Impact of Drought on the Energy Sector

NOAA-NIDIS Capstone Project

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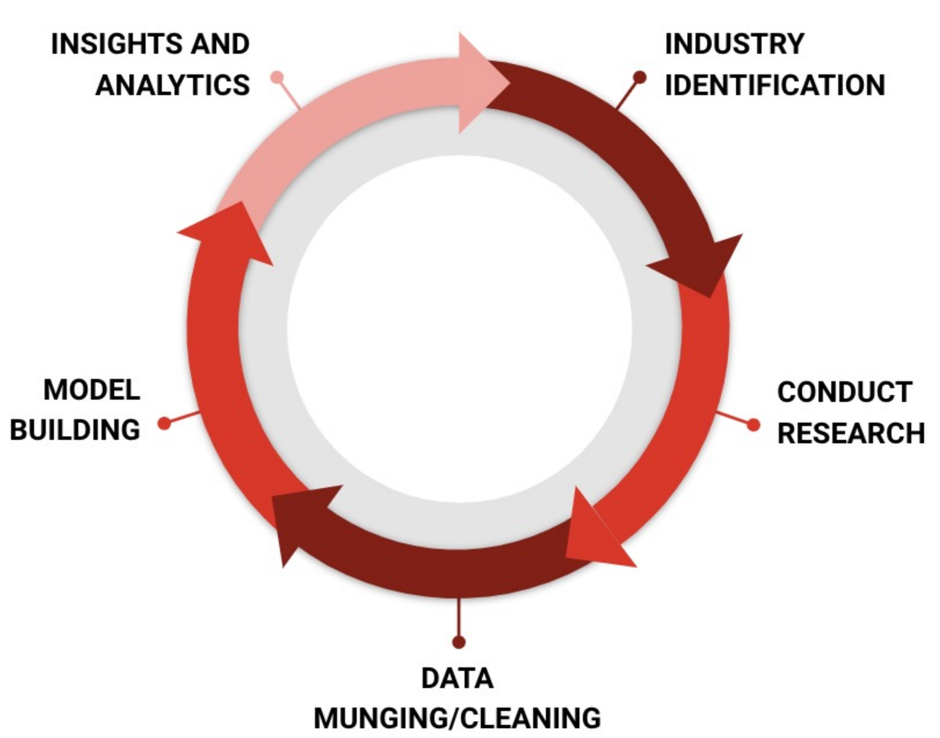
Introduction

Drought has plagued civilization for millennia and with the explosive population growth, it is placing much more pressure on water supplies. Hence, it is crucial to understand the impact of drought on different sectors of the economy with the everyday increase in population. The end goal of this project is to increase the dissemination of energy production variation given certain drought conditions, to the electricity producers in a way that allows them to anticipate changes in the energy prices and demand. The following are the key goals of the project:

- Correlation between drought affecting variables to check the influence of one variable over the other
- Predictive modeling to observe the trends through the years 2011-2020
- A complete database that relates electricity generation and consumption of power plants and water resources
- A front-end dashboard that visualizes trends and descriptive statistics for drought-affecting variables

Methodology



Data Collection and Analysis

While deliberating on the impacts of drought on the society we chose to focus on the energy sector and specifically on electricity price volatility. Low precipitation and high temperatures present unique challenges to the energy sector which are crucial to analyze and help energy producers and consumers take preventive measures. We analyzed the drought conditions- temperature and precipitation along with drought severity indices such as DSCI and PDSI(Palmer Severity Index) and energy generation-consumption data across the 6 northeastern states under NIDIS: Maine, Vermont, New Hampshire, Massachusetts, Connecticut, Rhode Island, and New York from 2011-to 2020. We collected data from different official government-sponsored sources, including US Energy Information Administration (EIA), US Geological Survey (USGS), National Oceanic and Atmospheric Administration (NOAA), and CDC.

