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# Stochastic Analysis of Wind, Solar, and Load Across New England



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*Paper Session 5A*

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# Overview

- Background
  - 2020 ISO-NE Variable Energy Resources (VER) Data Set
- Stochastic Time Series Analysis
  - Expansion of 2020 ISO-NE VER Data Set
  - Stochastic Engine (SE)
  - Key Performance Indicators (KPI) Analysis
    - Reliability of VER during cold snaps / heat waves
    - Probability of wind and solar droughts/lulls
    - Correlation of load, wind, and solar
    - Representative 8760s
    - Distributions of wind at peak(min) gross(net) load
    - Intra-day variability of VER (ramping)



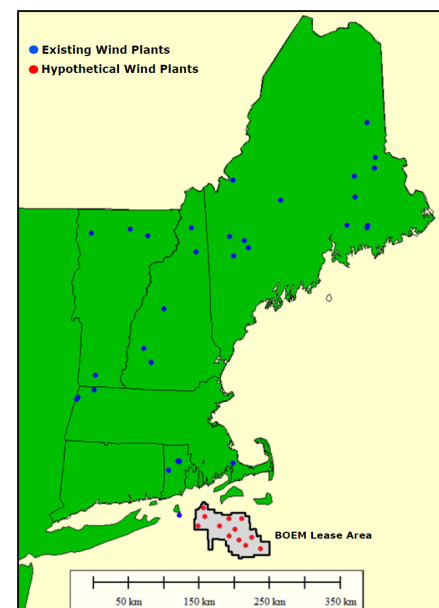
# Background

- During 2019 it became apparent to ISO-NE that a new consistent dataset of offshore wind was needed to serve as inputs to multiple studies across the organization
  - 2019 Economic Studies
  - Transmission Planning Study Assumptions
  - Energy Security Analysis
- ISO-NE hired DNV at the end of 2019 to use their weather modeling software and develop a historical data set of all existing wind plants and future offshore wind plants from 2012-2018. This work was presented to Planning Advisory Committee (PAC) in February 2020 with two presentations
  - [ISO-NE presentation](#) and [DNV presentation](#)
- In early 2020, DNV updated the data set with an additional year of historical data and recalibrated the models to create an updated 8 year data set from 2012-2019
- In Summer of 2020, the ISO hired DNV to create a stochastic data set from an expanded historical modeled data set from which the results of that study are being presented today
  - [July 22, 2020 ISO-NE PAC scope of work presentation](#)
  - [2020 ISO-NE Variable Energy Resource \(VER\) Data Series \(2000-2019\) Rev.3](#)
- In Fall of 2020, the ISO hired DNV to expand and recalibrate the historical data set to include 2020 historical data and additional hypothetical wind/solar plants
  - [2021 ISO-NE VER Data Series \(2000-2020\)](#) posted in Apr 2021
- New [Variable Energy Resources](#) page on our website was created to provide stakeholders a single convenient place to access this information



# 2020 ISO-NE VER Data Set

- The 2020 ISO-NE VER data set contained hourly time series data for load, solar, and wind in New England for 20 years (2000-2019)
- This data set was created using NASA satellite information and advanced modeling software from DNV to create historical time series profiles based on New England weather conditions
- The data set was then calibrated with available recorded data to get the best fit possible
  - NOTE: The data set will not match historical values hour-by-hour, since it is based on a model, but the data should still follow overall weather trends and magnitudes and be statistically similar to recorded values
- The data set included the following information
  - 37 existing onshore and 1 existing offshore wind plant wind speed profiles
  - 12 future offshore wind plant wind speed profiles (4 state contracted and 8 hypothetical in BOEM lease area south of Cape Cod)
  - Aggregate behind-the-meter solar photovoltaic (PV) power profiles by 8 Load Zones
  - Load (gross minus energy efficiency) and weather (temperature, relative humidity [RH], and global horizontal irradiance [GHI]) profiles by Load Zone

