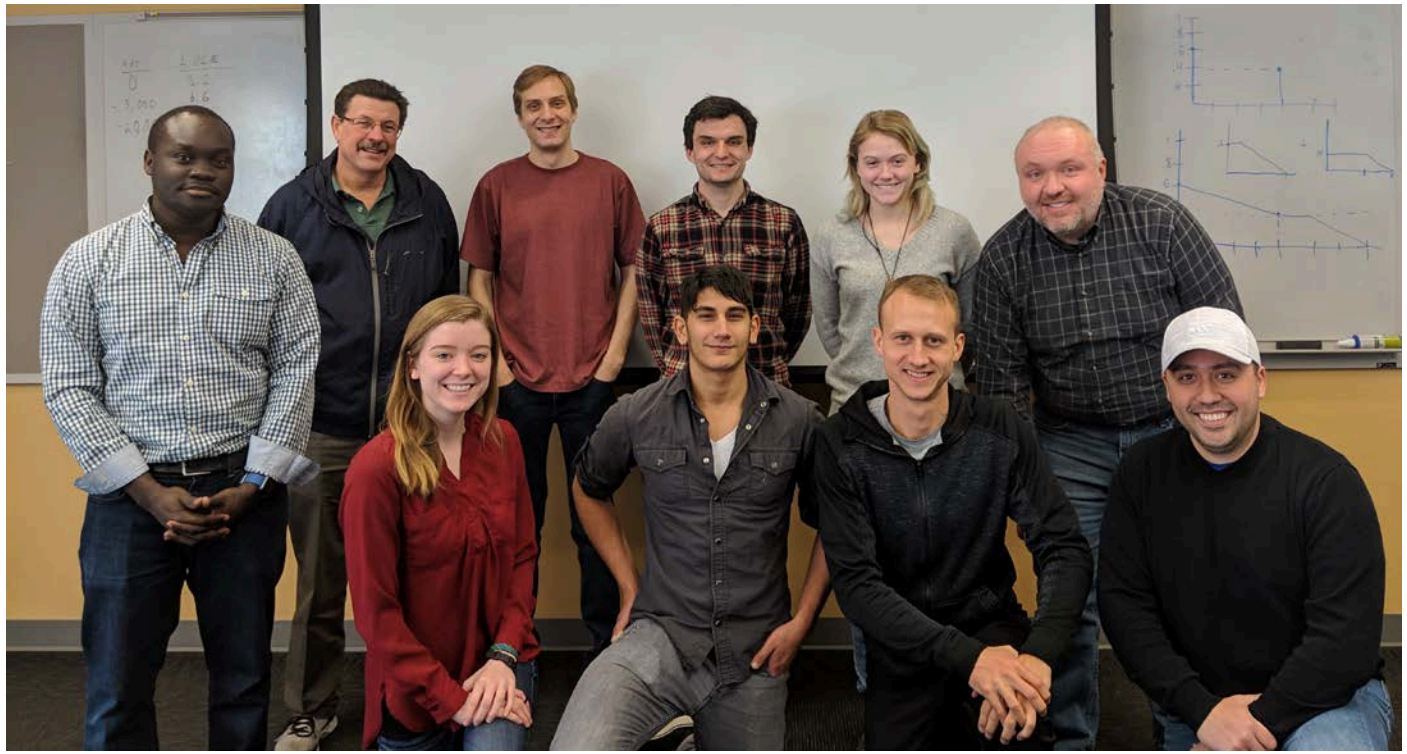
Power System Reliability with Increasing Renewables Study

ZARAN CLAES, SHANNON FOLEY, MATTHEW HUEBSCH, SHELBY PICKERING, IAN ROSTKOWSKI, DAVID TICKNOR

About the Senior Design Team



Goals of Study

Use historical data to determine likely places for solar and wind generating facilities

Using data, create grading criteria to create a model from

From the model, determine the effects that high amounts of wind and solar have on resource adequacy affects.

Create computer program via Python to run the PLEXOS model and reach an $LOLE_{(1)}$ of 0.1.

1. LOLE: loss of load expectation

Use of this Project

Renewable energy is variable, but the grid must remain reliable.

- Renewable energy such as solar and wind are the fastest growing types of energy
- Renewable energy is not perfectly predictable because it is based on weather
- New forms of generation (renewable) are replacing the older (non-renewable) sources that the grid was founded using

Goal: Analyze and quantify the impact of increasing renewable levels on the MISO power grid for intended users of MISO and their stakeholders

Functional and Non-Functional Requirements

Functional:

- Working PLEXOS models for 50/50 and 75/25
- LOLE and ELCC automation
- Cohesive data to present at end of project

Non-Functional:

- Two VMs used for the two different models
- Presentation to MISO on site in Eagan, MN
- PLEXOS Model that runs faster analysis than previous models

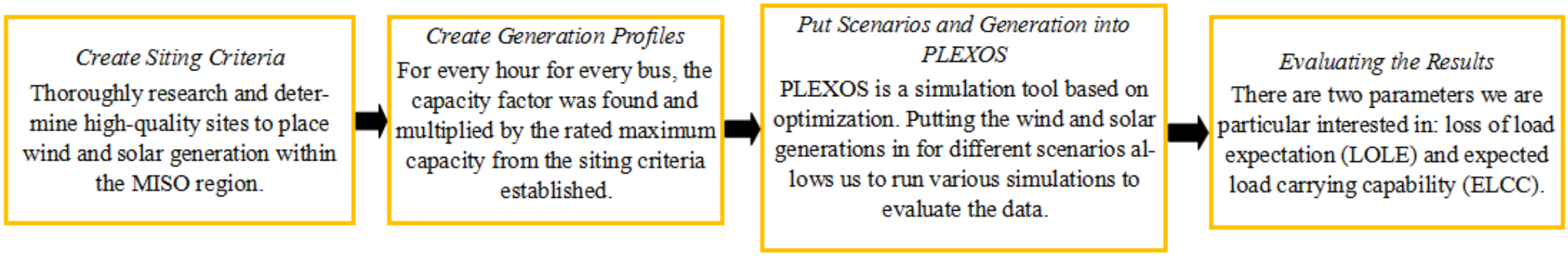
Key Metrics

- LOLE = loss of load expectation; NERC requirement that any location cannot expect to have a loss of load (due to under generation) that is greater than 1 day in 10 years
- ELCC = expected load carrying capacity; the amount of load that can be added for any specific amount of generation while maintaining the same LOLE.
- Capacity Factor = actual energy output / max possible energy output
- Capacity Credit = average energy production at peak net load / installed capacity over all 8760 hours per year

