ERCOT Energy Portfolio Optimization

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Goal of this Research

- Develop a quadratic program to determine an optimal mix (portfolio) of energy supplies which minimize the variability of the price of energy in the Texas electricity market.
- I will use the Efficient Frontier concept, a "modern" portfolio theory introduced by Harry Markowitz in 1952.
- When used in Electric Power System optimization Merlin and Back (1975), note that we are interested in both minimizing expected cost and minimizing risk. This is a multi-objective optimization problem and there is always a trade-off between these two objectives.

Background

- My study is focused exclusively on the Texas Electric Grid.
- The Texas Grid is managed by The Electric Reliability Council of Texas (ERCOT).
- ERCOT is a membership-based 501(c)(4) nonprofit corporation, governed by a board of directors and subject to oversight by the Public Utility Commission of Texas and the Texas Legislature.
- (ERCOT) manages the flow of electric power to 24 million Texas customers – representing about 90 percent of the state's electric load.
- ERCOT schedules power on an electric grid that connects more than 46,500 miles of transmission lines and 570+ generation units.

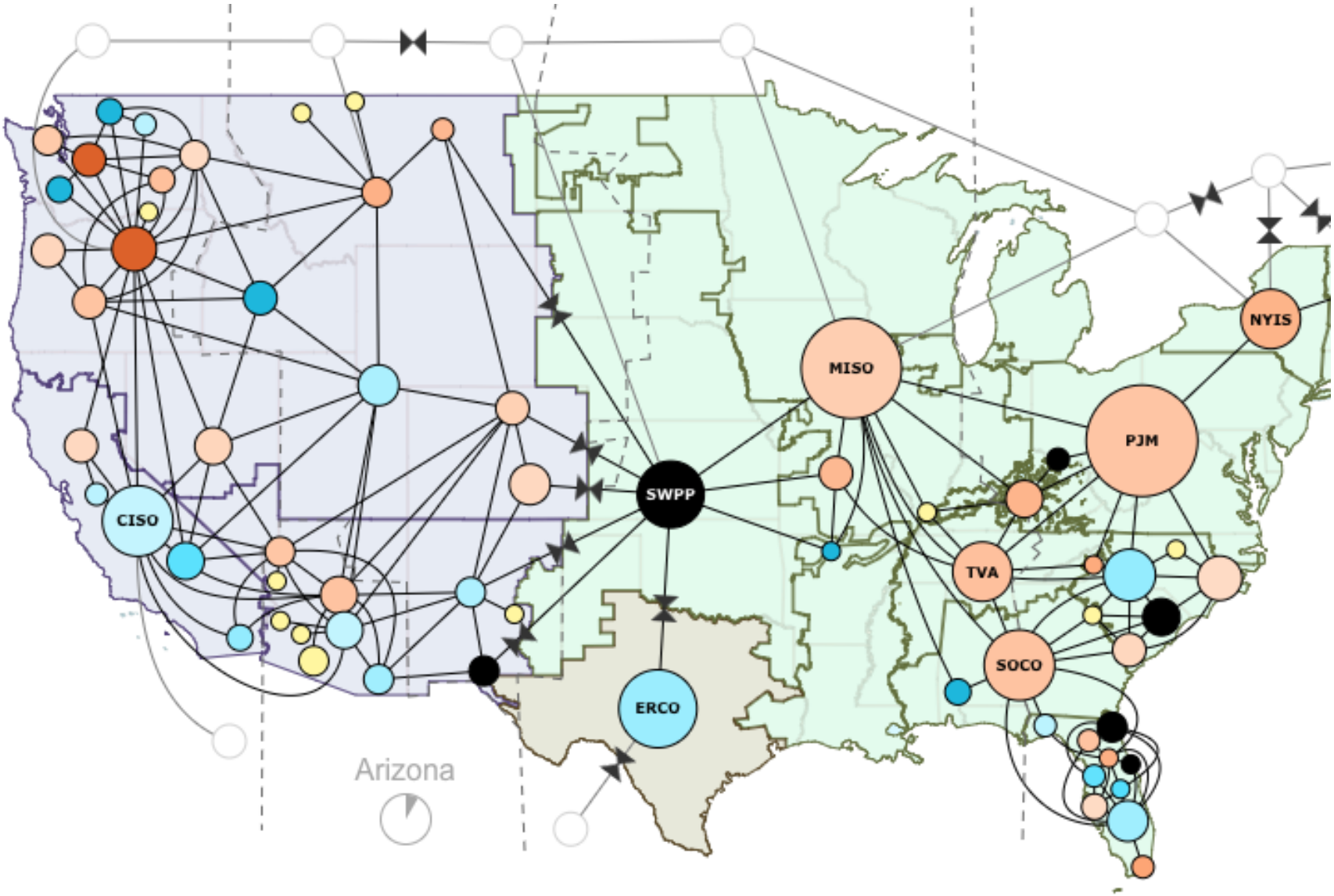
More Background

ERCOT is currently undergoing rapid change in several key areas.

