Working for Pacific Gas & Electric Company: Building Renewables Integration Tools

Carolyn Meldgin

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Outline

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  - Grid Reliability
  - Market Prices
- Challenges with Renewables Integration
  - California State Policy (SB 350—50% RPS target)
  - Intermittent resources
  - Ramp problem
- My Projects
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  - Energy Storage RFO
  - Capacity Price Modeling
- PG&E Compensation and Benefits
- Appendix (if time)
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  - …

Pacific Gas and Electric Company

- Natural gas and electric utility

- Transmission and delivery of energy

- Serves 16 million people (1/20 people in the US)

- 70,000 square mile service area

- I am a Senior Quantitative Analyst in PG&E's Energy Policy and Procurement division

California Electric Utility Service Areas

Energy Procurement Modeling and Analysis

Elamein Eisa   Bill Gavelis   Sergei Kotsan   Yumi Oum   Carolyn Meldgin   Sue Nee Tan   Yanping Chong   Jan Grygier   Enrique Mejorada

# Orientation: Grid Reliability

- http://fnetpublic.utk.edu/frequency map.html
- Electricity is generated:
  - Hydroelectric power plants
  - Nuclear power plants (last California nuclear will be shut down in 2025)
  - Coal (not in California!)
  - Gas fired power plants
  - Renewables
    - Solar
    - Wind
- Electricity is consumed:
  - Residential
 - Commercial
  - Industrial

Orientation: Prices

- Electricity markets are nodal
- Markets are varied: Day-Ahead and Real-Time, Ancillary Services

http://www.caiso.com/pages/pricemaps.aspx

Renewable Integration
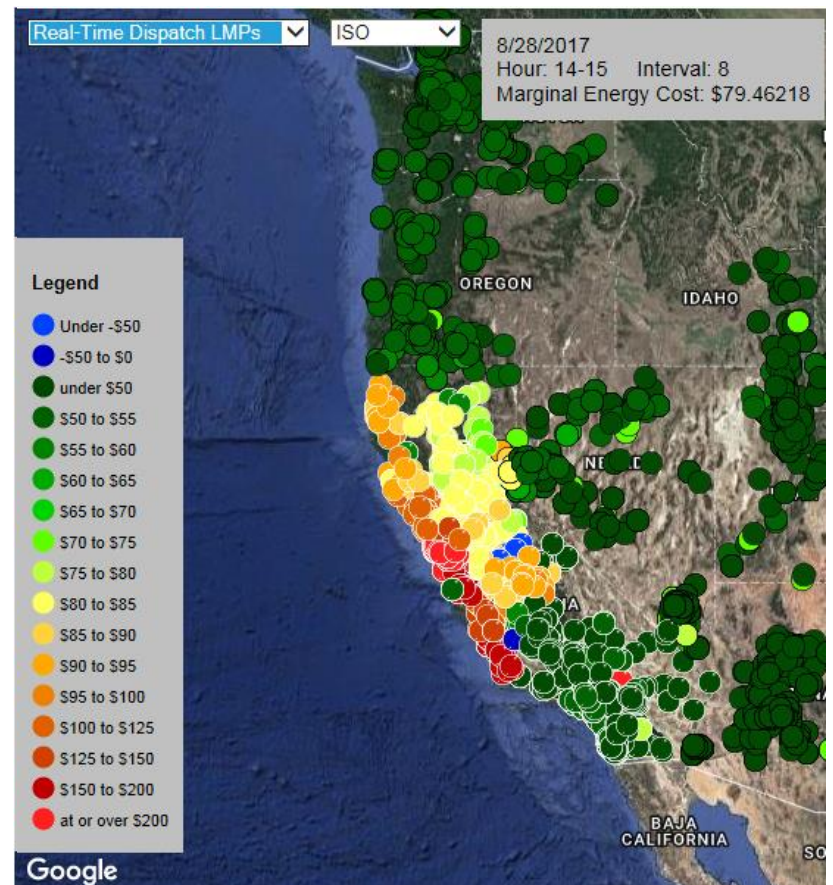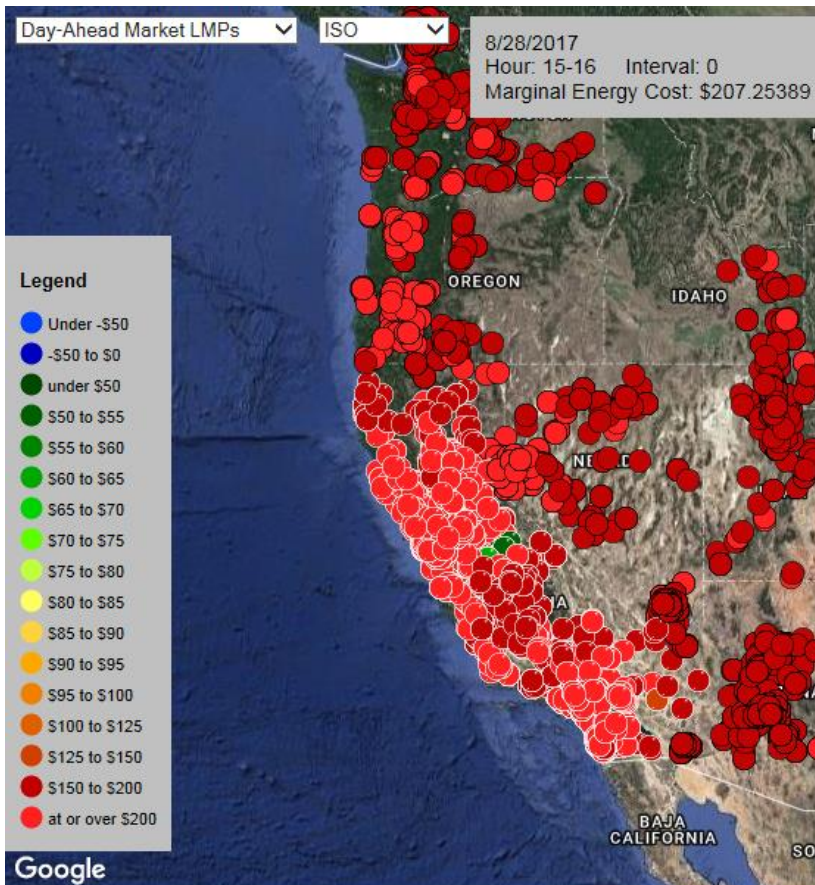
California State Policy: Senate Bill 350, signed October 2015, requires "retail sellers and publicly owned utilities to procure 50 percent of their electricity from eligible renewable energy resources by 2030." http://www.energy.ca.gov/portfolio/