Assumptions

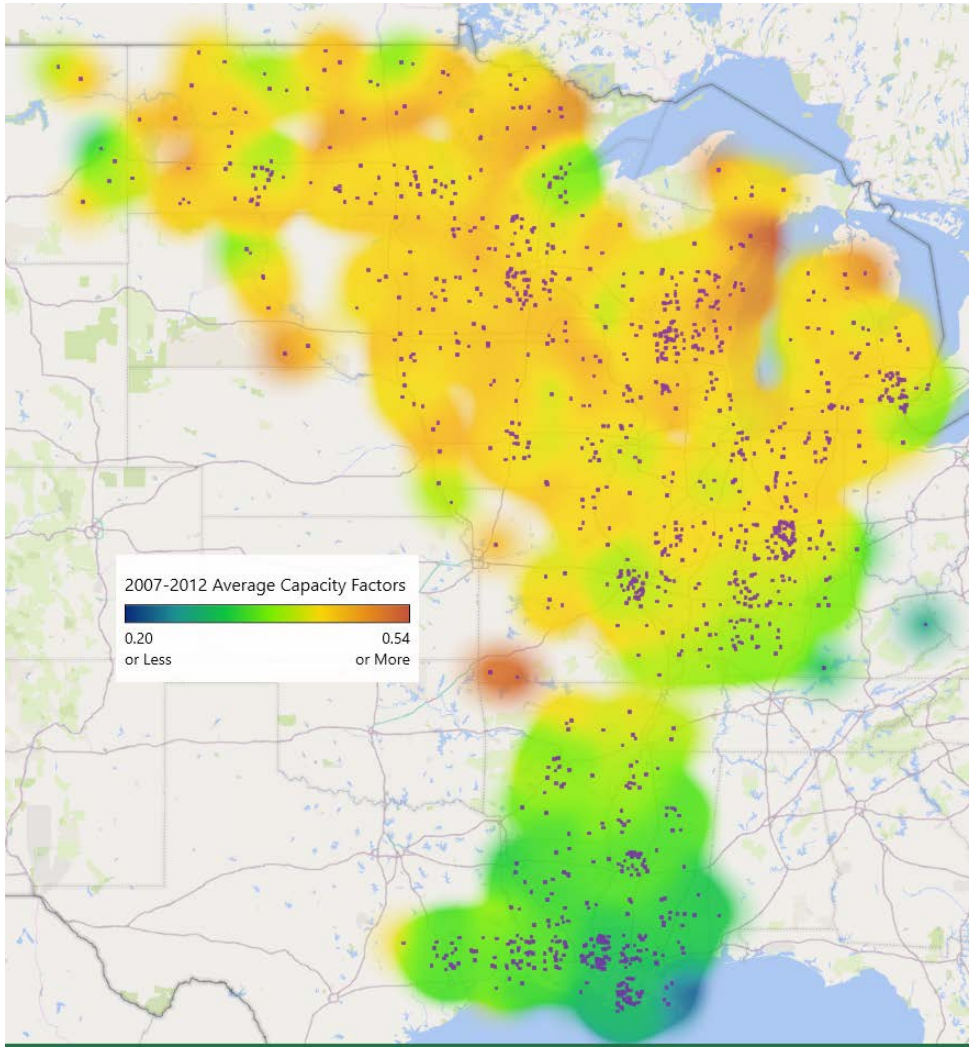
- Future with 50% wind and 50% solar
- Future with 25% wind and 75% solar
- 10, 30, 50, and 100 percent penetration levels
- Hydroelectric energy is always on
- Transmission is ignored
- Load and generation are always increasing
- Weather patterns repeat as they have in the past

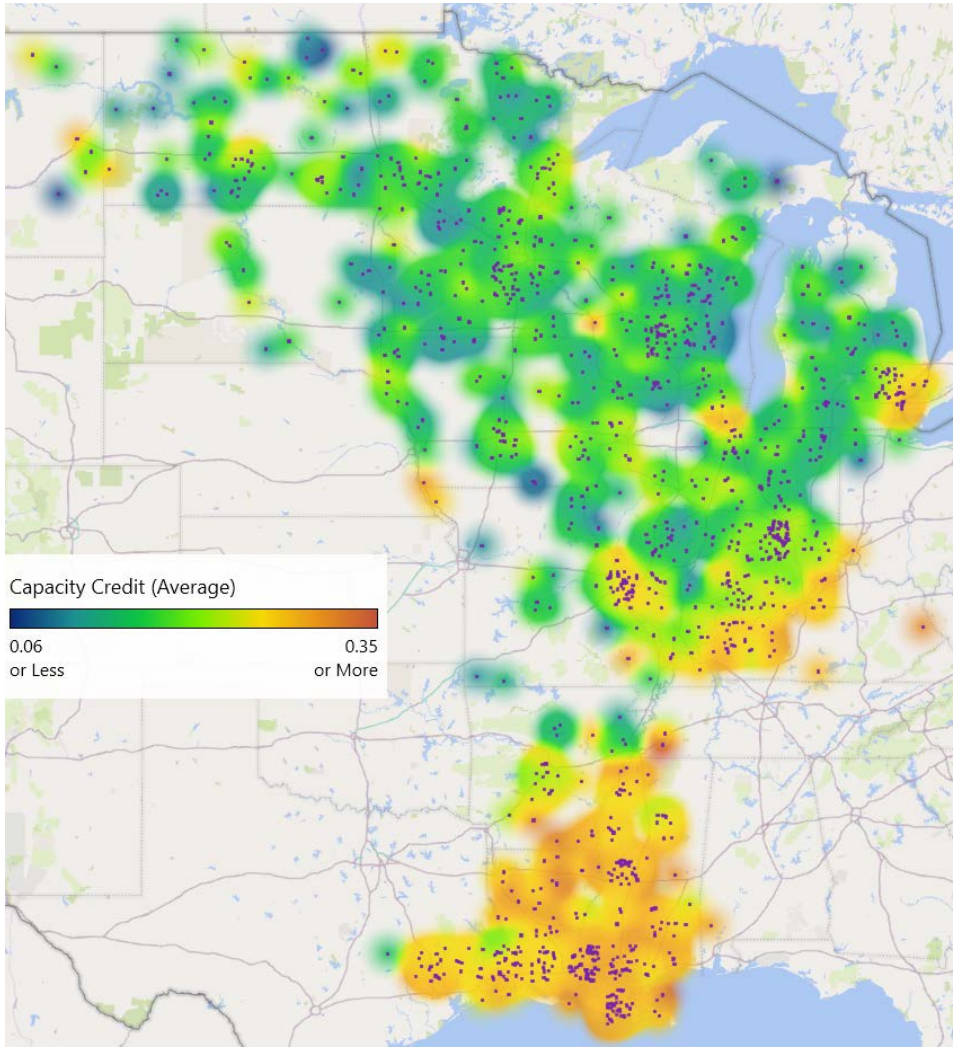
Design Approach



Siting Needed To Model Future

- Considerations for placement of renewable generation
  - Capacity Factor
  - Population Density
  - Economic Incentives
  - Capacity Credit
  - Presence in queue