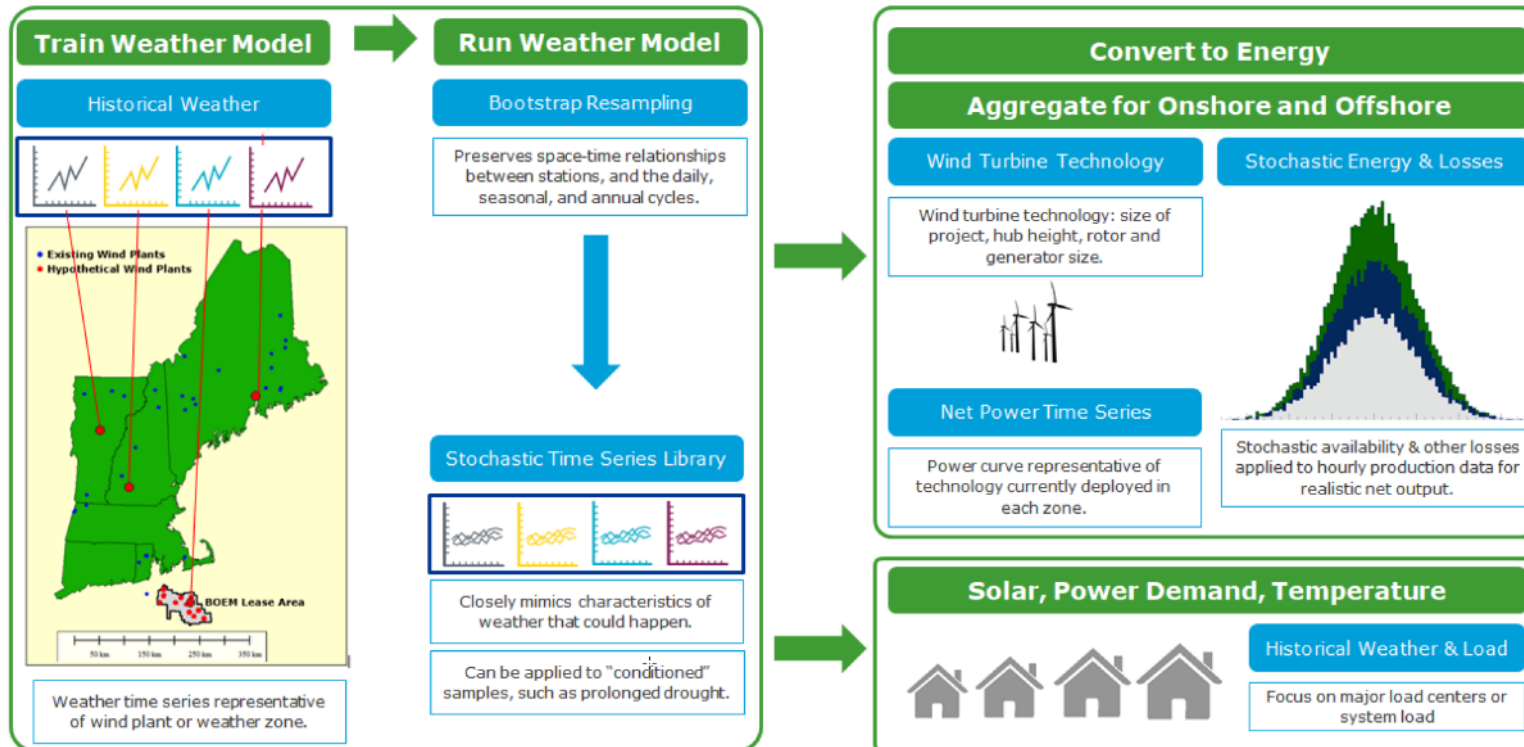


# Stochastic Engine

- The Stochastic Engine (SE) is a tool developed by DNV to statistically tackle time-series-based problems at scale. It can resample any time series (wind speed, irradiance, price, load) into parallel, plausible, scenarios while preserving all the relationships within the data and between the signals.
- The weather-to-generation models will then simulate the expected power production for each weather scenario, creating at least 20,000 years worth (1,000 20-year simulations) of hourly time series of weather and power outputs for each wind plant, zonal solar, and zonal load.
- Each time series will preserve the correlations from year-to-year, month-to-month, temperature-to-load, and zone-to-zone.
- Each 20-year simulation (also referred to as a realization) can be thought of as an alternate reality of weather conditions that have the same overall climate of New England.
- The stochastic data set is LARGE. It contains **175.2 million hours** worth of data and is **512 GB** in size.