Solar production varies from one day to the next --- One week in March 2017
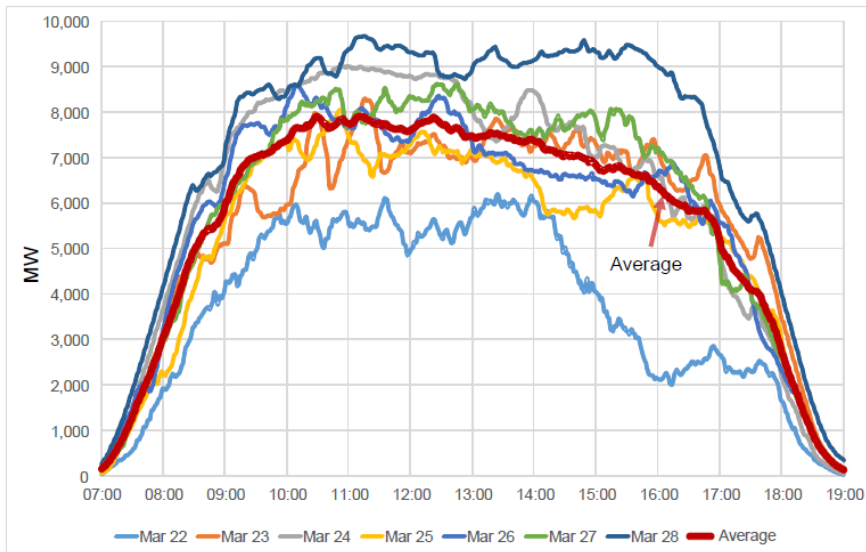
Net Load varies from one day to the next --- One week in March 2017
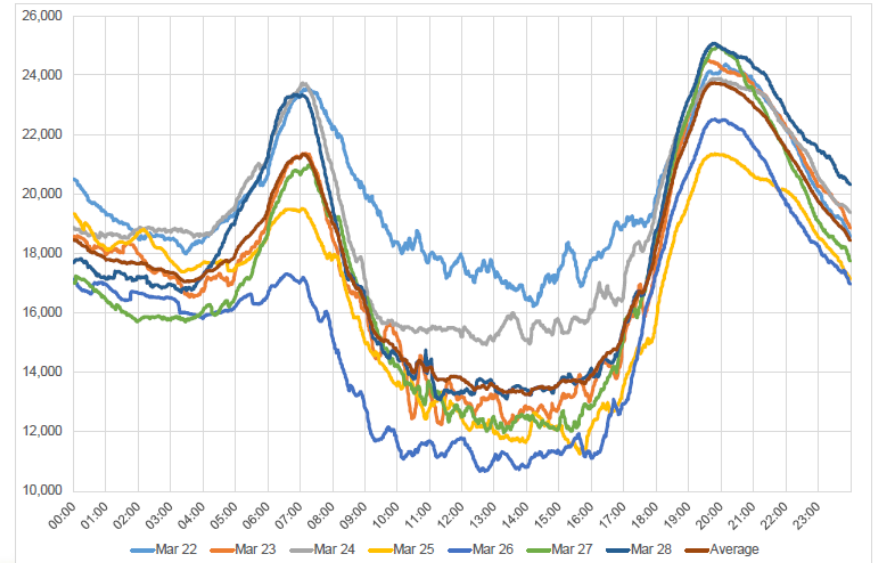
https://www.caiso.com/Documents/Agenda_Presentation_FlexibleResourceAdequacyCriteria_MustOfferObligations.pdf

