To Have Your Cake and Eat It Too: Mitigate Grid Constraints and Reduce Greenhouse Gases with Demand Response

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Agenda

Key research questions

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Secondary research findings

Coal behavior on grid

Oil behavior on grid

Carbon impact analysis methodology

Limitations of MER data

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Key Research Questions

Can demand response (DR) provide benefits for both greenhouse gas emissions and traditional load management?

What are the factors that determine when the grid is most "dirty"/carbon-intensive?

What data sources could be leveraged to obtain necessary information regarding the grid fuel mix and marginal fuel resources?

What strategies for event triggers could satisfy existing load management goals (peak reduction, reliability, etc.) while adding GHG reductions as an additional goal?

What DR technologies and strategies are most conducive to reducing GHG emissions?

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Data Gathering

Marginal Emissions Rate (MER) data

- Source: Third-party company
- Spans Mar '17 thru Jan '21
- Timeseries representing the carbon intensity of the marginal grid resource
- Available by ISO-NE load zone, but most zones similar
- Model-based

ISO-NE Grid Operations data

- Source: ISO-NE API
- Spans Jan '15 thru today (in this analysis)
- Multiple timeseries
  - Fuel mix (MW by type)
  - Marginal fuel type
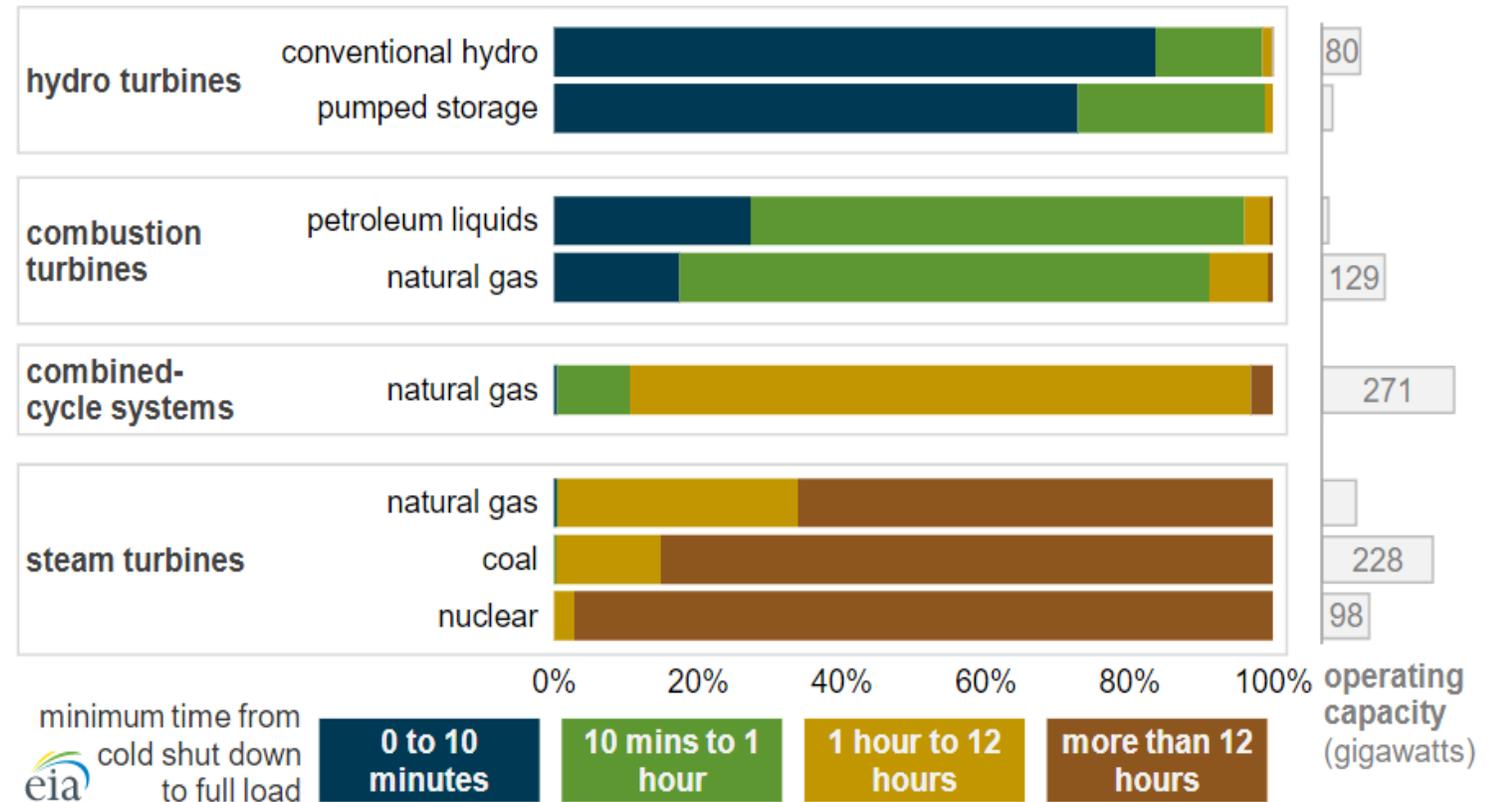 - LMP (real-time and day-ahead)
- Measured

Weather data

- Source: NOAA
- Spans Jan '15 thru today (in this analysis)
- Dry bulb temperature timeseries
- Measured

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Secondary Research Findings

- Most coal-fired power plants generate electricity with steam turbines and take over 12 hours to start up.