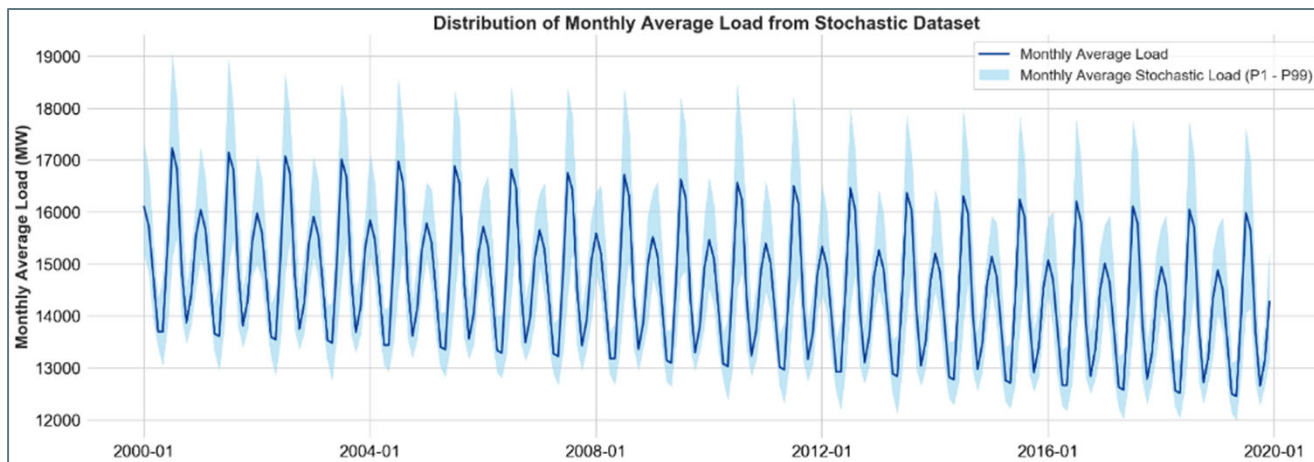


# Stochastic Engine, cont.



# Stochastic Engine, cont.

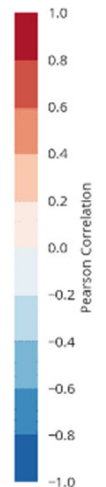
- The SE preserves all trends present in the original data set. The figure below presents the distribution of monthly mean load values calculated from the 20,000-year stochastic data set
- The original 20 years of input gross load data exhibited a downward trend, in part due to the implementation of energy efficiency programs in recent years. The stochastic data set preserves this trend



# Correlation of Load, Wind, and Solar

- Pearson correlation coefficients\* were computed based on hourly, monthly, and annual values.
- A Pearson correlation coefficient measures the statistical relationship between two continuous variables and is based on the method of covariance. It gives information about both the magnitude and direction of correlation between two variables.
- A negative correlation coefficient means the two variables are negatively correlated (one goes up when the other goes down) while a positive coefficient indicates the variables are positively correlated (both go up at same time).
- The table above presents a description of the degree of correlation quality as it relates to the Pearson coefficient. The tables on the following slides are also color coded with dark red indicating strong positive correlation, pale red/blue indicating weak correlation, and dark blue indicating strong negative correlation.

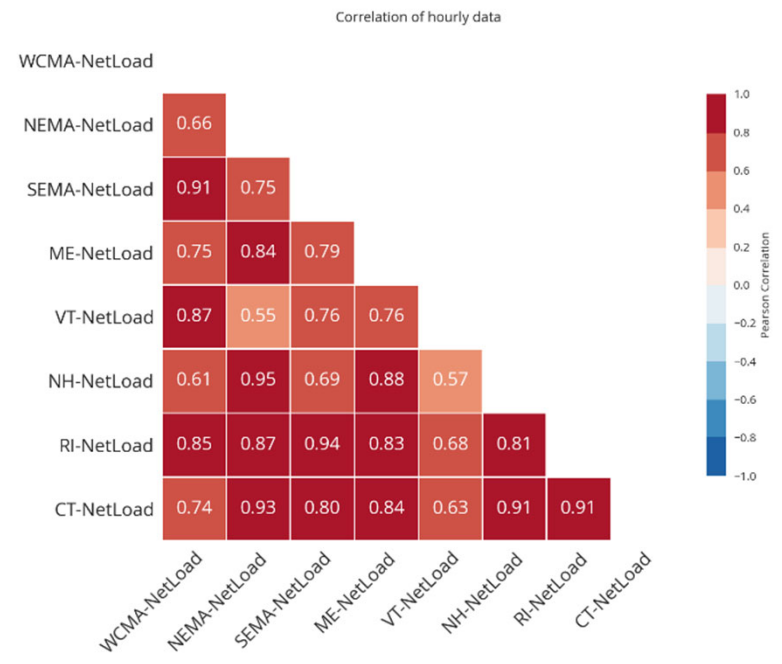
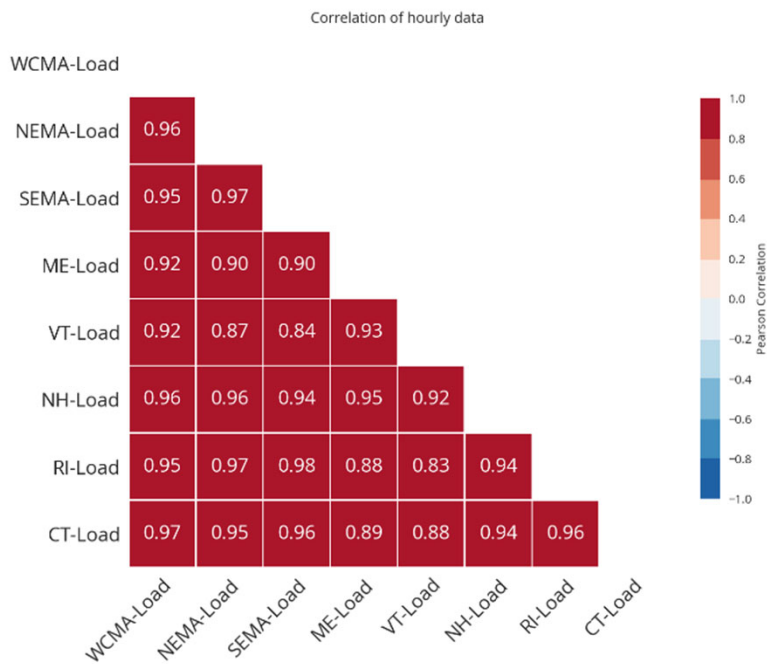
Quality of Correlation	Pearson Coefficient
Perfect	$\pm 1.00$
High	$\pm 0.50$ to $\pm 0.99$
Moderate	$\pm 0.30$ to $\pm 0.49$
Low	$\pm 0.01$ to $\pm 0.29$
None	0.00



\* "Statistics Solutions," [Online]. Available: <https://www.statisticssolutions.com/pearsons-correlation-coefficient/>. [Accessed 2021].



