When Even the Y Isn't Known

The Increasing Complexity of Load Forecasting

Indiana Utility Regulatory Commission
Contemporary Issues Technical Conference
June 6, 2024

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A Whole New Level of Complexity

- If we can't see it, how do we forecast it?
  - Behind the meter generation masking demand
  - Efficiency masking economic growth

- Policies reshaping the future
  - Climate change and electrification
    - State greenhouse reduction goals
    - Electric Vehicle mandates
    - The Inflation Reduction Act

- Lots of moving pieces: You don't know what you have until you add it up
  - Need an hourly modeling framework.

It all started a long time ago

- **Energy and Policy Conservation Act (1975), and 1975 Amendment**. Directed the Department of Energy (DOE) to establish energy conservation standards for consumer products.

- **The National Appliance Energy Conservation Act of 1987**. Established minimum efficiency standards for many common household appliances

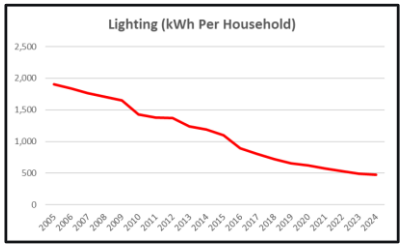
- **The Energy Policy Act of 1992 (EPAct).** Added standards for some fluorescent and incandescent reflector lamps, plumbing products, electric motors, commercial water heaters, and heating, ventilation, and air conditioning (HVAC) systems. EPAct also allowed for the future development of standards for many other end-uses.

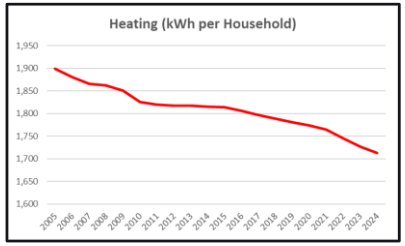
- **The Energy Policy Act of 2005 (EPAct).** Updated 1992 EPAct. Set new standards for 16 products and directed DOE to set standards via rulemaking for another five end-uses.

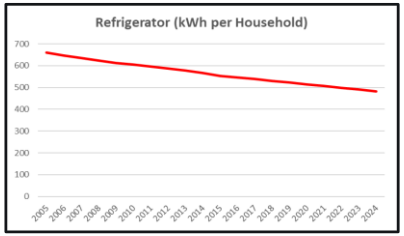
- **The Energy Independence and Security Act (EISA 2007).** Enacted new and updated standards for 13 end-uses. Effectively eliminated incandescent lightbulbs.

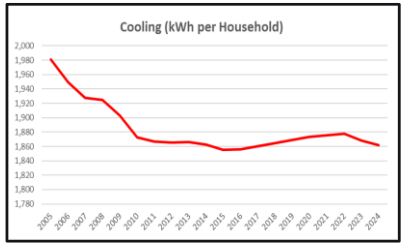
The electric industry joined in

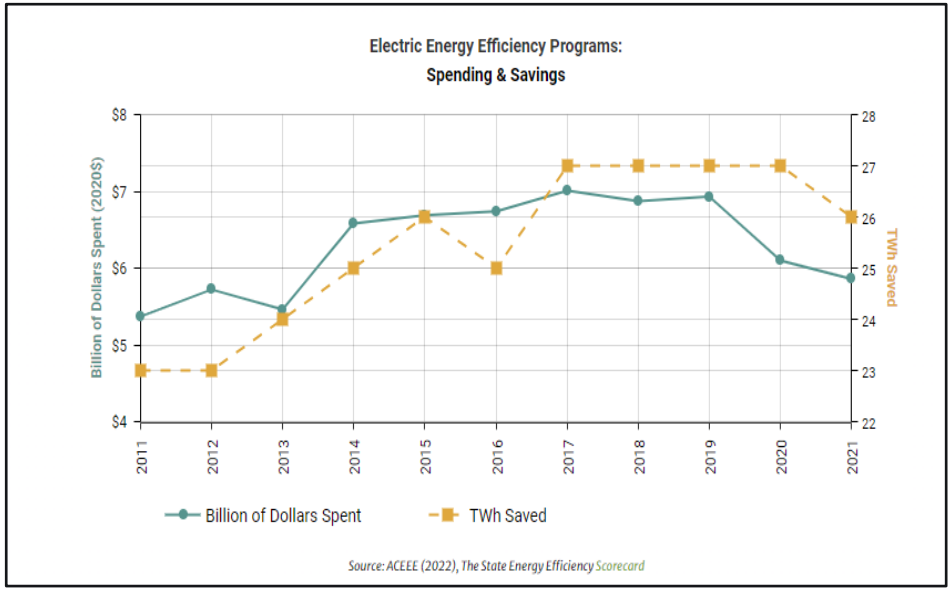
- Between 2011 and 2021, $70 billion spent on efficiency programs
  - 280 TWh Saved
  - Reducing electric requirements roughly 7.5%



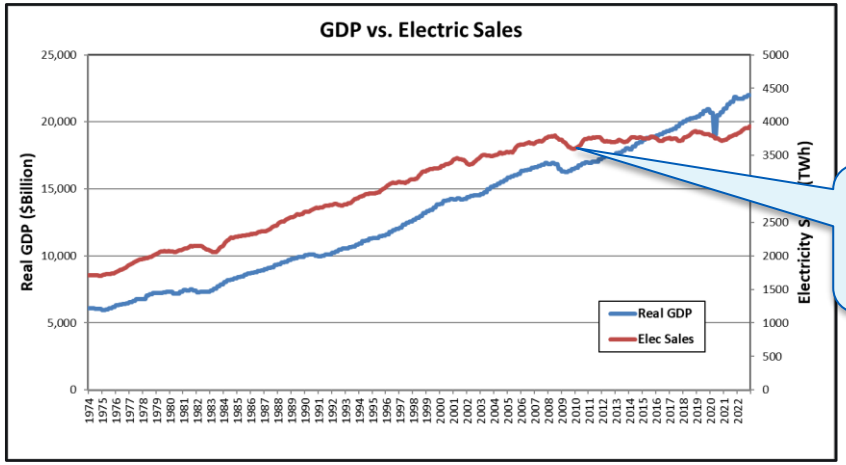








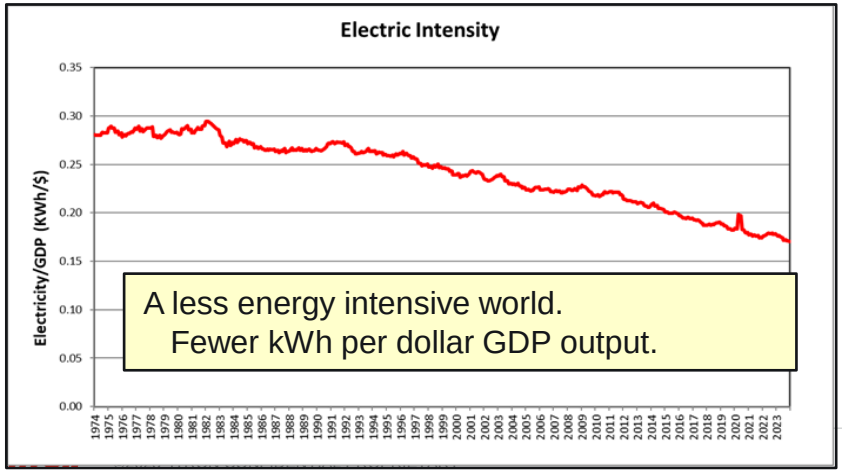
Altered relationship between electricity use and economic growth



Electric sales and GDP growth diverge

Period	Correlation
1974-1979	0.987
1980-1989	0.982
1990-1999	0.989
2000-2009	0.962
2010-2019	0.687
2020-2023	0.732

Sales were easy to forecast when the correlation with GDP was high.



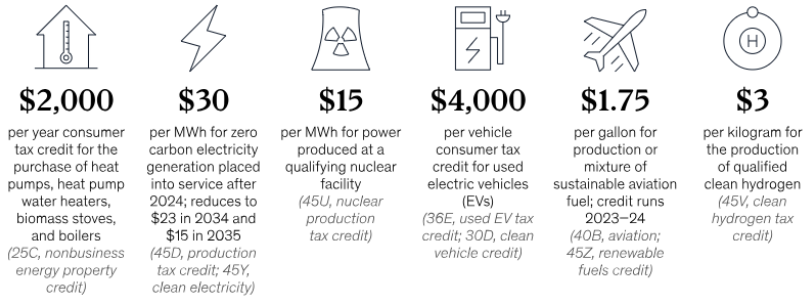
A less energy intensive world.
Fewer kWh per dollar GDP output.