- Most oil- and natural gas-fired power plants generate electricity with combustion engines or combined-cycle systems. Most systems reach full operations in one to 12 hours.

- 58% of New England's natural gas capacity has dual-fuel capability, which allows plants to stay operational during cold snaps in the winter.

U.S. electric generating capacity by minimum time from cold shut down to full load (2019)

		operating capacity (gigawatts)
hydro turbines	conventional hydro	80
	pumped storage	
combustion turbines	petroleum liquids	129
	natural gas	
combined-cycle systems	natural gas	271
steam turbines	natural gas	
	coal	228
	nuclear	98

minimum time from cold shut down to full load:
- 0 to 10 minutes
- 10 mins to 1 hour
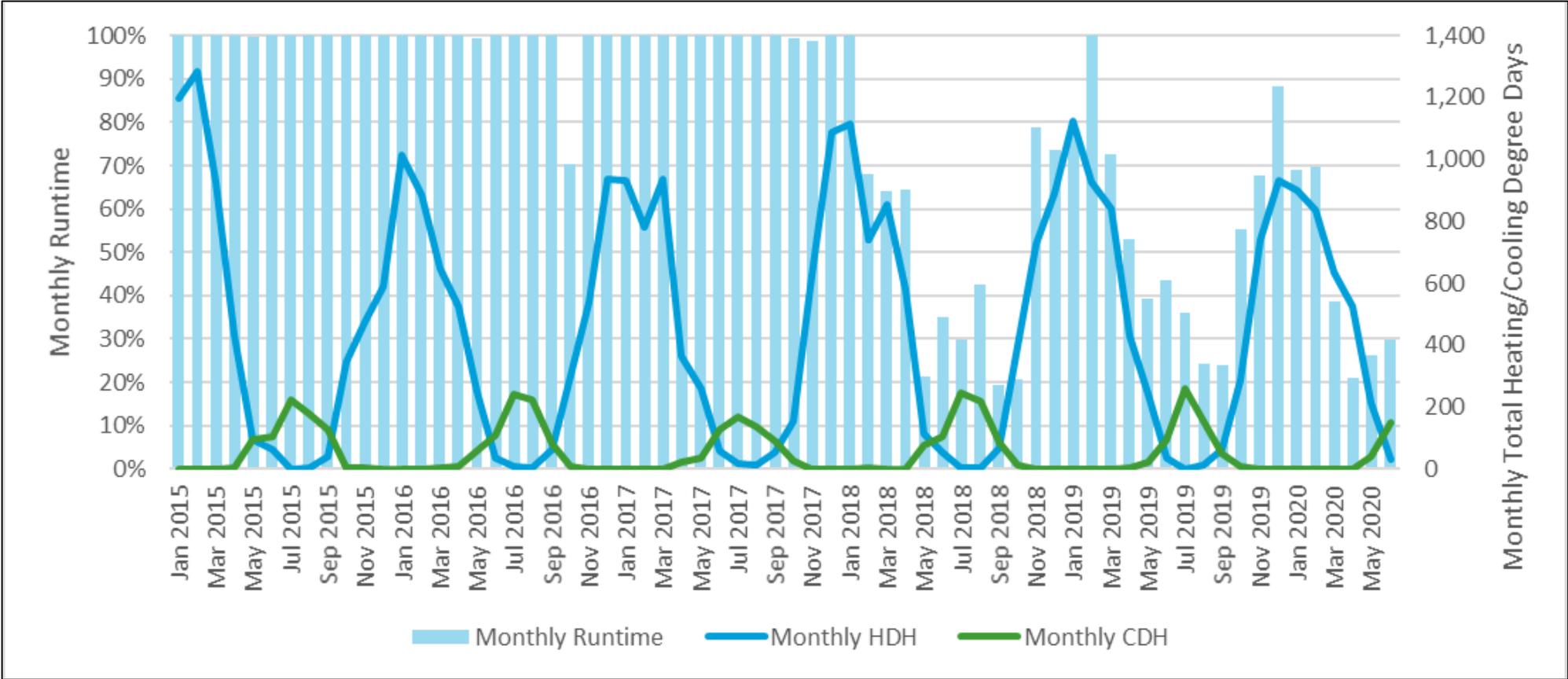- 1 hour to 12 hours
- more than 12 hours

Source: U.S. Energy Information Administration, *Annual Electric Generator Inventory*
Note: Only technology/fuel combinations with at least 10 gigawatts of operating capacity are shown.

Coal Behavior on ISO-NE Grid

- On a monthly basis, what percentage of the month is coal "online"?