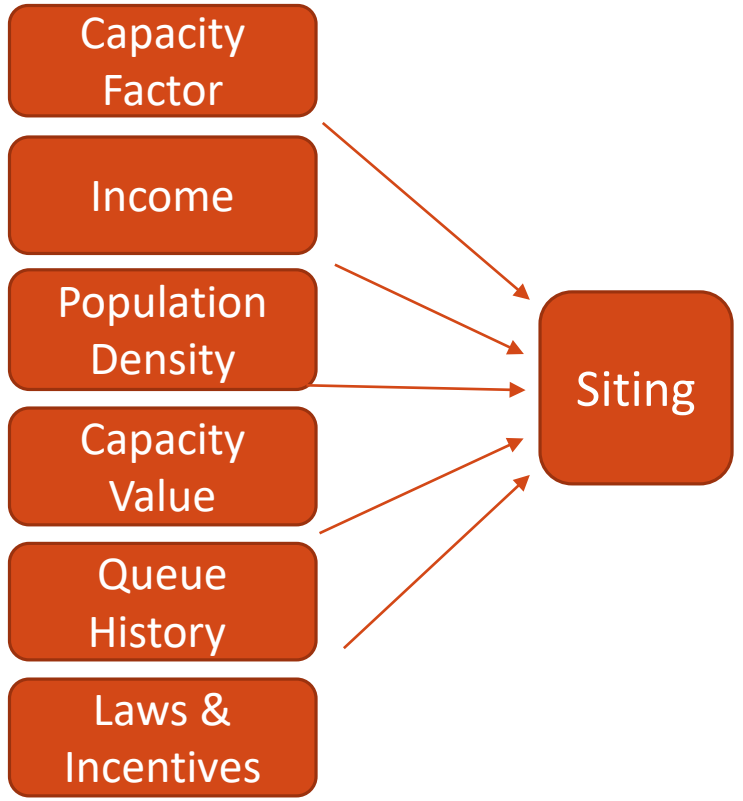




MISO Wind

Siting Overview

- Determines how solar and wind will be added to the system.
- Uses an equation to rank sites based on the data compiled by the team.
- Locations with higher rankings will have solar or wind added to their locations first.
- Equation takes 6 factors into account, and importance of these factors varies depending on technology and penetration level.



Siting Criteria

	Capacity Factor	Population Density	Queue	Incentives	Capacity Credit
Wind 10%	65%	15%	10%	10%	0%
Wind 30%	65%	15%	10%	10%	0%
Wind 50%	50%	10%	10%	10%	20%
Wind 100%	40%	10%	10%	10%	30%

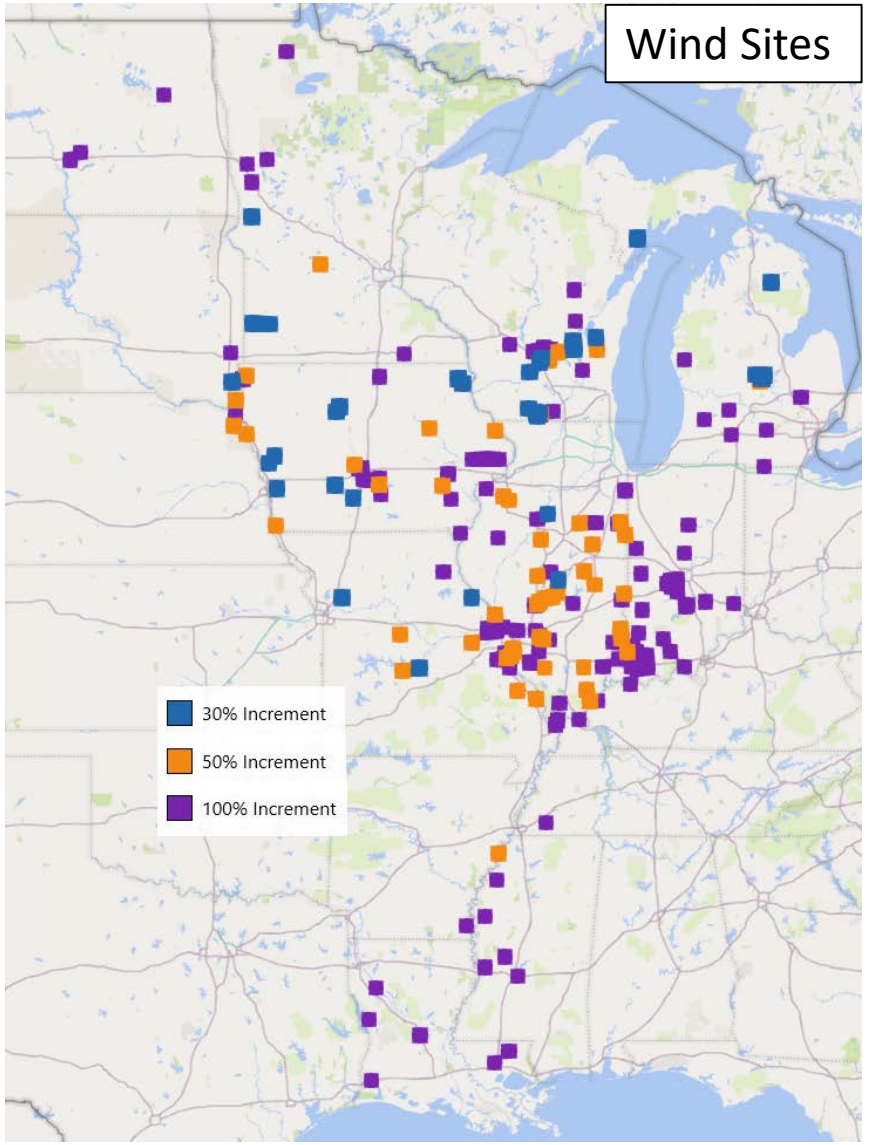
	Capacity Factor	Population Density	Queue	Incentives	Capacity Credit
Tracking 10%	65%	15%	10%	10%	0%
Tracking 30%	65%	15%	10%	10%	0%
Tracking 50%	50%	10%	10%	10%	20%
Tracking 100%	40%	10%	10%	10%	30%

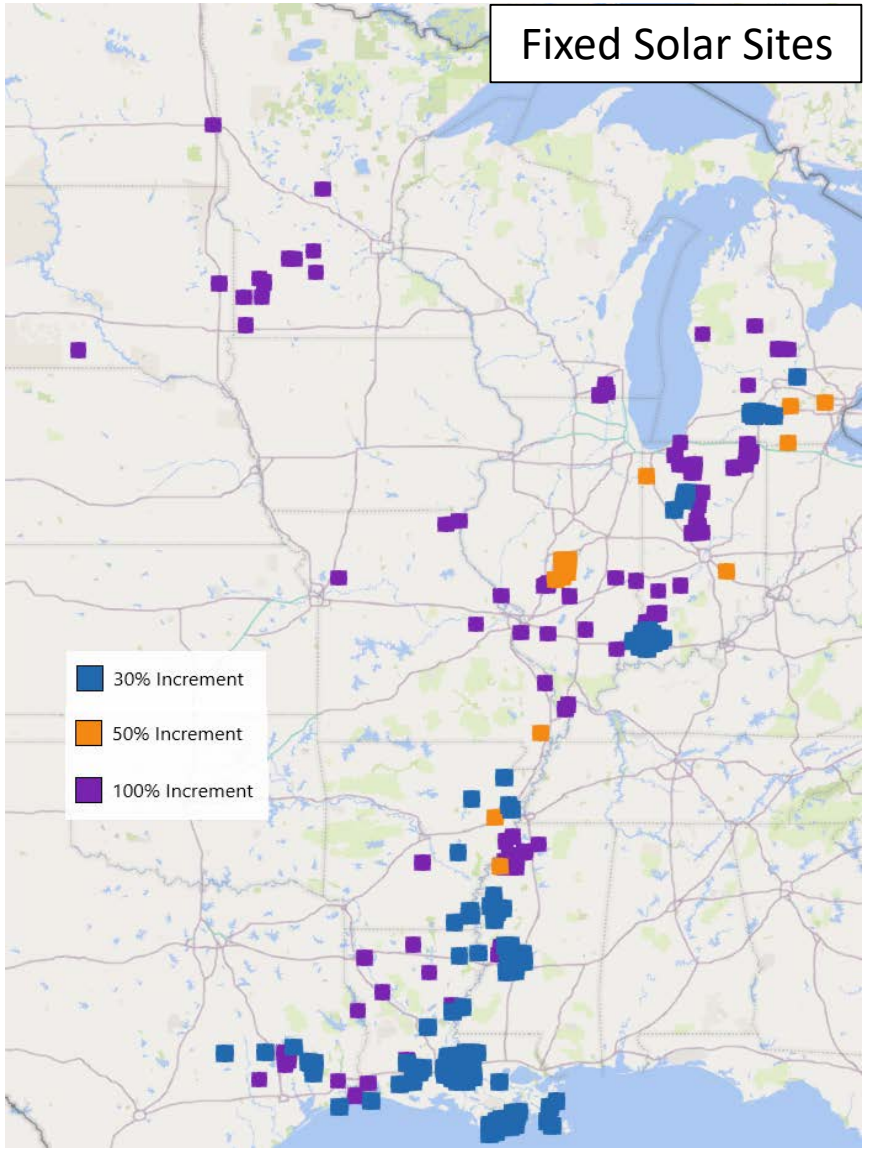
Siting Criteria (cont.)

