Appendix A

National Fuel Gas Distribution Corporation

December 22, 2022

CONTENTS

Appendix A: Modeling of Decarbonization Actions

I. Overview

Each decarbonization action is modeled independently, and each incorporates assumptions that are specific to the individual action and are detailed in this appendix. However, there are certain modeling concepts that apply to all decarbonization actions, and the modeling of each decarbonization action ultimately produces the same outputs. Each decarbonization action requires inputs related to when the decarbonization action begins (i.e., start year) and how quickly it increases over time. The modeling of each decarbonization action produces the same outputs including incremental installation and/or implementation costs, gas usage reductions and associated gas bill savings, electric usage increases and associated electric bill increases, and GHG emission reductions.

II. Global Assumptions

The global assumptions listed in the following tables are inputs that are consistently used throughout the modeling of decarbonization actions. For example, global assumptions include common conversion rates and inflation rates. With respect to Table A-1:

- Shrinkage refers to the difference between the amount of gas received by National Fuel's distribution system at its citygates and the amount of gas delivered through its customer meters.
- Gas higher heating value refers to the heat content of gas per volume. It allows for converting between volumetric measurements (e.g., Mcf) and heat content measurements (e.g., MMBtu).

Table A-1

National Fuel System Assumptions

Shrinkage Rate	1.72%
Gas Heating Value (MMBtu/Mcf)	1.033

Table A-2

Inflation Forecast

Inflation	GDP Chained Price Index (Q3 to Q3) [(1)]	Inflation Adj Factor (Cumulative since Q3 2022)
2022	7.30%	100.00%
2023	3.30%	103.30%
2024	2.20%	105.57%
2025	2.10%	107.79%
2026	2.10%	110.05%
2027	2.10%	112.36%
2028	2.00%	114.61%
2029	2.00%	116.90%
2030	2.00%	119.24%
2031	2.00%	121.63%
2032	2.00%	124.06%
2033	2.00%	126.54%
2034	2.00%	129.07%
2035	2.00%	131.65%
2036	2.00%	134.29%
2037	2.00%	136.97%
2038	2.00%	139.71%
2039	2.00%	142.51%
2040	2.00%	145.36%
2041	2.00%	148.26%
2042	2.00%	151.23%

(1) Sources: Blue Chip Economic Indicators, GDP Chained Price Index. April 11, 2022, at 5. BCEI Long-Range Consensus US Economic Projections, GDP Chained Price Index. March 11, 2022, at 14.

Table A-3

National Fuel Cost of Capital

	Ratios	Cost Rates	Weighted Rate
Long Term Debt	56.70%	5.62%	3.19%
Short Term Debt	0.00%	0.00%	0.00%
Customer Deposits	0.40%	0.85%	0.00%
Common Equity	42.90%	8.70%	3.73%
	100.00%		**6.92%**

Source: NY PSC Case 16-G-0257, Commission Order, Appendix 2, page 7 of 8

III. Energy Efficiency - Home Energy Reports

A. Methodology

Home Energy Reports ("HER") encourage participants to reduce their usage through personalized letters or emails. Each report contains the participant's energy usage compared to other similar homes in the same neighborhood or geographic area. The HER includes energy-saving tips and goals for the next mailing. Home Energy Report programs were analyzed to establish assumptions for customer adoption levels, reduction in gas usage, and associated program costs. This analysis utilized cost data and gas usage reduction data from HER programs implemented at National Grid's Rhode Island gas utility. Customer participation level is defined as a percentage of total residential customers. Using this data, the model estimates total emissions reduction and program costs specific to National Fuel. This data is used to compute a net present value of cost per emission savings ($/CO2e) based on customer participation levels in each scenario.

B. Assumptions, Inputs, Sources

All scenarios use the estimated cost and gas savings detailed in Table A-4. The estimated cost and energy savings per participant is calculated using information from National Grid Rhode Island's HER program.

Table A-4

Home Energy Report Cost and Saving Assumptions

Home Energy Report Cost ($2021/Customer)(1)	$2.96
Home Energy Report Savings (%/Year)(2)	0.90%

(1) Source: 2021-2023 National Grid Energy Efficiency Program Plan & 2021 Annual Energy Efficiency Program Plan.
(2) Source: "Impact Evaluation: Home Energy Reports Program - National Grid Rhode Island," Cadeo Group, August 28, 2020. Savings as a percentage of energy use.

C. Scenario Inputs

The Home Energy Report assumptions vary by scenario to reflect different customer participation levels. The Supply Constrained Economy ("SCE") Scenario assumes a start year of 2024 with 50% residential customer participation. The Long-Term Plan and Aggressive Scenario starts in 2024 and assumes a 100% residential customer participation level. Table A-5 presents annual customer participation levels.