# Correlation of Hourly Load – Gross and Net

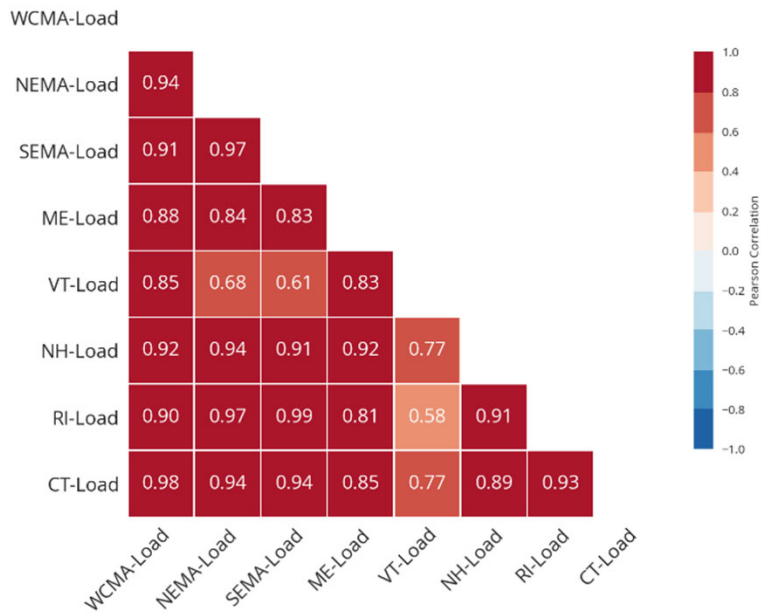


WCMA = Western/Central MA; NEMA = Northeast MA; SEMA = Southeastern MA

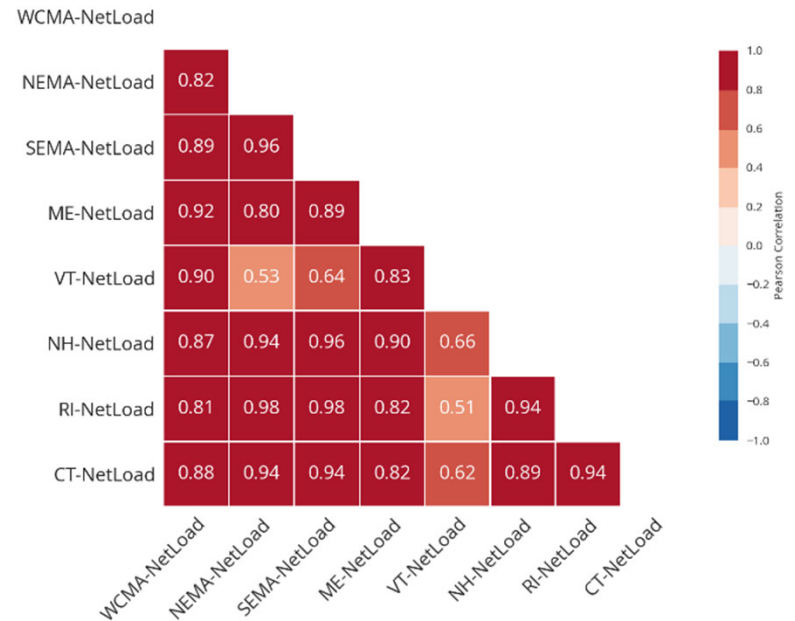


# Correlation of Monthly Average Load

Correlation of monthly data