Renewables like wind and solar are *intermittent*—they are there when the wind blows or the sun shines regardless of the demand for their power.

My Projects

1. Gas Burn Model (short horizon: 1-5 days forecast)
2. Storage RFO (medium horizon: 2-5 years)
3. Capacity Price Model (long horizon: 5-40 years)

1. Day-ahead Gas Burn Modeling

- PG&E traders procure natural gas at 6AM for use the following day by PG&E power plants

- The awards (how much power the plants are scheduled to generate) become available at 1PM

- If the amount of natural gas they procure differs from the amount burned by more than the size of our storage facility, they must buy or sell in the same-day market, exposing PG&E to additional risk

- With the additional volatility in the system due to renewable resources, it became more difficult to forecast gas burn
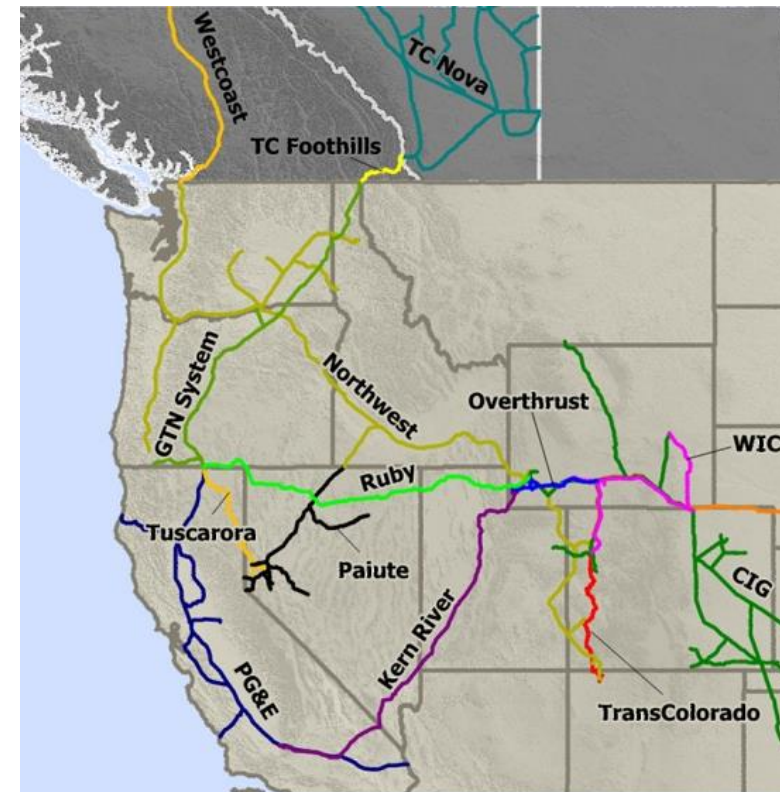
1. Day-ahead Gas Burn Modeling