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Coal Behavior on ISO-NE Grid

- Coal operation changed in early 2018
  - Ran almost always 2015-2018, became more responsive starting 2018
  - Total winter generation has dropped each year since 2015
  - These suggest a potential market change or the retirement of a key plant

- Coal startups range in duration but are relatively short
  - Average winter duration is 10 hours
  - 95% of coal startups last less than 40 hours
  - 90% of coal starts last less than 19 hours
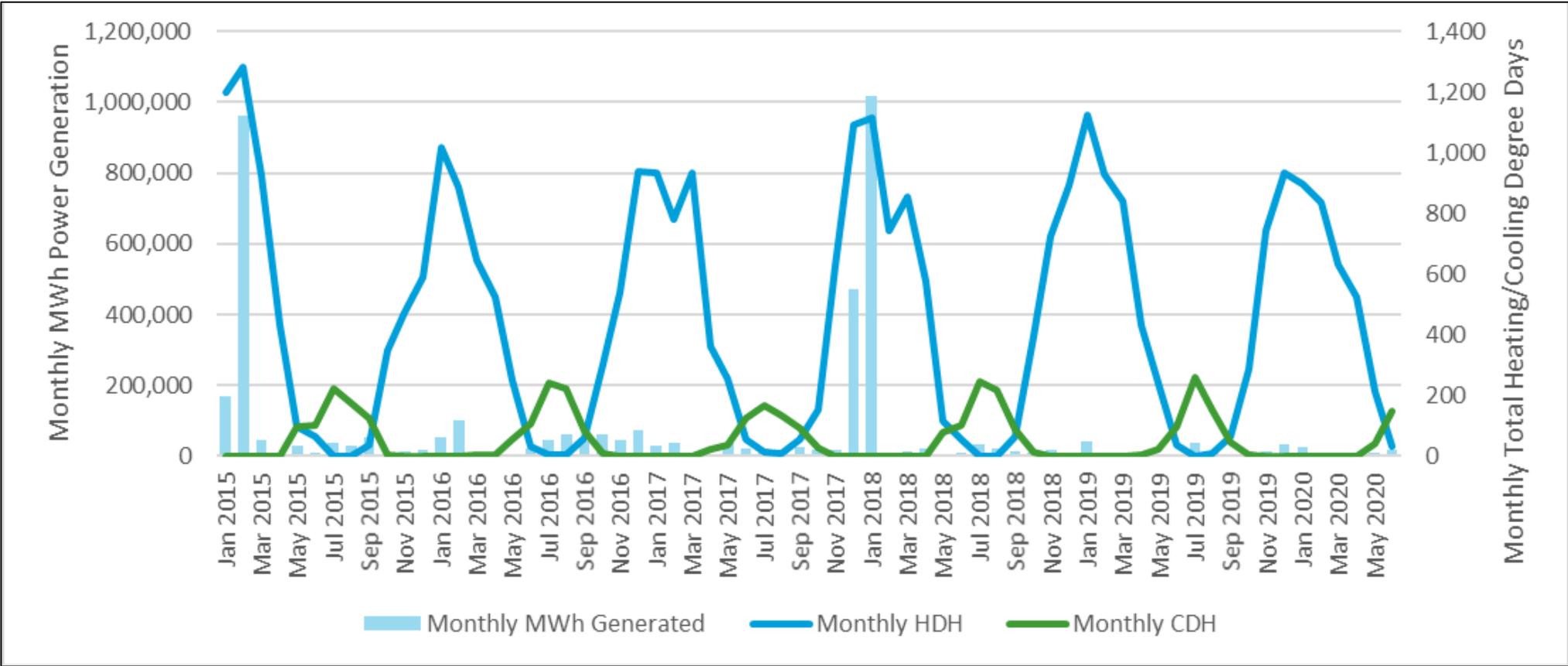
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Oil Behavior on ISO-NE Grid

