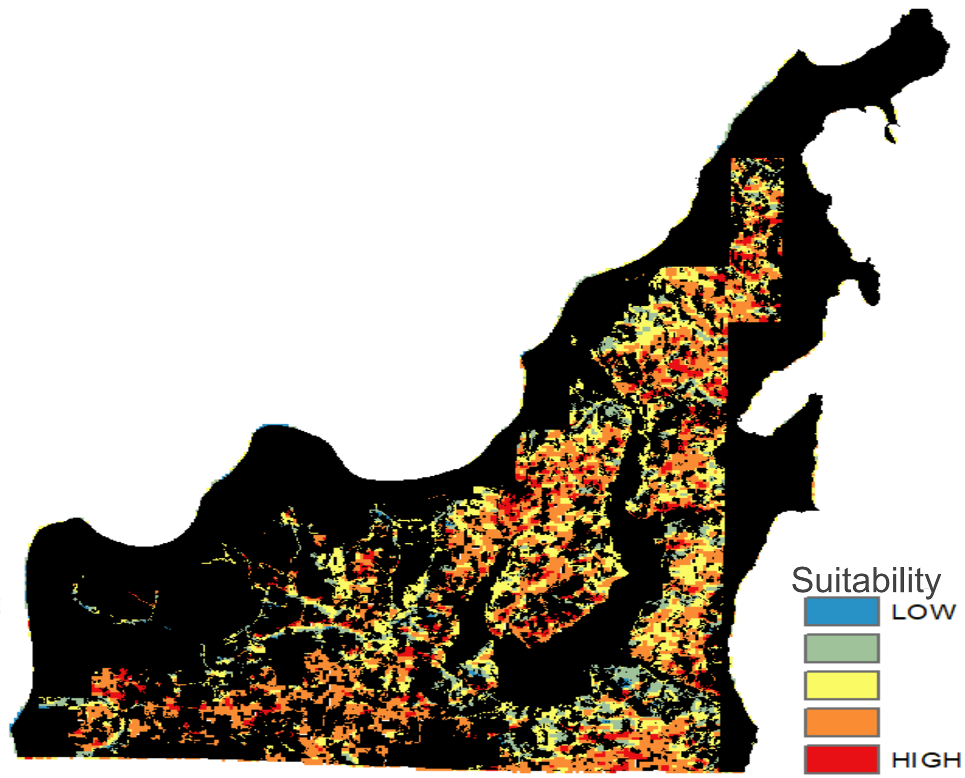
Variable	Reasons for Selection	Type	Data source
Wind power density	Wind potential is essential for wind energy production	Vector (Polygon)	National Renewable Energy Laboratory (NREL)
Airport	Conflicting land use preoccupied by human infrastructure	Vector (Point)	ESRI Maps & Data online database
Communication Tower		Vector (Point)	ESRI Maps & Data online database
Villages		Vector (Polygon)	Leelanau County GIS Office
Federal lands		Vector (Polygon)	USGS Small-Scale Data Download Portal
Wetlands, water body, and dunes	Avoiding ecological sensitive areas	Vector (Polygon)	State of Michigan GIS Open Data Portal
Roads	Avoid areas on the roads	Vector (Polyline)	Leelanau County GIS Office
Transmission lines	Reducing the cost of building new transmission lines	Vector (Polyline)	Homeland Infrastructure Foundation-Level Data (HIFLD)
Land use	Land use is a criterion representing the environmental impacts of the wind farms	Raster	Superzone Eight of the National Land Cover Database
Slope (Elevation)	Slope affects the ease of construction and maintenance	Raster	U.S. Geological Survey's (USGS) online National Map

Suitable Areas for Wind Turbines and Solar PV

- Total available area for wind turbines: 92.84 km^2 (22,094 acres)
- Total available area for solar PV: 213.4 km^2 (52,732 acres)



Wind Suitability

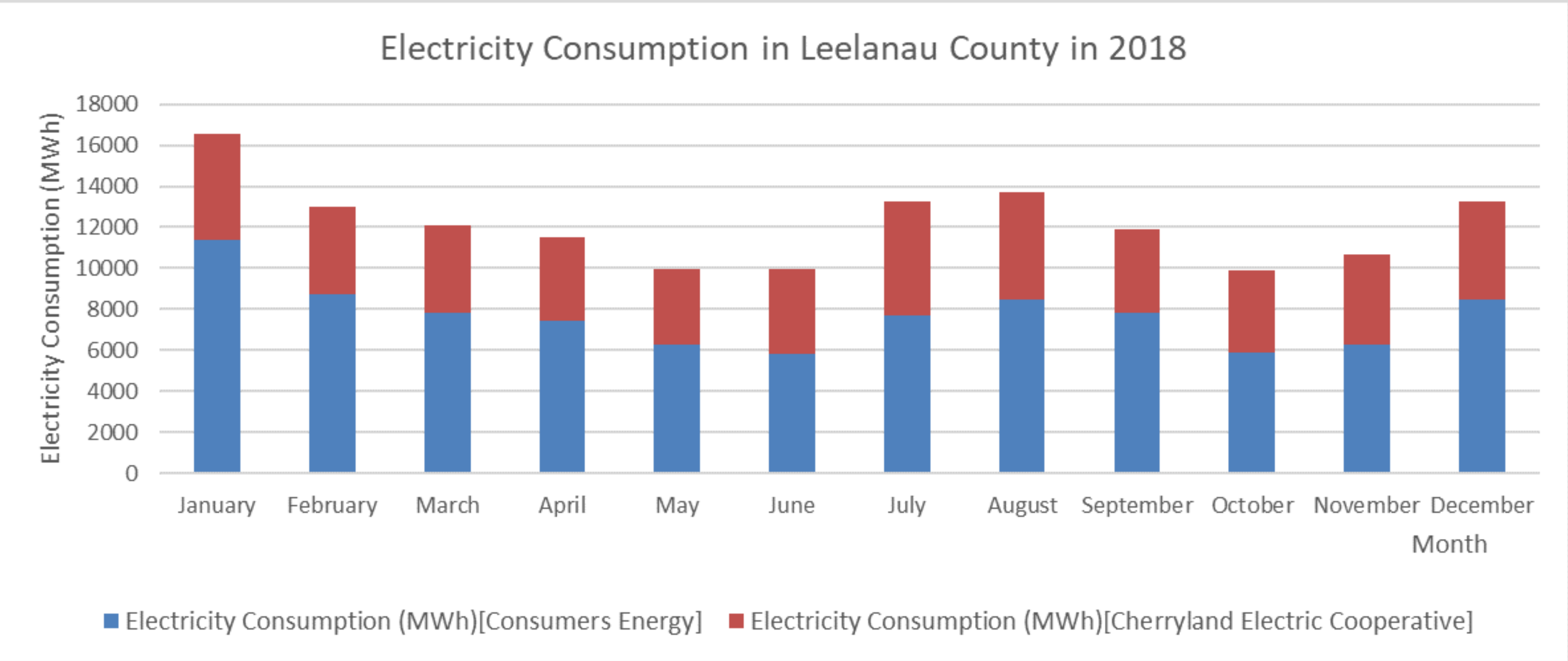


Solar Suitability

How much energy do we need?

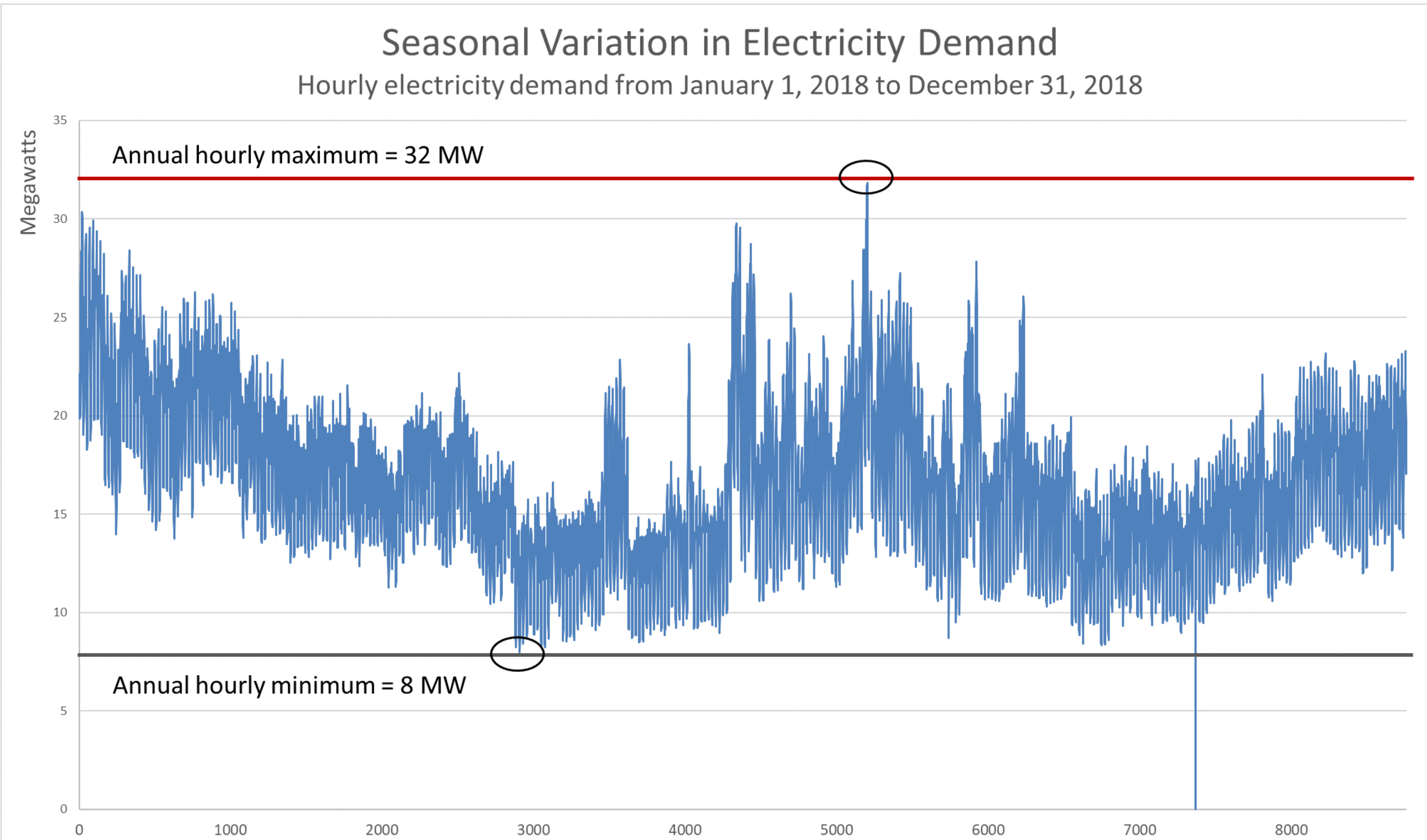
2018 Electricity Demand Profile in Leelanau County

- Total consumption in 2018 was 145.75 GWh (145 million kWh per year)
- In January, electricity usage was the highest, at 16.56 GWh (16.56 million kWh)