The 2022 Inflation Reduction Act

Efficiency and electrification is about to get super charged

- Targets reduction of green house gases through efficiency, building electrification, and EV adoption
  - $369 Billion targeted at reducing Greenhouse gases
  - Provides $18 billion in federal grants and $43 billion in tax credits for solar, efficiency, and electrification
  - Rebate funding will flow through the state energy efficiency entities starting this year

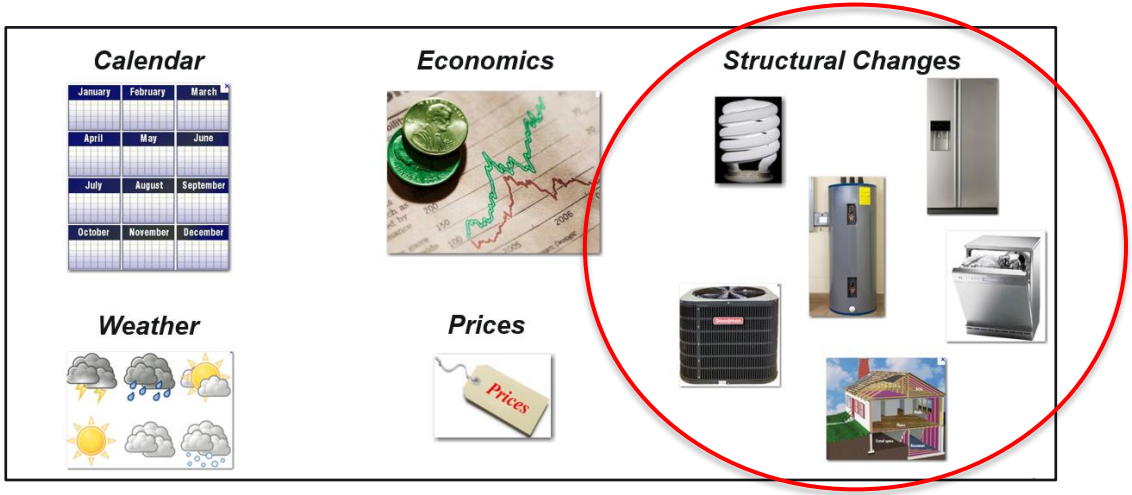
- Home Energy Rebate Program $8.8 Billion
- **Indiana**
  - Efficiency/Weatherization: $91.1 million
  - Electrification: $90.8 million
  - **Total: $181.9 million**



Note: This exhibit reflects the key statutory requirements for the cited tax provisions contained in the tax provisions in the Inflation Reduction Act, as well as those reported by the Congressional Budget Office and Joint Committee on Taxation. This analysis may differ from other analyses due to differences in methodology.
[1]Entities may need to meet certain domestic sourcing and procurement targets as well as prevailing wage/apprenticeship requirements.
Source: Inflation Reduction Act of 2022, H.R. 5376, 117th Cong. (2021–22)

McKinsey & Company

Can’t forecast energy without accounting for efficiency



- Impact of weather depends on the amount of air conditioning and heating loads in place
- Price, income, and GDP impacts depend on the efficiency of the underlying equipment
- Efficiency depends on appliance costs, standards, and tax credits and rebates

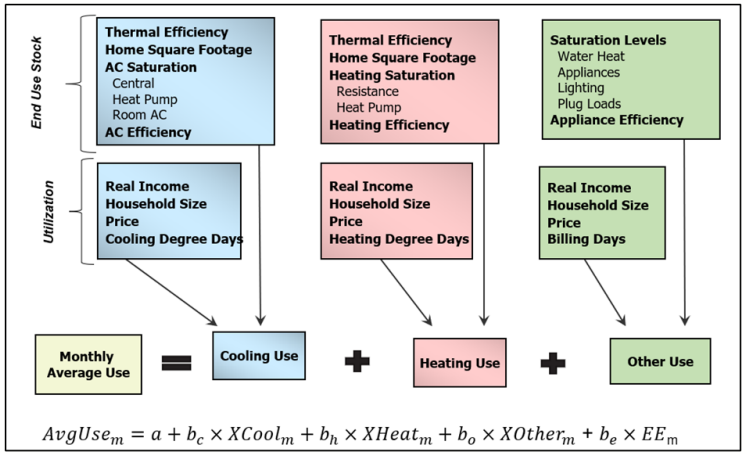
Need to be able to capture the interactions
All adds complexity to forecasting energy requirements

How Do We Do It
The SAE Model

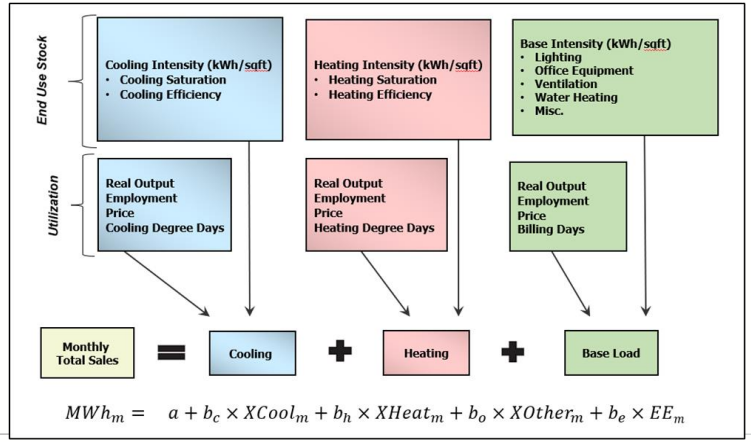
- Residential
  - End-use intensity
    - Saturation (ownership)
    - Efficiency (both standards and EE programs)
  - Square Footage
  - Thermal shell efficiency
  - Household size and income
  - Price
  - Weather (HDD and CDD)

- Commercial
  - End-use intensity
    - Efficiency (both standards and EE programs)
  - GDP and Employment
  - Price
  - Weather

Residential Model



Commercial Model



To see how policy is reshaping load: Just need to look at Vermont

Some of the most aggressive energy and clean air policies in the country

- Population 650,000 (Second smallest population)
- Burlington Metro Area 226,000
- Makes 2.5 million gallons of maple syrup per year
- Exports 500,000 Teddy Bears per year
- Montpelier: Smallest State Capital in the Country
  - No McDonalds, Starbucks, or Walmart

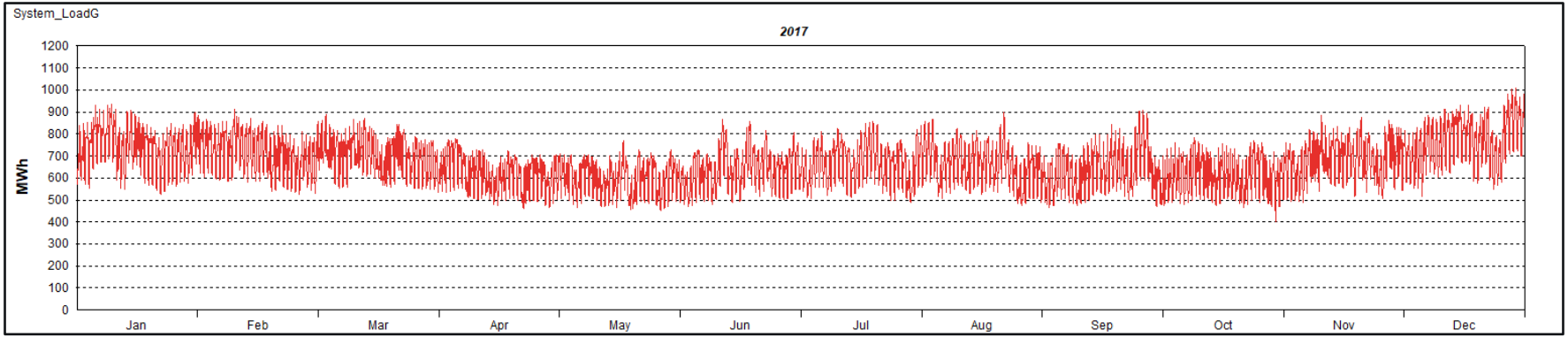
Vermont Legislation

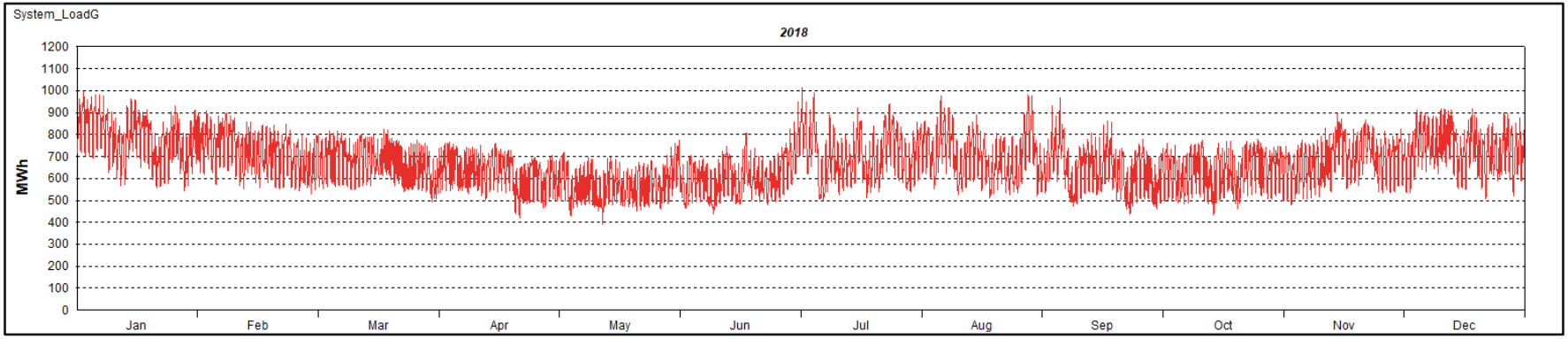
- Renewable Energy Standard (2015)
  - 75% renewable energy by 2032