- On a monthly basis, what percentage of the month is oil "online"?
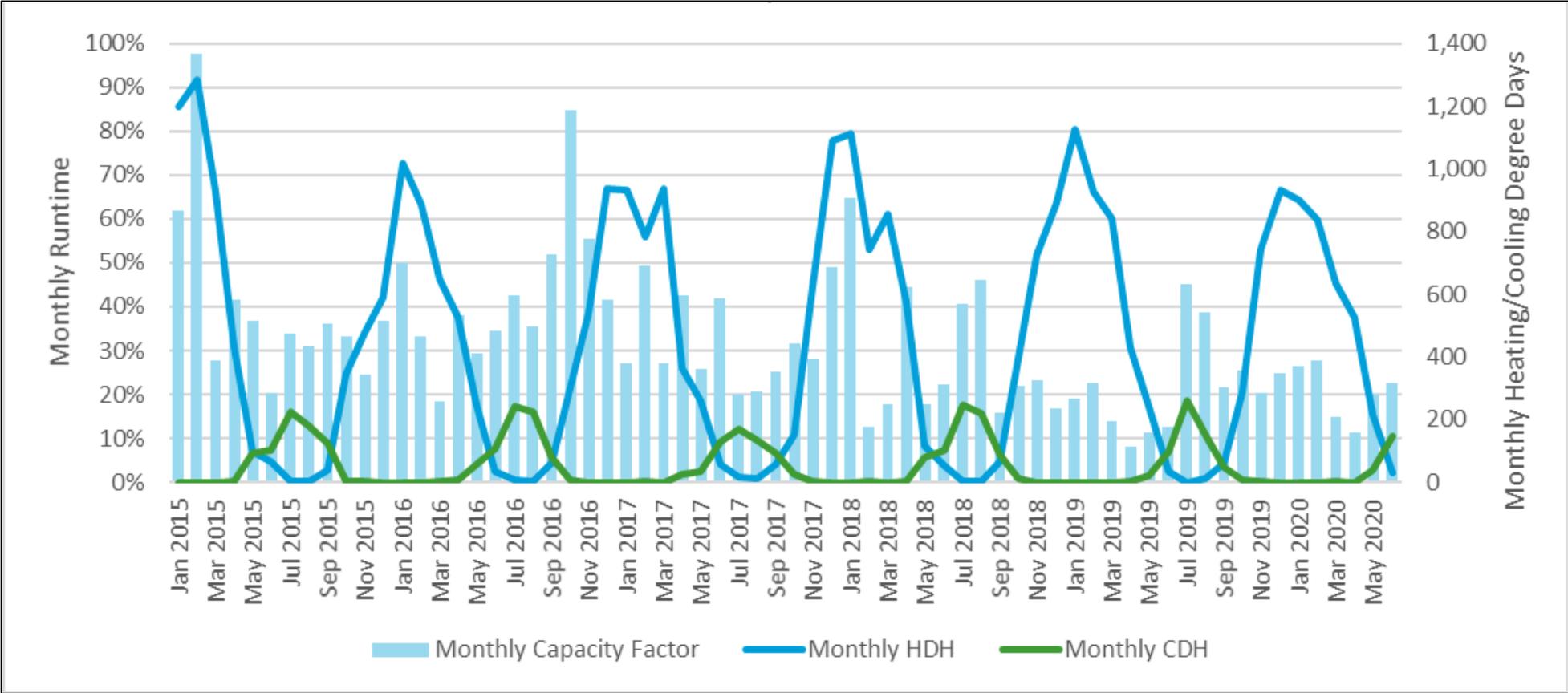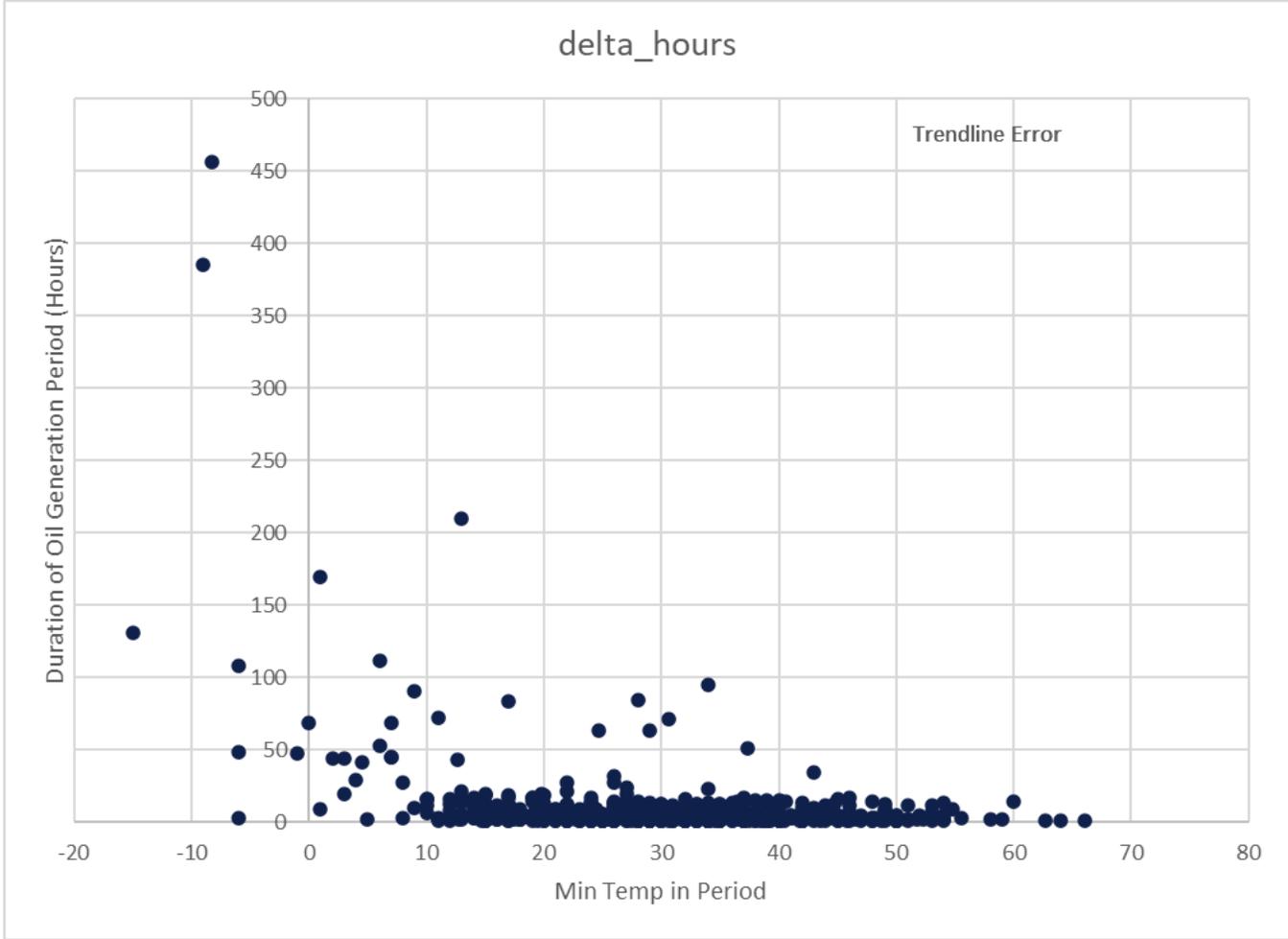
Oil Behavior on ISO-NE Grid

