Hypothesis testing on Operational Power Utility Data from US

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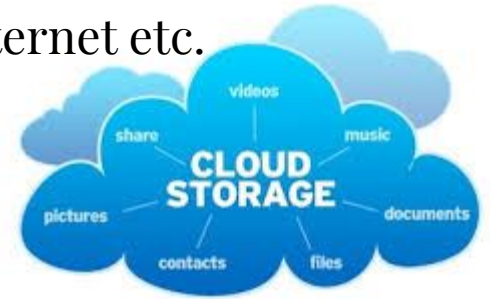
Presentation Duration : 20 min

Overview

- US primary energy consumption accounts for 17% of total global energy.

- Electricity power is one of the major energy sources in US.

- With advances in technology, we are increasingly becoming reliant on electricity with electric car, personal computer, cloud, internet etc.



Overview

- With every changing energy demands, a close analysis of the power utility operation is needed to forecast power needs in future.

- Hypothetical testing of annual power utility performance parameters will help understanding the trend in energy consumptions.

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Presentation Duration : 20 min

Objective: Electricity Consumption

- Evaluate the operational performance of collective power utilities of North America in four categories
  - Efficiency
  - Revenue
  - Total Electricity Transmitted
  - Seasonal Variability

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Data Source

- Annual summary of the operational data collected from various power utilities across Northern America.

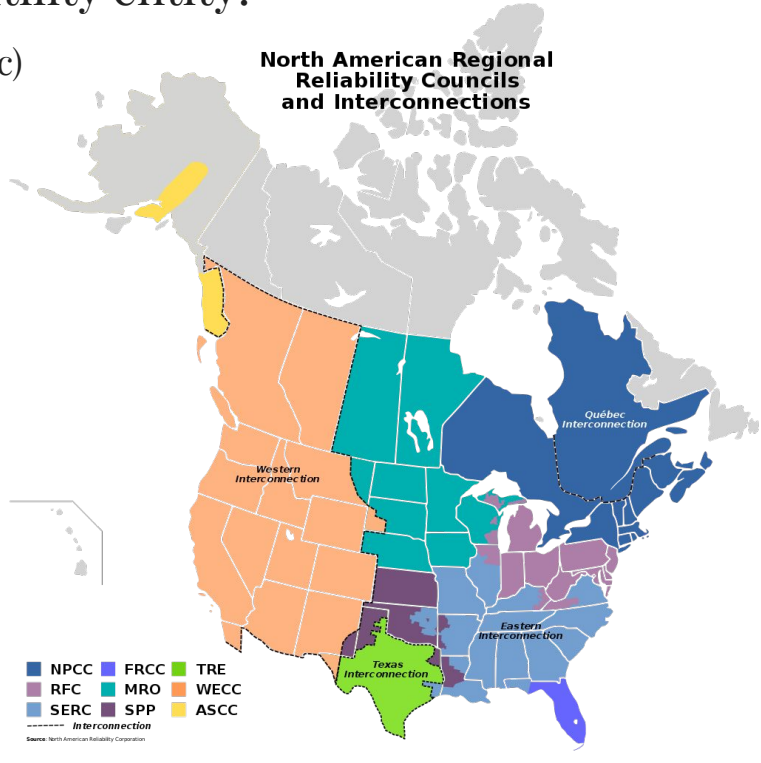
- Summary record from year 2012 and year 2018 (latest)

https://www.eia.gov/electricity/data/eia861/

Data Source

This data has many fields describing each power utility entity:

1. Utility Characteristics (State, NERC Region, Ownership Type etc)
2. Demand (Summer and Winter Peak Load)
3. Disposition (Total Energy Losses)
4. Electric Revenue (Retail Sales)
5. Total Energy Sources

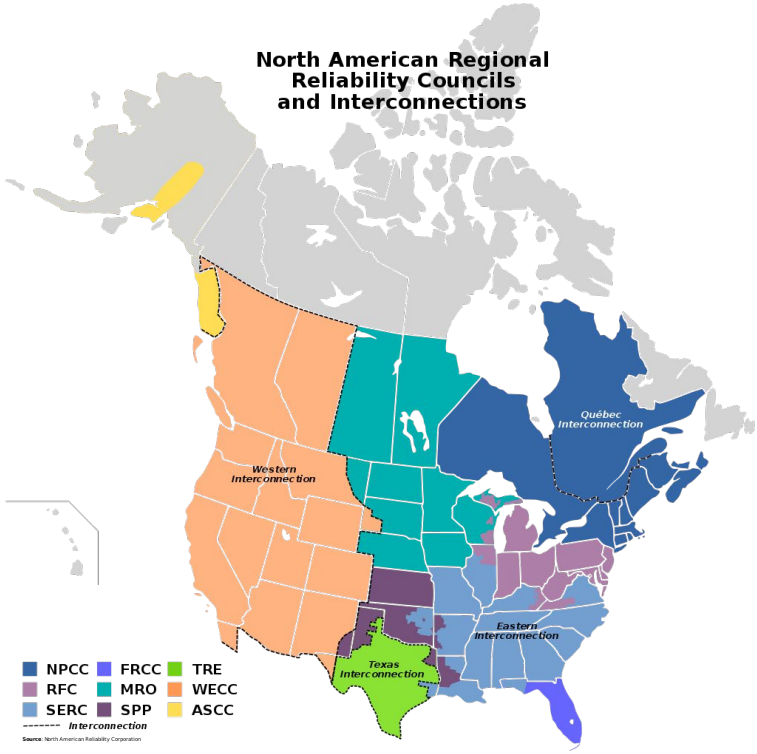


https://www.eia.gov/electricity/data/eia861/

Data Source: Utility Characteristics

Ownership Type	2012	2018
Behind the Meter	0	15
Community Choice Aggregator	0	19
Cooperative	812	806
Federal	8	8
Investor Owned	179	168
Municipal	828	830
Municipal Mktg Authority	19	15
Political Subdivision	100	104
Retail Power Marketer	175	272
State	20	17
Transmission	9	20
Wholesale Power Marketer	40	33

NERC Region	2012	2018	
AK	25	23	
ECAR	0	1	
ERCOT	0	4	
FRCC	40	40	
HI	3	3	
HICC	1	1	
MISO	0	52	↑
MRO	406	351	↓
NPCC	121	116	↓
NY	0	1	
RF	0	2	
RFC	317	291	↓
RFO	1	0	
SERC	519	528	↑
SPP	182	180	
TRE	100	96	
WECC	298	295	



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Hypothesis Testing: 2012 versus 2018

