Economic Planning for the Clean Energy Transition (EPCET) Pilot Study

2032 Multiple Weather Year Results

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ECONOMIC STUDIES AND ENVIRONMENTAL OUTLOOK

Overview

- EPCET Pilot Study overview
- Overview of Multiple Weather Year Analysis
- Production Cost Results
- Fuel Consumption Results
- Short Term Fuel Drawdown / Energy Drawdown Results

EPCET Pilot Study Overview

- As part of the 2021 Economic Study (Future Grid Reliability Study – Phase I), the ISO identified areas for improvement in our current Economic Study framework and software tools to perform the analyses
- The ISO filed Tariff revisions for Phase 1 of the Economic Studies process improvements with the Federal Energy Regulatory Commission on January 27, 2023, which were accepted and went into effect on March 31, 2023
- The overall goal of the EPCET study is to prepare our models, tools, and processes such that informative and actionable results can be more readily produced in future Economic Study cycles
- The EPCET is a pilot study and not an Economic Study under the Tariff. The EPCET is a research and development effort that will help inform future study work and the next steps of the Economic Study Process Improvements. As such, the ISO will not be pursuing a market efficiency Needs Assessment under the Tariff based on EPCET results.
- The EPCET study has three main objectives:
  - Take a deep dive into all input assumptions in economic planning analyses, propose updates to any assumptions based on our current experience, and test the effect of those modeling changes
  - Gain experience in the features and capabilities of our new economic planning software
  - Perform a trial run of the Economic Study process improvements

EPCET Pilot Study Scenarios

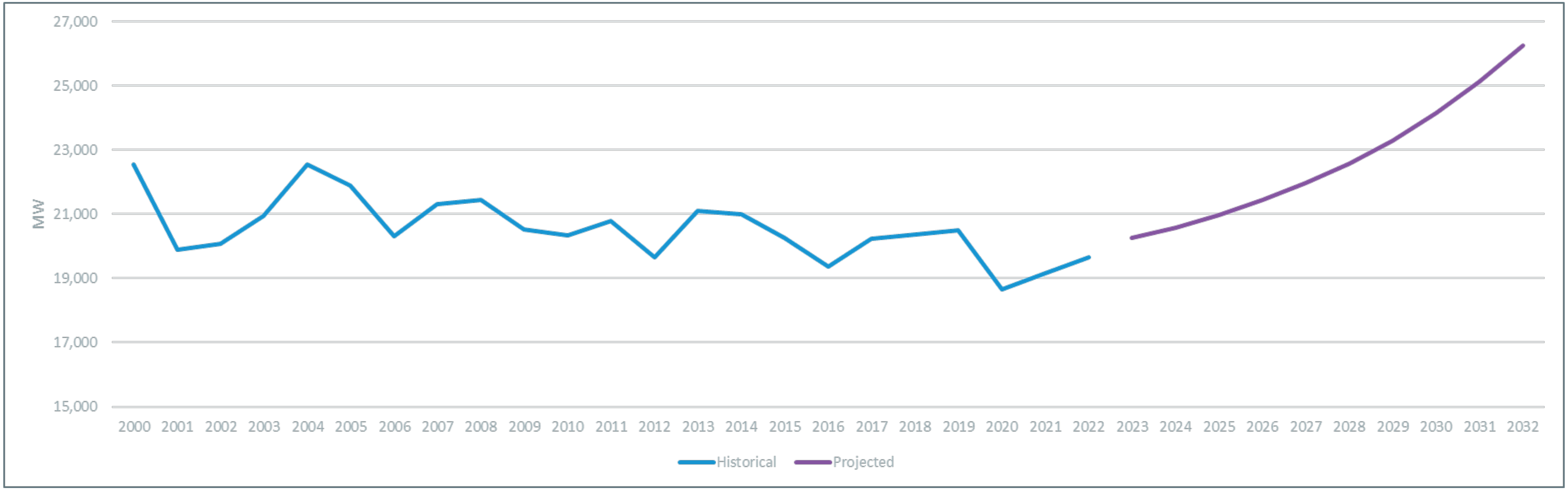
- ✓ **Benchmark scenario** – Model previous calendar year and compare it to historical system performance. This scenario's purpose is to test fidelity of models against historical performance and improve the models for future scenarios
- ✓ **Market Efficiency Needs scenario (MENS)**– Model future year (10-year planning horizon) based on the ISO's existing planning criteria to identify market efficiency issues that could meet the threshold of a market efficiency need and move on to the competitive solution process for market efficiency needs
- **Policy scenario** – Model future years (>10-year planning horizon) based on satisfying New England region and other energy and climate policies
- **Stakeholder Requested scenario** – After the initial results of the reference scenarios are presented to stakeholders, invite sensitivity requests to test the effect of a specific change to input assumptions (e.g., resource mix, transmission topology, etc.)

MULTIPLE WEATHER YEAR ANALYSIS OVERVIEW

Overview of Analysis

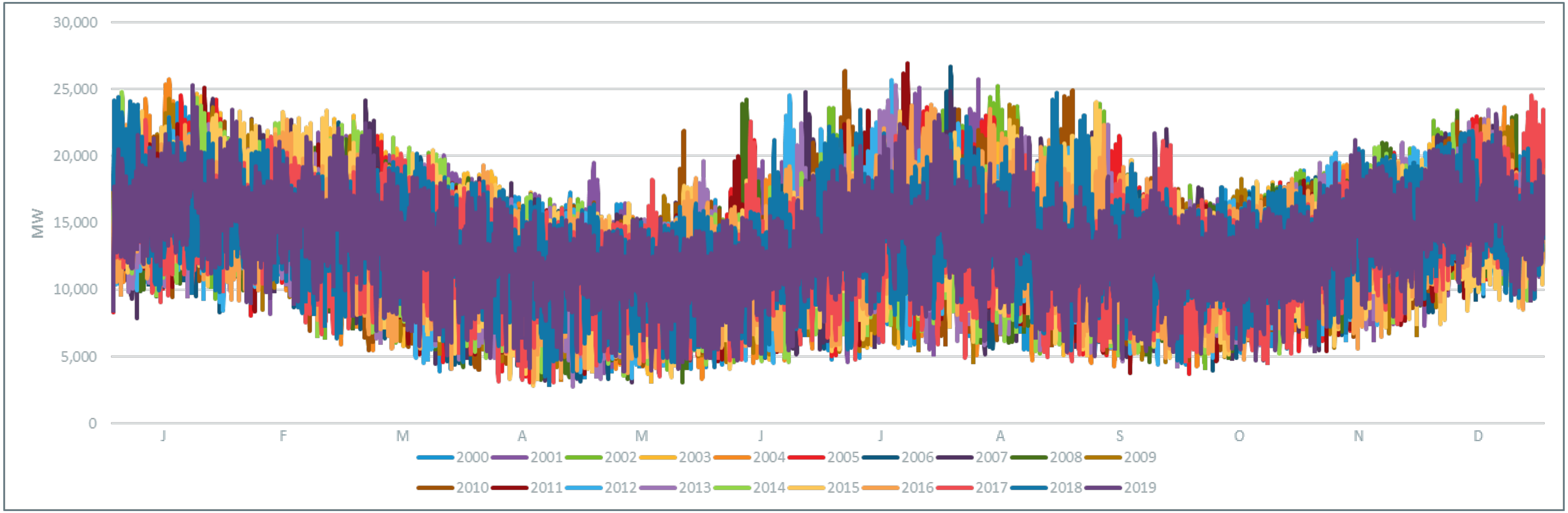
- The ISO has previously presented 2032 results for the Market Efficiency Needs scenario (MENS)
  - These models were both constrained and unconstrained, and the main purpose was to show the economic impacts of congestion of the currently planned system
- The ISO has since released the 2023 Capacity, Energy, Loads, and Transmission (CELT) Report which included new and augmented heating and transportation electrification forecasts
- The 10-year horizon electrification load has increased significantly from previous forecasts. In particular, the winter peak demand was expected to increase by nearly 3% annually
- To quantify the impacts of the increased electrification demand, the ISO has run 20 weather years of data through the 2032 MENS model with updated load profiles
- Generator outages have not been modeled in these scenarios

Historical & Projected Winter Peak Loads



- Winter peak loads have been trending downward in the past 20 years, with the all time record at 22,818 MW in January 2004
- Electrification is projected to rapidly increase winter peak loads, with the 2032 50/50 net load reaching 26,267 MW

Scaled 2032 Net Loads



- 2032 load profiles originated from the 2022 CELT Report, but heating and electrification profiles have been scaled to the 2023 CELT Report models and added to 50/50 base loads
- Minimum loads get lower in the spring/fall, with a minimum of 2,873 MW in the 2013 weather year
- These loads have been run through the 2032 MENS case for this analysis

PRODUCTION COST RESULTS

Overview of Results

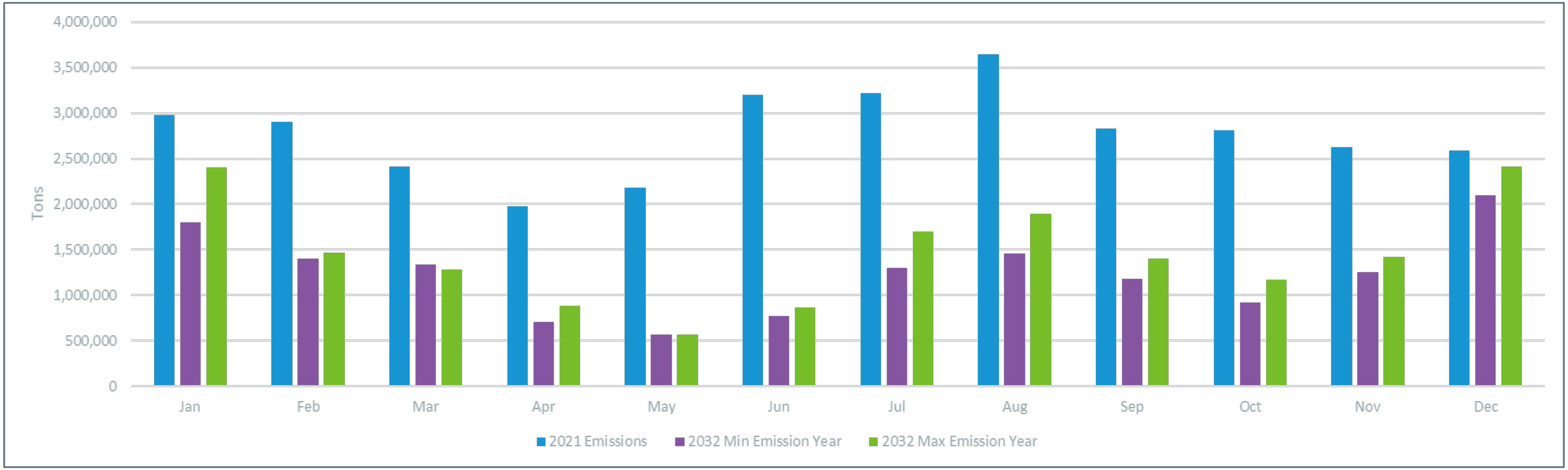
- Emissions are still significantly reduced compared to today's system, averaging 16.3 million tons of carbon per year (compared to 30.3 million tons in 2021)
  - Emission reductions are most prevalent in the spring, summer, and fall
- Production cost and LMPs are also lower than recently observed due to more zero cost energy resources being online in 2032. These zero cost resources mostly displace gas generation
- However, due to the additional electrified load and continued existence of fuel constraints, coal and oil generation are higher in the winter than in recent years
- The system may experience an increase in reliance on stored fuels (LNG, oil, and coal) in the winter despite the new wind, solar, and energy storage resources