- Data:
  - Temperature (historical and forecast)
  - Aggregate hourly prices (historical and forecast)
  - Hourly load/demand (historical and forecast)
  - Integrated Forward Market Awards (historical)
  - Solar generation (historical and forecast)
  - Wind generation (historical and forecast)
  - Gas burn (historical—I'm building the forecast)
  - Day of week/holiday
- Model is entirely automated
- Model core is a neural network

Flywheels

Pumped storage

Flow batteries

Tank 1

Tank 2

Pump 1
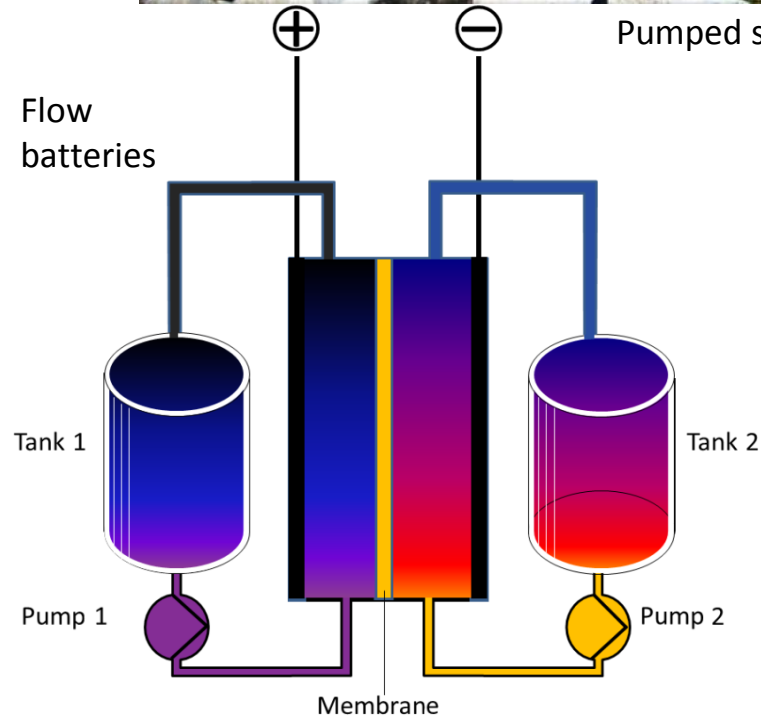
Pump 2

Membrane

Lithium-ion or other battery storage

2. Energy Storage RFO (Request for Offers)

- California AB 2868: State mandate to procure 1,325 MW of battery storage, of which 580MW is PG&E's share, online by 2024.

- Goal of my group is to find the cost and benefit of each offer: my piece was to find the costs of turn-key offers

- Example: bid data includes initial capital cost, battery pack replacement costs, maintenance costs. I calculate depreciation, taxes, insurance and property taxes, PG&E overhead (eg site security) to determine the annual costs over the asset's lifetime

- PG&E is not permitted to make money in energy sales, therefore the standard business model of selling for more than you buy is inverted: we calculate the cost and then charge customers to recover the costs

3. Capacity Price Modeling

- Power plants make money in two ways:
  - Selling their energy
  - Selling their capacity

- Capacity is the *ability* to produce power.
  - For example, an inefficient plant that we need for heat waves costs $180/kW-yr to operate. It gets $20/kW-yr from selling energy during heat waves, and we pay $160/kW-yr to keep it online.