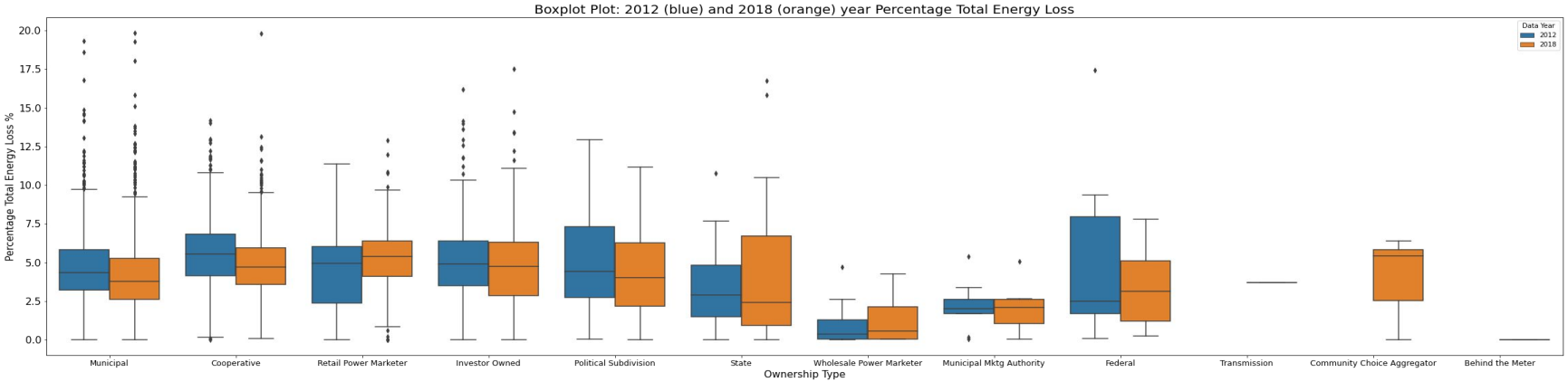
Efficiency

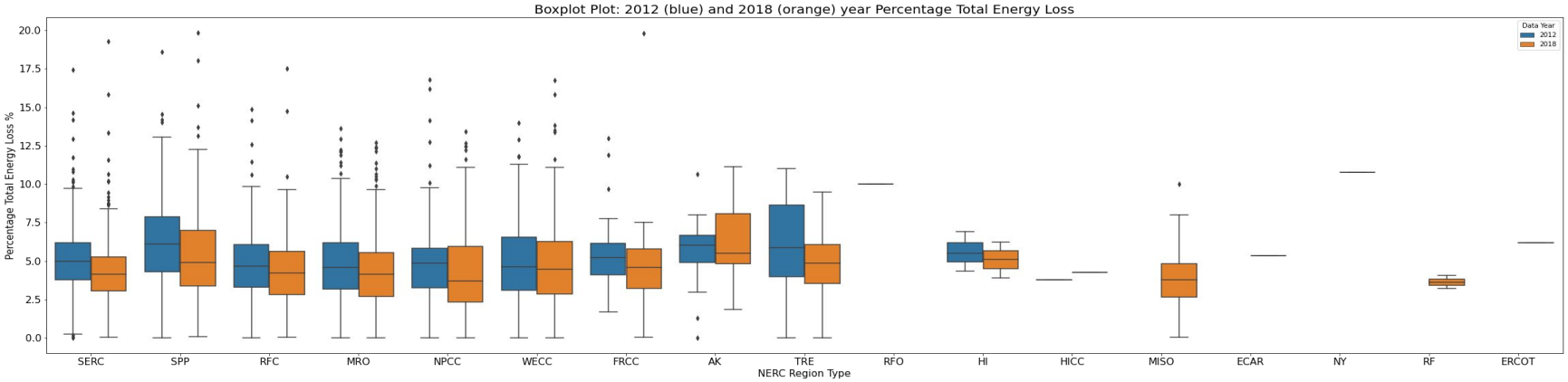
Ho: There is no significant difference in Energy Loss from 2012 year to 2018 year

Ha: There is a significant difference in Energy Loss from 2012 year to 2018 year

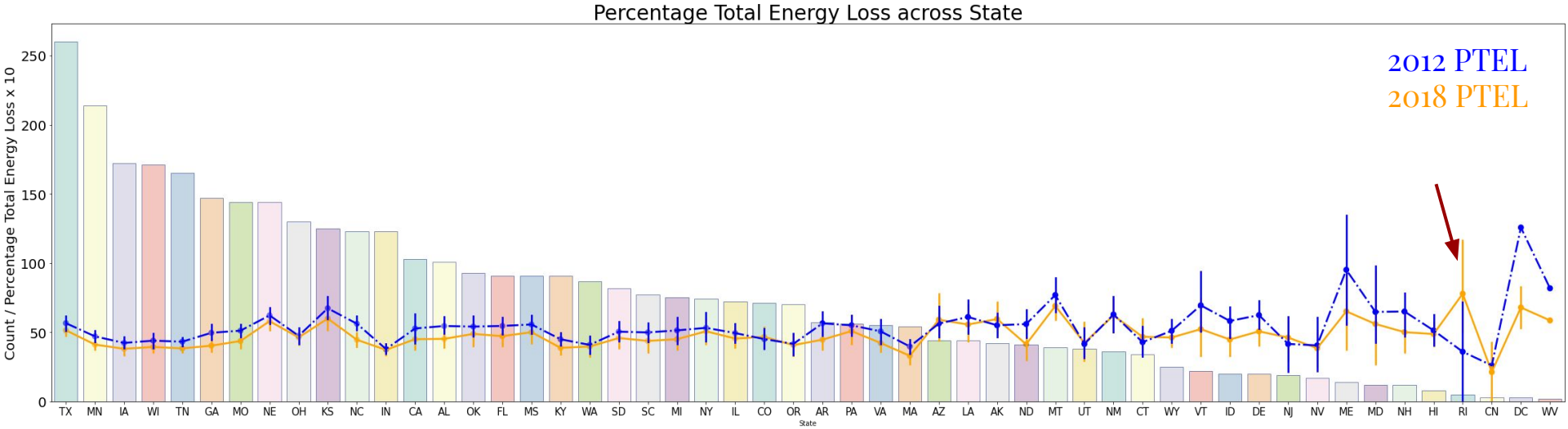
Total Percentage Energy Loss = Total Energy Loss / Total Disposition