- On a monthly basis, how much energy does oil produce?

Oil Behavior on ISO-NE Grid

- How does the duration of an oil "run" correlate with temperature?

Oil Behavior on ISO-NE Grid

- Oil startups range in duration but are relatively short
  - Average winter duration is 9.25 hours
  - 95% of oil startups last less than 27 hours
  - 90% of oil startups last less than 14 hours

- The relationship between oil startup duration and temperature needs to be explored more deeply
  - 68% of all startups lasting at least 50 hours recorded a minimum temperature below 20 F
  - However, only 10% of startups that recorded a minimum temperature below 20 F lasted at least 50 hours

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Carbon Impact Calculation Methodology

- Use site-level curtailment information to determine if each site is shifting load, shedding load, or using generation to reduce purchased power from the grid during events

- Use site-level kW reductions and site-specific strategy to determine if there are carbon reductions or penalties.

- Based on market research and the ISO NE data analytics findings, determine if the calculated reductions apply only to event hours or have more far-reaching effects.

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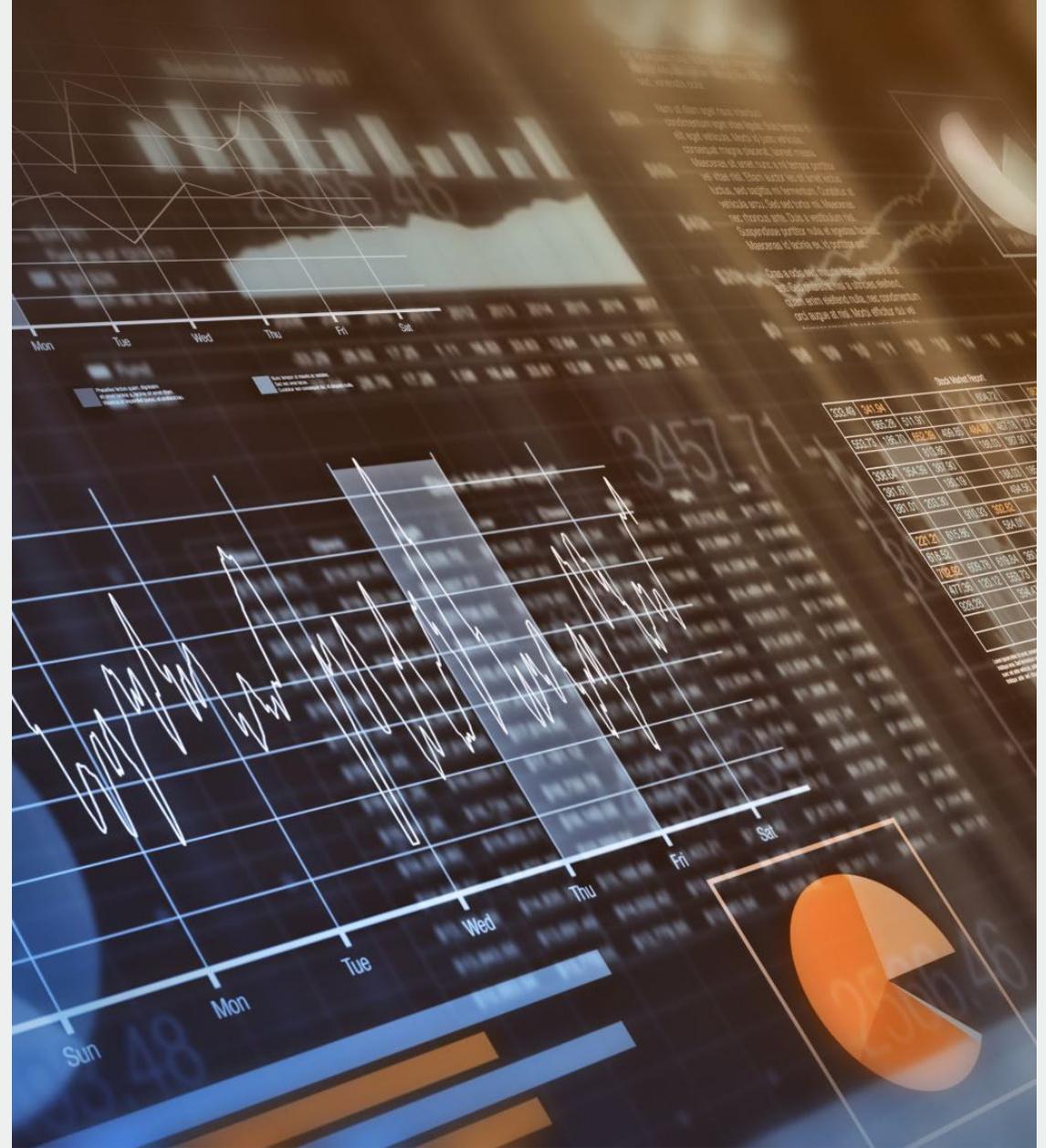
MER Data Analysis and Findings

