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Analysis of Winter Supplies from Gas-Fired Generators

Todd Schatzki, Ph.D.

December 9, 2025

Agenda

- Response to Feedback/Questions from November Stakeholder Meeting
- Summary of Results
- Methodology Recap
- Primer on Models Explored and Validation
- Preliminary Results
- Next Steps

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Response to Feedback/Questions from November Stakeholder Meeting

Response to Feedback/Questions from November Stakeholder Meeting (1)

- ***Q: Does the model account for locational constraints to the gas system?***
  - Assessment suggests that locational constraints to gas flows in New England pipeline system are limited
    - Complex system with multiple sources of supply located around the region – pipeline supplies (west and north), LNG terminals (north and internal), LDC LNG satellite/peakers (internal)
    - Observe delivery across the system under tight conditions
    - Observe displacement and counterflows (east to west, north to south) under tight conditions
    - A potentially constrained area (G-lateral) affects few resources (two gas-only plants, about 5% of gas-only capacity); complications in differentiating local and system availability
    - Generators throughout the region contract for firm transportation or peaking supplies (indicating uncertainty over delivery)
  - AG model accounts for physical flows – does not account for contractual arrangements

Response to Feedback/Questions from November Stakeholder Meeting (2)

- ***Q: How will the model account for future changes to the natural gas system in New England? The following specific potential changes were identified in the November stakeholder meeting:***
  - *Changes in the utilization of the Everett Terminal post-Mystic retirement*
  - *125 MMcf/day capacity on Iroquois pipeline to be contracted to NY LDCs*
  - The current model reflects empirical outcomes based on recent historical data
  - In principle, the model can adjust to account for infrastructure changes that would be expected to affect gas available to generators
  - Specific adjustments would depend on circumstances
  - As noted in the ISO's presentation, current thinking is that the model would be updated annually to reflect structural changes to the gas system – details on when such updates would occur are to be determined

Specific considerations:

- Everett Terminal. LDCs have historically contracted for gas service with the Everett Terminal, including the current contracts. These contractual arrangements have varied over time. Commercial gas supply arrangements (particularly with generators) are incremental to these LDC arrangements, reflecting profitability/value of incremental supplies.
- Iroquois Upgrades. Upgrades to the Iroquois pipeline (125 MMcf/day) (approved). Net impact would depend on corresponding changes to firm capacity for NY LDCs.

Response to Feedback/Questions from November Stakeholder Meeting (3)

- ***Q: How does the weekend dummy in the model account for gas being traded for the weekend strip?***
  - The weekend/holiday dummy captures changes in gas demand on weekends and holidays
  - Gas traded for the weekend strip can be nominated in varying quantities for each day of the weekend
  - In principle, these nominations reflect expected demand based on forecasted weather conditions for the weekend

Response to Feedback/Questions from November Stakeholder Meeting (4)

- ***Q: How does the model account for gas leaving for NY via New England along the Iroquois Pipeline?***
  - The pipeline gas capability is estimated using the deliveries to demand flow points within New England
  - Deliveries to NY through New England (and vice versa) are not accounted for explicitly
    - If included, such flows would appear on both sides of the gas flows equation (sources and uses), and therefore net out and have no impact on estimate of the capability of pipeline system to deliver gas into New England

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Summary of Gas Availability Model Results

Summary of Results

- **Today**:
  - Discuss preliminary results of the daily winter gas availability for generation (MMcf) model
  - Discuss preliminary estimated profiles of winter electric generation (MWh) from gas-only resources
- **Across years, model predicts mean daily gas availability of 1,196 MMcf/d (SD: 372)**
  - On average, this is sufficient to operate the gas-only fleet at its derated capacity (8,384 MW) for ~20 hours per day
- **However, estimated gas supply diminishes in colder weather because demand for gas for other uses, particularly heating, increases at lower temperatures**
  - For HDD < 45: mean = 1,244 MMcf/d (SD: 358)
  - For HDD ≥ 45: mean = 806 MMcf/d (SD: 228)
- The average hourly energy from gas-only fleet across 10 profiles each for the 24 RA winters:
  - For HDD < 45: mean = 6,794 MWh (SD: 1,468) → 81% of max possible
  - For HDD ≥ 45: mean = 4,516 MWh (SD: 1,367) → 54% of max possible

Methodology Recap

Two Key Steps: Model Development and Simulation of Available Supply from Gas Resources

Component	Purpose
Step 1: Develop Model of Daily Winter Gas Available for Generation (MMcf)	**Model Development:** Develop model of gas available to electric sector as a function of weather conditions and temporal variables **Data:** Model is fit ("trained") using historical data
Step 2: Use Model to Develop Profiles of Generation Supply Available from Gas Resources for Simulations in Resource Adequacy Analysis	**Simulations:** Estimated expected gas availability for resource adequacy (RA) simulations ▪ Available gas is translated into available electricity supply ▪ Estimates reflect assumed weather conditions in RA simulations ▪ Estimates include baseline (point) estimates and full distributions (reflecting model uncertainty, 10,000 simulated winters)

Key analysis features:

- Account for impact of gas system limitations on available winter supplies from gas-fired resources
- Account for relationship between weather conditions and temporal variables (e.g., weekday vs weekend/holidays, month, time trends) on available supplies
- Account for uncertainties in available supplies beyond the variables currently controlled for in the models

Step 1: Develop Model of Daily Winter Gas Available for Generation (MMcf)

- Gas available for electric power generation is estimated based on two sources of gas supply (pipeline and LNG terminals) net of demand from non-generator users
- We develop models for each supply and demand component
  - With this approach we account for distinct features of each component and create flexibility for simulations
  - Model is trained using historical winter data from 2015 to 2024

Gas Available for Electric Power Generators = **Step 1A: Pipeline Gas Supply** + **Step 1B: Gas Supply from LNG Terminals** − **Step 1C: Non-Generator Demand**

Step 1A – Pipeline Gas Supply
- Relatively fixed from day to day
- Estimated using a sources/uses framework

Step 1B – Gas Supply from LNG Terminals
- Estimated using regression model
- Daily supply reflects market response to daily exogenous weather and temporal conditions and annual market conditions

Step 1C – Non-Generator Demand
- Estimated using regression model
- Daily demand reflects daily exogenous factors (weather and temporal) and annual trends

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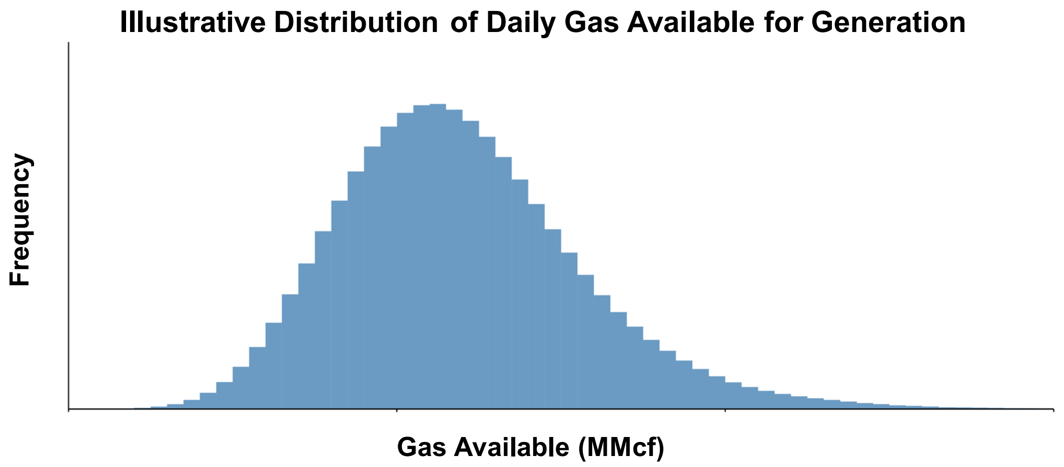
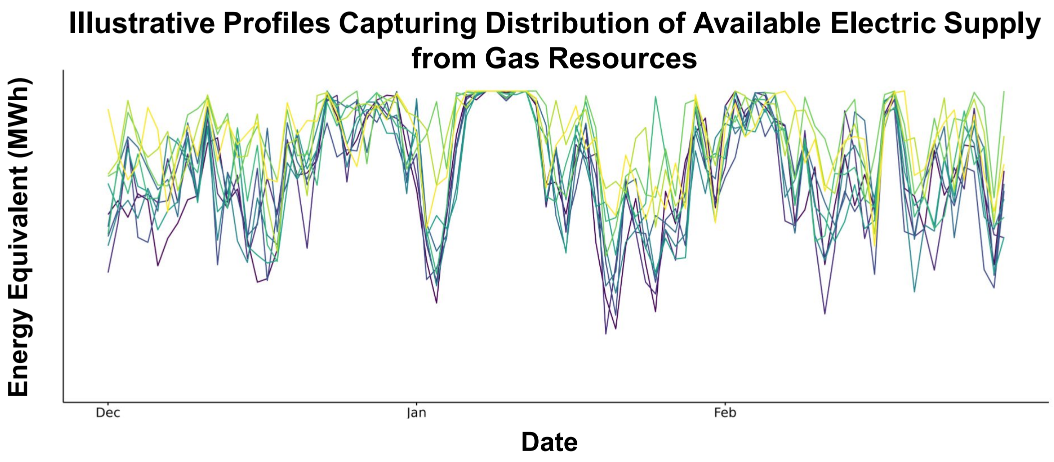
Step 2: Develop Profiles of Supply Available from Gas Generation Fleet for Simulations in Resource Adequacy Analysis

- **Step 2A:** Simulate distribution of daily gas available for electric power generation in each of 24 load winters used in RA simulations
  - The gas availability predictions are produced by feeding the model input data associated with the 24 load years
  - Thus, generated gas profiles align with the conditions of the specific load years used in the RA analysis
  - Distribution reflects uncertainty in estimated gas supply
- **Step 2B:** Translate daily gas availability (MMcf) to hourly electric supply from gas resources (MWh)
- **Step 2C:** For each load winter, develop 10 profiles of available gas electric supply representing distribution of uncertainty in estimated available electric supply
  - Choice of winter profiles will capture variation in winter gas scarcity (from "bad" to "good" winters)





Preliminary Results

Step 1A: Pipeline Gas Supply

Pipeline Gas Supplies Reflect All New England Sources and Uses of Gas

[A] Pipeline Gas Inflows from NY and Canada

=

Uses of Gas

[C] Non-Generator LDC + C&I Demand

+

[D] Generator Demand from LDCs

+

[E] Generator Demand from Interstate Pipeline

+

[F] Pipeline Exports to Canada

Non-Pipeline Sources of Gas

−

[B] Receipts from LNG Import Facilities

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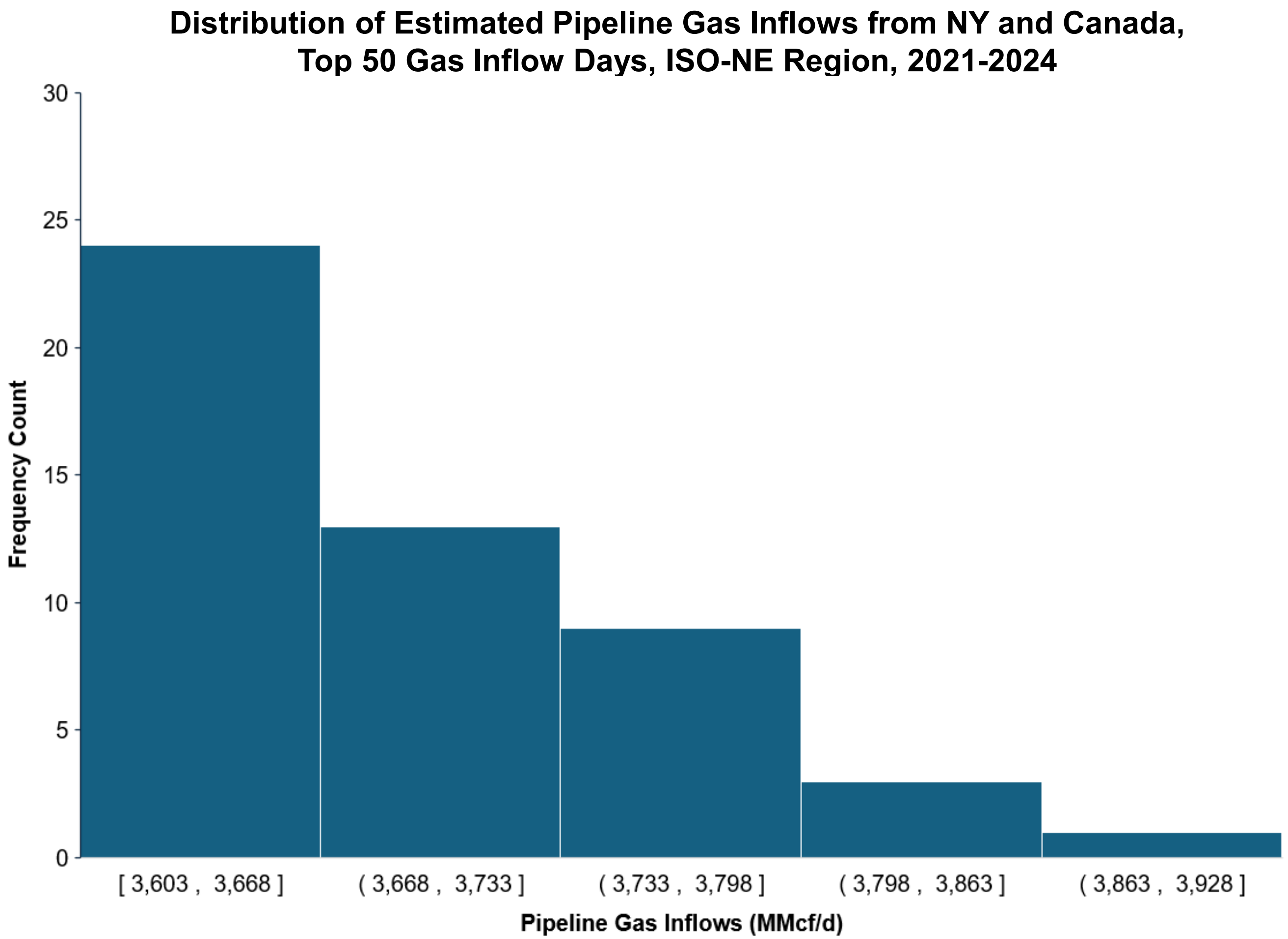
Daily Pipeline Supply Capacity Estimated by Sampling from the Top 50 Inflow Days (3,603–3,928 MMcf/d)



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Primer on Models Explored for Non-Generator Demand and LNG Supply, and Validation of Model Choice

Primer on Model Estimation Methods Explored

- **Ordinary Least Squares (OLS) Regression:** Finds the best-fit line associating inputs (e.g., weather, weekday/weekend) to outcomes; standard statistical approach with easily interpretable results
- **Regularized Regressions:** Extensions of OLS that penalize model complexity to prevent overfitting, particularly useful for forecasting when inputs are numerous and correlated
  - **Lasso Regression:** Applies a penalty that drops less important predictors (performs variable selection)
  - **Ridge Regression:** Applies a penalty that shrinks coefficients of less important predictors without dropping them
- **Tobit Regression** (LNG Only): Specialized model used when the dependent variable is censored (e.g., LNG sendouts cannot fall below zero on warm days) to ensure unbiased estimates
- More complex machine learning approaches (e.g., Random Forests, Neural Networks) were considered but not pursued to mitigate risk of overfitting given the modest number of observations

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Primer on Model Validation

- **Validation Methodology:**
  - **Stratified Split:** To rigorously assess predictive performance, we utilize a standard 80/20 train-test split
    - Data is split into training (80%) and testing (20%) sets
    - Split is stratified to ensure cold days are proportionately represented in both samples
  - **Blind Evaluation:** Train exclusively on the 80% train split to prevent data leakage
  - **Performance Metric:** Evaluate accuracy by calculating the Root Mean Square Error (RMSE) on the withheld 20% test set
- **Key Performance Metrics:**
  - **Overall Accuracy:** Average RMSE across all days in the test sample
  - **Cold Weather Accuracy:** Average RMSE specifically for very cold days (HDD > 45) in the test sample
- We ignore **R-squared** (in-sample fit metric) since it is a poor indicator of future predictive performance
  - Furthermore, standard R-squared is not applicable to Tobit model

Step 1B: Gas Supply from LNG Terminals

Daily LNG Supply Model

- Daily LNG supply predicted by regression model

$$Daily\ Supply\ from\ LNG = a + B * weather\ variables + C * temporal\ variables + D * Annual\ Dummies$$

- Reflects key economic features:
  - Reflects total supply from LNG terminals
  - Annual dummies to account for variation in annual total LNG sendout
- Consider four regression models
  - OLS linear regression model
  - Two types of regularized regression models (Lasso and Ridge)
  - Tobit regression model, that accounts for truncation of supply quantities at zero

LNG Supply Model Variables

Weather variables

For ME and NEMA regions:

- **Temperature** – Heating Degree Days (HDD), derived from Dry Bulb Temp (°F)
- **Humidity** – Dew Point Temp (°F)
- **Wind Speed** – Meters per second
- **Cloud Coverage** – 0-8, in Oktas, measuring from clear sky to fully overcast
- **Global Horizontal Irradiance** (W/m^2) (measure of sunniness)
- **Temperature transformations**
  - HDD lags from the past one, two, and three days
  - Seven-day moving average of HDD

Temporal variables

- Calendar Dummies
  - Weekend/Holiday
  - December
  - January

Annual Dummies

- Dummies for winter seasons from 2014/15 to 2024/25 to control for variation in total seasonal sendout

LNG Supply Model Performance and Selection Choices

- Across the four models considered, Tobit performs the best on the coldest days based on out of sample error
- Ridge performs slightly better across all days but performs worse on cold days
- Tobit accounts for left-censoring from near-zero sendout days, which other models don’t, resulting in unbiased estimates
- Based on these considerations, we chose Tobit as the most appropriate model for estimating LNG supply

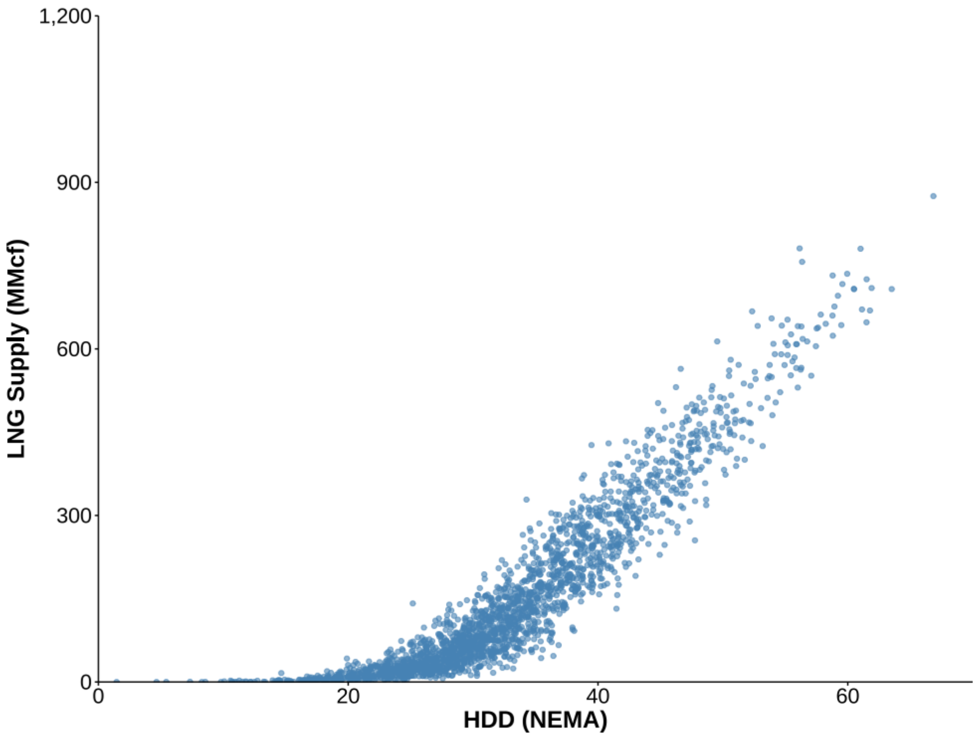
Out of Sample Root Mean Squared Error

	OLS	Tobit	Ridge	Lasso
All	124.07	123.93	122.85	124.32
Subset HDD > 45	236.92	236.11	246.98	242.90

Baseline Values of LNG Supply: Lowest and Highest Annual Dummies

Reflects daily estimates of supply given weather and temporal variables

Baseline LNG Sendout Estimates and HDD (New England Region, Minimum Annual Dummy)



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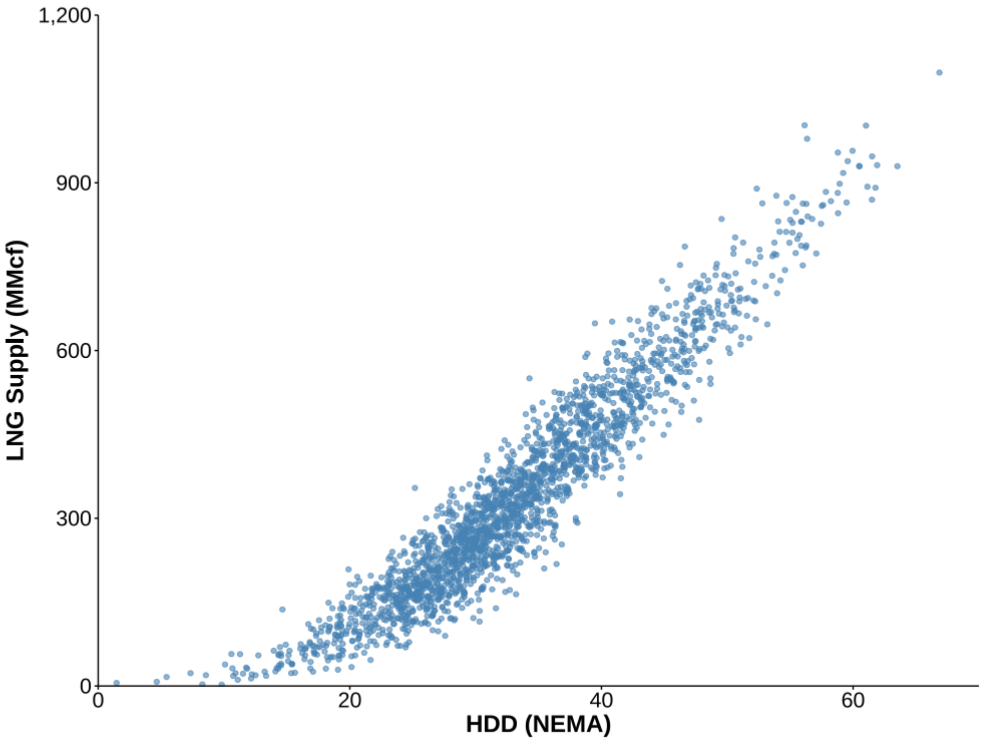
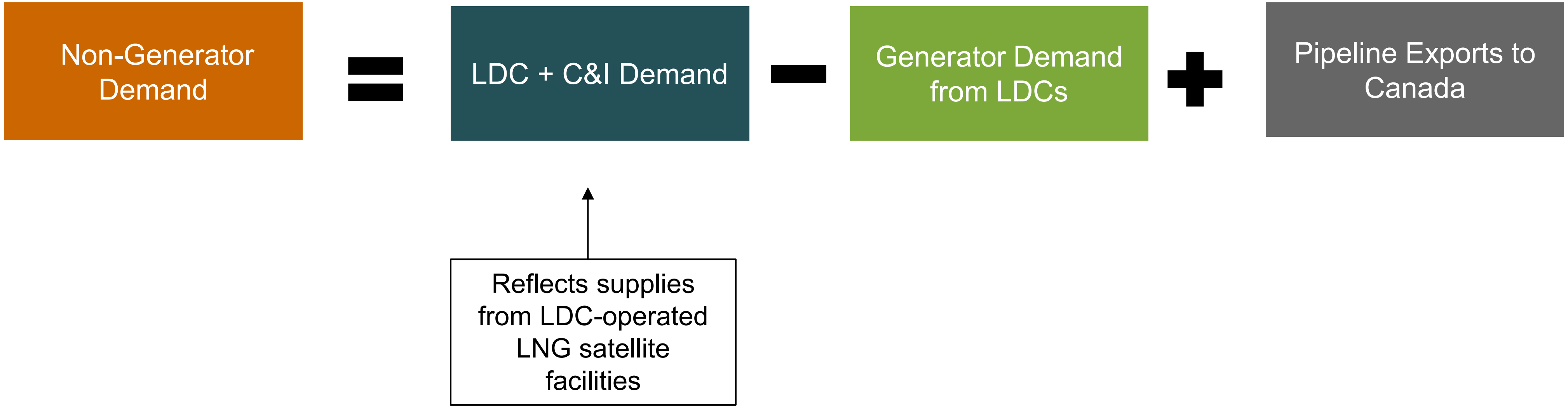


Range between max and min daily sendout is 222 MMcf per day (based on annual dummies)

Step 1C: Non-Generator Demand

Non-Generator Demand is Constructed Through End-User Demand, Separate From Electric Generator Demand



Daily Non-Generator Gas Demand

- Daily non-generator gas demand predicted by regression model
  - Select model with best fit, especially on colder days

$$Daily\ Non{-}Generator\ Demand = \\ a + B * weather\ variables + C * temporal\ variables + d * year$$

- Model estimated using similar exogenous weather and temporal variables from same time period as LNG model
- Reflects key economic features:
  - Reflects total non-generator demand
  - Consider time trend to capture long-term trends in non-generator gas demand due to macroeconomic factors (e.g., population or economic growth) and policy changes (e.g., electrification)
- Consider three regression models
  - OLS linear regression model
  - Two types of regularized regression models (Lasso and Ridge)

Non-Generator Demand Model Variables

Weather variables

For ME and NEMA regions:

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- **Global Horizontal Irradiance** (W/m^2) (measure of sunniness)
- **Temperature transformations**
  - HDD lags from the past one, two, and three days
  - Seven-day moving average of HDD
  - 2nd and 3rd degree HDD polynomials capturing non-linearity between temperature and demand

Temporal variables

- Calendar Dummies
  - Weekend/Holiday
  - December
  - January
- Linear Time Trend
  - Captures technology trends over time such as heating electrification
  - Alternative time trend specifications considered (e.g., non-linear; interactions with HDD), but resulting models did not fit or predict high temperatures as well as a linear trend

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Non-Generator Demand Model Performance and Selection Choices

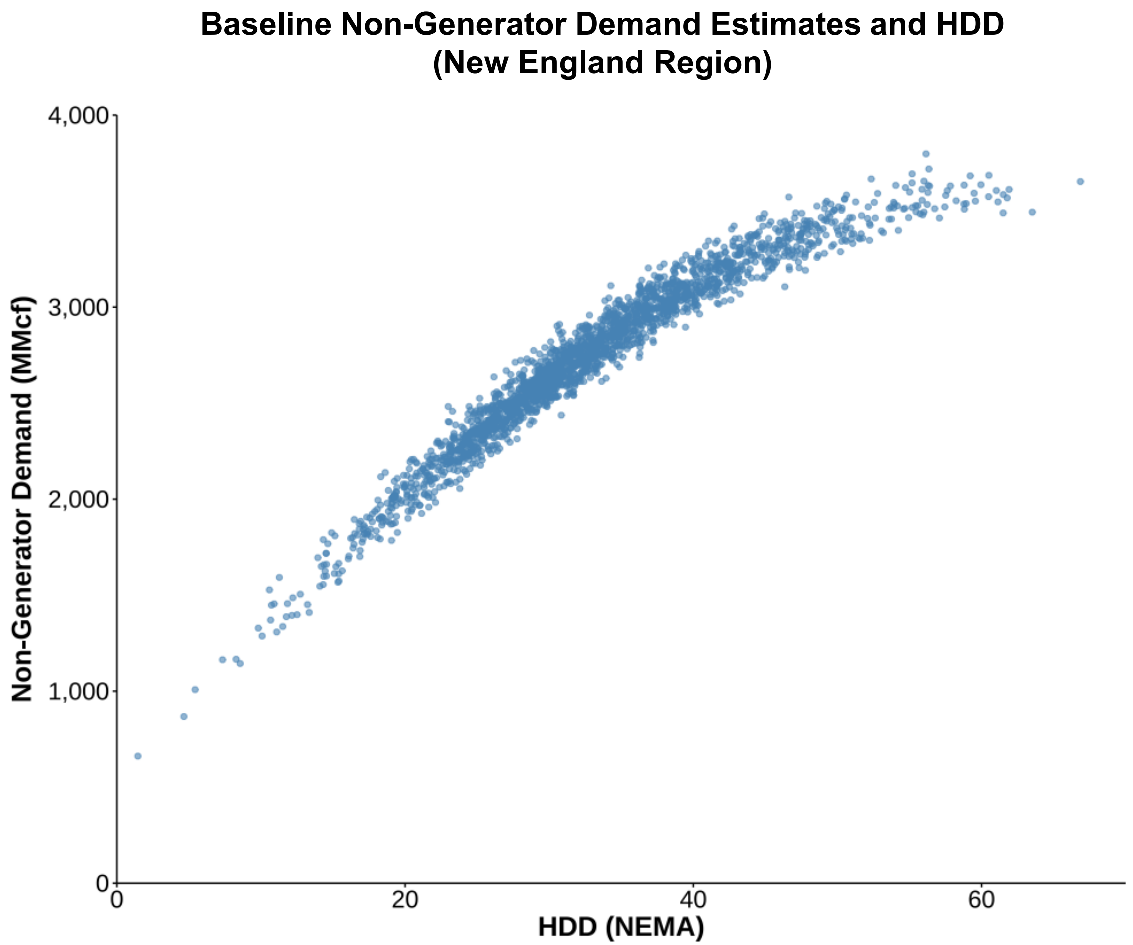
- Among the three models, Lasso has the best performance based on out of sample error both across all days and across cold days
- Therefore, we chose Lasso as the most appropriate model for estimating non-generator demand

Out of Sample Root Mean Squared Error

	OLS	Ridge	Lasso
All	112.57	126.50	110.58
Subset HDD > 45	193.35	189.25	173.82

Non-Generator Gas Demand: Baseline Values

Reflects daily estimates of gas available given weather and weekday variables



Daily Gas Available for Generation (MMcf): Integrating Steps 1A, 1B & 1C

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Step 1: Develop Model of Daily Winter Gas Available for Generation (MMcf)

- Gas available for electric power generation is estimated based on two sources of gas supply (pipeline and LNG terminals) net of demand from non-generator users
- We develop models for each supply and demand component
  - With this approach we account for distinct features of each component and create flexibility for simulations

Gas Available for Electric Power Generators = Pipeline Gas Supply + Gas Supply from LNG Terminals − Non-Generator Demand

Step 1A – Pipeline Gas Supply
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Step 1C – Non-Generator Demand
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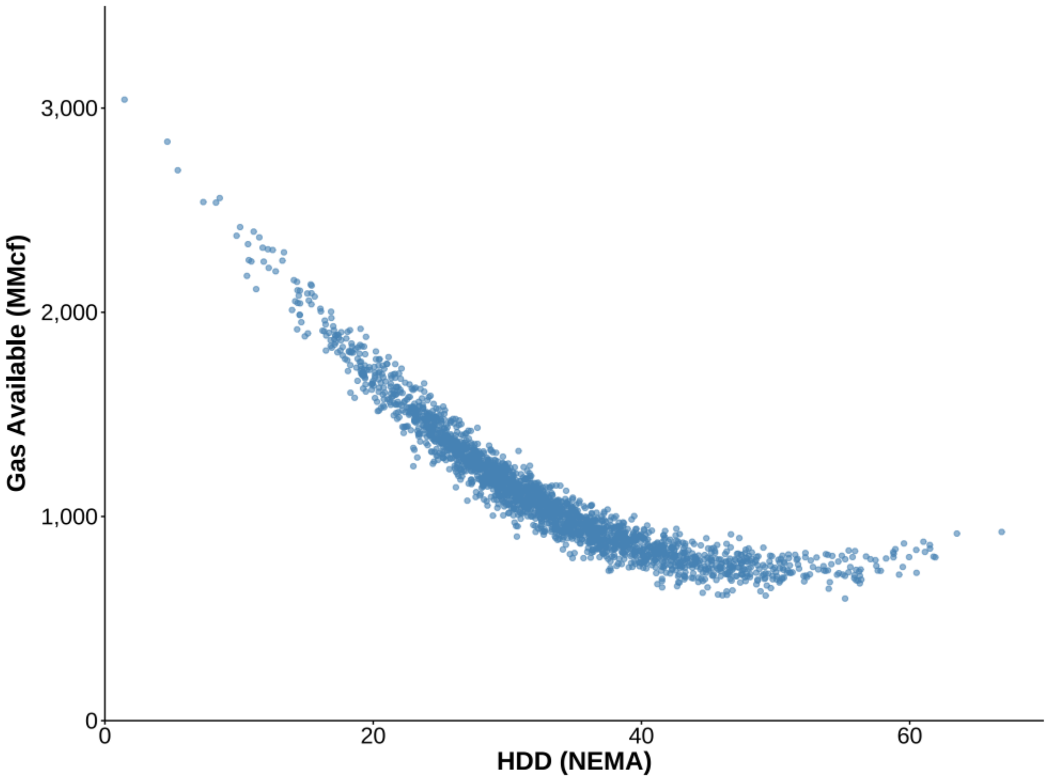
Baseline Values of Gas Available for Electric Generation Using the Lowest and Highest Intercepts in LNG Supply Model

Baseline Gas Available for Electric Generation and HDD (New England Region, Minimum Annual Dummy)



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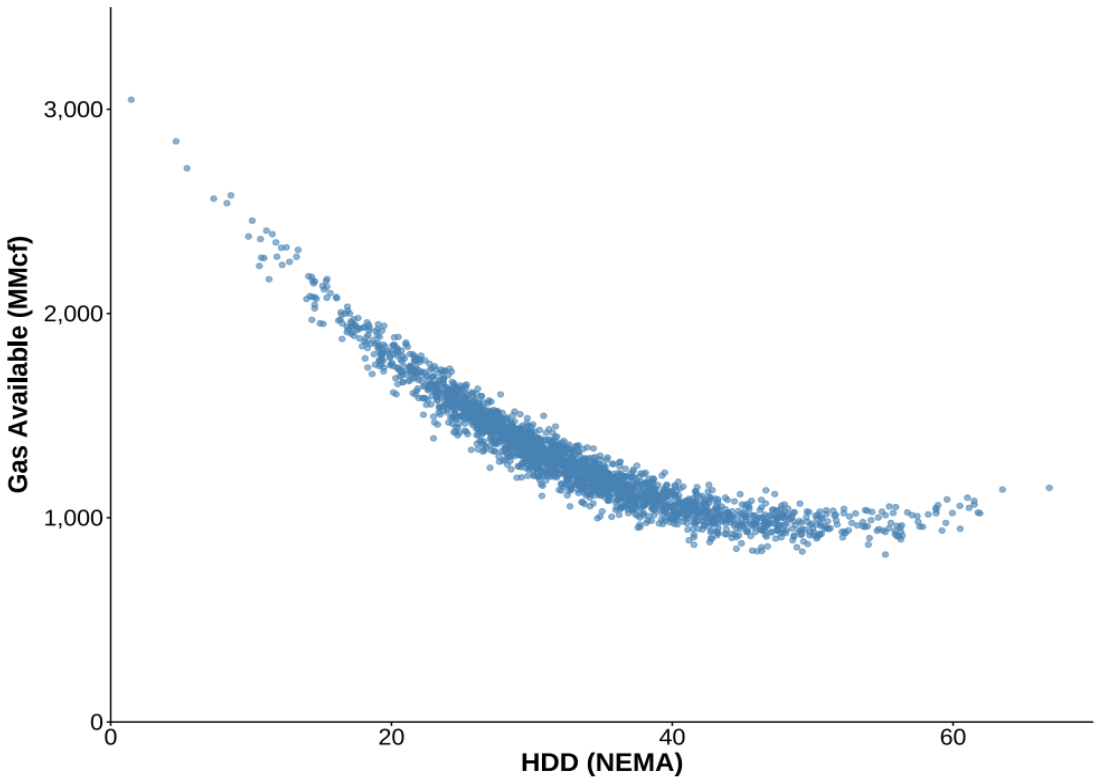


Step 2: Develop Profiles of Supply Available from Gas Generation Fleet for Simulations in Resource Adequacy Analysis

Step 2A: Simulating Distribution of Daily Gas Available for Power Generation

Stochastic Estimates Account for Uncertainty in Estimates of Daily Gas Available for Power Generation

Baseline Prediction

Pipeline Gas Supply Capability + LNG Supply from Import Terminals − Non-Generator Demand = Gas Available for Electric Power Generators

+ Deviations Based on Top 50 Gas Inflows

+ Residual* from LNG Supply Model

+ Residual* from Non-Generator LDC Demand Model

* Residual = Fitted – Actual from Regression Prediction Model

- Within-winter variation illustrated
- Does not capture variation across winters accounted for with annual LNG supply dummy

Stochastic Prediction

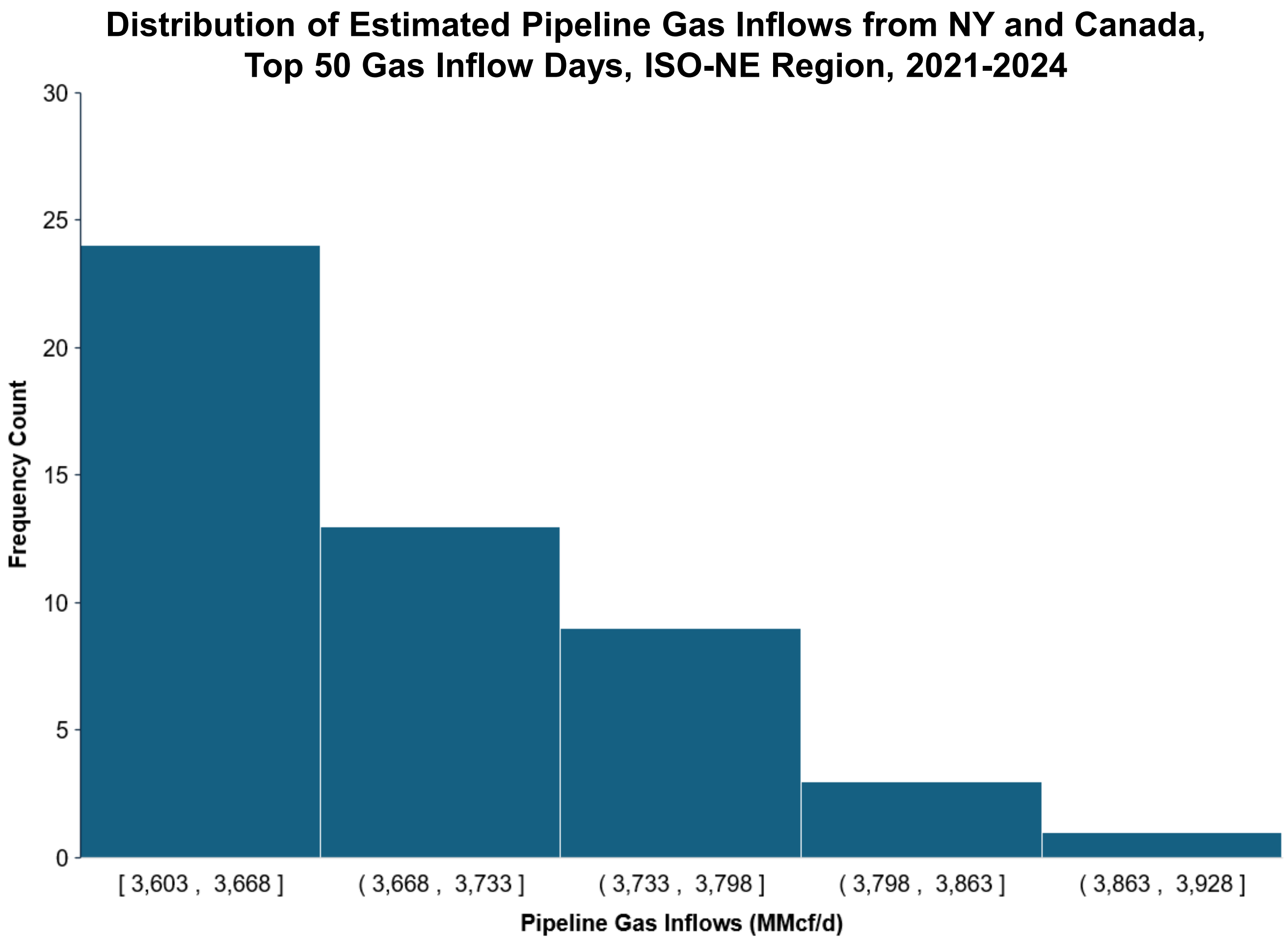
Pipeline Gas Supply Capability + LNG Supply from Import Terminals − Non-Generator Demand = Gas Available for Electric Power Generators

Stochastic Daily LNG Sendout Predictions Were Further Adjusted

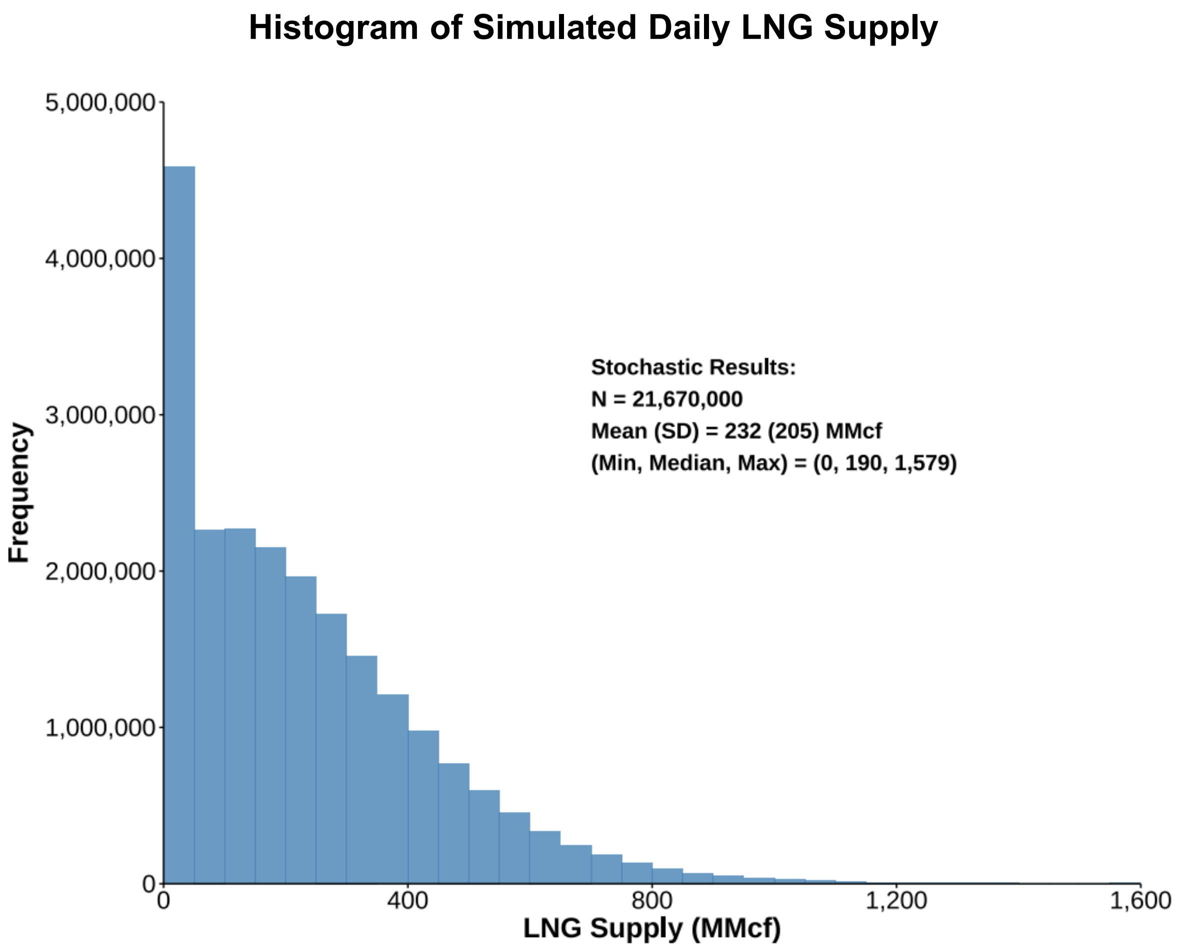
- **Cap on Daily LNG Sendouts**
  - Daily LNG sendout is capped at 1.59 Bcf to align with the historical coincidental maximum sendout observed from the three terminals (1.44 Bcf) × 110%
  - This cap ensures model predictions remain within realistic limits

- **Adjustment to Align Total Seasonal Sendout with Historical Levels**
  - Adjustment to account for model's tendency to overestimate the impact of daily temperature on LNG supply and underestimate the impact of constraints on annual total supply due to pre-season contracts
  - Daily predictions are scaled to account for difference between total annual predicted sendout and historical annual sendout

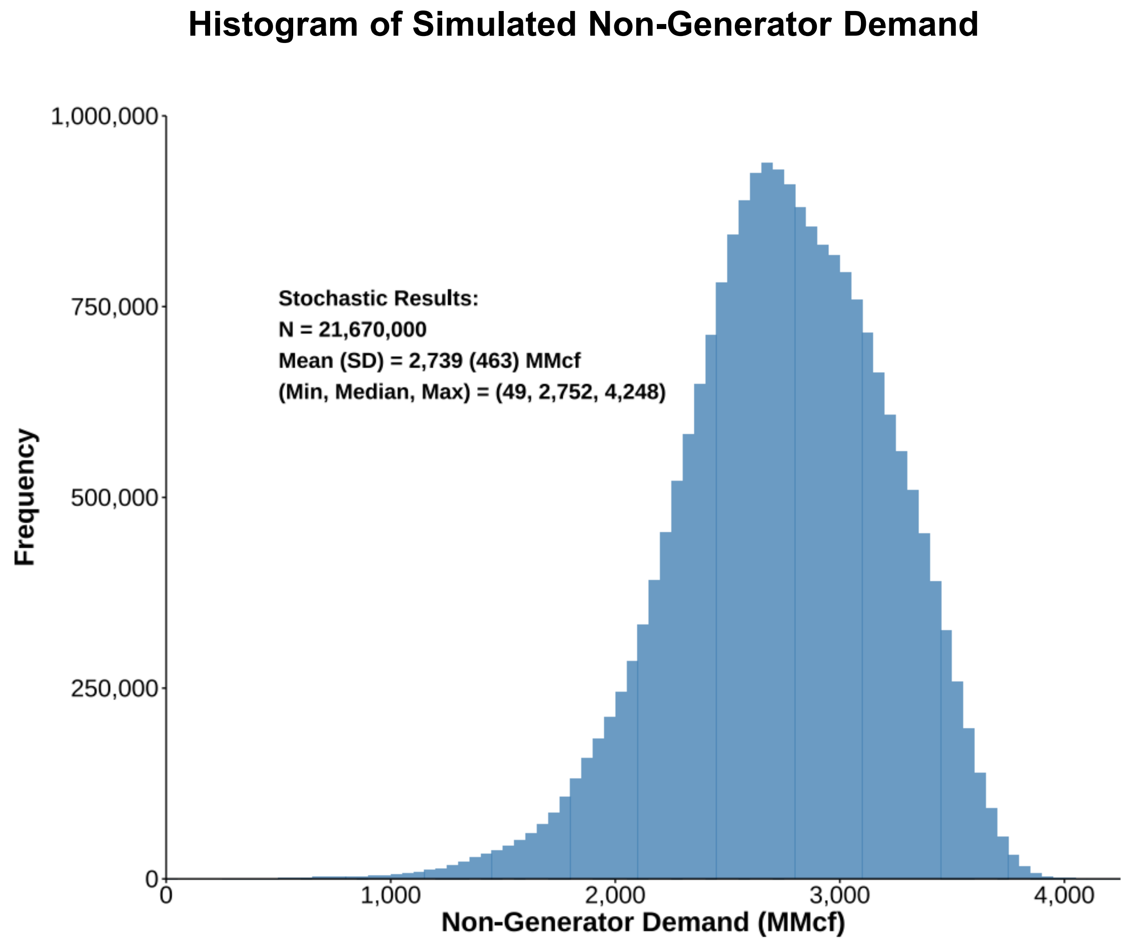
Distribution of Daily Pipeline Supply Capacity (3,603–3,928 MMcf/d)



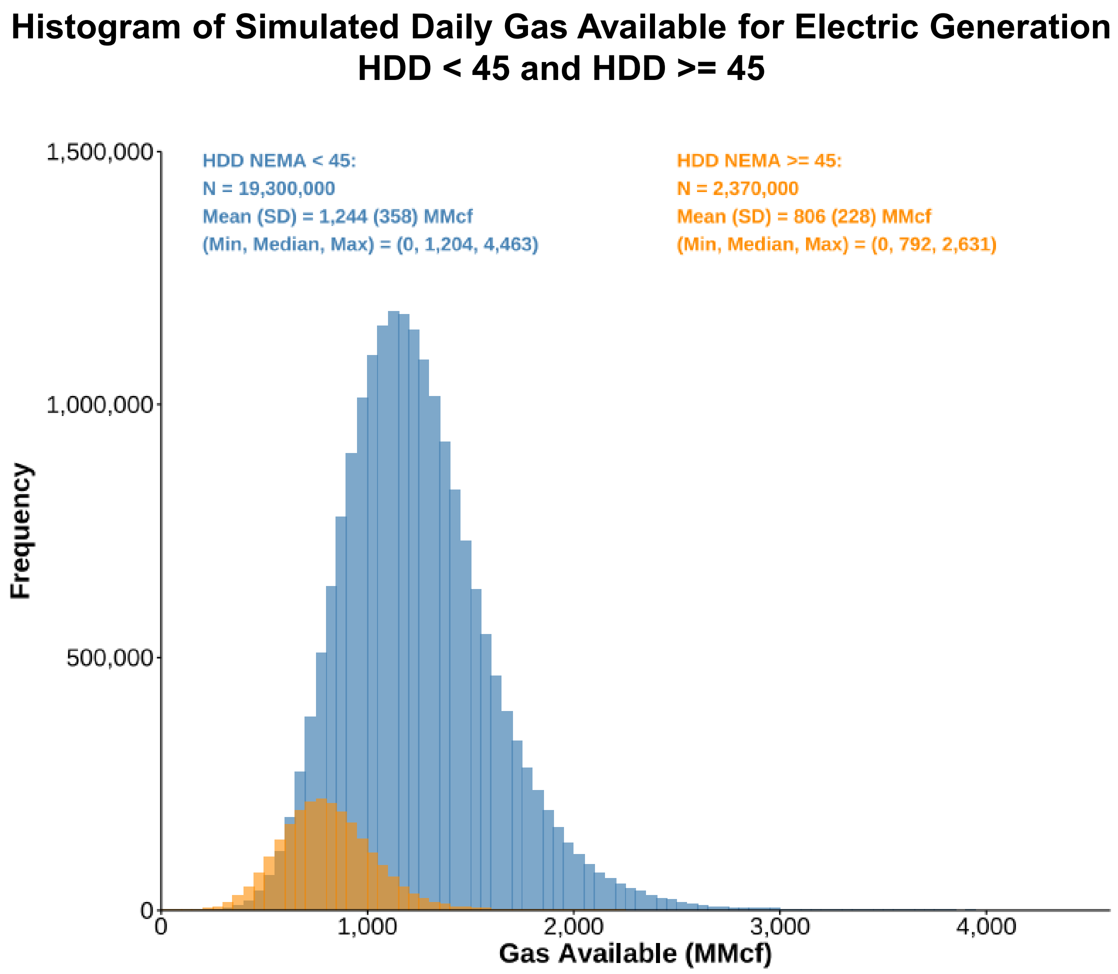
Distribution of Stochastic Daily LNG Supply



Distribution of Stochastic Daily Non-Generator Demand Model



Gas Available for Electric Generation: Distribution of Values by HDD



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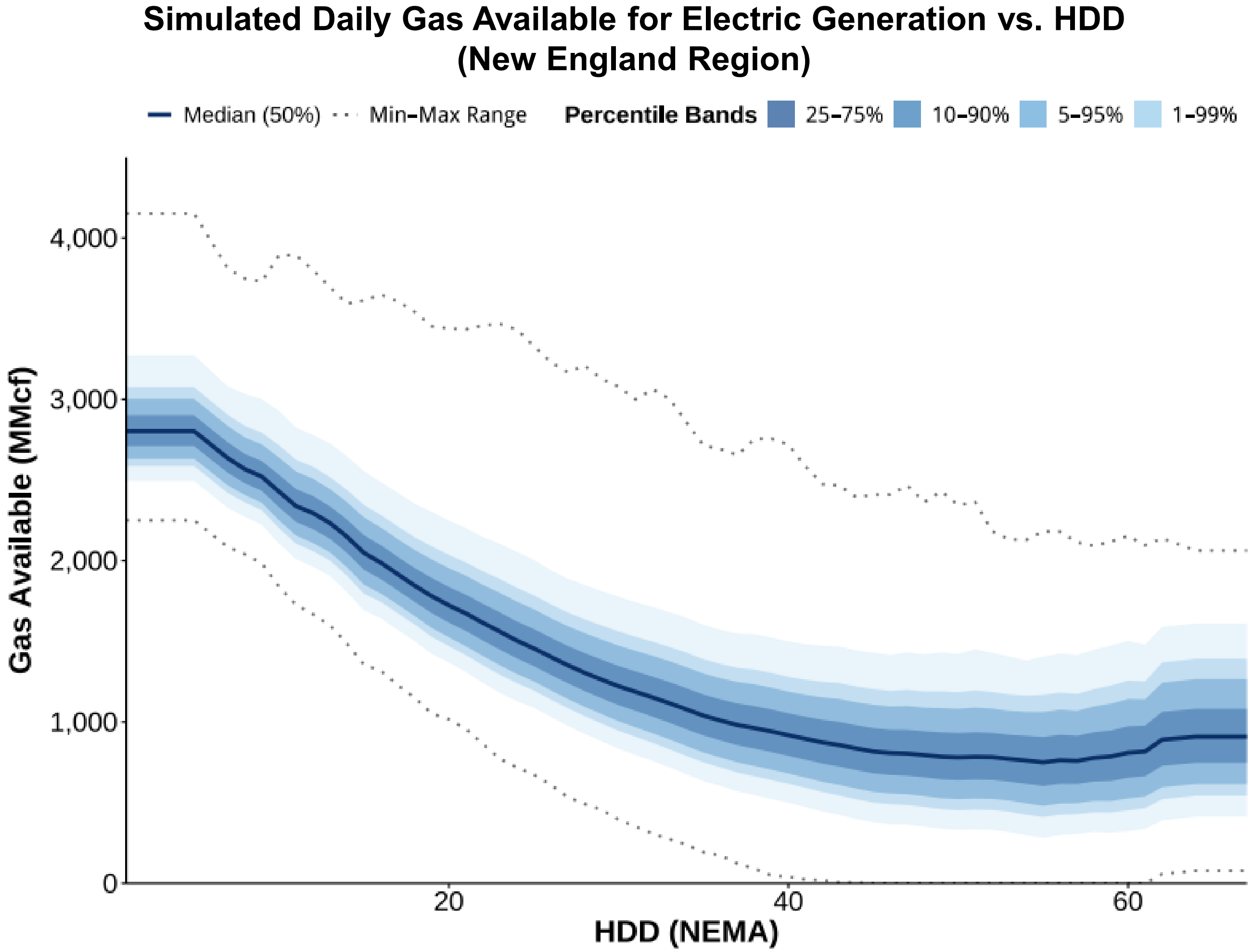

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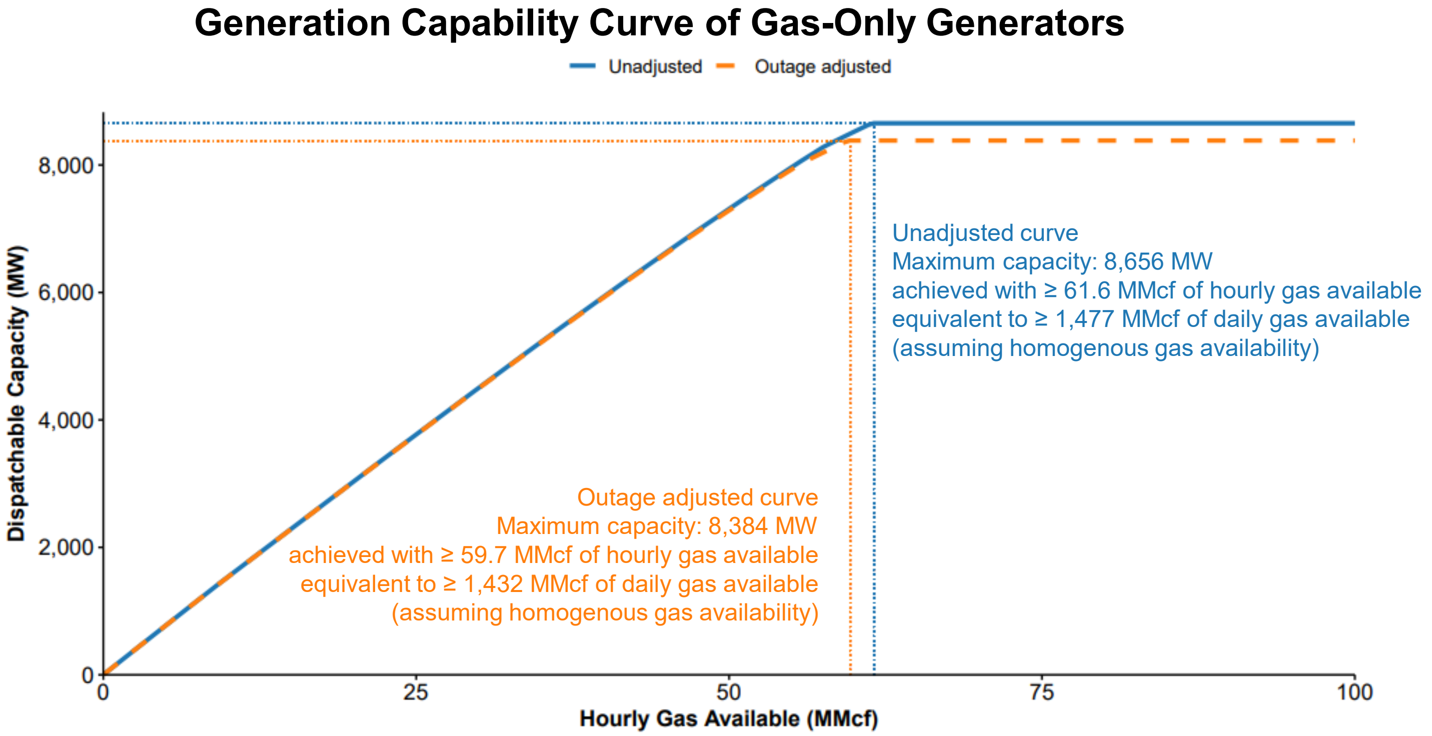
Step 2B: Translating Daily Gas Supply to Hourly Available Energy (MWh) & Step 2C: Development of Gas Profiles

Daily Gas Availability Is Allocated Hourly Based on Load, Then Converted to MWh Equivalent

Running the entire gas-only fleet at derated SCC capacity (8,384 MW) requires 59.7 MMcf/hour

Allocation Methodology:

- **Hourly Allocation**: Distribute daily available gas (MMcf) across 24 hours using forecast load shape
- **Build and Derate Fleet Stack:** Rank gas-only units by fully-loaded heat rate (most to least efficient) and apply ~~EFOR-d~~ EFORd to derate winter SCC
- **Dispatch Through Stack**: For each hour, run available gas through the stack until either available gas is exhausted or capacity of the entire fleet is reached



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Gas Profiles Reflect Distribution of Potential Available Energy

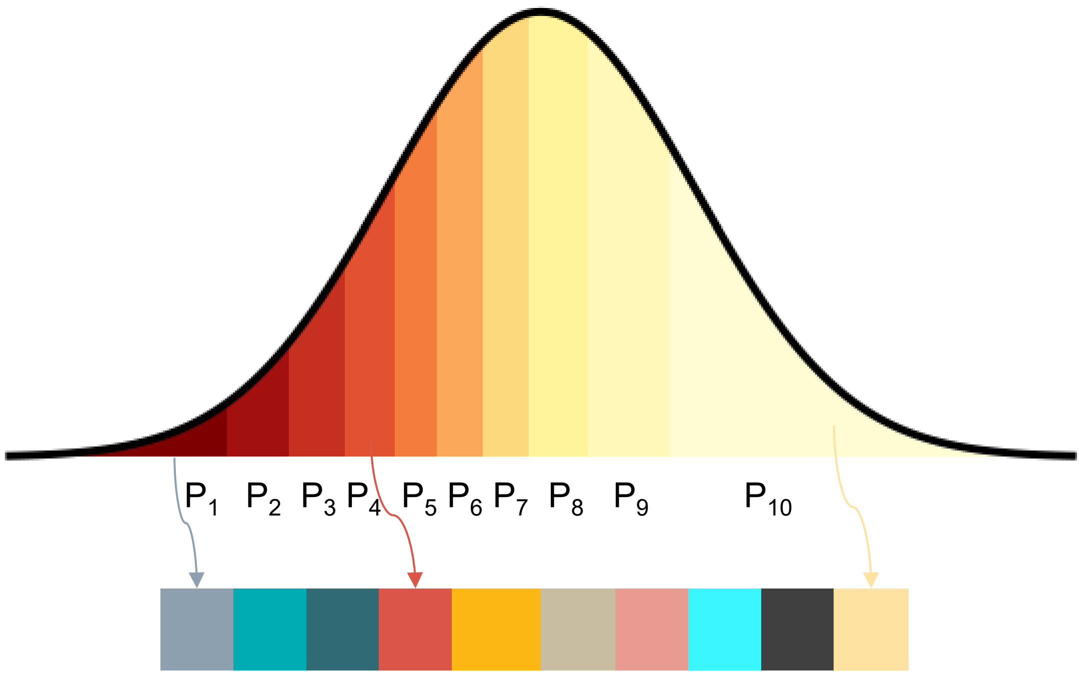
Steps:

- Step 1: Simulate 10,000 winters for each RA winter
- Step 2: Calculate **"availability" metric** for each of the 10,000 simulated winters – **measured as worst consecutive two-day stretch of gas availability**
- Step 3: Sort winters by the metric
- Step 4: Group sorted winters into 10 buckets based on the metric percentile thresholds (P_1, P_2,… P_{10})
  - Thresholds are specified in next slide
- Step 5: Select 10 profiles as the median winter from the 10 buckets (M_1, M_2,… M_{10})

Features:

- Based on sample of simulated winters
- Profiles are a set of 10 of the 10,000 simulated winters that reflect the distribution of potential winters
- Winter availability metric chosen to capture relative scarcity of gas-fired generation across winters
- Buckets not necessarily equally weighted, to better account for tail of distribution

Illustrative Distribution of "Availability" Metric Across (Worst Consecutive 2-day Stretch of Gas Availability)



10 Gas Profiles for Simulation

Gas Profiles: Profile Buckets

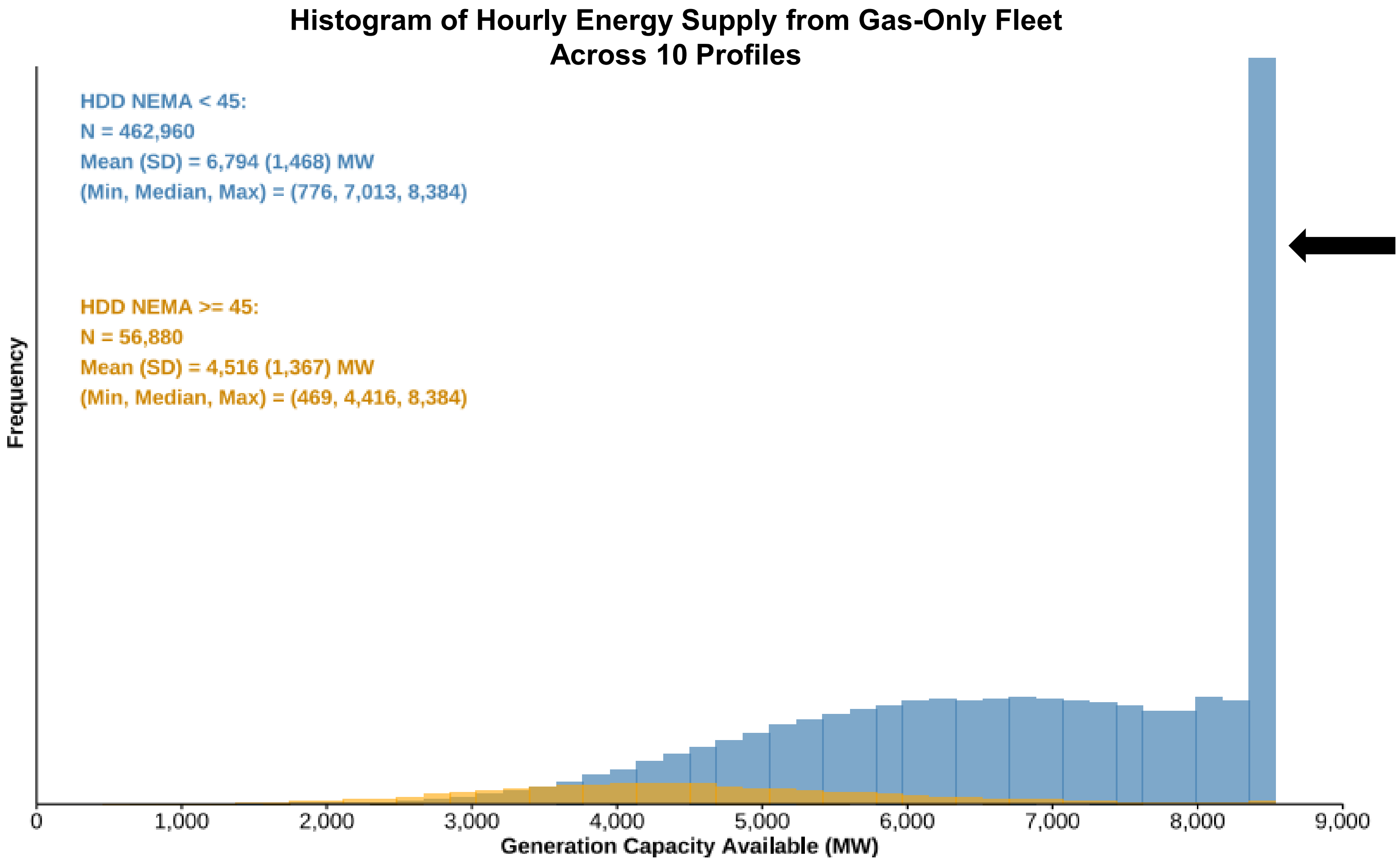
- Profile buckets are not equally sized, but more granular at the left tail of the distribution to better capture winters with less available gas (given greater expected RA impact)
- Each selected profile is weighted by a probability mass that corresponds to the size of the percentile range of its bucket
  - For example, Profile 1 has a small range (0% - 2%) but a small probability (2%)
- This approach will more reliably capture the impact of gas system constraints on RA

ISO-NE Gas System Modeling - Gas Profile Generation
Probability Weights Assigned to Gas Availability Profiles

Profile	Percentile Range	Number of Winters	Probability Mass	Profile-to-Profile Difference
1	0 – 2 %	200	2%	-
2	2 – 5 %	300	3%	1%
3	5 – 10 %	500	5%	2%
4	10 – 17 %	700	7%	2%
5	17 – 25 %	800	8%	1%
6	25 – 35 %	1,000	10%	2%
7	35 – 47 %	1,200	12%	2%
8	47 – 62 %	1,500	15%	3%
9	62 – 80 %	2,000	18%	3%
10	80 – 100 %	2,000	20%	2%

Notes:
[1] Table displays the probability that each gas profile reflects, based on 10,000 simulated winters per load winter.
[2] Each profile represents a median gas availability from within the pool of simulated winters that it reflects.

Summary of Results: Estimation of Hourly Available Energy Across 10 Profiles from Gas-Only Fleet

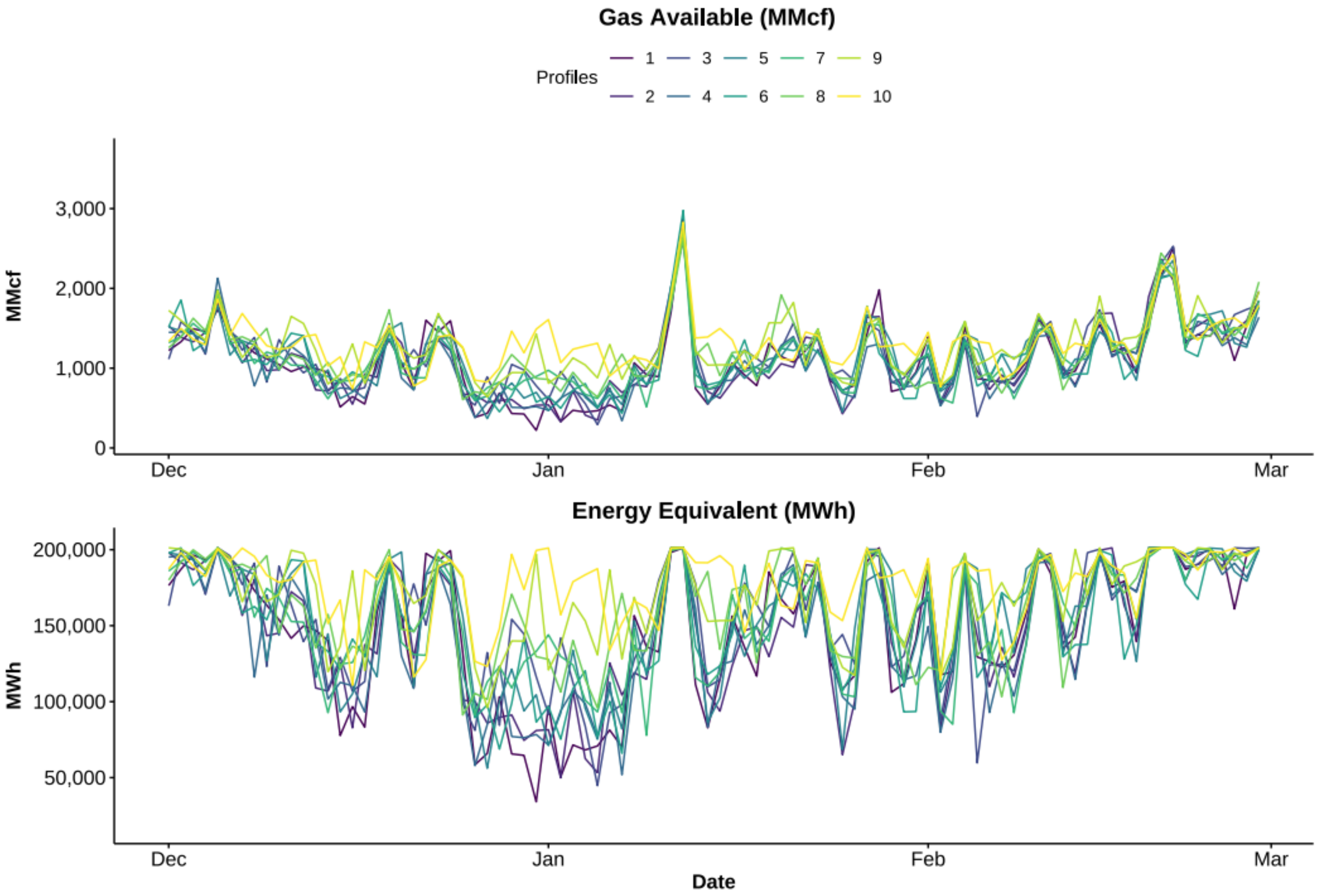


Simulated hourly gas-only energy supply at the **maximum** in the majority of hours on non-cold days (NEMA HDD < 45)

Gas Profiles

- Gas profiles show day-to-day variation, with daily values of a lower-availability profile not always being less than the values of higher-availability profiles

Daily Gas Availability and Energy Equivalent
10 Profiles Selected Using Worst Consecutive 2-day Stretch of Gas Availability Metric
Winter 2017/18 (Climate-Adjusted)



Next Steps

Next Steps

- 2026: Discuss firm fuel contracting

Thank You

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Appendix

LNG Terminals Supply: Tobit Model Estimates

Econometric model estimates using Tobit specification, which accounts for censoring of dependent variable (LNG supply)

Regression Coefficients Summary
Trained on Historic Weather for Winter Months, January 2015 – December 2024

Base Intercept	- 808.41

Temporal Variables

Calendar Variable	**Weekend/Holiday Dummy**	- 35.06
	January Dummy	34.76
	December Dummy	- 49.29
Winter-Specific Intercept Adders	**2014/15**	24.09
	2015/16	106.40
	2016/17	- 43.56
	2017/18	- 12.27
	2018/19	88.33
	2019/20	116.55
	2020/21	121.51
	2021/22	- 26.82
	2022/23	-100.38
	2023/24	*Omitted*
	2024/25	19.10

Weather Variables

		ME	NEMA
Weather Controls	**HDD/Dry Bulb Temp**	18.72	6.50
	Dew Point Temp	15.54	- 12.49
	Wind Speed	- 30.78	50.77
	Cloud Coverage	9.26	93.01
	Global Horizontal Irradiance	0.02	- 0.02
HDD Lags	**HDD 1-day**	- 1.82	- 1.80
	HDD 2-day	5.02	- 1.81
	HDD 3-day	3.11	- 4.43
HDD Moving Average	**HDD 7-Day**	- 10.27	10.82

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Non-Generator Demand: Lasso Model Estimates

Regression Coefficients and Variable Selection Summary
Trained on Historic Weather for Winter Months, January 2015 – December 2024

Base Intercept	561.59

Temporal Variables

Calendar Variable	Weekend/Holiday Dummy	- 56.45
	Time Trend	19.14
	January Dummy	37.74
	December Dummy	- 19.15

Weather Variables

		ME	NEMA
Weather Controls	HDD/Dry Bulb Temp	3.43	83.97
	Dew Point Temp	- 0.63	- 11.72
	Wind Speed	- 0.11	33.00
	Cloud Coverage	- 4.25	23.47
	Global Horizontal Irradiance	0.01	- 0.02
HDD Lags	HDD 1-day		- 6.31
	HDD 2-day	3.17	1.65
	HDD 3-day	- 0.32	- 0.00
HDD Polynomial	HDD 2nd Degree		- 0.78
HDD Moving Average	HDD 7-Day	0.01	3.48

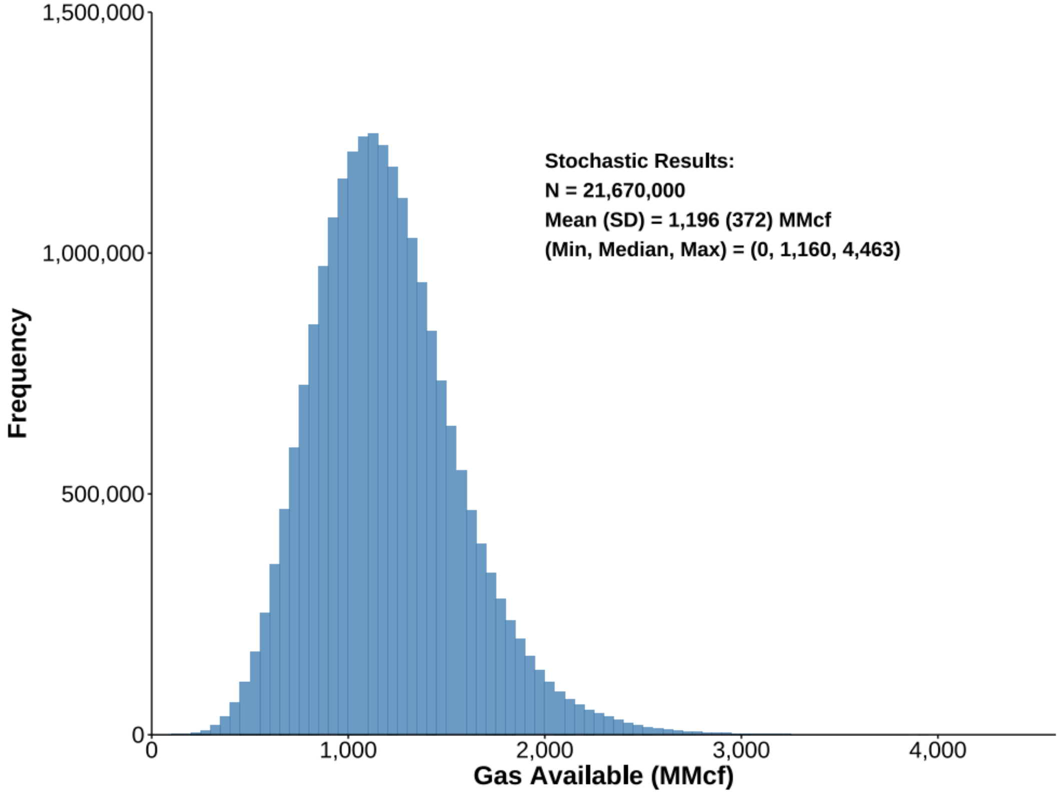
Note:
[1] Cells shaded in light blue indicate variables that were included in the model but were dropped by the Lasso specification.

ANALYSIS GROUP

Gas Available for Electric Generation: Distribution of Values

Reflects distribution of residuals from pipeline supply, LNG terminal supply and non-generator demand models to account for unexplained variation

Histogram of Simulated Daily Gas Available for Electric Generation



ANALYSIS GROUP

Summary of Results: Estimation of Available Energy Excluding Max Hours

Histogram of Hourly Energy from Gas-Only Resources Across 10 Profiles
(Excluding Hours when Capacity reaches Max)