Electricity Demand Profile in Leelanau County

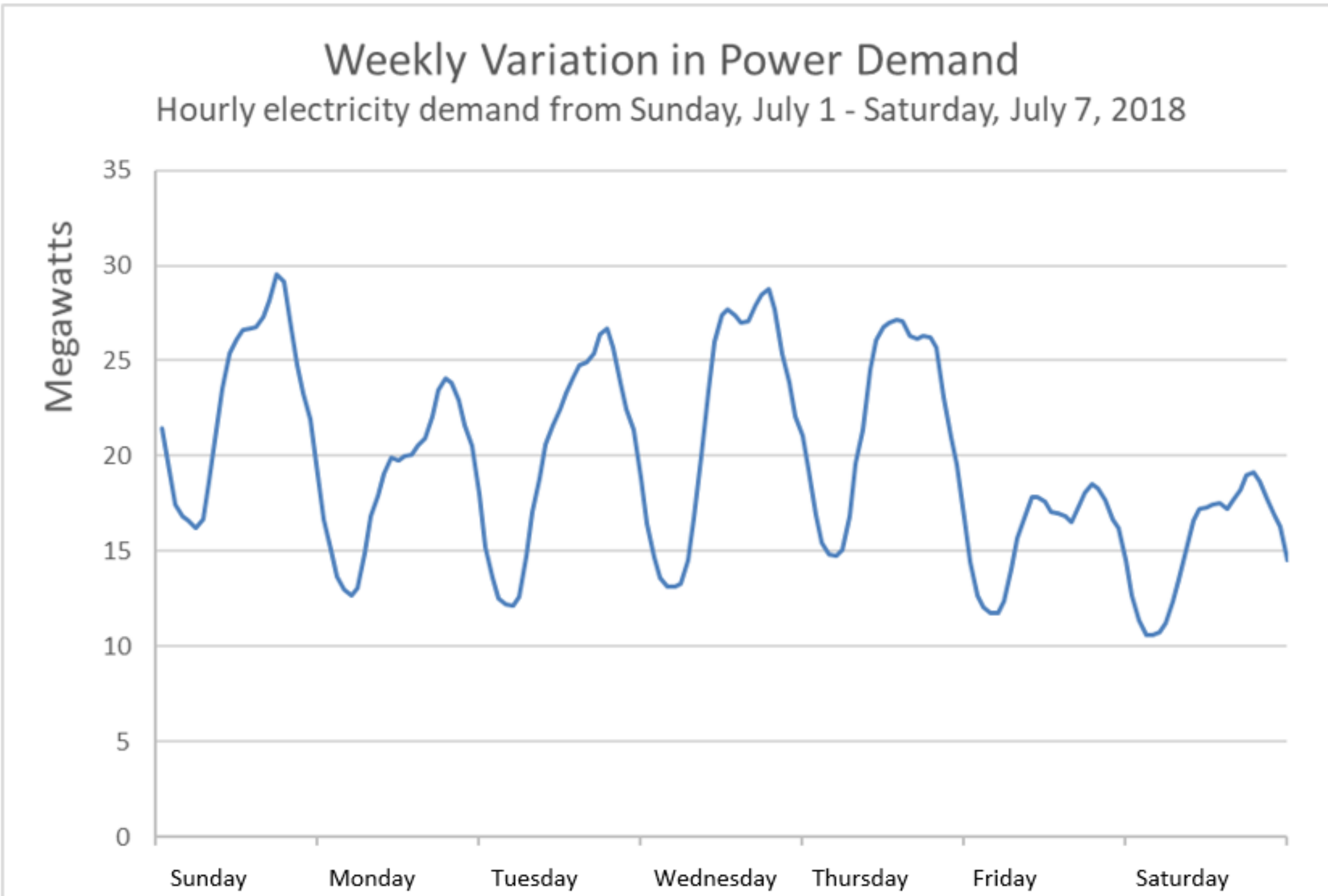
- Peak load: 32 MW; Base load: 8 MW; Average load: ~20 MW



Objective 2: Energy Storage

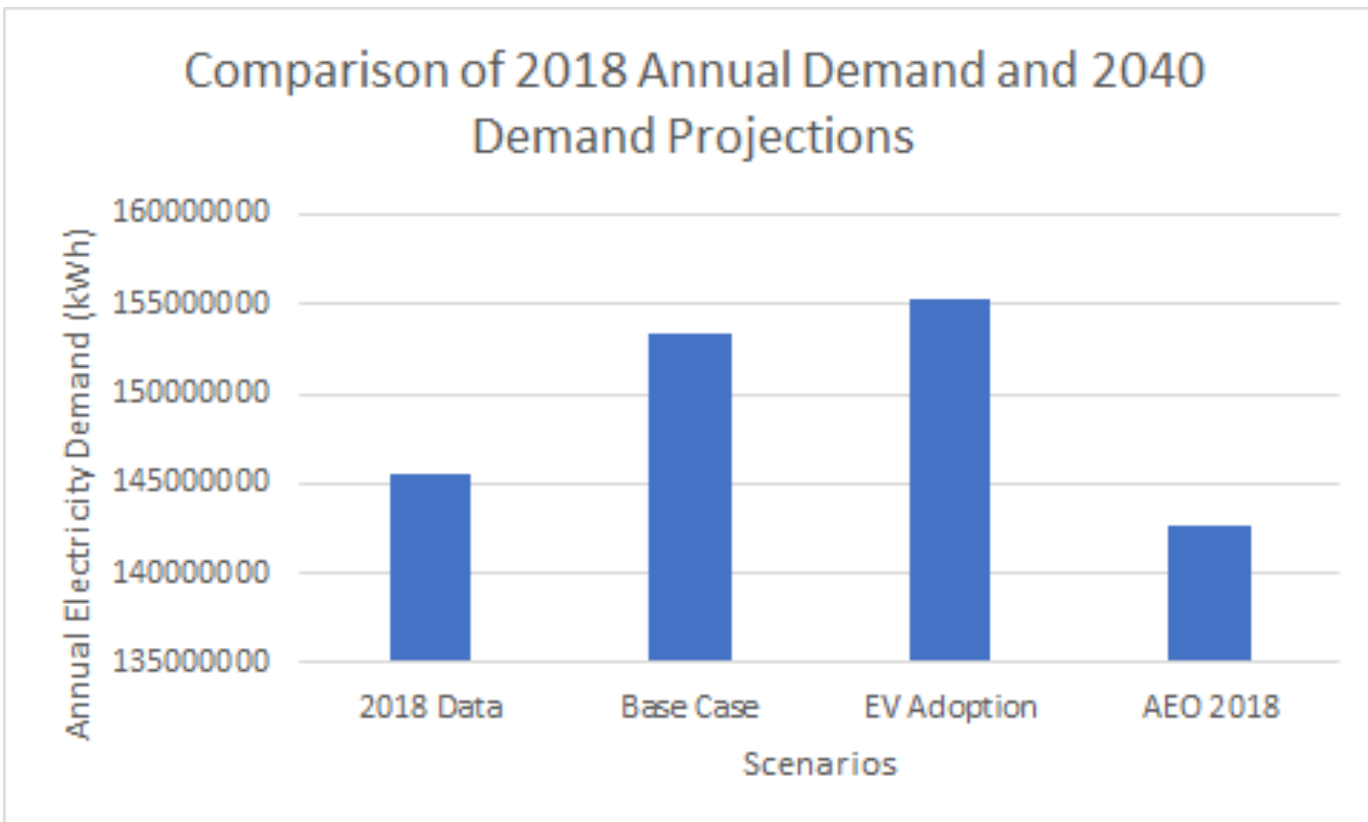
Electricity Demand Profile in Leelanau County

- Daily peak electricity use: 550 MWh (550,000 kWh)

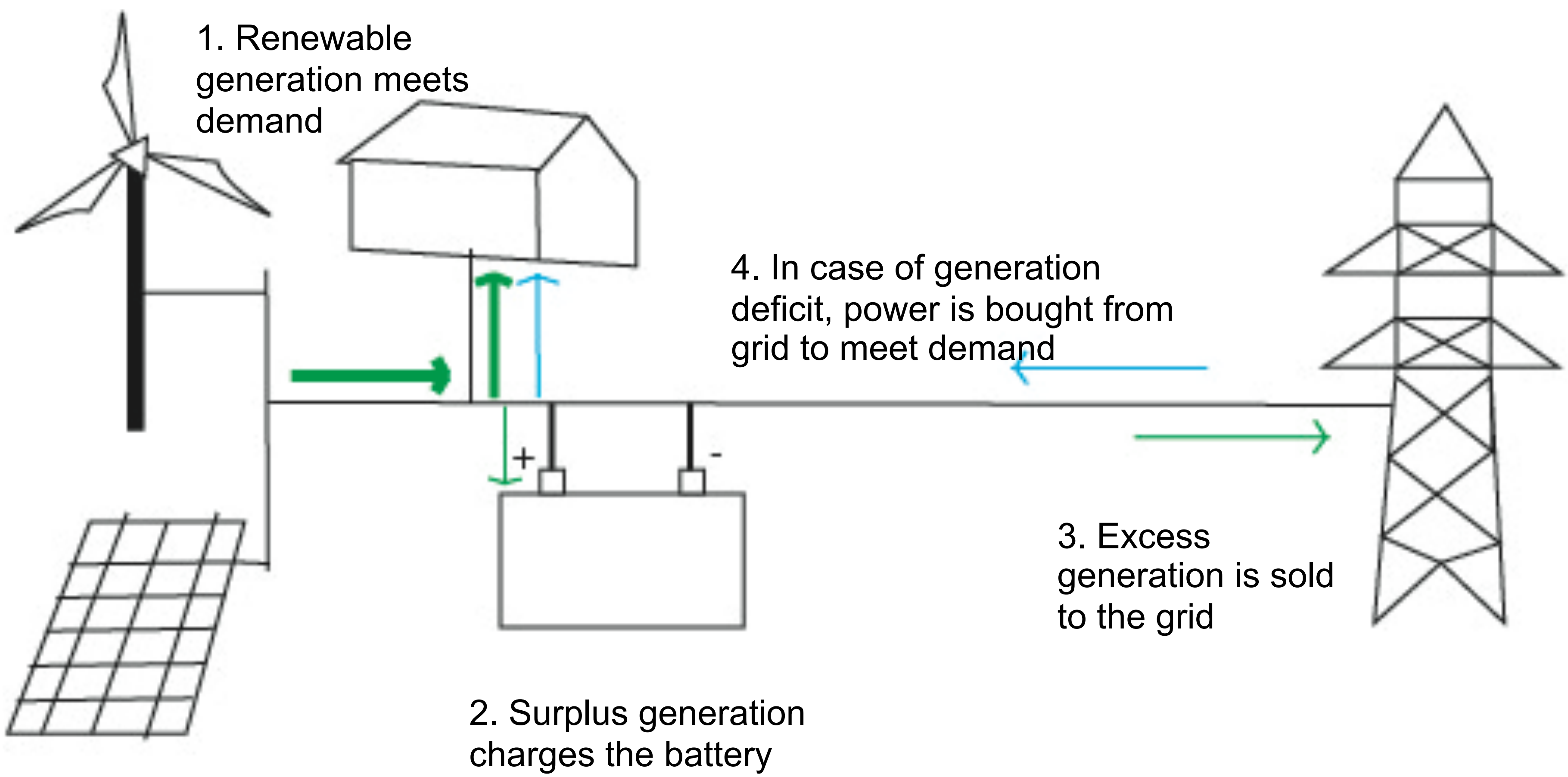


Demand Projections

- 2018 Countywide electricity use data provided by Consumers Energy and Cherryland Electric Cooperative
- Base Case Scenario: Projections proportional to County Population
- EV Adoption Scenario: Base Case Scenario w/ 40 percent fleet replacement
- AEO 2018 Scenario: Growth in County demand is proportional to the growth in annual US-wide demand (based on Annual Energy Outlook 2018)