Key questions to answer:

- How closely does the MER data mirror what we know is happening on the grid (from fuel mix data)?

- Can we use MER data as an accurate proxy for real-time grid carbon intensity?

MER Data Analysis and Findings

Legend: MER — Coal (MW) — Oil (MW) — Dry bulb temp (F)
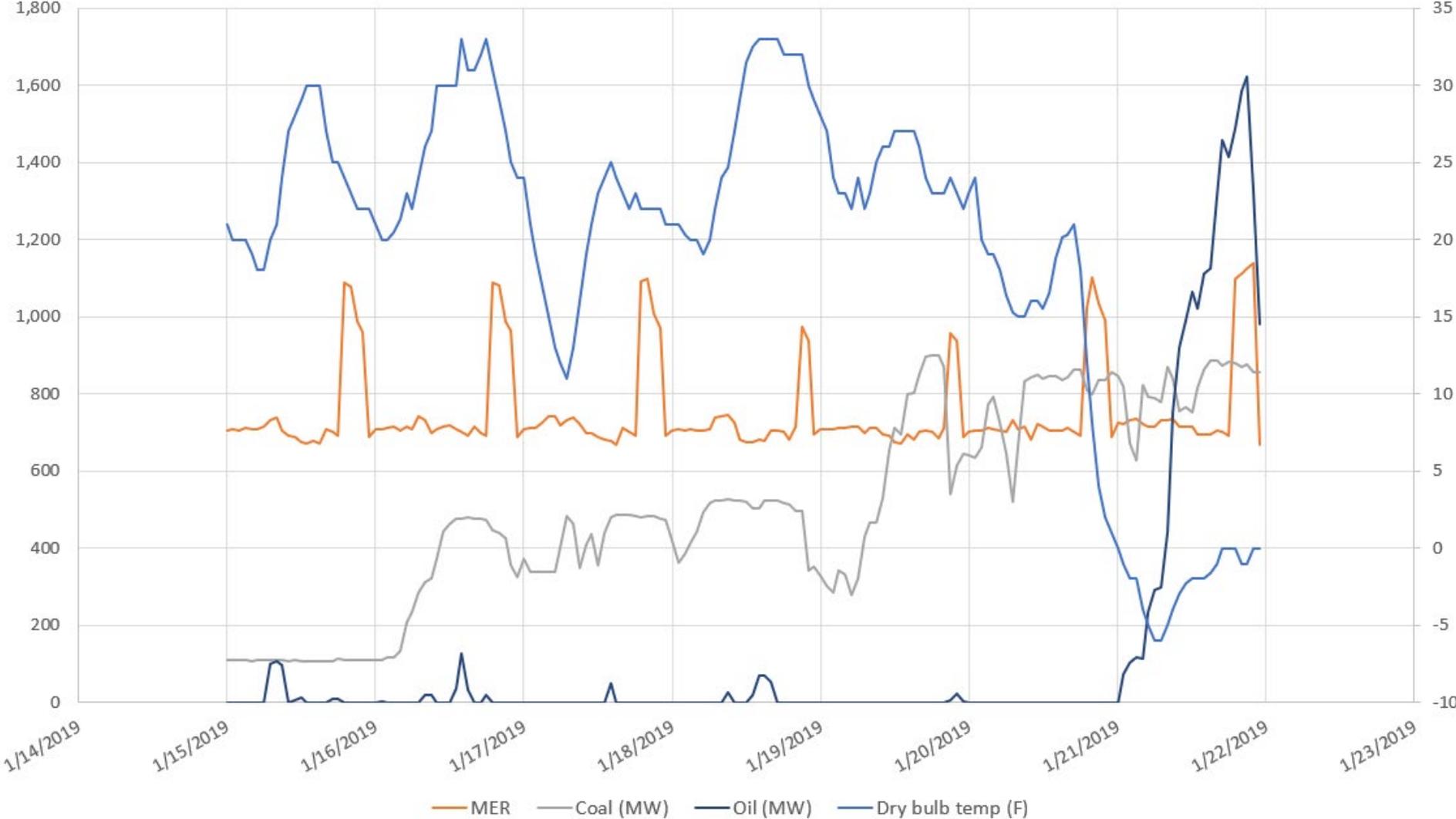
MER Data Findings

- MER data does not closely mirror grid activity during the coldest (or warmest) periods
  - Data is highly-periodic, with spikes occurring around the same time each day
  - Spikes do not align with periods of high coal or oil generation, as we'd expect
  - As a model-based data set, MERs don't yet accurately reflect grid carbon intensity during extreme weather events—there are just fewer of those periods to train the model!
- For the purposes of this research, model-based MER data is not an accurate carbon signal that can be used to measure program impacts.