Generation by Fuel Type for 20 Weather Years (GWh)

	ADR	COAL	OIL	LFG/MSW /WOOD	LNG	NG	NUC	HYDRO	PV	LBW	OSW	IMPORTS	Total
Max	7	694	1,731	6,493	4,103	28,941	29,600	6,258	15,083	4,542	14,513	27,174	132,130
Min	0	167	80	6,172	546	21,746	29,600	5,723	13,494	3,889	12,546	26,908	127,620
Mean	2	456	822	6,334	2,146	24,867	29,600	6,001	14,501	4,193	13,830	27,041	129,781

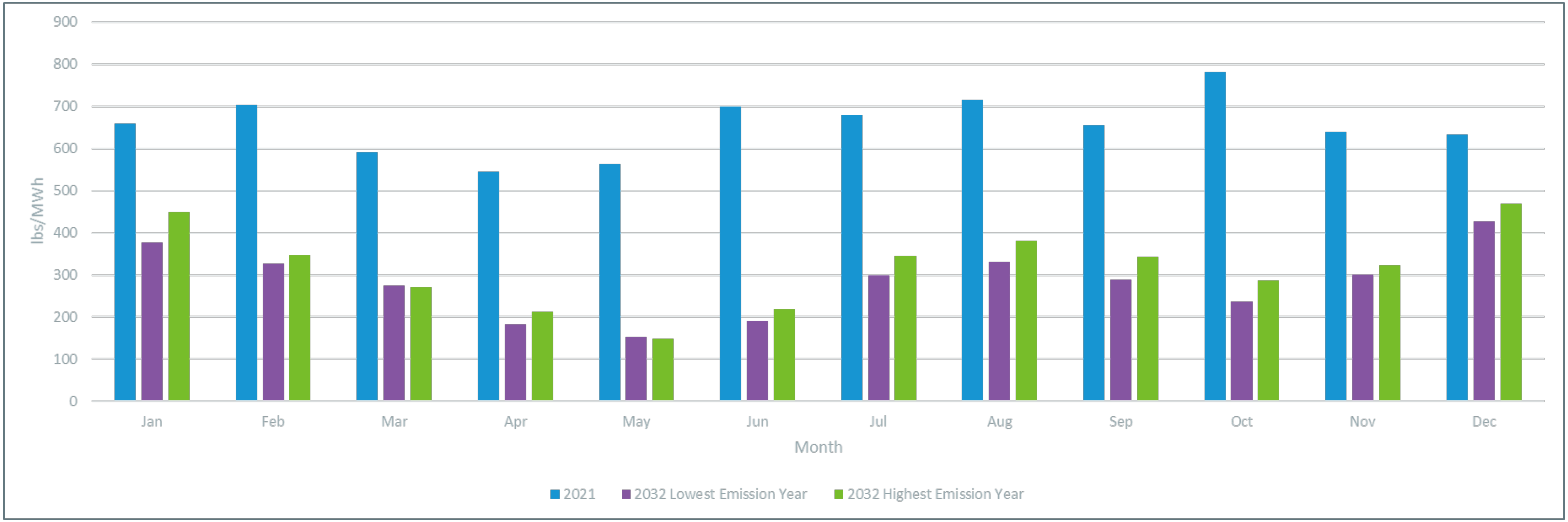
- New PV, OSW, and imports via NECEC reduce average gas generation by ~47% compared to 2019-2022 historical averages
  - Mean of 27,000 GWh (NG plus LNG) in 2032 vs. 51,000 GWh mean from 2019-2022
- Mean of coal and oil generation increase by ~45% compared to 2019-2022
  - Mean of 1,278 GWh in 2032 vs. 900 GWh from historical 2019-2022 average
  - Years with cold winters had increased generation from oil and coal - the 2015 weather year had 2.4 TWh

Monthly Emissions for 20 Weather Years



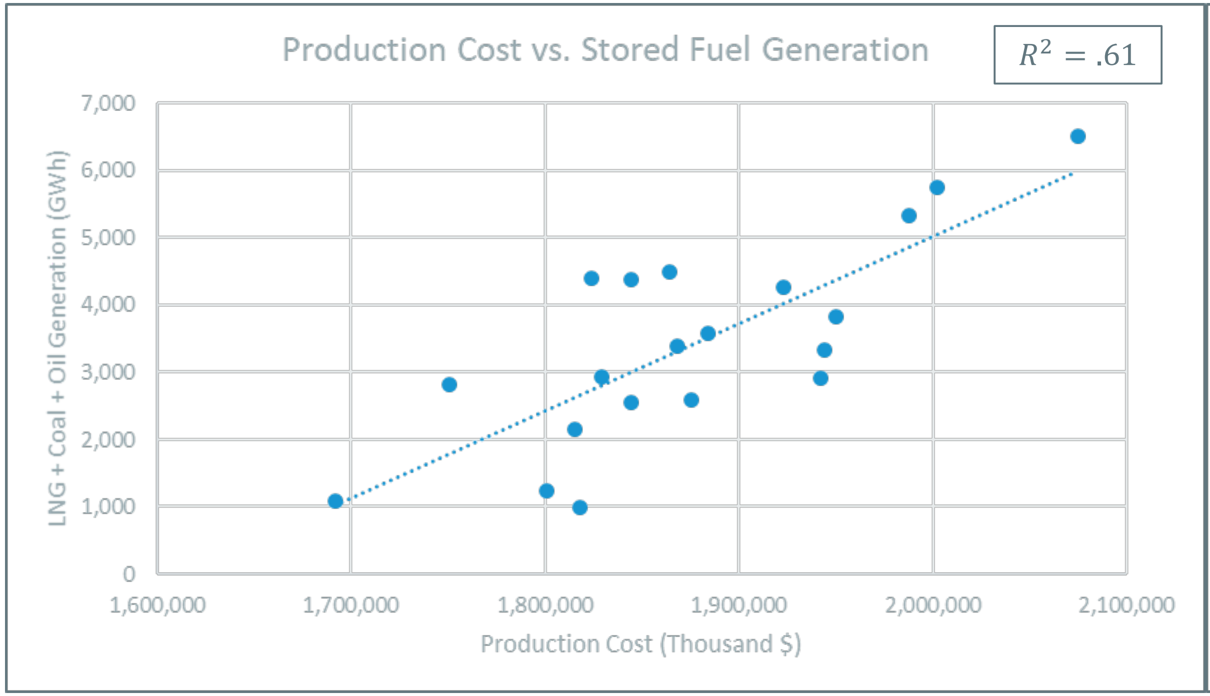
- The largest emission reductions have been achieved in the spring, summer, and fall months. Winter emissions are reduced less due to NG + LNG constraints and higher electrified load
  - The winter months become the highest emitting months in all 2032 models
- In 2021, New England generator carbon emissions totaled 30.3 million tons
- The 2032 generator air emissions ranged from 15.1 million to 17.2 million tons. Emissions averaged 16.3 million tons (a 46% reduction)

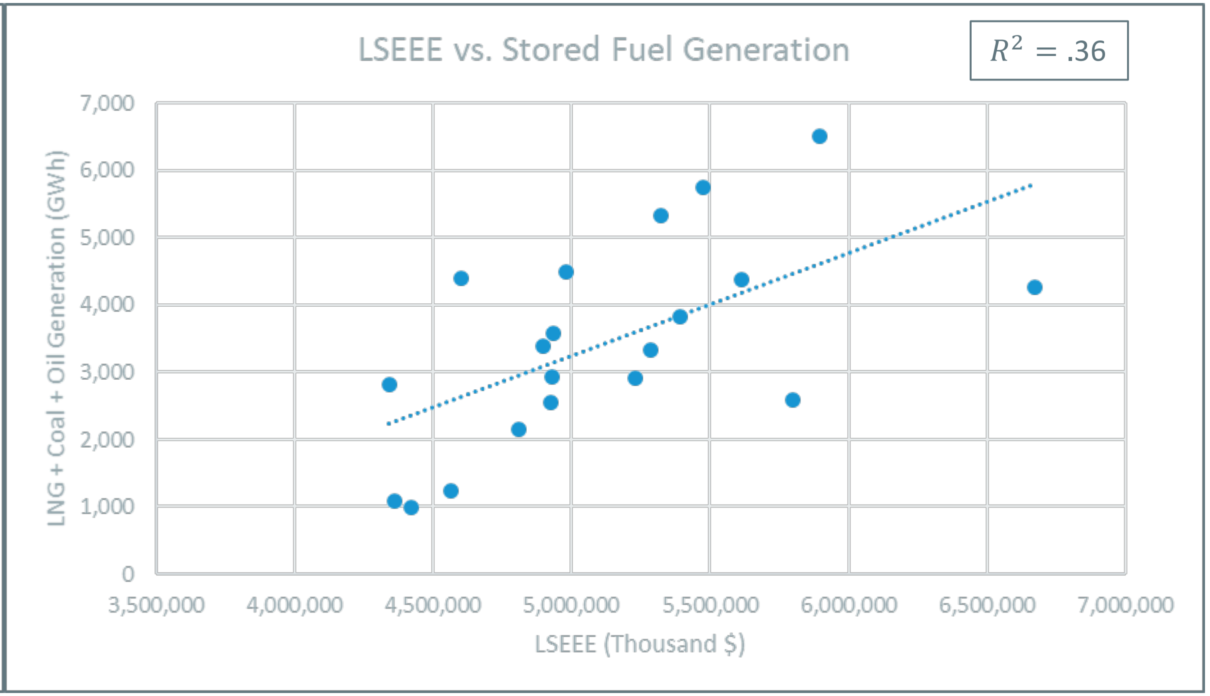
Monthly Emission Rates for 20 Weather Years