- Why model capacity prices (out to 2060)?
  - Portfolio decisions: buy a plant? Sell a plant?
  - Rate forecasting
  - Long-term strategy

PG&E Stock Price since 1990

California Electricity Crisis
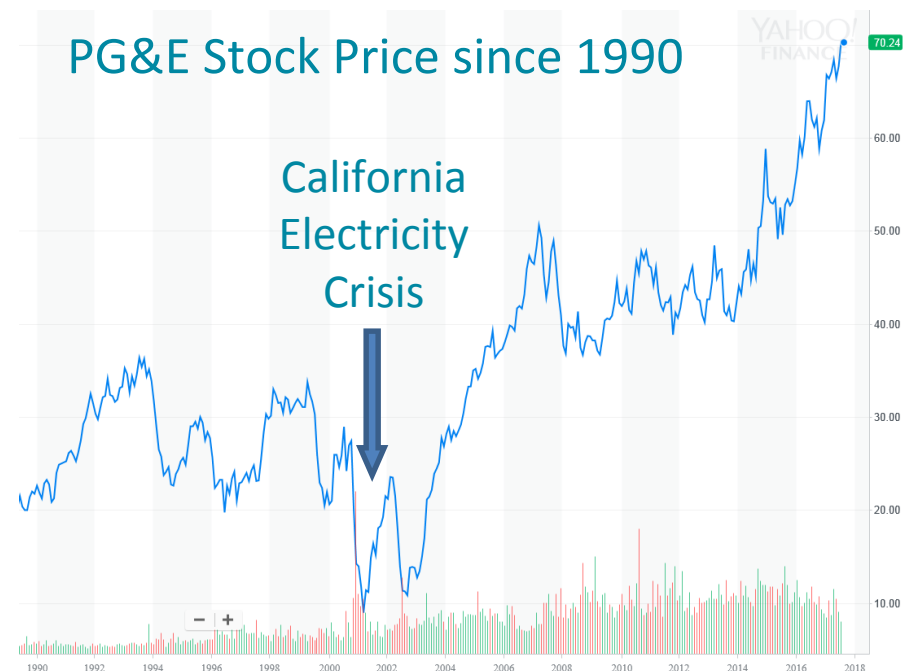
3. Capacity Price Modeling

- Previous model considered:
  - Short run costs of gas-fired power plants (these are typically on margin)
  - Long run costs of building new gas-fired power plants when we showed a need for new capacity (10+ years)

- Battery industry anticipates a drop in battery costs, so we are testing a new version of the model which includes battery storage as a candidate marginal resource

- Questions:
  - Is there enough total energy (batteries are a net load)?
  - How much do batteries affect energy prices? Batteries can make money through price arbitrage. The more batteries there are on the system, the flatter the prices will be during the day, and the less money they can make.
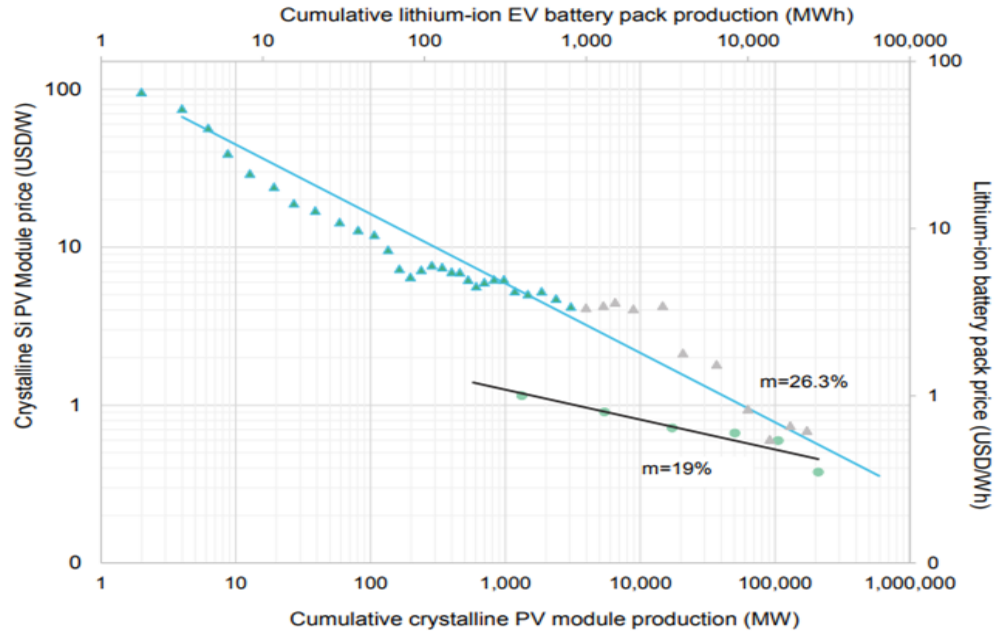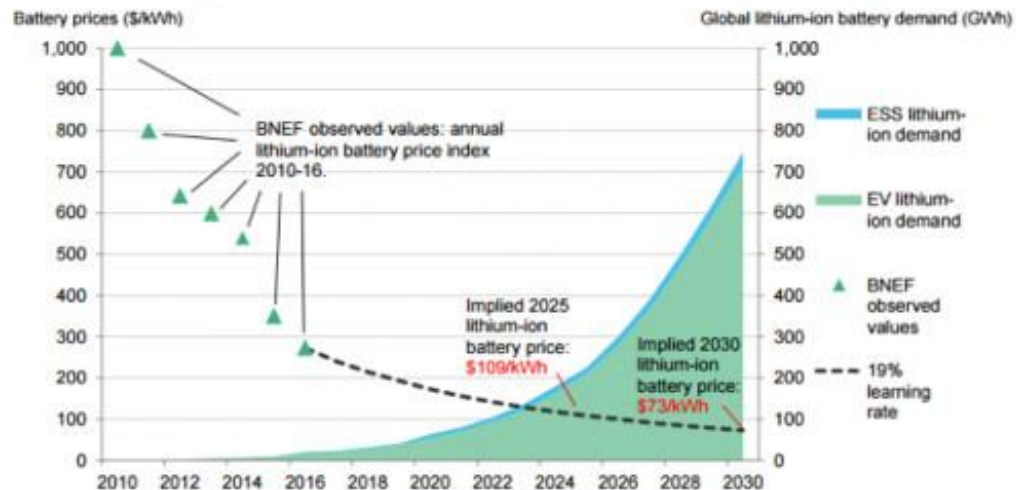
Source: Bloomberg New Energy Finance