Data Collection and Analysis

Dataset Summary:

- Time Scope: 2011-2020
- 54 Features 840 Observations
- Data for 7 North-Eastern States
- Plant level data at the county level for all 7 states aggregated at the state level

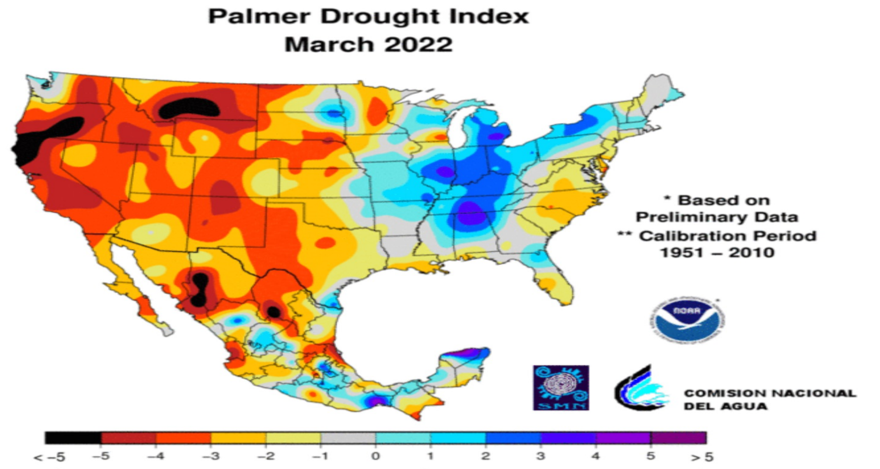
#	Column
0	Year
1	Month
2	State
3	Revenue(Thousand $)
4	Consumption(Megawatthours)
5	Customers(Count)
6	Price(Cents/kWh)
7	Precipitation
8	Temperature
9	Drought_index
10	D0
11	D1
12	D2
13	D3
14	D4
15	PDSI
16	CAPACITY_MW
17	NET_GEN_MWH
18	CAPACITY_MWH

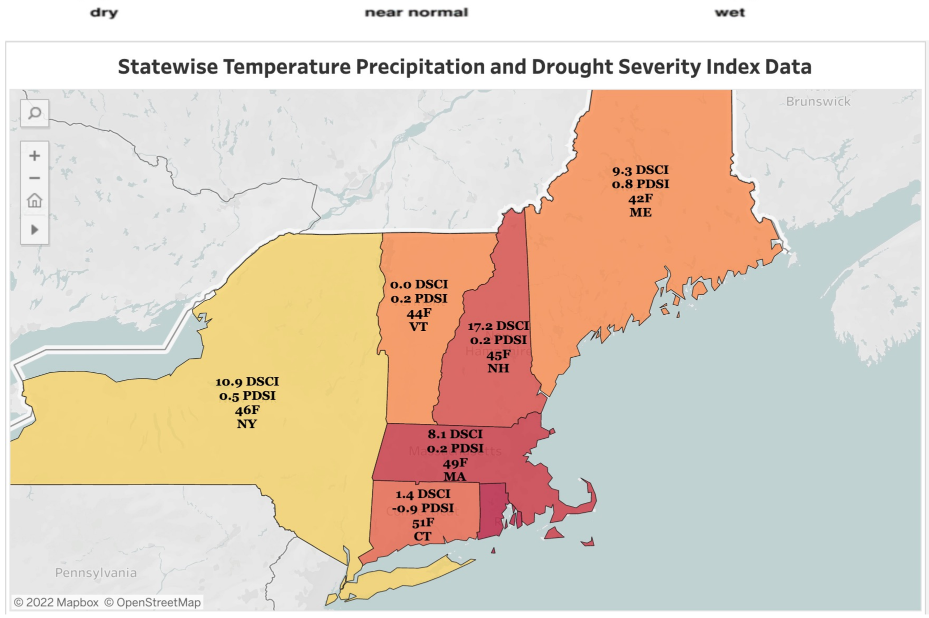
#	Column
0	Plant id
1	Plant name
2	County
3	State
4	state county fips
5	water source
6	Latitude
7	Longitude
8	elevation_in_feet
9	com_id
10	gen type
11	CAPACITY_MW
12	CHP
13	USGS_WATER_TYPE
14	MODEL_COOL_TYPE
15	MODEL WD
16	MODEL_MIN_WD
17	MODEL_MAX_WD
18	EIA_COOL_TYPE
19	EIA_WD
20	EIA_WD_INRANGE
21	COMP_COOL_TYPE
22	COMP_DATA_SOURCE
23	COMP_WD
24	COMP_TOTAL_WD
25	COMP_WD_INRANGE
26	NET_GEN_MWH
27	MAX_WITHDRAWAL
28	MIN_CONSUMPTION
29	MAX_CONSUMPTION
30	MIN_CONSUMPTION.1
31	Precipitation_1971-2000
32	Precipitation_2011