	Capacity Factor	Population Density	Queue	Incentives	Capacity Credit
Fixed 10%	65%	15%	10%	10%	0%
Fixed 30%	65%	15%	10%	10%	0%
Fixed 50%	50%	10%	10%	10%	20%
Fixed 100%	40%	10%	10%	10%	30%

	Capacity factor	Population Density	County Income
Rooftop 10%	25%	35%	40%
Rooftop 30%	30%	35%	35%
Rooftop 50%	35%	35%	30%
Rooftop 100%	40%	35%	25%

Siting Results





Why PLEXOS?

- PLEXOS is a software that allows us to perform economic analysis on the power grid.
- Looking at the system with 50% wind and 50% solar power, and another where it is 75% wind and 25% solar power.
- Siting analysis and historic weather patterns
- PLEXOS returns useful information about the system..
- Scenarios make changing settings easy

PLEXOS - Scenarios

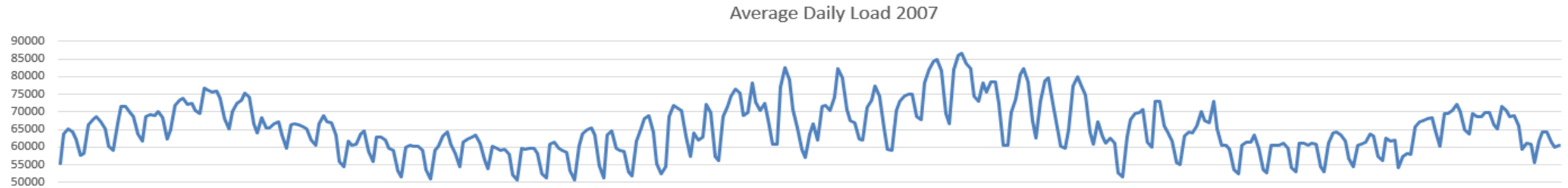
For this study, the following models have been built:

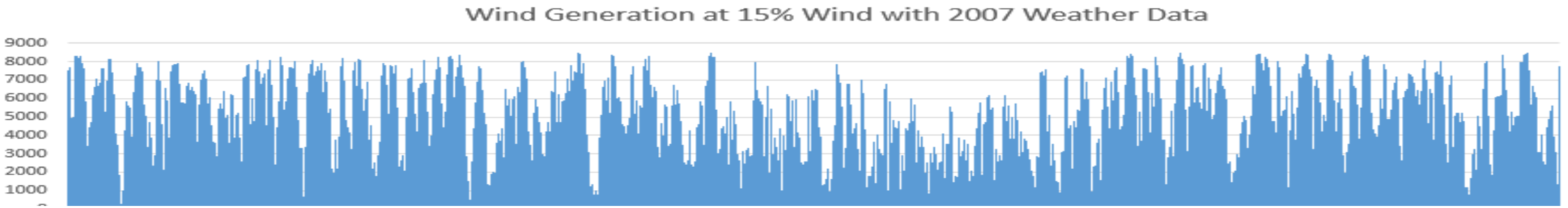
- Comparison Model: Includes zero renewables. Is checked against the other penetration levels in order to determine ELCC(1) of added renewables..
- 10% Model: Includes all of MISO's current wind and solar generation.
- 30%, 50%, and 100% (both for 50/50 and 75/25): Additional renewable generation added up to the stated penetration percentage. Like the 10%, these are checked against the comparison model to calculate respective ELCC(1) values.