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ISO-NE Marginal Data Analysis

- Hypothesis: If the marginal resource is the one that would decrease output during a demand response event...then we need to know:
  - When is the marginal resource "dirtiest?"
  - What other predictors are associated with those events?

- Key questions to answer:
  - How does the marginal grid resource change by TOD and temperature?
  - When the grid is "dirtiest," which fuel is on the margin?
  - *Fill in this sentence:* The grid is "dirtiest" when _____ fuel is on the margin, which typically aligns with _____ conditions (cold temperatures, high LMPs, high total grid MW, etc.).

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ISO-NE Marginal Data Analysis: Our Approach

- Quantify the percentage of hours that various fuel types were "on the margin" (per ISO-NE data) during cold-temp periods

- Focused on coal, oil, and natural gas

- Accounted for time-of-day (TOD) and temperature effects by:
  - Conducting hourly analysis
  - Iterating through successively colder temperature bins to highlight trends

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ISO-NE Marginal Data Analysis: Results

Coal

	<= 30 F	<= 25 F	<= 20 F	<= 15 F	<= 10 F	<= 5 F	<= 0 F
0	6.1%	7.1%	7.5%	6.7%	3.6%	4.1%	2.3%
1	5.8%	7.0%	7.5%	5.3%	4.5%	3.3%	3.1%
2	6.3%	7.7%	8.0%	6.5%	4.1%	4.3%	6.3%
3	6.4%	8.4%	7.8%	6.6%	5.2%	4.4%	5.1%
4	5.4%	7.1%	6.8%	6.9%	6.2%	5.5%	4.6%
5	4.6%	5.7%	5.5%	3.8%	3.4%	3.3%	2.6%
6	4.6%	5.5%	5.8%	5.1%	3.7%	2.0%	3.5%
7	4.1%	4.5%	4.2%	3.9%	3.8%	2.0%	2.2%
8	4.4%	4.9%	4.5%	3.2%	2.3%	0.9%	0.0%
9	4.4%	5.1%	4.6%	2.8%	2.1%	1.3%	4.3%
10	5.3%	5.9%	4.4%	1.1%	1.4%	2.9%	11.5%
11	5.2%	5.2%	4.4%	2.4%	0.6%	1.3%	5.0%
12	5.7%	6.2%	4.1%	2.0%	0.8%	1.5%	0.0%
13	6.1%	5.1%	4.0%	1.9%	0.8%	0.0%	0.0%
14	4.8%	4.8%	4.0%	4.5%	3.4%	0.0%	0.0%
15	5.6%	5.7%	4.3%	3.8%	5.4%	5.6%	0.0%
16	3.6%	3.2%	3.1%	2.2%	2.8%	2.4%	0.0%
17	3.3%	2.7%	2.4%	1.4%	1.6%	1.6%	5.3%
18	4.6%	4.9%	3.9%	2.5%	3.6%	7.5%	18.2%
19	4.5%	4.6%	4.8%	3.9%	3.8%	5.7%	25.9%
20	4.6%	4.9%	6.0%	4.1%	2.8%	2.7%	3.6%
21	4.9%	5.4%	5.5%	4.9%	5.1%	6.0%	6.3%
22	6.2%	6.9%	7.7%	7.5%	6.8%	4.7%	7.5%
23	6.7%	7.7%	8.3%	8.2%	6.6%	7.1%	4.3%

Temp ↓ Marginality ↓

Oil

	<= 30 F	<= 25 F	<= 20 F	<= 15 F	<= 10 F	<= 5 F	<= 0 F
0	4.3%	6.4%	8.5%	13.1%	17.6%	21.5%	27.7%
1	4.0%	6.1%	8.7%	13.5%	18.8%	22.1%	28.6%
2	3.9%	6.1%	8.8%	13.4%	20.4%	24.4%	34.7%
3	4.0%	6.4%	8.8%	12.3%	20.0%	24.7%	36.4%
4	3.7%	5.8%	8.1%	11.6%	19.4%	23.3%	27.5%
5	3.9%	6.0%	8.5%	12.3%	17.8%	21.7%	30.3%
6	3.2%	4.8%	6.5%	9.4%	12.3%	15.8%	18.6%
7	4.4%	6.3%	8.8%	12.7%	13.1%	17.7%	19.4%
8	4.0%	6.0%	8.6%	11.0%	14.8%	15.2%	16.4%
9	5.3%	8.3%	10.9%	16.8%	16.9%	17.6%	6.4%
10	5.9%	8.8%	12.7%	19.1%	20.1%	19.4%	7.7%
11	6.2%	8.8%	13.0%	16.1%	21.5%	13.3%	20.0%
12	7.0%	10.1%	15.3%	21.4%	21.2%	16.7%	33.3%
13	8.5%	12.1%	15.0%	16.2%	20.0%	15.9%	17.6%
14	9.6%	14.3%	18.5%	26.1%	26.2%	24.0%	14.3%
15	8.2%	12.2%	16.8%	22.6%	25.0%	22.5%	7.7%
16	6.6%	10.3%	14.6%	19.4%	25.4%	22.4%	26.3%
17	6.3%	8.0%	11.7%	12.9%	14.6%	14.4%	18.4%
18	6.0%	8.0%	10.5%	13.8%	17.4%	9.7%	0.0%
19	4.9%	6.8%	9.7%	13.7%	17.1%	19.5%	22.2%
20	5.1%	7.5%	10.7%	16.2%	19.4%	22.4%	25.5%
21	4.3%	6.6%	10.5%	14.7%	16.9%	22.3%	25.0%
22	4.5%	6.5%	10.2%	15.5%	15.8%	19.0%	20.6%
23	4.7%	6.7%	10.0%	16.2%	17.7%	21.8%	29.6%

