2023 ISO-NE Electric Generator Air Emissions Results

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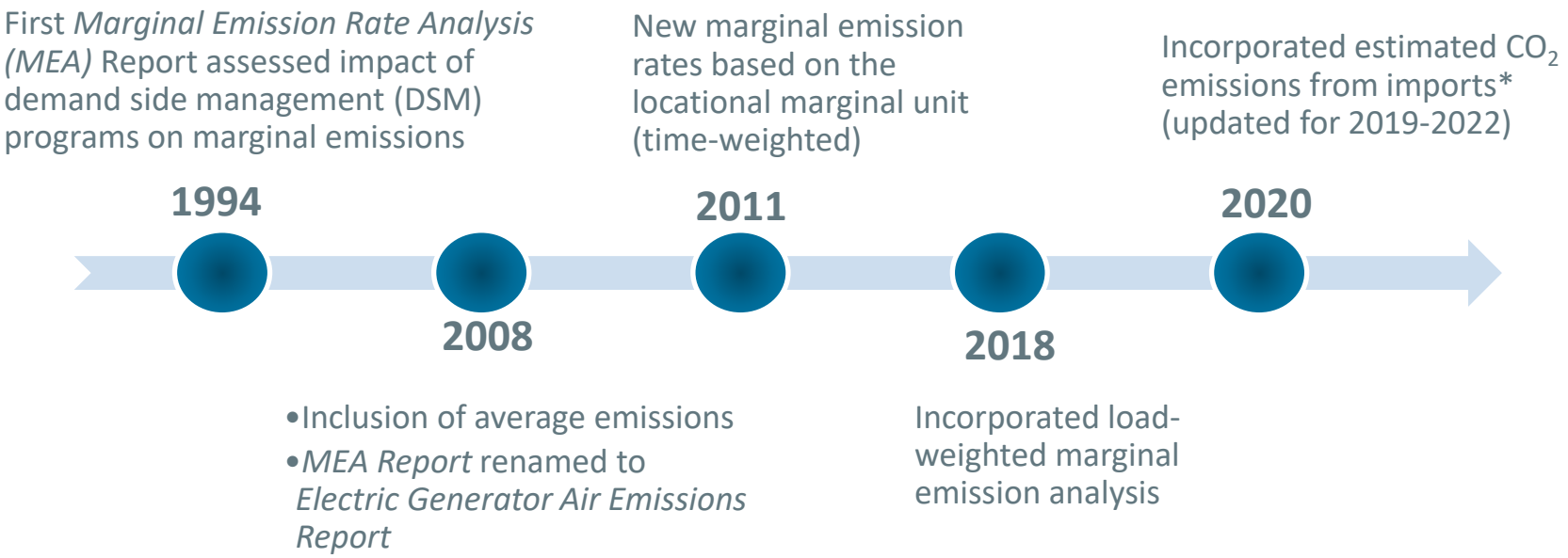
Outline

- 2023 Emissions Report Overview
- 2023 System Conditions
- 2023 Average Emissions
- 2023 Load-Weighted Emissions
- 2023 Time-Weighted Emissions
- Key Takeaways
- Next Steps

2023 Emissions Report

Background

The annual ISO New England (ISO) *Electric Generator Air Emissions Report* (*Emissions Report*) provides a comprehensive analysis of New England electric generator air emissions (NO_X, SO_2, and CO_2) and a review of relevant system conditions for calendar year 2023.



* https://www.iso-ne.com/static-assets/documents/2022/06/estimating_envtl_attributes_imports_2022625.pd

2023 Emissions Report

Coverage

- NO_X, SO_2, and CO_2 Emissions
  - ISO New England generation, which by definition **excludes** behind-the-meter generators and imports
  - Total generation emissions by state (in ktons*)
  - Annual and monthly average emission rates, including imports (in ktons)

- Locational Marginal Emission Rates
  - Locational Marginal Unit (LMU), locational marginal price (LMP)-based method of identifying marginal units

* The mass value of “tons” is equivalent to a U.S. short ton, or 2,000 lbs, and “ktons” is equivalent to 2,000,000 lbs. The emissions report also shows values in metric tons, where one metric ton = 2,204.6 lbs.

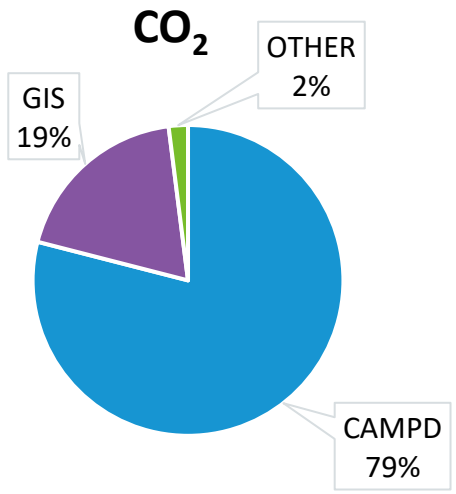
2023 Emissions Report

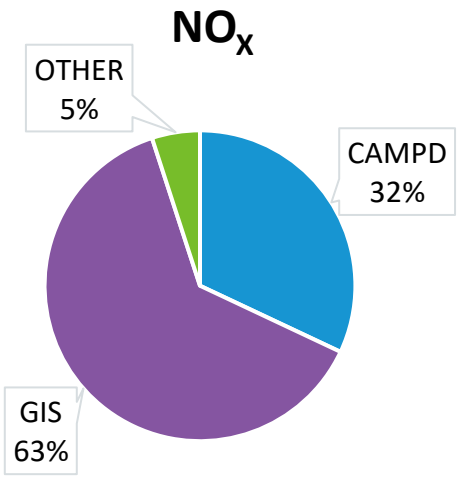
Air Pollutant Characterization

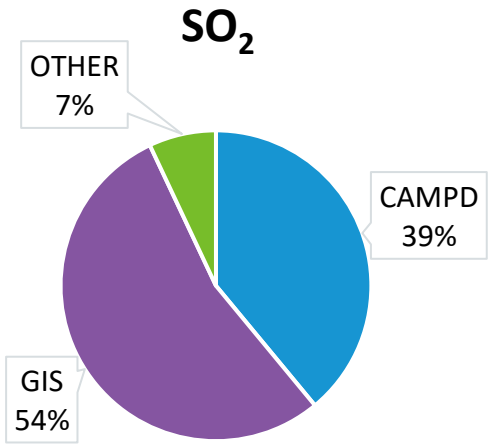
- CO_2
  - The primary greenhouse gas (i.e. gases that trap heat in the atmosphere) emitted through burning of fossil fuels
  - Five New England states have established economy-wide CO_2 emission reduction targets of at least 80% by 2050 (mostly below 1990 levels)
- SO_2
  - One of the six criteria air pollutants regulated under the EPA's National Ambient Air Quality Standards (NAAQS)
  - Primarily emitted through burning of fossil fuels and is an indicator for SO_X
  - Contributes to acid rain and particulate matter (PM) formation
- NO_X
  - Poisonous and highly reactive gas formed when fossil fuel is burned at high temperatures
  - Contribute to PM formation and ground-level ozone on hot summer days
  - NO_2 (indicator for NO_X), ozone, and PM are criteria air pollutants regulated under NAAQS

2023 Emissions Report

Data Sources







- U.S. EPA Clean Air Markets Program Database (**CAMPD**) is the main source of emissions data
- For units without CAMPD emissions*:
  - NEPOOL Generator Information System (**GIS**) monthly data
  - U.S. EPA's latest eGRID database or assumed emission rates based on unit type and age (**OTHER**)
- CO_2 emissions from imports
  - eGRID CO_2 total output emission rate (lb/MWh) from NYISO balancing authority
  - Canada's Greenhouse Gas Inventory Report

*See Appendix for details

2023 Emissions Report

Overall Summary - 2022 to 2023 Average New England Generation Emissions

-48%

in SO_2 *total emissions* (ktons)

-4%

in CO_2 *total emissions* (ktons)

-13%

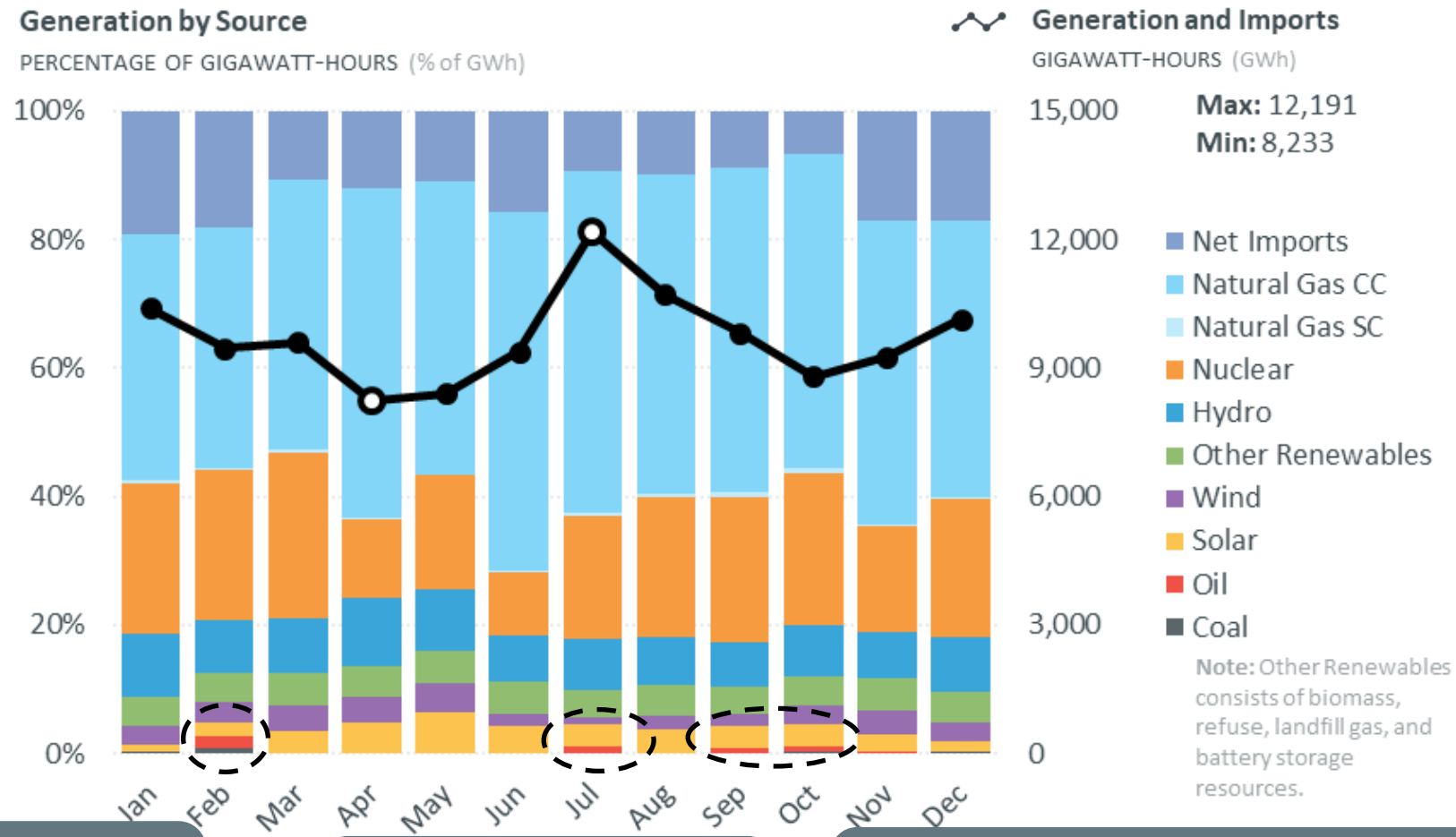
in NO_X *total emissions* (ktons)

- Annual load, energy prices, and peak demand decreased in 2023 compared to 2022, resulting in overall emission reductions for all three pollutants
- New England load in 2023 was lower than in 2022 due to mild weather conditions and growth of behind-the-meter (BTM) solar
- Oil and coal generation decreased while natural gas generation increased in 2023 largely due to planned and unplanned outages of nuclear generators and reductions in net interchange

2023 SYSTEM CONDITIONS

2023 ISO-NE Monthly Generation by Resource Type, including Net Imports

Percent of Total Generation (% GWh) and GWh



A 2-day cold snap in February led to high natural gas prices resulting in more coal and oil generation. Despite sub-zero temperatures, demand was low since the winter peak occurred on a weekend.

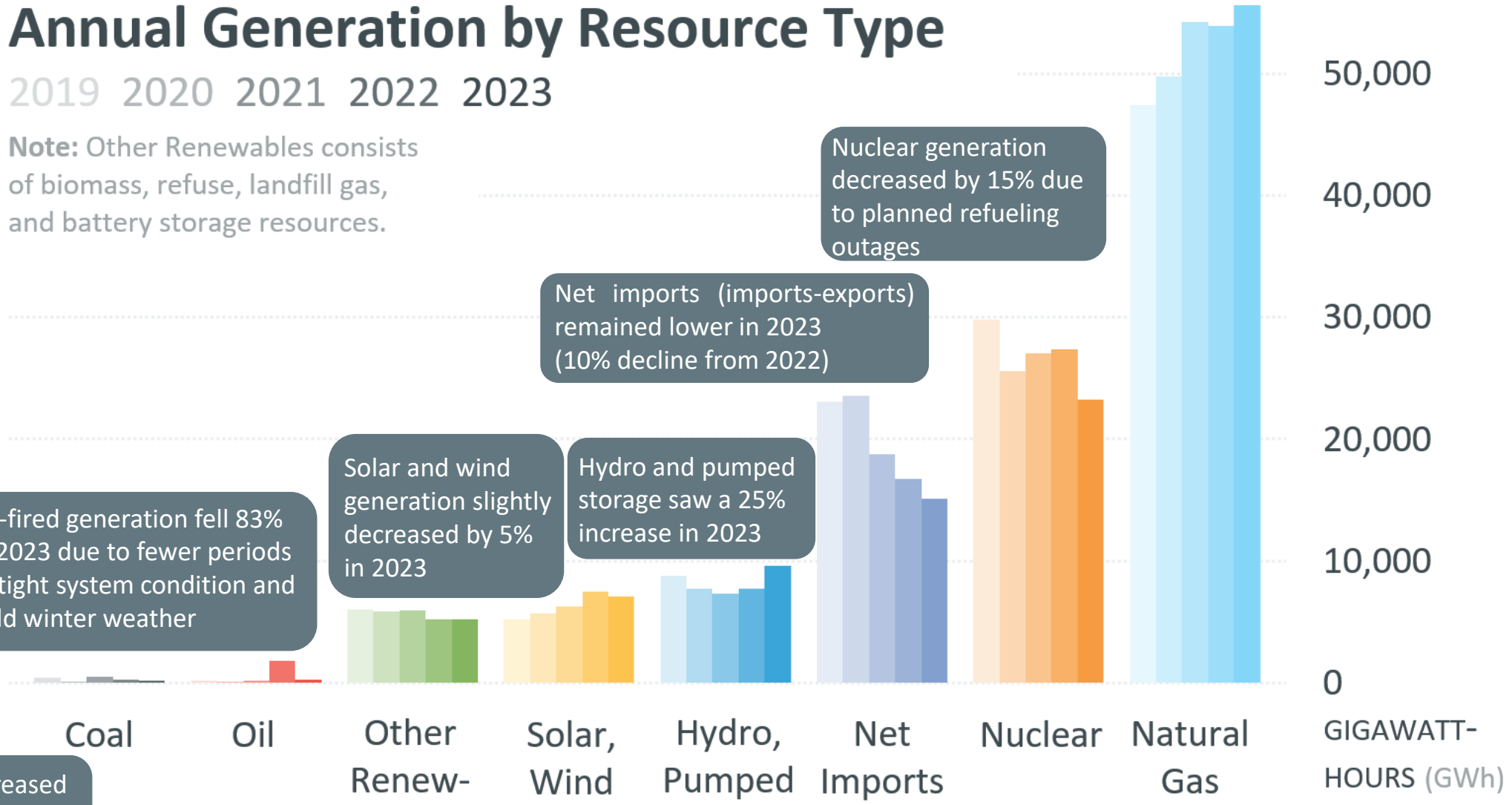
Heat waves in July increased oil and coal generation to meet cooling demand

A heat wave in September following a mild summer led to a slight uptick in oil generation. Tight system conditions in October due to unplanned outages also increased oil and coal generation

Annual Generation by Resource Type

2019 2020 2021 2022 2023

Note: Other Renewables consists of biomass, refuse, landfill gas, and battery storage resources.