- Demand Increase
- Structural Change
- Changes in Regulatory environment
- Change in ERCOT's Service Territory
- Weather Uncertainty

United States Power Grid

- Western Interconnection, ERCOT, Eastern Interconnection



Demand Increse

- ERCOT Generated Model for Peak Summer Demand

Peak Demand and Energy Forecast Summary

Year	Summer Peak Demand (MW)	Energy (TWh)
2017	72,934	356
2018	74,149	362
2019	75,588	371
2020	76,510	376
2021	77,417	380
2022	78,377	385
2023	79,348	389
2024	80,315	393
2025	81,261	398
2026	82,286	417

Structural Change

Energy source portfolio changes

- More Wind and Solar sources online
- More Natural Gas integration
- Coal plant retirement schedules

Demand Shifters

- Electric vehicles have less than 1% market share today
- The future will look very different
- The electricity demands from electric vehicles on the power grid will be non-trivial
- Turns out the future is hard to predict, BUT future demands need to be provisioned for today.

Changes in Regulatory Environment

Electricity Market Reform

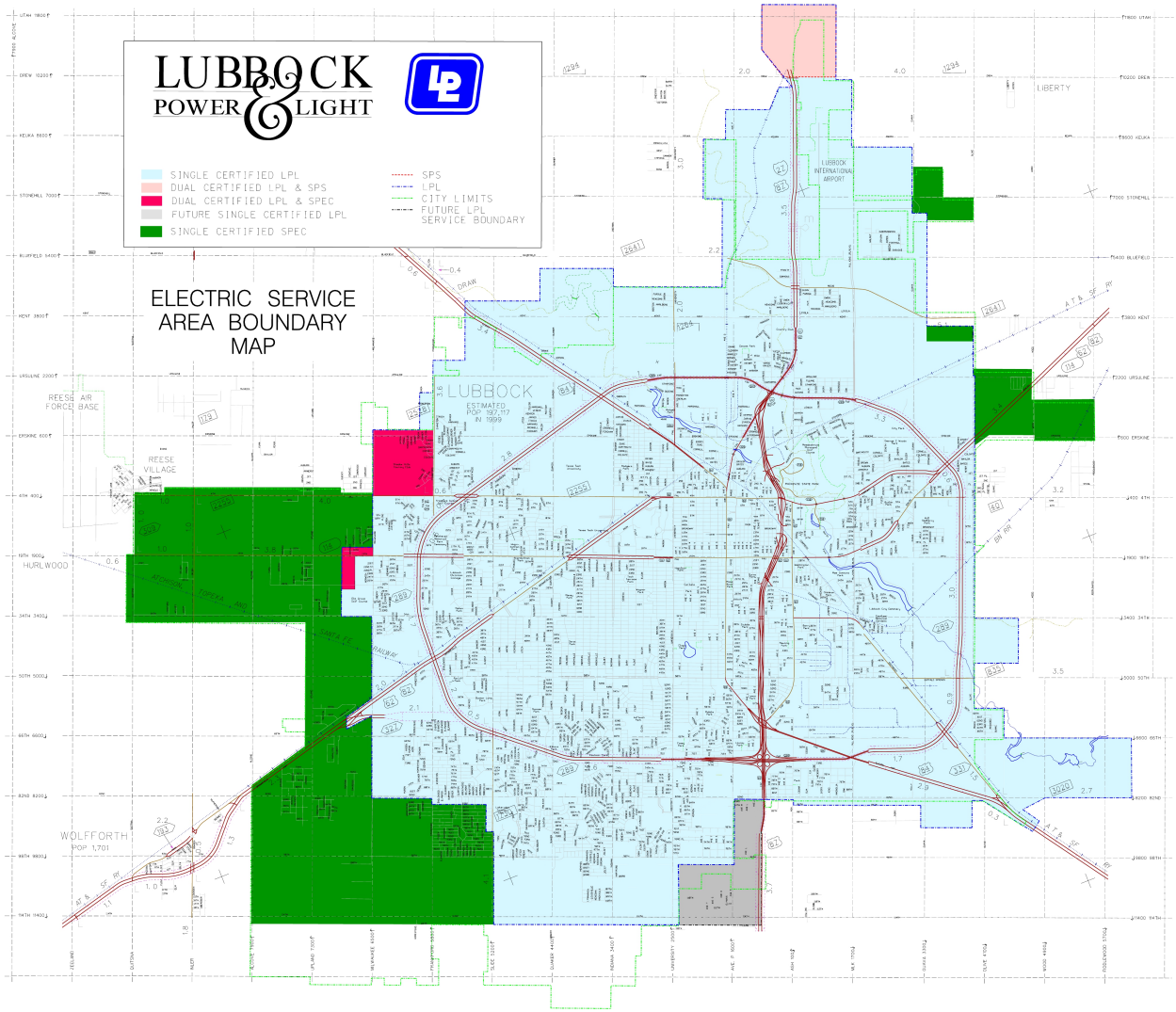
- Move away from vertically integrated electricity markets
- Move toward Investor Owned Utilities (IOU's)
- Development of Spot Market and Day Ahead Transaction Markets
- More sophisticated Cost Plus Pricing Models