Compensation and Benefits

- Attractive base salary for quantitative analysts (individual contributors)

- 10-15% annual bonus

- Up to 6% 401k matching (national average is ~2%)

- Pension plan

- 18 vacation days per year for new employees

- 14 weeks of maternity leave, 8 weeks of paternity leave

- Excellent medical, dental, and vision coverage, for self, spouse, and dependents
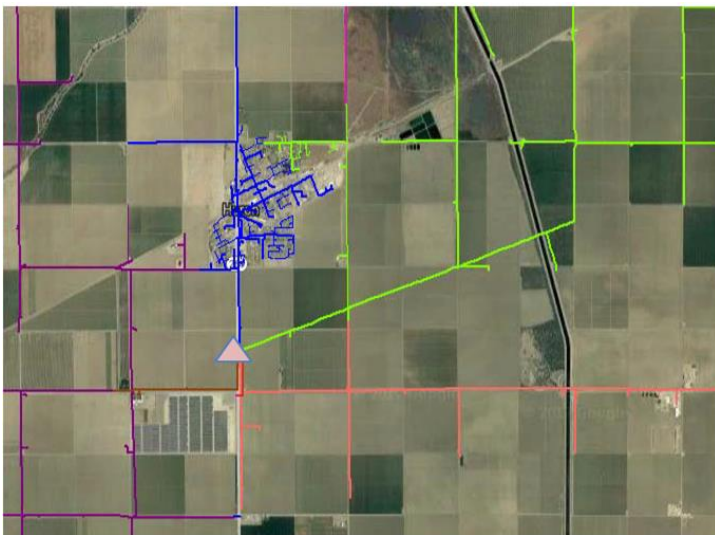
APPENDIX

Tools and Skills

- Data analysis: SQL, SAS JMP, Excel, Teradata SQL Assistant, [Python, Oracle SQL Developer, Toad, Tableau]

- Languages: Matlab, VBA, SQL, JSL, [SAS, Python]

- Model building: Modeling techniques (neural networks, clustering algorithms...), SAS JMP, statistics