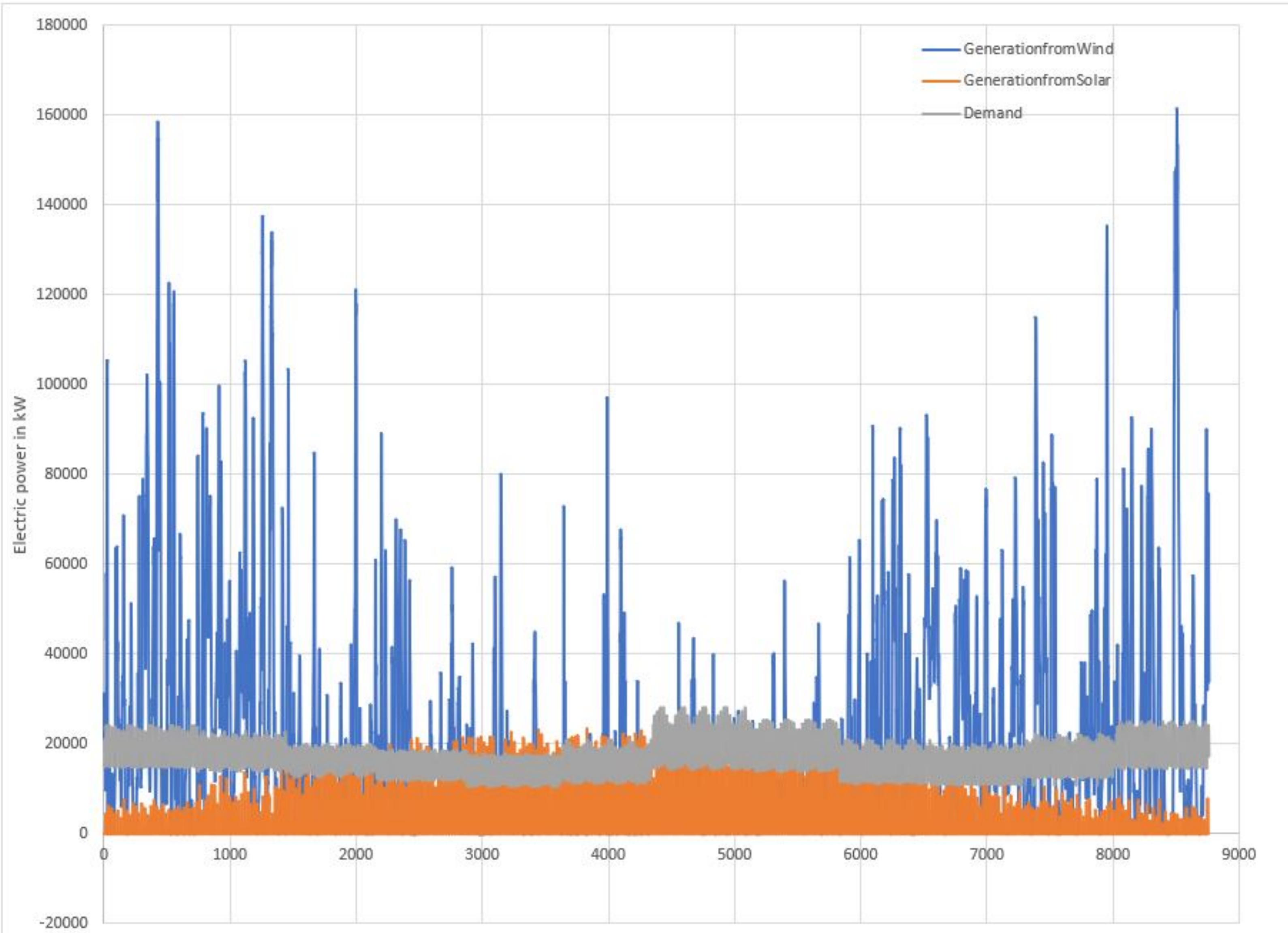


Model: Renewable Generation and Energy Storage Sizing



Objective 4: 100% RE Plan

Results: 13*3.4MW wind turbines, 100 MWh battery, 27 MW solar PV

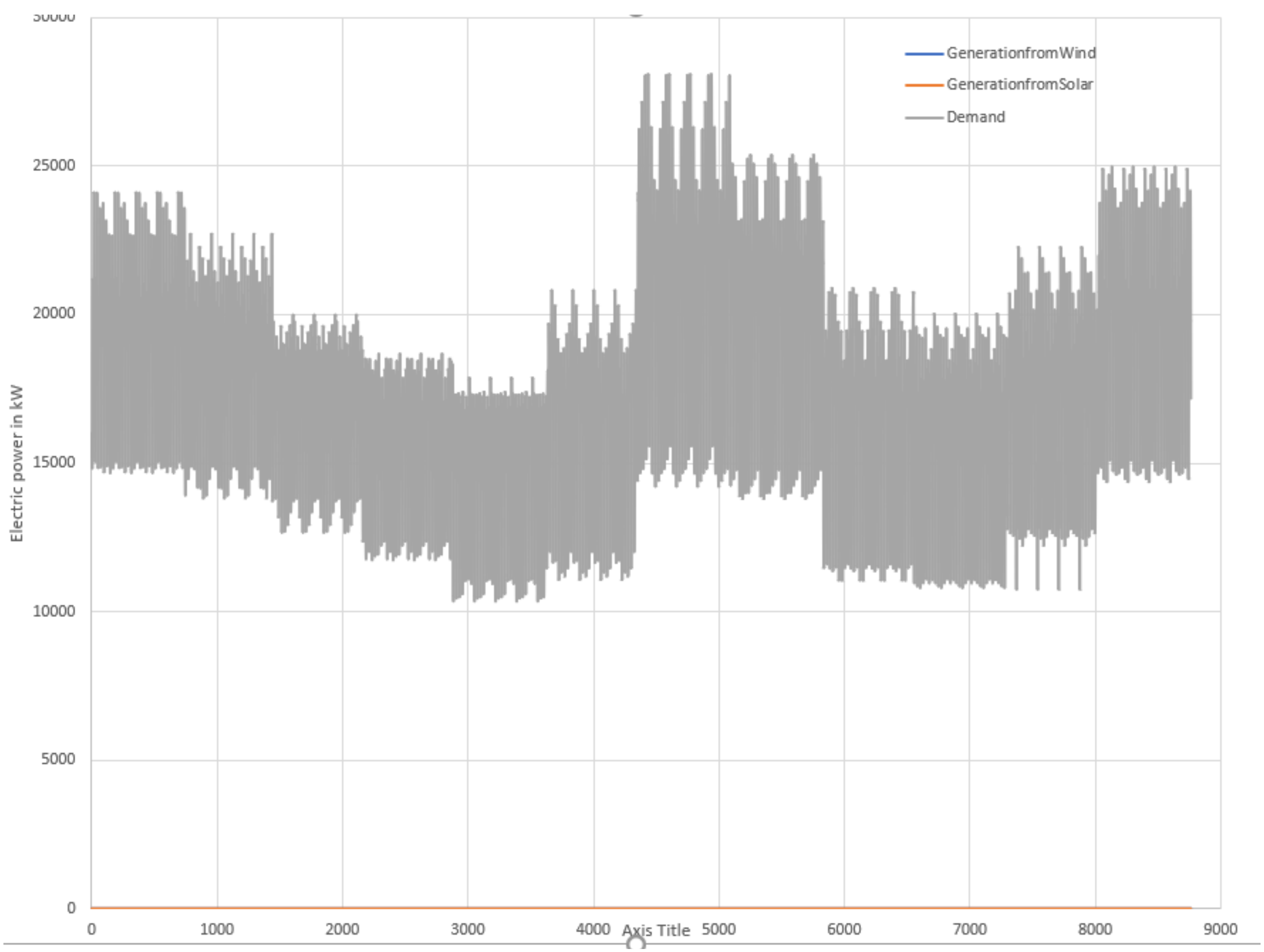


Methods: Parameters for Decision-Making

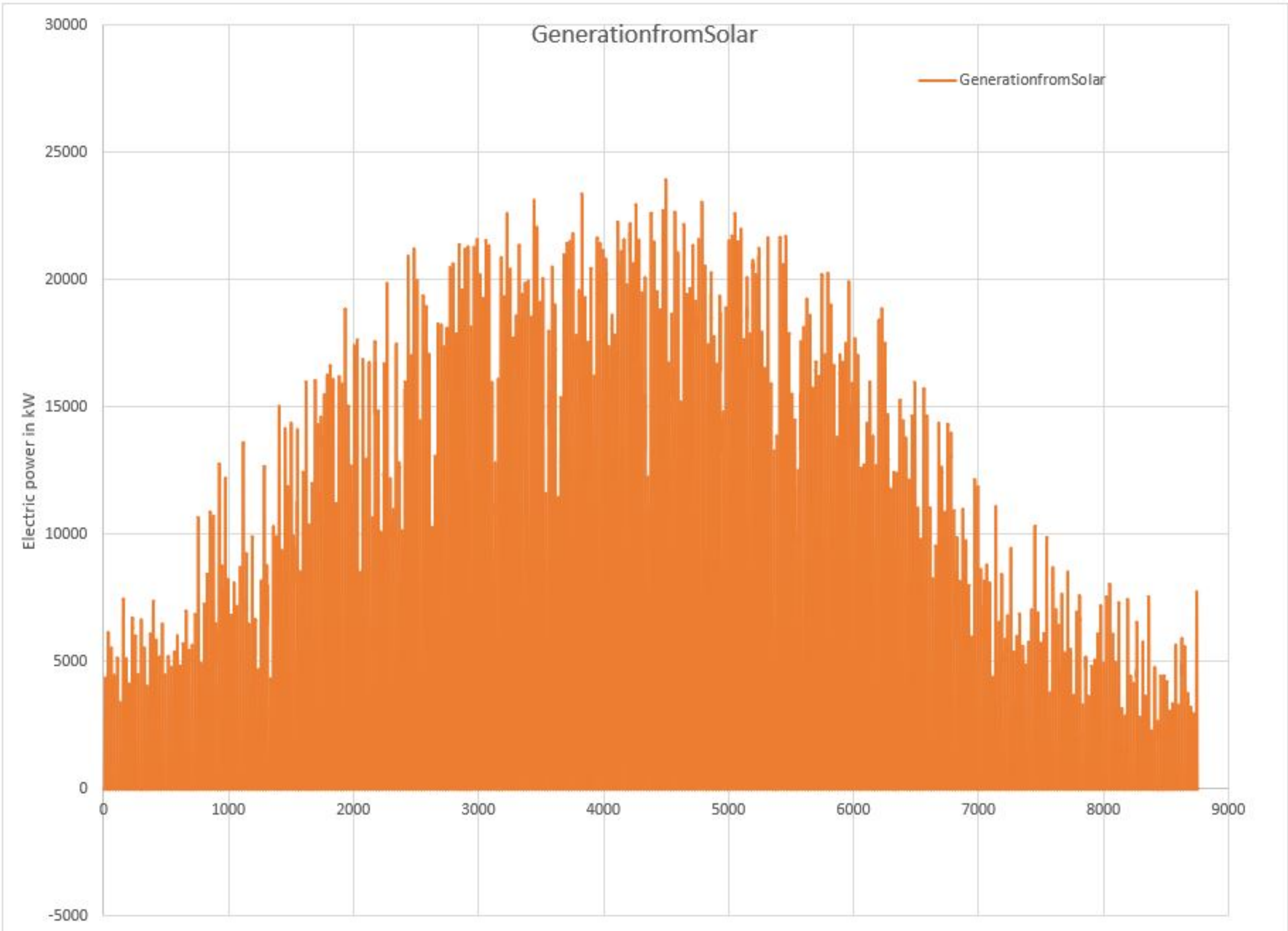
- Demand Met: Percentage of hours that the demand is met by the renewable energy system
- Energy Sold to the Grid: Surplus renewable generation sold to the grid
- Energy Bought from the Grid: Demand(kWh) unmet by the renewable energy system
- Estimated LCOE: Cost of Electricity ($/kWh)

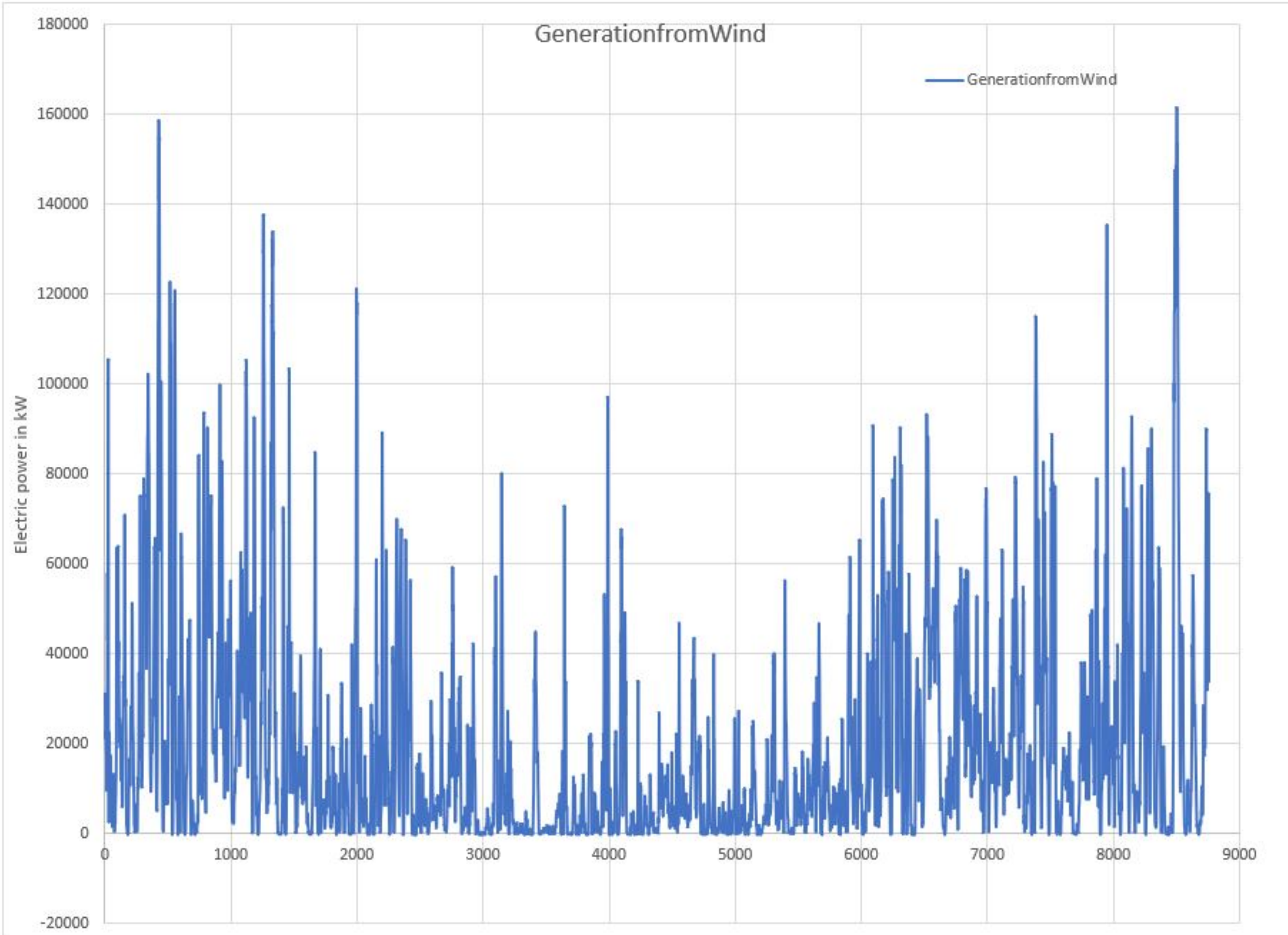
How did we decide how much to build?