NERC & Ownership: PTEL



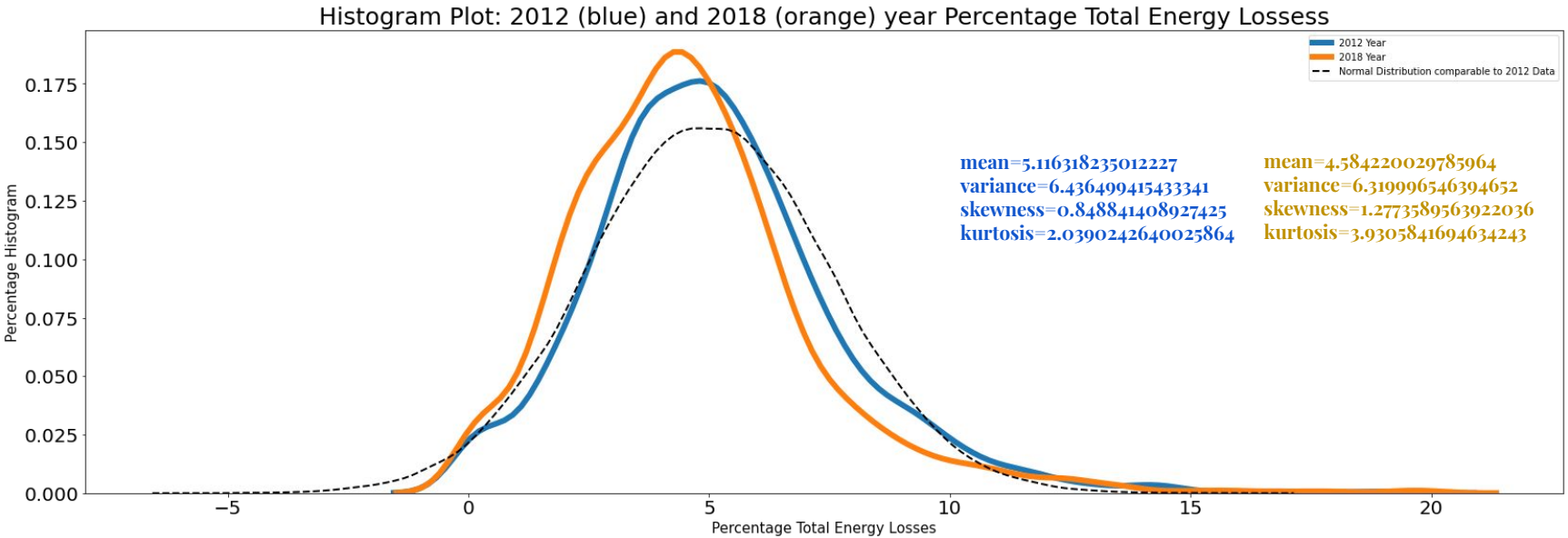


State-Wise: PTEL



- Consistent pattern of energy loss reduction across various states.

PTEL: 2012 vs 2018



Shapiro-Wilk Test for Normality for PTEL 2012 : statistics = 0.96385, p value = 2.09548e-21

Shapiro-Wilk Test for Normality for PTEL 2018 : statistics = 0.93158, p value = 9.12833e-29

T-Test for normal distribution : statistic=6.51014, p-value=8.48453e-11 (Null hypothesis Rejected)

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Presentation Duration : 20 min

Hypothesis Testing: 2012 versus 2018

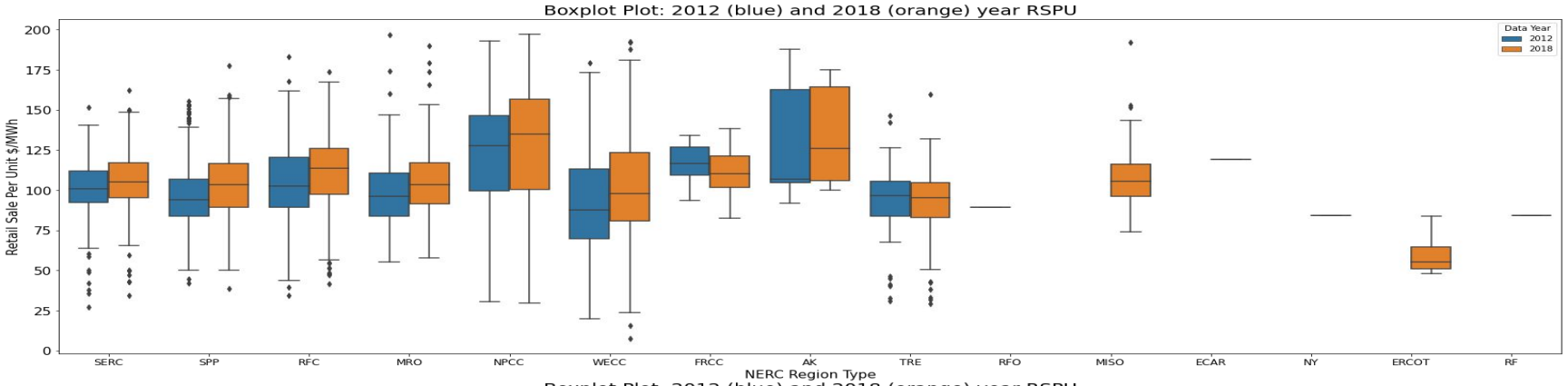
Revenue

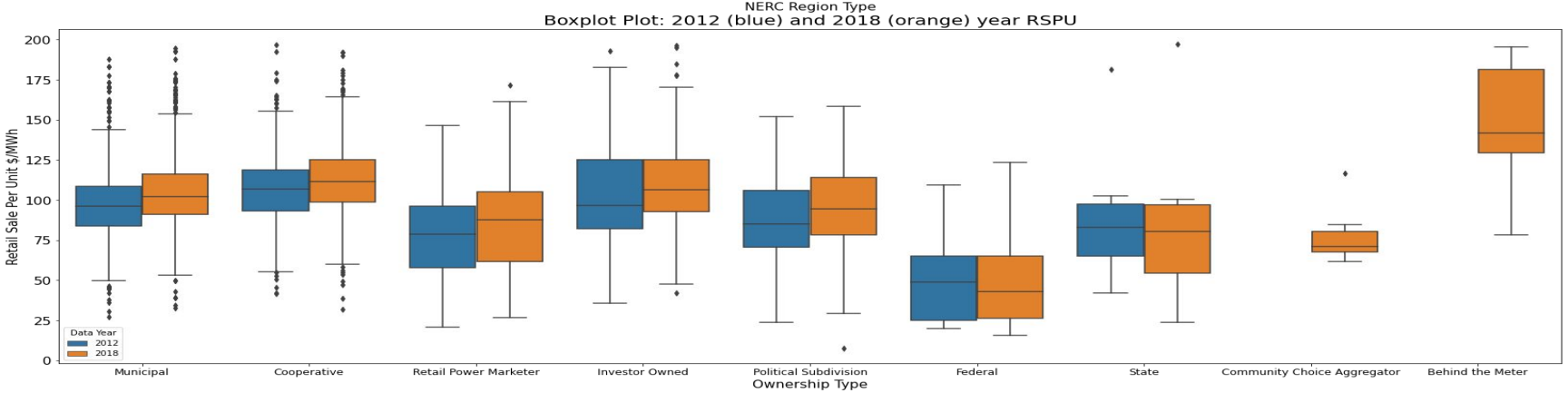
Ho: There is no significant difference in Retail Sales from 2012 year to 2018 year

Ha: There is a significant difference in Retail Sales from 2012 year to 2018 year