Coal generation decreased year-over-year at 44% from 2022

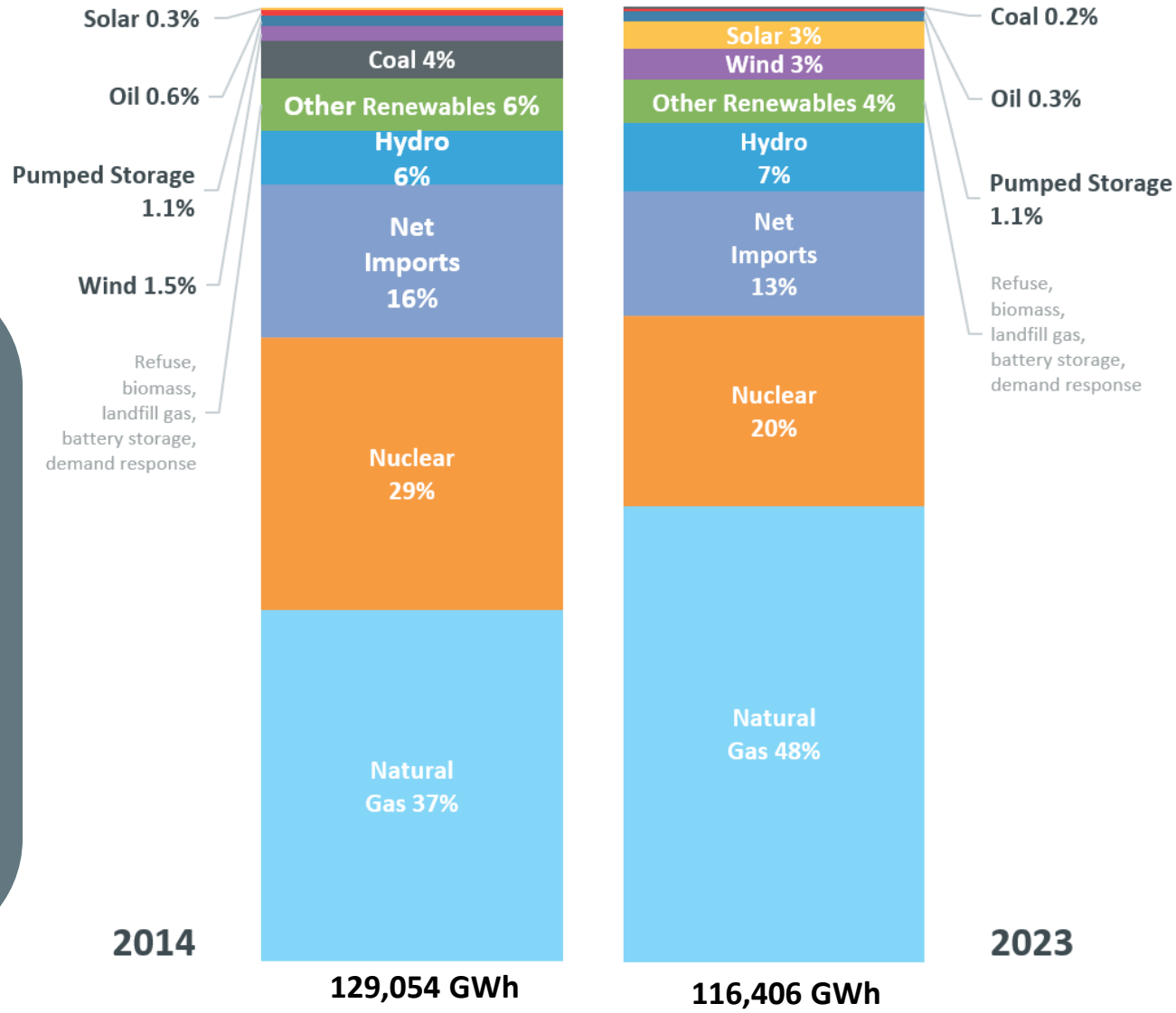
Based on Primary Fuel Type of generators from the 2024 CELT Report: [2024 CELT Report]

Shift in New England's Sources of Energy

2014 vs. 2023

Since 2014, the generation mix has shifted away from high carbon emitting resources (i.e. oil and coal) to lower-carbon-emitting resources like natural gas and carbon free resources such as solar and wind.

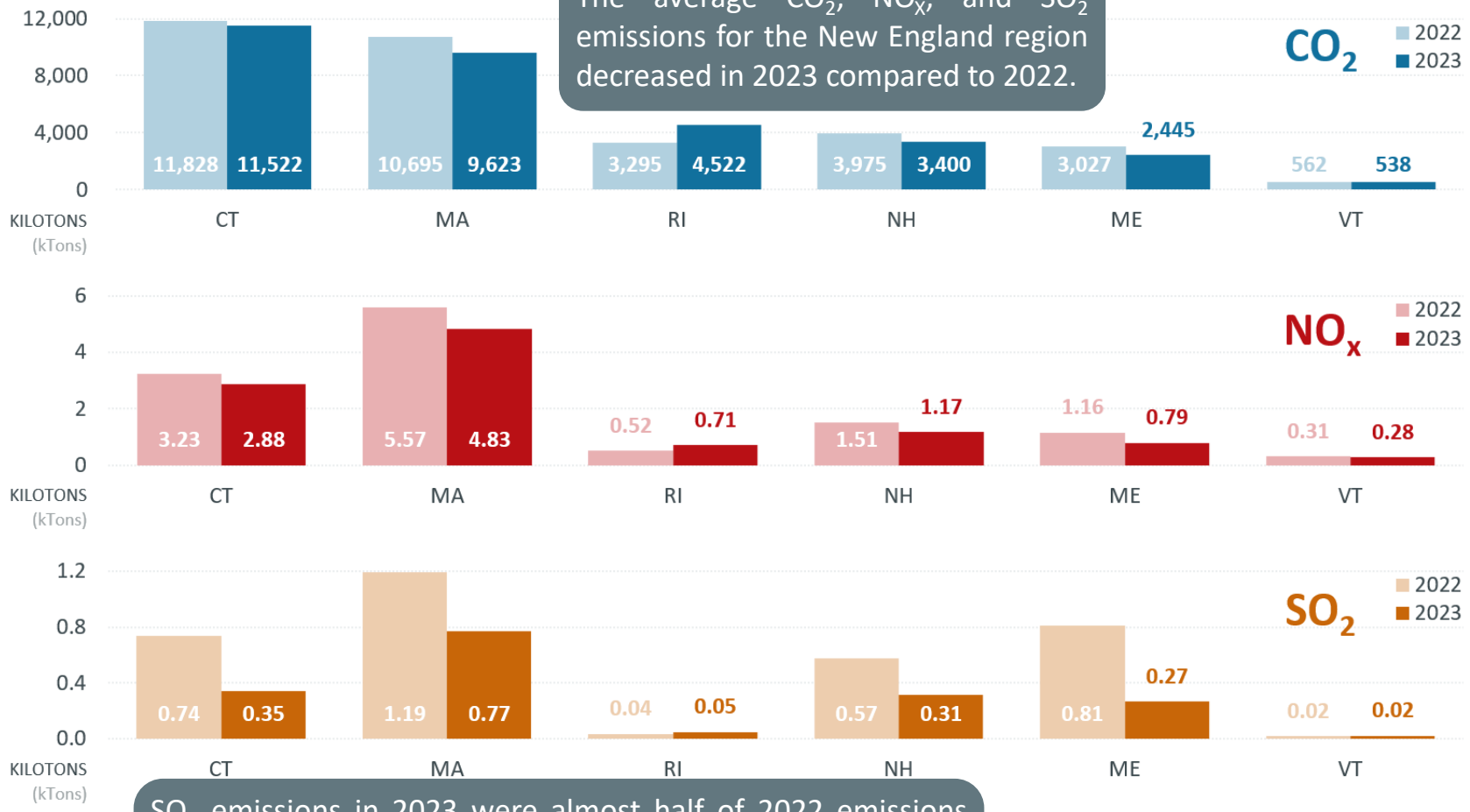
Notably, nuclear generation and net imports have decreased in the last 10 years, which was offset by an increase in natural gas generation.



2023 ISO NEW ENGLAND AVERAGE EMISSIONS

2022 & 2023 Average Annual New England Generation Emissions

By State (ktons)



The average CO_2, NO_X, and SO_2 emissions for the New England region decreased in 2023 compared to 2022.

New England total CO_2
32,050 (2023)
33,382 (2022)

New England total NO_X
10.66 (2023)
12.30 (2022)

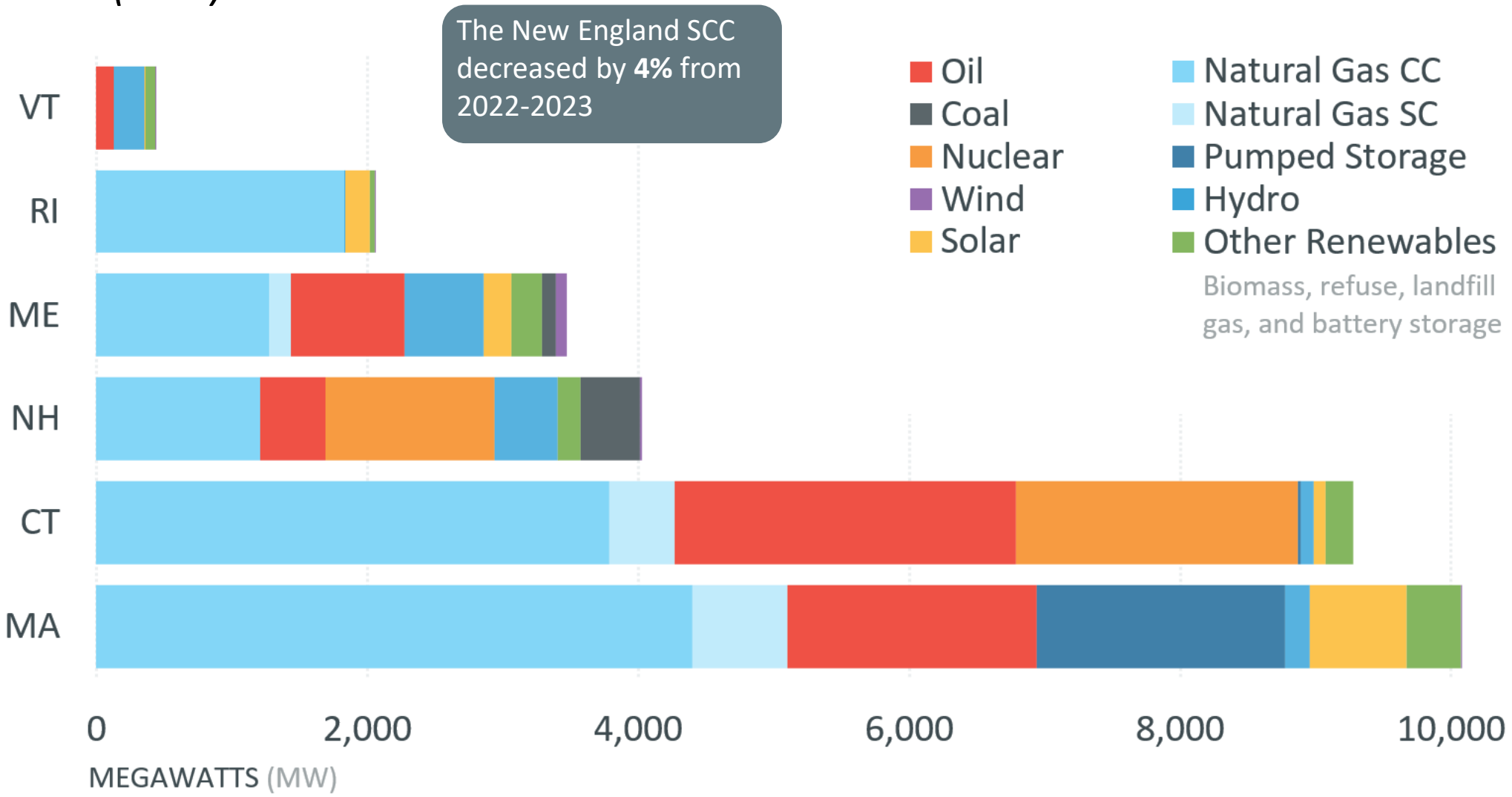
New England total SO_2
1.77 (2023)
3.38 (2022)

SO_2 emissions in 2023 were almost half of 2022 emissions (2022 was a year marked by increased oil-fired generation due to natural gas pipeline constraints that made oil and sometimes coal more economical to run)