Changes in Environmental Regulations

- Move toward renewable energy sources
- Move away from Nuclear

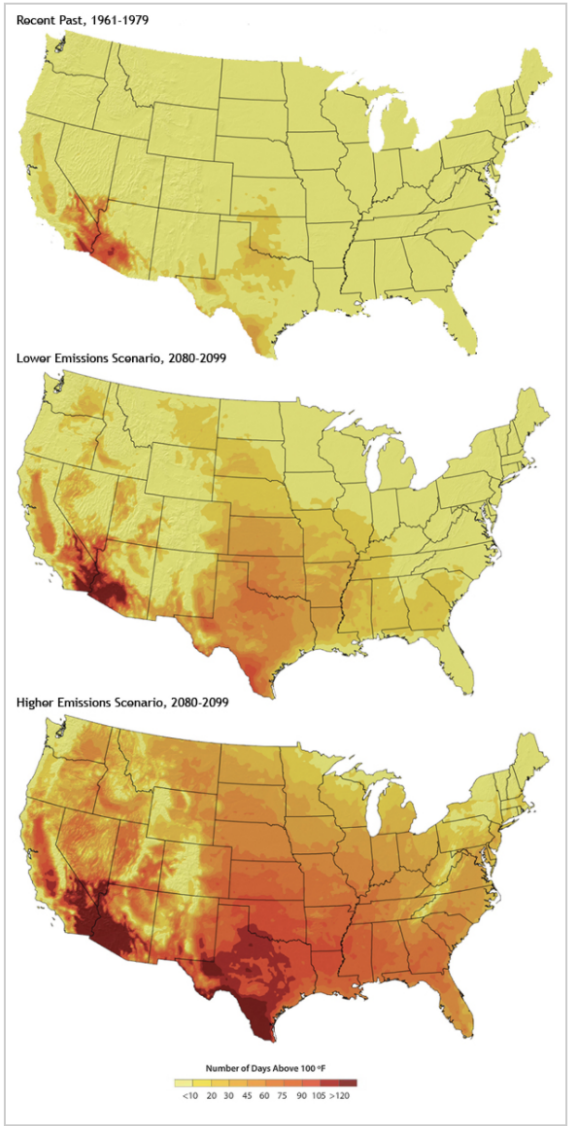
Change in ERCOT's Service Territory

- Lubbock will add 600 MW of demand load



Weather Uncertainty

- Texas summers are always hot!!! and getting hotter???



Optimization Model

Quadratic Programing Model

$$\min_{x_i} \frac{1}{2} x' H x + f' \text{ subject to } \begin{cases} Ax \leqslant b, \\ Aeqx = beq, \\ x \geqslant 0 \end{cases}$$

Optimization Model

Data

- Expected average price of source energy in 20XX
- Data from ERCOT Price Projection Model

Source	Expected Price ($/MWh)
Coal	$E(p_1)$
Hydro	$E(p_2)$
Natural Gas	$E(p_3)$
Nuclear	$E(p_4)$
Biomass	$E(p_5)$
Geo	$E(p_6)$
Solar	$E(p_7)$
Wind	$E(p_8)$

Optimization Model

Data

- Standard deviation of energy source prices in 20XX

Source	σ (\$/MWh)
Coal	σ_1
Hydro	σ_2
Natural Gas	σ_3
Nuclear	σ_4
Biomass	σ_5
Geo	σ_6
Solar	σ_7
Wind	σ_8

Optimization Model

Constraints

- Meet projected demand, ie. 2026 Energy Forecast of 417 TWh
- Keep Texas electricity rates competitive, therefore, ensure expected cost of energy portfolio under XXX $/MWh

Gaol

- Formulate a quadratic program to minimize the risk of obtaining energy, while satisfying the maximum expected energy cost constraint described above.