Table A-5

Customer Participation by Scenario 2023-2042

Year	Total Residential Customers	SCE Participation (%)	LTP Participation (%)	Aggressive Participation (%)
2023	506,539	0%	0%	0%
2024	508,683	100%	50%	100%
2025	510,682	100%	50%	100%
2026	513,168	100%	50%	100%
2027	514,695	100%	50%	100%
2028	516,228	100%	50%	100%
2029	517,764	100%	50%	100%
2030	519,306	100%	50%	100%
2031	520,852	100%	50%	100%
2032	522,402	100%	50%	100%
2033	523,957	100%	50%	100%
2034	525,517	100%	50%	100%
2035	527,082	100%	50%	100%
2036	528,651	100%	50%	100%
2037	530,224	100%	50%	100%
2038	531,803	100%	50%	100%
2039	533,386	100%	50%	100%
2040	534,974	100%	50%	100%
2041	536,566	100%	50%	100%
2042	538,164	100%	50%	100%

IV. Energy Efficiency – Weatherization

A. Methodology

Residential weatherization involves upgrades to a home's building envelope through various measures. Individual weatherization measures were analyzed to establish assumptions for customer adoption levels, reduction in gas usage, and associated program costs. This analysis utilized cost, applicability percentages, and gas savings from a residential weatherization study conducted for National Fuel.[1] Cadmus evaluated seven weatherization measures: air leakage sealing, attic insulation, rim and band joist insulation, wall insulation, floor insulation, window upgrades, and duct sealing and insulation. Measure cost and gas savings are differentiated

1 Residential Weatherization Potential Study Report," The Cadmus Group, Inc. ("Cadmus"), prepared for National Fuel Gas Distribution Corporation, November 2, 2022. ("Cadmus Weatherization Study", provided as Appendix F).

based on income level for low- and moderate-income ("LMI") customers, and standard income customers. The Cadmus Weatherization Study identified total technical potential and maximum achievable potential for residential weatherization programs within National Fuel's customer base.

B. Assumptions, Inputs, Sources

Each scenario utilizes the cost and gas usage reduction presented in Table A-6.

Table A-6

Cost and Gas Use Reduction by Weatherization Measure

	Applicability		Gas Savings (Mcf)(3)		
Measure	Standard Income	Low and Moderate Income(2)	Standard Income	Low and Moderate Income1	Installation Cost ($2022/Unit)
Air Leakage Sealing	30%	44%	7.6	7.6	$ 680
Insulation-Attic Insulation	47%	47%	4.5	9.4	$ 2,558
Insulation - Rim and Band Joist Insulation	68%	69%	1.4	1.5	$ 63
Insulation - Wall Insulation	27%	27%	8.3	16.5	$ 1,404
Insulation - Floor Insulation	14%	14%	22.8	11.4	$ 1,423
Window	37%	55%	5.6	18.4	$ 13,753
Duct Sealing and insulation	5%	5%	0.7	0.9	$ 1,442

(1) Source: Cadmus Weatherization Study
(2) Low and Moderate-Income segments presented the same assumed applicability rate and gas savings.
(3) Annual savings assume furnace heating system.

Table A-7 depicts the breakdown of National Fuel's customer base by income level.

Table A-7

National Fuel Customer Population by Income 2022

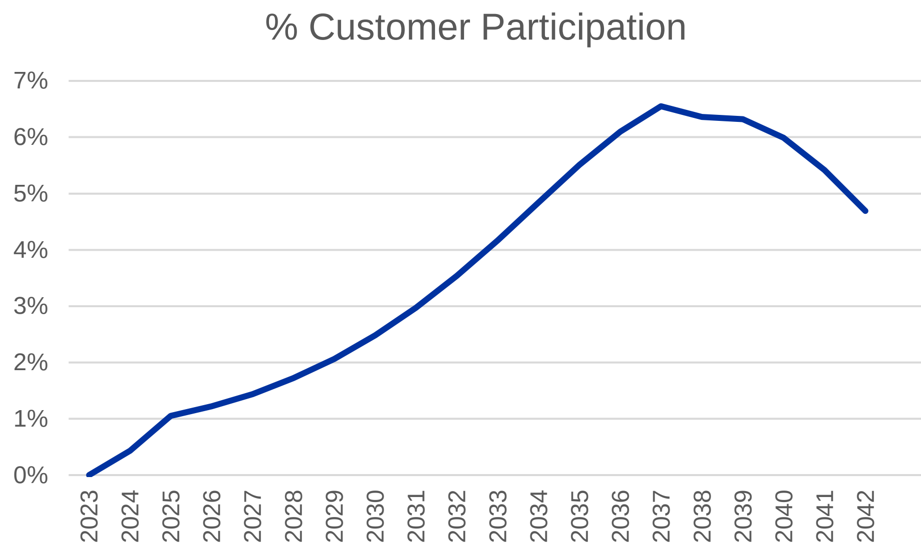
Percentage of Standard Income Participants	53%
Percentage of Low- and Moderate-Income Participants	47%

Source: Cadmus Weatherization Study

Figure A-1 on the following page depicts the Cadmus developed ramp rate utilized to determine annual program participation rate. Cost, gas savings, customer breakdown by income, and the participation ramp rate are all sourced from the Cadmus Weatherization Study.

Figure A-1

Residential Weatherization Customer Participation Ramp Rate



Source: Cadmus Weatherization Study. Aggressive ramp rate reduced to 85% of total per Cadmus Weatherization Study and adjusted for a 2024 start year.