1. ELCC: expected load carrying capacity

PLEXOS – 6 Years of Input Data

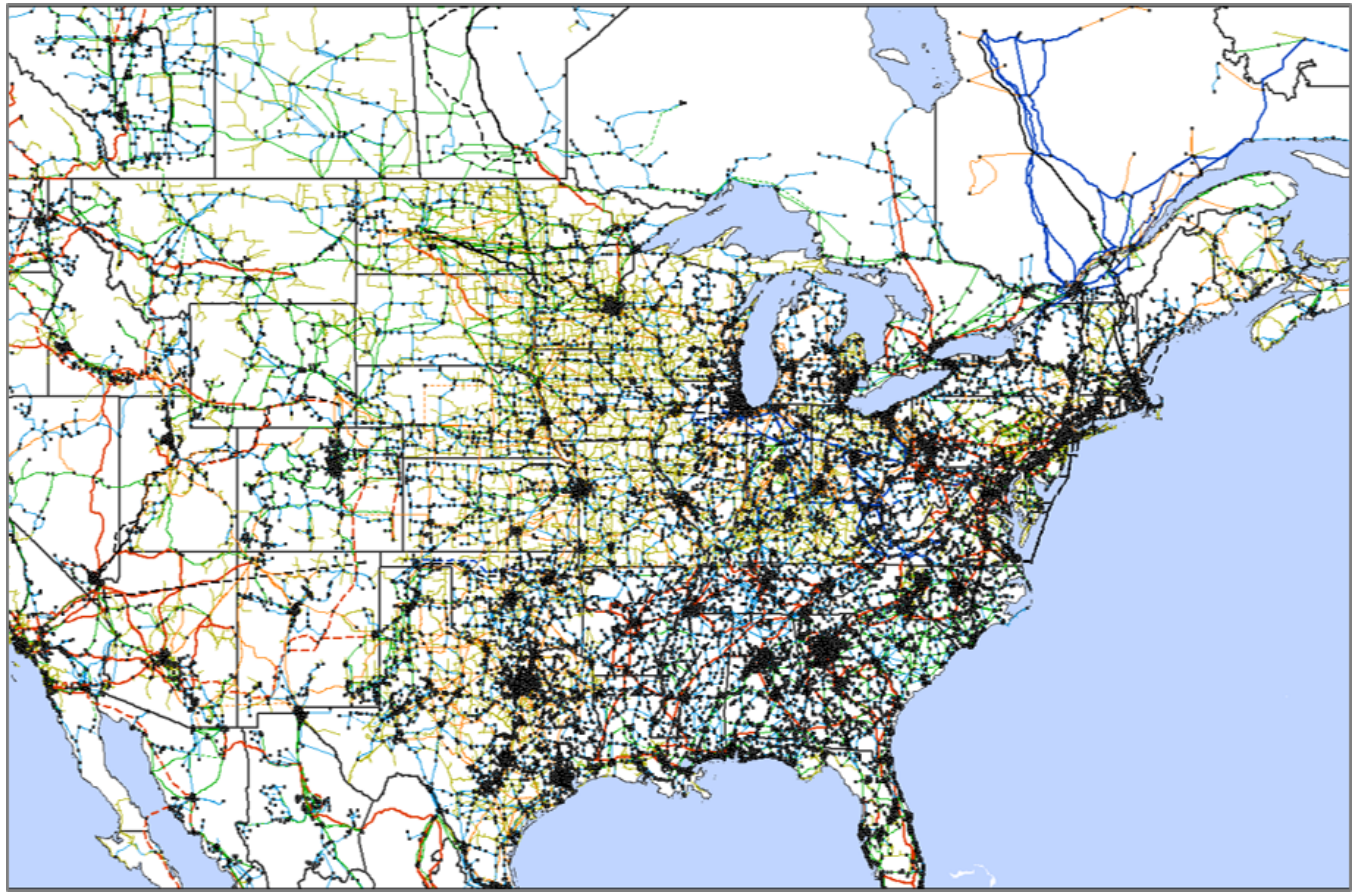
- Changing weather patterns are put into PLEXOS to analyze stability of the grid with this amount of renewable energy.
- The 50/50 model and the 75/25 model have adjusted load running from 2007 to 2012.
- PLEXOS simulates the 2017 load six times with 2007 – 2012 weather patterns.
- The fixed load is adjusted for each year such that all years return an LOLE of 0.1. From this, we can find an average ELCC derived from all years





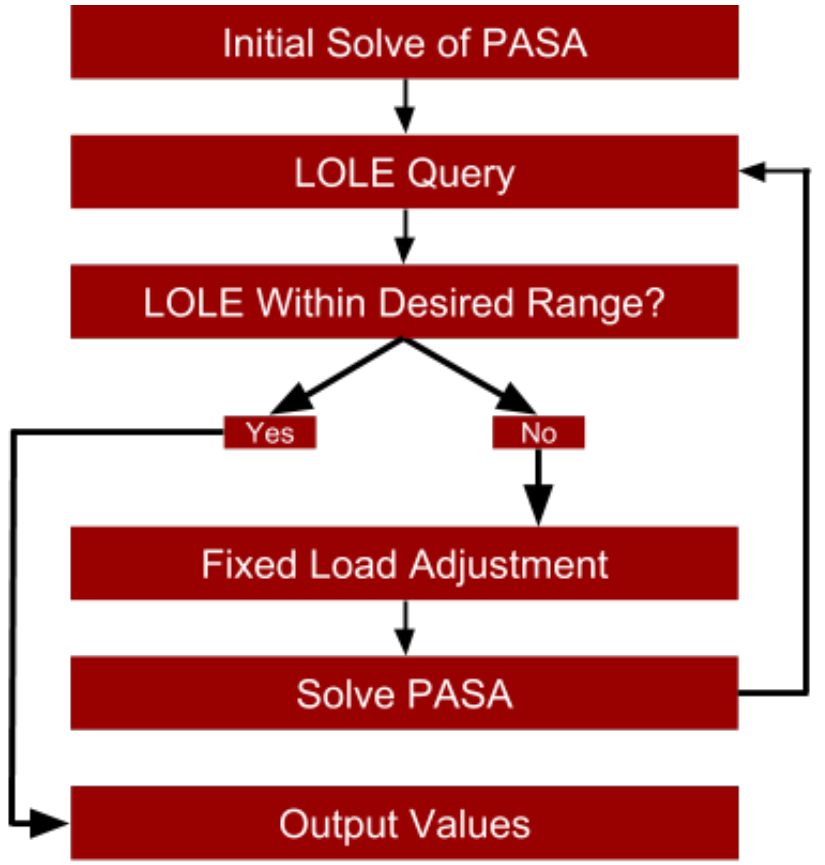
The Condensed PLEXOS Model

- We reduced model from many nodes to a single MISO 'node'.
- This allows for PLEXOS to run simulations more quickly. Runs only take 20 minutes instead of several days.
- Also made creation of the model much simpler because we could sum generation instead of location based generation.



PLEXOS LOLE Automation Script

- What does the script do?
  - Finds Fixed Load needed to have yearly LOLE(1) of 0.1
- What is needed to run?
  - PLEXOS .xml model
  - Any input .CSV files needed for PASA running
- How does it do it?
  - Reads in LOLE value from solved PASA
  - Calculates Fixed Load adjustment needed to push LOLE(1) to 0.1
  - Solves PASA with adjusted Fixed Load
- Outputs?
  - CSV with iterations
  - Iteration Run Time
  - Fixed Load results



1. LOLE: loss of load expectation

Quantifying Results

Base Case - Zero Renewables:

Fixed Load	-5900	MW	1	1/1/2010	12/31/2010	MISO Renewables Off
Fixed Load	-5600	MW	1	1/1/2009	12/31/2009	MISO Renewables Off
Fixed Load	-6200	MW	1	1/1/2008	12/31/2008	MISO Renewables Off
Fixed Load	-5600	MW	1	1/1/2011	12/31/2011	MISO Renewables Off
Fixed Load	-6350	MW	1	1/1/2007	12/31/2007	MISO Renewables Off
Fixed Load	-5900	MW	1	1/1/2012	12/31/2012	MISO Renewables Off

50/50 - 30% Penetration Case :

Fixed Load	25600	MW	1	1/1/2011	12/31/2011	RPL30
Fixed Load	26600	MW	1	1/1/2010	12/31/2010	RPL30
Fixed Load	17300	MW	1	1/1/2009	12/31/2009	RPL30
Fixed Load	36000	MW	1	1/1/2012	12/31/2012	RPL30
Fixed Load	17800	MW	1	1/1/2008	12/31/2008	RPL30
Fixed Load	23750	MW	1	1/1/2007	12/31/2007	RPL30

ELCC(1) Calculation:

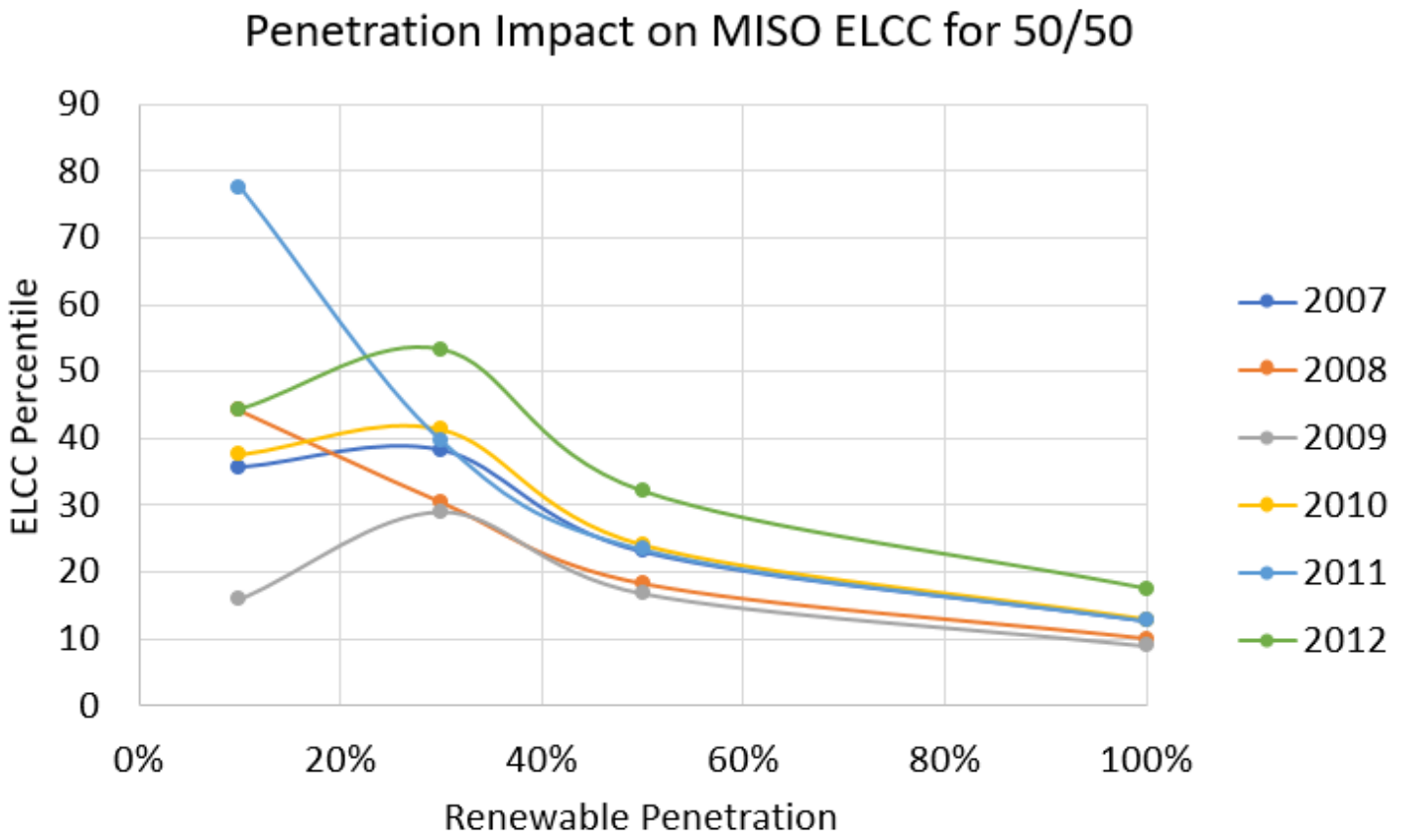
Year	30% - Base	ELCC (MW)
2007	23750+6350	= 30100
2008	17800+6200	= 24000
2009	17300+5600	= 22900
2010	26600+5900	= 32500
2011	25600+5600	= 31200
2012	36000+5900	= 41900

1. ELCC: expected load carrying capacity

Results

Decrease of ELCC(1) as Renewable Generation increases

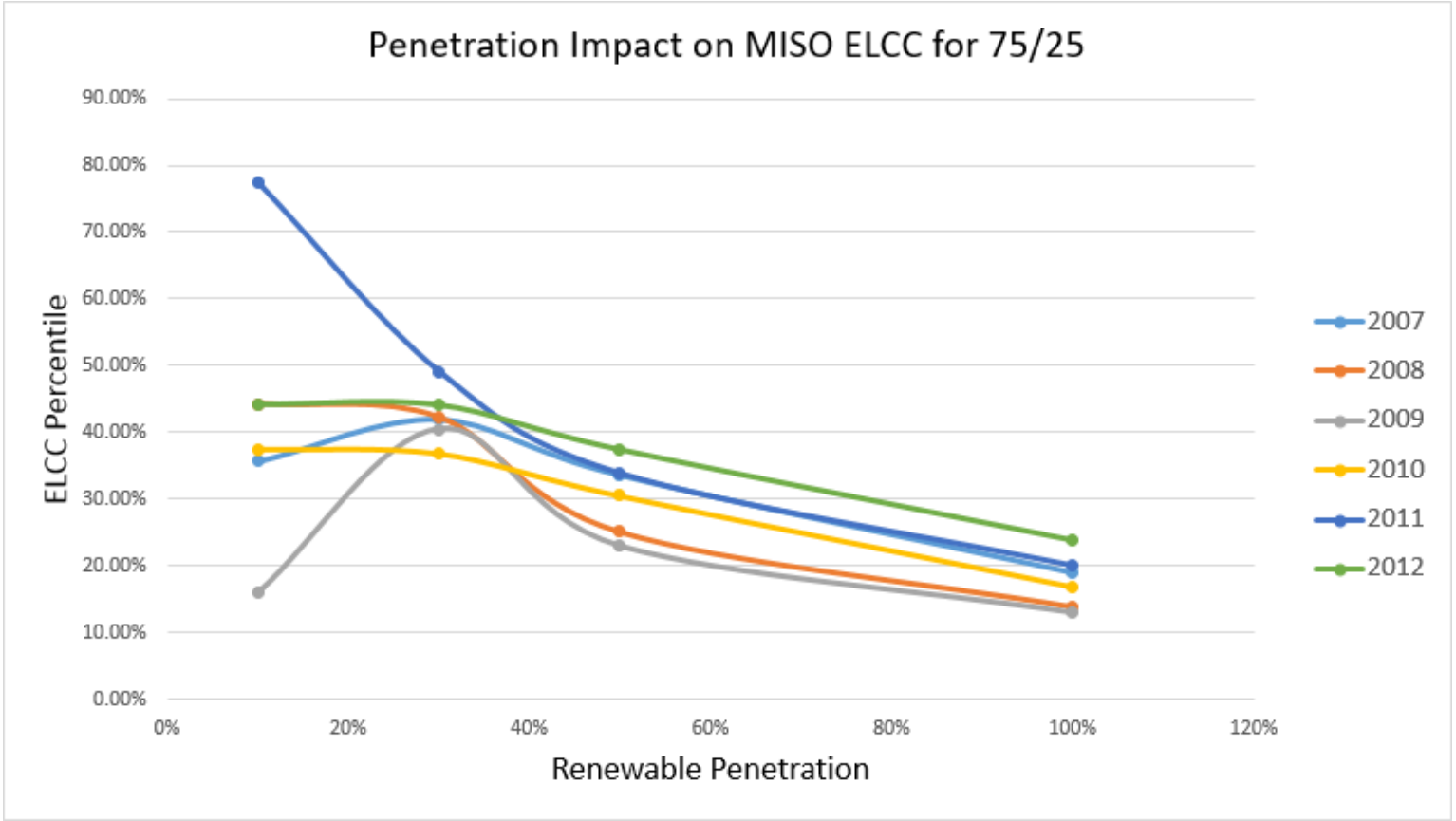
Most likely caused by renewable generation being variable and unpredictable