- Global Warming Solutions Act (GWSA) (2020)
  - Green House Gas (GHG) 25% below 2005 levels by 2025
  - 40 percent below 1990 by 2030
  - 80 percent below 1990 levels by 2050
  - Climate Action Plan (CAP),
    - Provides significant funding for solar, building electrification (heat pumps), EV incentives, and energy efficiency
    - Adopted California zero emissions vehicle standard

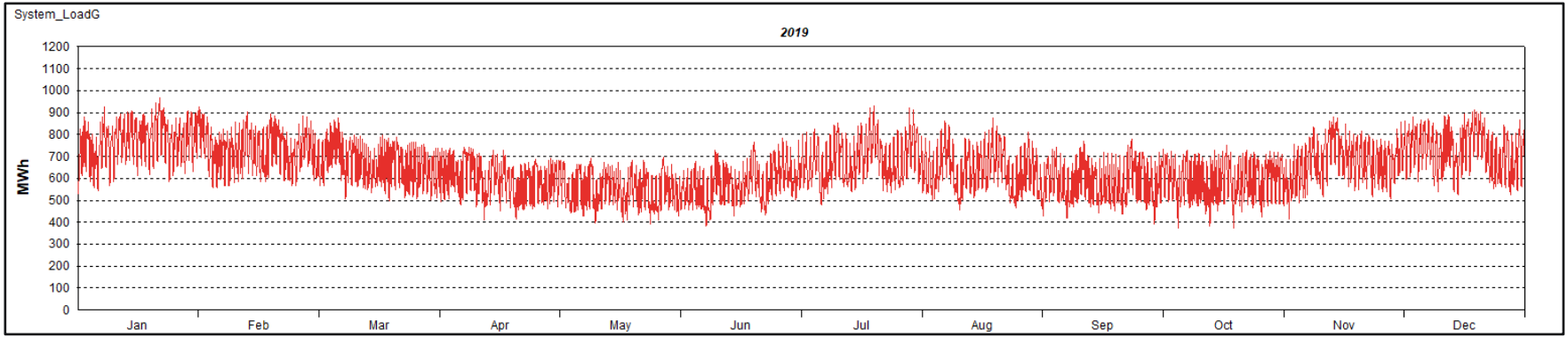
- Affordable Heat Act (2023)
  - Requires fossil fuel providers (heating oil, propane, gas) to offset heating fuel sales with clean heat credits
    - Purchase credits or earn credits by displacing greenhouse gases through weatherization and converting to non-fossil fuel heating options (e.g. heat pumps)