C. Scenario Inputs

The residential weatherization scenarios differ with respect to the customer participation level assumptions and the measures that are included in the program. The SCE scenario assumes a start year of 2024 with 75% of the max achievable participation for both LMI and standard income customers. The Long-Term Plan and the Aggressive Scenario starts in 2024 but assumes 100% of the maximum achievable participation for both LMI and standard income customers. The LTP eliminated certain more expensive measures from the standard income program (i.e., windows, attic insulation, and duct sealing and insulation) while eliminating only duct sealing and insulation from the LMI program. Table A-8 presents weatherization measures included in each scenario.

Table A-8

Residential Weatherization Measures Included by Scenario

Measure	SCE & Aggressive	LTP
Air Leakage Sealing	Both LMI & Standard	Both LMI & Standard
Insulation - Attic	Both LMI & Standard	**LMI ONLY**
Insulation - Rim and Band Joist	Both LMI & Standard	Both LMI & Standard
Insulation - Wall	Both LMI & Standard	Both LMI & Standard
Insulation - Floor	Both LMI & Standard	Both LMI & Standard
Windows	Both LMI & Standard	**LMI Only**
Duct Sealing and Insulation	Both LMI & Standard	**Not Included**

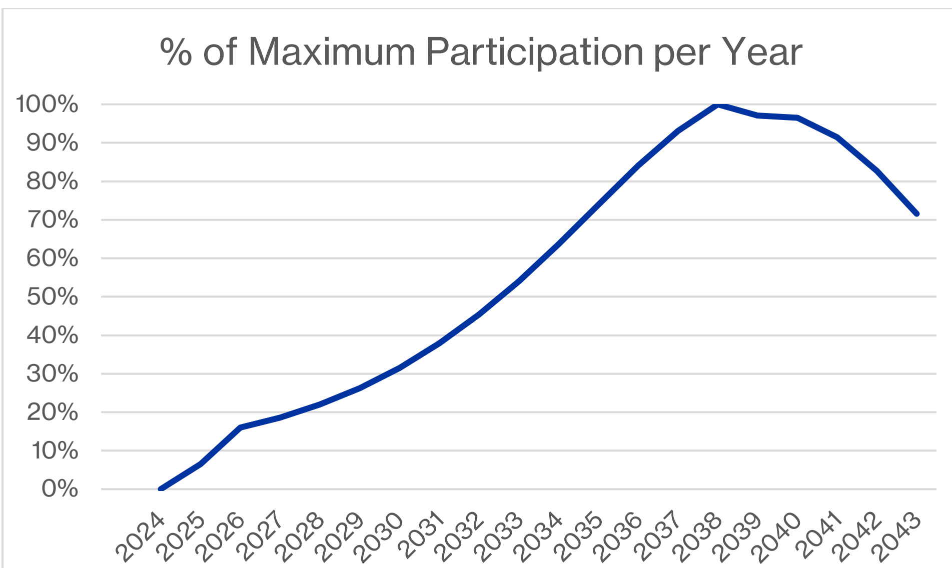
V. Electrification – Generic Assumptions (Applicable to All Classes)

A. Overview

Electrification is the process of replacing gas powered technologies with electric technologies. Electrification options are modeled separately for National Fuel's residential, small commercial, large multi-family (i.e., public authority housing), universities, and industrial customer segments. Conversion options rely on current heat pump technologies including standard air-source heat pumps ("ASHP"), cold climate ASHP, and ductless mini-split heat pumps. The model assumes that electrification conversions occur either at the end of equipment life or at the time of new builds. Annual conversion counts by equipment type are calculated by applying a ramp rate schedule, shown below in Figure A-2, to a specified maximum participation rate, which is multiplied by number of potential conversions (i.e., equipment retirements and new builds) in each year. The ramp rate from Cadmus' Residential Weatherization Study is relied on to produce an increase in the electrification participation rate over time. The ramp rate schedule's gradual increase accounts for the time required to reach full program implementation; the decline in participation after reaching 100% in 2038 reflects the challenge of reaching difficult to convert customers after the program has been in place for more than a decade.

Figure A-2

Electrification Customer Participation Ramp Rate



Source: Cadmus Weatherization Study

B. Electrification Options Modeled

All modeled options are detailed in Table A-9. The residential electrification model focuses on the electrification of space heating and conversion of gas appliances including cooking ranges, dryers, and water heaters. The residential electrification model differentiates among several residential subgroups including typical homes (less than 80 years old) and older homes (80+ years old), furnace and boiler heating systems, and provides analysis focused on full electrification versus hybrid heating systems. Residential electrification options can be specified independently for typical homes or old homes (e.g., gas clothes dryers in typical homes could be converted to electric while clothes dryers in old homes might not be converted). In addition, electrification of each appliance type can be specified independently (e.g., boilers could be kept as gas while furnaces are converted to electric).

Electrification options for small commercial, large multi-family, universities and industrial segments are restricted to full electrification of heating load only. Heating load is separated from processing load for large multi-family, universities and industrial segments based on analysis of National Fuel's EMM Equipment customer database. Heating load associated with equipment that is also used for processing load is excluded from electrification potential.