- Average emission rates are significantly reduced from 2021, falling to a range of 293-320 lbs/MWh from the historical 2021 rate of 658 lbs/MWh
  - Emission rates are for New England generation only, does not include imports or energy efficiency
- Just as with overall emissions, the reductions are lowest in the winter months. The spring and fall months experience the greatest reduction in emission rates
  - Winter emission rates could still reach 450-500 lbs/MWh in 2032

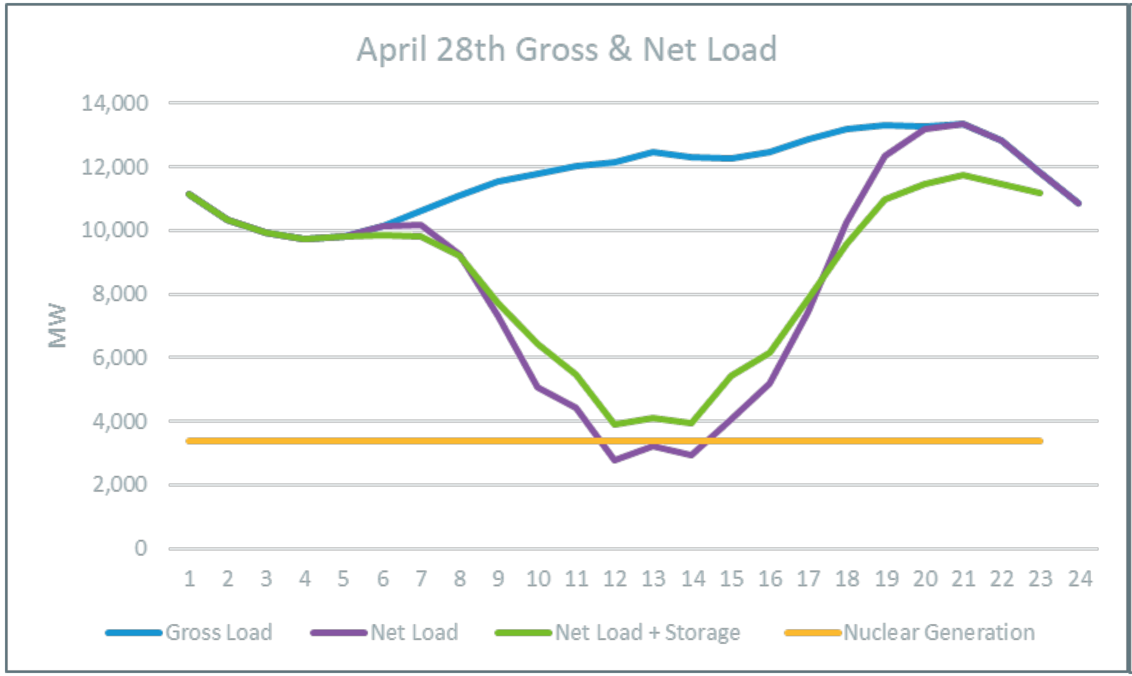
Production Cost and LSEEE for 20 Weather Years

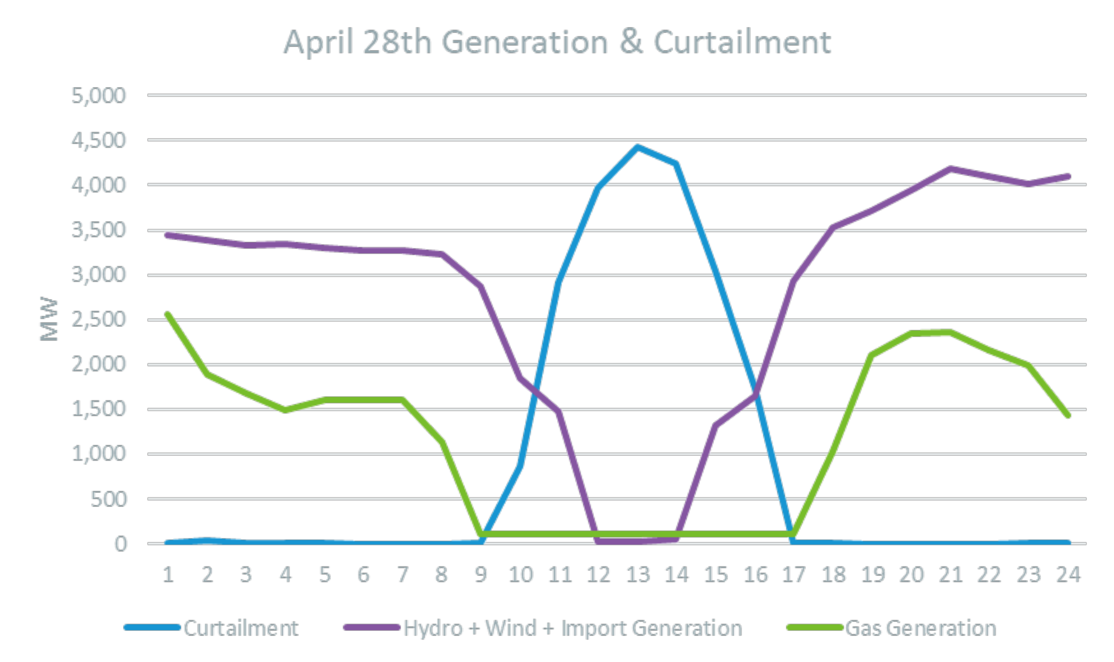




- Production costs range from $2.07 billion to $1.69 billion, with an average of $1.88 billion
- LSEEE range from $6.67 billion to $4.34 billion, with an average of $5.12 billion
- Higher production costs and LSE energy expenses are positively associated with colder winters, which have higher load and require more expensive stored fuel (LNG, coal, and oil) generation to run

Minimum Load Dispatch





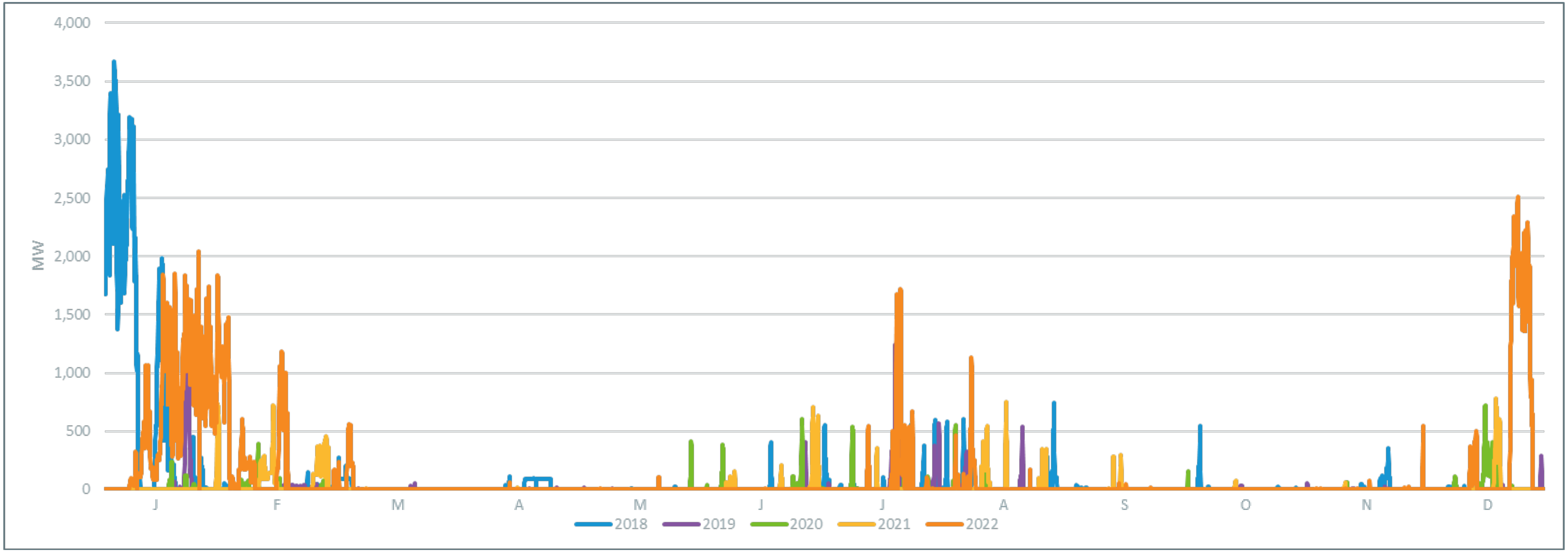
- Net load reaches 2,873 MW on April 28th, 2032 (2013 weather year) at 1 PM. Load is reduced by 9.3 GW from BTM-PV
- Load is kept above the nuclear generation level by energy storage. The model has perfect foresight and dispatches the energy storage fleet optimally, which may not be replicable in a bid based market. Also, there are no cycling or ramping limits on modeled BESS units
- Ramping flexibility is being provided by curtailment of wind/imports. The flexibility demand on gas generators is not especially high, but it could be on a day with less wind/imports to curtail