We look at the demand

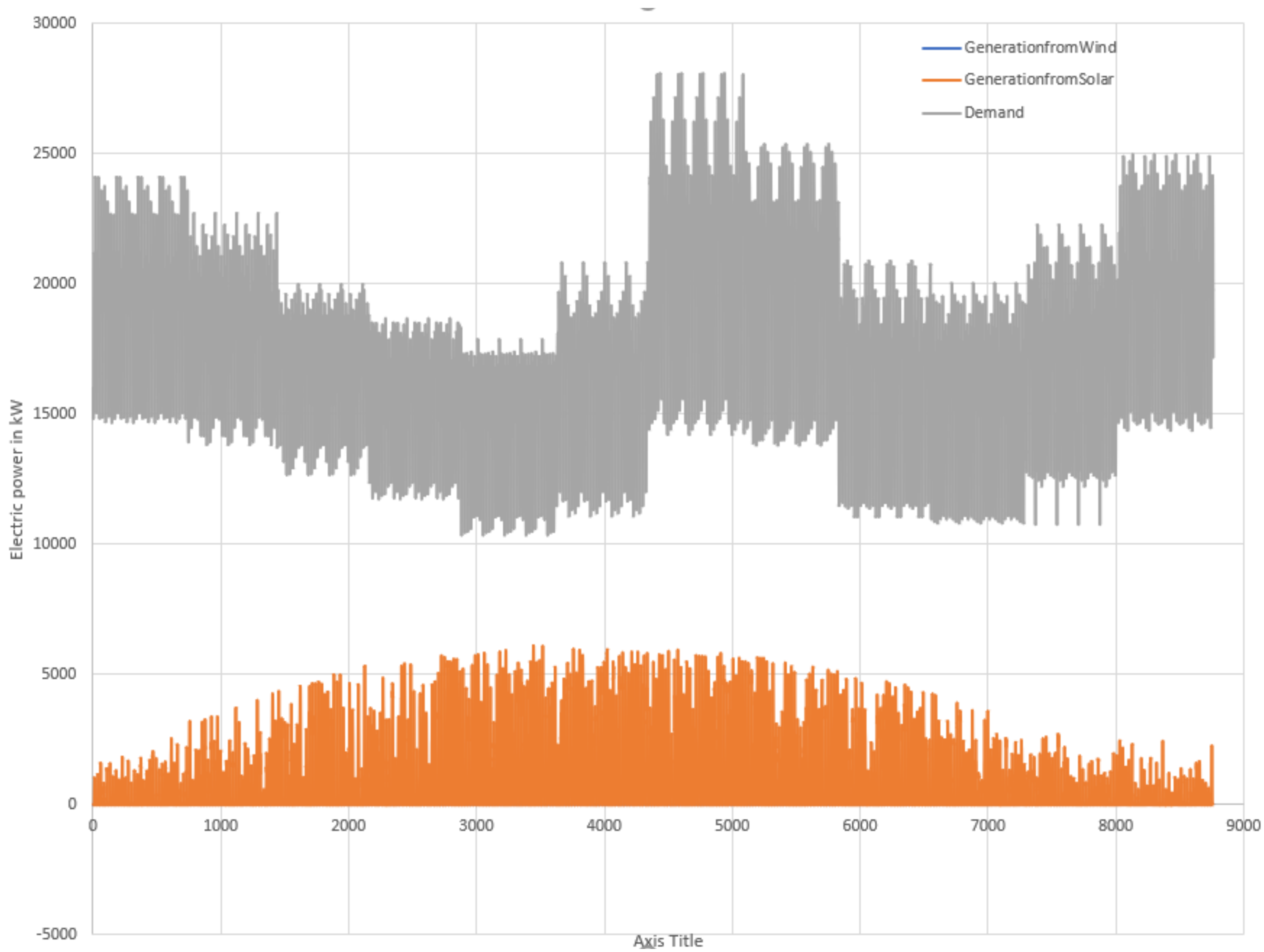


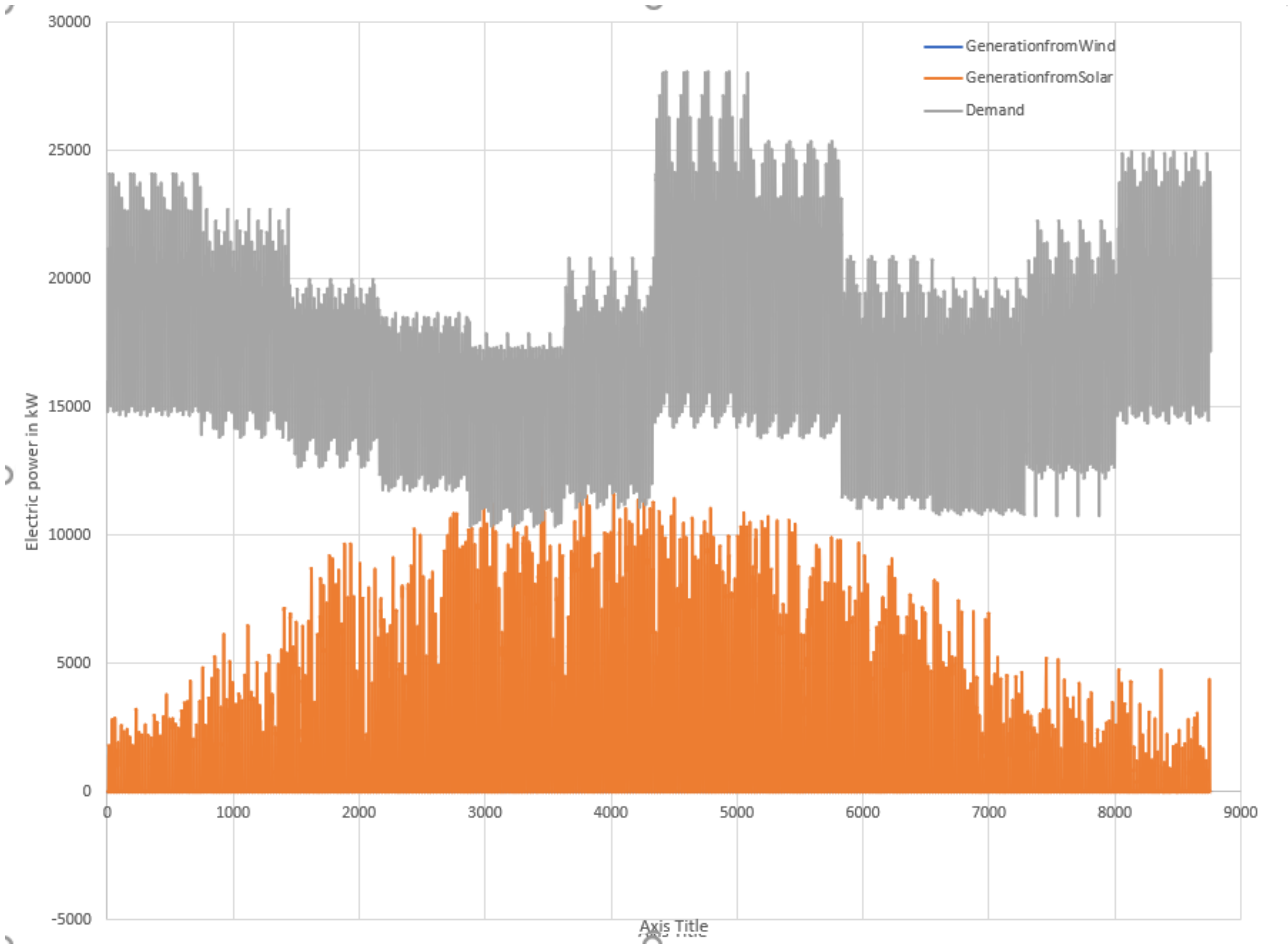
Compare the solar and wind generation



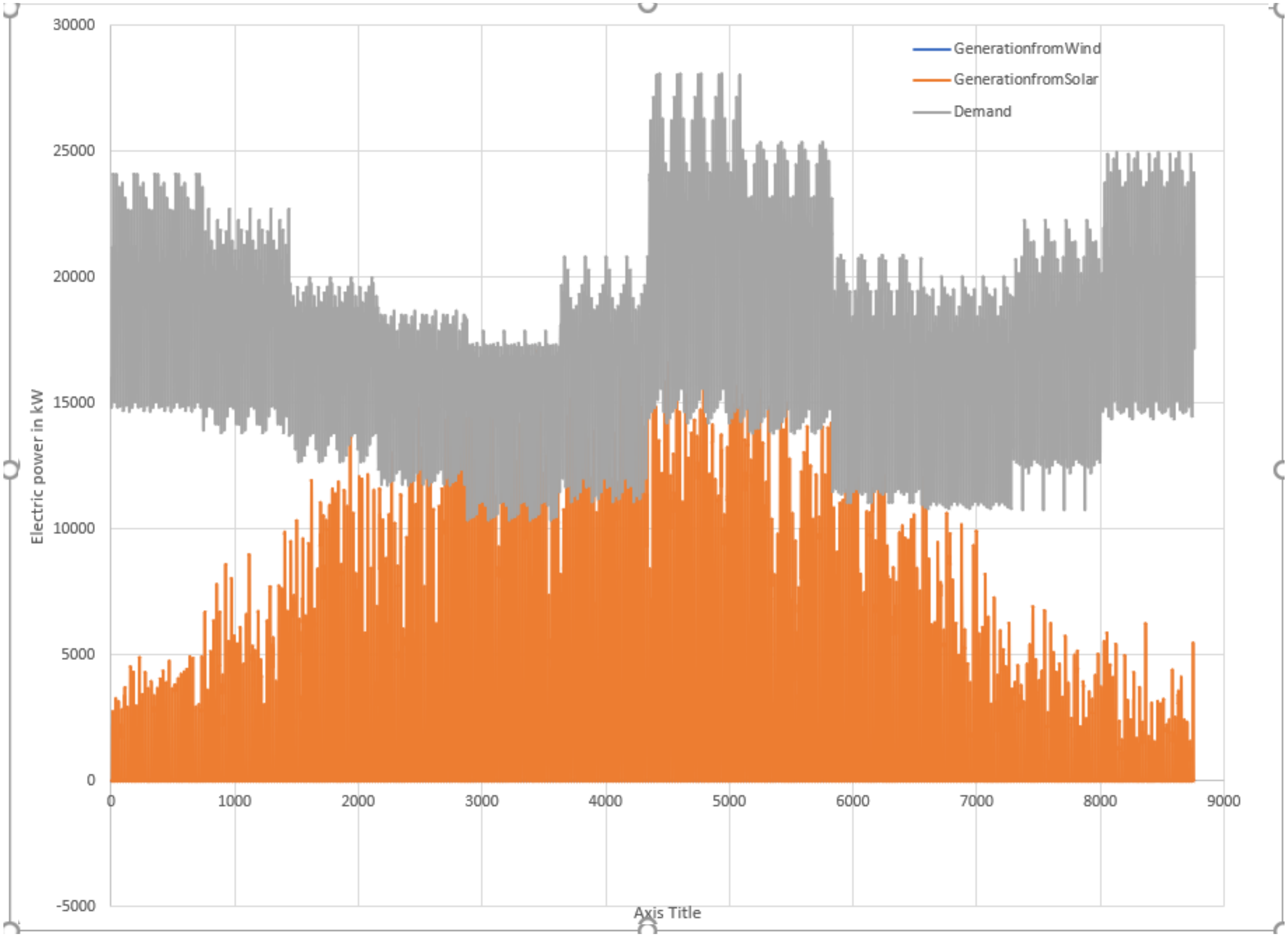

GenerationfromWind
GenerationfromWind
Electric power in kW
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
-20000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000