Table A-9

Electrification Conversion Options

Natural Gas Appliance Type	Residential	Small Commercial, Universities, Large Multi-Family, Industrial
Forced Air Furnace, Heaters[2]	Full electrification w/ ASHP	Full electrification w/ ASHP
	Hybrid gas/electric HVAC System	
Boiler	Full electrification w/mini-splits	Full electrification w/mini-splits
Water Heating w/ Tank	Gas Tankless	
	ASHP w/ tank	
Tankless Water Heater	ASHP w/ tank only for old homes	
Clothes Dryers	Convert to electric	
Gas Range	Convert to electric	

C. Net Installed and Operating Costs

Participant net installed costs are costs to purchase and install new equipment minus replacement cost of retired (or avoided new) equipment compared to baseline equipment included in the Reference Case. Because heat pumps also provide for space cooling in addition to heating, the electrification model assumes that participants avoid the cost of replacing their

2 Non-residential heaters include space heating furnaces, unit heaters, infra-red heaters, make-up air heaters and rooftop heaters.

central air conditioning (AC) or window AC units. Participant central air or window ac units are assumed to reach end-of-life concurrent with furnace and/or boiler conversions.

Participant net operating costs account for both the increase in participant's electric bill resulting from increased electrical use and reduction in gas bill resulting from decreased gas use due to their electrification conversion. In full electrification cases where gas service is terminated, the gas customer charge is also subtracted from participant's net operating cost.

D. Seasonal Electric and Gas Usage

Net changes in annual electric and gas usage due to conversions are allocated to winter, shoulder, and summer seasons. Heating usage is allocated between winter and shoulder seasonal usage based on proportion of total annual normal heating degree days ("HDDs")[3] associated with days with an HDD greater than or less than an assumed 35 HDD setpoint compared. The winter season is assumed to occur during the 76 days in the year with a normal HDD greater than or equal to the assumed 35 HDD setpoint. The shoulder season is assumed to occur during the by proportion of heating days in the year with a daily normal HDD greater than or equal to 247 days in the year with a normal HDD less than the assumed 35 HDD setpoint.

The summer cooling season is assumed to occur during 25 days in the year with a normal cooling degree days ("CDD") greater than 5 CDDs.[4] Net change in summer peak electric kW demand associated with cooling is calculated as (space cooling kWh) / (25 cooling days x 24 hours).

Table A-10

Heating and Cooling Seasonal Definitions

Heating/Cooling Season	Load Type	Definition	Normal HDD	% HDDs / CDDs	Number of Days in Normal Year
Winter	Heating	HDD >= 35	3,555	45%	76
Shoulder	Heating	HDD < 35	2,912	55%	247
Total Heating	Heating	HDD>0	6,467	100%	323
Summer	Cooling	CDD > 5	n/a	100%	25

3 HDD is a unit of measure used to relate a day's temperature to the energy consumption associated with space heating. HDD = 65 minus average daily temperature. Days with average daily temperatures above 65 degrees have HDD of 0 (i.e., HDD does not go negative).

4 Source: NOAA 1981-2010 normal Cooling Degree Days, Climate Region: 3009 (NY, Great Lakes). CDD is a unit of measure used to relate a day's temperature to the energy consumption associated with air conditioning. CDD = average daily temperature minus 65 degrees. Days with average daily temperature less than 65 degrees have CDD of 0 (i.e., CDD does not go negative).

E. Winter and Summer Peak kW Demand

Net change in winter peak electric kW demand associated with heating conversions is calculated by allocating heating net kWh to winter and shoulder seasons and dividing resulting winter kwh by (76 winter heating days x 24 hours). Electric water heaters, dryers and cooking ranges are assumed to run all-year round with peak winter and summer kW demand contributions equal to their annual kWh usage divided by 8760 hours in the year. Electric fans and pumps are assumed to run at constant level throughout 323 heating and 25 cooling days but assumed to not run on the 17 moderate weather days.

VI. Electrification - Residential

A. Methodology

The residential electrification model includes electrification of space heating and conversion of gas appliances including cooking ranges, dryers, and water heaters. This analysis allows for differentiation among several residential subgroups including typical versus older homes (80+ years old) and furnace versus boiler heating systems. In addition, the analysis provides for analysis of full electrification versus hybrid heating systems.

The residential electrification model starts with the residential customer count forecast. Appliance-specific market saturation percentages and assumed equipment lifespans are applied to estimate potential conversions. An assumed maximum annual participation rate is applied to a ramp rate schedule and annual potential conversions, resulting in number of conversions, before calculating natural gas use and GHG emission reductions.

B. Assumptions, Inputs, Sources

Residential cost and energy use assumptions for each baseline and conversion equipment type are from a residential home energy study performed for National Fuel,[5] which provides cost and energy usage electrification conversion data for a typical western New York home. The CJ Brown Study also includes estimates of the increased costs required to fully electrify an 80+ year-old home due to prevalence of knob-and-tube wiring. The LTP model includes two furnace conversion options for residential homes: (1) 100% electrification with a cold climate air source heat pump that relies on electric for heating on all days and (2) hybrid gas/electric heating system that relies on a gas furnace on colder days and a standard electric air-source heat pump on less cold days.[6] Input appliance life, cost, and energy use data for residential electrification are provided in the following tables.

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5 Residential Home Energy Analysis," C.J. Brown Energy ("CJ Brown"), prepared for National Fuel Gas Distribution Corp. New York Division, August 2022 Update. ("CJ Brown Study.") Provided in Appendix G.

6 Assumes a 35 HDD setpoint for switching between gas furnace and ASHP heat source.

Table A-11

Residential Baseline Natural Gas and Air Conditioning Equipment Assumptions

Load Type	Baseline Equipment	Appliance Life Expectancy: Min Life[1]	Max Life[1]	Modeled	Replacement Cost ($2022)[2]	Annual Usage[2]: ccf	kWh
Space Heating	Gas Furnace	16	27	22	$4,460	819	
Space Heating	Gas Boiler[3]	20	30	25	$5,800	900	
Space Cooling	Central AC	11	25	n/a	$3,500		1,341
Space Cooling	Window AC[4]			n/a	$500		1,073
Fans & Pumps	Fans			n/a	Incl above		552
Water Heating	Gas Storage Tank	6	20	13	$2,101	200	
Water Heating	Gas Tankless	6	20	13	$4,000	148	
Cooking	Gas Range	9	15	12	$1,000	35	
Clothes Drying	Gas Dryer	8	18	13	$920	35	

(1) Source: U.S. Energy Information Administration, Assumptions to the Annual Energy Outlook 2022: Residential Demand Module. Table 5. Minimum and maximum life expectancies of equipment in years. March 2022.
(2) Source: CJ Brown Study
(3) Boiler annual ccf/year calculated as Forced Air Furnace ccf/year multiplied by ratio of baseline equipment gas boiler to gas furnace natural gas usage from National Grid 2021 Long-Term Capacity Report Appendices Table A-7. Boiler replacement cost estimate from HomeAdvisor (December 12, 2022) (https://www.homeadvisor.com/cost/heating-and-cooling/gas-boiler-prices/)
(4) Residential Window AC annual kWh assumes 2 window AC units per hours each running at 1.2 KW compared to three-ton central air unit running at 3 kW.

Table A-12

Residential Gas Furnace Conversion: 100% Electrification Cost and Usage

Gas Furnace Conversion Option 1: Cold Climate Air Source Heat Pump				
Load Type	Conversion Equipment	Energy Type	First Cost ($2022)	Annual Usage (kWh)
Space Heating	Cold Climate ASHP	Electric	$22,200	10,527
Space Cooling	Cold Climate ASHP	Electric	incl above	969
Fans & Pumps	Fans	Electric	incl above	494
Water Heating	ASHP Storage Tank	Electric	$3,500	1,077
Cooking	Electric Range	Electric	$750	821
Clothes Dryer	Electric Dryer	Electric	$770	821

Source: CJ Brown Study

Table A-13

Residential Gas Furnace Conversion: Hybrid Heating System Cost and Usage

Gas Furnace Conversion Option 2: Hybrid Heating System					
Load Type	Conversion Equipment	Energy Type	First Cost ($2022)	Annual Usage (ccf)	Annual Usage (kwh)
Space Heating	Furnace	Gas	$5,060	393	
Space Heating	Standard ASHP & Fans	Electric	$5,040		3,988
Space Cooling	Standard ASHP	Electric	incl above		1,341
Water Heating	Tankless	Gas	$4,000	148	
Cooking	Gas Range	Gas	$1,000	35	
Clothes Dryer	Gas Dryer	Gas	$920	35	

Source: CJ Brown Study

Table A-14

Residential Boiler Conversion, Typical Home: Ductless Mini-split ASHP

Gas Boiler Conversion Option 1: Cold Climate Mini-Split Air Source Heat Pump				
Load Type	**Conversion Equipment**	**Energy Type**	**First Cost ($2022)**	**Annual Usage (kWh)**
Space Heating	Ductless Mini-Split ASHP	Electric	$19,000	11,021
Space Cooling	Ductless Mini-Split ASHP	Electric	incl above	1,341
Water Heating	ASHP Storage Tank	Electric	$3,500	1,077
Cooking	Electric Range	Electric	$750	821
Clothes Dryer	Electric Dryer	Electric	$770	821

Source: CJ Brown Study

Table A-15

Cost to Electrify an 80+ Year-Old Home

Category	Item	Cost ($2022)
Electrical Service	Upgraded 200 Amp Service	$4,500
	New Lines Throughout House	$14,000
	Plaster Patching	$1,000
Heating / Cooling	Ductless Mini-splits 4-6 units	$19,000
Water Heating	Heat Pump Water Heater	$3,900
	220 Elec Line from Panel	$300
Cooking	220 Elec Line from Panel	$800
	Electric Range	$750
Clothes Drying	220 Elec Line from Panel	$600
	Electric Dryer	$770

Source: CJ Brown Study

Existing market saturation for each baseline gas equipment type is based on a residential market study performed for National Fuel.[7] The residential electrification model assumes that boilers are allocated on equal percentage basis to houses built prior to 1941 versus houses built between 1941 and 1970. Houses built prior to 1941 are assumed to require significant electrical upgrades as shown in Table A-15, above. Allocation of housing stock by age is based on 2014 property tax database for zip codes comprising National Fuel's New York service territory. The model assumes that new gas customers from new construction will use air furnaces and not use boiler systems, which are more expensive than furnace systems and lack air conditioning from a hydronic system.

[7] "2021 Residential Market Study: National Fuel," JRB Insights, August 5, 2021. ("JRB Residential Market Study.") Provided in Appendix H.

Table A-16

National Fuel Residential Customer Market Saturation by Appliance

Residential	Existing Stock as of 2023	New Construction 2024-2042
Natural Gas Forced Air Furnace	68%	100%
Natural Gas Boiler	23%	0%
Natural Gas Water Heater w/ Tank	69%	89%
Natural Gas Tankless Water Heater	9%	11%
Natural Gas Clothes Dryer	55%	55%
Natural Gas Range	56%	56%

Source: JRB Residential Market Study

Table A-17

Age of Homes Built in 1970 or Earlier [(1)]

Age of Home	% of Homes
Built prior to 1941 [(2)]	53%
Built between 1941 and 1970 [(3)]	47%
Subtotal	100%

(1) Source: 2014 property tax database

(2) Assumes prevalence of knob-and-tube electrical wiring in homes built prior to 1941.

(3) Residential furnace systems became more prevalent than boiler systems starting in the 1970s.

Table A-18

Percentage of Homes with Air Conditioning [(1)]

Residential	Existing Stock as of 2023	New Construction 2024-2042
% of Accounts heated with gas furnaces with Central Air (Electric)	73%	90%
% of Accounts heated with gas furnaces with Window AC (Electric)	11%	4%
% of Accounts heated with gas boilers with Window AC (Electric)	42%	42%

(1) Source: JRB Residential Market Study

C. Scenario Inputs

The SCE Scenario assumes residential electrification starts in 2025 with percentage of gas furnaces to hybrid heating system conversions and other non-heating gas appliance conversions at appliance end-of-life ramping up over time to a maximum participation rate of 50%. It is assumed that customers in old homes or heating with boilers do not electrify.

The Aggressive Scenario assumes residential electrification starts in 2025 with percentage of gas furnace, boiler conversions and other non-heating gas appliance full electric conversions at appliance end-of-life ramping up over time to maximum participation rate of 100%. Furnaces are converted to fully electric cold climate ASHPs; boilers are converted to ductless mini-split ASHPs. Old homes are assumed to be electrified.

The LTP assumes residential electrification starts in 2025 with percentage of gas furnace to hybrid heating system conversions and other non-heating gas appliance conversions at appliance end-of-life ramping up over time to maximum participation rate of 100%. It is assumed that customers in old homes or heating with boilers do not electrify.

The resulting percentage of appliance converted by 2042 is shown in Table A-19.

Table A-19

Percentage of Residential Appliances Converted to Electric by 2042

Baseline Gas Equipment	SCE Scenario	Aggressive Scenario	LTP
Gas Forced Air Furnace	24% (hybrid)	48% (full electric)	48% (hybrid)
Gas Boiler	0%	42% (full electric)	0%
Gas Water Heating w/ Tank	39%	74%	74%
Gas Tankless Water Heater	39%	74%	74%
Gas Clothes Dryer	39%	74%	74%
Gas Range	41%	78%	78%

VII. Electrification – Small Commercial

A. Methodology

The model includes small commercial electrification options that target conversion of space heating from gas furnace and boilers for National Fuel's SC3 rate class. The small commercial electrification model assumes that baseline small commercial gas furnaces are converted to ASHPs, while gas boilers are replaced with ductless mini-split ASHPs.

Similar to the residential electrification, the small commercial electrification model starts with the SC3 customer count forecast, to which appliance specific market saturation percentages and assumed equipment lifespans are applied to estimate potential conversions. An assumed maximum annual participation rate is applied to a ramp rate schedule and annual potential conversions, resulting in number of conversions, from which net installed cost, natural gas use and GHG emission reductions can be computed.

B. Assumptions, Inputs, Sources

Small commercial furnace and boiler annual gas usage estimates are calculated by scaling the Company's estimates for residential furnace and boiler annual gas usages by ratio of National Fuel's New York average small commercial SC-03 annual normalized heat load to residential SC-01 annual normalized heat load. Similarly, small commercial central air annual kwh usage is calculated by multiplying the Company's residential estimate provided in CJ Brown's study by the Company's ratio of SC-03 annual normalized heat load to SC-01 annual normalized heat load.

Small commercial annual kWh usages for each baseline and electrification equipment type are calculated by multiplying National Fuel's annual ccf usage estimates discussed above for small commercial furnaces and boilers and applying ratios from National Grid's 2021 Natural Gas Long-Term Capacity Report ("National Grid's LTCR").[8] Therefore, small commercial annual kWh usage estimates for electrification conversion equipment from National Grid's LTCR are calibrated to National Fuel's service territory, accounting for differences in average customer consumption, building size and temperature patterns between the two service territories.

Calibration adjustments made to small commercial equipment annual kwh usage estimates are as follows:

- Small commercial ASHP annual kWh usage is calculated by multiplying National Fuel's annual ccf estimates for a small commercial gas furnace by ratio developed using data of small commercial ASHP annual kWh usage divided by annual ccf usage for gas furnace.
- Similarly, the small commercial ductless mini-split ASHP annual kWh usage is calculated by multiplying National Fuel's annual ccf estimates for a small commercial gas boiler by ratio developed using data from National Grid's LTCR of small commercial ductless mini-split ASHP annual kWh usage divided by annual ccf usage for gas boiler.
- Small commercial room AC annual kWh usage is calculated by multiplying the Company's central air annual kWh usage estimate by ratio of National Grid's small commercial room AC annual kWh usage to National Grid's small commercial ducted AC annual kWh usage as reported in National Grid's LTCR.
- Annual kWh usage for fans associated with baseline gas furnace and boilers are calculated by multiplying National Fuel's annual ccf estimates for a small commercial gas furnace and gas boiler, respectively, by ratio developed using data from National Grid's LTCR of annual kwh divided by annual ccf estimates for each furnace and boiler appliance type.

Small commercial cost assumptions for each baseline and conversion equipment type are sourced from National Grid's LTCR.

Table A-20

Small Commercial Baseline Natural Gas and Air Conditioning Equipment

Baseline	Equipment	Appliance Life Expectancy			Replacement Cost ($2022)(2)	Annual Usage	
		Min(1)	Max (1)	Modeled		ccf	kWh
Space Heating	Gas Furnace & Fans	16	27	22	$12,361	3,038	1,961
Space Heating	Gas Boiler & Fans	20	30	25	$18,831	3,338	1,340
Space Cooling	Central AC	11	25	n/a	$21,197		4,975
Space Cooling	Room AC			n/a	$3,648		6,805

(1) Source: U.S. Energy Information Administration, Assumptions to the Annual Energy Outlook 2022: Residential Demand Module. Table 5. Minimum and maximum life expectancies of equipment in years. March 2022.
(2) Source: National Grid's LTCR, escalated by 7.3% inflation from $2021 to $2022 dollars.

[8] National Grid. *Natural Gas Long-Term Capacity Second Supplemental Report for Brooklyn, Queens, Staten Island and Long Island ("Downstate NY")*, Appendix, June 2021.

Table A-21

Small Commercial Gas Furnace Conversion: ASHP Cost and Usage

Gas Furnace Conversion Option: Cold Climate Air Source Heat Pump				
Load Type	Conversion Equipment	Energy Type	First Cost (1) ($2022)	Annual Usage(2) (kWh)
Space Heating	ASHP	Electric	$41,809	29,263
Space Cooling	ASHP	Electric	incl above	4,975

(1) Source: National Grid's LTCR, escalated by 7.3% inflation from $2021 to $2022 dollars.
(2) ASHP cooling electric load assumed to be same as Baseline central AC.

Table A-22

Small Commercial Boiler Conversion: Ductless Mini-split ASHP Cost and Usage

Gas Boiler Conversion Option: Ductless Mini-Split Cold Climate Air Source Heat Pump				
Load Type	Conversion Equipment	Energy Type	First Cost ($2022)	Annual Usage (kWh)
Space Heating	Ductless Mini-Split ASHP	Electric	$68,601	26,801
Space Cooling	Ductless Mini-Split ASHP	Electric	incl above	6,805

(1) Source: National Grid's LTCR, escalated by 7.3% inflation from $2021 to $2022 dollars.
(2) Ductless mini-split ASHP cooling electric load assumed to be same as baseline room AC.

Space heating market saturation for National Fuel's small commercial class is assumed to be 50% gas furnace and 50% natural gas boiler. Air conditioning market saturation for National Fuel's small commercial customers is adopted from National Grid's LTCR.

Table A-23

Small Commercial National Fuel Market Saturation by Appliance

Appliance	Existing Stock as of 2023	New Construction 2024-2042
Natural Gas Forced Air Furnace	50%	50%
Natural Gas Boiler	50%	50%

Table A-24

Small Commercial Air Conditioning Market Saturation(1)

Assumed % of Businesses with Air Conditioning (Electric)	Existing Stock as of 2023	New Construction 2024-2042
% Businesses heated with gas furnaces / heaters with Central Air(2)	70%	70%
% Businesses heated with gas furnaces / heaters with Room AC	29%	29%
% Businesses heated with gas boilers with Room AC	29%	29%

(1) Source: National Grid's LTCR
(2) Sum of Central A/C and Packaged A/C.

C. Scenario Inputs

The SCE Scenario assumes small commercial electrification starts in 2025 with percentage of gas furnaces to ASHP conversions at appliance end-of-life ramping up over time to a maximum participation rate of 50%. These assumptions result in 23% of furnaces being converted to full electric ASHP by 2042. It is assumed that customers heating with boilers do not electrify.

The Aggressive Scenario assumes small commercial electrification starts in 2025 with percentage of gas furnace and boiler conversions at appliance end-of-life ramping up over time to maximum participation rate of 100%. Furnaces are converted to ASHPs; boilers are converted to ductless mini-split ASHPs. These assumptions result in 45% of furnaces and 40% of boilers converted to full electrification ASHP by 2042.