FUEL CONSUMPTION RESULTS

Overview of Results

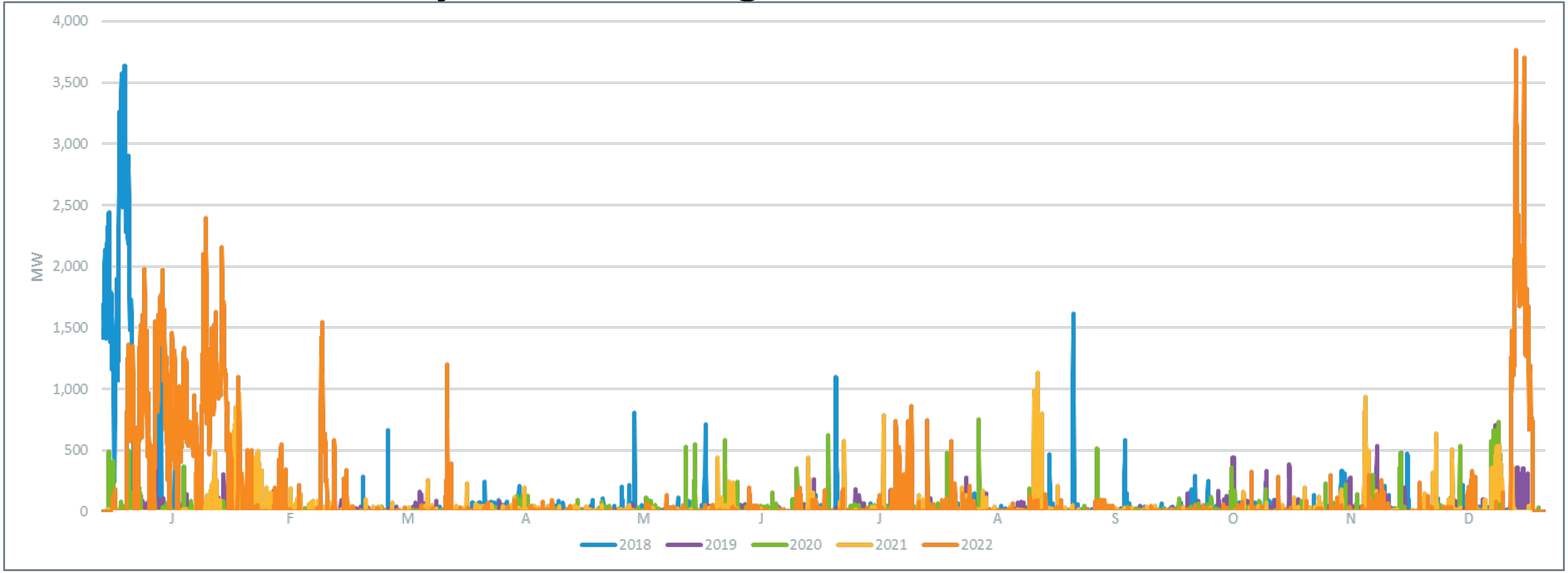
- With the additional electrified winter load, the ISO has observed significant stored fuel generation in winter months. Despite the contribution of new wind, PV, and imports, the stored fuel consumption is increased compared to historical levels
- Daily pipeline gas and LNG consumption was constrained according to the ICF natural gas topology tool. However, LNG total inventories were not constrained, and there was no modeling of refueling
  - Oil inventories were also not constrained. However, drawdowns have been tracked for each fuel type
  - Rather than performing a reliability analysis by tracking inventories, this analysis seeks to examine the total fuel demand
- Based on available generators and input fuel prices, dispatch order is (roughly):
  - NG -> LNG -> Coal -> Heavy Oil -> Light Oil
- The slides in this section will show hourly historical (2018-2022) and modeled (2032 model year, 2000-2019 weather year) stored fuel generation, as well as fuel drawdowns over modeled 2032 winters (Oct – April)

2018-2022 Hourly Historical Heavy Oil Generation



- Past few winters have been relatively mild besides the start of 2018 and two periods of high oil generation in 2022

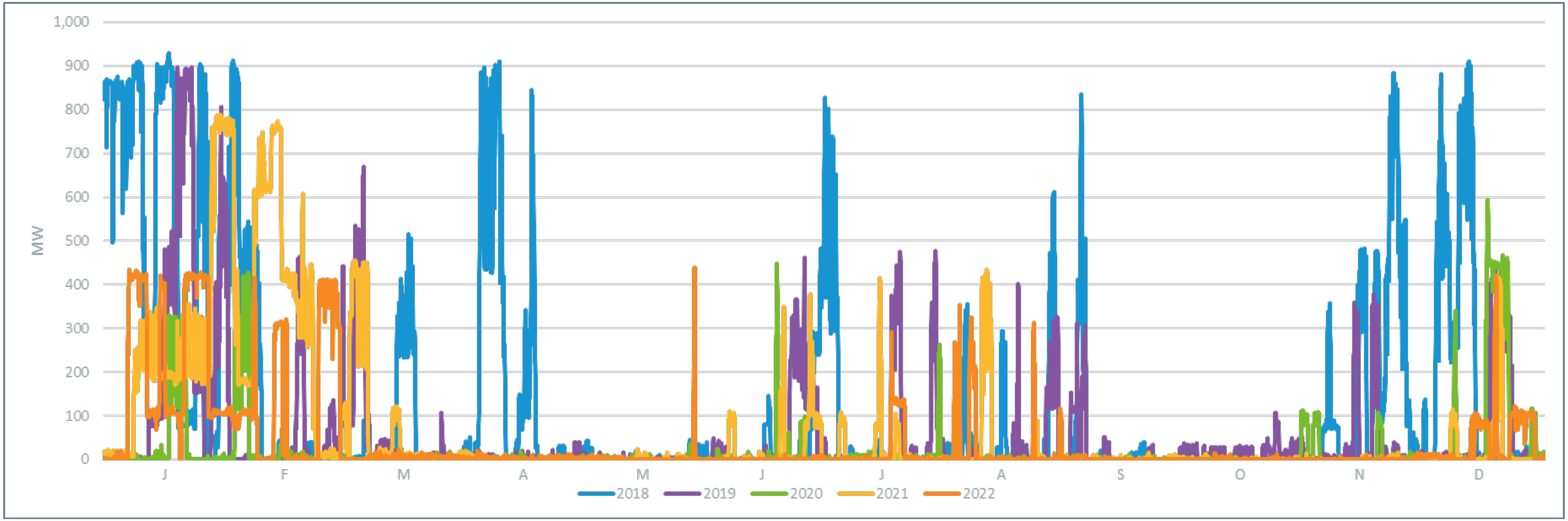
2018-2022 Hourly Historical Light Oil Generation



- Similar trends to heavy oil – aside from some summer peak conditions, generation is relatively low except for early 2018 winter and early/late 2022 winter