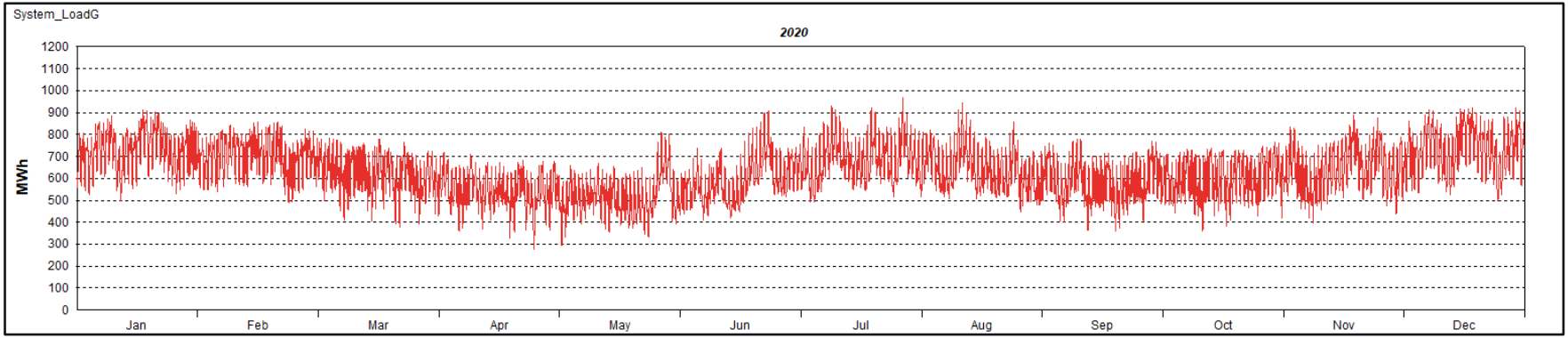
Vermont System Load – 2017 and 2018



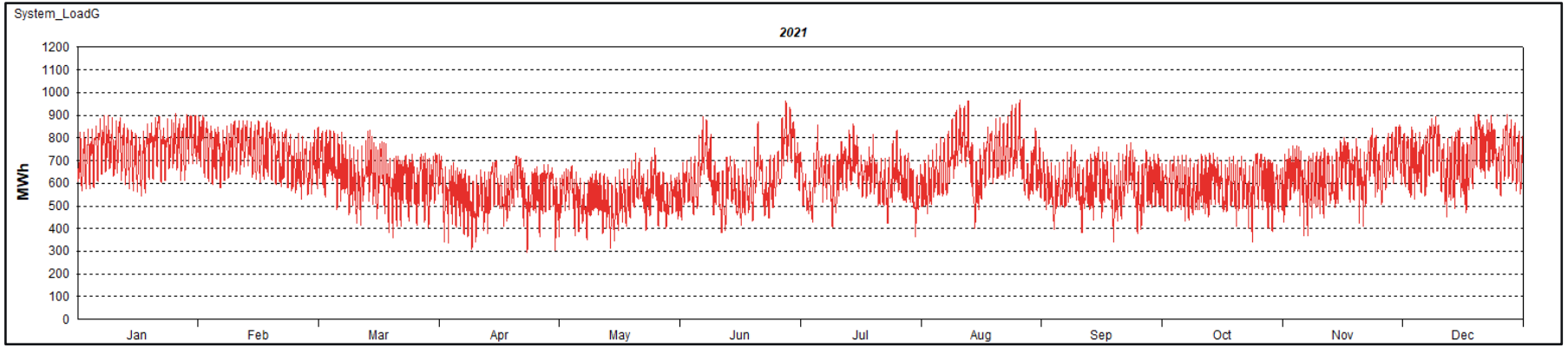


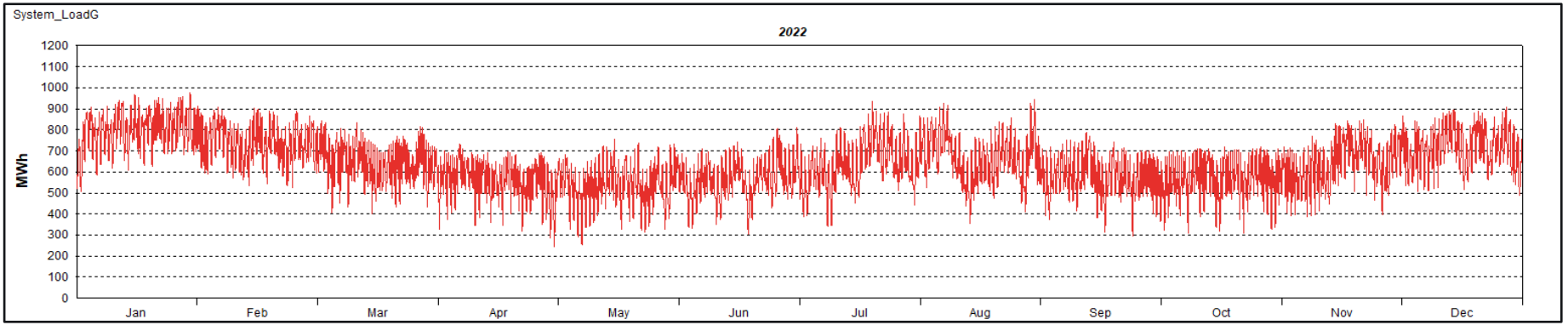
Vermont System Load – 2019 and 2020





Vermont System Load – 2021 and 2022



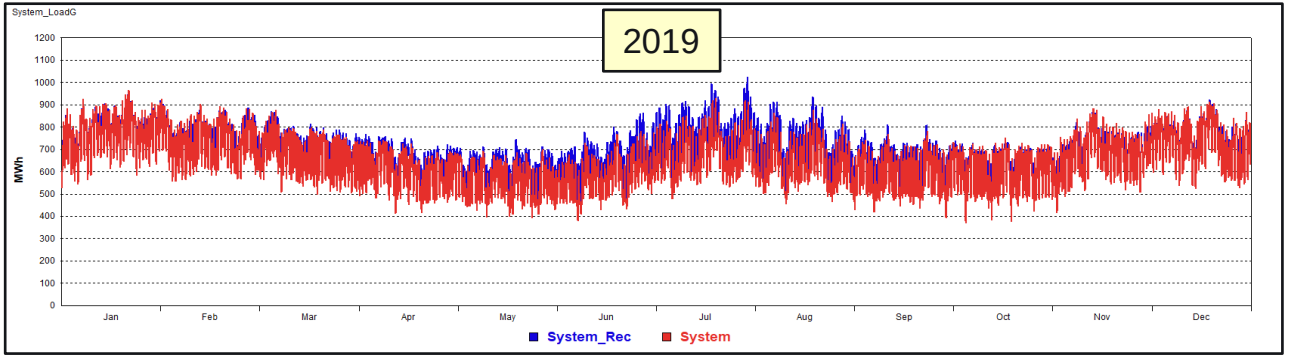


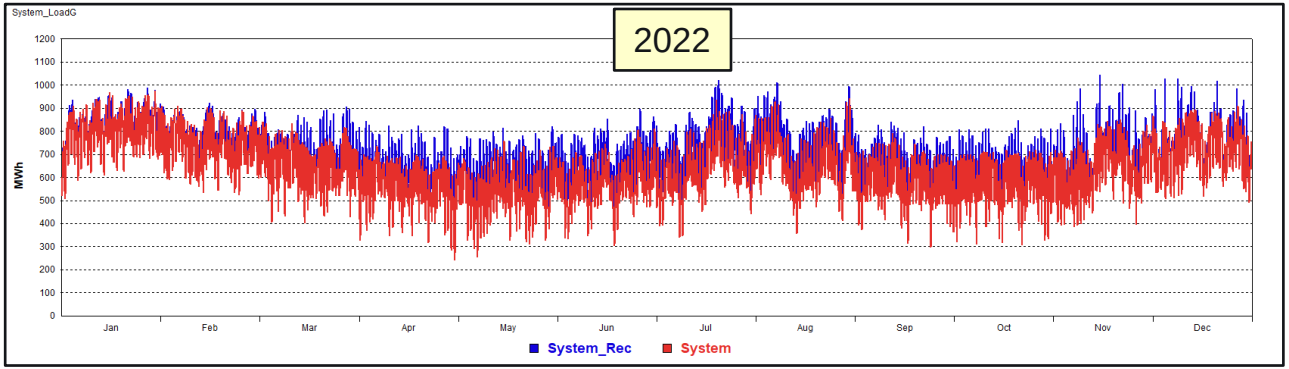
Vermont Load

- Red is what we see and measure
- Blue is what we think is used

- We no longer even know the one thing we could count on – a measure of how much electricity is consumed

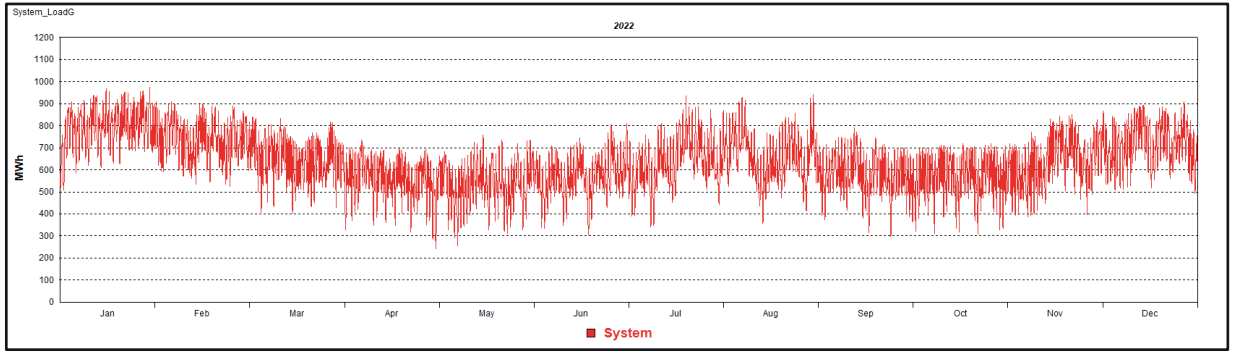
- Even Y isn't known





First step, add back in Solar - Reconstituted Loads (2022)

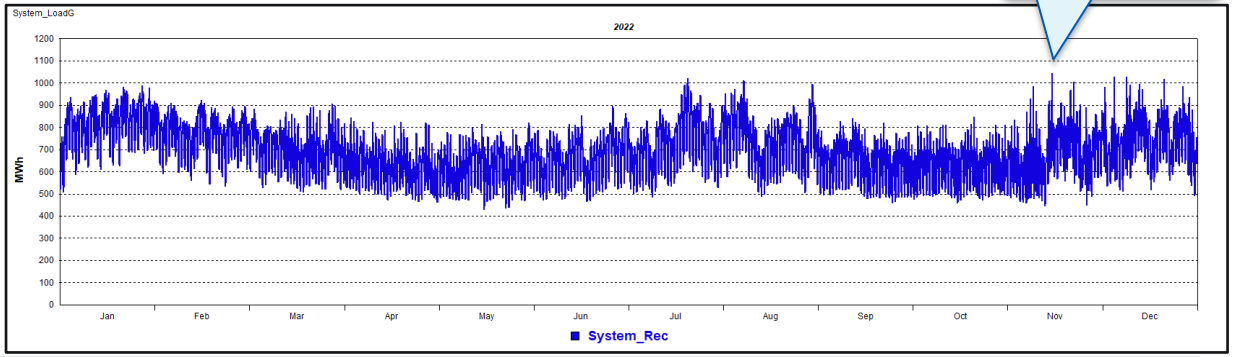
What's Measured



- Working with BTM installed solar capacity and grid-level solar generation profile
- System peaks in November on a 32-degree day

When Reconstituted for Solar

Peaked in November



Peak time shifts

- 2019
  - Measured peak between 6:00 PM and 8:00 PM
  - Reconstituted peak between 1:00 PM and 3:00 PM
  - 2022
  - Measured peak between 6:00 PM and 8:00 PM
  - Reconstituted peak 10:00 AM to 12:00 PM
  - Fall and Spring Reconstituted Peaks
    - 2019: between 5:00 PM and 6:00 PM
    - 2022: between 9:00 AM and 10:00 AM

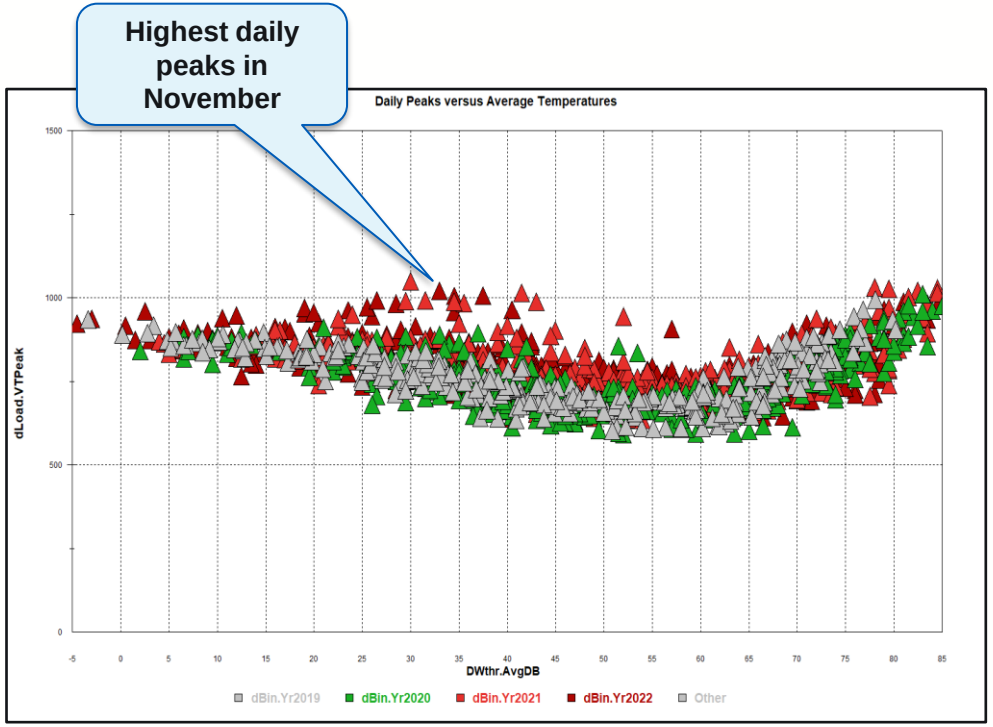
Date	PeakTime	Measured	PeakTimeRec	Reconstituted
Jan-19	1/21/2019 17:00	966.2	1/21/2019 17:00	966.2
Feb-19	2/12/2019 17:00	901.3	2/12/2019 17:00	901.3
Mar-19	3/7/2019 18:00	875.2	3/7/2019 18:00	875.2
Apr-19	4/9/2019 18:00	742.2	4/1/2019 11:00	771.8
May-19	5/28/2019 18:00	697.6	5/20/2019 14:00	743.8
Jun-19	6/27/2019 19:00	781.4	6/28/2019 15:00	863.8
Jul-19	7/20/2019 20:00	928.8	7/30/2019 13:00	1,024.5
Aug-19	8/19/2019 18:00	877.7	8/19/2019 14:00	936.3
Sep-19	9/23/2019 18:00	780.9	9/11/2019 13:00	811.1
Oct-19	10/17/2019 18:00	752.8	10/17/2019 18:00	752.8
Nov-19	11/13/2019 17:00	881.3	11/13/2019 17:00	881.3
Dec-19	12/19/2019 7:00	912.8	12/19/2019 9:00	923.7