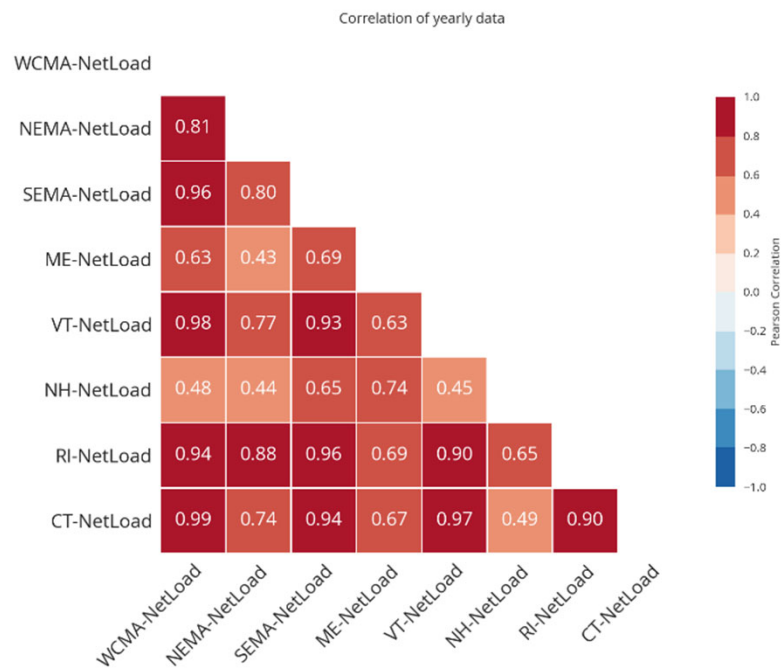
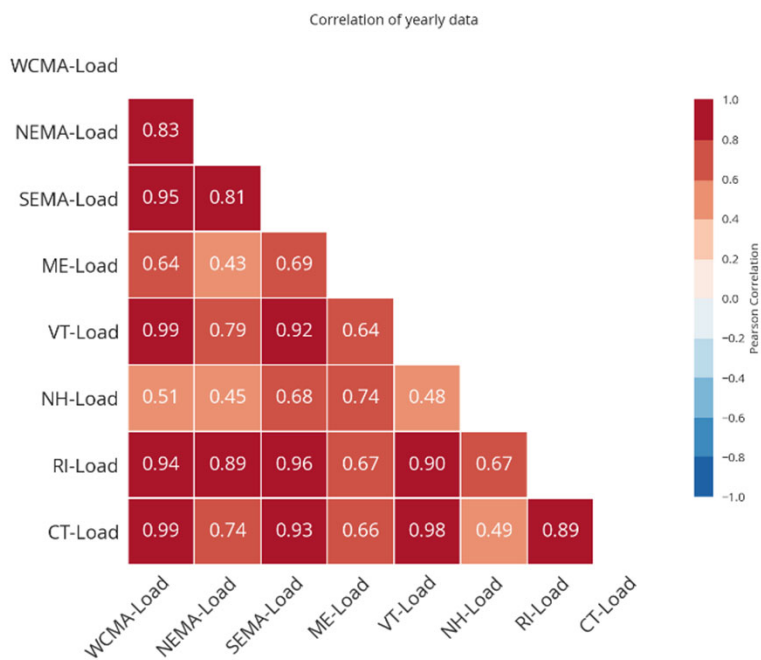
Correlation of monthly data



WMCA = Western/Central MA; NEMA = Northeast MA; SEMA = Southeastern MA



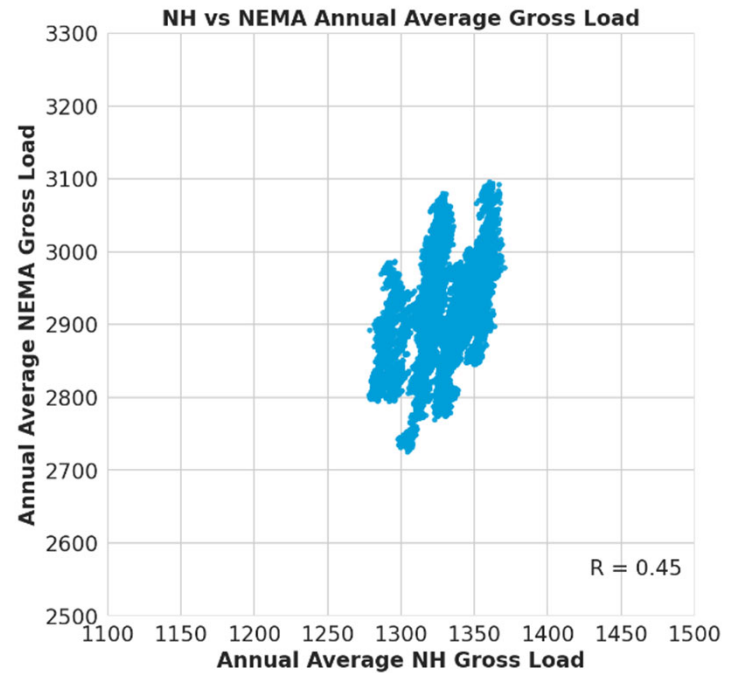
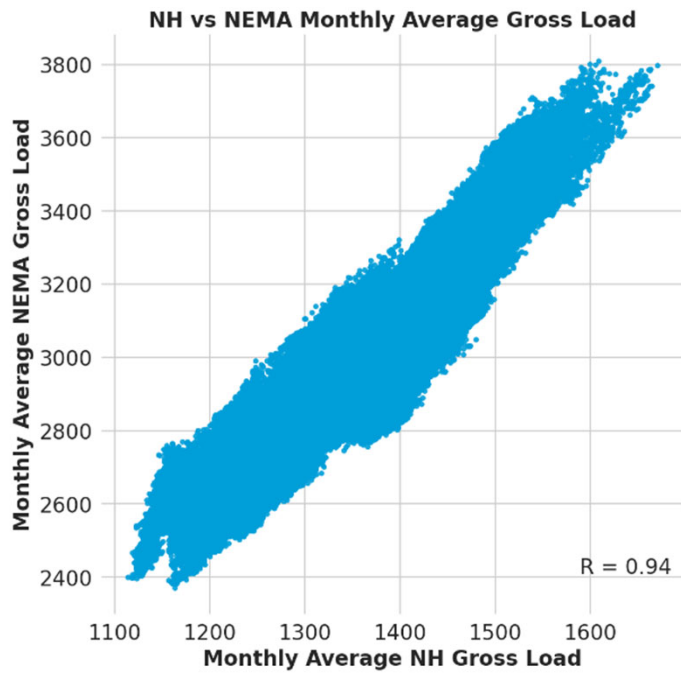
# Correlation of Yearly Average Load