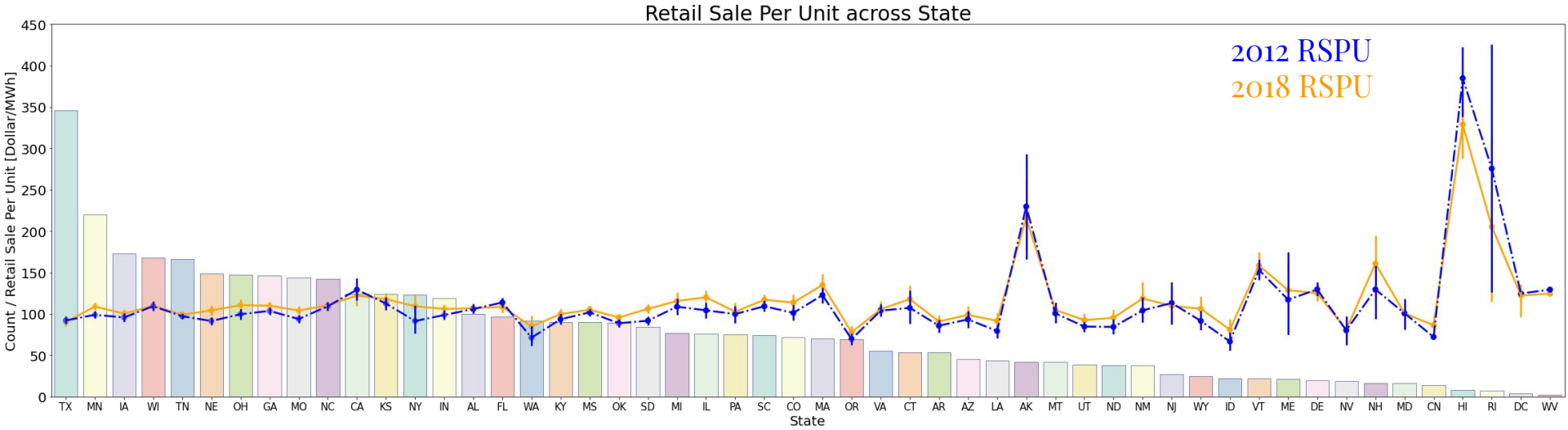
Retail Sale per Unit = Retail Sale Amount / Total Unit Sold

NERC & Ownership: RSPU



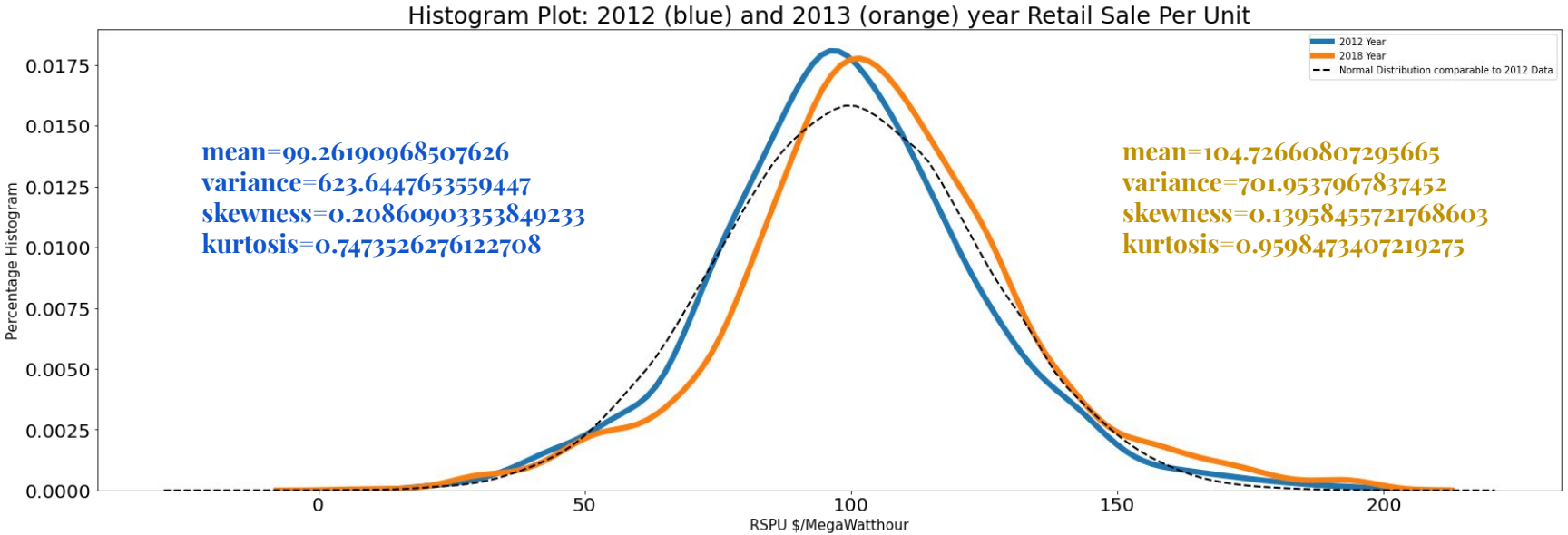


State-Wise: RSPU



- Consistent pattern of increasing RSPU for majority of states
- Alaska, Hawaii and Rhode Island have the highest RSPU

RSPU: 2012 vs 2018



Shapiro-Wilk Test for Normality for RSPU 2012: statistics = 0.9920864701271057, p-value = 7.2779906545861195e-09

Shapiro-Wilk Test for Normality for RSPU 2018: statistics = 0.9873939752578735, p-value = 1.3191064993783863e-12

T-test for normal distribution: statistic=-6.76166, pvalue=1.55841e-11 (Null hypothesis Rejected)

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Presentation Duration : 20 min