Keep adding the generation to meet the demand

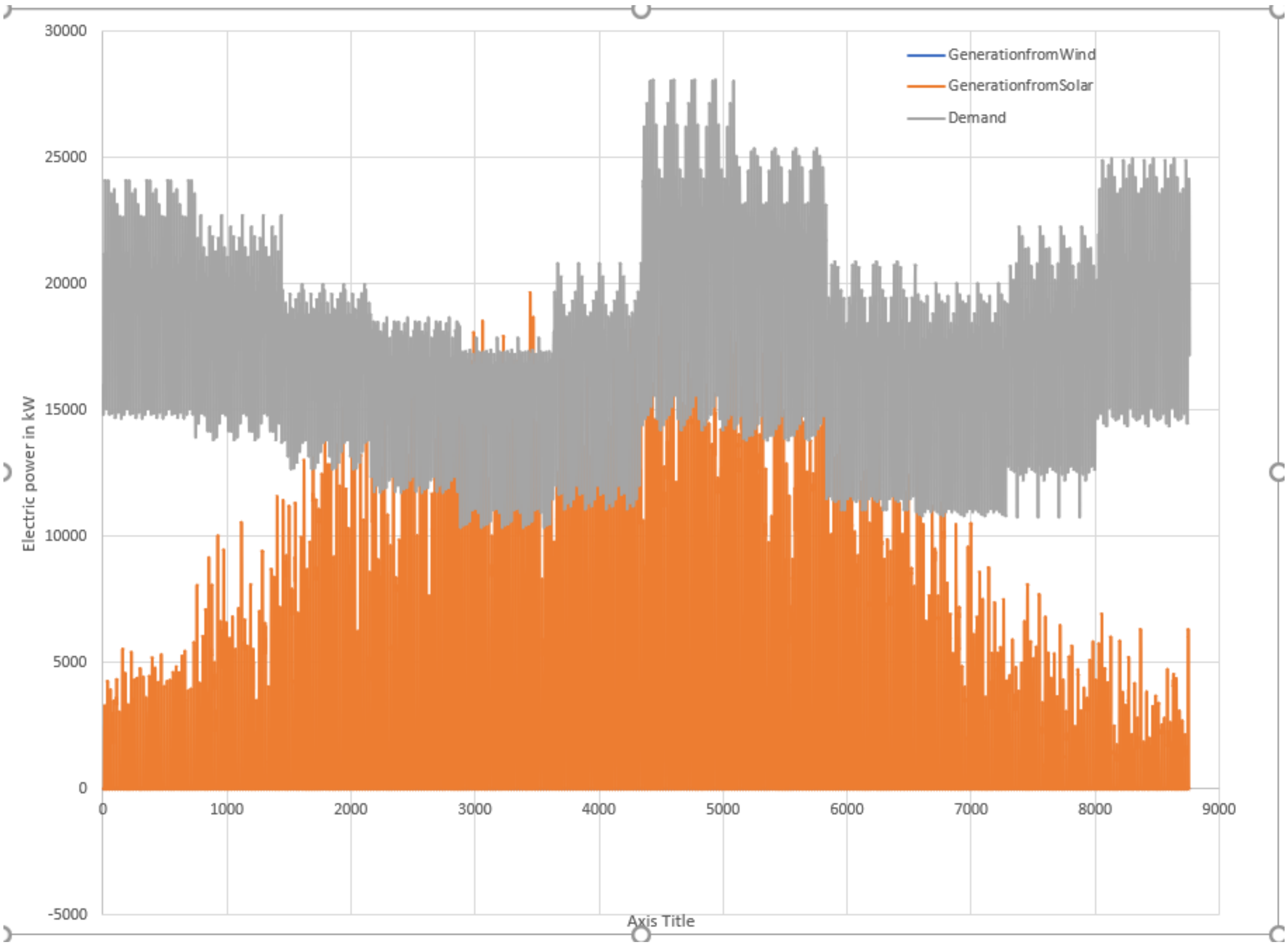




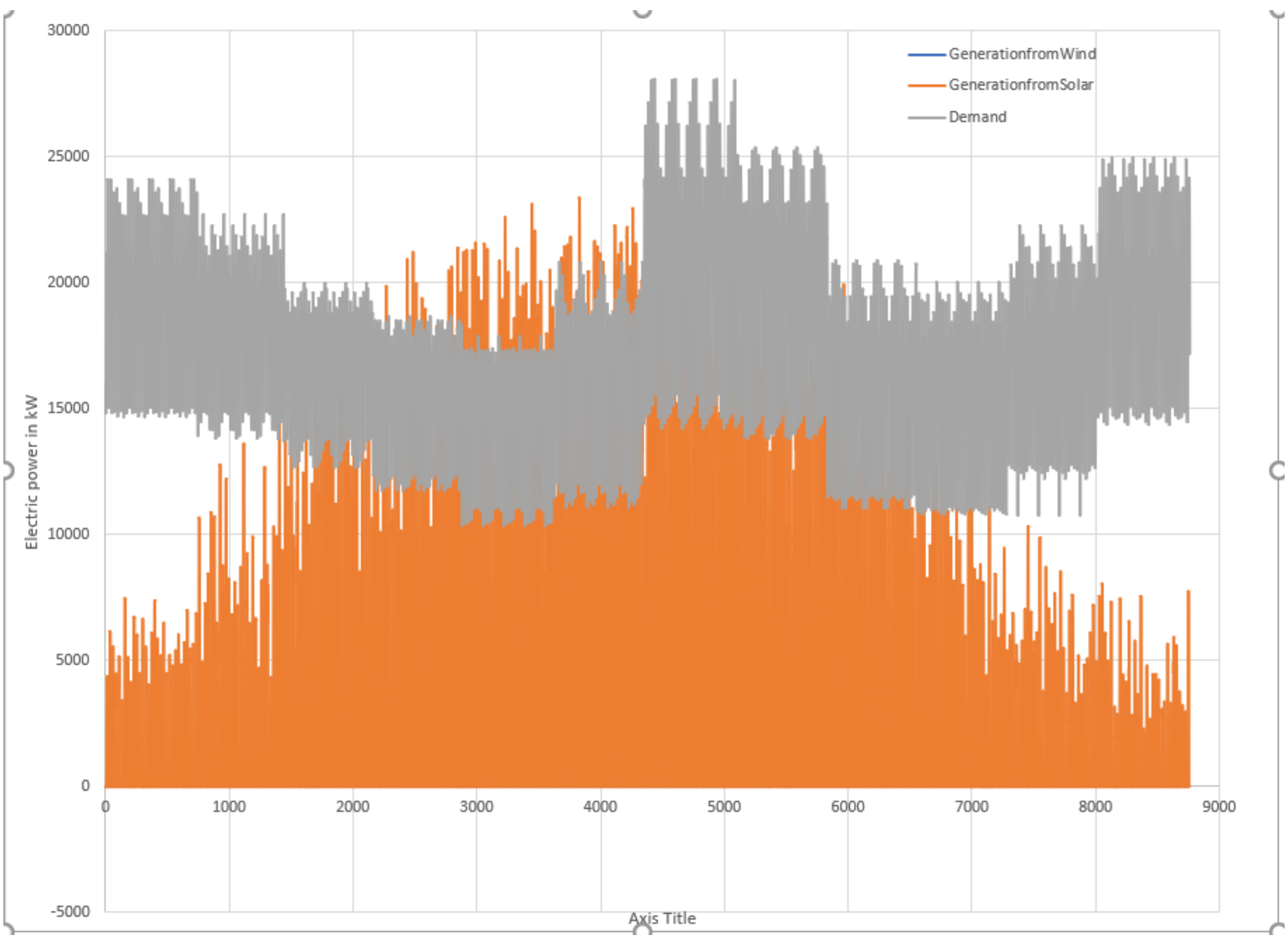
30000
25000
20000
15000
10000
5000
0
-5000
Electric power in kW
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
Axis Title
GenerationfromWind
GenerationfromSolar
Demand



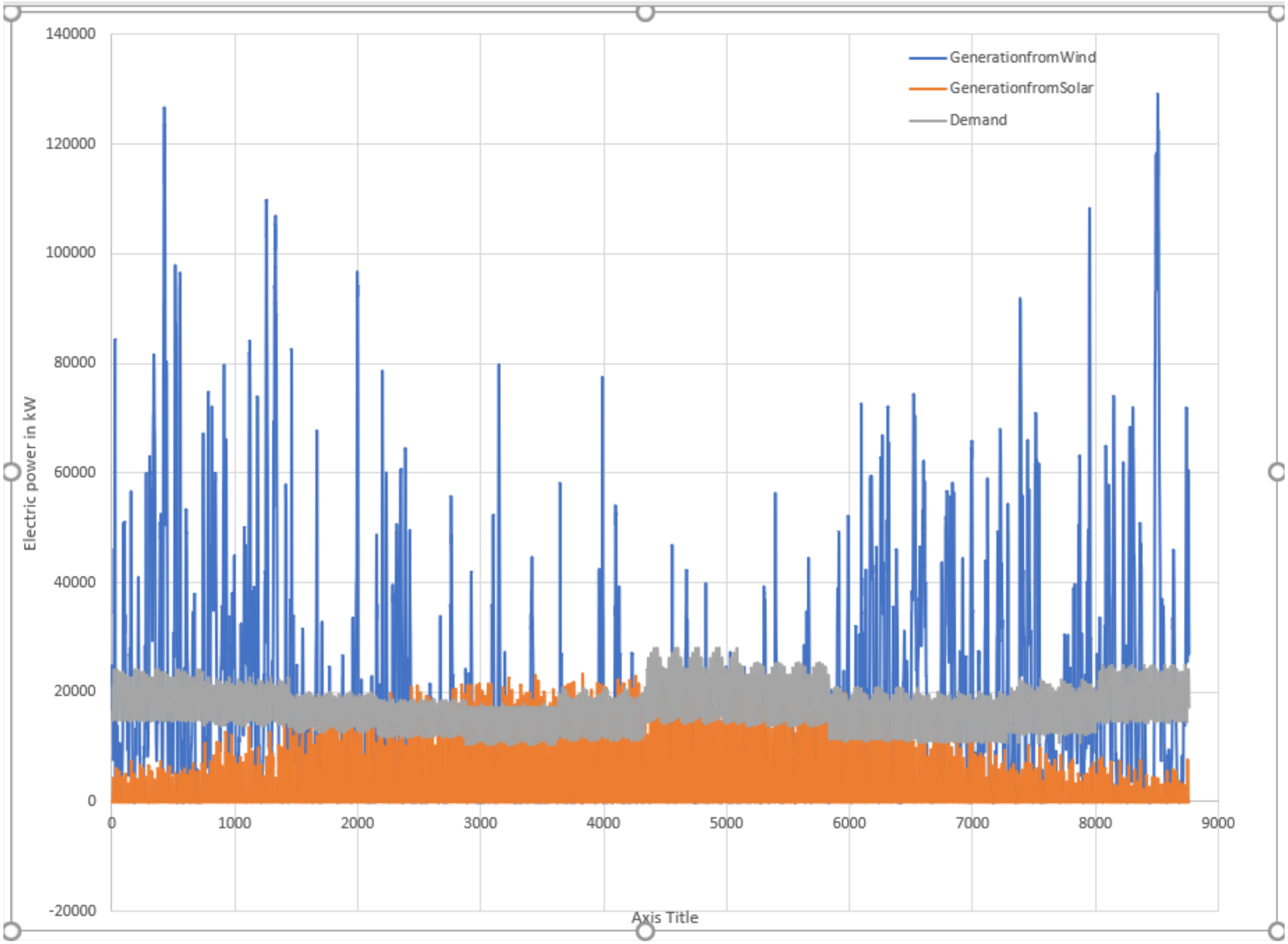
GenerationfromWind
GenerationfromSolar
Demand
Electric power in kW
30000
25000
20000
15000
10000
5000
0
-5000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
Axis Title