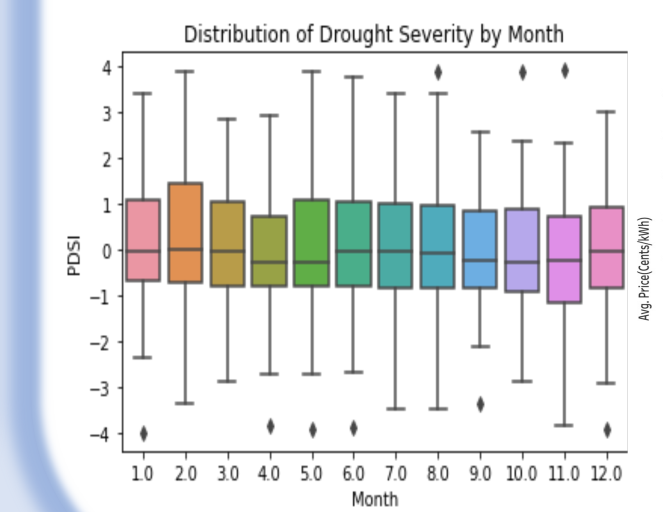
Drought Severity Classification

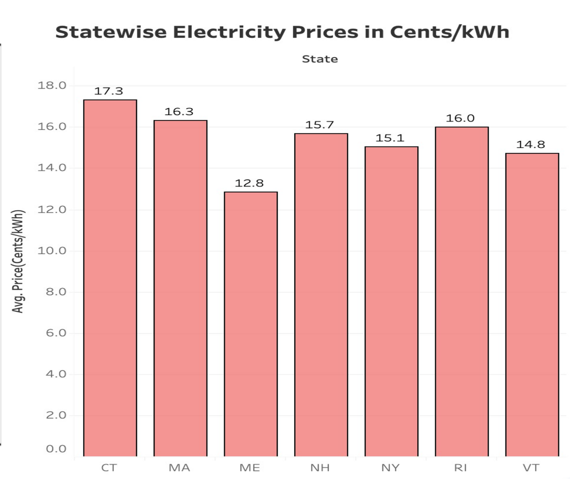
Category	Description	Possible Impacts	Ranges: Palmer Drought Index	CPC Soil Moisture Model (Percentiles)	USGS Weekly Streamflow (Percentiles)	Standardized Precipitation Index (SPI)	Objective Short and Long-term Drought Indicator Blends (Percentiles)
D0	Abnormally Dry	Going into drought: short-term dryness slowing planting, growth of crops or pastures. Coming out of drought: some lingering water deficits; pastures or crops not fully recovered	-1.0 to -1.9	21-30	21-30	-0.5 to -0.7	21-30
D1	Moderate Drought	Some damage to crops, pastures; streams, reservoirs, or wells low, some water shortages developing or imminent; voluntary water-use restrictions requested	-2.0 to -2.9	11-20	11-20	-0.8 to -1.2	11-20
D2	Severe Drought	Crop or pasture losses likely; water shortages common; water restrictions imposed	-3.0 to -3.9	6-10	6-10	-1.3 to -1.5	6-10
D3	Extreme Drought	Major crop/pasture losses; widespread water shortages or restrictions	-4.0 to -4.9	3-5	3-5	-1.6 to -1.9	3-5
D4	Exceptional Drought	Exceptional and widespread crop/pasture losses; shortages of water in reservoirs, streams, and wells creating water emergencies	-5.0 or less	0-2	0-2	-2.0 or less	0-2