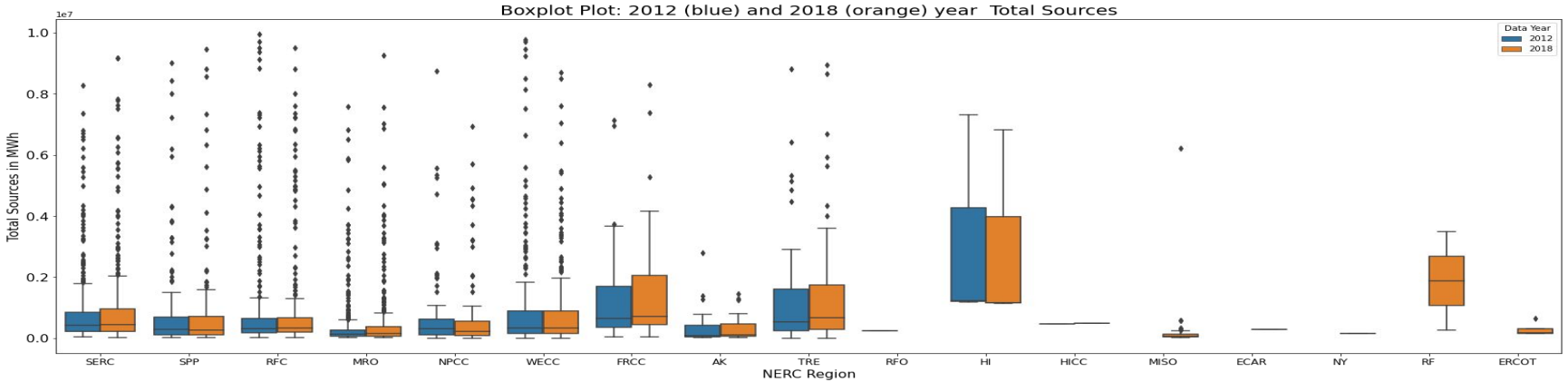
Hypothesis Testing: 2012 versus 2018

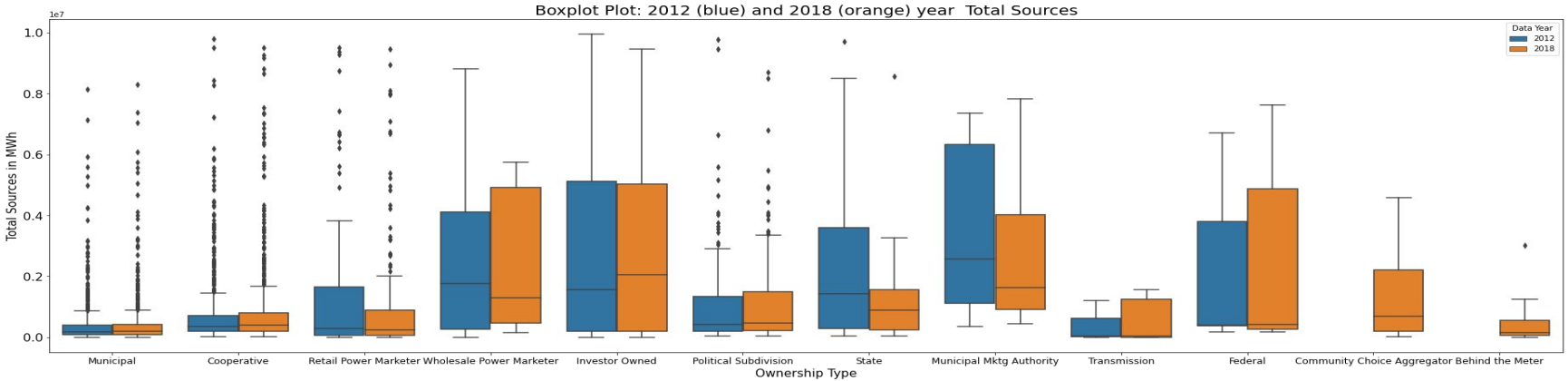
Total Electricity

Ho: There is no significant difference in Total Energy from 2012 year to 2018 year

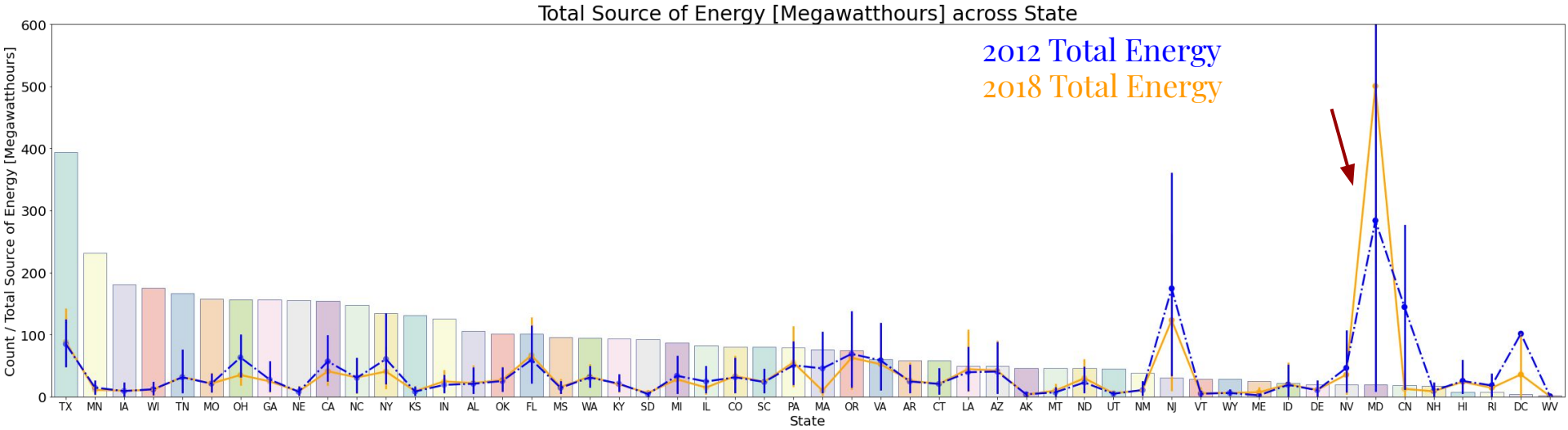
Ha: There is a significant difference in Total Energy from 2012 year to 2018 year