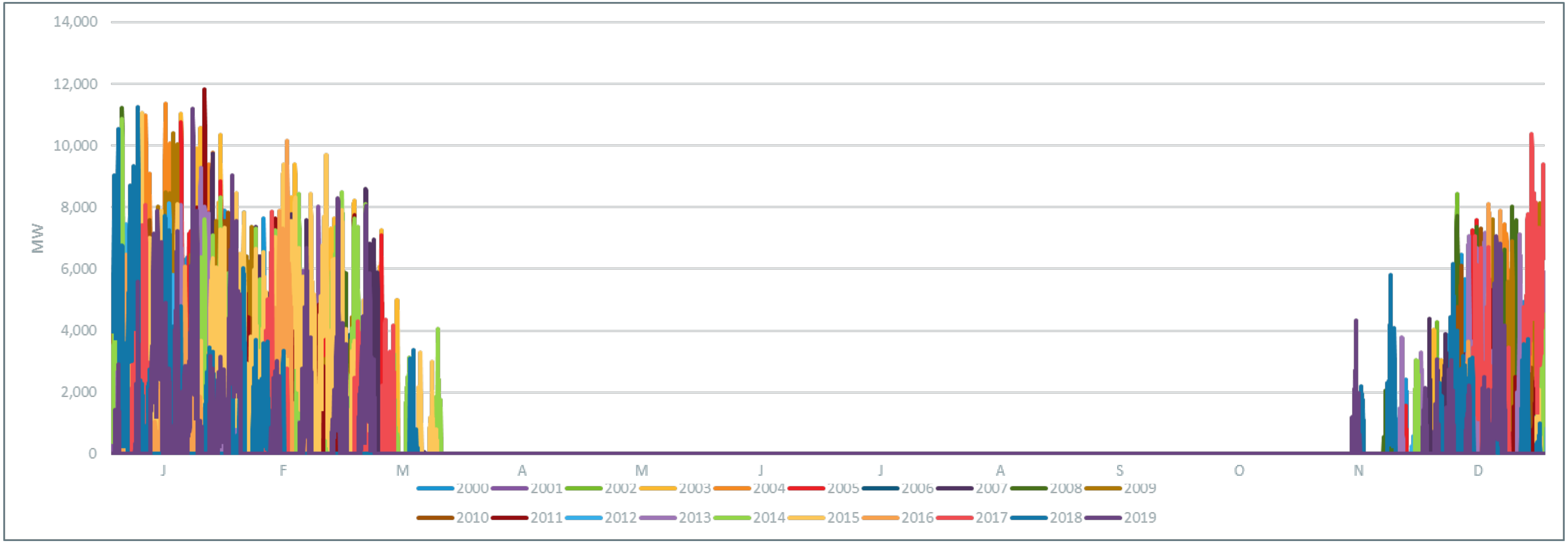
PRELIMINARY RESULTS, DO NOT CITE

2018-2022 Hourly Historical Coal Generation



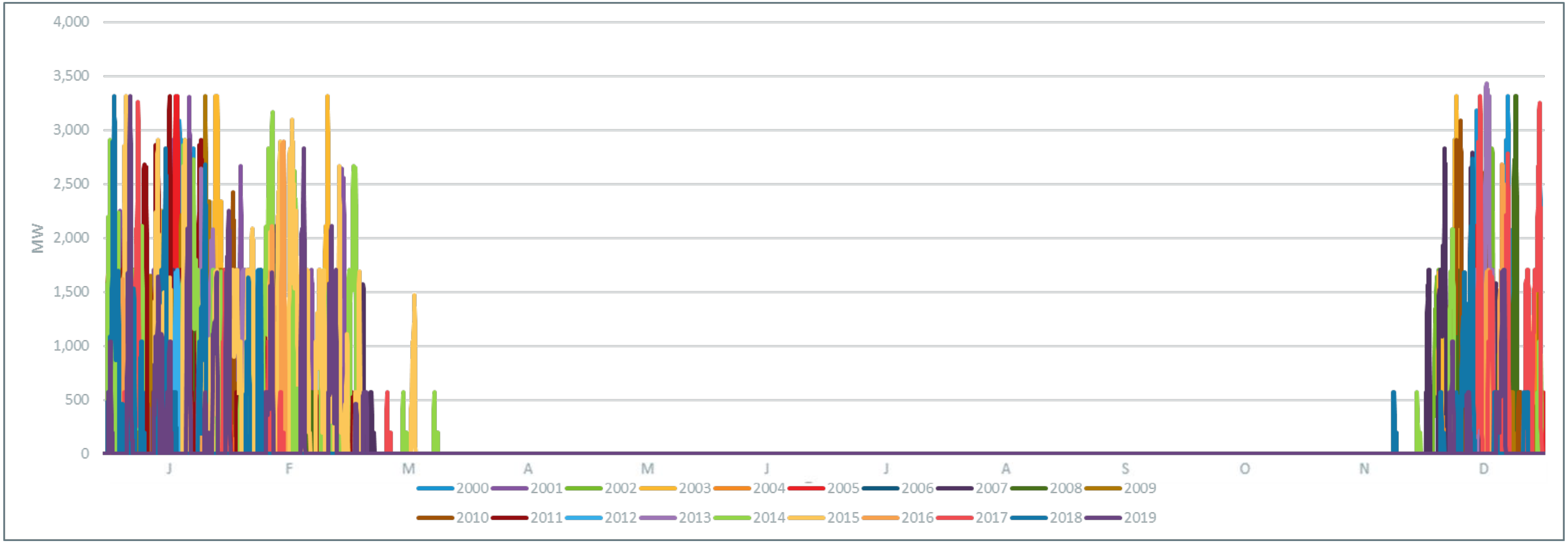
- Coal generation has declined with the retirement of legacy coal units
- In recent years, coal units have mostly run during winter periods

Hourly LNG Generation for 20 Weather Years



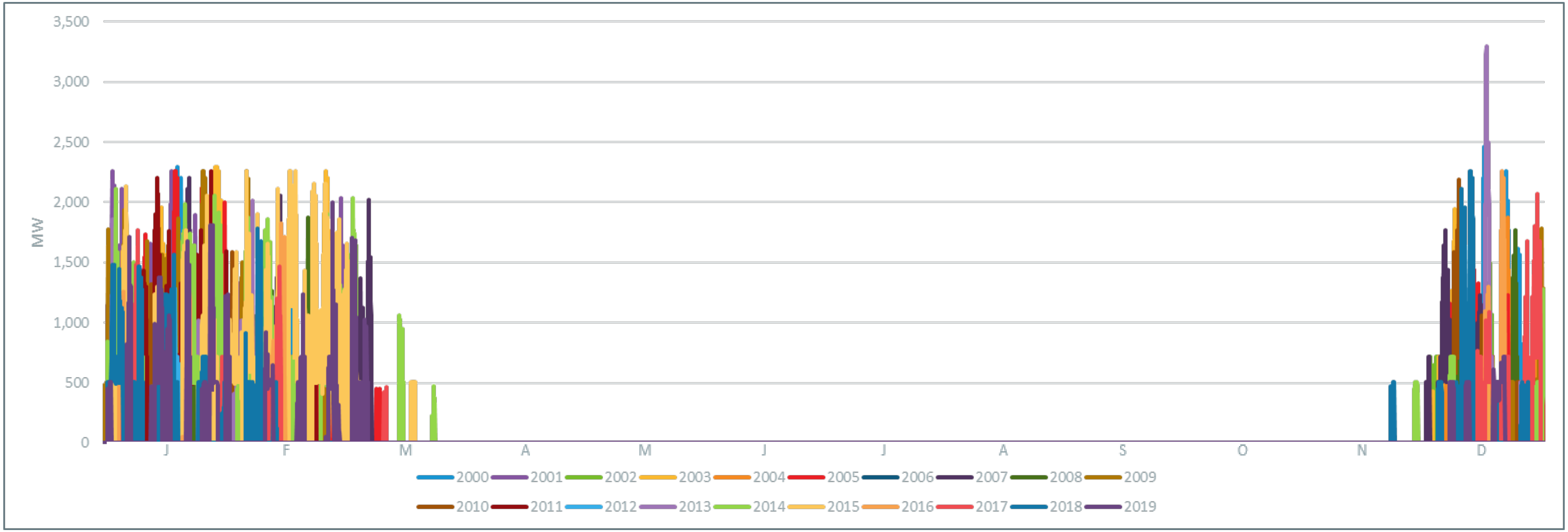
- Average peak generation of 9,996 MW and annual generation of 2,146 GWh
- 2015 weather year generated 4,103 GWh from LNG (~45 Bcf for electric sector)
- Daily LNG allocations allow for more generation in evening when middle of the day PV reduces demand for electric gas generation

Hourly Heavy Oil Generation for 20 Weather Years



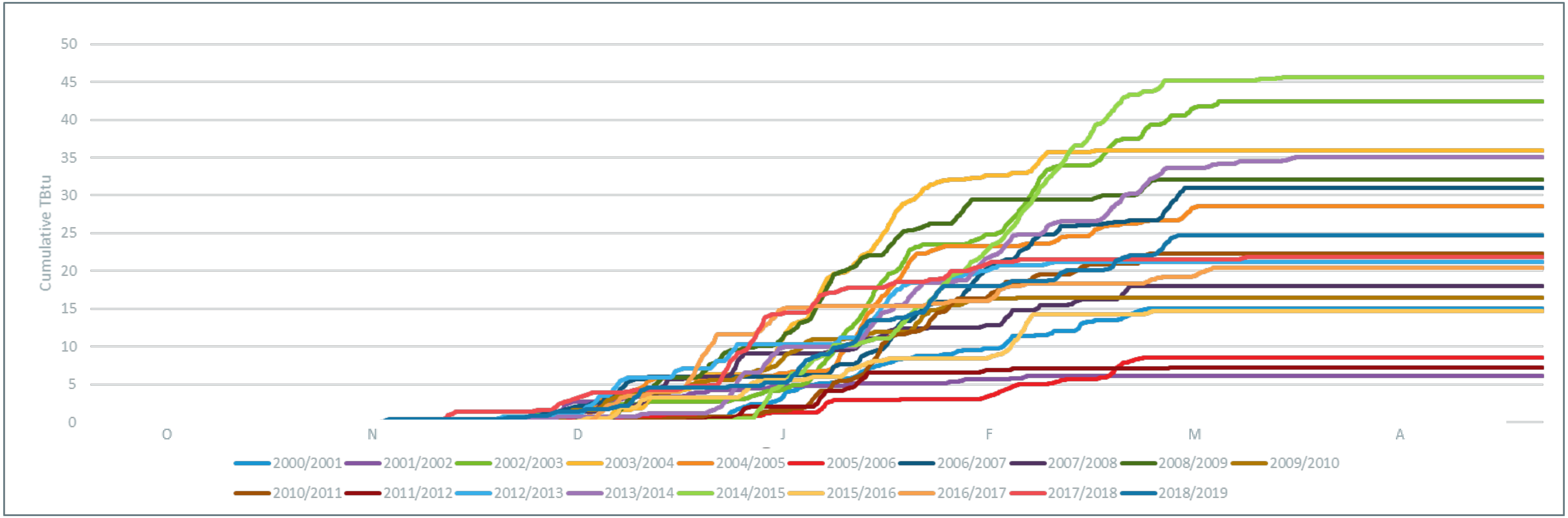
- Average peak generation of 2,980 MW and annual generation of 488 GWh
- 2015 weather year generated 1,017 GWh from heavy oil
- Many weather years have at least some hours when every heavy oil unit is online

Hourly Light Oil Generation for 20 Weather Years



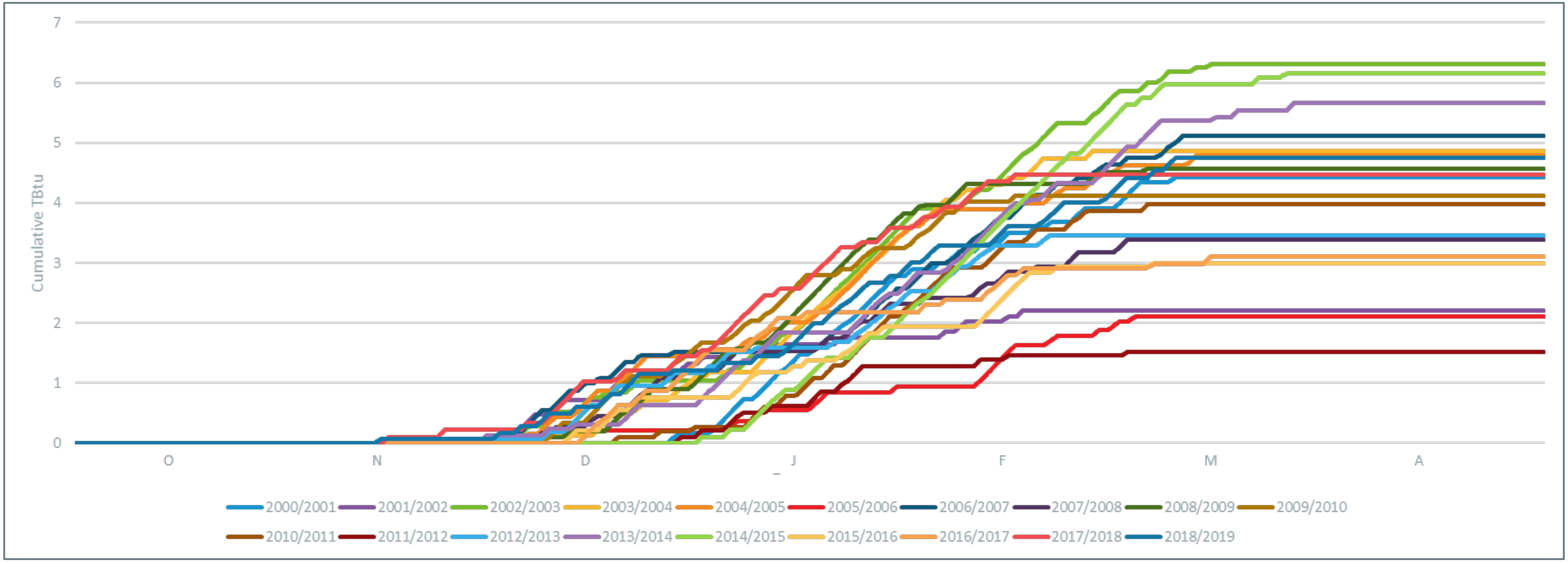
- Average peak generation of 2,127 MW and annual generation of 334 GWh
- 2015 weather year generated 715 GWh from light oil