WMCA = Western/Central MA; NEMA = Northeast MA; SEMA = Southeastern MA



# Monthly vs. Annual Correlation

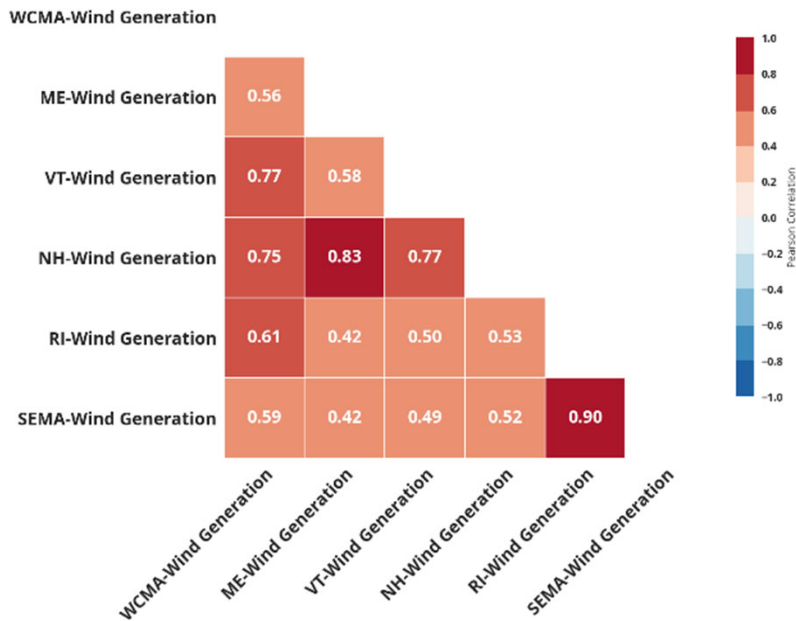


NEMA = Northeast MA

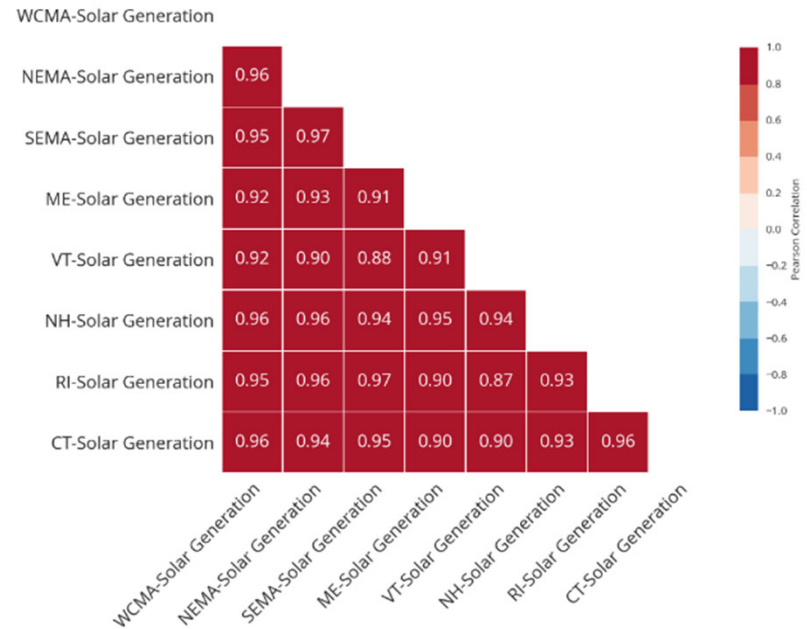


# Correlation of Hourly Wind and Solar

Correlation of hourly data



Correlation of hourly data

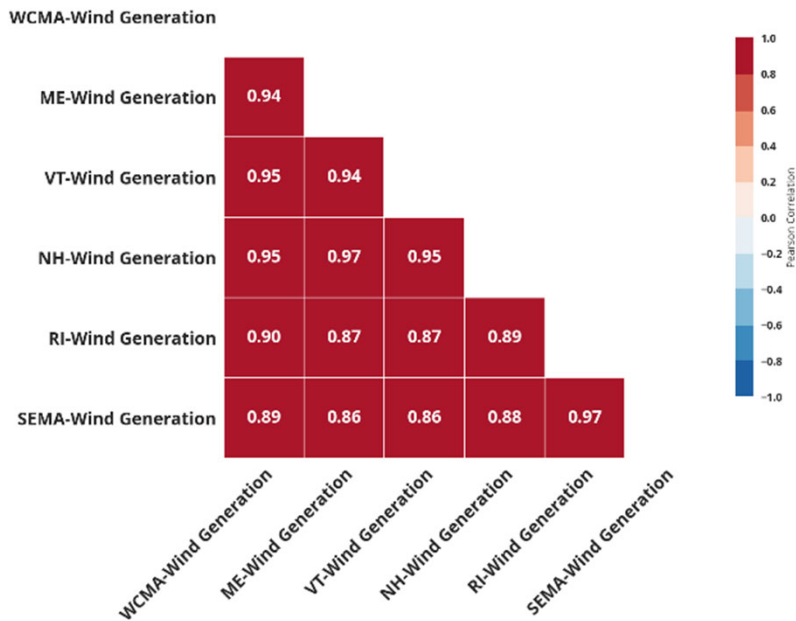


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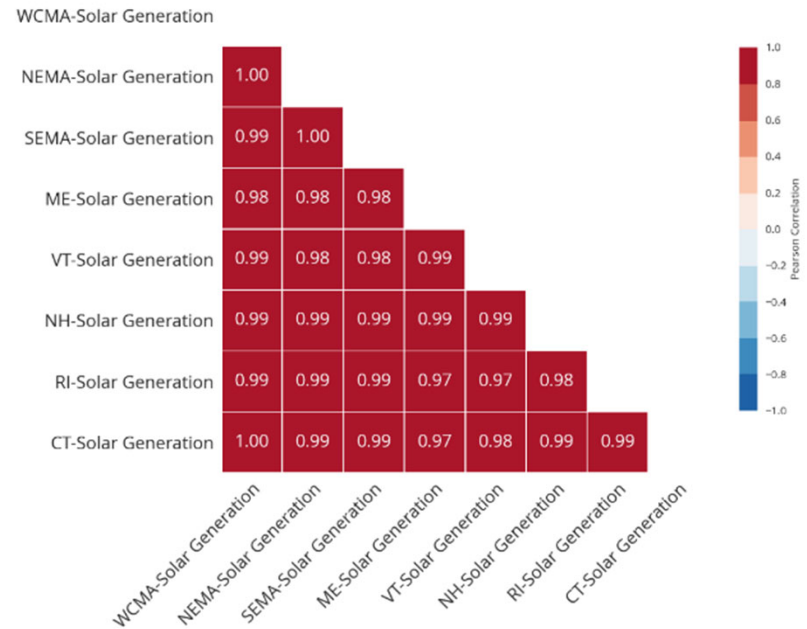