Date	PeakTime	Measured	PeakTimeRec	Reconstituted
Jan-22	1/29/2022 17:00	976.0	1/27/2022 10:00	989.0
Feb-22	2/5/2022 18:00	908.7	2/15/2022 9:00	920.6
Mar-22	3/1/2022 18:00	842.3	3/29/2022 10:00	905.4
Apr-22	4/7/2022 19:00	733.9	4/4/2022 9:00	844.1
May-22	5/16/2022 18:00	756.5	5/31/2022 12:00	819.4
Jun-22	6/26/2022 21:00	804.5	6/27/2022 10:00	894.6
Jul-22	7/20/2022 21:00	933.7	7/21/2022 14:00	1,020.4
Aug-22	8/30/2022 18:00	942.6	8/8/2022 11:00	1,009.2
Sep-22	9/12/2022 20:00	789.2	9/12/2022 10:00	841.4
Oct-22	10/26/2022 19:00	717.4	10/21/2022 9:00	845.9
Nov-22	11/21/2022 19:00	848.6	11/15/2022 9:00	1,042.9
Dec-22	12/27/2022 19:00	908.4	12/5/2022 9:00	1,028.6

Not only is solar shifting loads, but so are heat pumps

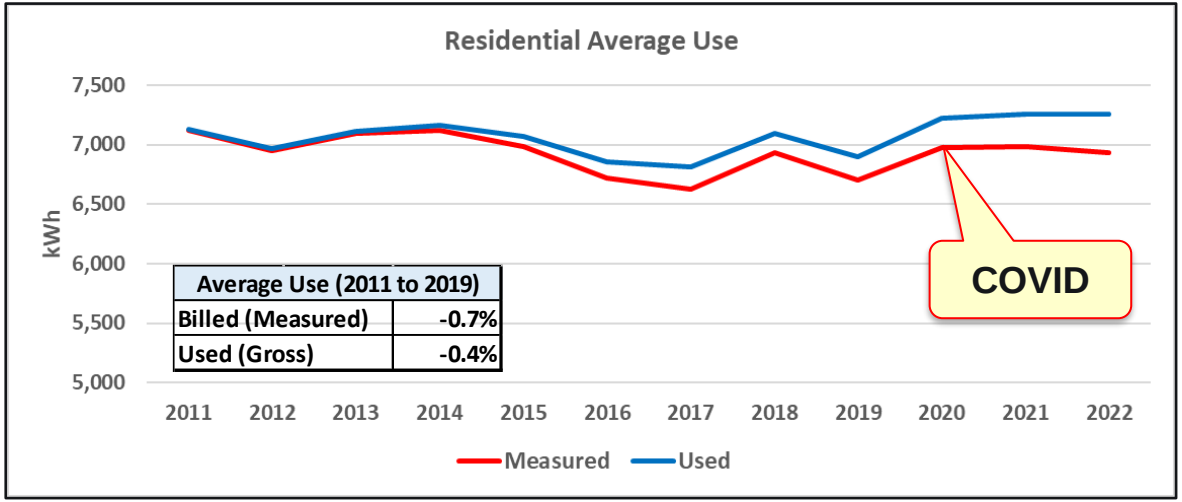
Daily peaks (reconstituted) vs. temperature

- In 2021 and 2022, highest daily peaks in occur in November
  - Daily peaks are consistently higher between 25 and 60 degrees
- The 2021 and 2022 coldest temperature peaks are no higher than prior years
- Indicates how supplemental heat pumps are being used
  - Running through the fall with maximum output
  - Running at a lower rate or not at all on the coldest days
    - The primary heating system is doing all or most of the work
- Does November become the new peak month?



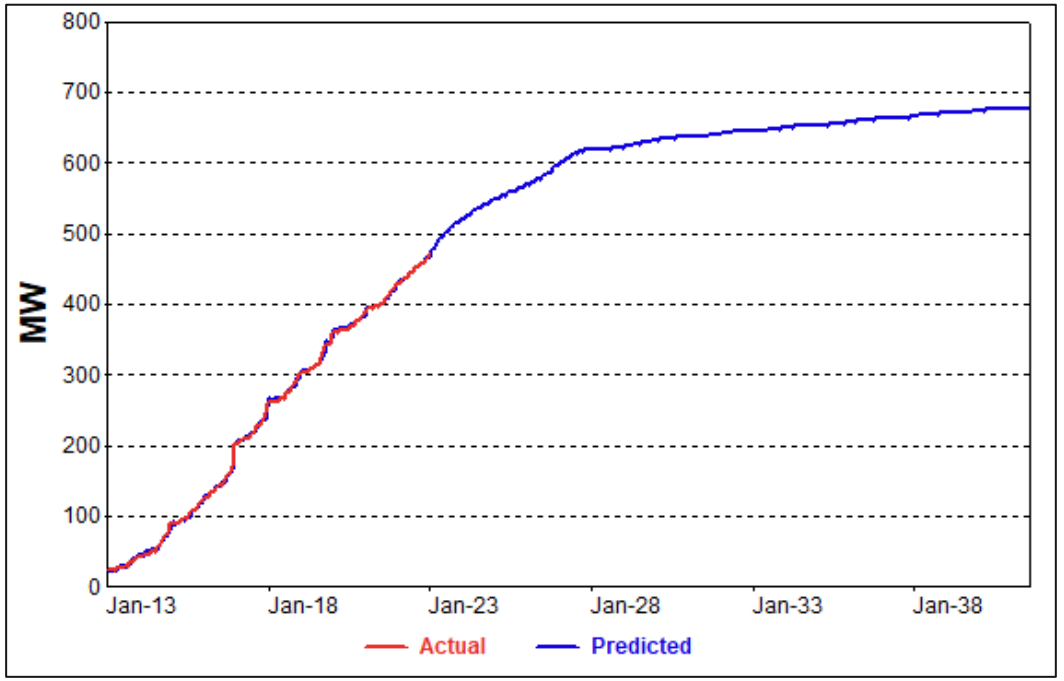
Solar also masks customer use

- Want to forecast energy use. Not just what's purchased (billed sales).
  - Add back in what we think is own-use (vs sold back to the utility). Another estimate of Y.
  - Billed use (prior to COVID) is declining 0.7% per year
    - Efficiency 0.4%
    - Solar 0.3%



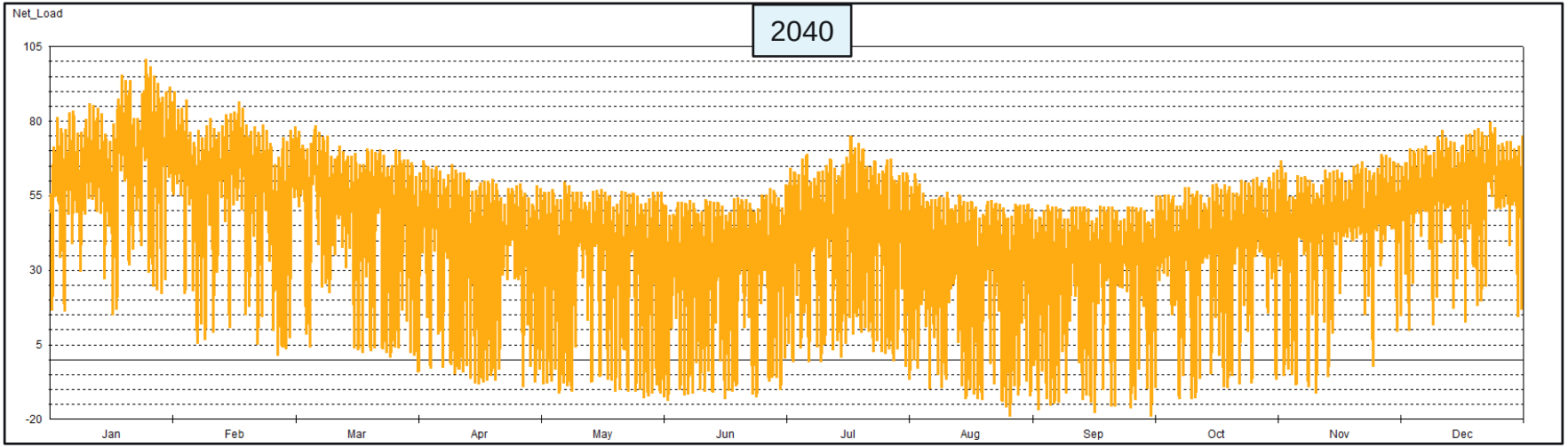
Solar capacity continues to increase

- Inflation Reduction Act extends and increases the federal tax credit from 26% to 30%
- Tax credits plus favorable payment for excess generation translate into continued strong PV adoption
  - Paying average retail rate (16.6 cents per kWh)