NERC & Ownership: Total Energy Consumed



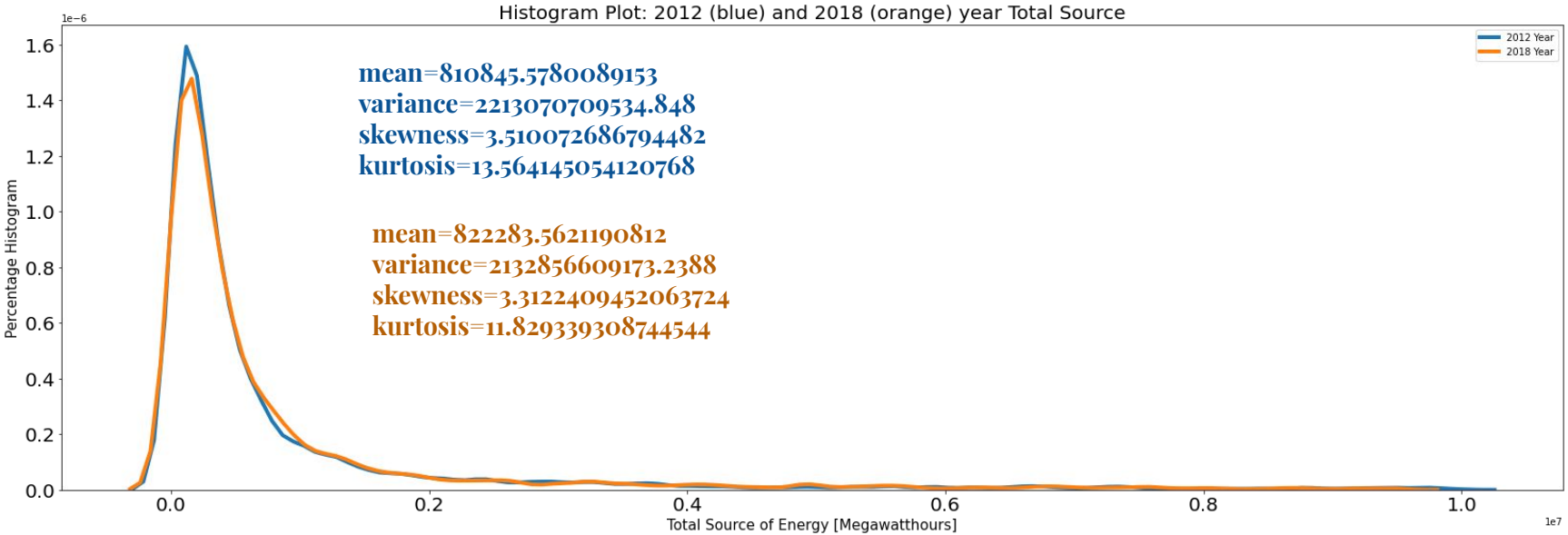


NERC & Ownership: State-wise



- Except Maryland, all the states shows a reduction in total electricity transmitted

Total Energy: 2012 vs 2018



Kruskal-Wallis for non-normal distribution: statistic=0.040316 , pvalue=0.84086 **(Null hypothesis not Rejected)**

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Presentation Duration : 20 min

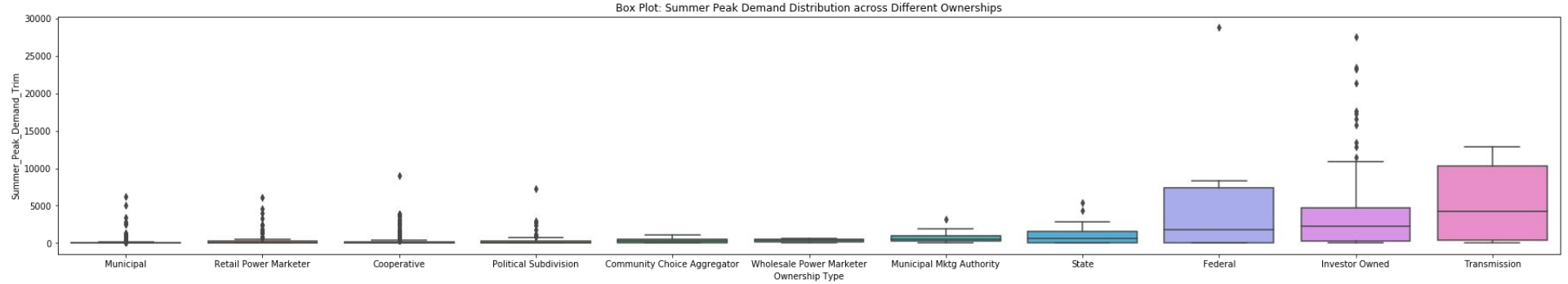
Hypothesis Testing: Summer vs Winter Peak

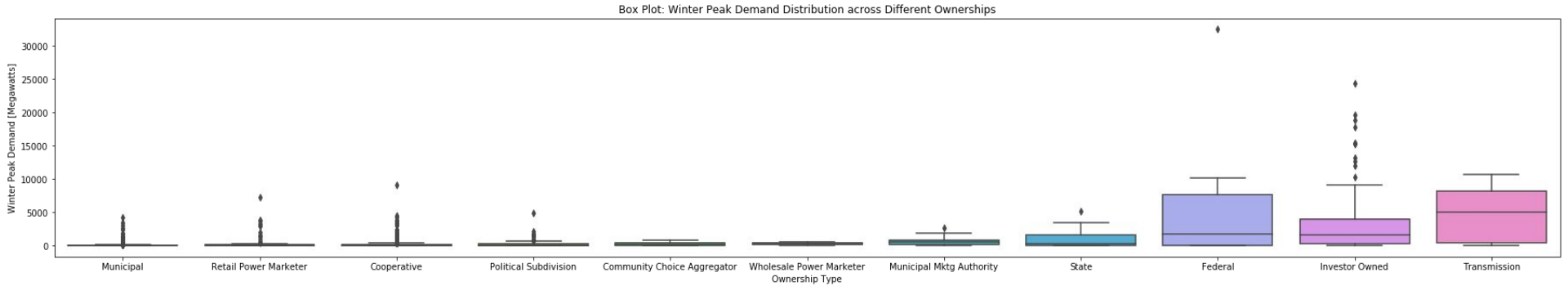
Variability

Ho: There is no significant difference between the summer peak load and winter peak load of year 2018

Ha: There is a significant difference between the summer peak load and winter peak load of year 2018

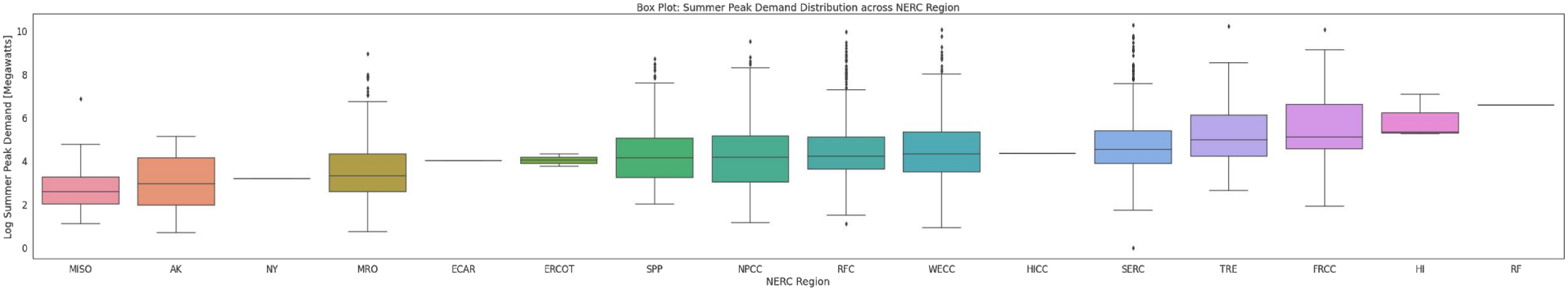
Ownership Type: Summer vs Winter Demands