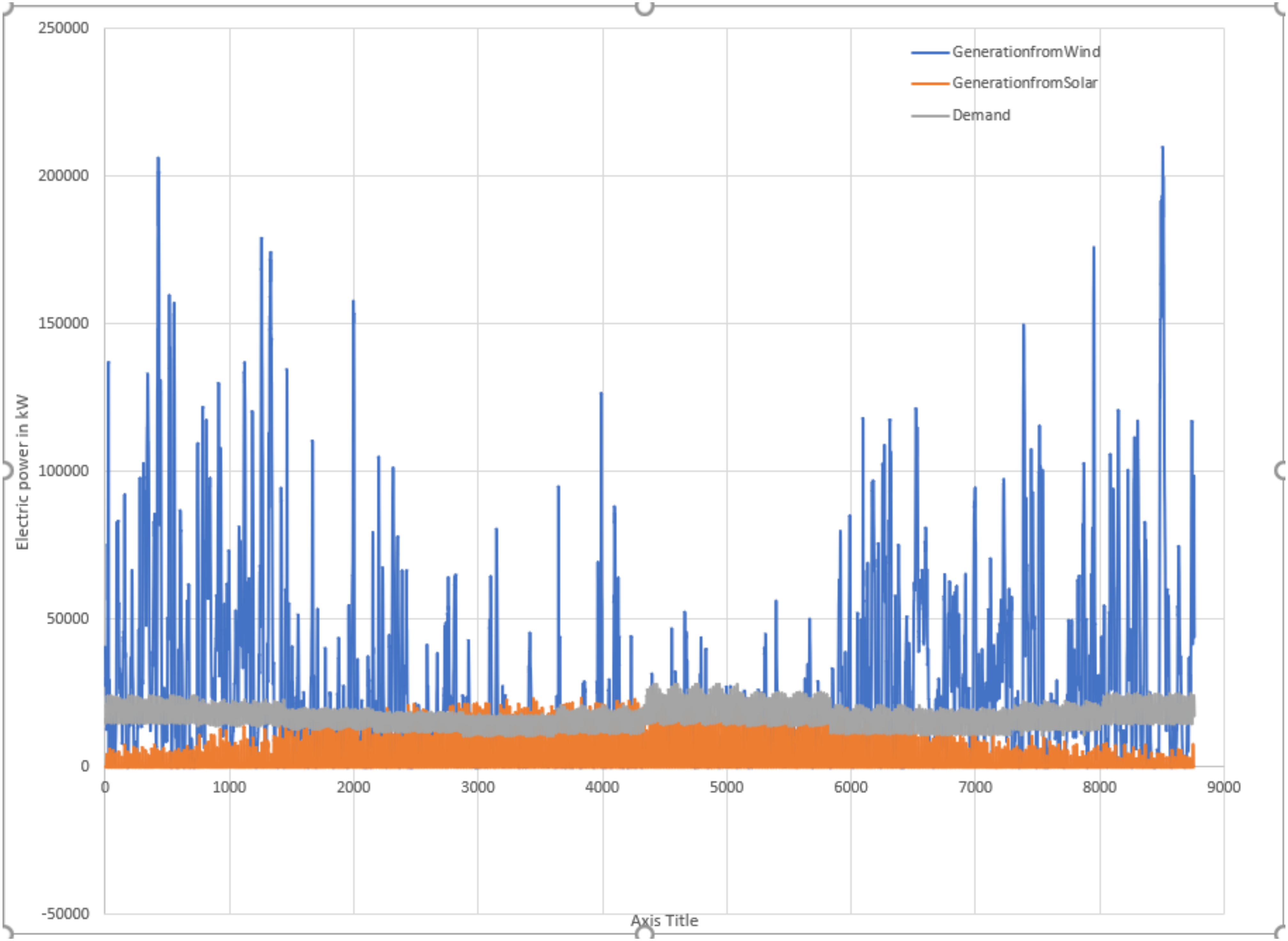
GenerationfromWind
GenerationfromSolar
Demand
Electric power in kW
Axis Title
30000
25000
20000
15000
10000
5000
0
-5000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000



GenerationfromWind
GenerationfromSolar
Demand
Electric power in kW
Axis Title
30000
25000
20000
15000
10000
5000
0
-5000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000

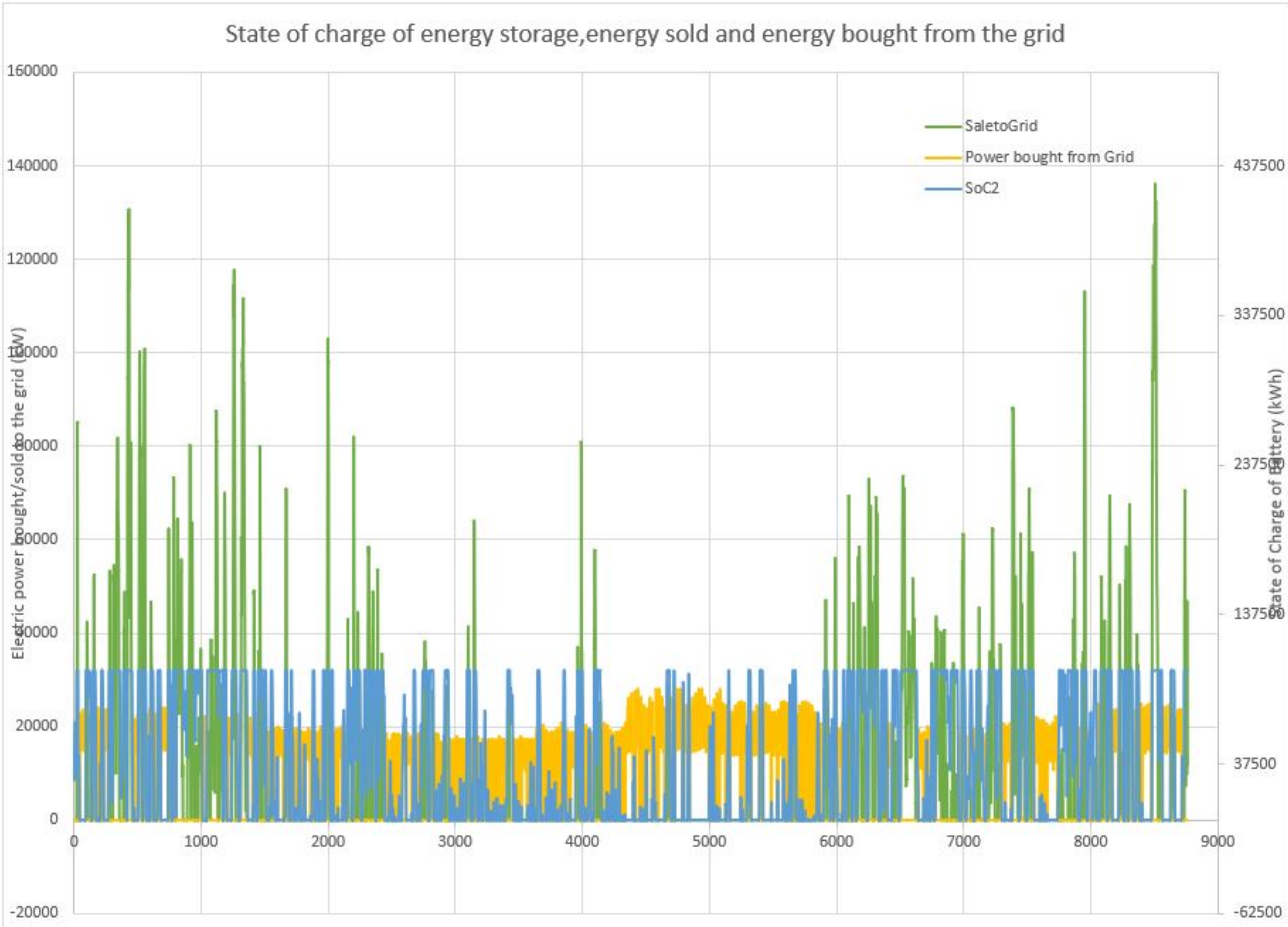


140000
120000
100000
80000
60000
40000
20000
0
-20000
Electric power in kW
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
Axis Title
GenerationfromWind
GenerationfromSolar
Demand



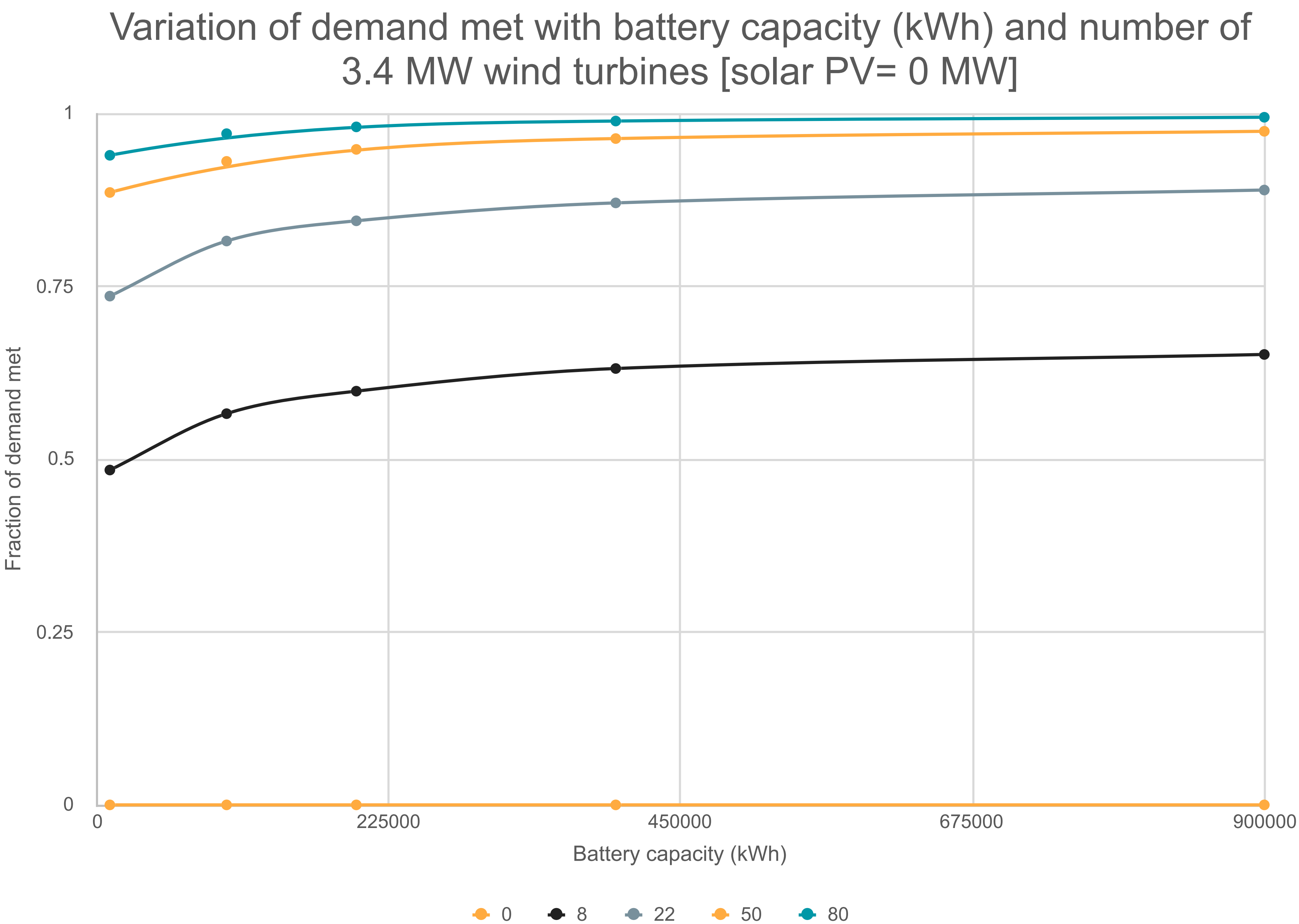
GenerationfromWind
GenerationfromSolar
Demand
Electric power in kW
250000
200000
150000
100000
50000
0
-50000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
Axis Title