Loads at some delivery points go negative

Unless you start capping solar and reducing incentives

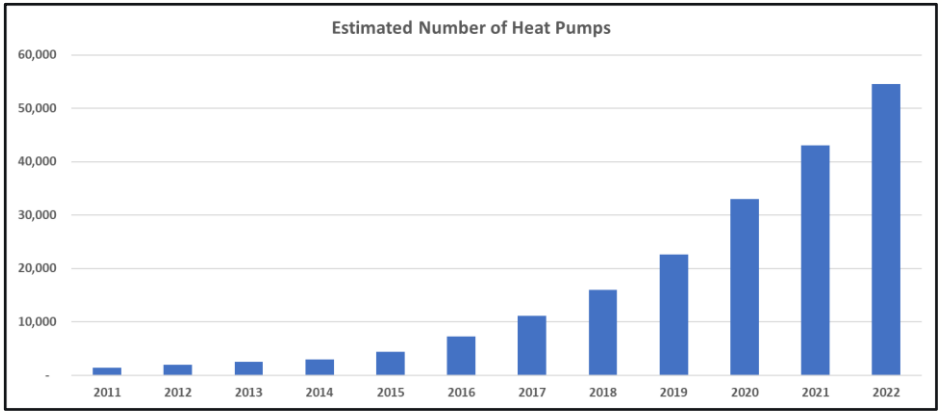


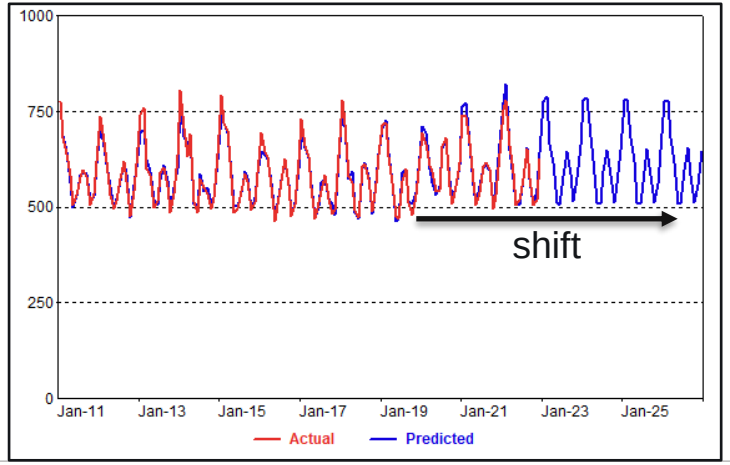
Or start adding battery storage

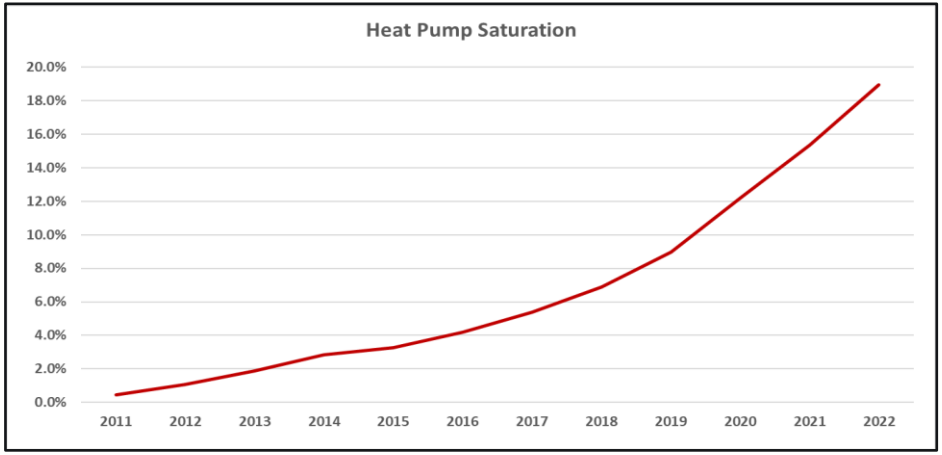
Heat pump adoption masks COVID impacts

» What we thought was all COVID related behavior (elevated residential customer use) is partly masking increases in cold climate heat pump (CCHP) adoption.

- Over 45,000 heat pumps since 2019.
- Saturation increases from 5% to 20%.

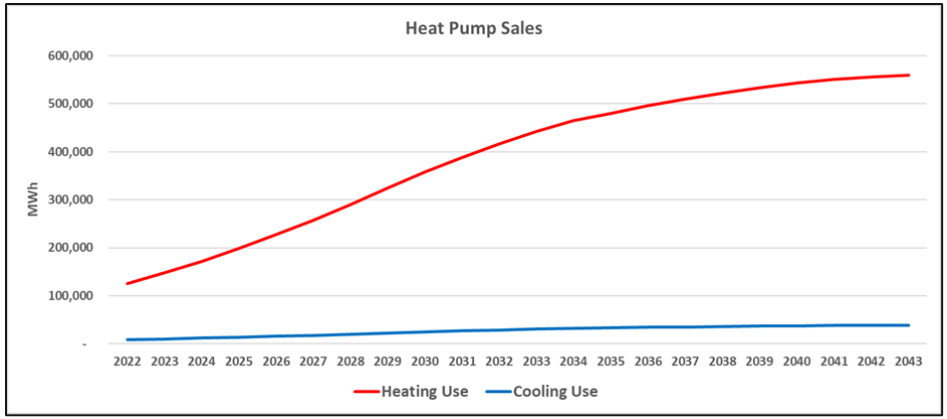


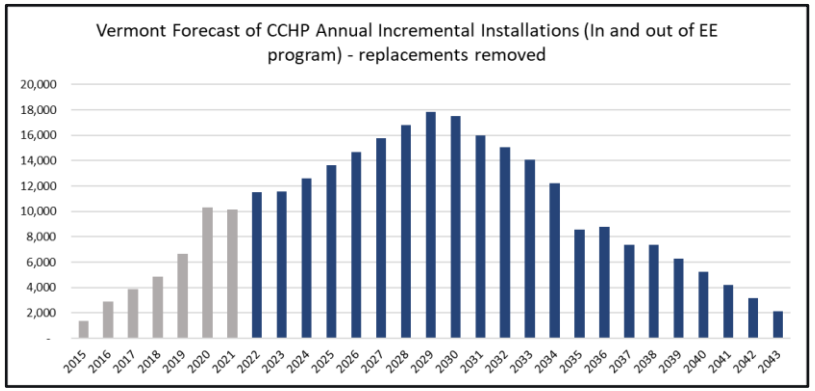


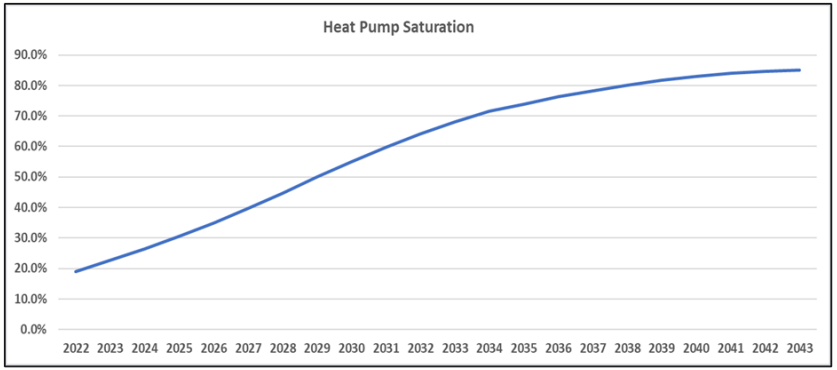


Heat pumps are a key technology to meet CAP

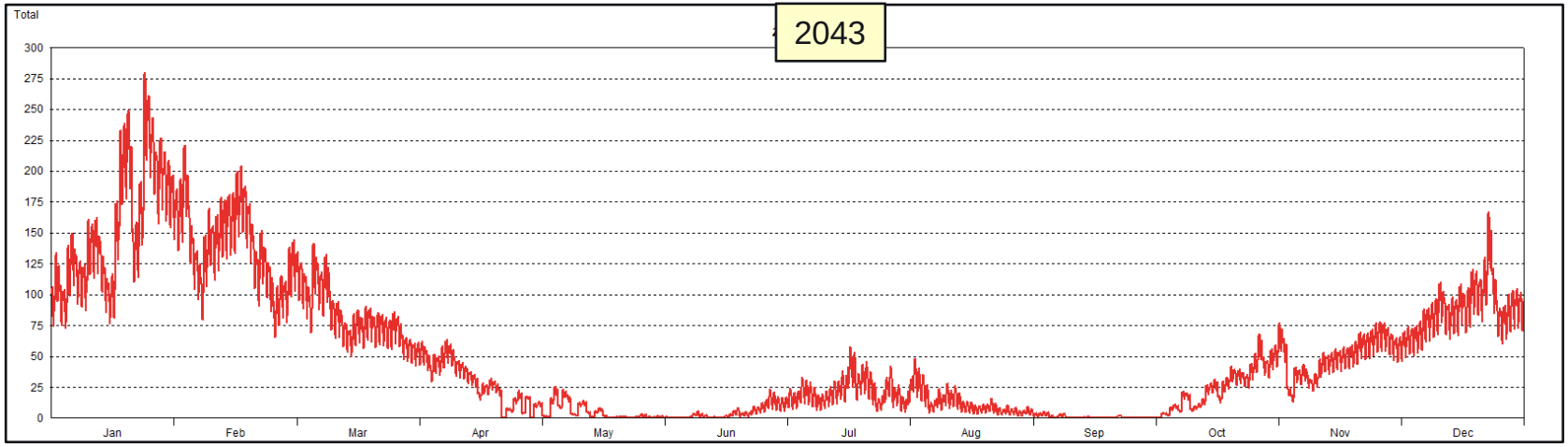
- Currently adding approximately 10,000 units per year – projected to increase to nearly 18,000 per year by 2030.
  - 50% saturation by 2030
  - 85% saturation by 2043
- Primary target: homes heating with oil and propane