Increasing Drought Severity









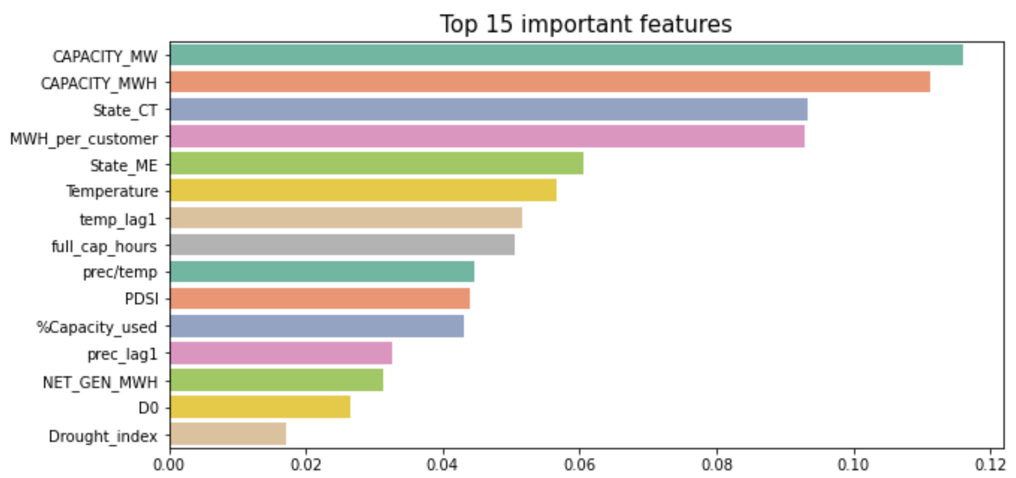
Machine Learning Models

- **Feature Engineering**
  - Binning and bucketing
    - E.g., Top 10% in the Drought index
  - Feature transformation and feature combination
    - E.g., Precipitation/ Temperature
    - Top 25% in temperature and consumption

- **Model selection**
  - Traditional statistical models
    - Linear Regression
    - Lasso Regression
  - Tree-based models
    - Random Forest (BEST MODEL)
    - Gradient Boost Trees