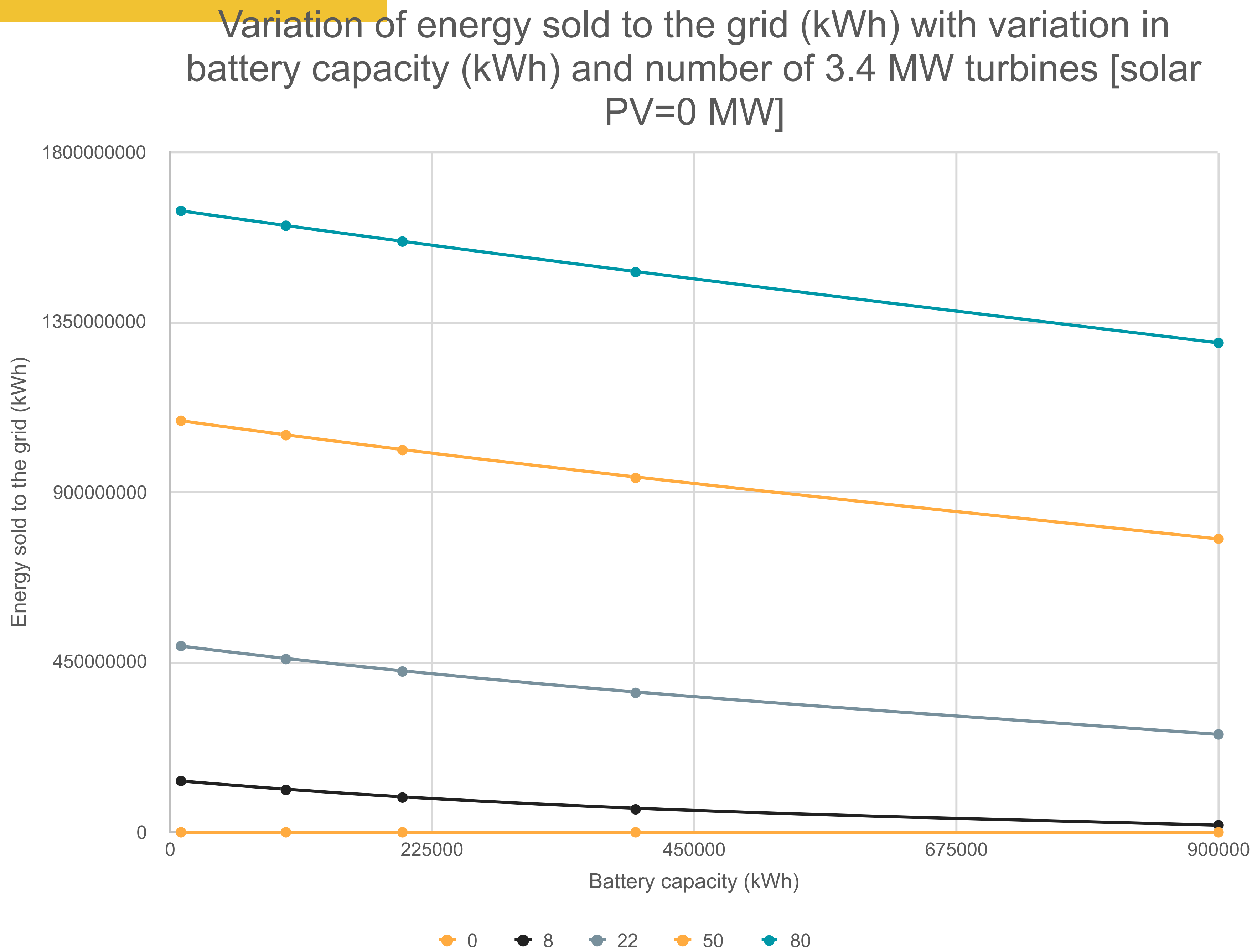
Objective 4: 100% RE Plan



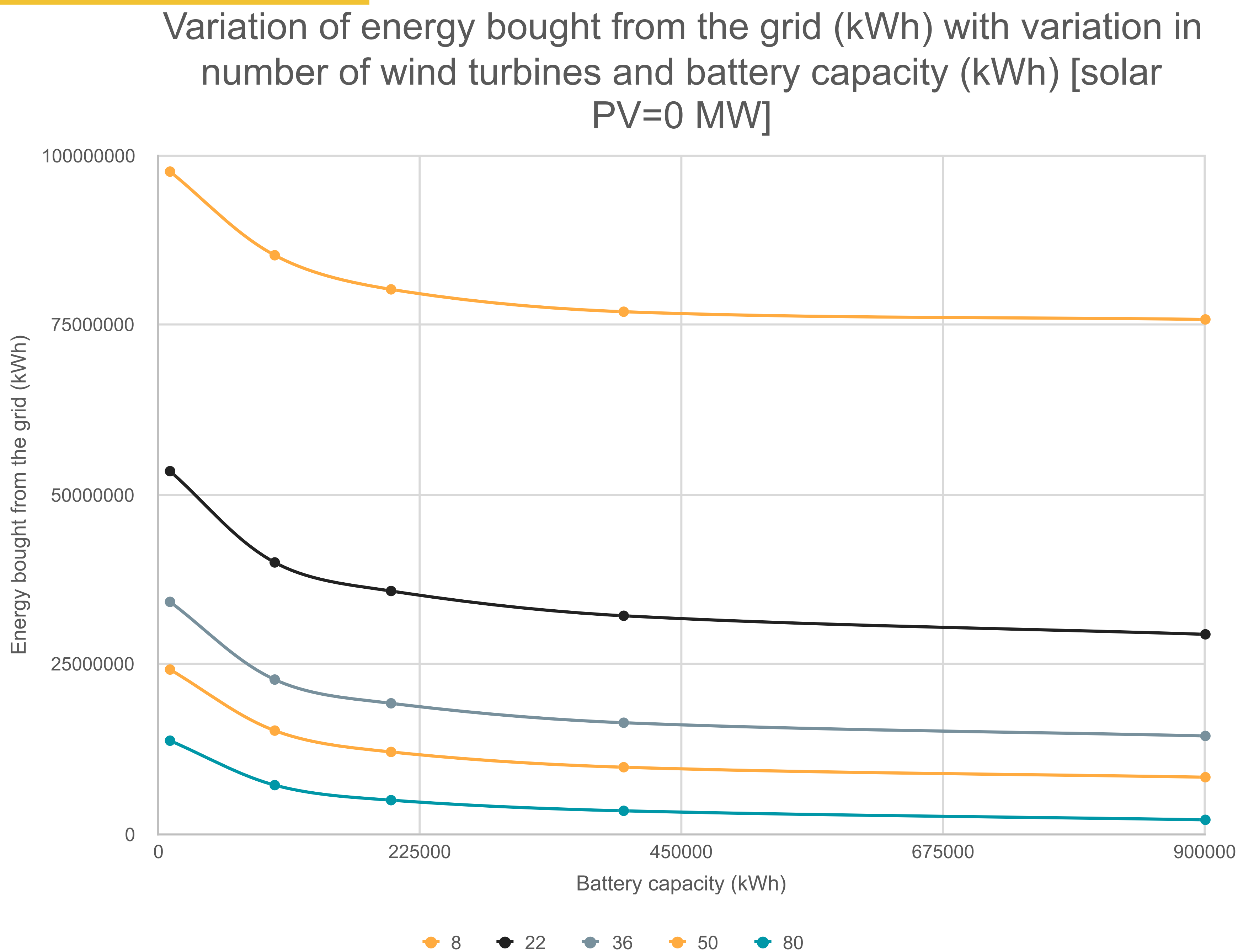
91.2% Demand met, 74.81 GWh (74.81 million kWh) sold, 12.2 GWh (12.2 million kWh) bought, total land occupied=17 km^2 (4200 acres out of 222000 acres of County)

Objective 4: 100% RE Plan

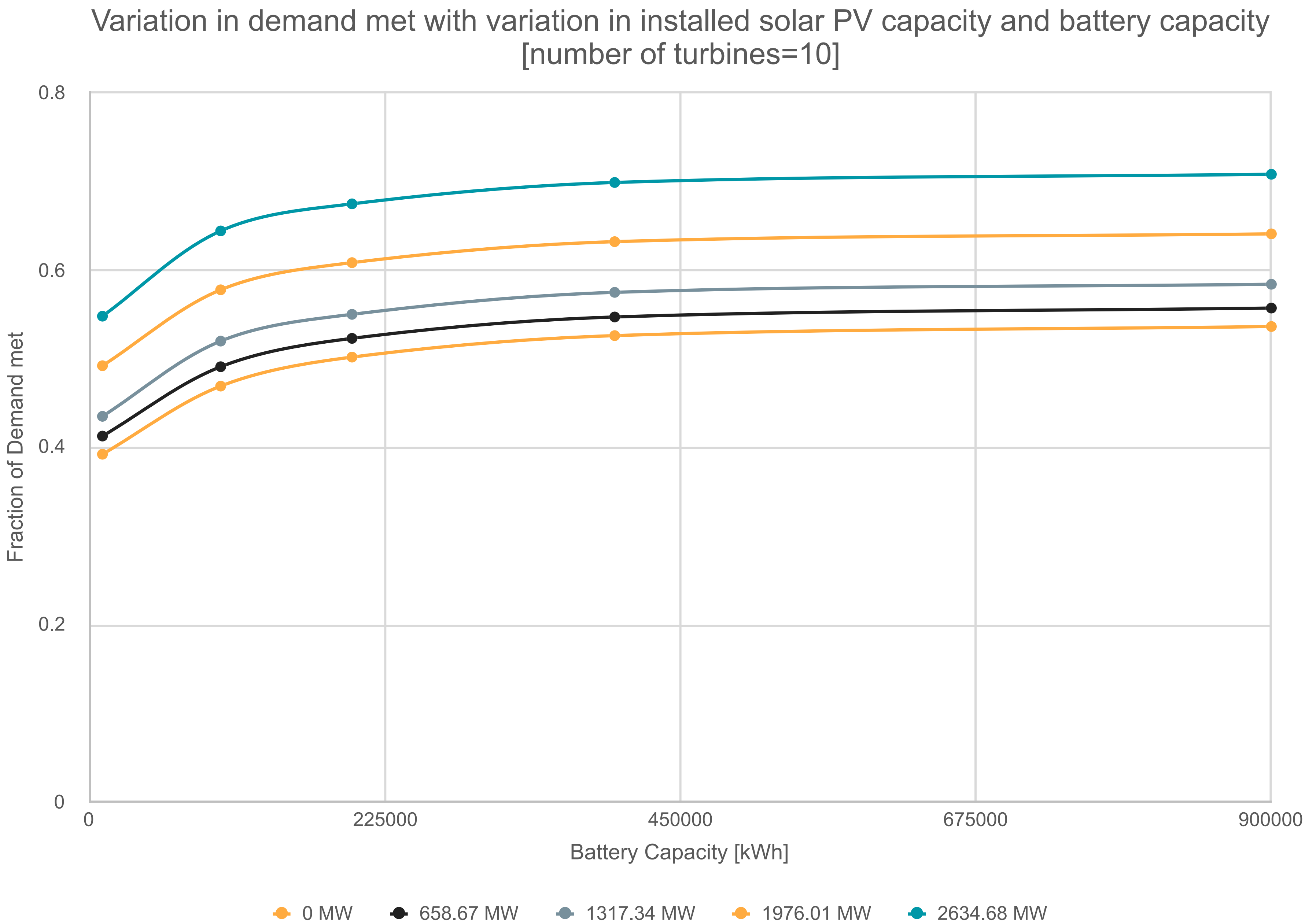



Variation of energy sold to the grid (kWh) with variation in battery capacity (kWh) and number of 3.4 MW turbines [solar PV=0 MW]
Energy sold to the grid (kWh)
1800000000
1350000000
900000000
450000000
0
0
225000
450000
675000
900000
Battery capacity (kWh)
0
8
22
50
80