1. ELCC: expected load carrying capacity

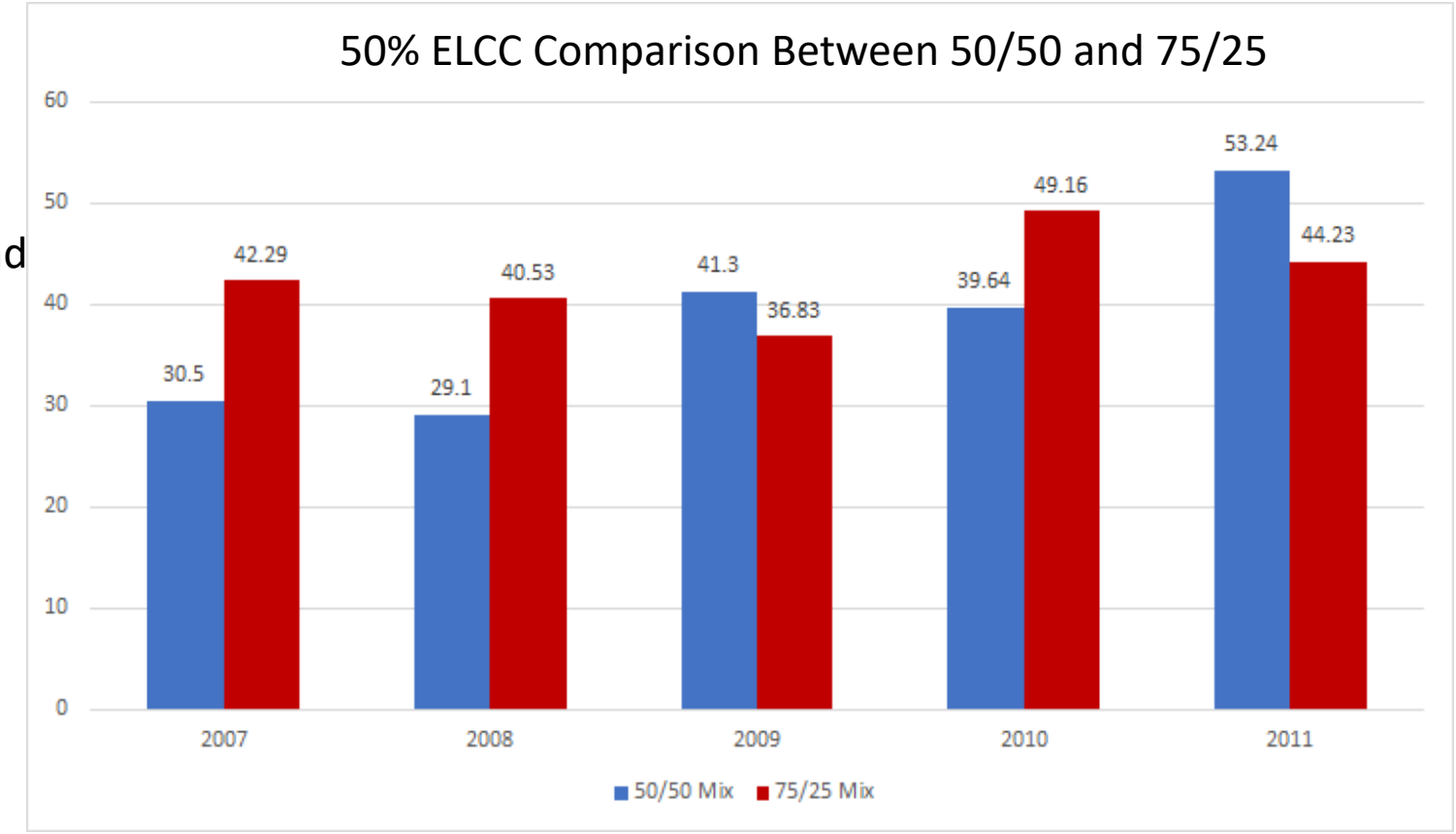
Results

The 75/25 Model follows similar trends to the 50/50 Model – ELCC still steadily decreases as penetration increases