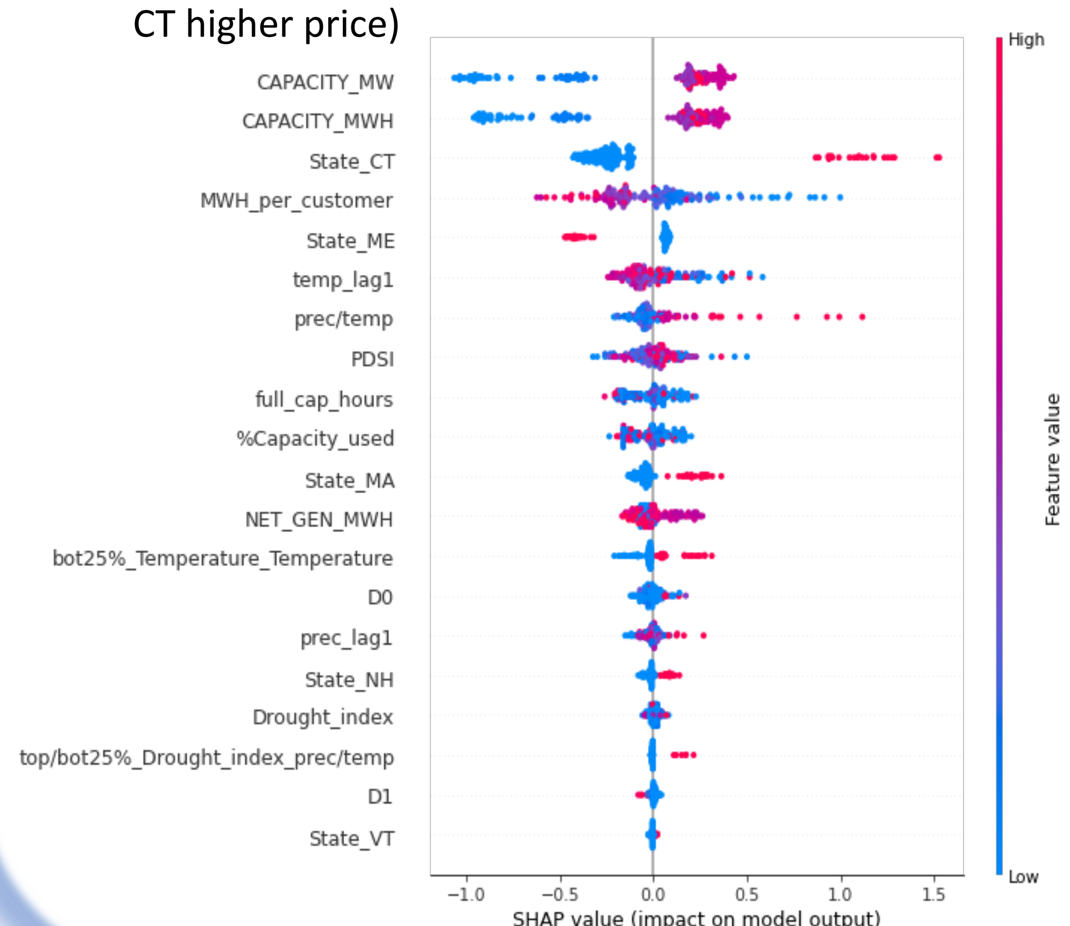
- **Hyperparameters Tuning**
  - **Random Forest** (BEST MODEL)
    - Bootstrap, Max depth, Max features,
    - Min samples leaf, Min samples split,
    - N estimators.

Results



High electricity price is positively correlated with

- High temperature in the previous period
- Low electricity consumption per customer
- High PDSI value (Palmer Drought Severity Index)
- High Precipitation/Temperature
- State particular characteristics (ME lower price vs CT higher price)



Limitations and Challenges

- Lack of adequate domain knowledge in drought and energy fields
- Gathering proper data: Data was very dispersed across both drought(weather-related) and energy websites
- Relying on industry experts and resources to understand which indices to use for drought measurement and determinants of drought conditions

Conclusions

Model Performance (MAE, in cents/kWh)

3.5 ----> 0.85

Improving model performance to predict electricity prices with more accuracy

Project Impact:

Enables individuals and businesses to better understand and plan for electricity consumption

Enables government organizations to take preventive measures to support low-income communities if the electricity prices are forecasted to increase due to drought conditions.

Pitfalls:

Correlation vs. Causation, our model results only shows correlation, while it does not imply causation.

Future Work

- Considering more external and environmental factors like snowfall, cost of fuel, location of the plants, transmission, and distribution systems and government regulations into the model.
- Developing a front-end tool that supports utilities and communities to do electricity price forecasting.
- Applying this project analysis to Western and Central US states which are more impacted by drought conditions

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Git-hub and Dashboard Links

- https://github.com/chinarbu/BU_NIDIS_TeamA1_Capstone
- https://public.tableau.com/app/profile/chinar.boolchandani/viz/BU-NIDIS-Capstone-ImpactofDroughtonEnergy/NIDIS-Drought_Electricity_Prices#1