NOTE: Values shown may not sum correctly due to rounding

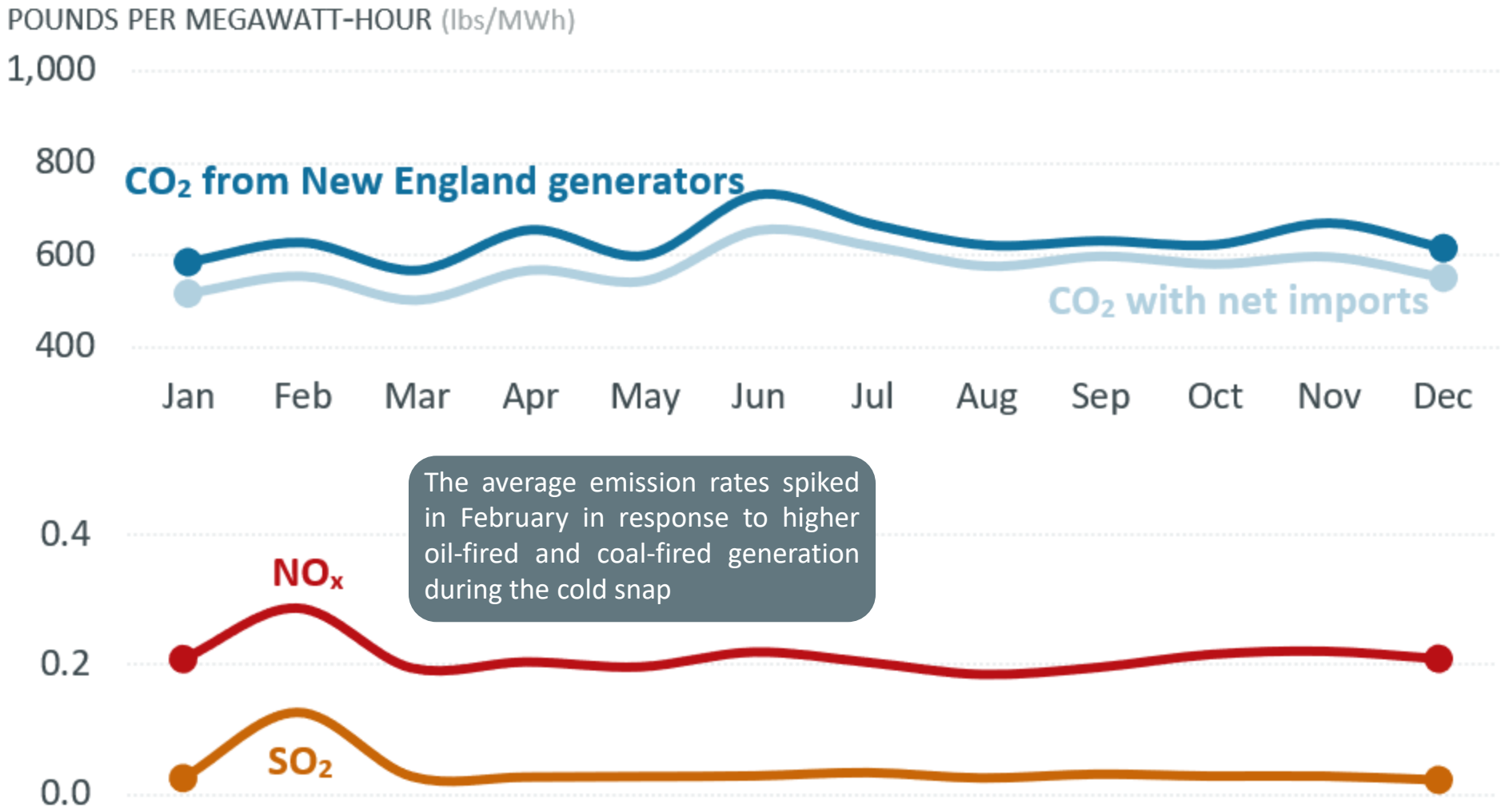
2023 ISO-NE Summer Claimed Capability (SCC)

By State (MW)



2023 ISO-NE Monthly Average Emission Rates (lbs/MWh)

New England Generation Only for SO_2, NO_x, and CO_2, and with Imports for CO_2



Impact of Imports and Exports on 2023 Average Annual CO_2 Emissions and Emission Rates

32,050 ktons (New England)
+ 2,048 ktons (imports)
– 883 ktons (exports)

→ **+4%** in CO_2 *total emissions* (ktons)

633 lbs/MWh (New England generators only)
571 lbs/MWh (New England generators plus net imports)

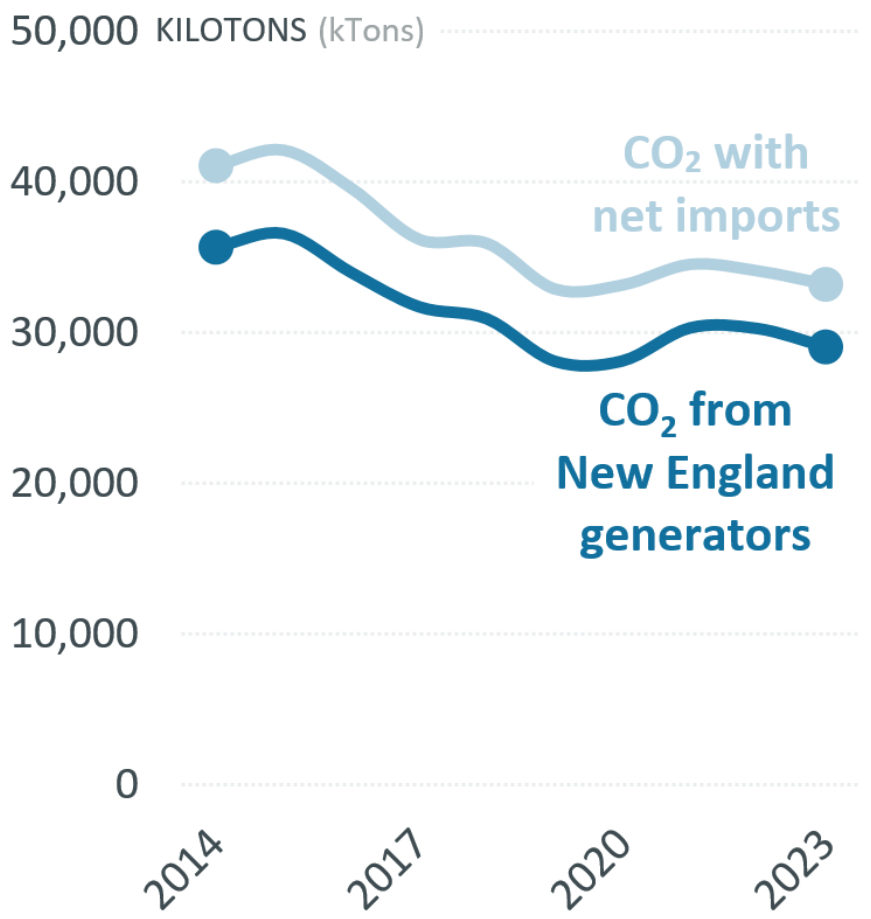
→ **-11%** in CO_2 *Emission rate* (lbs/MWh)

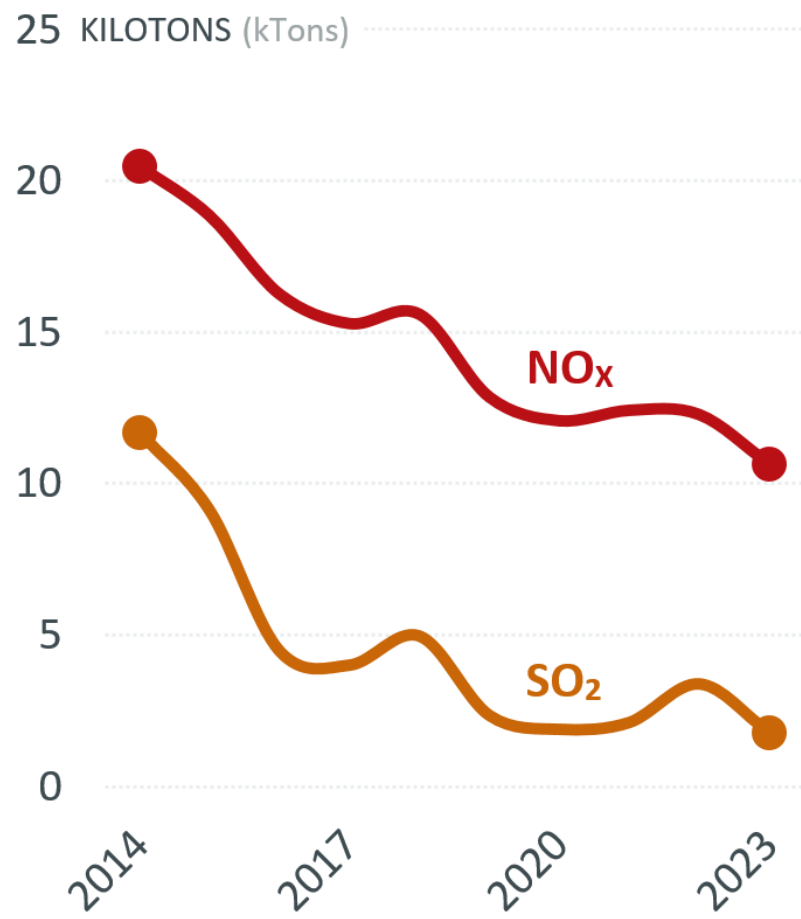
See Appendix for details

- Assumed emission import rates (based on annual averages):
  - New Brunswick and Quebec values are the average of the 2020-2022 rates, and New York is the eGRID2022 value
    - New Brunswick: 680 lbs/MWh
    - New York: 504 lbs/MWh
    - Quebec: 3.9 lbs/MWh

2014 – 2023 ISO-NE Annual Average Emissions (ktons)

New England Generation Only for SO_2, NO_X, and CO_2, and with Imports for CO_2

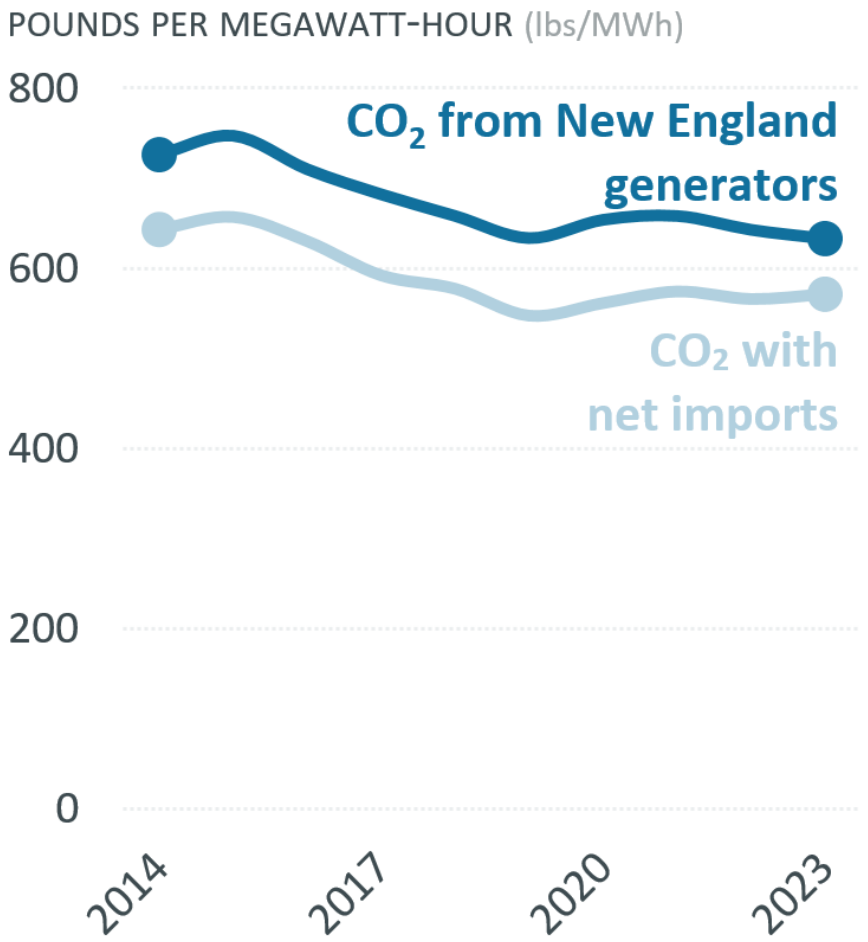


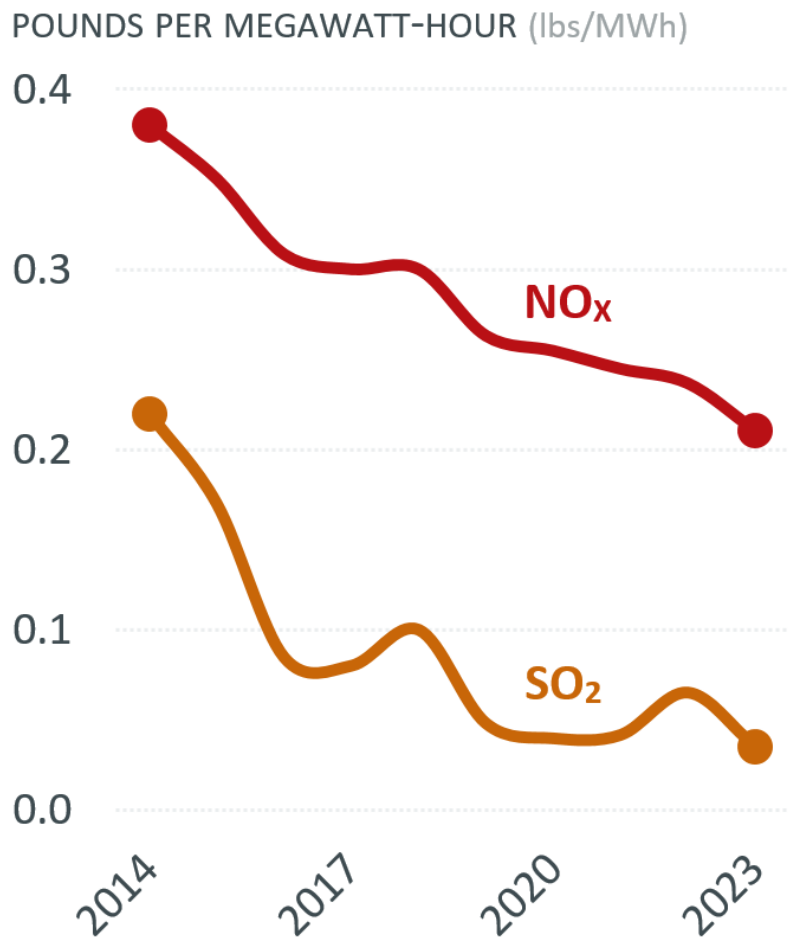


-18% CO_2 **-48%** NO_X **-85%** SO_2

2014 – 2023 ISO-NE Annual Average Emission Rates (lbs/MWh)

New England Generation Only for SO_2, NO_X, and CO_2, and with Net Imports for CO_2





-13% CO_2 **-45%** NO_X **-84%** SO_2

2023 ISO NEW ENGLAND MARGINAL EMISSIONS ANALYSIS

Locational Marginal Unit (LMU)

- *Percent Marginal by Fuel Type*
- *Marginal Emission Rates*

Marginal Emissions Analysis

Overview

- Locational Marginal Units (LMUs) are identified by Locational Marginal Price (LMP)
  - Based on historical real-time generation dispatch records

- Marginal emissions are calculated by summing the monthly percentage (of time or load) marginal from all identified LMUs, multiplying the results by relevant individual generator emission rates, and then dividing by the total on-peak or off-peak hours in the year

$$\frac{\sum_{k=1}^{\text{LMP marginal units}} \sum_{h=1}^{\text{on-peak hours in year}} (\%\ \text{of LMP Unit Marginal}_{k,h} \times \text{On-Peak Emission Rate}_{k,m})}{\text{On-Peak Hours in Year}}$$

- The percentage that each generator is marginal was calculated using two different approaches:
  - **Load-weighted LMUs**, reflecting the load associated with the marginal unit
    - Assumes that under a constrained system, marginal resources do not equally contribute to meeting load
  - **Time-weighted LMUs**, reflecting the time for which a resource was marginal
    - Assumes if there are multiple marginal resources within a time interval (constrained system), then the resource equally contribute to meeting the load

Marginal Emissions Analysis

Marginal Unit Scenarios

1. All-LMUs
   - Includes all Locational Marginal Units (including imports) identified by the 5-minute LMPs
   - Reflects all hours in a calendar year and units with and without associated air emissions