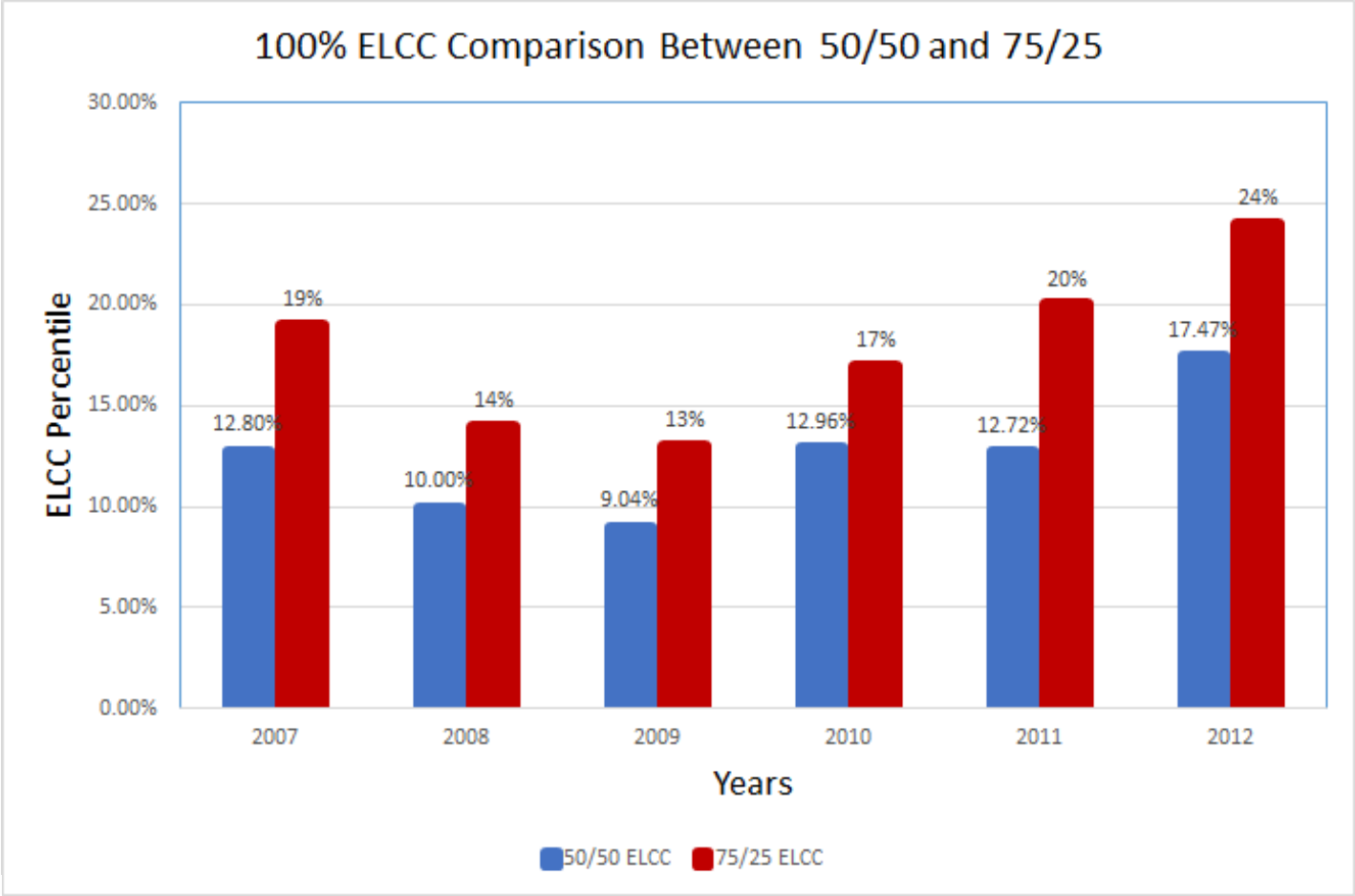
Results

- Renewable Demographic being studied
  - 75% Wind mix
  - 25% Solar Mix
- ELCC on average Increases with more Wind

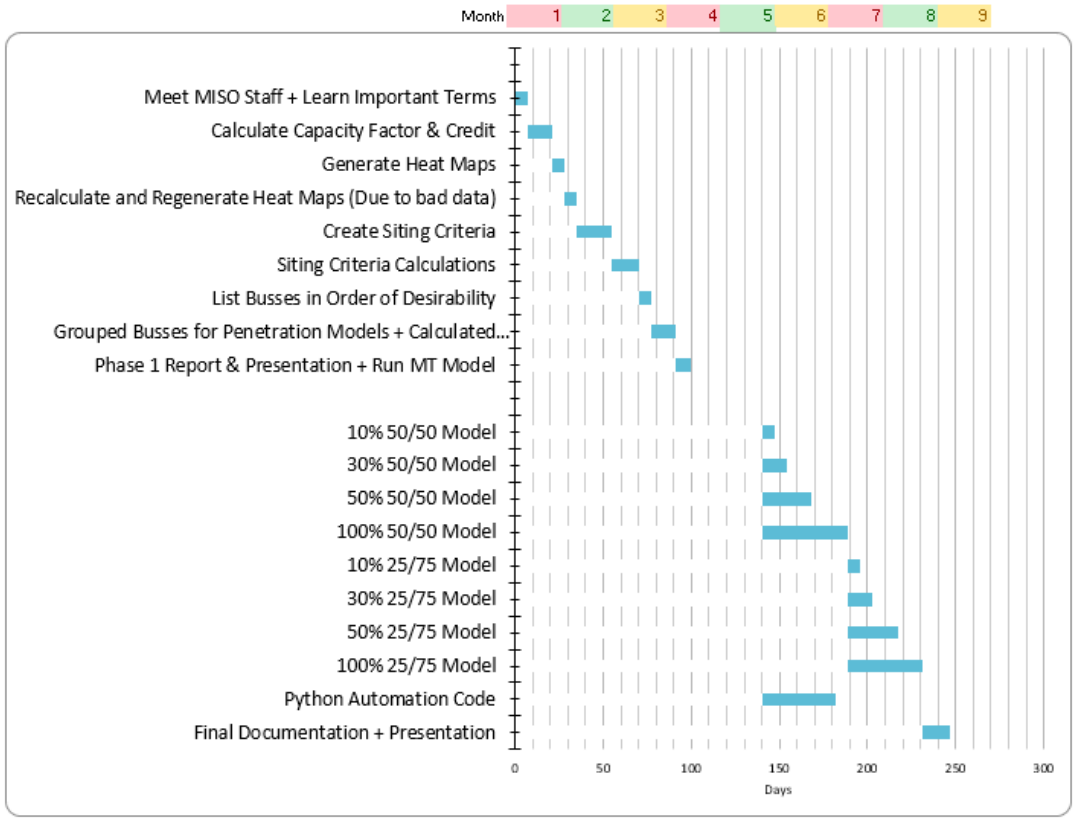


Results

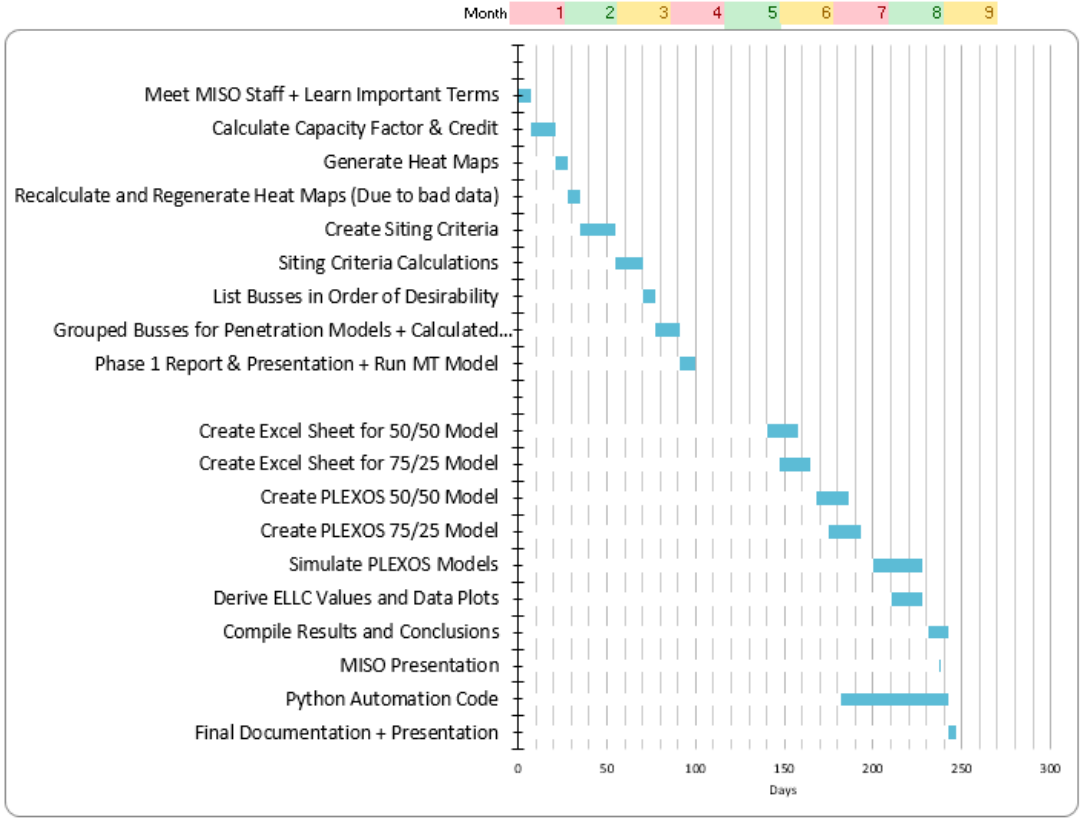
Average ELCC of the 75/25 Model is greater than that of the 50/50 Model across all years by 100% penetration



Project Schedule



Original Schedule (Fall Semester)



Actual Schedule

Special Thank You

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Questions?

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