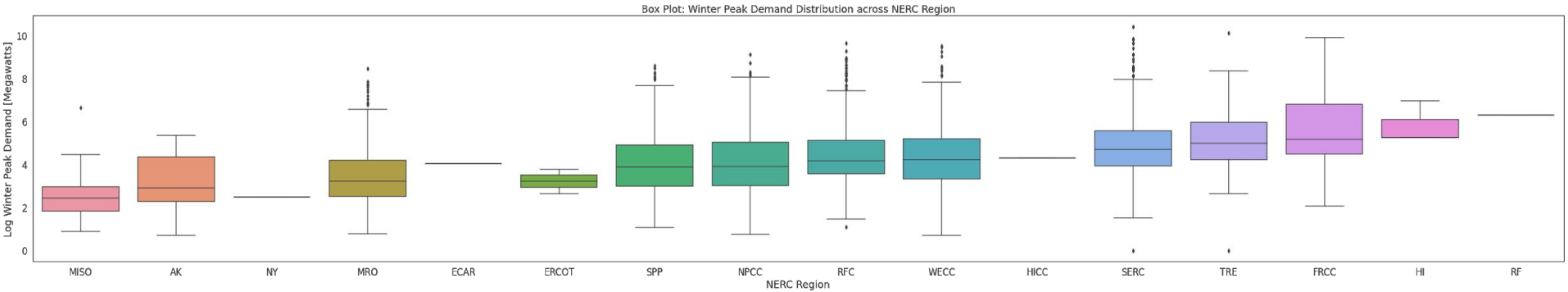




Overall similar distribution with subtle differences in Peak Demands

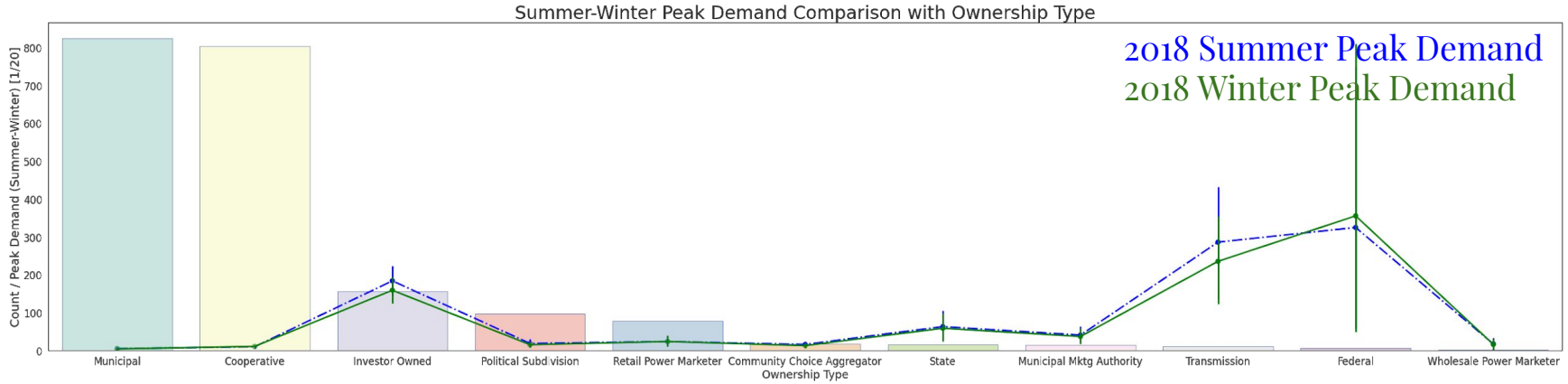
NERC Region: Summer vs Winter Demands

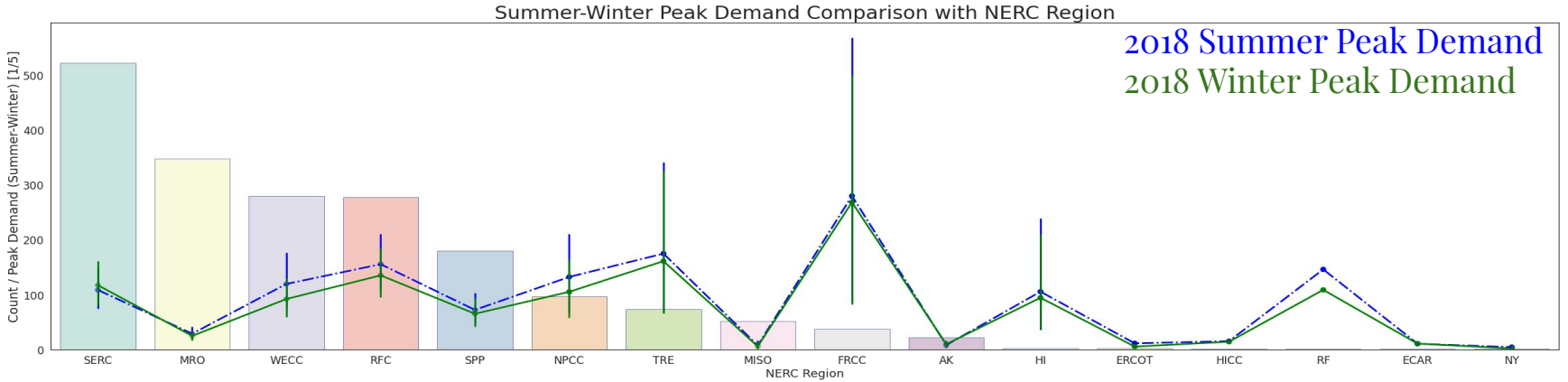




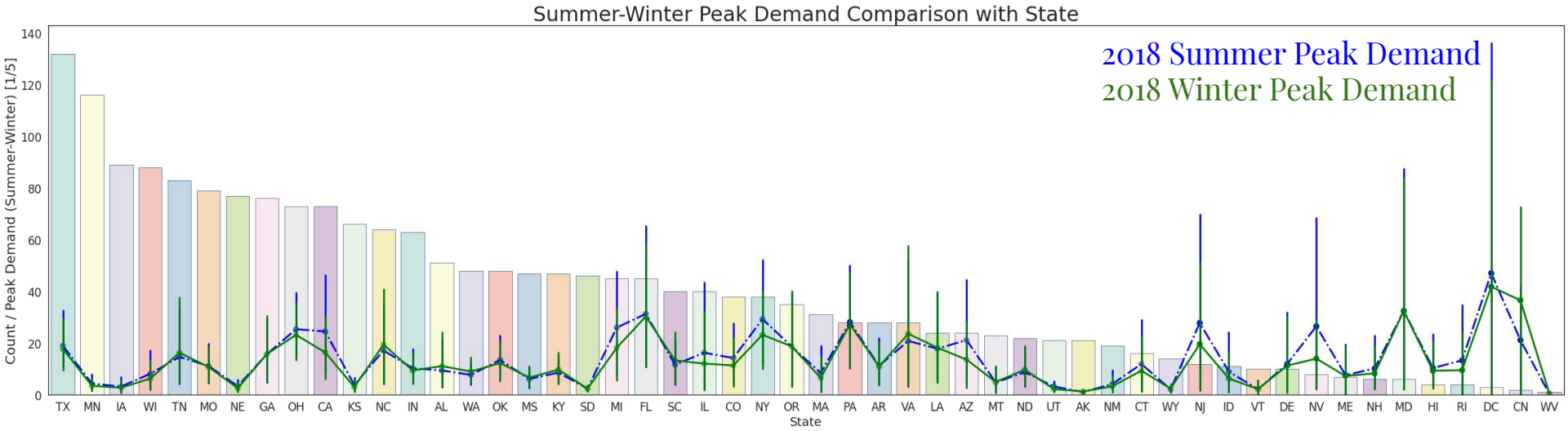
Overall similar distribution with subtle differences in Peak Demands