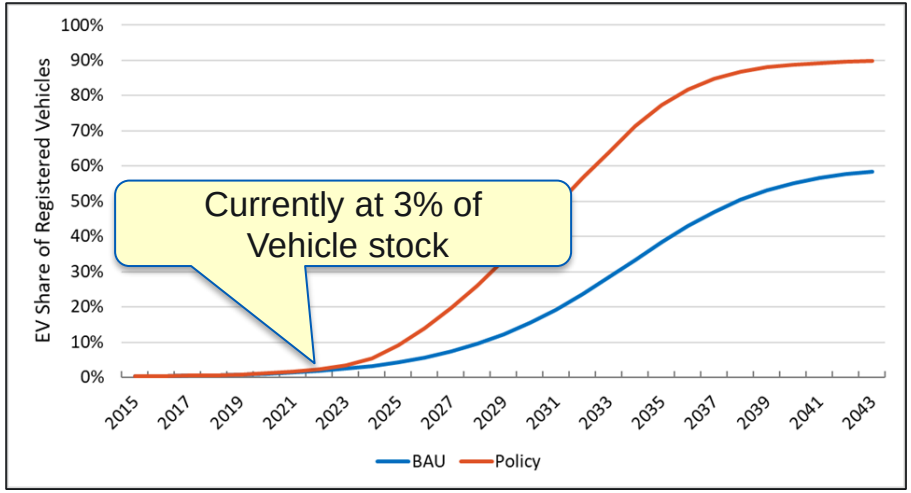
Heat Pump Load Forecast

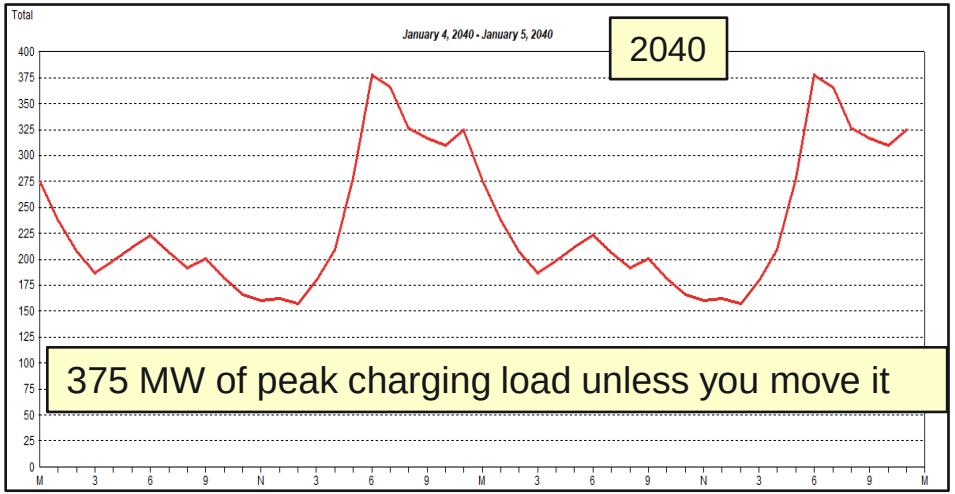


- Combine shapes with energy results in **275 MW peak heat pump load at 7:00 AM**
  - Assuming we get everyone to use their heat pump “correctly”

Aggressive EV Adoption Path

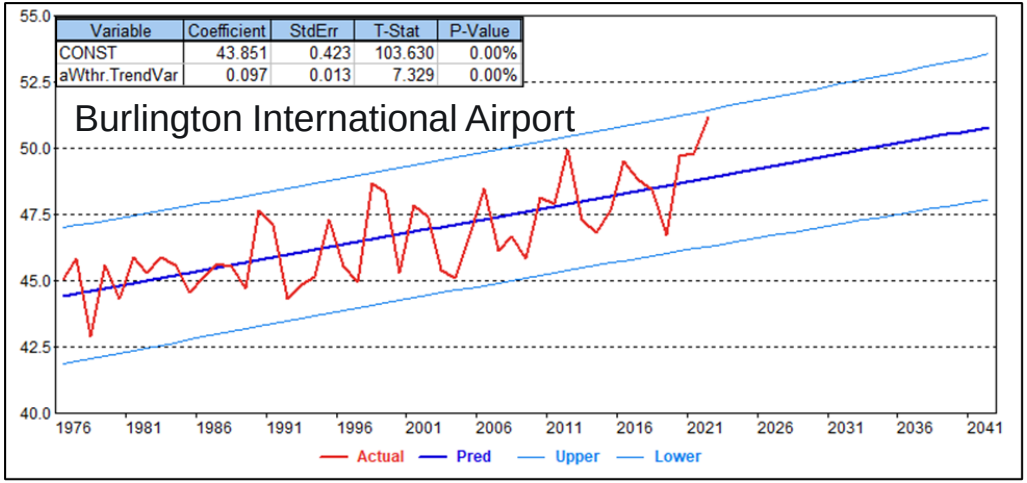
- Vermont has adopted the California Advanced Clean Cars II rule along with New York, New Jersey, Massachusetts, Connecticut, Rhode Island, Oregon, and Washington)
  - Requires zero-emission vehicles to reach 35% of new car sales by 2026, 68% by 2030, and 100% by 2035. 90% EV saturation by 2043.
  - Vehicle incentives extended as part of the Inflation Reduction Act