Cumulative LNG Drawdown for 19 Winters



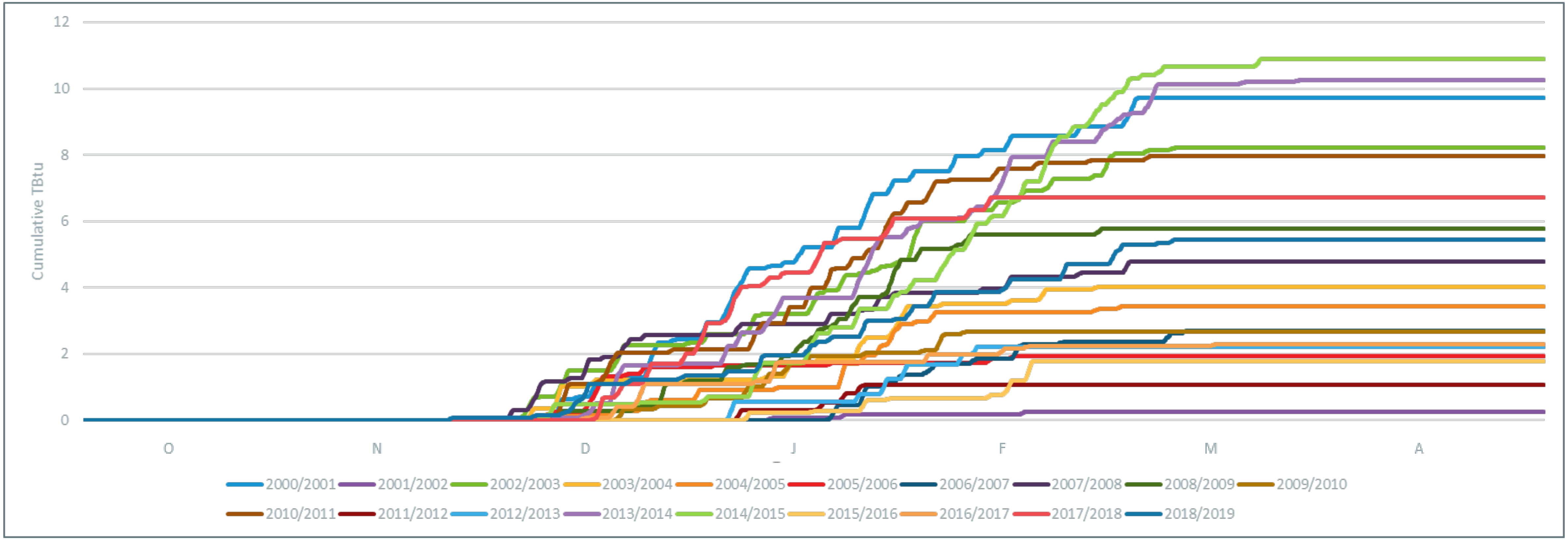
- 2014/2015 winter is highest drawdown scenario, consuming 45.6 Bcf of LNG
- Approximate storage capacities of LNG facilities:
  - Everett: 3.5 Bcf, St. John: 10.4 Bcf, Northeast: 3.1-5.2 Bcf
  - Total of 19.1 Bcf
- To fulfil LNG demand for highest demand weather years, replenishment of LNG storage facilities would be needed
  - If the inventory could not be replenished, other stored fuel types (coal, heavy oil, and light oil) would have to increase their generation

Cumulative Coal Drawdown for 19 Winters



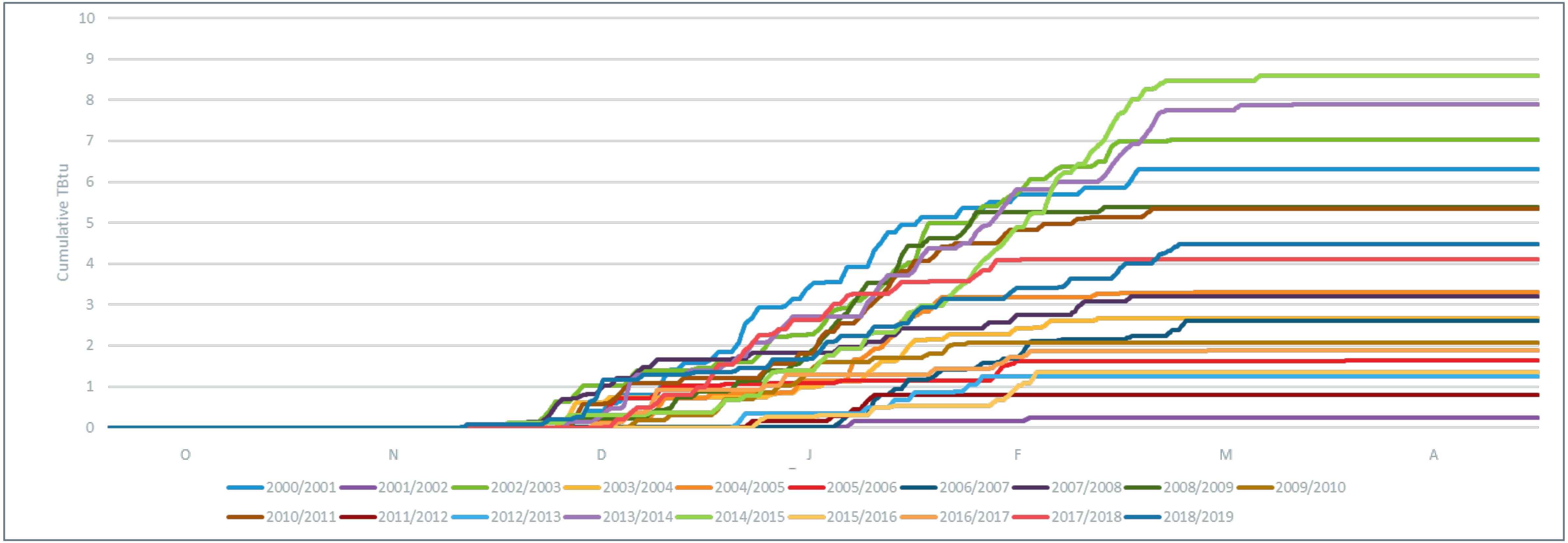
- 2002/2003 winter is highest drawdown year, consuming 6.3 TBtu of coal

Cumulative Heavy Oil Drawdown for 19 Winters



- Oil inventories were not constrained in model, but aggregate fuel inventory of heavy oil units is 25.3 TBtu (~185 million gallons)
  - Depending on the pre-winter fuel level, oil replenishment is likely to be needed to satisfy high demand years
  - 2014/2015 winter consumes 10.9 TBtu (~80 million gallons)

Cumulative Light Oil Drawdown for 19 Winters



- Oil inventories were not constrained in model, but aggregate fuel inventories of light oil units is 9.3 TBtu (~67 million gallons)
  - To satisfy fuel demand of high drawdown years, replenishment is likely needed
  - 2014/2015 winter consumes 8.6 TBtu (~63 million gallons)

Discussion of Fuel Drawdowns

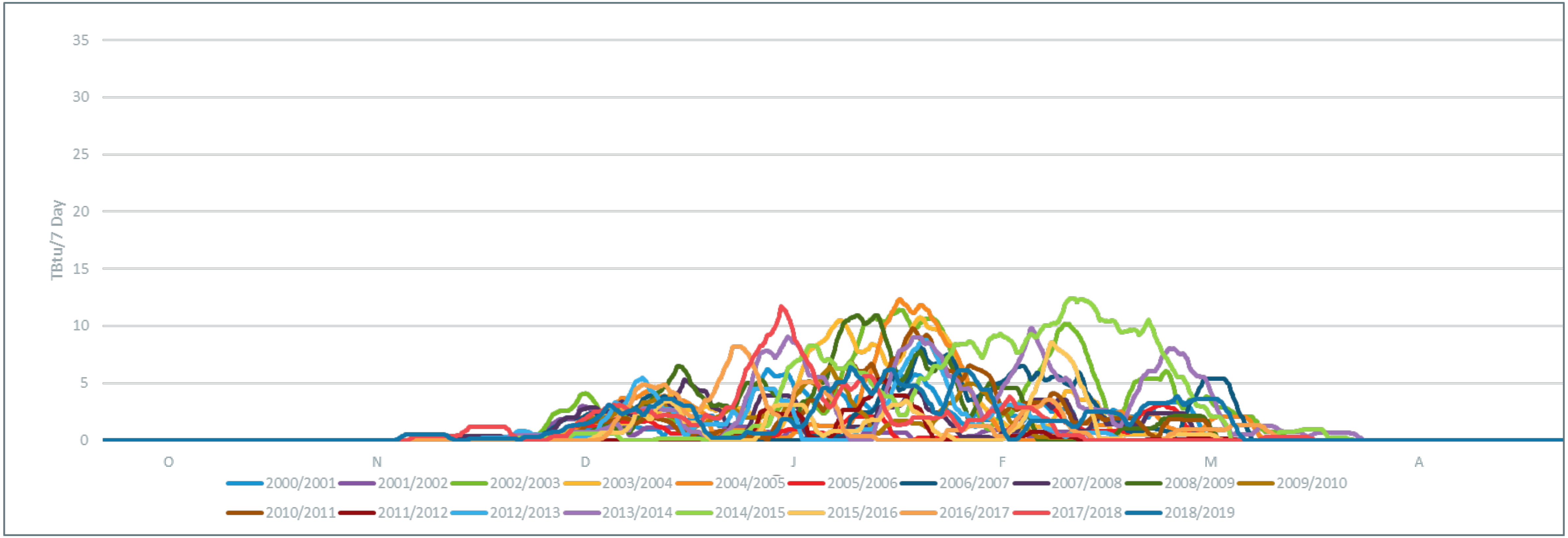
- Mild winters continue to not need significant generation from stored fuels. However, moderate and cold winters still have a significant need for stored fuels
- Large portions of the total stored fuel inventories were consumed in the worst case year, making it extremely likely that deliveries/refills would be needed:
  - LNG: 45.6 Bcf consumed out of 19 Bcf inventory (240% consumed)
  - Heavy Oil: 10.9 TBtu (80 million gallons) consumed out of 25 TBtu inventory (44% consumed)
  - Light Oil: 8.6 TBtu (63 million gallons) consumed out of 9 TBtu inventory (96% consumed)
- Assuming an average tanker size of 3.1 Bcf, 15 LNG tankers would be needed over a 2014/2015 weather year winter
  - From the 2018-2021 period, New England received between 11 and 14 tankers per winter
- Fuel drawdowns can happen particularly fast over relatively short periods