# Correlation of Monthly Wind and Solar

Correlation of monthly data



Correlation of monthly data

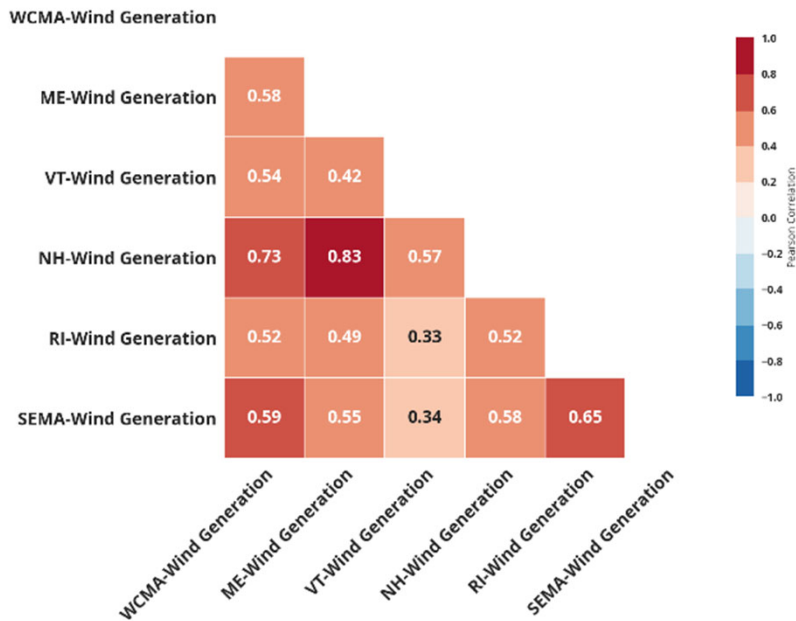


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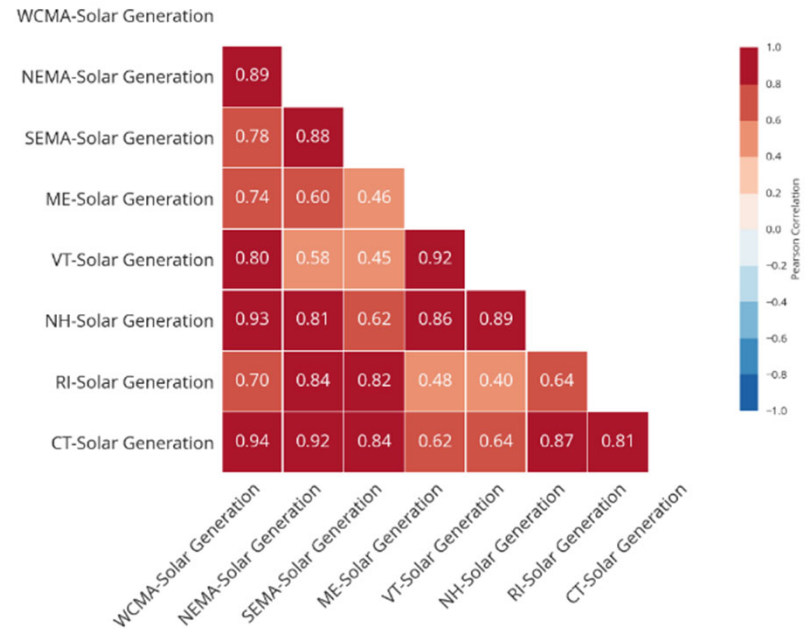


# Correlation of Yearly Wind and Solar

Correlation of yearly data



Correlation of yearly data



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# Overall New England Correlation

- Hourly load, wind, and solar by Load Zone and overall

	ME	NH	VT	CT	RI	SEMA	WCMA	NEMA	ISO-NE
Load - Wind	-0.01	0.00	0.01		-0.03	-0.03	-0.04		-0.02
Net Load - Wind	0.05	0.02	0.22		0.09	0.11	0.14		0.10
Solar - Wind	-0.12	-0.08	-0.24		-0.18	-0.16	-0.19		-0.18
Load - Solar	0.36	0.37	0.30	0.36	0.38	0.36	0.36	0.39	0.39
Net Load - Solar	-0.20	0.14	-0.66	-0.03	-0.32	-0.54	-0.65	0.08	-0.23
Load - Solar+Wind	0.18	0.31	0.31		0.18	0.13	0.36		0.34
Net Load - Solar+Wind	-0.06	0.13	-0.62		-0.09	-0.14	-0.65		-0.15
Load - Offshore Wind									-0.00
Net Load - Offshore Wind									0.10
Solar - Offshore Wind									-0.17
Onshore Wind - Offshore Wind									0.51

WCMA = Western/Central MA; NEMA = Northeast MA; SEMA = Southeastern MA



# Overall New England Correlation, cont.

- Monthly load, wind, and solar by Load Zone and overall

	ME	NH	VT	CT	RI	SEMA	WCMA	NEMA	ISO-NE
Load - Wind	0.07	-0.08	0.32		-0.42	-0.43	-0.08		-0.24
Net Load - Wind	0.28	0.01	0.59		-0.24	-0.15	0.33		-0.03
Solar - Wind	-0.73	-0.66	-0.78		-0.66	-0.65	-0.80		-0.70
Load - Solar	-0.24	-0.08	-0.51	0.08	0.25	0.23	-0.03	0.13	0.06
Net Load - Solar	-0.51	-0.22	-0.81	-0.09	-0.03	-0.20	-0.53	-0.03	-0.24
Load - Solar+Wind	-0.02	-0.19	-0.52		-0.40	-0.43	-0.04		-0.26
Net Load - Solar+Wind	0.13	-0.21	-0.80		-0.31	-0.26	-0.53		-0.33