Temp ↓ Marginality ↑

Natural Gas

	<= 30 F	<= 25 F	<= 20 F	<= 15 F	<= 10 F	<= 5 F	<= 0 F
0	62.6%	57.7%	53.4%	46.9%	39.9%	35.6%	34.6%
1	63.5%	59.0%	54.3%	51.2%	45.4%	39.6%	41.8%
2	62.9%	57.7%	54.5%	48.3%	43.5%	32.5%	24.2%
3	62.2%	57.4%	54.5%	50.4%	43.3%	37.4%	35.4%
4	63.7%	58.9%	55.8%	51.6%	41.3%	35.6%	45.0%
5	63.3%	59.2%	56.0%	52.5%	45.9%	40.1%	42.8%
6	61.5%	58.9%	56.3%	53.4%	49.3%	44.3%	41.9%
7	61.9%	59.5%	55.4%	49.4%	46.0%	39.6%	36.7%
8	66.5%	62.5%	58.8%	54.9%	48.1%	40.3%	38.8%
9	65.3%	61.5%	56.1%	48.2%	41.7%	39.6%	51.1%
10	66.2%	64.4%	58.5%	48.8%	39.3%	35.9%	42.3%
11	66.7%	64.0%	57.7%	49.9%	42.9%	44.9%	35.0%
12	66.1%	62.6%	56.7%	46.3%	40.9%	40.9%	20.8%
13	63.9%	61.1%	56.4%	48.9%	40.0%	52.3%	41.2%
14	64.7%	59.0%	53.2%	40.2%	35.9%	30.0%	33.3%
15	66.1%	62.3%	56.5%	45.2%	31.3%	28.2%	46.2%
16	64.0%	61.3%	53.6%	48.8%	37.3%	25.9%	36.8%
17	59.5%	58.4%	53.5%	48.3%	41.6%	35.2%	44.7%
18	59.3%	57.5%	54.3%	48.0%	42.5%	41.9%	59.1%
19	63.8%	61.8%	59.3%	50.1%	44.8%	35.8%	33.3%
20	65.1%	60.7%	57.4%	50.3%	46.3%	38.1%	38.2%
21	67.1%	61.7%	59.2%	51.7%	44.7%	37.5%	36.3%
22	64.6%	59.3%	57.8%	49.7%	43.4%	43.1%	44.9%
23	60.9%	56.1%	52.5%	45.7%	42.7%	34.6%	36.5%

Temp ↓ Marginality ↓

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2020/2021 Season Event Hour Carbon Intensity by Marginal Fuel

Hour ending	Hydro	Natural Gas	Wind	Oil	Wood	Marginal Emissions Rate (MER) MT CO_2/MWh
17	0%	87%	10%	2%	2%	0.4008
18	14%	70%	16%	0%	0%	0.2996
19	3%	86%	10%	0%	0%	0.3711
Fuel Emissions rates (MT CO_2/MWh)	0.0	0.43	0.0	1.49	0.0	N/A

2020/2021 Season Carbon Impact By Technology

Hour ending	Battery Reduction	Interruptible Reduction	Interruptible - Generators			Total
			Reduction	Increase	Net	
17	0.55	6.25	0.84	-1.23	-0.39	6.40
18	0.48	4.87	0.64	-1.25	-0.61	4.74
19	0.58	4.47	0.78	-1.23	-0.45	4.61
Total	1.61	15.59	2.25	-3.71	-1.45	15.75

Key Takeaways

58% of New England's natural gas plants have dual-fuel capability, which allows plants to stay operational using oil during cold snaps in the winter. As the OAT drops, oil becomes more marginal, while natural gas becomes less marginal.

For the purposes of this research, model-based MER data is not an accurate carbon signal that can be used to measure program impacts.

The study found that battery storage and curtailment participants can successfully reduce grid demand and GHG emissions. However, participants using diesel generators in their reduction strategies could increase emissions.

With careful program design considerations related to dispatch strategy and technologies, it is feasible to achieve GHG reduction goals alongside traditional load management objectives.

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Questions?

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