NERC & Ownership: Summer vs Winter Demands



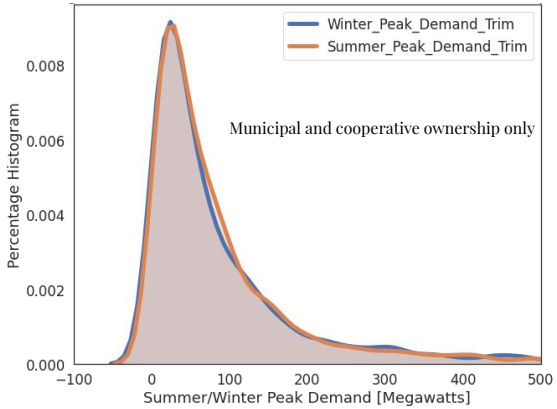


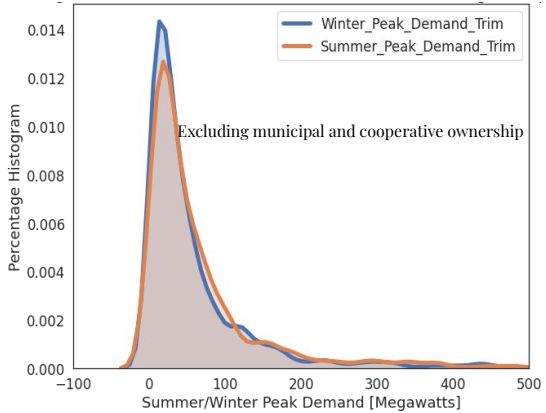
State-wise: Summer vs Winter Demands

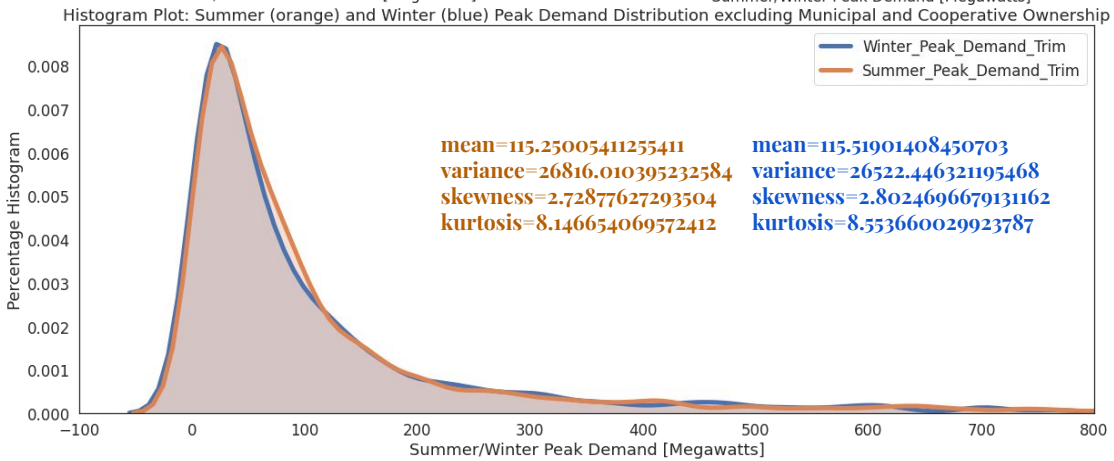


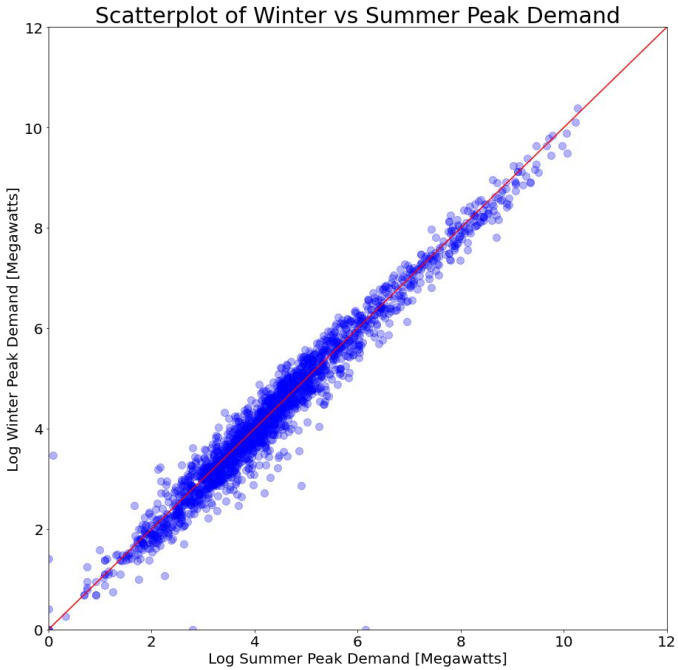
- Majority states shows very similar peak demand
- However, states like California, Michigan, Illinois, Colorado, New York, Arizona, New Jersey, and Nevada shows lower winter peak demands

Statistical Testing: Summer vs Winter Demands









Wilcoxon signed rank test for non-normal distribution:
statistic=878444.0, pvalue=2.342e-05

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Presentation Duration : 20 min

Conclusion

- The operational performance of power utility across North America shows some useful insights in predicting future electricity trends
  - The efficiency of power transmission is improving
  - The retail price per unit is increasing
  - Total Electricity consumption is the same on yearly basis
  - Seasonal variability of electricity demand is present

Limitation

- For complete analysis, data from year 2013 to year 2017 must be taken into account

Questions?

Appendix

Statistical Testing: Summer vs Winter Demands

1. The Summer and Winter peak demands of 2018 are independent and uncorrelated
2. The samples are representative of the population of the power utility entities of North America
3. The TELP distribution are not normally distributed
4. Summer and winter peak load in 2018 year are significantly different
5. Distribution behaviour is highly dependent on the ownership category

PTEL: 2012 vs 2018 (T-Test Results)

1. The test variable (TELP) is continuously distributed
2. The TELP measurements from 2012 and 2018 are independent and uncorrelated
3. The samples are representative of the population of the power utility entities of North America
4. The TELP distribution are normally distributed
5. Variances of TLEP of 2012 and 2018 year are approximately equal

The t-test yields a t value of 6.510 with a p value of small value of ~ 8.5e10^-11.

Hence, the null hypothesis is **statistically rejected** and its is inferred that the mean reduction of 6.5% of total energy losses is observed in the year 2018.