- Industry knowledge: California state policy, Markets (energy, capacity, ancillary services; day ahead, real time), Power plant types and specifics, tax law, portfolio management, nodal pricing (Full Network Model), electric vehicles (laws and consumer adoption models),...
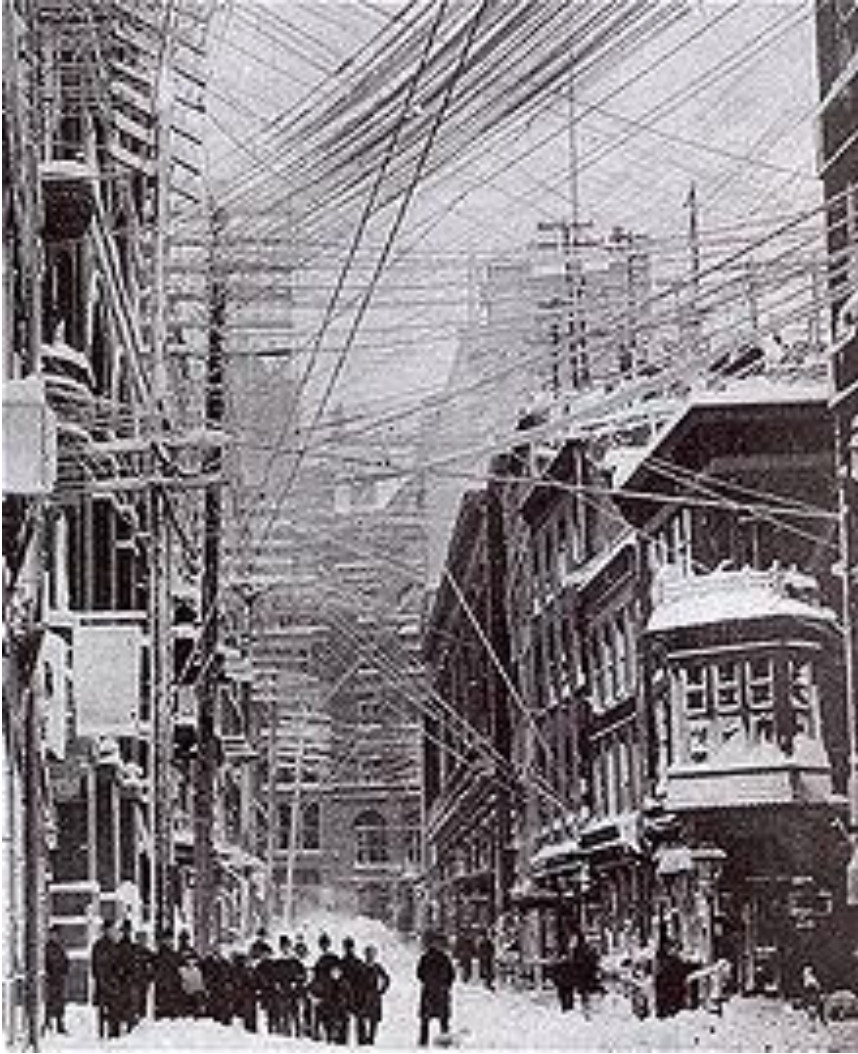
Big Data

- Customer usage
- Nodal prices
  - Day Ahead
  - Real Time
  - Ancillary Services
- Weather
- 5 min actual generation from every power plant PG&E contracts with
- Forecasts of price, load, weather
- Awards
- Lots more

Smart Grid

- Smart devices: controlled by utility or pre-set to not run (as much) during peak load hours

- Signaling prices to users: opt-in alerts to reduce load, for a rebate

- PG&E Demo D Pilot: Huron Substation is at risk of "reverse flow overload conditions" due to low load and high solar generation, and "load overload conditions" due to high load in peak hours. Link

Symbols:		Huron Feeders:	
△ = Huron Bank 1		1112 = ——	1106 = ——
		1116 = ——	1108 = ——

"Natural Monopoly"

New York City, 1888

"A **natural monopoly** is a monopoly in an industry in which it is most efficient (involving the lowest long-run average cost) for production to be permanently concentrated in a single firm rather than contested competitively…..This tends to be the case in industries where **capital costs predominate**, creating economies of scale that are large in relation to the size of the market, and hence creating high barriers to entry; examples include public utilities such as water services and electricity."

Jeffrey M. Perloff, Professor in the Department of Agricultural and Resource Economics at UC Berkeley

Typical Spring Day

https://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf