Exhibit 1
Curriculum Vitae & Testimony

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EDUCATION

Ph.D. program (coursework), Nuclear Engineering, University of California, Berkeley

M.S. in Energy and Resources, University of California, Berkeley
Thesis: Safety and Environmental Hazards of Nuclear Reactor Designs

B.S. in Physics, University of Massachusetts, Amherst

PROFESSIONAL EXPERIENCE

2010 - Present Analysis Group, Inc., Boston, MA
Principal
Vice President

2007 - 2010 MA Department of Public Utilities, Boston, MA
Chairman
Member, Energy Facilities Siting Board
Manager, New England States Committee on Electricity
Treasurer, Executive Committee, Eastern Interconnect States' Planning Council
Representative, New England Governors' Conference Power Planning Committee
Member, NARUC Electricity Committee, Procurement Work Group

2003 - 2007 Analysis Group, Inc., Boston, MA
Vice President
Manager ('03 – '05)

2000 - 2003 Lexecon Inc., Cambridge, MA
Senior Consultant
Consultant ('00 – '02)

1998 - 2000 Massachusetts Department of Environmental Protection, Boston, MA
Environmental Analyst

1991 - 1998 Massachusetts Department of Public Utilities, Boston, MA
Senior Analyst, Electric Power Division

1988 - 1991 University of California, Berkeley, CA
Research Assistant, Safety/Environmental Factors in Nuclear Designs

TESTIMONY IN THE LAST EIGHT YEARS

Rebuttal Testimony on Reopening of Paul J. Hibbard before the State of Illinois Commerce Commission on Behalf of Commonwealth Edison Company, Docket No. 18-0843, May 31, 2019.

Direct Testimony on Reopening of Paul J. Hibbard before the State of Illinois Commerce Commission on Behalf of Commonwealth Edison Company, Docket No. 18-0843, March 4, 2019.

Pre-Filed Testimony of Paul J. Hibbard before the Connecticut Siting Council on Behalf of NTE Connecticut LLC, Docket No. 470, January 18, 2019.

Post-Settlement Testimony of Paul J. Hibbard before the Maryland Public Service Commission on behalf of The Applicants, Case No. 9449, January 5, 2018.

Rebuttal Testimony of Paul J. Hibbard before the Public Service Commission of the District of Columbia on behalf The Applicants, Formal Case No. 1142, October 27, 2017.

Rebuttal Testimony of Paul J. Hibbard before the State of Vermont Public Service Board on behalf of Vermont Gas Systems Inc., Docket No.s 8698 and 8710, September 26, 2016.

Affidavit of Paul J. Hibbard before the Federal Energy Regulatory Commission, Docket No. ER16-1751-000, May 20, 2016.

Testimony of Paul J. Hibbard before the Senate Committee on Global Warming and Climate Change, *Power System Reliability in New England: Meeting Electric Resource Needs in an Era of Growing Dependence on Natural Gas*, November 24, 2015.

Declaration of Paul J. Hibbard and Andrea M. Okie, in the United States Court of Appeals for the District of Columbia Circuit, Case No. 15-1363 (and consolidated cases), December 8, 2015.

Direct Testimony of Paul J. Hibbard, Florida Public Service Commission, on Behalf of Calpine Construction Finance Company, L.P., July 2014 before the Florida Public Service Commission, Docket No. 140110-E1, July 14, 2014.

Federal Energy Regulatory Commission, Docket Nos. ER14-1050-000 and ER14-1050-001, Testimony of Paul Hibbard and Todd Schatzki on Behalf of ISO New England Inc., February 12, 2014.

Testimony of Paul J. Hibbard to the Maine Public Utilities Commission on behalf of Loring Holdings LLC. Conducted a financial and ratepayer analysis of the benefits of a project to develop a power plant and natural gas pipeline in the State of Maine, describing results (2014-2015).

Rebuttal Testimony of Paul Hibbard, State of Minnesota, Minnesota Public Utilities Commission, on behalf of Calpine Construction Finance Company, L.P., MPUC Docket No. E-002/CN-12-1240, October 18, 2013.

Direct Testimony of Paul Hibbard, State of Minnesota, Minnesota Public Utilities Commission, on behalf of Calpine Construction Finance Company, L.P., MPUC Docket No. E-002/CN-12-1240, September 27, 2013.

Testimony of Paul J. Hibbard before the Massachusetts Department of Public Utilities on behalf of the Massachusetts Department of Energy Resources, DPU 13-07, May 31, 2013.

Testimony of Paul J. Hibbard before the House Committee on Energy and Commerce, Subcommittee on Energy and Power, *The Role of Regulators and Grid Operators in Meeting Natural Gas and Electric Coordination Challenges*, March 19, 2013.

Testimony of Paul J. Hibbard on behalf of the Massachusetts Department of Energy Resources, on the ratepayer and social benefits of reducing methane leaks from a local natural gas distribution company's system (2013)

Testimony of Paul J. Hibbard before the California Legislature, *The Economic Impacts of RGGI's First Three Years*, California Select Committee on the Environment, the Economy, and Climate Change, March 27, 2012.

Testimony of Paul J. Hibbard before the New Hampshire Legislature, *RGGI and the Economy Following the Dollars, NH House Committee on Science, Technology, and Energy*, February 14, 2012.

Testimony of Paul J. Hibbard before the Massachusetts Legislature, *RGGI and the Economy – Following the Dollars, Massachusetts Senate Committee on Global Warming and Climate Change*, February 13, 2012.

PUBLICATIONS AUTHORED IN THE LAST TEN YEARS

Paul G. Hibbard, Susan F. Tierney and Pavel G. Darling, *An Expanding Carbon Cap-and-trade Regime? A Decade of Experience with RGGI Charts a Path Forward*, Article for the Electricity Journal, June 2018.

Paul J. Hibbard., Susan F. Tierney, Pavel G. Darling and Sarah Cullinan, *The Economic Impacts of the Regional Greenhouse Gas Initiative on Nine Northeast and Mid-Atlantic States*; Review of RGGI's Third Three-Year Compliance Period (2015-2017), April 2018.

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Paul J. Hibbard and Andrea M. Okie, *Ohio's Electricity Future: Assessment of Context and Options*, Report of Advanced Energy Economy, April 2015.

Susan Tierney, Paul Hibbard, and Craig Aubuchon, *Electric System Reliability and EPA's Clean Power Plan: The Case of PJM*, Report for the Energy Foundation, March 16, 2015.

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Andrea M. Okie, Paul J. Hibbard, and Susan F. Tierney, *Tools States Can Utilize for Managing Compliance Costs and the Distribution of Economic Benefits to Consumers Under EPA's Clean Power Plan*, Electricity Forum, February 2015.

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Susan Tierney, Paul Hibbard, and Andrea Okie, *Solar Development Incentives: Status of Colorado's Solar PV Program, Practices in Other States, and Suggestions for Next Steps*," June 30, 2011.

Susan F. Tierney, Paul J. Hibbard, Michael J. Bradley, Christopher Van Atten, Amlan Saha, and Carrie Jenks, *Ensuring a Clean, Modern Electric Generating Fleet while Maintaining Electric System Reliability*, August 2010.

"Transmission Planning," comments to FERC Technical Conference on Transmission Planning Processes Under Order No. 890, Docket No. AD09-8-000, Philadelphia, PA, September, 2009.

Exhibit 2
Public Health and Environmental Impacts of Options to Meet Resource Needs
Analysis of Resource Options in Liberty Utilities' LCIRP
June 2019

Liberty Utilities (EnergyNorth Natural Gas) Corp. (Liberty, or the Company) has identified options to meet resource needs identified in its Least Cost Integrated Resource Plan (LCIRP), including potential expansion of the capacity of the Concord Lateral, and development of the Granite Bridge Pipeline (Granite Bridge Project).

In addition to helping continue to meet the needs of existing customers in its service territory, both options would allow some New Hampshire residents and businesses to switch to natural gas (service conversions) for heating, cooking, hot water, and/or process needs (service needs), from other fuels. In providing an alternative service need option, the projects reviewed open the door to achieving reductions in emissions of pollutants, to the extent that they would displace the use of higher-emitting sources for meeting heating and other service needs. Reducing local sources of pollution provides public health and environmental benefits in New Hampshire, potentially reducing premature deaths, respiratory and other health impacts, and the risks associated with climate change. This could also support New Hampshire's compliance with emission and air quality requirements under the Clean Air Act (CAA).

This document assesses the potential public health and environmental impacts of the options reviewed in the Company's LCIRP with respect to these potential shifts in customer fuel use. The focus is on pollutants and impacts for which there is sufficient knowledge and data to estimate changes in emissions, and associated impacts on public health and the environment.

How might projects lead to public health and environmental impacts?

In response to increasing demand for natural gas inside and outside Liberty's service territory, the development of the resource/supply options identified in the Company's LCIRP would increase access to natural gas for thousands of residents and businesses across southern New Hampshire, including residents that currently meet their heating and other service needs through older equipment and higher-emitting resources.

In addition to service conversion impacts, the options could reduce public health environmental impacts compared to the status quo by reducing Liberty's heavy-duty truck traffic that currently delivers liquid fuel to satellite fuel centers across the state, reducing the pollutants associated with delivery operations. Specifically, Liberty currently contracts for hundreds of truck deliveries of propane and liquefied natural gas (LNG) to satellite storage tanks, which are used to support wintertime operations. Liberty expects that these can be greatly reduced once the Granite Bridge Project is online.[1] In addition service conversions to natural gas could eliminate truck deliveries of oil and propane to individual homes and businesses previously needed to serve new Liberty customers prior to their conversion.

[1] The Granite Bridge Project would reduce propane and LNG truck traffic to facilities in Nashua, Manchester, Concord, and Tilton. See New Hampshire Public Utilities Commission, Docket No. DG 17-198, Liberty Utilities (EnergyNorth Natural Gas) Corp. d/b/a Liberty Utilities, Approval of Natural Gas Supply Strategy, Pre-Filed Testimony of Susan L. Fleck and Francisco C. Dafonte, December 21, 2017, p. 18, available at http://www.puc.state.nh.us/Regulatory/Docketbk/2017/17-198/INITIAL%20FILING%20-%20PETITION/17-198_2017-12-22_ENGI_PDTESTIMONY_FLECK_DAFONTE.PDF.

What are the potential benefits?

- The combustion of fuel to meet home and business heating is a source of local pollutants - including nitrogen oxides (NO_x), sulfur dioxide (SO_2), particulate matter (PM), mercury (Hg), carbon dioxide (CO_2) and methane (CH_4), the latter two of which are associated with climate change.

- These pollutants lead to or exacerbate premature deaths, asthma, and other major health problems for the state's residents, and increase the economic and environmental risks of climate change. For example, the New Hampshire Department of Environmental Services (NH DES) estimates that one premature death due to air pollution results in $9.35 million in costs, one asthma-related emergency room visit costs $440, and one lost work day averages $150.[2] NH DES estimates that fine particulate matter and ozone alone accounted for approximately $3.8 billion in health impacts in New Hampshire from 2013 through 2015.[3]

- Residents and businesses in New Hampshire require fuel for heating and other winter service needs - fuel such as oil, propane, natural gas, biomass/wood, and electricity. Opening access to natural gas will necessarily displace the use of other energy sources for heating needs that are less clean and less efficient. Specifically, other than natural gas, the dominant sources of fuel for heating and other service needs in New Hampshire are oil and propane. The corresponding reduction in emissions from service conversions is driven both by the lower emission rates of natural gas relative to other sources, and by the installation at the point of service conversions of more efficient equipment for meeting service needs.

- Both the Concord Lateral and Granite Bridge options would open access to natural gas to meet service needs. For example, Liberty estimates that during the first year after Granite Bridge comes into service, it would add approximately 1,800 residential customers and over 500 commercial and industrial (C&I) customers. In each subsequent year, Liberty expects to add additional customers; for example, by 2037/2038, they estimate additions of over 1,000 residential customers and over 200 C&I customers. These customers will be choosing natural gas for heating over oil, propane, or some other heating source and would not have access to natural gas without the Granite Bridge Project.[4] Thus, over time, as these customers select natural gas for heating, the state will avoid additional emissions of NO_x, SO_2, PM, Hg, CO_2, and CH_4, and realize corresponding health benefits compared to emissions produced from more polluting sources such as oil or propane.

- Health benefits derive from fewer emission of pollutants associated with negative health impacts:

[2] "Considerable variability in valuation exists. Valuations presented here are interpolated median 2011 valuations." New Hampshire Department of Environmental Services, State of New Hampshire Air Quality – 2017: Air Pollution Trends, Effects and Regulation, March 2018, available at https://www.des.nh.gov/organization/commissioner/pip/publications/documents/r-ard-17-01.pdf, Table 4.2, p. 64-65.
[3] Figure reported in 2010 dollars. Economic impacts of air pollution consider ozone and particulate matter pollution together. New Hampshire Department of Environmental Services, State of New Hampshire Air Quality – 2017: Air Pollution Trends, Effects and Regulation, March 2018, available at https://www.des.nh.gov/organization/commissioner/pip/publications/documents/r-ard-17-01.pdf, Table 4.3, p. 66.
[4] Expected customer growth stems from new service and service conversions within the Company's existing service territory and - in the case of the Granite Bridge option - new access to natural gas along the route of the Project in towns that currently do not have access to natural gas. Liberty Utilities has noted that without Granite Bridge, it may need to stop providing natural gas services to new customers. See New Hampshire Public Utilities Commission, Docket No. DG 17-198, Liberty Utilities (EnergyNorth Natural Gas) Corp. d/b/a Liberty Utilities, Approval of Natural Gas Supply Strategy, Pre-Filed Testimony of Susan L. Fleck and Francisco C. Dafonte, December 21, 2017, p. 23, available at http://www.puc.state.nh.us/Regulatory/Docketbk/2017/17-198/INITIAL%20FILING%20-%20PETITION/17-198_2017-12-22_ENGI_PDTESTIMONY_FLECK_DAFONTE.PDF.

- Nitrogen oxides are implicated in a wide variety of health and environmental impacts. Health impacts include respiratory infection and disease, such as asthma. Environmental effects include acid rain, haze, and nutrient pollution in coastal waters.[5]

- Sulfur dioxide is implicated in a wide variety of health and environmental impacts. Like NO_x, health impacts include respiratory infection and disease, such as asthma. Environmental effects include acid rain and haze.[6]

- Particulate matter is implicated in a wide variety of health and environmental impacts. Health impacts include negative effects on the heart and lungs, such as respiratory disease and non-fatal heart attacks. Environmental effects include acid rain, depletion of nutrients in soil and water, and negative effects on the diversity of ecosystems.[7]

- Mercury is implicated in a wide variety of health and environmental impacts. Some of the health impacts include headaches, changes in nerve response, and poor performance on test of mental function. Prolonged high exposure can cause kidney effects, respiratory failure, and death. Environmental effects are concentrated in animals that eat fish. Due to mercury exposure, these animals are subject to reduced reproduction, slower growth and development, and abnormal behavior, and even death.[8]

- Emissions of greenhouse gases contribute to the social, economic and environmental risks associated with climate change.

What options for meeting expected demand were considered in assessing the health and environmental impacts?

The Concord Lateral and the Granite Bridge Project were reviewed by Liberty as resource options to reliably meet future customer demand identified in its LCIRP. In order to understand how these options may affect public health and the environment in New Hampshire, we review the potential of each option relative to circumstances absent either project (the status quo). Thus, we analyze the following three scenarios related to natural gas supply and demand in and around Liberty's service territory going forward:

1. **Status Quo:** If Liberty does not move forward with any resource options reviewed in its LCIRP, any potential new customers - whether new to the service territory or those that otherwise would be willing to switch to natural gas for service needs - will be unable to meet their space heating needs through natural gas and must use heating technologies reliant upon other fuel sources such as oil, propane, biomass, and electricity. Under the Status Quo option, we assume that additional customers to Liberty's service territory use oil, propane, biomass, and electric heating technologies in the same proportion as current customers in the counties encompassing Liberty's existing service territory, and that no existing customers will switch to natural gas. Likewise for customers along the proposed Granite Bridge pipeline route, we assume they will use (or continue to use) oil, propane, biomass, and electric heating technologies in the same proportion as current

[5] "Nitrogen Dioxide (NO_2) is one of a group of highly reactive gases known as oxides of nitrogen or nitrogen oxides (NO_x) […] NO_2 is used as the indicator for the larger group of nitrogen oxides." EPA, Basic Information about NO_2, accessed September 5, 2018, available at https://www.epa.gov/no2-pollution/basic-information-about-no2#Effects.
[6] EPA, Sulfur Dioxide Basics, accessed September 5, 2018, available at https://www.epa.gov/so2-pollution/sulfur-dioxide-basics.
[7] EPA, Health and Environmental Effects of Particulate Matter (PM), accessed September 5, 2018, available at https://www.epa.gov/pm-pollution/health-and-environmental-effects-particulate-matter-pm.
[8] EPA, Basic Information about Mercury, accessed September 5, 2018, available at https://www.epa.gov/mercury/basic-information-about-mercury; Health impacts listed are from inhaling elemental mercury, EPA, Health Effect of Exposures to Mercury, accessed September 5, 2018, available at https://www.epa.gov/mercury/health-effects-exposures-mercury.

residents in the county encompassing the proposed pipeline route. The Status Quo option formed the basis of comparison for the two other options we considered.

2. **Granite Bridge:** The Granite Bridge Project will enable additional customers to meet their service needs through natural gas technology. For estimating customer additions and service conversions, we relied on Liberty's growth projections included in their LCIRP. This includes growth in natural gas use for customers in Liberty's existing service territory, including both new build as well as service conversions for customers in the service territory but currently meeting service needs through alternative fuels. We also use Liberty's projections of new customers in the communities of Raymond, Epping, and Candia (i.e. those along the Granite Bridge Project's proposed route).
3. **Concord Lateral Expansion:** Like the Granite Bridge project option, expanded capacity on the Concord Lateral will enable additional customers to meet their service needs through natural gas technology. For this we relied on the same growth projections as in the analysis of the Granite Bridge project. However, in this option, the potential new customers in Raymond, Epping, and Candia will not have access to natural gas and will therefore remain on their current heating technologies.

We made these comparisons under two forecasts of additional customers covering different time periods:[9]

1. **IRP:** The IRP scenario is based on forecasts of additional customers identified by Liberty for its LCIRP. The LCIRP forecast begins in the 2017/2018 gas year and ends five years later in the 2021/2022 gas year.
2. **GB-LR:** The GB-LR scenario reflects long-run impacts due to the Granite Bridge project. A forecast of additional customers generated by Liberty that assumes Granite Bridge comes online in 2022/2023 forms the basis for the GB-LR scenario, which is one year later than in the LCIRP forecast (a timing difference that does not materially affect the analysis). The time period for the GB-LR scenario extends to the 2037/2038 gas year.

Finally, for the purposes of this analysis we focus initially only on the heating portion of service needs. That is, we recognize that there are additional benefits of service conversions associated with switching to natural gas not only for heating, but also for other services, such as hot water, cooking, and potentially other commercial/industrial processes. However, since it is difficult to obtain data on or forecast what portion of service conversion customers would use natural gas for these other service needs, we assume in effect that natural gas is only used for heating in our calculations. In this sense, we may significantly understate the potential benefits of natural gas service conversions in New Hampshire.

What heating technologies were considered?

We considered the following heating technologies that reflect options used by residents in the counties encompassing Liberty's existing service territory, as well as (where relevant) those counties encompassing the proposed route of the Granite Bridge pipeline.[10] The forecasted additional customers reflect existing residents and businesses that switch to natural gas, as well as new development. We assume that without access to natural gas, (1) service conversion customers would remain on their existing lower efficiency heating technologies, and (2) new development customers would select a higher efficiency non-gas option, such as a high efficiency oil boiler or a high efficiency electric heat pump.

[9] Our analysis also relies on a forecast of gas consumed per customer. This forecast does not change across the two forecasts of additional customers.
[10] Belknap, Hillsborough, Merrimack, and Rockingham counties. These counties cover the path of the Granite Bridge project and Liberty's current natural gas service territory.

Thus we present results for both standard and high-efficiency options, and assume similar efficiencies for all classes of customers.[11]

1. *Natural gas-fired space heating*: high-efficiency option only
2. *Oil-fired space heating*: standard-efficiency and high-efficiency options
3. *Propane-fired space heating*: standard-efficiency and high-efficiency options
4. *Biomass-fired space heating*: standard-efficiency (as modeled by the median efficiency of a range of wood stoves and boilers used for home heating) and high-efficiency (as modeled by the 90th percentile efficiency of a range of wood stoves and boilers used for home heating) options.[12]
5. *Electric heating*: standard-efficiency (as modeled by electric baseboard heating) and high-efficiency (as modeled by a high-efficiency heat pump) options. We assume, however, that customers using a heat pump will require a back-up source of heating, which we consider to be electric baseboard heating. While the precise share of heating load served by a back-up heating source varies, it is well documented that heat pumps do not typically supply the entirety of the required heating load.[13] In our calculations, we assume that in New Hampshire a supplemental heating source is used for twenty five percent of total winter heating load.
6. *Other*: this category includes customers who have either no heating system, or some other technology such as solar, which generates no emissions.

By how much will emissions decrease under the IRP scenario?

Table 1 – Aggregate, cumulative emission estimates for the IRP scenario
Total emissions from using heating technologies under the Status Quo, Granite Bridge, and Concord Lateral Expansion options.

IRP	Status Quo	Granite Bridge Option	Concord Lateral Option
NO_x (lbs)	995,514	383,102	385,690
SO_2 (lbs)	230,746	118,962	119,453
PM (lbs)	367,469	30,779	31,795
Hg (oz)	123.9	16.8	17.3
CO_2e (tons)	406,401	297,498	297,966

Table 1 presents estimates of aggregate emissions of residential and C&I customers for the IRP scenario under the Status Quo, Granite Bridge, and Concord Lateral Expansion options. As Table 1 illustrates, the Granite Bridge option results in the lowest quantity of emissions for all pollutants.

[11] We compared our selected residential heating technology efficiencies with estimates of C&I heating technology efficiencies derived from the SEEAT model (discussed in more detail below) and found the efficiencies to be similar.
[12] Our median efficiency wood stove is a hydronic, non-catalytic stove fueled by cord wood. Our high efficiency wood stove is a hydronic, non-catalytic stove fueled by wood pellets.
[13] See, for example, a 2016 CADMUS study evaluating heat pumps in Massachusetts and Rhode Island, in which the study concludes, among other things, that "In most cases, [dual mini-split heat pumps] served as secondary systems, either to provide heat for a single space or to provide supplemental heat in addition to a primary system" (CADMUS, "Ductless Mini-Split Heat Pump Impact Evaluation," December 30, 2016 at 21).

Table 2a – Per-residential customer average annual emissions
Average annual emissions from using heating technologies driven by natural gas, oil, propane, biomass, and electricity.

	Natural Gas	Oil		Propane		Biomass		Electric	
Efficiency	*High*	*Standard*	*High*	*Standard*	*High*	*Standard*	*High*	*Baseboard*	*Heat Pump*
NO_x (pounds)	6.71	20.55	17.93	18.03	15.73	31.75	27.27	9.38	4.84
SO_2 (pounds)	2.08	4.61	4.02	4.87	4.25	2.05	1.76	5.68	2.94
PM (pounds)	0.54	1.23	1.07	0.54	0.66	76.31	65.54	--	--
Hg (ounces)	0.0003	0.0041	0.0036	--	--	--	--	--	--
CO_2e (tons)	5.21	8.49	7.41	7.09	6.19	9.18	7.88	6.65	3.43

Table 2a presents annual average emissions per residential customer for different fuel types and efficiencies (under the IRP scenario).[14]

Table 2b – Per-commercial customer average annual emissions
Average annual emissions from using heating technologies driven by natural gas, oil, propane, biomass, and electricity.

	Natural Gas	Oil		Propane		Biomass		Electric	
Efficiency	*High*	*Standard*	*High*	*Standard*	*High*	*Standard*	*High*	*Baseboard*	*Heat Pump*
NO_x (pounds)	32.60	99.88	87.10	87.63	76.42	154.29	132.51	45.56	23.54
SO_2 (pounds)	10.12	22.40	19.54	23.66	20.63	9.95	8.55	27.61	14.26
PM (pounds)	2.62	5.99	5.22	2.62	3.21	370.80	318.45	--	--
Hg (ounces)	0.0014	0.0201	0.0175	--	--	--	--	--	--
CO_2e (tons)	25.32	41.27	35.99	34.47	30.06	44.60	38.30	32.30	16.69

Table 2a presents annual average emissions per commercial customer for different fuel types and efficiencies (under the IRP scenario).

Figures 1a and Figure 1b illustrate the cumulative lifetime emissions associated with forecasted additional residential and C&I customers (including additional customers within Liberty's existing service territory as well as the additional customers Liberty anticipates serving under the Granite Bridge Project option) for the IRP scenario.

[14] The annual average is a simple average over the 5-year period associated with the IRP scenario. Because average consumption per customer changes each year, actual annual values differ slightly over time compared to what is shown in the table.

Figure 1a – Cumulative lifetime emissions for the IRP scenario
Additional residential customers[15]

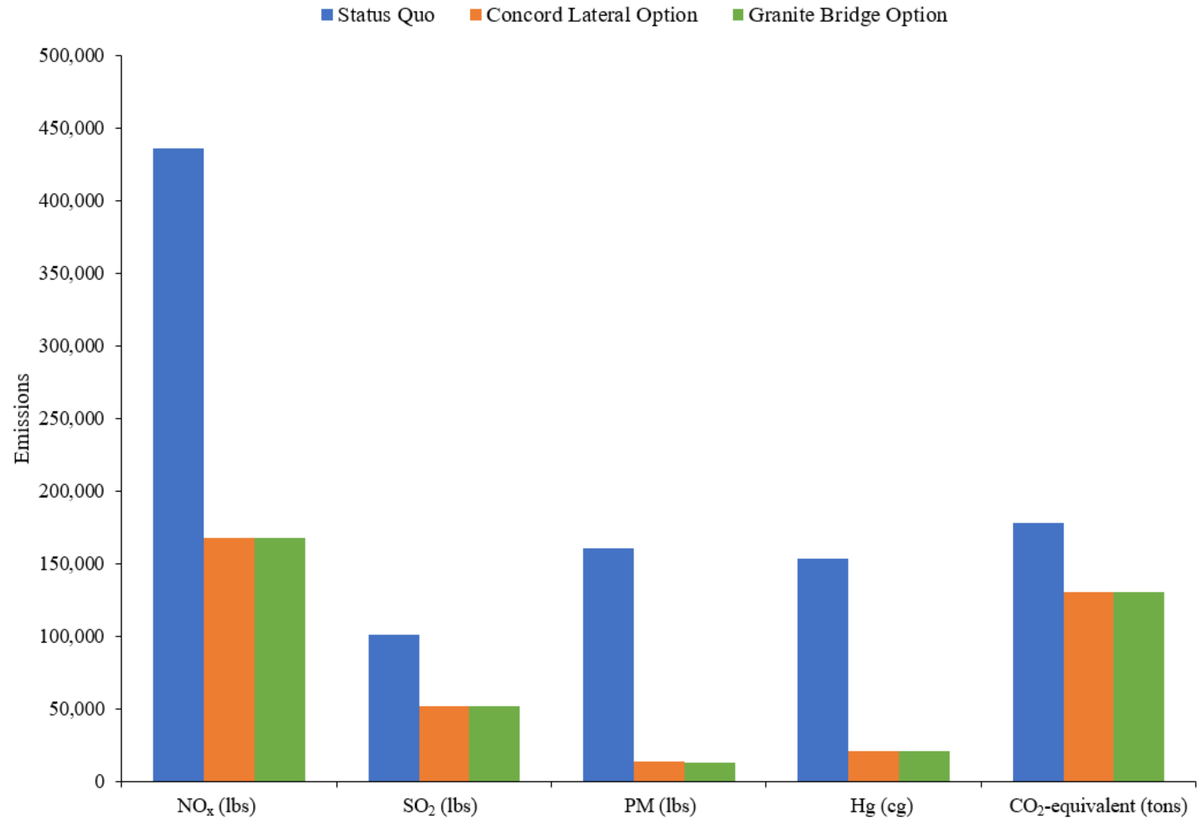

Table 3 – Data underlying Figure 1a

		NO_x (lbs)	SO_2 (lbs)	PM (lbs)	Hg (cg)	CO_2-equivalent (tons)
Status Quo	New Customers In Existing Territory	435,360	100,901	160,883	153,598	177,722
	New Customers in Epping, Raymond, Candia	218	52	59	82	90
	Total	**435,578**	**100,953**	**160,942**	**153,680**	**177,812**
Concord Lateral Option	New Customers In Existing Territory	167,534	52,023	13,460	20,887	130,099
	New Customers in Epping, Raymond, Candia	218	52	59	82	90
	Total	**167,753**	**52,075**	**13,519**	**20,969**	**130,189**
Granite Bridge Option	New Customers In Existing Territory	167,534	52,023	13,460	20,887	130,099
	New Customers in Epping, Raymond, Candia	84	26	7	11	66
	Total	**167,619**	**52,049**	**13,467**	**20,898**	**130,165**

[15] Please note that for display purposes, different units are used for each pollutant shown. Specifically, NO_x, SO_2, and PM are in pounds, Mercury is in centigrams, and CO_2 is in tons.

Figure 1b – Cumulative lifetime emissions for the IRP scenario
Additional C&I customers

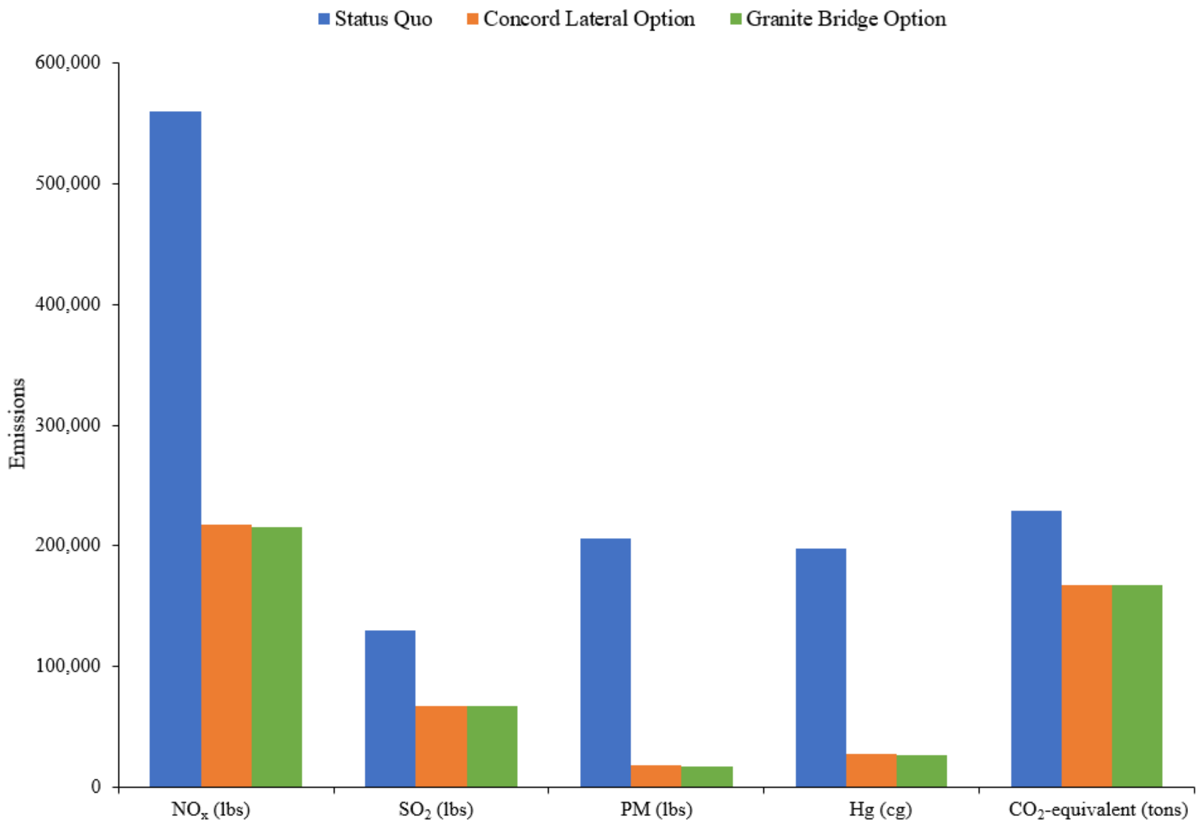

Table 4 – Data underlying Figure 1b

		NO_x (lbs)	SO_2 (lbs)	PM (lbs)	Hg (cg)	CO_2-equivalent (tons)
Status Quo	New Customers In Existing Territory	555,931	128,845	205,439	196,136	226,941
	New Customers in Epping, Raymond, Candia	4,005	948	1,088	1,500	1,648
	Total	**559,936**	**129,793**	**206,527**	**197,636**	**228,589**
Concord Lateral Option	New Customers In Existing Territory	213,933	66,431	17,188	26,672	166,129
	New Customers in Epping, Raymond, Candia	4,005	948	1,088	1,500	1,648
	Total	**217,938**	**67,379**	**18,276**	**28,171**	**167,777**
Granite Bridge Option	New Customers In Existing Territory	213,933	66,431	17,188	26,672	166,129
	New Customers in Epping, Raymond, Candia	1,551	482	125	193	1,204
	Total	**215,483**	**66,912**	**17,312**	**26,865**	**167,334**

As the figures and underlying tables illustrate, the Granite Bridge project option produces the least amount of cumulative emissions over time compared to either the Status Quo option or the Concord Lateral Expansion option.

By how much will emissions decrease under the GB-LR scenario?

Table 5 – Aggregate, cumulative emission estimates for the GB-LR scenario
Total emissions from using heating technologies under the Status Quo, Granite Bridge, and Concord Lateral Expansion options.

GB-LR	Status Quo	Granite Bridge Option	Concord Lateral Option
NO_x (lbs)	13,629,053	5,250,732	5,521,009
SO_2 (lbs)	3,157,123	1,630,470	1,681,805
PM (lbs)	5,062,057	421,858	527,957
Hg (oz)	1,682	231	282
CO_2e (tons)	5,558,784	4,077,459	4,126,312

Table 5 presents estimates of aggregate emissions of residential and C&I customers for the GB-LR scenario under the Status Quo, Granite Bridge, and Concord Lateral Expansion options. As in the IRP scenario, the Granite Bridge option produces the fewest cumulative emissions across all three options considered for each pollutant assessed.

Table 6a – Per-residential customer average annual emissions
Average annual emissions from using heating technologies driven by natural gas, oil, propane, biomass, and electricity.

	Natural Gas	Oil		Propane		Biomass		Electric	
Efficiency	*High*	*Standard*	*High*	*Standard*	*High*	*Standard*	*High*	*Baseboard*	*Heat Pump*
NO_x (pounds)	6.56	20.10	17.53	17.64	15.38	31.06	26.67	9.17	4.74
SO_2 (pounds)	2.04	4.51	3.93	4.76	4.15	2.00	1.72	5.56	2.87
PM (pounds)	0.53	1.21	1.05	0.53	0.65	74.64	64.10	--	--
Hg (ounces)	0.0003	0.0040	0.0035	--	--	--	--	--	--
CO_2e (tons)	5.10	8.31	7.24	6.94	6.05	8.98	7.71	6.50	3.36

Table 6a presents annual average emissions per residential customer for different fuel types and efficiencies (under the GB-LR scenario).[16]

Table 6b – Per-commercial customer average annual emissions
Average annual emissions from using heating technologies driven by natural gas, oil, propane, biomass, and electricity.

	Natural Gas	Oil		Propane		Biomass		Electric	
Efficiency	*High*	*Standard*	*High*	*Standard*	*High*	*Standard*	*High*	*Baseboard*	*Heat Pump*
NO_x (pounds)	31.25	95.72	83.48	83.98	73.24	147.87	126.99	43.67	22.56
SO_2 (pounds)	9.70	21.47	18.73	22.68	19.77	9.54	8.19	26.46	13.67
PM (pounds)	2.51	5.74	5.00	2.51	3.07	355.37	305.20	--	--
Hg (ounces)	0.0014	0.0193	0.0168	--	--	--	--	--	--
CO_2e (tons)	24.26	39.55	34.49	33.03	28.81	42.74	36.71	30.96	15.99

Table 6b presents annual average emissions per commercial customer for different fuel types and efficiencies (under the GB-LR scenario).

Figures 2a and Figure 2b illustrate the cumulative lifetime emissions associated with forecasted additional residential and C&I customers (including additional customers within Liberty's existing service territory

[16] The annual average is a simple average over the 20-year period associated with the GB-LR scenario. As average consumption per customer changes each year, actual annual values differ slightly over time.

as well as the additional customers Liberty anticipates serving under the Granite Bridge Project option) for the GB-LR scenario.

Figure 2a – Cumulative lifetime emissions for the GB-LR scenario
Additional residential customers

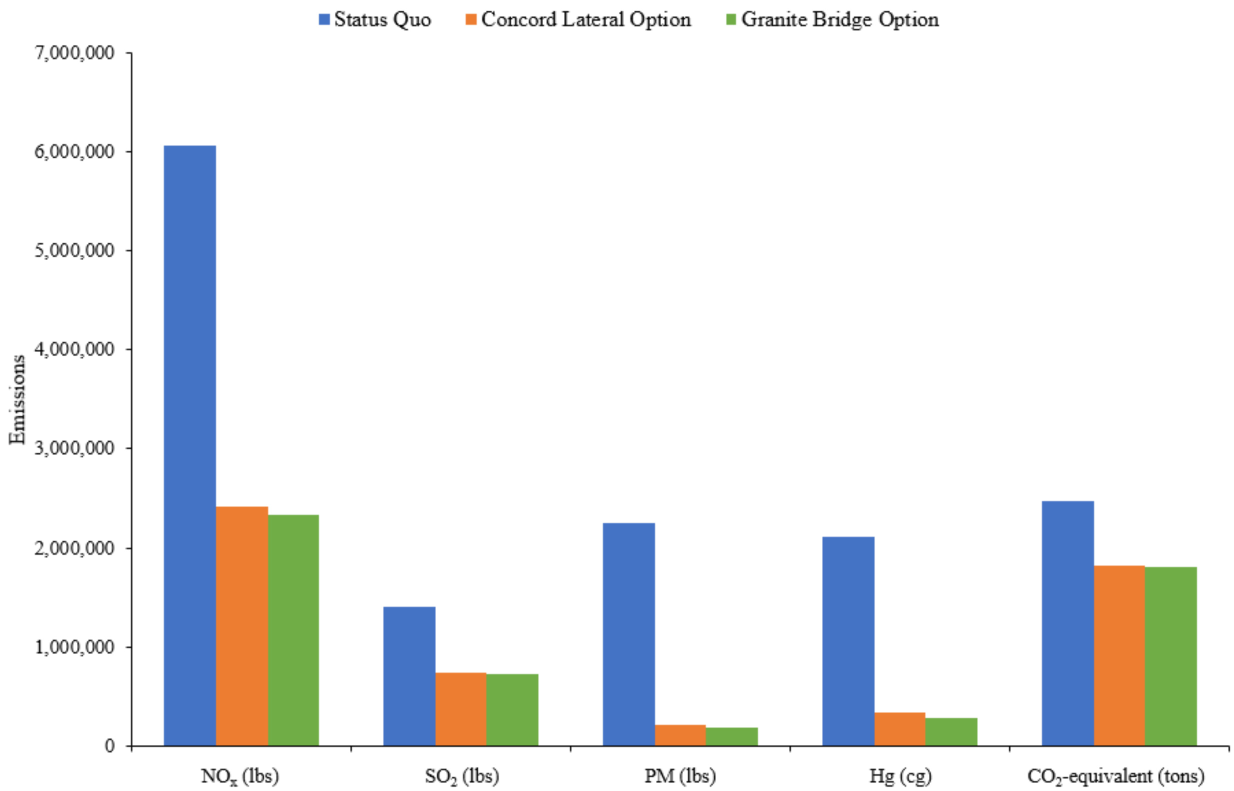

Table 7 – Data underlying Figure 2a

		NO_x (lbs)	SO_2 (lbs)	PM (lbs)	Hg (cg)	CO_2-equivalent (tons)
Status Quo	New Customers In Existing Territory	5,927,124	1,372,010	2,221,205	2,069,077	2,416,742
	New Customers in Epping, Raymond, Candia	128,168	30,328	34,819	47,988	52,735
	Total	**6,055,291**	**1,402,338**	**2,256,024**	**2,117,065**	**2,469,477**
Concord Lateral Option	New Customers In Existing Territory	2,283,100	708,954	183,430	284,640	1,772,942
	New Customers in Epping, Raymond, Candia	128,168	30,328	34,819	47,988	52,735
	Total	**2,411,267**	**739,282**	**218,249**	**332,628**	**1,825,677**
Granite Bridge Option	New Customers In Existing Territory	2,283,100	708,954	183,430	284,640	1,772,942
	New Customers in Epping, Raymond, Candia	49,627	15,410	3,987	6,187	38,538
	Total	**2,332,727**	**724,364**	**187,417**	**290,827**	**1,811,480**

Figure 2b – Cumulative lifetime emissions for the GB-LR scenario
Additional C&I customers

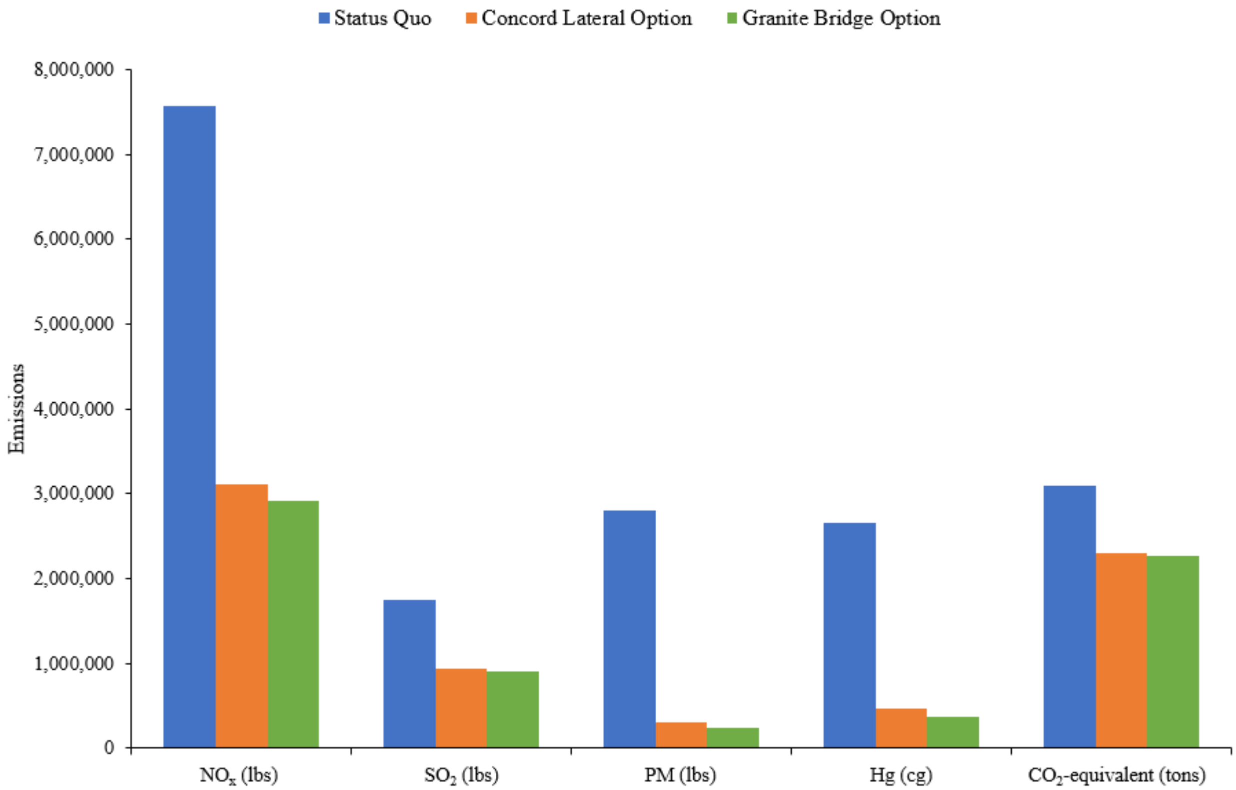

Table 8 – Data underlying Figure 2b

		NO_x (lbs)	SO_2 (lbs)	PM (lbs)	Hg (cg)	CO_2-equivalent (tons)
Status Quo	New Customers In Existing Territory	7,260,873	1,680,747	2,721,031	2,534,671	2,960,569
	New Customers in Epping, Raymond, Candia	312,889	74,038	85,001	117,150	128,738
	Total	**7,573,762**	**1,754,785**	**2,806,033**	**2,651,821**	**3,089,307**
Concord Lateral Option	New Customers In Existing Territory	2,796,853	868,486	224,706	348,691	2,171,898
	New Customers in Epping, Raymond, Candia	312,889	74,038	85,001	117,150	128,738
	Total	**3,109,742**	**942,524**	**309,708**	**465,842**	**2,300,636**
Granite Bridge Option	New Customers In Existing Territory	2,796,853	868,486	224,706	348,691	2,171,898
	New Customers in Epping, Raymond, Candia	121,152	37,620	9,734	15,104	94,081
	Total	**2,918,006**	**906,106**	**234,440**	**363,796**	**2,265,979**

As the above figures and tables illustrate, under the GB-LR scenario, the Granite Bridge project option produces the fewest emissions across all those pollutants considered compared to either the Status Quo or the Concord Lateral Expansion options.

What are the potential health benefits?

AG modeled the potential health benefits associated with the Granite Bridge option and Concord Lateral Expansion option relative to the Status Quo option under each demand forecast scenario using the EPA

Co-Benefits Risk Assessment (COBRA) Health Impacts Screening and Mapping Tool.[17,18] COBRA estimates annual health impacts based on user-specified emissions changes from a projected baseline emission levels of either 2017 or 2025. We select 2025 as our baseline emissions level and discount monetary benefits at a 3 percent discount rate back to 2017 dollars.

Table 9 – Total Residential and Commercial & Industrial Health Impacts

		IRP	GB - LR
		Average Annual Impact	Average Annual Impact
Granite Bridge Relative to Status Quo	$ Total Health Benefits (low estimate)	1,057,086	800,789
	$ Total Health Benefits (high estimate)	2,387,346	1,808,520
Concord Lateral Relative to Status Quo	$ Total Health Benefits (low estimate)	955,083	743,554
	$ Total Health Benefits (high estimate)	2,156,979	1,679,259
Differential	$ Total Health Benefits (low estimate)	102,004	57,236
	$ Total Health Benefits (high estimate)	230,366	129,262

Referring to Table 9 depicting total customer health impacts,[19] the Granite Bridge option has a $102,000 to $230,000 annual average health benefit over the Concord Lateral Expansion option in the IRP scenario. Additionally in the GB-LR scenario, the Granite Bridge option has a $57,000 to $129,000 annual average health benefit over the Concord Lateral Expansion option.[20]

[17] The COBRA model is available for download here: https://www.epa.gov/statelocalenergy/co-benefits-risk-assessment-cobra-health-impacts-screening-and-mapping-tool. COBRA is a tool used to approximate air quality impacts and associated costs. See EPA, User's Manual for the Co-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA) Version: 3.2, available at https://www.epa.gov/statelocalenergy/users-manual-co-benefits-risk-assessment-cobra-screening-model, p. 15.

[18] In order to capture the impacts of customers using natural gas for heating relative to a more polluting source, we adjust emissions in the oil, wood, other (propane), electric power sector, and natural gas combustion emission tiers of COBRA. For example, in the residential Granite Bridge Relative to Status Quo Scenario, status quo heating system emissions for the annual average number of projected new customers are subtracted from the appropriate emissions source tiers in COBRA. The profile of different heating systems used in the status quo is based on the US Census Bureau 2013-2017 American Community Survey, see tables A5a and A5b in the Technical Appendix for additional detail. Conversely, efficient natural gas heating system emissions for the same annual average number of projected new customers are added to the residential natural gas combustion emission tier in COBRA. The COBRA model measures fuel combustion emissions for the commercial and industrial sectors separately. These results allocate 80% of Commercial & Industrial emission changes to the Commercial/Institutional emission tiers in COBRA, and 20% to the Industrial emission tiers in COBRA based on the division of electricity sales by sector in the 2017 EIA 861 data for New Hampshire. The same methodology for the adjustment of emissions tiers described above for residential health benefits is also used for the commercial and industrial health benefits. The calculations assume all PM emissions are $PM_{2.5}$.

[19] The annual average number of projected new customers assumed in each case are as follows:
IRP: In the Granite Bridge relative to Status Quo scenario, we assume an annual average of 1,710 new residential and 484 new commercial & industrial (C&I) customers in Liberty's existing service territory and new Epping, Raymond, and Candia territory combined will switch from status quo heating systems to efficient natural gas heating systems over the 5 year period 2017-2022. In the Concord Lateral relative to Status Quo scenario, new customers in Epping, Raymond, and Candia remain on status quo heating systems.
GB-LR: In the Granite Bridge Relative to Status Quo scenario, we assume an annual average of 1,418 new residential and 357 new C&I customers in Liberty's existing service territory and new Epping, Raymond, and Candia territory combined will switch from status quo heating systems to efficient natural gas heating systems over the 21 year period 2017-2038. In the Concord Lateral relative to Status Quo scenario, new customers in Epping, Raymond, and Candia remain on status quo heating systems.

[20] If a 7% discount rate is used, the health benefits vary as follows: The Granite Bridge option has $91,000 to $205,000 average annual benefit over the Concord Lateral option in the IRP scenario, and $51,000 to $115,000 in the GB-LR scenario.

Emissions benefits from reduced truck traffic

Delivery trucks currently supply the network of on-system propane and LNG tanks used by Liberty as supplemental resources to meet winter demand. Liberty notes that the Granite Bridge project option will enable Liberty to eliminate the need for operation of the satellite propane facilities, and substantially reduce the need for the LNG facilities, and thus nearly eliminate this truck traffic.[21] The consequent reduced truck traffic will lead to further reductions in emissions not already captured. It should be further noted that there would be local reductions in delivery truck traffic for residential and business customers using natural gas heating technology that otherwise would have used oil or propane.

We estimate the potential emission reductions and associated public health benefits from reduced deliveries of propane and/or LNG to Liberty's satellite storage tanks. Liberty estimates that it currently requires approximately 235 deliveries each winter to supply its network of propane storage tanks, a number that could increase if tanks were used to support growth in demand.[22] We therefore assess the reduction of emissions associated with eliminating 235 deliveries; we also estimate what the impacts would be for 300 deliveries to approximate what the benefits would be if avoiding increased deliveries to meet future growth. Table 10 shows our estimates of annual emission reductions from reduced delivery truck traffic. Table 11 shows the annual health impacts of these emission reductions.

Table 10 – Annual reductions in emissions associated with reduced delivery truck traffic (estimates in pounds)

	235 trucks	300 trucks
CO_2e (CO_2 + CH_4)	49,594.5	63,312.1
NO_x	285.7	364.7
$PM_{2.5}$	6.7	8.5

Note: We assume each delivery amounts to one diesel truck achieving 6.4 mpg covering a distance of 60 miles. Sources of emission derived from EPA.

[21] The Granite Bridge Project would reduce propane and LNG truck traffic to facilities in Nashua, Manchester, Concord, and Tilton. See New Hampshire Public Utilities Commission, Docket No. DG 17-198, Liberty Utilities (EnergyNorth Natural Gas) Corp. d/b/a Liberty Utilities, Approval of Natural Gas Supply Strategy, Pre-Filed Testimony of Susan L. Fleck and Francisco C. Dafonte, December 21, 2017, p. 18, available at http://www.puc.state.nh.us/Regulatory/Docketbk/2017/17-198/INITIAL%20FILING%20-%20PETITION/17-198_2017-12-22_ENGI_PDTESTIMONY_FLECK_DAFONTE.PDF.

[22] Liberty received 704 deliveries of propane and LNG over the past three calendar years, and this number is projected to increase over the next few years. Assuming the same number of deliveries each year, we approximate Liberty requiring 235 deliveries each winter. See New Hampshire Public Utilities Commission, Docket No. DG 17-152, Liberty Utilities (EnergyNorth Natural Gas) Corp. d/b/a Liberty Utilities, Approval of Natural Gas Supply Strategy, Direct Testimony of William Killeen, April 30, 2019, pp. 4-5, available at http://www.puc.state.nh.us/Regulatory/Docketbk/2017/17-152/TESTIMONY/17-152_2019-04-30_ENGI_DTESTIMONY_KILLEEN_SUPPLEMENTAL_FILING_RESPONSE_ORDER_26225.PDF.

Table 11 – Annual health impacts of reductions in emissions associated with reduced delivery truck traffic[23]

		Average Annual Impact
235 Trucks Off the Road	$ Total Health Benefits (low estimate)	717
	$ Total Health Benefits (high estimate)	1,619
300 Trucks Off the Road	$ Total Health Benefits (low estimate)	915
	$ Total Health Benefits (high estimate)	2,067

[23] Health impact estimates use the COBRA model, as described above. COBRA estimates annual health impacts based on user-specified emissions changes from a projected baseline emission levels of either 2017 or 2025. We select 2025 as our baseline emissions level, and subtract the emissions projected from 235 or 300 trucks off the road from the highway heavy duty diesel truck emissions tier in COBRA. Monetary benefits are discounted at a 3 percent discount rate back to 2017 dollars.

Technical Appendix

Analytic Method

We estimate annual emissions from using natural gas, oil, propane, biomass, or electricity for space heating over both a 5-year and 21-year period based on estimates of additional residential and commercial and industrial (C&I) customers in Liberty's New Hampshire service territory as well as potential new customers in Epping, Raymond, and Candia that fall outside Liberty's current service area and that would be able to be served by the Granite Bridge project. Potential emission and health impacts stem from the lower level of emissions from using natural gas compared to the alternative sources of home heating considered in our analysis.

Our method for estimating annual emissions for each fuel involves two primary estimates. First, we estimate annual energy demand required for heating based on customer average consumption estimates from Liberty. Second, we estimate annual emissions of various pollutants associated with our estimated demand using emissions factors. After estimating annual emissions, we calculate total emissions as the sum across all years. We describe each step outlined above more fully below.

Annual Energy Demand: For each year and each technology option (described in the next section), we estimate energy demand in MMBtu using Eq. (1) below:[24]

$$\text{(Energy Demand)} = \text{(Annual Load)} / \text{(Heating Technology Efficiency)} \qquad (1)$$

where 'Annual Load' refers to the projected annual energy required (in MMBtu) to heat either a residential or commercial and industrial space in Liberty's New Hampshire service territory. AG received per customer demand projections for 2017/2018 through 2037/2038 from Liberty Utilities. To translate these demand projections at point of end-use to Annual Load estimates, we assume the annual demand projections reflect the demand of customers using a mix of high-efficiency natural gas heating (see Table A1 below) and lower efficiency natural gas heating, which we take to be 0.793.[25] In particular, we assume a 50-50 split between high- and low-efficiency gas technology. This assumption reflects the fact that the per-customer demand projections received from Liberty incorporate both existing customers who will likely be using lower-efficiency natural gas heating technologies and entirely new natural gas customers that will likely use high-efficiency natural gas heating technologies. Based on our assumed technology efficiencies for the natural gas heating option, we then back out an estimate for 'Annual Load.'[26]

Air Pollutant Emissions: To estimate emissions, we apply emission factors for each considered pollutant to each technology. Discussed more fully below, we source emissions factors from the Gas Technology Institute's Source Energy and Emissions Analysis Tool (SEEAT),[27] EPA, and ISO-NE. With the exception of particulate matter (PM) and mercury (Hg), our emission factors consider both emissions due

[24] The formula for a heat pump varies slightly from the formula presented in Eq. (1), since the "efficiency" of heat pumps typically is presented in units of Btu produced per watt-hr consumed. For heat pumps, we use the following formula:

$$\text{(Energy Demand)} = \text{(Annual Load)} / \text{(HSPF)} \times 1000 \times (0.00341 \text{ MMBtu/kW-hr})$$

where Annual Load has units of MMBtu, HSPF has units of Btu per watt-hour, the factor of 1000 converts watt-hours per Btu to kW-hrs per MMBtu, and the final conversion factor translates Energy Demand from kW-hrs to MMBtu.

[25] Mass Save, "Massachusetts Technical Reference Manual for Estimating Savings from Energy Efficiency Measures; 2016-2018 Program Years – Plan Revision," October 2015, 436 pages).

[26] For example, consider a hypothetical demand projection in 2018 of 100 MMBtu. If the heating technology option equals 75 percent, then the annual heating load must be 100 × 0.75 = 75 MMBtu (See Eq. (1)).

[27] http://seeatcalc.gastechnology.org/.

to fuel combustion as well as emissions from upstream processing (such as extracting, processing, and transportation).

To estimate emissions for wood, we source emission factors from EPA. All emissions calculations are derived from downstream combustion and we assume no emissions from the upstream processing of wood.[28]

We estimate emissions in pounds using Eq. (2) below:

$$(\text{Emissions}) = (\text{Energy Demanded}) \times (\text{Emission Factor}) \tag{2}$$

where 'Energy Demanded' is described above in Eq. (1) and 'Emission Factor' describes the pounds of emissions per MMBtu of energy demanded at the point of end-use.

We assume that emission factors remain fixed in each year of our analysis.[29]

In the sections below, we describe in more detail the heating technology options and the emission factors we use to estimate emissions.

Technology Options

We consider the following five heating technologies. The forecasted customer additions represent customers from new development (that is, residential customers or businesses that move into Liberty's service territory, undertake new construction, and install a gas-fired heating technology) or customers who switch from a non-gas fired heating technology to natural gas. We assume that any customer who installs natural gas heating technology in a new development or switches to natural gas would install a high efficiency system. For this reason, we only consider one natural gas technology efficiency. However, without natural gas expansion, the additional customers would either remain on their existing, what we assume to be lower efficiency, heating option (this would be relevant for the existing residents and businesses who would elect to switch to natural gas), or convert to a higher efficiency non-gas technology such as a high-efficiency oil boiler or a high efficiency electric heat pump (this would be relevant for the portion of additional customers from new build.). For this reason, for every non-gas technology considered, we assume a standard-efficiency (that is, low-efficiency) option along with a corresponding high-efficiency option. We further assume that among the additional customers projected by Liberty, half the additions will be due to existing customers switching to natural gas, while the other half will derive from new build.

1. **Natural Gas:** heating provided by a higher efficiency natural gas-burning boiler.
2. **Standard- and High-Efficiency Oil:** heating provided by one of two types of oil-burning boilers.
3. **Standard- and High-Efficiency Propane:** heating provided by one of two types of propane-burning boilers.

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[28] Downstream emissions factors for wood were sourced from the EPA. Carbon dioxide and methane emissions are pulled directly from "EPA, Emission Factors for GHG Inventories, March 9, 2018." Emissions for particulate matter, sulfur dioxide, and nitrogen oxide are pulled from "EPA, AP 42, Fifth Edition, Volume 1, Chapter 1: External Combustion Sources." Table 1.10-1 includes emission factors for the pollutants and different types of residential wood heaters (wood stoves, pellet stoves, masonry heaters). Households using wood heating vary in their use of forced air heating versus hydronic heating and in the type of wood they use, so a simple average of the emission factors for each pollutant for each type of heating was used to estimate emissions factors for wood heating for PM, SO_2, and NO_x. We ignore upstream emission factors for wood, which are difficult to consistently aggregate across source.

[29] This implies little degradation in boiler efficiency and a relatively unchanged pollutant content of distillate oil and natural gas.

4. **Standard- and High-Efficiency Biomass:** heating provided by one of two types of wood-burning stoves/boilers.
5. **Standard- and High-Efficiency Electric:** heating provided by electric baseboards (the standard-efficiency option) or a high efficiency electric heat pump (the high-efficiency options); we make the assumption that a heat pump requires 25 percent of the building's heating load to be served by an electric baseboard back-up heating system.

Table A1 presents our assumptions regarding the technological efficiency associated with each heating option. We derive these efficiencies from the Massachusetts Technical Reference Manual.[30] We derive efficiencies for biomass heating technology from EPA, which reports efficiencies across a range of wood stoves used for heating.[31] We assume the same heating technology efficiencies for residential as well as commercial and industrial customers.

Table A1
Summary of Heating Technology Combinations and Efficiency Assumptions

Heating Option	Efficiency
Natural Gas	0.894
Standard Efficiency Oil	0.75
High Efficiency Oil	0.86
Standard Efficiency Propane	0.75
High Efficiency Propane	0.86
Standard Efficiency Biomass	0.73
High Efficiency Biomass	0.85
Baseboard Electric Heat	1
High Efficiency Heat Pump	9.6 HSPF

Emission Factors

The combustion of oil, propane, biomass, and natural gas for heating emits various air pollutants. Methane leaks from natural gas lines and the extraction, processing, and transportation of natural gas, propane, and oil also emit air pollutants. We consider both sources of emissions in our analysis. There is also an upstream and downstream combustion emissions component for the generation of electricity that we apply to the use of electric heating technologies.

For upstream emissions, we utilize the SEEAT tool's New Hampshire emission factors for NO_x, SO_2, CH_4, and CO_2. For downstream emissions for oil, propane, biomass, and natural gas, we use EPA emissions factors for NO_x, SO_2, PM,[32] Hg, CH_4, and CO_2 (we do not consider any upstream emissions of

[30] Mass Save, "Massachusetts Technical Reference Manual for Estimating Savings from Energy Efficiency Measures; 2016-2018 Program Years – Plan Revision," October 2015, 436 pages).

[31] The EPA-Certified Wood Stove Database (https://cfpub.epa.gov/oarweb/woodstove/index.cfm?fuseaction=app.about) provides a list of all residential wood heaters approved by the EPA for sales in the United States, including room heaters (e.g., wood stoves/pellet stoves) and central heaters (e.g., outdoor wood boilers). The database includes a range of wood heaters with different levels of efficiency. A standard efficiency wood heater was estimated using the median efficiency across all approved room heaters and central heaters (Maine Energy System's PE32 Hydronic Heating Non-Catalytic Stove using Wood Pellets). A high efficiency wood heater was estimated using the 90th percentile across all approved room heaters and central heaters (Polar Furnace Manufacturing, Inc.'s Classic Edge 550 Hydronic Heating Non-Catalytic Stove using Cord Wood).

[32] PM emission factors are calculated as the sum of condensable PM and filterable PM emission factors. Condensable PM is the particulate matter collected using EPA Method 202. Filterable PM is the particulate matter collected on, or prior to, the filer of an EPA Method 5 (or equivalent) sampling train. See note (c) in Table 1.4-2, available at https://www3.epa.gov/ttn/chief/ap42/ch01/final/c01s04.pdf. PM emission factors are reported as PM_{10} or $PM_{2.5}$ based on the fuel

particulate matter or mercury). For downstream emissions for electricity, we use the ISO-NE December 2017 marginal emission rate for all locational marginal units for NO_x, SO_2, and CO_2.[33] For downstream electricity CH_4 emissions, we use SEEAT and the December 2017 ISO-NE marginal fuel mix.[34] We do not consider particulate matter or mercury emissions from electric generation.[35] Table A2 below illustrates the upstream and combustion emission factors that we consider.

Table A2[36]
Emission Factors for Nitrogen Oxide, Sulfur Dioxide, Particulate Matter, Mercury, Methane, and Carbon Dioxide (lb/MMBtu)

upstream	NO_x	SO_2	PM	Hg	CH_4	CO_2	Source
Natural Gas	0.594	0.302	--	--	6.451	127.8	SEEAT
Oil	0.500	0.272	--	--	0.403	166.6	SEEAT
Propane	0.454	0.375	--	--	0.522	161.3	SEEAT
Electric	Dependent on Electric Generation Fuel Mix						SEEAT

combustion							
Natural Gas	0.037	0.0006	0.0075	2.5E-07	0.0022	117.0	EPA
Oil	0.143	0.0015	0.0143	3.0E-06	0.0066	163.1	EPA
Propane	0.142	0.0011	0.0077	--	0.0066	138.6	EPA
Biomass	0.358	0.0231	0.8613	--	0.0159	206.8	EPA
Electric	0.070	0.0498	--	--	0.0062	173.5	ISO-NE/SEEAT

type and diameter of the particles released. PM_{10} is particulate matter 10 micrometers or less in diameter. $PM_{2.5}$ is particulate matter 2.5 micrometers or less in diameter. We assume PM_{10} and $PM_{2.5}$ to be equivalent in terms of emission factors for biomass, because a large share (~93%) of PM_{10} from wood/bark waste external combustion is $PM_{2.5}$. See South Coast Air Quality Management District, Final - Methodology to Calculate Particulate Matter (PM) $_{2.5}$ and PM $_{2.5}$ Significance Thresholds, Table A, available at http://www.aqmd.gov/home/rules-compliance/ceqa/air-quality-analysis-handbook/pm-2-5-significance-thresholds-and-calculation-methodology.

[33] ISONE, "2017 ISONE Electric Generator Air Emissions Report," April 2019, Appendix Table 9.

[34] ISONE, "2017 ISONE Electric Generator Air Emissions Report," April 2019, Figure 4-6: 2017 percentage of time various fuel types were marginal—all LMUs.

[35] Downstream emission factors for particulate matter (PM) and mercury (Hg) from electric-generated heating were calculated by taking a weighted average of emissions factors for the various fuels making up the New England marginal fuel mix. We derive weights from the 2017 ISO-NE marginal fuel mix (see ISO-NE, "2017 ISONE Electric Generation Air Emissions Report", April 2019). Approximately 60% of the New England's marginal fuel mix (natural gas, oil, and coal) emits small amounts of particulate matter and mercury in the fuel combustion process, while the remainder of the marginal fuel mix emits zero emissions. To estimate combustion emission factors, we use the EPA AP 42, Fifth Edition (Volume I, Chapter 1: External Combustion Sources), available at https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors. Assuming common firing configurations for natural gas, oil, and coal, we find a de minimis increase in total emissions for PM and Hg for electric-fired generation. The presence of emission control devices in certain New England natural gas-, oil- and coal-fired power plants would further reduce PM and Hg estimates for electric-generated heating in New Hampshire.

[36] We consider distillate fuel oil No. 2. For NO_x, SO_2, PM and Hg, we use the EPA AP 42, Fifth Edition (Volume I, Chapter 1: External Combustion Sources), available at https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors. For distillate fuel oil, Table 1.3-1 reports a NO_x emission factor of 20 lb/10^3 gallons. Table 1.3-1 also reports an SO_2 distillate fuel oil emission factor of 142S lb/10^3 gallons, where S refers to the percent of sulfur content by weight (see Table 1.3-1 note b). We assume S = 0.0015, noting that the EIA states that "[s]ince 2006, most distillate fuel has had less than 15 parts per million (ppm) of sulfur" (see EIA, "Large reduction in distillate fuel sulfur content has only minor effect on energy content," February 24, 2015, available at: https://www.eia.gov/todayinenergy/detail.php?id=20092; see also Vermont Dept. of Environmental Conservation, "Sulfur Content in Heating Oil – Fact Sheet," which indicates that 15ppm equals 0.0015 percent by weight). Table 1.3-1 finally reports a filterable PM emission factor for distillate fuel oil of 2 lb/10^3 gallons. To convert to lb/MMBtu, we divide by 140 MMBtu/10^3 gallons (see AP 42, at p. 1.3-8). Finally, Table 1.3-10 reports an Hg emission factor for distillate oil of 3 lb/10^{12} Btu. To convert to lb/MMBtu, we divide by 10^6. For natural gas, Table 1.4-1 reports a NO_x emission

Because of losses in the production and distribution process, every one MMBtu of natural gas combusted in a home boiler requires more than one MMBtu to have been extracted (the same idea applies to other fuels). A complete assessment of air pollutant emissions requires assessing the emissions due to these "upstream" losses. We assume losses in each upstream process (extraction, processing, transportation, and distribution) based on SEEAT's assessment of losses for New Hampshire. Table A3 illustrates these losses. To fix ideas, Table A3 implies that 5.1 percent (1 - 0.949) of energy is lost in the extraction of fuel oil, and that 1 percent of natural gas is lost in the distribution phase.

Table A3a
Upstream Losses Assumed by SEEAT and Adopted by AG

	Extraction	Processing	Transportation	Distribution	Total
Natural Gas	0.962	0.97	0.99	0.99	0.915
Oil	0.949	0.891	0.997	0.996	0.840
Propane	0.946	0.936	0.992	0.992	0.871

Note: 'Total' is derived by taking the product across the extraction, processing, transportation, and distribution loss estimates. Note that the SEEAT tool considers residual fuel oil, while our analysis considers distillate fuel oil.

Table 3b
Upstream Losses Assumed by SEEAT and Adopted by AG: Electricity

	Extraction	Processing	Transportation	Conversion	Distribution	Total
Coal	0.993	0.996	0.98	0.318	0.955	0.294
Oil	0.963	0.938	0.988	0.271	0.955	0.231
Natural Gas	0.962	0.97	0.993	0.472	0.955	0.418
Renewable Natural Gas	1	0.8	0.993	0.413	0.955	0.313
Nuclear	0.99	0.962	0.999	0.326	0.955	0.296
Hydro	1	1	1	1	0.955	0.955
Biomass	0.994	0.95	0.975	0.244	0.955	0.215
Wind	1	1	1	1	0.955	0.955
Solar	1	1	1	1	0.955	0.955
Geothermal	1	1	1	1	0.955	0.955
Other	1	1	1	0.203	0.955	0.194

Note: 'Total' is derived by taking the product across the extraction, processing, transportation, and distribution loss estimates.

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factor of 38 lb/10^6 scf after applying a reduction for boilers with selective non-catalytic reduction (SNCR) control. Table 1.4-2 reports a SO_2 emission factor for natural gas of 0.6 lb/10^6 scf. Table 1.4-2 also reports a total PM emission factor for natural gas of 7.6 lb/10^6 scf. Table 1.4-4 reports a Hg emission factor of 2.6E-04. To convert to all to lb/MMBtu, we divide by 1,020 Btu/scf (see AP 42, at section 1.4.1). For propane, Table 1.5-1 reports a NO_x emission factor of 13 lb/10^3 gallons. Table 1.5-1 also reports a total PM emission factor for natural gas of 0.7 lb / 10^3 gallons. For SO_2 for propane, we use the Emissions Inventory Improvement Program, A National Methodology and Emission Inventory for Residential Fuel Combustion. Table 2 reports an SO_2 emission factor for propane of 0.1 lb / 10^3 gallons. To convert to lb/MMbtu, we divide by 91.5 MMBtu / 1,000 gallons. For biomass, table 1.10-1 reports an average NO_x emissions factor of 6.2 lb/ton. Table 1.10-1 reports an average SO_x emission factor for biomass of 0.4 lb/ton. Table 1.10-1 reports an average PM emission factor for biomass of 14.9 lb/ton. To convert to lb/MMBtu, we divide by 17.30 MMBtu/ton (see AP 42, at section 1.10.3). For methane and carbon dioxide, we use EPA's Emission Factors for Greenhouse Gas Inventories, March 9, 2018 update (available at: https://www.epa.gov/sites/production/files/2018-03/documents/emission-factors_mar_2018_0.pdf). EPA reports No. 2 oil's CH_4's emission factor as 3.0 g / MMBtu and CO_2's emission factor as 73.96 kg / MMBtu. EPA reports natural gas's CH_4's emission factor as 1.0 g / MMBtu and CO_2's emission factor as 53.06 kg / MMBtu. EPA reports propane's CH_4's emission factor as 3.0 g / MMBtu and CO_2's emission factor as 62.87 kg / MMBtu. EPA reports biomass CH_4's emission factor as 7.2 g / MMBtu and CO_2's emission factor as 93.8 kg / MMBtu. To convert to lb / MMBtu, we multiply by 0.002205 (for CH_4) and 2.205 (for CO_2), since 2.205 pounds equals 1 kilogram.

To combine the upstream and combustion emissions factors, we follow the same method as SEEAT, adding a weighted average upstream emission factor with the combustion emission factor for each pollutant.[37] We summarize this method below in Eq. (3):

$$\text{(Composite Emission Factor)} = \text{(Weighted Upstream Emission Factor)} + \text{(Combustion Emission Factor)} \quad (3a)$$

$$\text{(Weighted Upstream Emission Factor)} = \text{(Upstream Emission Factor)} \times (1 - \text{'Total'}) / (\text{'Total'}) \quad (3b)$$

where ‘Total’ refers to the product of the loss estimates for extraction, processing, transportation, and distribution shown in Table A3a and Table A3b.

The electric generation upstream emissions factor has an additional step. The result from Eq. (3b) for each fuel type is multiplied by the share of a specified electric generation fuel mix, and then summed across all fuel types in the electric generation mix to come up with a single upstream emissions factor representative of the share of emissions of each electric generation fuel type. We used the marginal ISO-NE electric generation fuel mix from December 2017.[38]

Table A4 below presents our resulting composite emission factors for NO_x, SO_2, PM, Hg, CH_4, and CO_2.

Table A4
Composite Emission Factors (lb/MMBtu)

	NO_x	SO_2	PM	Hg	CH_4	CO_2
Natural Gas	0.093	0.029	0.0075	2.5E-07	0.605	128.91
Oil	0.238	0.053	0.0143	3.0E-06	0.084	194.87
Propane	0.209	0.055	0.0022	--	0.084	162.42
Biomass	0.358	0.023	0.8613	--	0.016	206.79
Electric	0.145	0.088	--	--	0.630	189.82

Note: The emissions factors for Biomass reflect combustion only. The emission factor for PM and Hg reflects combustion only. Furthermore, for oil, the combustion factor for PM reflects filterable PM only.

Aggregating annual technology specific emissions to overall option specific emissions

In order to estimate emissions for the three options considered in our analysis (Status Quo, Granite Bridge, and Concord Lateral Expansion), we undertake the following steps:

1. Applying the method discussed above, we estimate emissions for a representative residential or C&I customer in each year for each heating technology.
2. In each year, we multiply the cumulative new customers forecasted for that year[39] by a year-specific weighted average of per residential or per C&I customer emissions. The annual weighted average per customer emissions depends on the heating technology profile assumed for a given scenario, explained in more detail below.

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[37] See Gas Technology Institute, Full-Fuel-Cycle Energy and Emission Factors for Building Energy Consumption – 2018 Update, at p. A-6 - A-7.
[38] ISONE, "2017 ISONE Electric Generator Air Emissions Report," April 2019, Figure 4-6: 2017 percentage of time various fuel types were marginal—all LMUs.
[39] That is, the emissions from new customers added in year one continue to be counted cumulatively over the full period analyzed.

3. In the *Status Quo* option, we assume additional customers use heating technologies in proportion to the current share of New Hampshire home heating technologies as reported by the American Community Survey,[40] net of natural gas.[41] Specifically, for additional customers within Liberty's existing service territory, we use the non-natural gas heating technologies from counties encompassing this area (i.e. Rockingham, Hillsborough, Merrimack, and Belknap counties) as shown in Table A5a below. For additional customers along the proposed pipeline route (i.e. in Epping, Raymond, and Candia), we use the non-natural gas heating technologies specific to the county encompassing the proposed pipeline route (Rockingham County), as shown in Table A5b below. We use the same shares to distribute the additional C&I customers.[42]

4. In the *Granite Bridge Project* option, we assume all cumulative customer additions will be heating their homes with natural gas.

5. In the *Concord Lateral Expansion* option, we assume new customers in the existing Liberty service territory will be heating their homes with natural gas, but that forecasted new customers outside Liberty Utilities' existing service territory (i.e. those in Epping, Raymond, and Candia) will heat their homes with the share of technologies as shown in Table A5b.

Table A5a[43]
Heating technologies (net of natural gas) used by New Hampshire residents in the counties encompassing Liberty's existing service territory

	Household Count	Share
Oil	147,039	55.4%
Propane	54,336	20.5%
Electricity	34,270	12.9%
Wood	21,584	8.1%
Other Non-Emitting	8,399	3.2%

Table A5b[44]
Heating technologies (net of natural gas) used by New Hampshire residents in Rockingham County, which encompasses the proposed route of the Granite Bridge project pipeline

	Household Count	Share
Oil	60,148	59.1%
Propane	21,280	20.9%
Electricity	11,678	11.5%
Wood	5,596	5.5%
Other Non-Emitting	3,134	3.1%

[40] US Census Bureau, 2013-2017 American Community Survey 5-Year Estimates, House Heating Fuel, available at https://factfinder.census.gov
[41] We net out natural gas since we assume that under the Status Quo option, no expansion of natural gas heating technology will be possible.
[42] The American Community Survey only reports a heating technology profile for residential customers.
[43] Counties encompassing Liberty's existing service territory include Rockingham, Hillsborough, Merrimack, and Belknap. Home-heating types were collected and aggregated for in 2017. We used the US Census Bureau, 2013-2017 American Community Survey 5-Year Estimates, House Heating Fuel, available at https://factfinder.census.gov.
[44] Rockingham County encompasses the proposed route of the Granite Bridge project pipeline. Home-heating types were collected for Rockingham County in 2017. We used the US Census Bureau, 2013-2017 American Community Survey 5-Year Estimates, House Heating Fuel, available at https://factfinder.census.gov.

Details regarding emission reductions from reduced delivery truck traffic

In order to estimate emissions impacts from reduced delivery truck traffic, we make the following assumptions:

- Between 235 deliveries (in the short term)[45] and 300 deliveries (in the long term) would no longer be needed.
- Each delivery requires a truck to travel a distance of 60 miles.
- We model each delivery truck as a class VIIIa vehicle (gross weight of 33,001 to 60,000 lbs) that burns diesel and achieves an average fuel economy of 6.4 miles per gallon.[46]

To estimate emissions, we use data published by EPA. In particular, EPA reports a diesel fuel mobile consumption CO_2 emission factor of 10.21 kg CO_2 per gallon and a diesel fuel mobile consumption CH_4 emission factor in medium- and heavy-duty vehicles of 0.0051 grams CH_4 per mile.[47] For heavy duty diesel trucks, EPA reports a NO_x emission factor of 9.191 grams per mile and a $PM_{2.5}$ emission factor of 0.215 grams per mile.[48] Using these emission rates and our assumptions about number of vehicles, miles traveled, and fuel economy, we calculate the annual emissions benefit for CO_2-e, NO_x, and $PM_{2.5}$ as follows (note that we convert methane into equivalent CO_2 impacts by taking methane's global warming potential to be 25 times that of carbon dioxide's):

- Total miles driven = (number of deliveries) × (average number of miles driven)
- CO_2-e: (Total miles driven) × (CH_4/mile) × 25 + (Total miles driven) / 6.4 mpg × (CO_2 per gallon)
- NO_x: (Total miles driven) × (NO_x/mile)
- $PM_{2.5}$: (Total miles driven) × ($PM_{2.5}$/mile)

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[45] Liberty received 704 deliveries of propane and LNG over the past three calendar years, and this number is projected to increase over the next few years. Assuming the same number of deliveries each year, we approximate Liberty requiring 235 deliveries each winter. See New Hampshire Public Utilities Commission, Docket No. DG 17-152, Liberty Utilities (EnergyNorth Natural Gas) Corp. d/b/a Liberty Utilities, Approval of Natural Gas Supply Strategy, Direct Testimony of William Killeen, April 30, 2019, pp. 4-5, available at http://www.puc.state.nh.us/Regulatory/Docketbk/2017/17-152/TESTIMONY/17-152_2019-04-30_ENGI_DTESTIMONY_KILLEEN_SUPPLEMENTAL_FILING_RESPONSE_ORDER_26225.PDF.

[46] See EIA Table 2.8 Motor Vehicle Mileage, Fuel Consumption, and Fuel Economy, 1949-2010, available at: https://www.eia.gov/totalenergy/data/annual/showtext.php?t=pTB0208.

[47] See "Emission Factors for Greenhouse Gas Inventories," March 9, 2018 update (available at: https://www.epa.gov/sites/production/files/2018-03/documents/emission-factors_mar_2018_0.pdf)

[48] See "Average In-Use Emissions from Heavy Trucks," October 2008 update (available at: https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100EVY6.TXT). We assume class VIIIa vehicles which reflect a standard oil and propane delivery truck.