2. Emitting-LMUs
   - Excludes all non-emitting units, such as nuclear, pumped storage, hydro-electric generation, and other renewables (such as wind, etc.) with no associated air emissions
   - Reflects only hours in a calendar year when emitting units are marginal and excludes the impact of non-emitting units on the margin

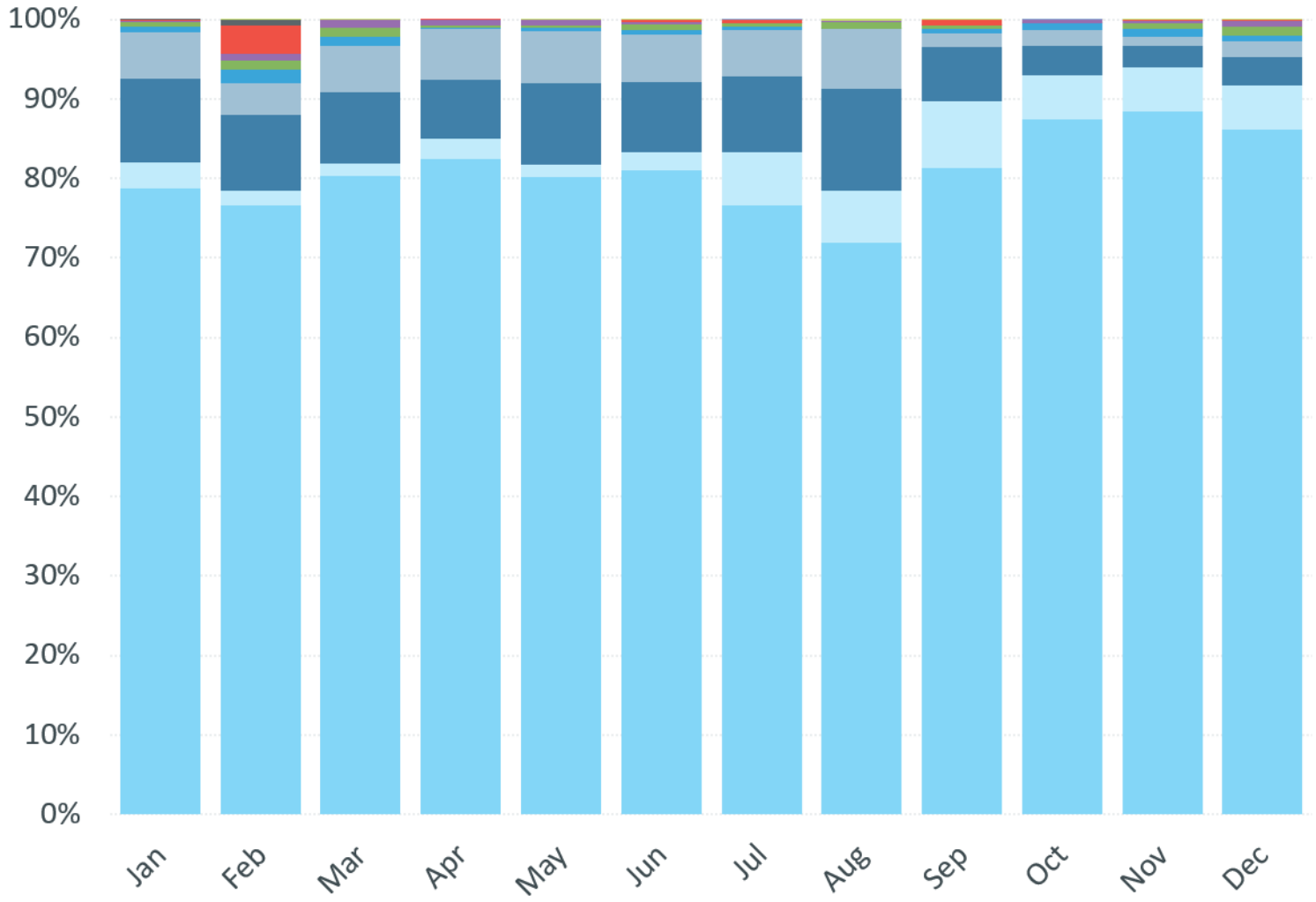
2023 Monthly Percent of Load Unit Types Were Marginal

All-LMUs – Load-Weighted

Oil was marginal for **0.6%** of the load (down from 4% in 2022)

Wind was marginal for only **0.4%** of the load since wind resources are located in export-constrained areas

Natural gas was the primary marginal fuel type, serving **84%** of the load in 2023



Note: Other Renewables consists of biomass, refuse, landfill gas, and battery storage resources.

2023 Monthly Percent of Time Unit Types Were Marginal

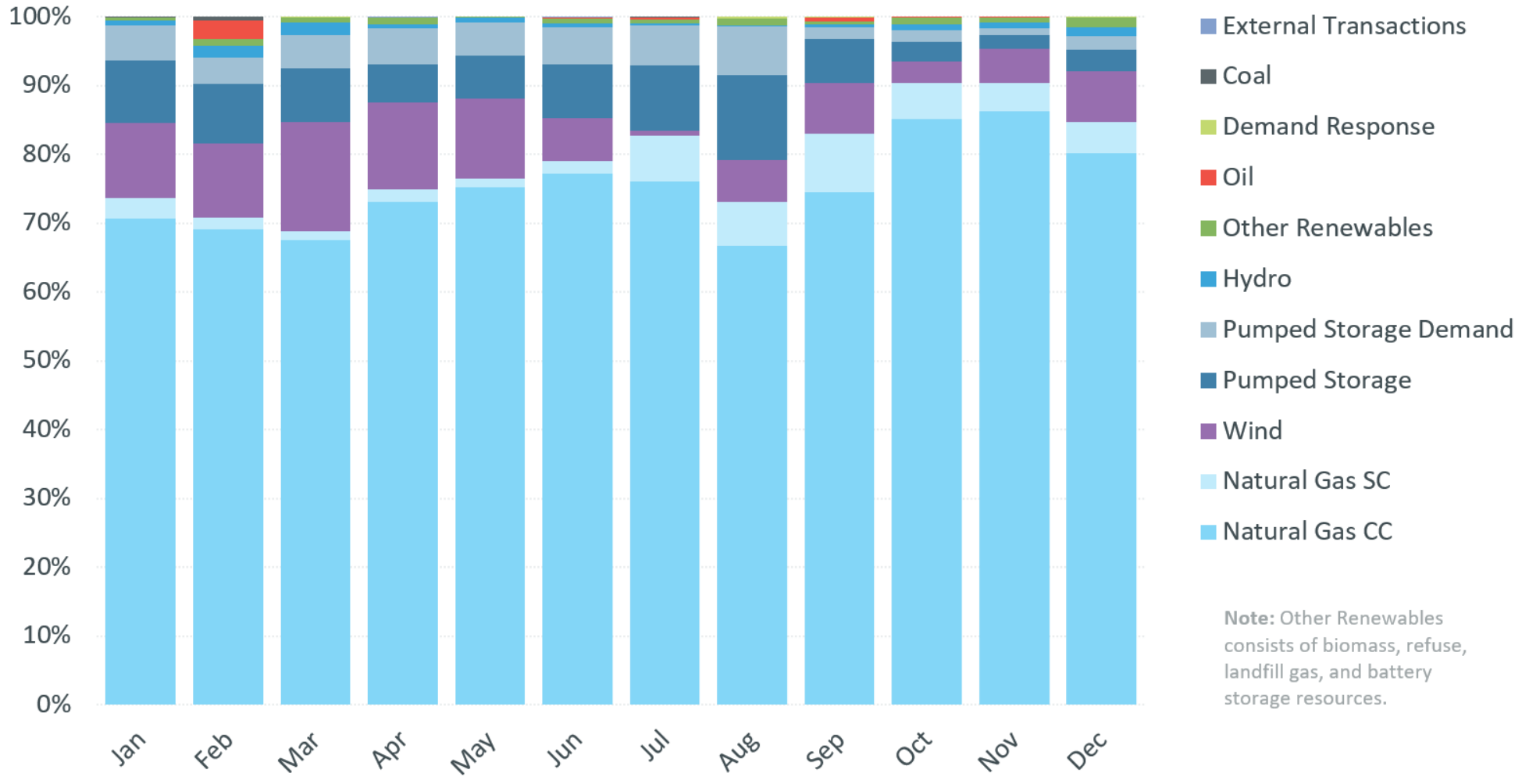
All-LMUs – Time-Weighted

Oil was marginal for only **0.3%** of the time (down from 3% in 2022)

Wind was marginal **8%** of the time (vs. **0.4%** using the load-weighted approach)

Other renewables was marginal for **0.8%** of the time

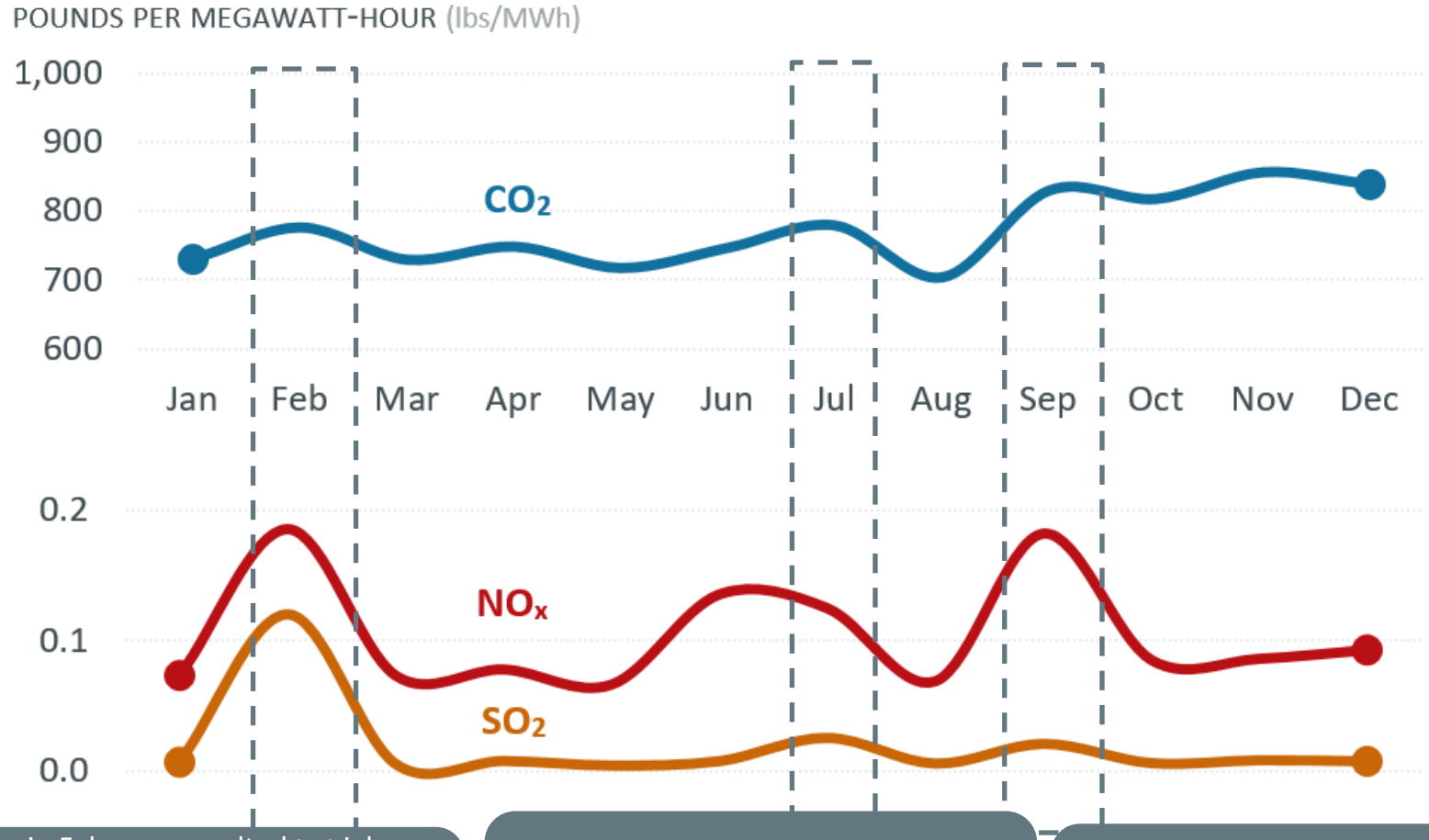
Natural gas was the primary marginal fuel type for **79%** of the time



Note: Other Renewables consists of biomass, refuse, landfill gas, and battery storage resources.

2023 Monthly Marginal Emission Rates (lbs/MWh)

All-LMUs – Load-Weighted



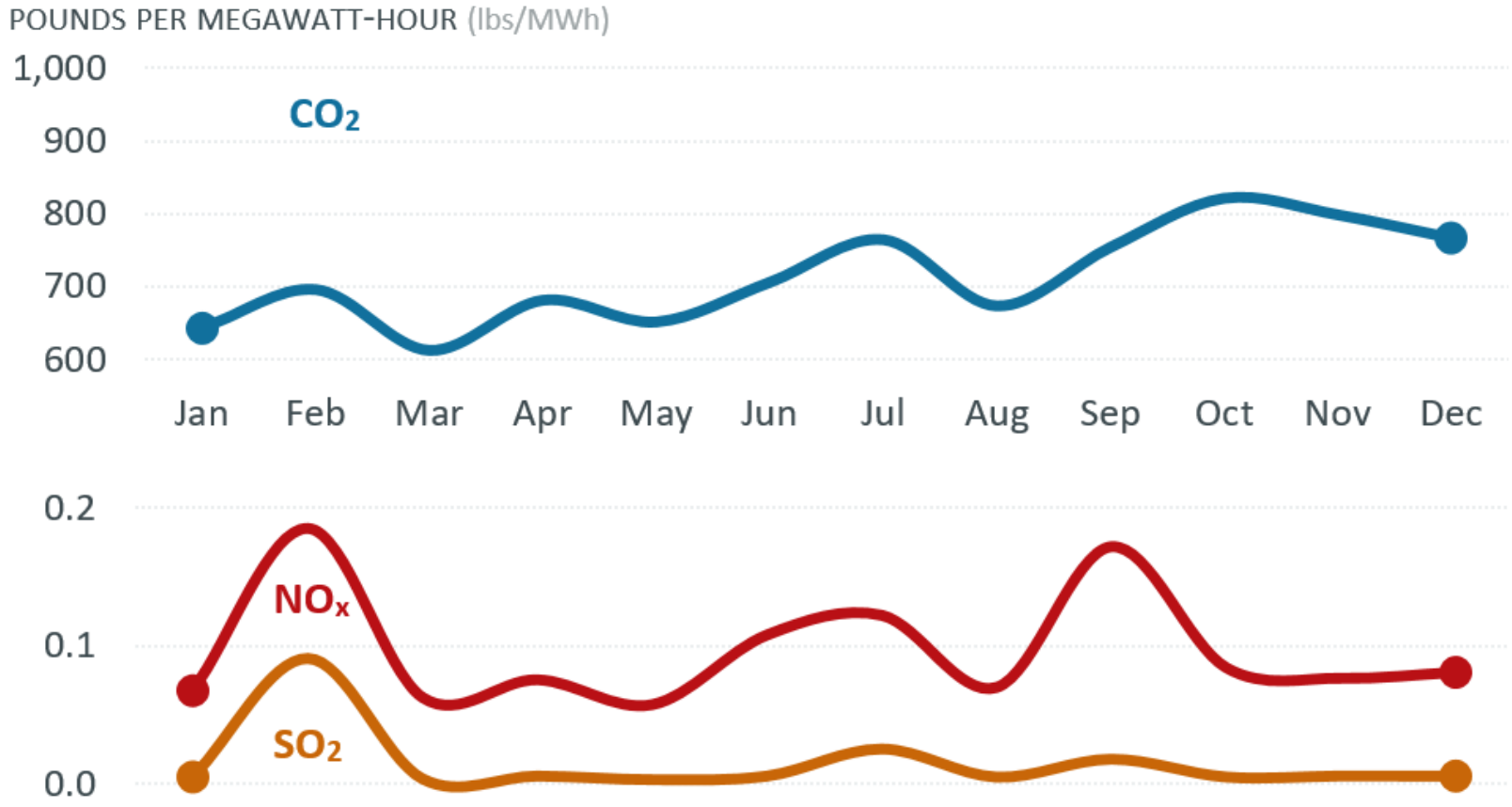
2-day cold snap in February resulted in higher natural gas prices that made oil and coal resources on the margin for more of the load resulting in higher marginal emission rates

Heat waves in July lead to more oil on the margin resulting in higher marginal emission rates

The highest peak demand in 2023 occurred in September during a heat wave that lead to oil resources on the margin more frequently

2023 Monthly Marginal Emission Rates (lbs/MWh)

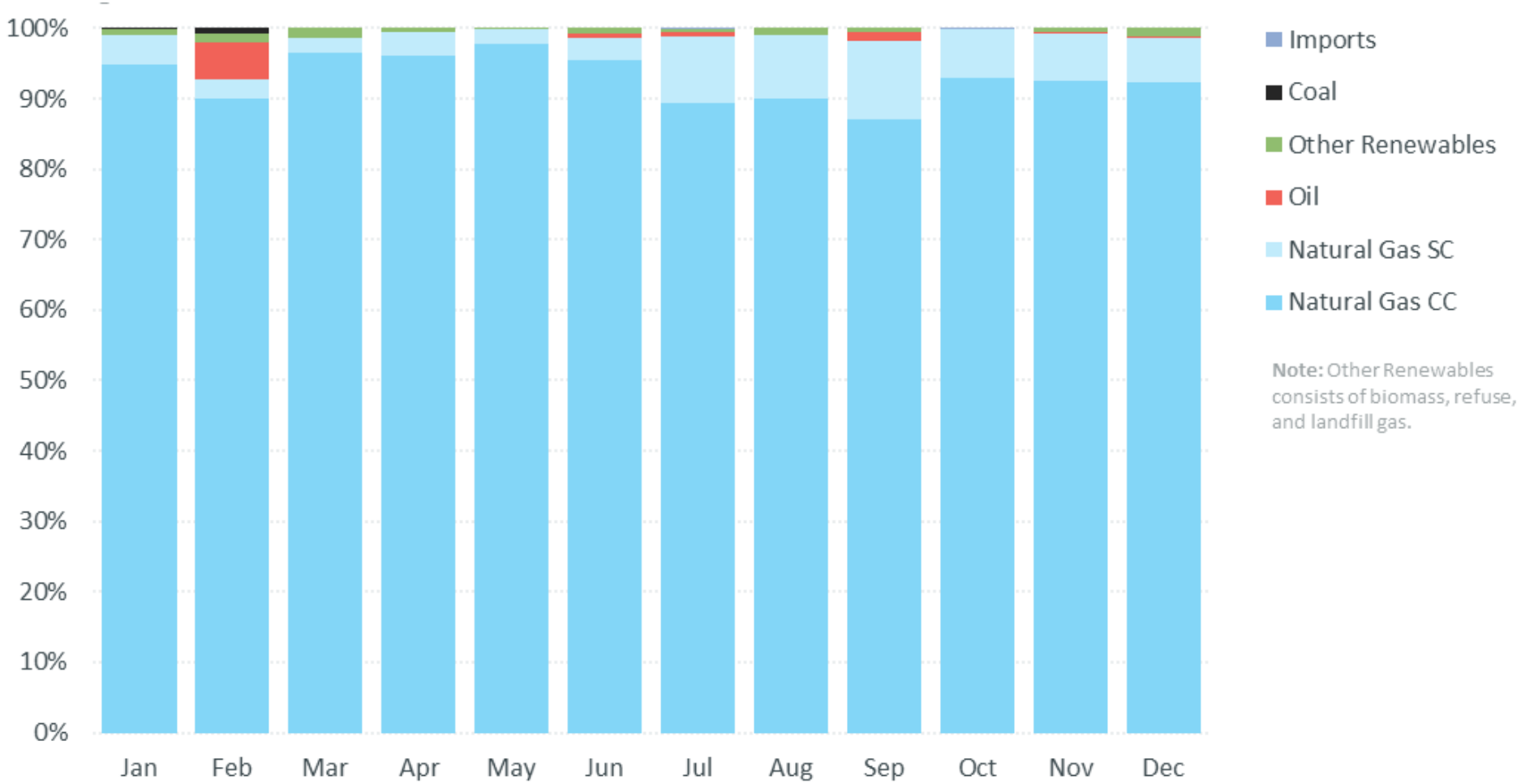
All-LMUs – Time-Weighted



Time-weighted marginal emission rates exhibited the same trend as the load-weighted rates, except, the time-weighted rates are slightly lower due to increased contribution of wind generators

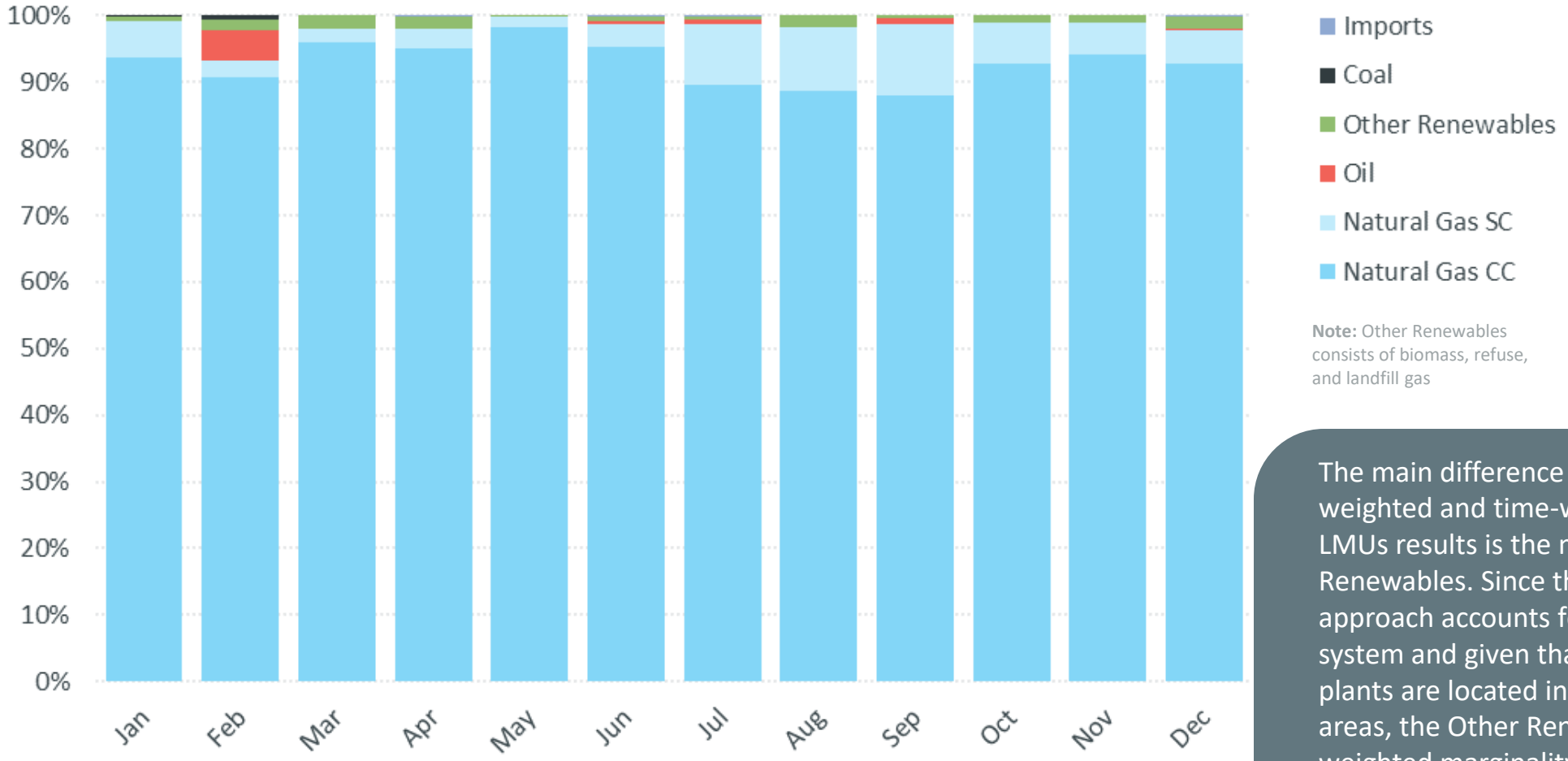
2023 Monthly Percent of Load Unit Types Were Marginal

Emitting-LMUs – Load-Weighted



2023 Monthly Percent of Time Unit Types Were Marginal

Emitting-LMUs – Time-Weighted

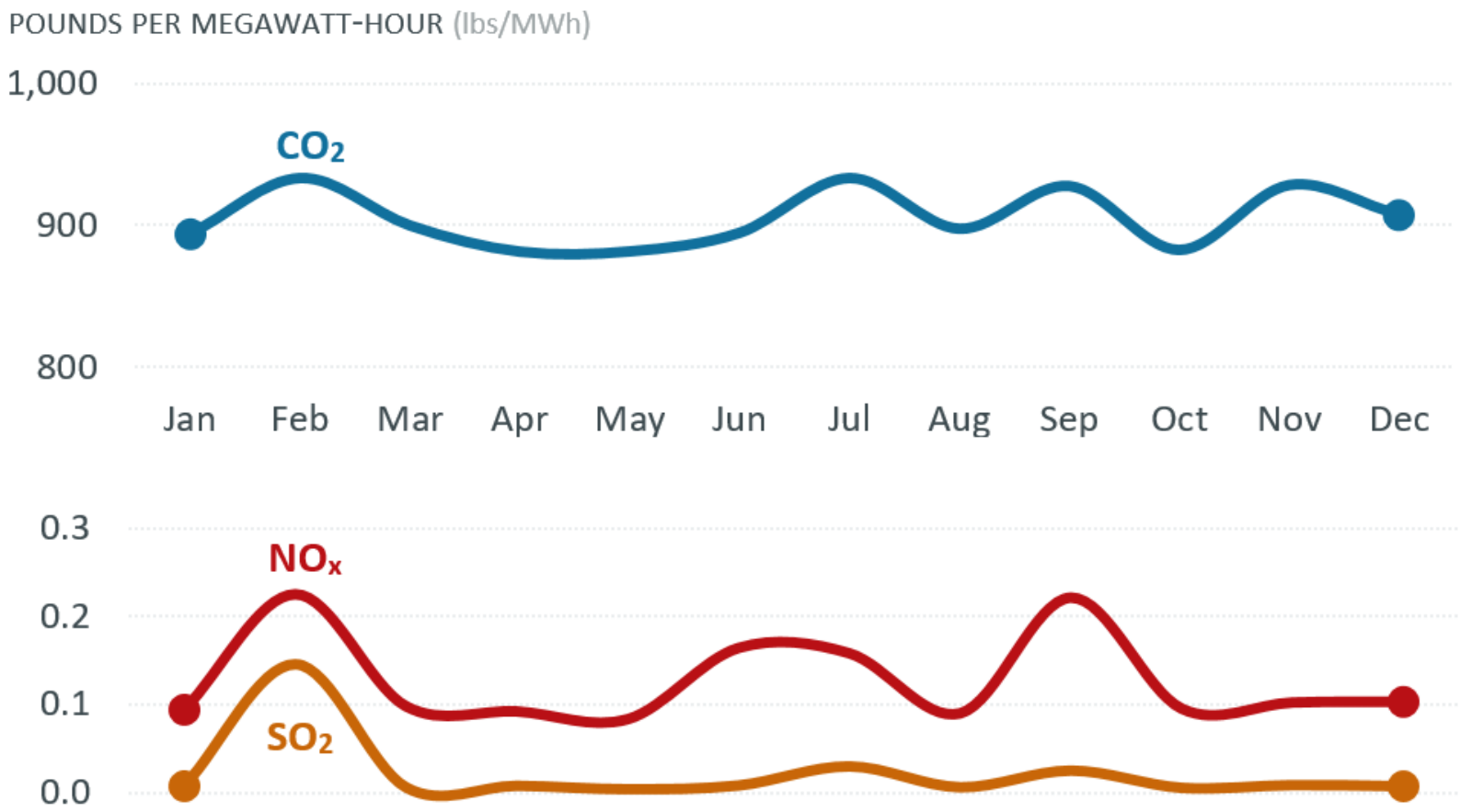


Note: Other Renewables consists of biomass, refuse, and landfill gas

The main difference between the load-weighted and time-weighted emitting-LMUs results is the marginality of Other Renewables. Since the load-weighted approach accounts for congestion on the system and given that many biomass plants are located in export-constrained areas, the Other Renewables' load-weighted marginality was less than the time-weighted.

2023 Monthly Marginal Emission Rates (lbs/MWh)

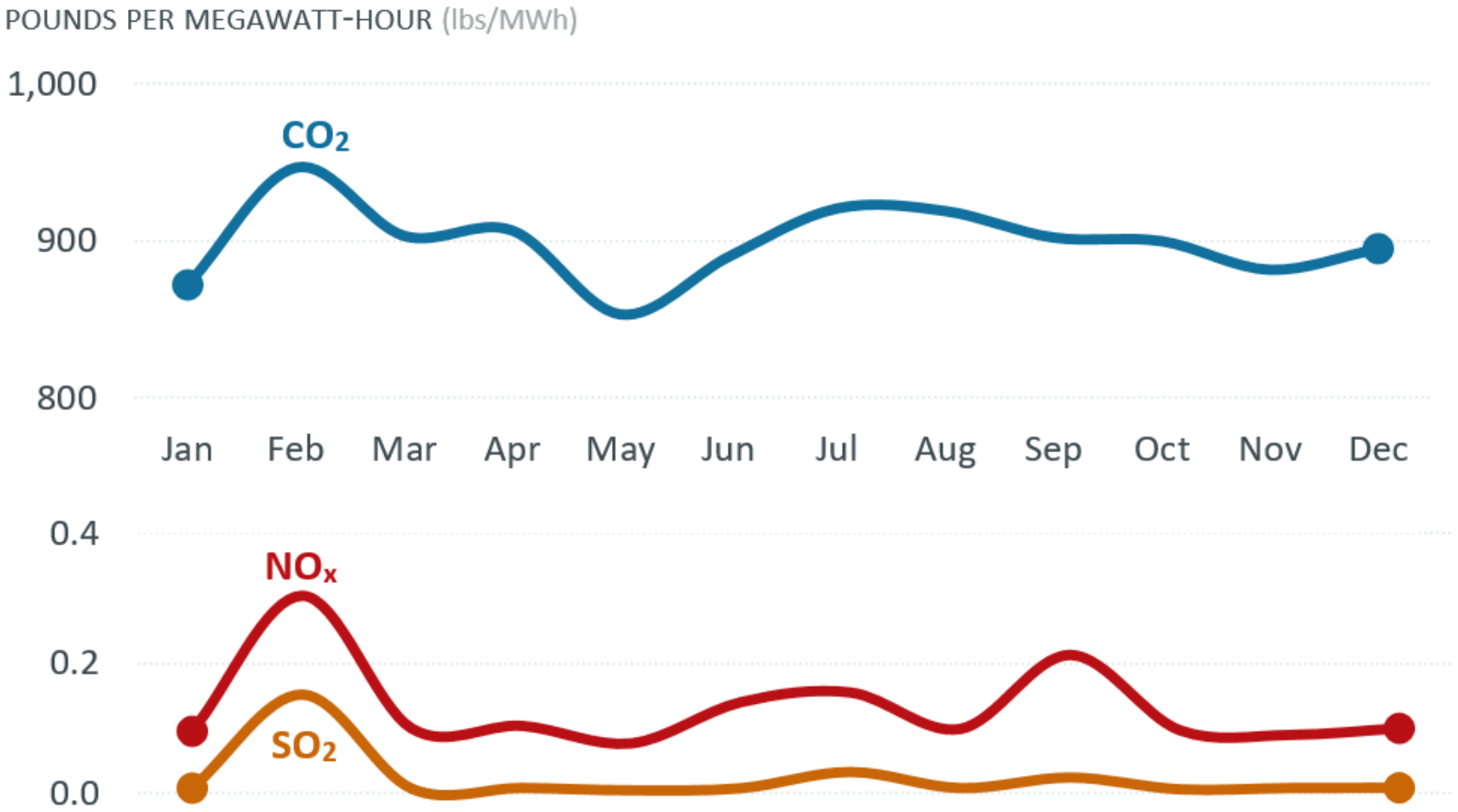
Emitting-LMUs – Load-Weighted



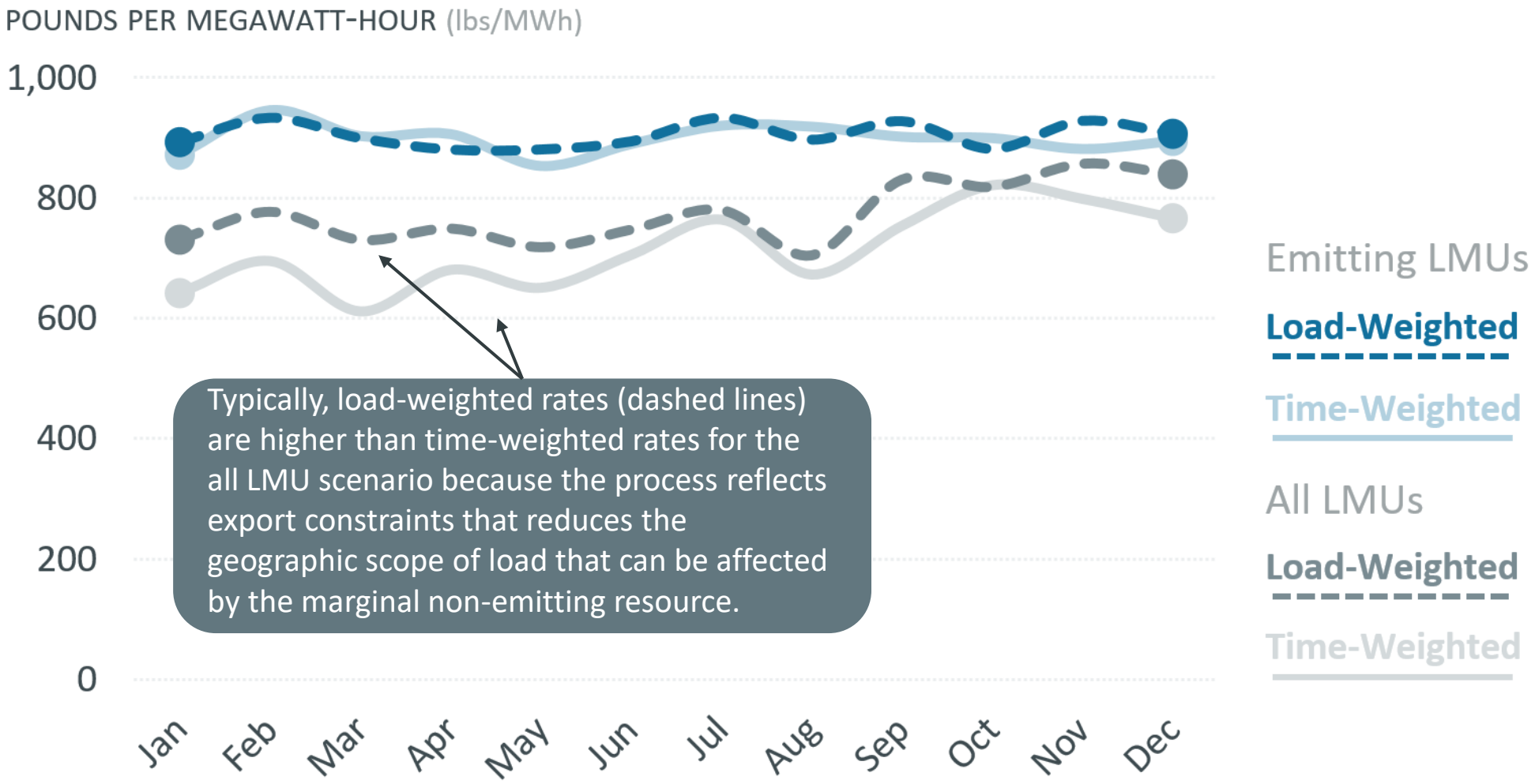
Since the emitting-LMU scenario excludes non-emitting resources from the marginal emission rate calculation, this resulted in higher emission rates compared to the "all-LMU" scenario.

2023 Monthly Marginal Emission Rates (lbs/MWh)

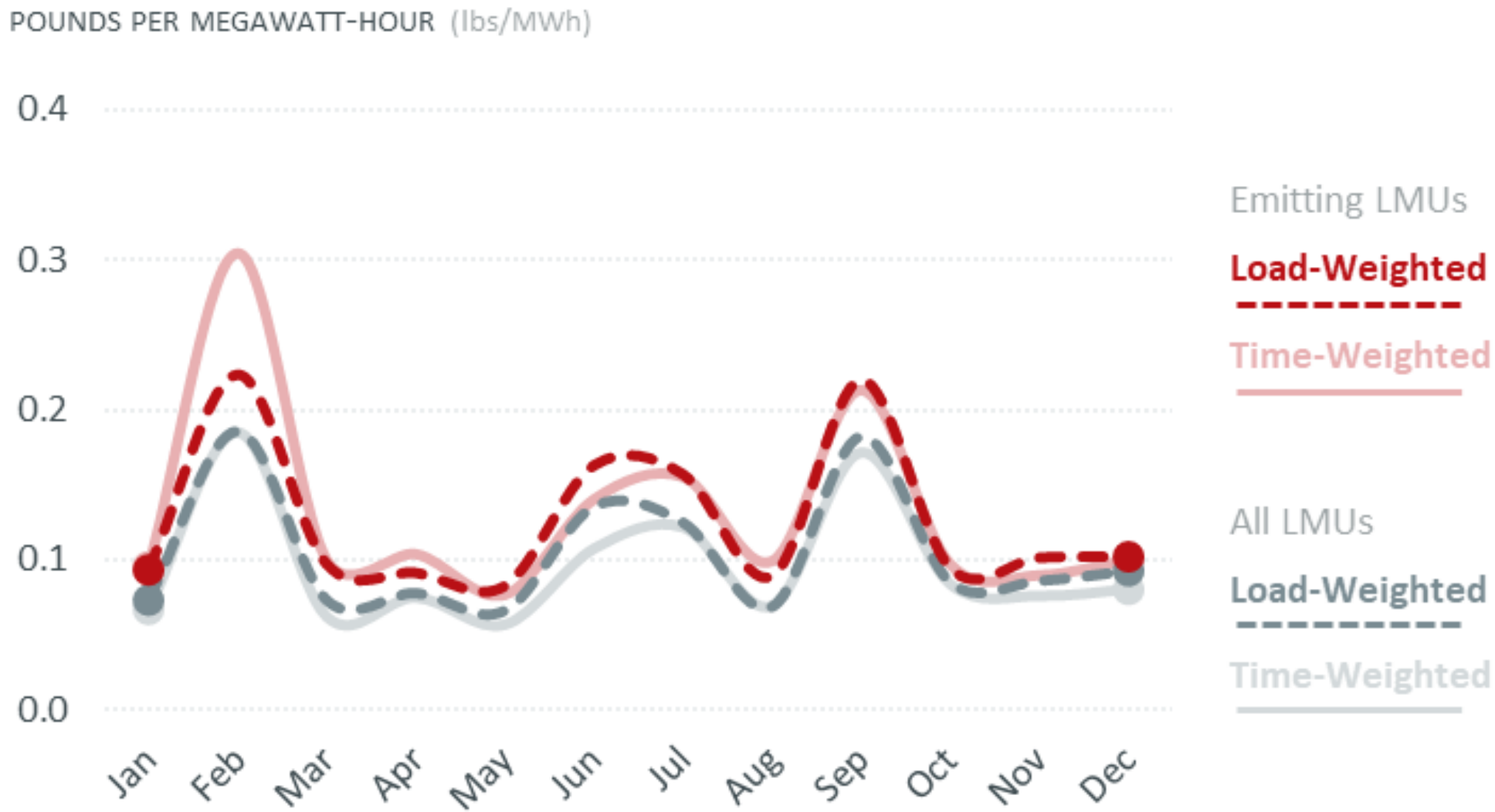
Emitting-LMUs – Time-Weighted



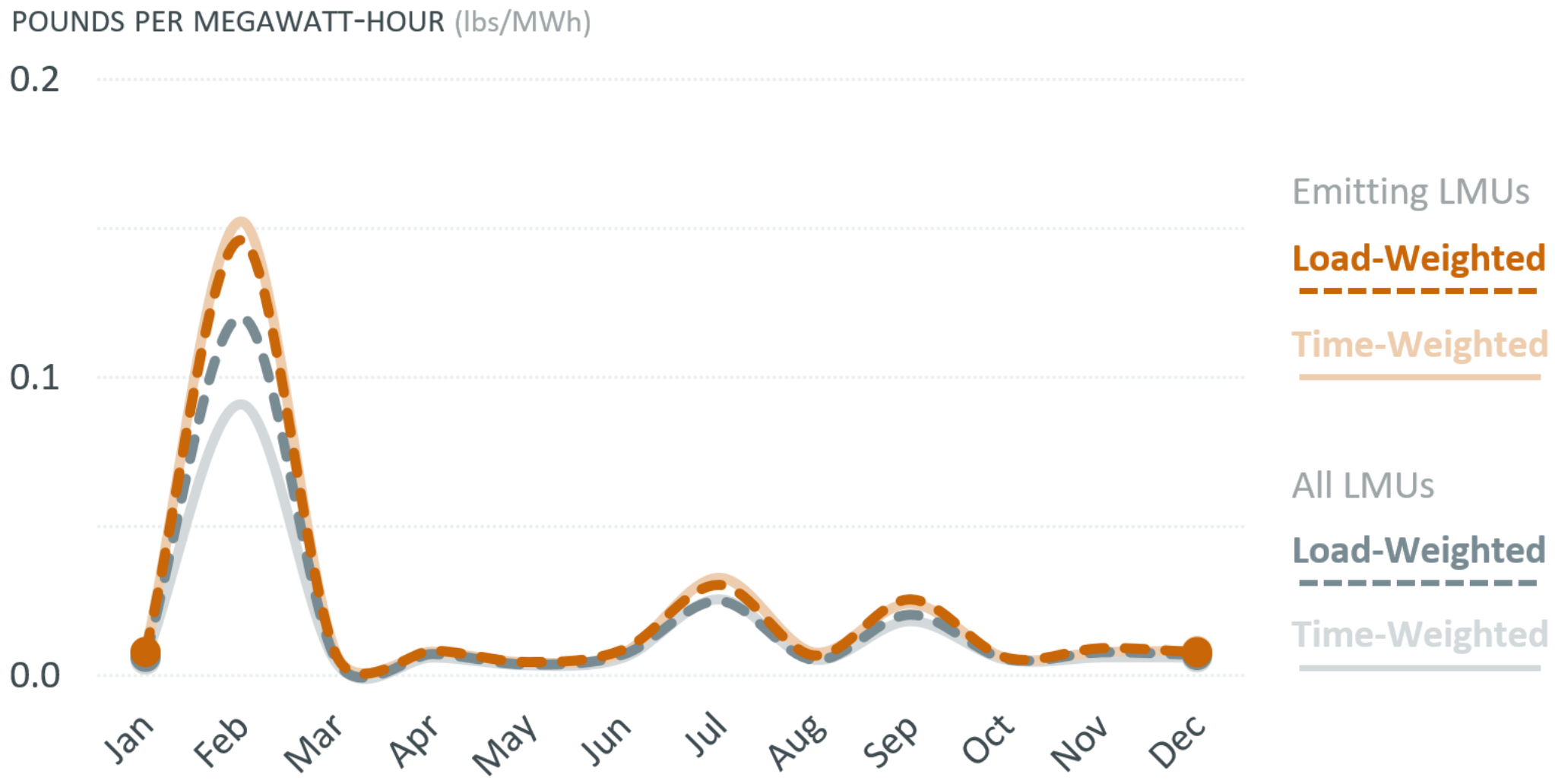
2023 Monthly Marginal CO_2 Rates (lbs/MWh)



2023 Monthly Marginal NO_X Rates (lbs/MWh)



2023 Monthly Marginal SO_2 Rates (lbs/MWh)

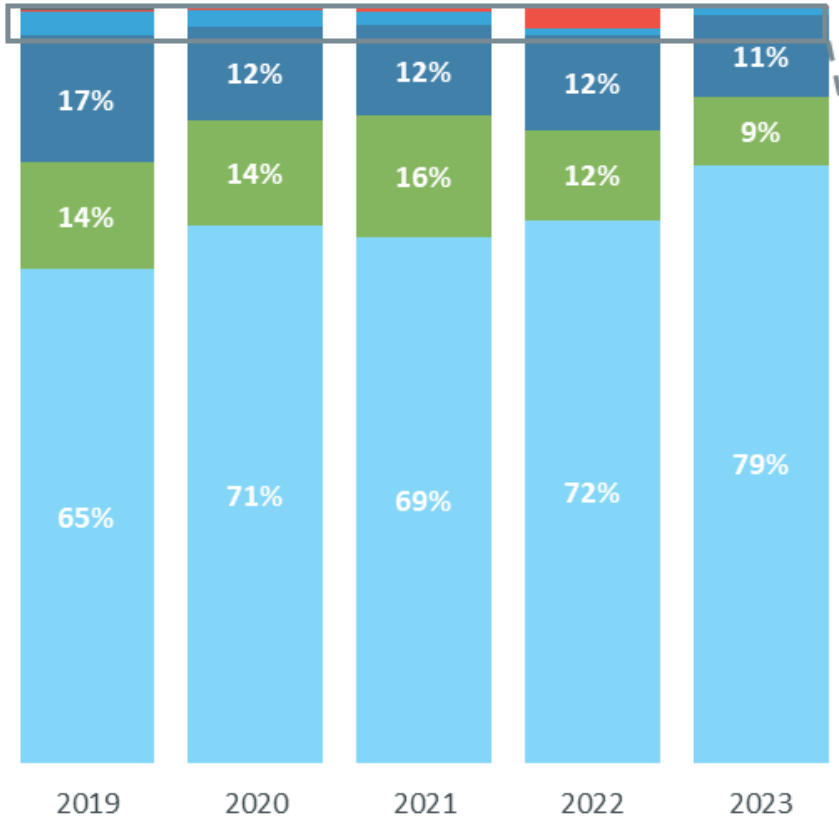


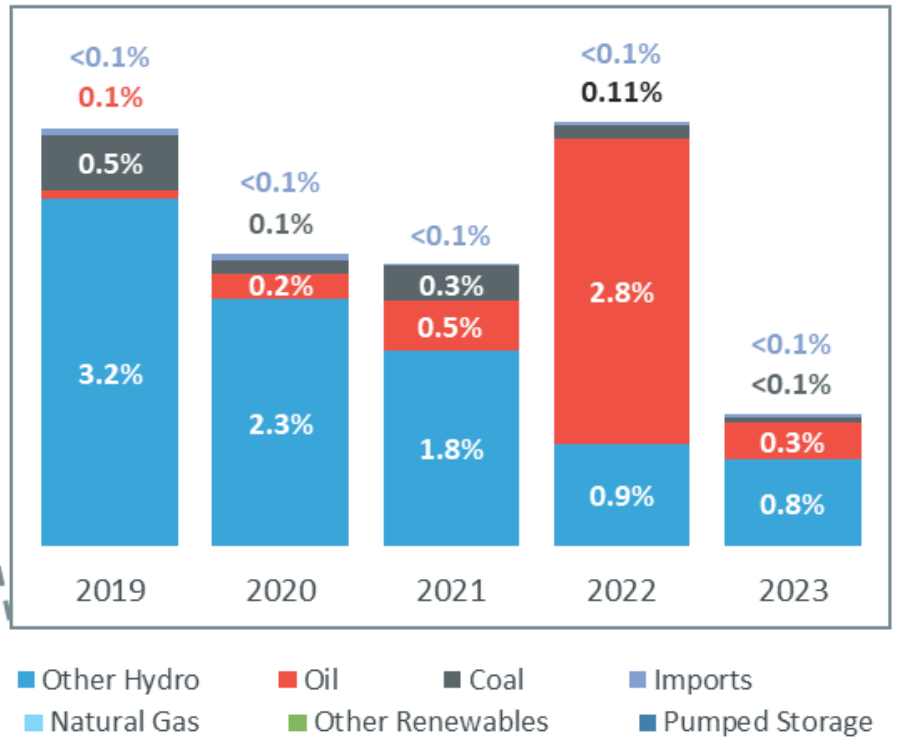
2019 – 2023 Percent of Time Unit Type Was Marginal

All-LMUs – Time-Weighted

The Pumped Storage category includes both pumped storage generation and pumped storage demand. In 2023, the generation and demand components were marginal 7% and 4% of the time, respectively.

In 2023, wind was marginal for 8% of the time. Biomass, refuse, landfill gas, battery storage resources, and demand response were also marginal at times.



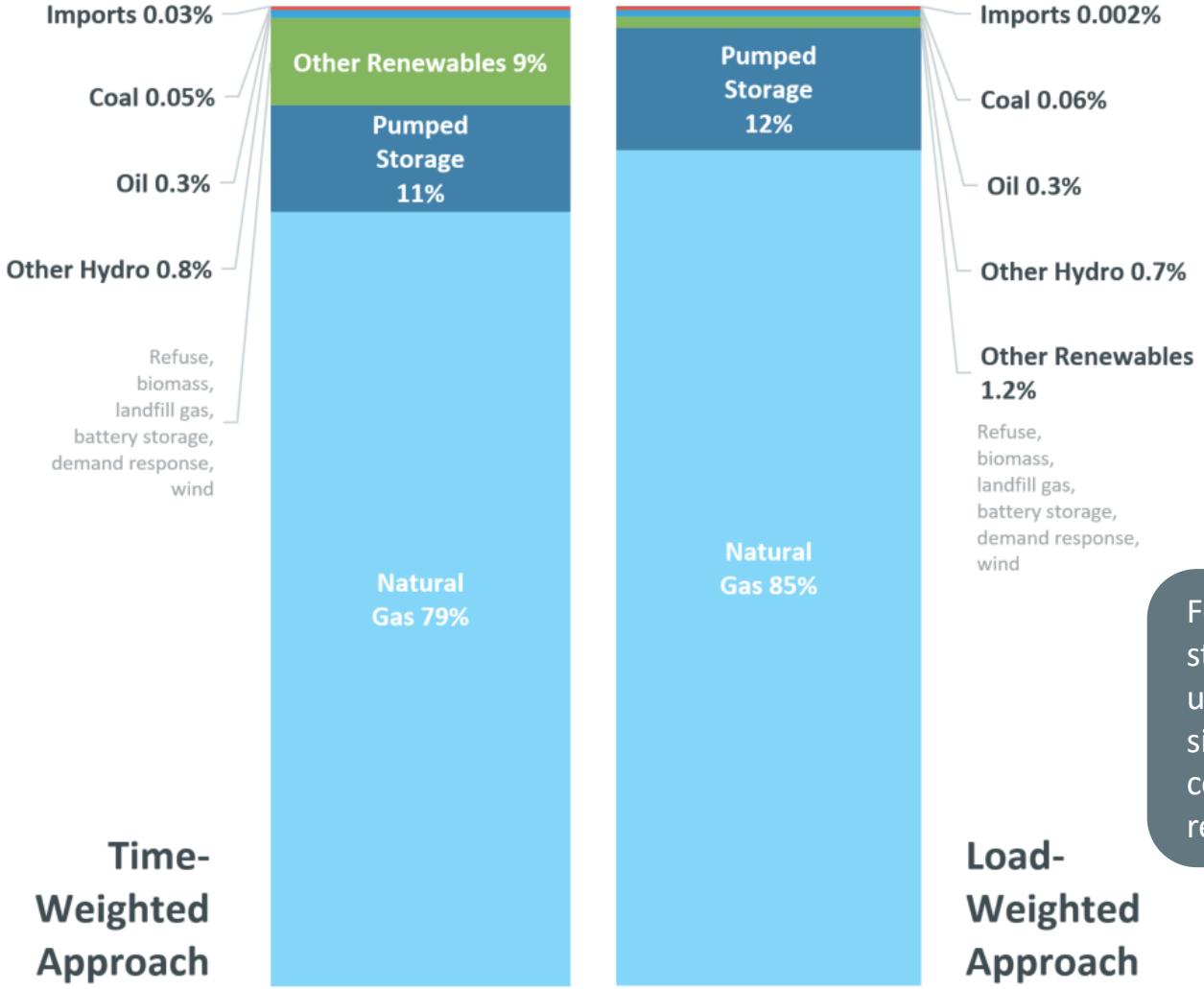


Note: Other Renewables consists of biomass, refuse, landfill gas, battery storage resources, demand response, and wind.

2023 Percent of Time/Load Unit Type Was Marginal

All-LMUs – Time- and Load-Weighted

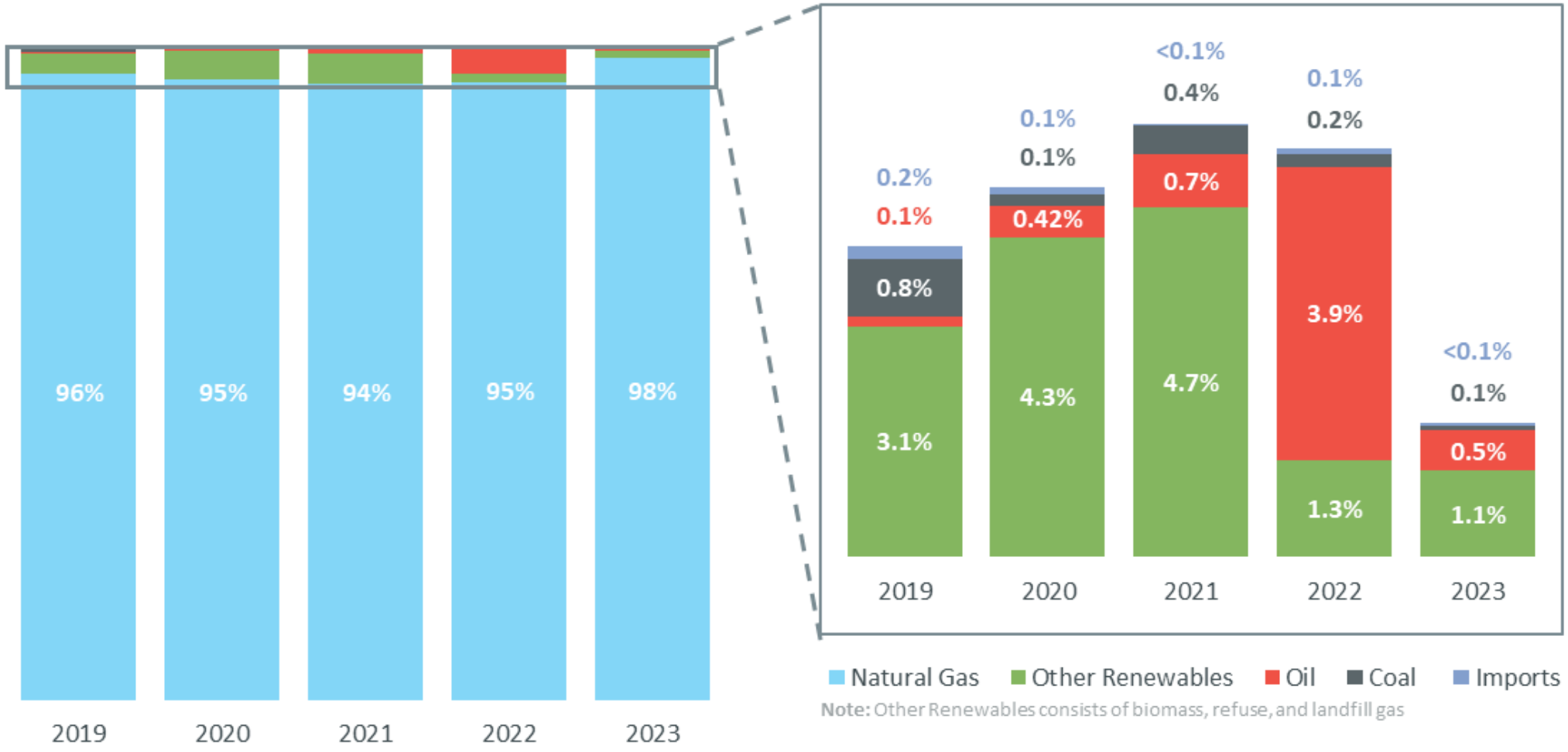
In the Other Renewables category, wind was marginal 8% of the time based on the time-weighted approach, but only 0.4% for the load-weighted. The remaining marginal units in that category consists of wood/wood waste solids, refuse plants, and demand response resources.



Fossil fuel resources and pumped storage are typically more marginal under the load-weighted approach since they are not located in export constrained areas like other renewables and imports.

2019 – 2023 Percent of Time Unit Type Was Marginal

Emitting-LMUs – Time-Weighted

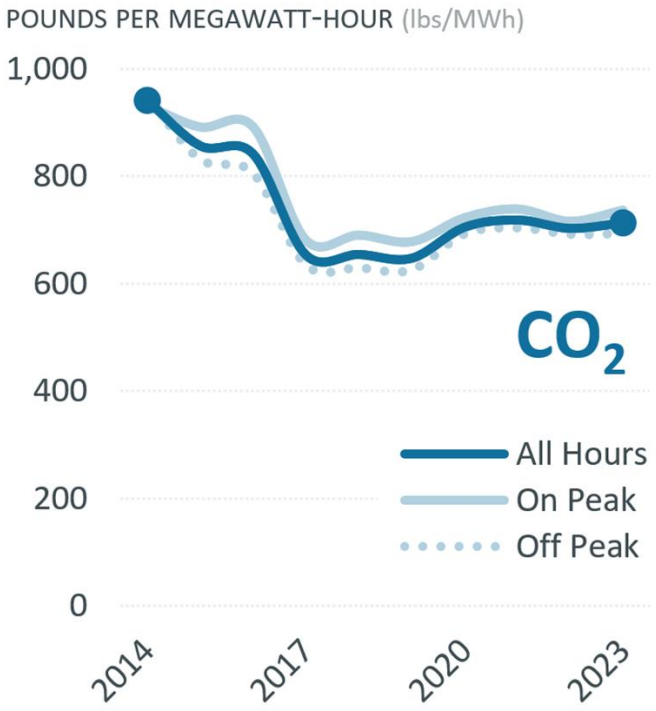


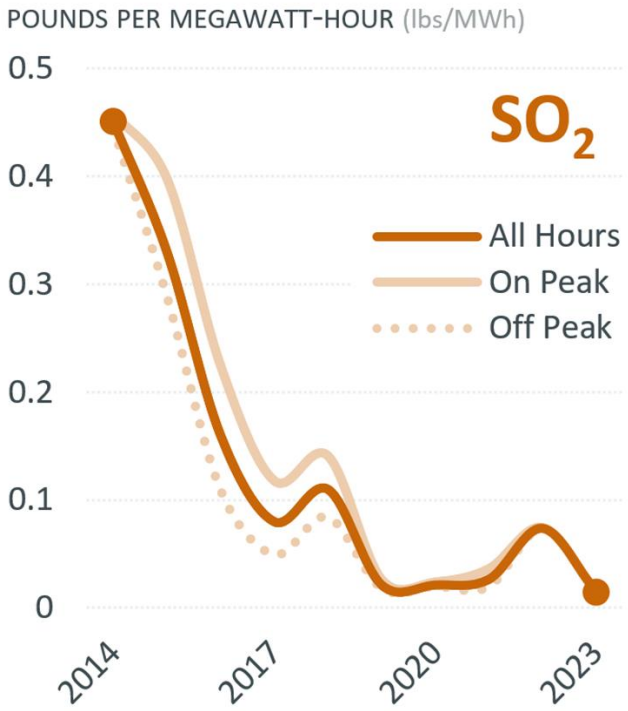
2023 Percent of Time/Load Unit Type Was Marginal

Emitting-LMUs – Time- and Load-Weighted

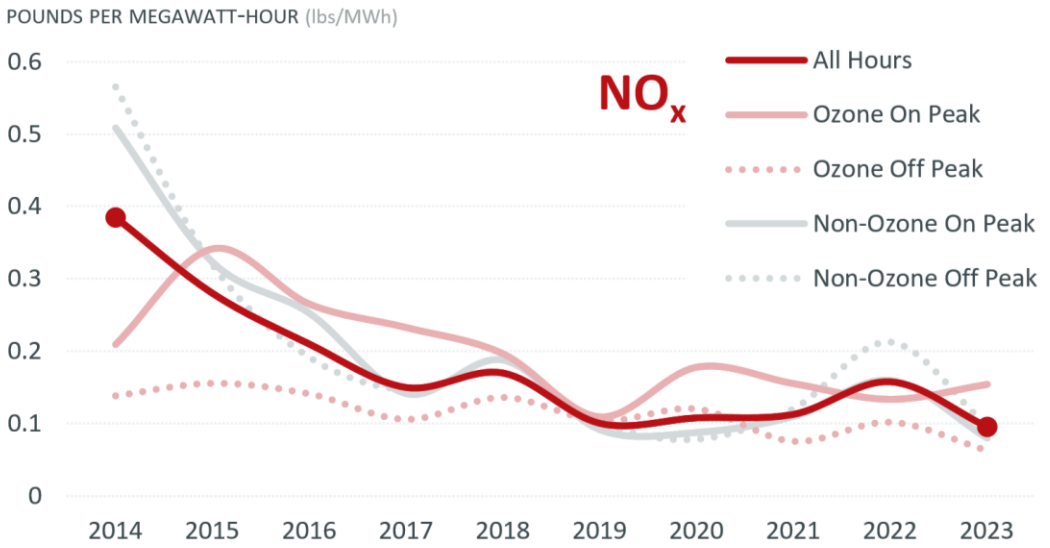
2014 – 2023 Marginal Emission Rates (lbs/MWh)

All-LMUs – Time-Weighted



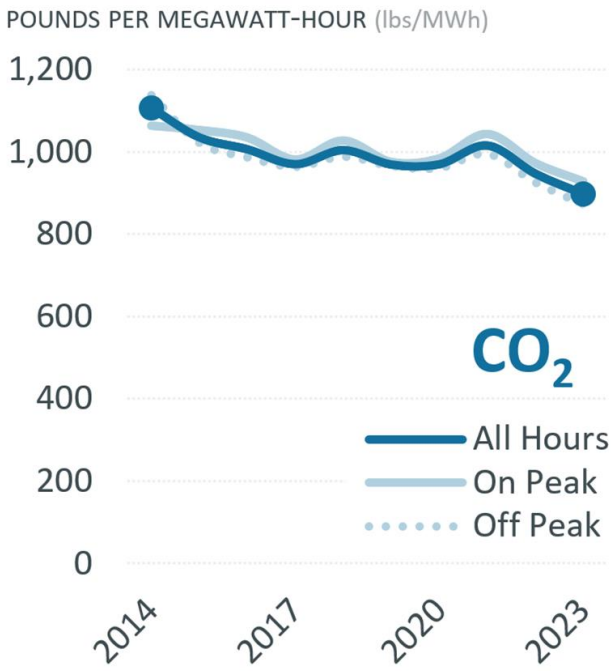


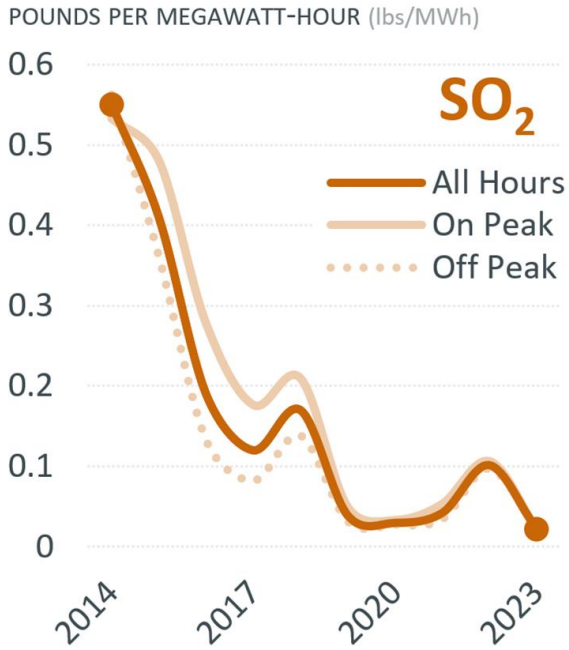
Overall decreasing trend in the marginal emission rates for SO_2, NO_X, and CO_2 in the past 10 years



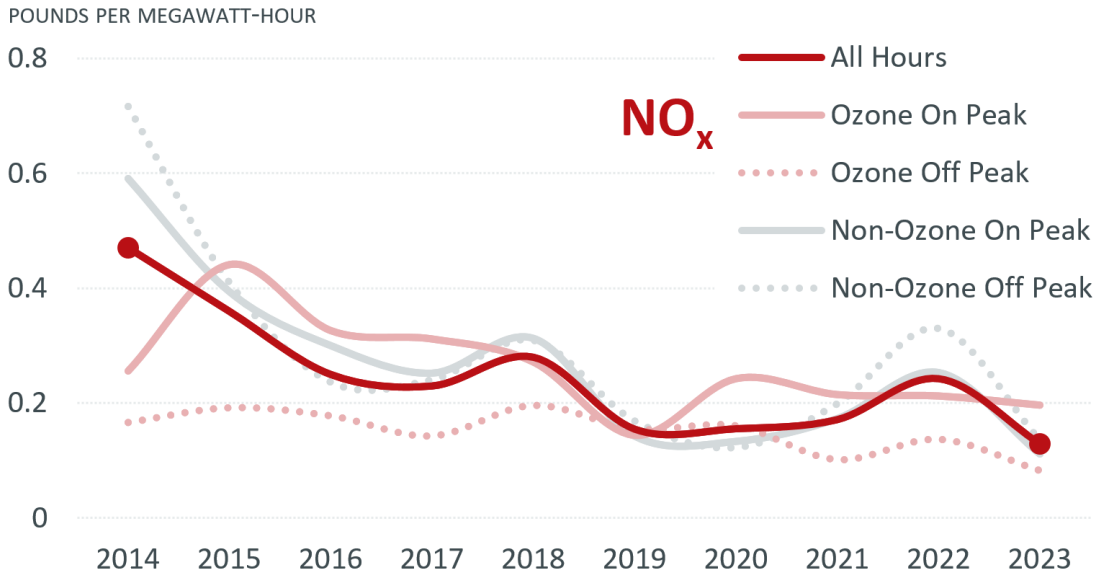
2014 – 2023 Marginal Emission Rates (lbs/MWh)

Emitting-LMUs – Time-Weighted



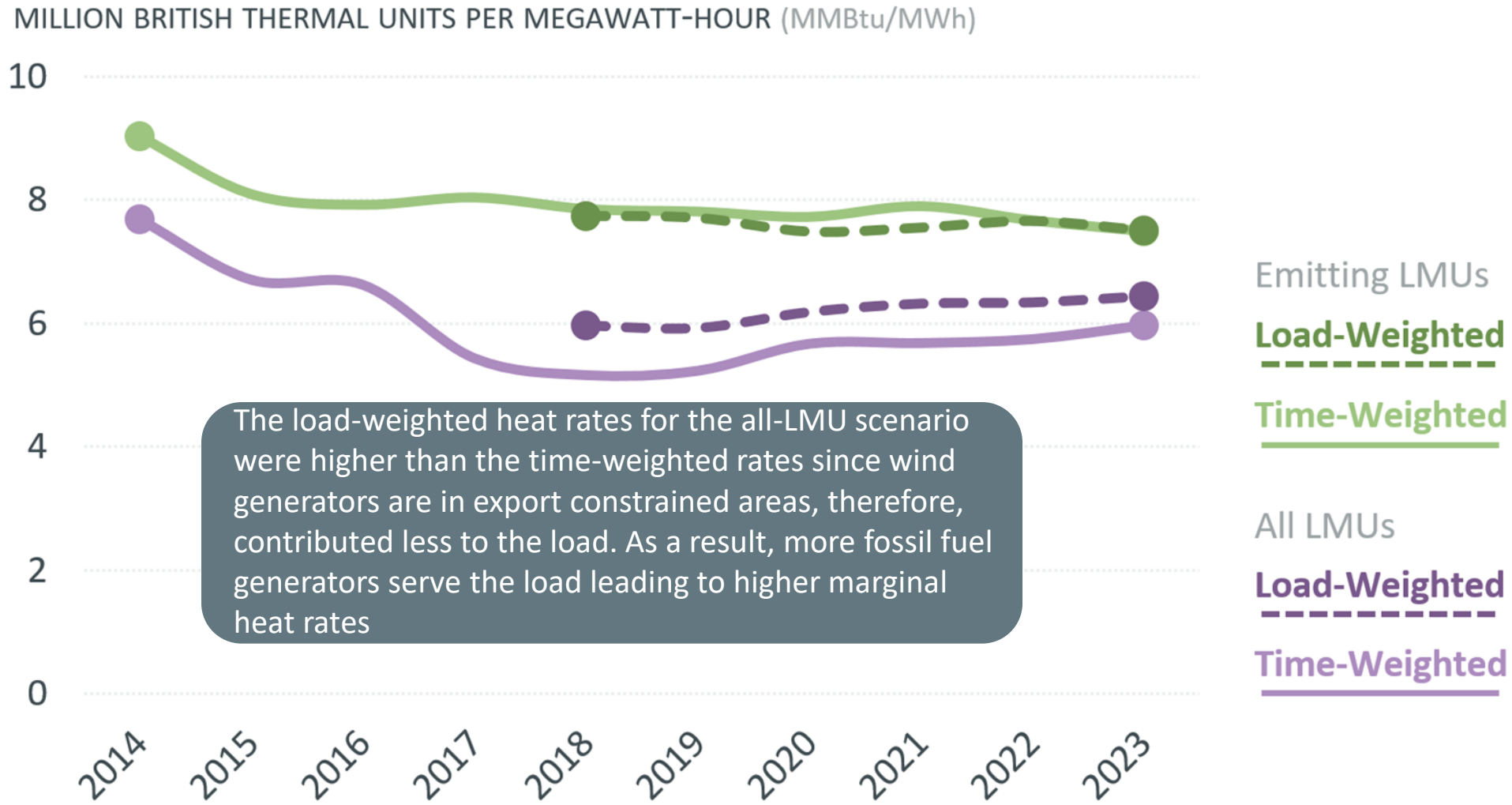


The emitting-LMU emission rates are higher than the all-LMU because the all-LMU scenario includes zero-air-emission resources that lower the marginal emission rate



2014 – 2023 Time-Weighted Marginal Heat Rates (MMBtu/MWh)

Load-Weighted values shown for 2018 - 2023



See Appendix for details

Key Takeaways

- The results of the 2023 emissions analysis showed a reduction in emissions of all three pollutants CO_2, NO_X, and SO_2
- The emission reductions can be attributed to:
  - Mild summer and winter weather and growth in BTM solar resulted in lower average loads than prior year
  - Stored fuel from higher carbon emitting resources such as oil and coal were not needed as often in 2023 as compared to 2022

Next Steps

- Post final 2023 *Emissions Report* in Q4 2024
  - Executive Summary
  - Appendix spreadsheet with all figures and tables

Questions

Appendix – Data Sources for Resources with No Reported Emissions Data

- For those resources that do not have EPA CAMPD, NEPOOL GIS, or eGRID emissions data, emission rates must be assumed in some other way. Examples of those types of situations are:
  - Fuel cells that have no reported data, or biomass units that are not required to report emissions
    - The assumed emission rate is calculated based on the average reported rate for existing resources of the same unit and fuel type
  - New natural gas or oil-fired units with no available data
    - The assumed emission rate is calculated based on the average reported rate of other existing units of the same type and similar age

Appendix – 2022-2023 Changes in Energy, Demand, and Generation

- Net Energy for Load (NEL) decreased 4,204 GWh (- 4%)
  - 118,930 GWh in 2022 to 114,726 GWh in 2023
- New England Generation decreased 2,599 GWh (- 3%)
  - 103,887 GWh in 2022 to 101,289 GWh in 2023
- Net Flow Over External Ties decreased 1,672 GWh (- 10%) (importing)
  - 16,776 GWh in 2022 to 15,104 GWh in 2023
- Summer Peak Demand decreased 1,356 MW (- 2%)
  - 24,445 MW in 2022 vs. 24,043 MW in 2023
- Energy Generation by Primary Fuel Types (from 2022 to 2023)
    - Natural Gas (NG): +1,716 GWh (+ 3%)
    - Coal: - 139 GWh (- 44%)
    - Oil: - 1,523 GWh (- 83%)
    - Nuclear: - 4,183 GWh (- 15%)
    - Other Renewables: - 28 GWh (- 0.5%)
    - Wind and Solar: - 345 GWh (- 5%)
  - Increase in hydro generation
    - Hydro: + 1,903 GWh (+ 25%)

Appendix – 2022 & 2023 Annual Average Emissions and Emission Rates for New England Generation and Imports

2022 and 2023 ISO New England Average Emissions (ktons) and Emission Rates (lbs/MWh)						
	2022 Emissions (ktons)	2023 Emissions (ktons)	Total Emissions % Change	2022 Emission Rate (lbs/MWh)	2023 Emission Rate (lbs/MWh)	Emission Rate % Change
New England Generation Only						
NO_X	12.30	10.66	-13.3	0.24	0.21	-11.1
SO_2	3.38	1.77	-47.7	0.07	0.03	-46.4
CO_2	33,382	32,050	-4.0	643	633	-1.5
Total System Emissions with Imports						
CO_2	34,106	33,215	-2.6	566	571	0.9

- Assumed emission import rates (based on annual averages):
  - New Brunswick and Quebec values are the average of the 2020-2022 rates, and New York is the eGRID2022 value
    - New Brunswick: 680 lbs/MWh
    - New York: 504 lbs/MWh
    - Quebec: 3.9 lbs/MWh

Appendix – Marginal Emission Rates (lbs/MWh)
2022 vs. 2023 Time-Weighted and Load-Weighted

2022 and 2023 Annual Time-Weighted and Load-Weighted LMU Marginal Emission Rates (lbs/MWh, %)						
	Time-Weighted			Load-Weighted		
All LMUs	2022 Annual Rate	2023 Annual Rate	Percent Change 2022 to 2023	2022 Annual Rate	2023 Annual Rate	Percent Change 2022 to 2023
	(lb/MWh)	(lb/MWh)	(%)	(lb/MWh)	(lb/MWh)	(%)
All LMUs						
NO_X	0.16	0.10	-39%	0.17	0.10	-39%
SO_2	0.07	0.01	-80%	0.08	0.02	-78%
CO_2	704	714	1%	778	773	-1%
Emitting LMUs						
NO_X	0.24	0.13	-47%	0.23	0.13	-45%
SO_2	0.10	0.02	-78%	0.10	0.02	-79%
CO_2	948	899	-5%	947	905	-4%

Appendix – Marginal Heat Rates 2014-2023 (MMBtu/MWh)

LMU Marginal Heat Rate 2014 to 2023 (MMBtu/MWh) (a)				
	Time-Weighted		Load-Weighted	
Year	All LMUs	Emitting LMUs	All LMUs	Emitting LMUs
2014	7.692	9.034		
2015	6.707	8.096		
2016	6.625	7.925		
2017	5.428	8.043		
2018	5.153	7.855	5.962	7.744
2019	5.223	7.815	5.918	7.716
2020	5.664	7.728	6.178	7.491
2021	5.676	7.902	6.313	7.557
2022	5.739	7.672	6.333	7.665
2023	5.964	7.495	6.433	7.510

(a) Prior to 2018, only the time-weighted approach was used to calculate marginal heat rate.