Load - Offshore Wind									-0.25
Net Load - Offshore Wind									-0.05
Solar - Offshore Wind									-0.66
Onshore Wind - Offshore Wind									0.88

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# Overall New England Correlation, cont.

- Yearly load, wind, and solar by Load Zone and overall

	ME	NH	VT	CT	RI	SEMA	WCMA	NEMA	ISO-NE
Load - Wind	0.42	0.21	-0.02		0.02	0.01	0.12		0.09
Net Load - Wind	0.42	0.22	0.01		0.03	0.04	0.12		0.10
Solar - Wind	-0.05	0.01	-0.18		-0.09	-0.21	-0.07		-0.11
Load - Solar	0.05	0.37	-0.16	0.20	0.40	0.45	0.16	0.36	0.24
Net Load - Solar	-0.02	0.32	-0.28	0.17	0.30	0.35	0.06	0.33	0.18
Load - Solar+Wind	0.42	0.32	-0.16		0.08	0.06	0.17		0.16
Net Load - Solar+Wind	0.42	0.31	-0.25		0.07	0.07	0.08		0.15
Load - Offshore Wind									0.06
Net Load - Offshore Wind									0.07
Solar - Offshore Wind									-0.18
Oushore Wind - Offshore Wind									0.63

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# Conclusions

- To accurately plan for the clean energy transition, system planners need technically sound, historical wind data to apply to planned wind resources, specifically offshore wind
- Hourly correlations highlighted wind and solar were negatively correlated, which shows the benefit of a diversity of variable energy resources
- The data revealed the NH and NEMA Load Zones in New England may be potentially preferable locations for additional development of solar resources due to remaining load that still has a positive correlation
- Another interesting outcome was the weak-to-no-correlation of load and offshore wind in the different time frames
- This new set of data will aid in planning a reliable system as we transition to cleaner, more variable resources



# Questions