COMBINED SHORT TERM FUEL DRAWDOWN & ENERGY DRAWDOWN

Short Term Drawdown Overview

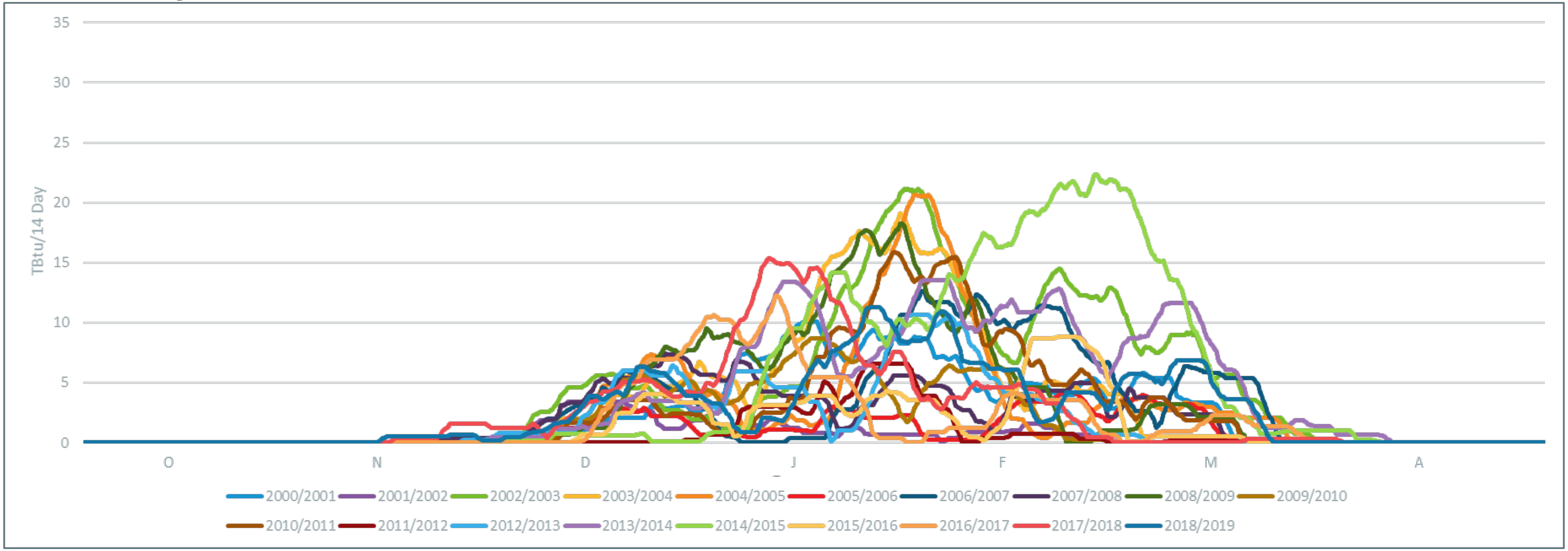
- To gauge the total energy which will have to be provided by stored fuels, the hourly drawdowns have been combined
- Then, the drawdowns have been summed over seven, fourteen, and twenty one days
  - These are indicators of how much stored fuel must be available for use before a refill of stored fuel inventories
- Finally, the TBtu drawdowns have been roughly converted to MWh energy
  - For a heat rate of 8 MMBtu/MWh, 1 TBtu is roughly equivalent to 0.125 TWh
  - If all stored fuels were removed, this is the amount of energy the system would need from additional resources to ride out the cold snap

7 Day Stored Fuel Drawdown for 19 Winters



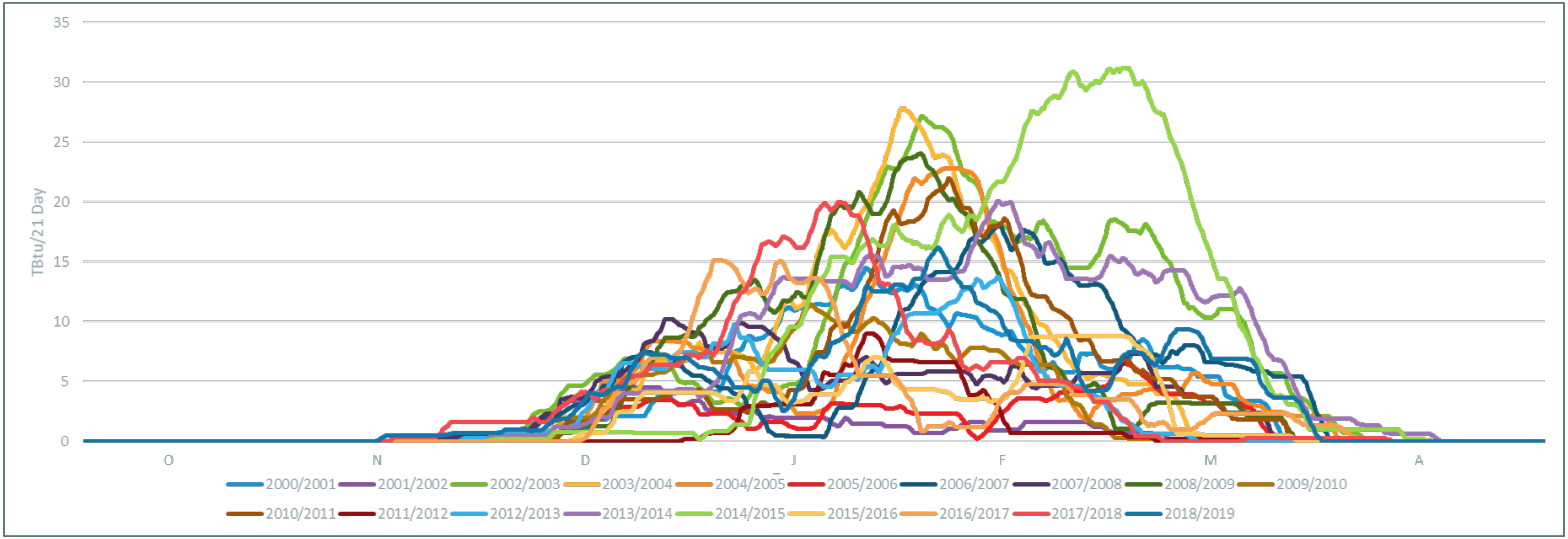
- Multiple weather years consume 10 – 13 TBtu over a one-week period

14 Day Stored Fuel Drawdown for 19 Winters



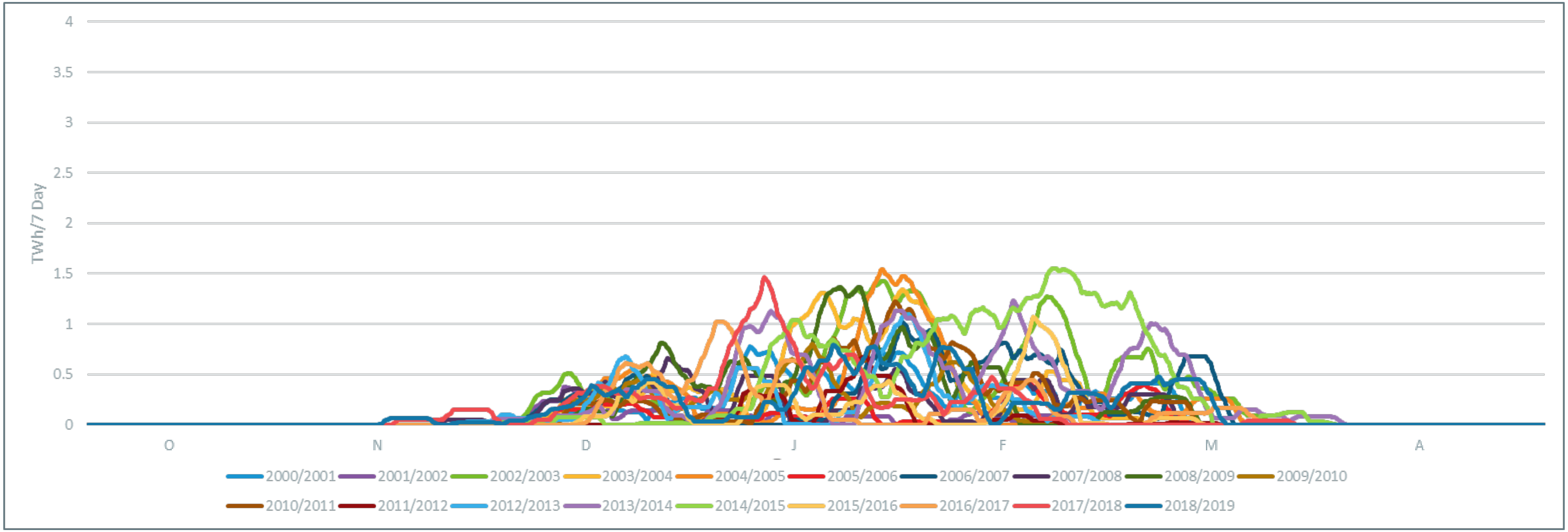
- Over a two-week window, the 2015 weather year now has the most significant drawdown, consuming 22 TBtu over two weeks