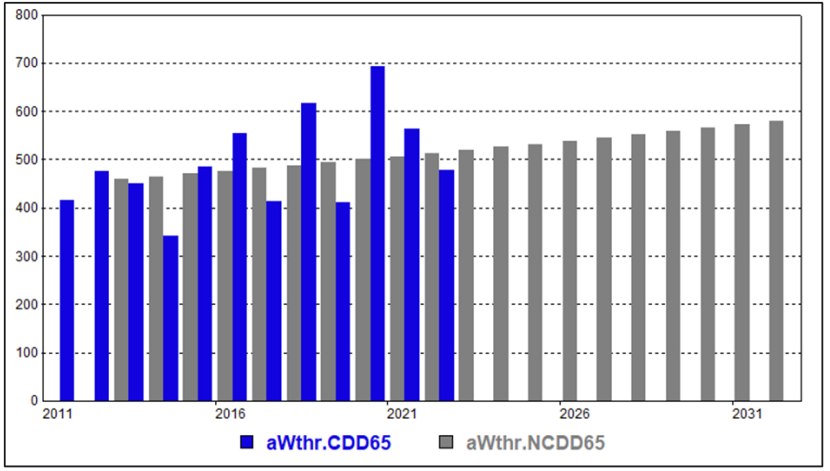


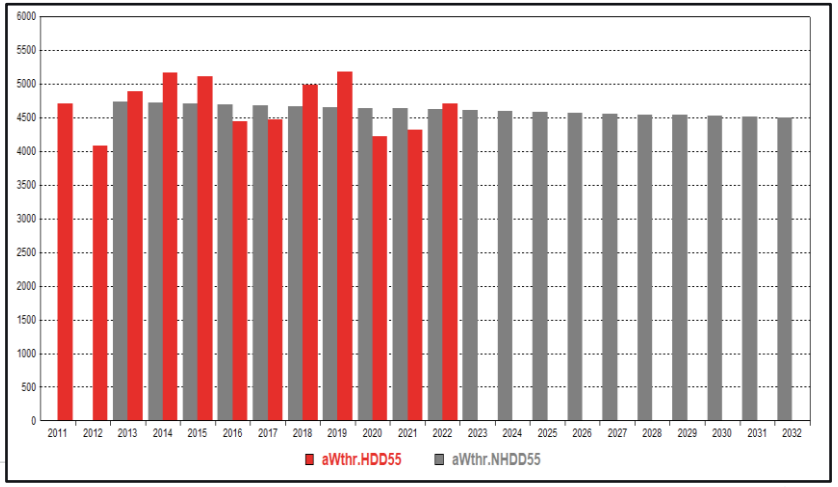


And it's still getting warmer

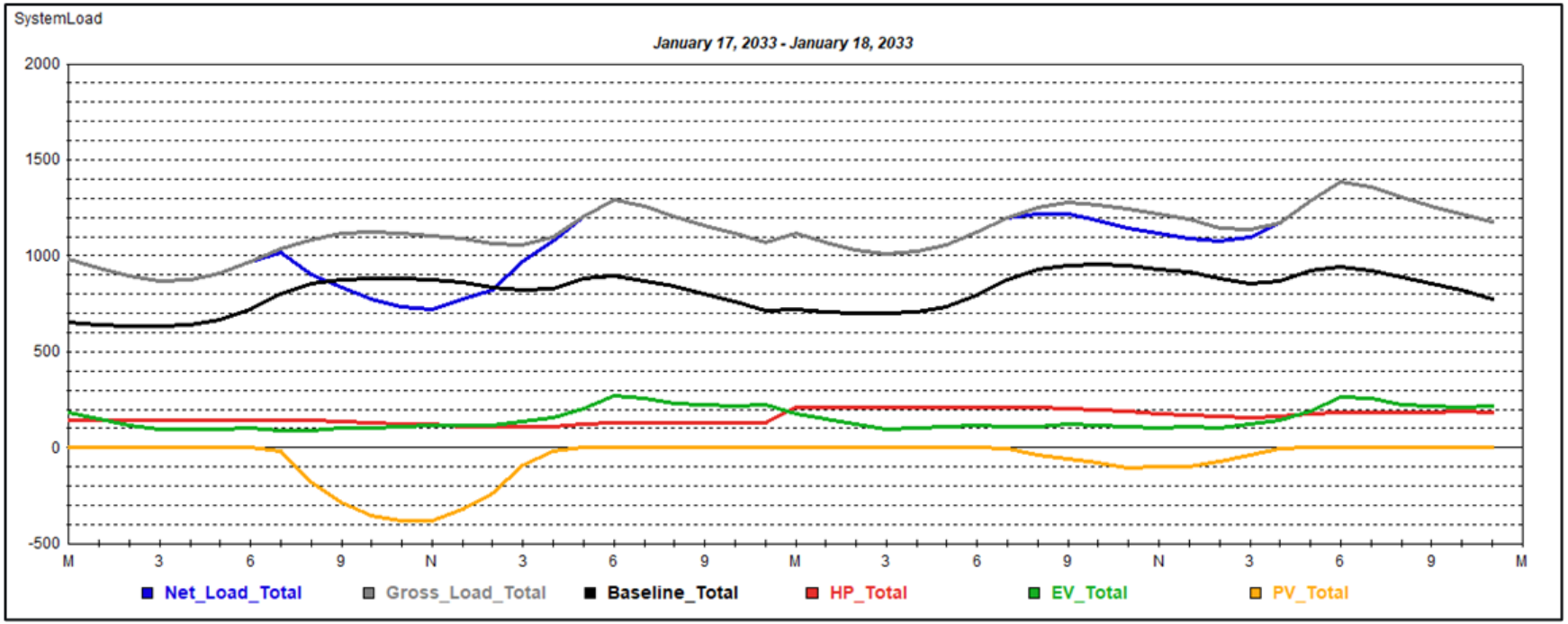
- Average temperature increasing 0.097 degrees per year
  - Nearly 1 degree per decade





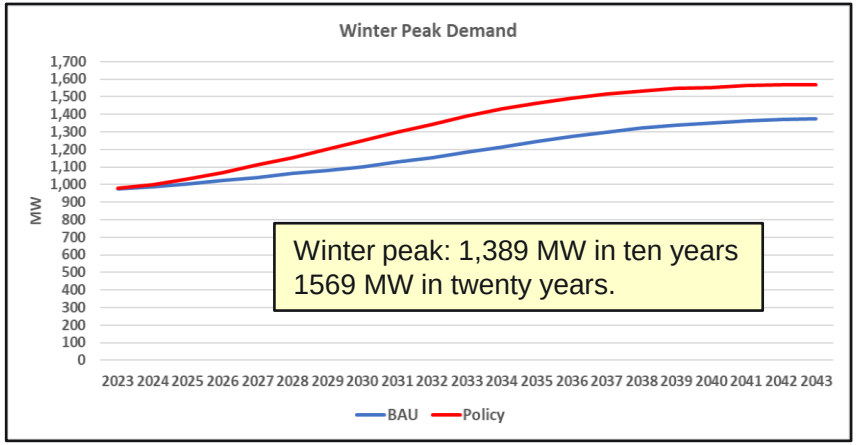


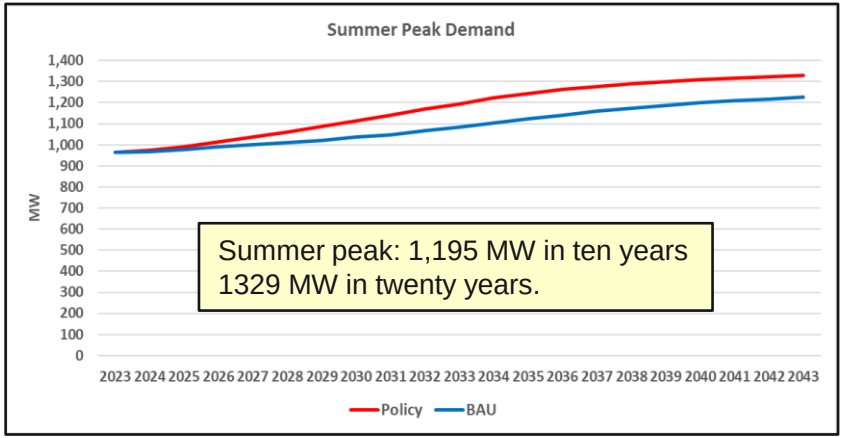
When you put it all together



No idea what the capacity requirements looks like until you add it up

How does this impact demand





Shift from summer to winter peak.
Add 40% load growth in 10 years and 60% in 20 years

- The resource side – now need to manage load growth when there once wasn't any
  - Battery energy storage systems (BESS)
  - EV charging controls and incentive pricing
  - TOU pricing
  - Interruptible load rates and direct load control

How accurate is the forecast?

- Vermont system demand has been increasing less than 0.5% per year over the last ten years
  - Now projecting 3.6% growth over the next ten years

- High level of uncertainty
  - Forecast hinges on significant government action, laws, and incentives
  - People don't always respond like we think they will

- Need to recognize what we have is a scenario. Need to bound with other possibilities.
  - Income constraints: Heat pumps are expensive even with incentives
    - Lower heat pump market penetration
  - EV targets: Need significant investment in charging infrastructure and vehicles with extended driving distance (Vermont is a relatively rural state, long distances to travel)
    - Takes longer to reach 100% saturation

Is Accuracy Even the Right Question ?

The newest unknown – data centers

» Goldman Sachs projects 15% annual data center (DC) load growth through 2030.
  - DC energy requirements increase from 3% to 8% of total U.S. power requirements.

  • AI is fueling demand, requires enormous amounts of power
  • “Training” ChatGPT-3 consumed over 1,287 MWh. With hundreds of millions of daily queries using about as much power as 33,000 households (JLL).

» **In Indiana**
» Meta announced plans to build $800 million, 700,000 sf data center designed to support AI
  - 3 times the power per sqft than traditional data center processing

  • In November 2023, Quantum Corridor a public /private partnership with the state launched first network in North America to achieve a capacity of 40 terabits per second.

The challenge: forecasting data center loads

» Large discrete load additions
  - Data centers (DC) can vary from 20 MW to 500 MW power requirements with 80% plus load factors.

» Will it happen?, tends to be a rather secretive industry, playing off one utility against another
  - Utilities often required to sign NDA
  - Still concentrated: 80% of data center capacity is still being built in Northern Virginia, 90% when you add Phoenix and Seattle.

» How do you forecast discrete loads?
  • Each DC treated as a separate load forecast
    - Probability DC will locate in service area.
    - Probability DC will be permitted and constructed
    - Timing and probability of load addition occurring (transmission capacity and demand).
  • With enough historical load can potentially model at the aggregate level (e.g., Dominion)
    - Would expect an S-shape adoption path

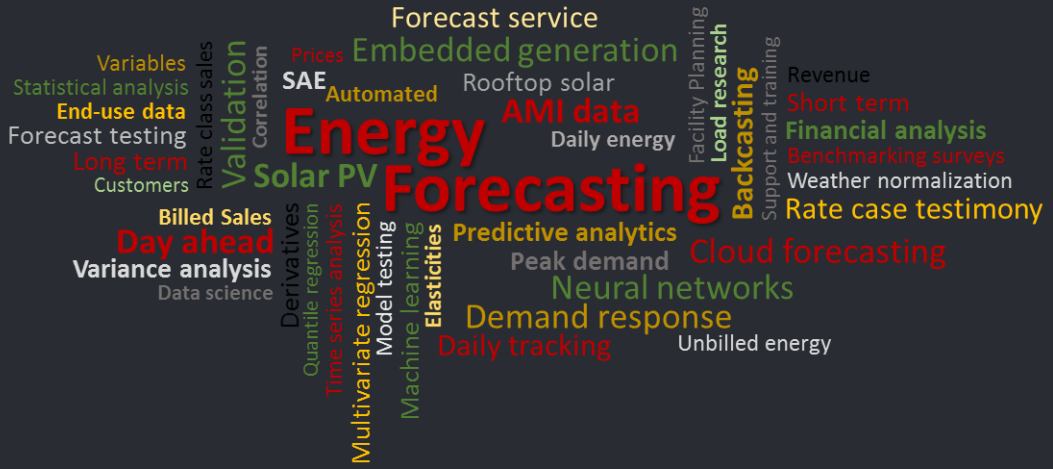
What we can say?

- Forecasting is significantly more complex – need to understand and be able to model the interactions of the factors that drive electricity sales and demand
  - Today's forecast requires and hourly modeling framework and understanding how new technologies work and impact loads
    - Heat pumps
    - EV charging
    - Data centers
    - Solar

- Energy use and loads can be impacted through standards, incentives, and law (we can move the needle)
  - But significant future load-level uncertainties
    - Timing: How quickly can incentives, rebates, and laws impact customer purchases and investments
    - Behavior: People don't always do what we expect

- And even the one thing we knew for sure, measured energy use (the Y), isn't so sure anymore.

Thoughts?



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Thank You

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