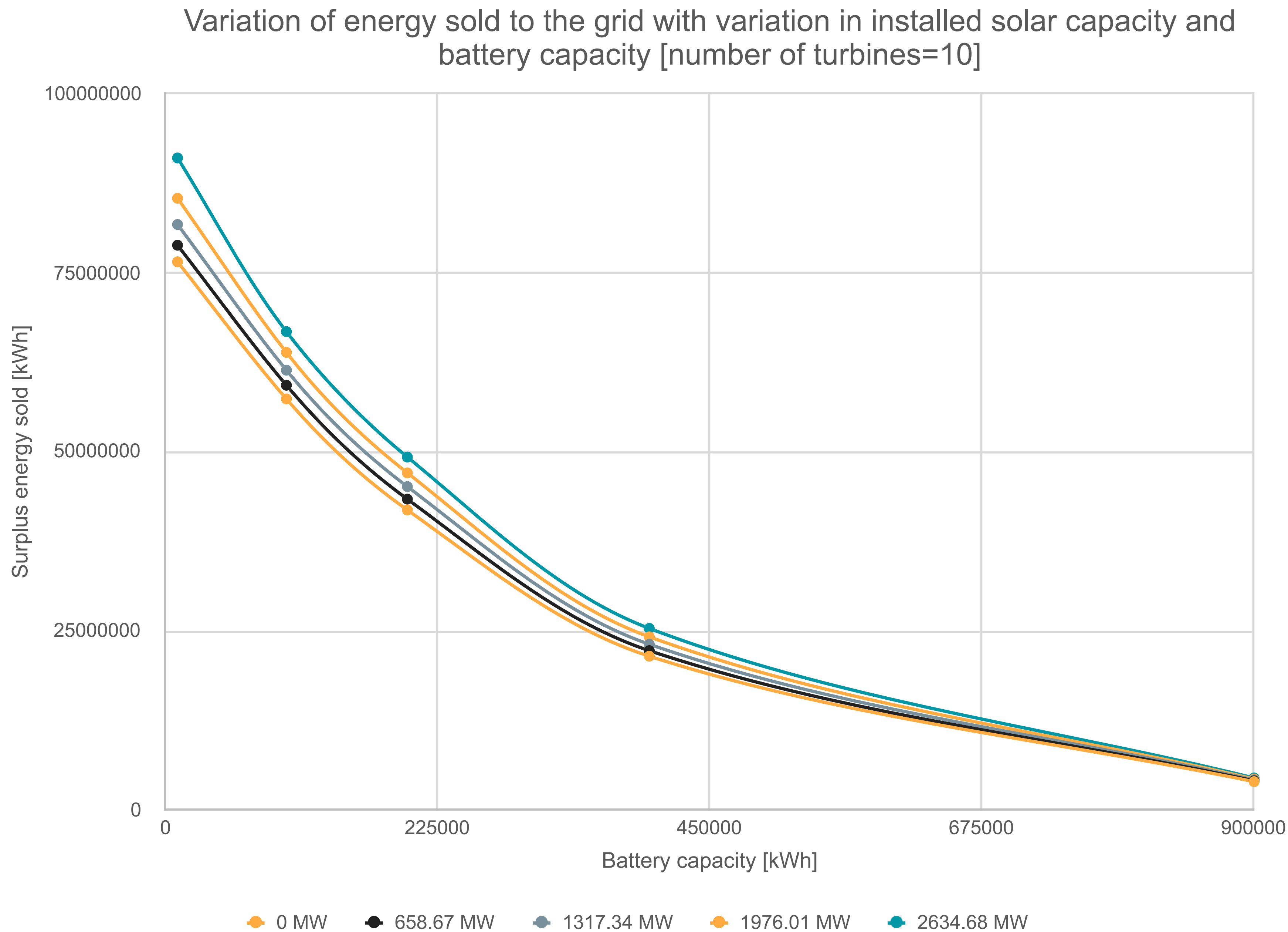
Objective 4: 100% RE Plan



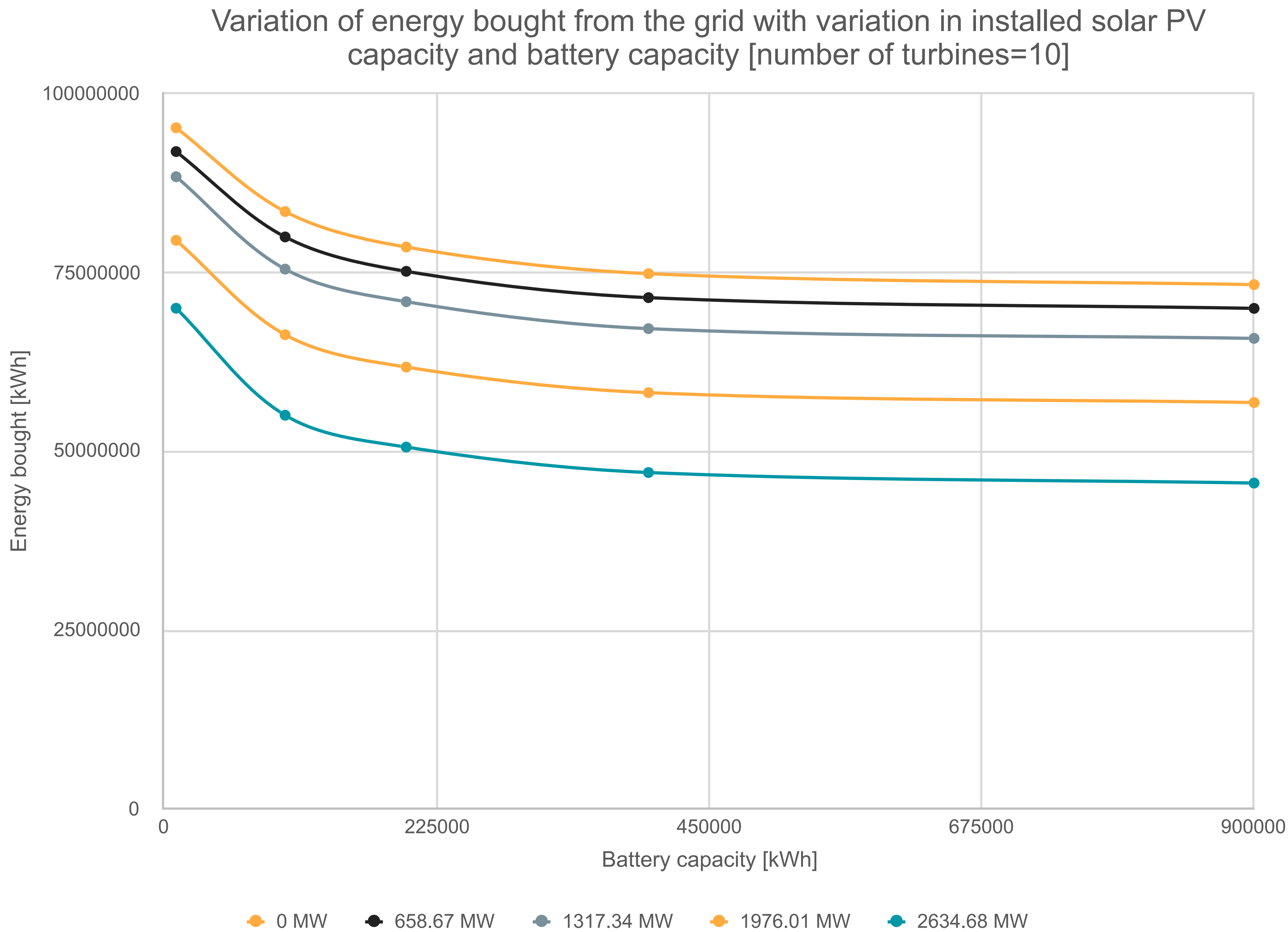
Objective 4: 100% RE Plan



Objective 4: 100% RE Plan



Objective 4: 100% RE Plan



What does this mean for you?

- Current County Population = 21764
- Per Capita electricity consumption = 6662 kWh/year
- Average Energy Expenditure for the entire County ≅ $14.5 Million/year

Would you choose to implement a renewable energy system to save on your utility bills?

https://datausa.io/profile/geo/leelanau-county-mi/

Highlights

- The projected annual demand for 2040 is 153.42 GWh in the base case scenario, 155.36 GWh in the EV adoption scenario
- The County has 92.84 km^2 (22094 acres) available land area for total windfarm development and 213.4 km^2 (52732 acres) available land area for solar PV deployment
- Potential to generate 209.76 GWh/year from solar PV and 1960.23 GWh/year from wind turbines if all the available land is developed
- There is potential to reduce land use for generation significantly through rooftop solar PV
- Excess generation from the installed renewable capacity can be 5-6 times larger than the annual energy demand and investment in capacity building requires setting constraints on the excess generation

Shortcomings

- Demand projections are tied to county population in base case scenario
- Presence of multiple variables makes system optimization difficult
- Potential for energy arbitrage is neglected
- Aging and proximity of transmission infrastructure have not been modelled into the system assumptions
- Rooftop solar and onsite wind turbines have not been accounted for as an additional source of energy generation

Future Work

- Creation of a decision support tool to evaluate combinations of Solar PV and Wind Farm deployment
- Potential demand reduction due to onsite generation needs to be accounted for
- Potential for Demand response and energy arbitrage needs to be evaluated

Acknowledgements

Northport Energy Team

League of Women Voters Leelanau County

Consumers Energy

Cherryland Electric Cooperative

Dr. Gregory Keoleian

Dr. Geoffrey Lewis

Maryam Arbabzadeh

References

https://www.northportenergy.org/

https://datausa.io/profile/geo/leelanau-county-mi/#housing

http://www.benchmarksnorthwest.org/userfiles/uploads/PopProj2015to2040-Leelanau-26089.pdf

https://en.wind-turbine-models.com/turbines/1282-vestas-v136-3.45

Ong, S., Campbell, C., Denholm, P., Margolis, R., & Heath, G. (2013). Land-use requirements for solar power plants in the United States (No. NREL/TP-6A20-56290). National Renewable Energy Lab.(NREL), Golden, CO (United States).

Denholm, P., Hand, M., Jackson, M., & Ong, S. (2009). Land use requirements of modern wind power plants in the United States (No. NREL/TP-6A2-45834). National Renewable Energy Lab.(NREL), Golden, CO (United States).

Becker, T. A., Sidhu, I., & Tenderich, B. (2009). Electric vehicles in the United States: a new model with forecasts to 2030. Center for Entrepreneurship and Technology, University of California, Berkeley, 24.

Kelly, J. C., MacDonald, J. S., & Keoleian, G. A. (2012). Time-dependent plug-in hybrid electric vehicle charging based on national driving patterns and demographics. Applied Energy, 94, 395-405.

Budischak, C., Sewell, D., Thomson, H., Mach, L., Veron, D. E., & Kempton, W. (2013). Cost-minimized combinations of wind power, solar power and electrochemical storage, powering the grid up to 99.9% of the time. journal of power sources, 225, 60-74.

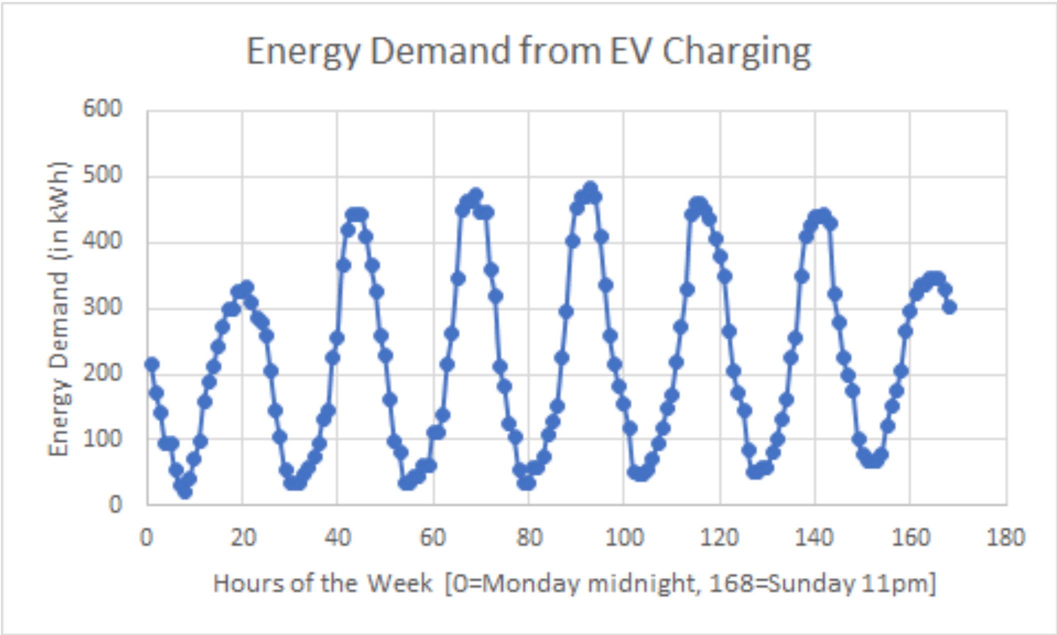
Appendix

System Assumptions

- Out of the total land utilized for a solar farm installation, 75 percent is covered with solar panels
- Land area per wind turbine is 0.621 km^2 and land area per MW for solar is 0.4 km^2
- The system starts operating on January 1, 2040 at midnight.
- Energy Storage System starts with zero state of charge
- Any surplus generation can be sold to the grid and any deficit can be met from the grid
- Electricity is not purchased from the grid for energy arbitrage
- Every RE installation is assumed to be located close to transmission lines and there is no requirement of infrastructure upgrades
- Base Case Assumption: Annual energy demand is proportional to the annual county population;Low Demand Assumption: Based on US-wide growth rate in Annual Energy Outlook 2018

EV Demand Projections

- EV penetration assumed to cap at 40%
- Additional demand from EV charging is superimposed on the Base Case Projections
- EV Demand varies over the week but the trend is assumed to be constant over the span of the year



Modelling Financial Constraints

Rate for Grid Electricity	0.1	$/kWh	County average [current]
Installed Cost of SPV	1060000	$/MW	[NREL Solar Industry Benchmark 2018]
Installed Cost of WT	1590000	$/MW	[NREL Cost of Wind 2016]
Installed Cost of Battery	273	$/kWh	[Lazard projections]
O&M Cost of SPV	28000	$/MW-yr	[NREL Solar Industry Benchmark 2018]
O&M Cost of WT	52000	$/MW-yr	[NREL Cost of Wind 2016]
O&M Cost of Battery	0.0273	$/kWh-yr	[Lazard projections]

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