21 Day Stored Fuel Drawdown for 19 Winters



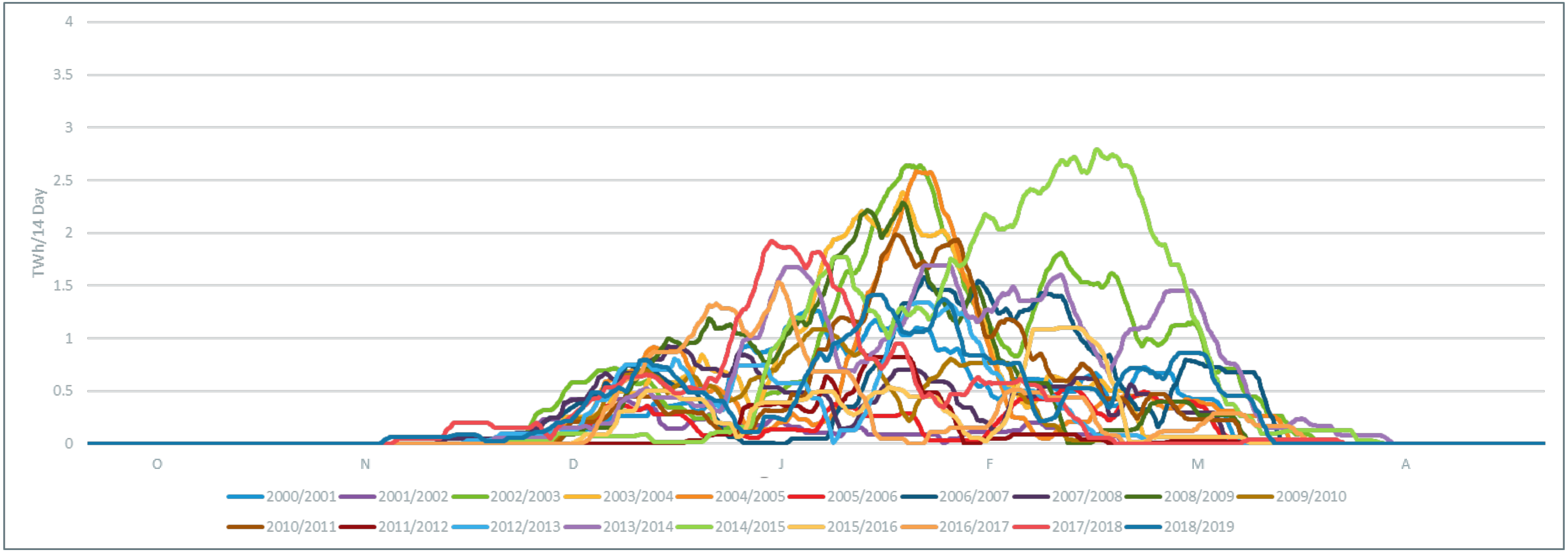
- Over a three-week window, the 2015 weather year consumes 31 TBtu of stored fuels

7 Day Energy Drawdown for 19 Winters



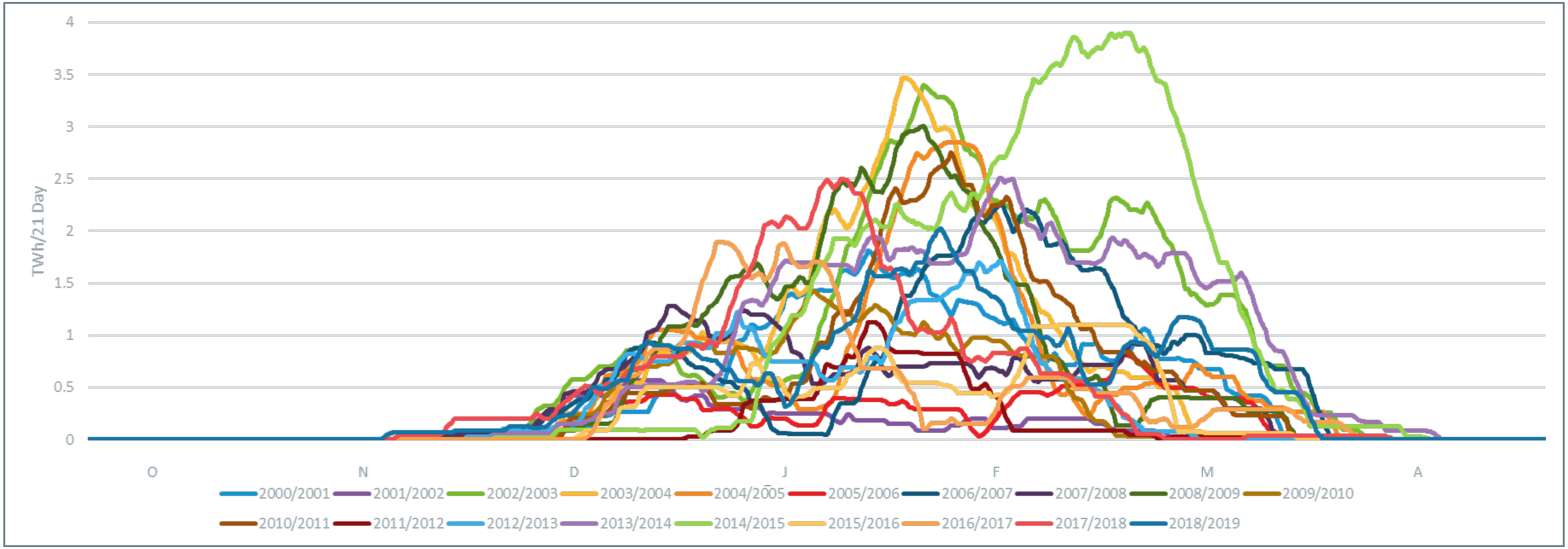
- Assuming 1 TBtu of fuel drawdown is equivalent to 0.125 TWh (@ 8 MMBtu/MWh), multiple winters draw down ~1.5 TWh
- For comparison:
  - Existing pumped storage reservoirs ~= 0.011 TWh

14 Day Energy Drawdown for 19 Winters



- The 2015 weather year consumes almost 2.8 TWh of stored energy over a two-week window, with five other winters consuming more than 2 TWh
- In FGRS Alternative D, there was 2.3 TWh of energy storage

21 Day Energy Drawdown for 19 Winters



- Over a three-week window, stored fuels provide almost 3.9 TWh of energy for the 2014/2015 winter

Energy Drawdown Equivalents (2014-2015 Cold Snap)

	Nameplate (MW)	Average Daily Generation (GWh)	Capacity Factor (%)	7 Day Average Generation (GWh)	14 Day Average Generation (GWh)	21 Day Average Generation (GWh)
PV	11,660	25.59	9.14	179.11	358.22	537.34
LBW	1,376	14.41	43.63	100.85	201.70	302.54
OSW	3,163	45.31	59.68	317.14	634.27	951.41
Total	16,199	85.30	-	597.09	1,194.19	1,791.28

- The total energy provided from stored fuels over a 7, 14, and 21 day period were 1.5, 2.8, and 3.9 TWh
- Maintaining the existing ratio, the system would need another 40,659 MW of PV, LBW, and OSW to provide the same amount of energy (plus energy storage to shift the energy from when it is produced to when it is needed)
- Wind resources tend to be generating more than PV resources during this cold snap. To replace the equivalent amount of energy with just LBW and OSW, an additional 16,289 MW of wind would be needed (and would likely still require new energy storage units)

Discussion of Short Term Drawdowns

- More mild winters may not have a huge demand for stored fuel
- However, moderate and severe winters have large demands, often concentrated over one or two week stretches of cold
- Additional PV and wind resources beyond what is already in the model may help alleviate demand for dispatchable generation, but needed volume of energy is significant
  - Some additional energy storage will likely be needed to shift the energy from when it is produced to when it will be needed
- It is likely that some of the modeled stored fuel resources will retire by 2032, further decreasing the inventory the region has available

TAKEAWAYS AND NEXT STEPS

Takeaways

- Winter peaks are projected to increase significantly due to electrification over a 10 year period
- Despite additional PV, OSW, and imported hydro, the demand for dispatchable generation may increase in winter conditions
- Stored fuels are projected to provide significant amounts of energy for future winters. However, it is likely that some of these resources will retire by 2032
  - The modeled gas constraints assumed continued existence of the Everett facility. A reduced LNG capacity would lead to an increased demand on other stored fuel resources

Next Steps

- For the August PAC:
  - Additional Policy scenario results
  - RENEW MENS sensitivity
- The ISO welcomes any comments or requests for sensitivities from the PAC
  - Please send comments and sensitivity requests to PACMatters@iso-ne.com

Questions

Acronyms

ACDR	Active Demand Capacity Resource	EE	Energy Efficiency
ACP	Alternative Compliance Payments	EFORd	Equivalent Forced Outage Rate demand
AGC	Automatic Generator Control	EIA	U.S. Energy Information Administration
BESS	Battery Energy Storage Systems	EPECS	Electric Power Enterprise Control System
BTM PV	Behind the Meter Photovoltaic	EV	Electric Vehicle
BOEM	Bureau of Ocean Energy Management	FCA	Forward Capacity Auction
CCP	Capacity Commitment Period	FCM	Forward Capacity Market
CELT	Capacity, Energy, Load, and Transmission Report	FGRS	Future Grid Reliability Study
CSO	Capacity Supply Obligation	FOM	Fixed Operation and Maintenance Costs
Cstr.	Constrained	HDR	Hydro Daily, Run of River
DER	Distributed Energy Resource	HDP	Hydro Daily, Pondage
DR	Demand-Response	HQ	Hydro-Québec

Acronyms, cont.

HY	Hydro Weekly Cycle	OSW	Offshore Wind
LBW	Land Based Wind	O&M	Operation and Maintenance
LFG	Landfill Gas	PHII	Phase II line between Radisson and Sandy Pond
LFR	Load Following Reserve	PV	Photovoltaic
LMP	Locational Marginal Price	RECs	Renewable Energy Credits
LSEEE	Load-Serving Entity Energy Expenses	RFP	Request for Proposals
MSW	Municipal Solid Waste	RGGI	Regional Greenhouse Gas Initiative
NECEC	New England Clean Energy Connect	RPS	Renewables Portfolio Standards
NESCOE	New England States Committee on Electricity	SCC	Seasonal Claimed Capability
NG	Natural Gas	Uncstr.	Unconstrained
NICR	Net Installed Capacity Requirement	VER	Variable Energy Resource
NREL	National Renewable Energy Laboratory		