The LTP assumes small commercial electrification starts in 2025 with percentage of gas furnace to ASHP conversions at appliance end-of-life ramping up over time to maximum participation rate of 100%. These assumptions result in 45% of furnaces converted to full electrification ASHP by 2042. It is assumed that customers heating with boilers do not electrify.

VIII. Electrification –Large Multi-Family, Universities, and Industrial

A. Methodology

Electrification options modeled for large multi-family (e.g., public authority housing), universities, and industrial customer segments include full electrification of space heating load associated with gas furnaces, heaters[9] and boilers. This electrification analysis assumes that heating load associated with baseline gas furnaces and heaters is converted to ASHPs, while heating load from boilers are replaced with ductless mini-split ASHPs.

In contrast to the residential and small commercial electrification models, the large multi-family, universities, and industrial electrification models start with total customer segment forecasted throughput, which is then allocated between heating load and process load. Unlike residential and small commercial customers, these larger customers may have multiple heating units which are likely not retired at the same time. Electrification conversions are likely to occur in multiple phases as individual units reach end-of-life.

[9] Heaters includes space heating furnaces, unit heaters, infra-red heaters, make-up air heaters, and rooftop heaters.

A. Assumptions, Inputs, Sources

Heating load is separated from processing load for large multi-family, university and industrial segments based on ratios calculated using National Fuel's EMM Equipment customer database. Heating load associated with equipment that is also used for processing load is excluded from electrification potential.

Large multi-family, university and industrial equipment costs and energy usage estimates for both baseline and conversion technologies are scaled from the Company's small commercial estimates while maintaining the small commercial ratio of costs to energy usage. These assumptions are presented in Tables A-25 and A-26.

Table A-25

Heating Load as % of Customer Segment Throughput by Appliance

Baseline Gas Equipment	Large Multi-Family	University	Industrial
Forced Air Furnace and Heaters(1)	22%	3%	4%
Natural Gas Boiler, Ductless	46%	67%	17%

(1) Source: Based on analysis of National Fuel's EMM Equipment customer database.

Table A-26

% of Customer Segment Throughput by Appliance

Baseline Gas Equipment	Large Multi-Family(1)	University(1)	Industrial(2)
% of Furnace and Heater Systems with Central AC(3)	15%	15%	70%
% of Furnace and Heater Systems with Room AC	54%	54%	29%
% of Boiler Systems with Room AC	54%	54%	29%

(1) Source: National Grid's 2021 Natural Gas Long-Term Capacity Report, estimates for Large Multi-Family
(2) Source: National Grid's 2021 Natural Gas Long-Term Capacity Report, estimates for Small Commercial
(3) Sum of Central A/C and Packaged A/C.

B. Scenario Inputs

The SCE Scenario assumes that large multi-family, university and industrial heating load electrification starts in 2025 with the percentage of gas furnaces to ASHP conversions at appliance end-of-life ramping up over time to a maximum participation rate of 50%. It is assumed that customers heating with boilers do not electrify.

The Aggressive Scenario assumes large multi-family, university and industrial heating load electrification starts in 2025 with the percentage of gas furnace and boiler conversions at appliance end-of-life ramping up over time to maximum participation rate of 100%. Furnaces are converted to ASHPs; boilers are converted to ductless mini-split ASHPs.

The LTP assumes large multi-family, university and industrial heating load electrification starts in 2025 with percentage of gas furnace to ASHP conversions at appliance end-of-life ramping up over time to maximum participation rate of 100%. It is assumed that customers heating with boilers do not electrify.

The resulting percentage of appliances converted by 2042 is presented in Table A-27 on the following page.

Table A-27

Percentage of Appliances Converted by 2042

SCE Scenario

Baseline Gas Equipment	Large Multi-Family	University	Industrial
Natural Gas Forced Air Furnace	24%	24%	24%
Natural Gas Boiler	0%	0%	0%

Aggressive Scenario

Baseline Gas Equipment	Large Multi-Family	University	Industrial
Natural Gas Forced Air Furnace	47%	47%	47%
Natural Gas Boiler	42%	42%	42%

LTP

Baseline Gas Equipment	Large Multi-Family	University	Industrial
Natural Gas Forced Air Furnace	47%	47%	47%
Natural Gas Boiler	0%	0%	0%

IX. Industrial – Process Energy Efficiency

A. Methodology

Industrial energy efficiency includes measures that target process load efficiency. Energy efficiency measures were modeled using customer adoption levels, reduction in gas usage, and associated program costs. This analysis utilized costs from a Guidehouse decarbonization pathways study for National Fuel.[10] These inputs are used to model energy efficiency potential within National Fuel's industrial customers. The model uses customer participation and gas reduction to compute an associated emissions reduction. Finally, the model uses customer participation and cost inputs to calculate a total program cost for industrial energy efficiency.

B. Assumptions, Inputs, Sources

These costs apply only to energy efficiency measures for process load.

10 "Meeting the Challenge: Scenarios for Decarbonizing New York's Economy," Guidehouse Inc., February 19, 2021. Provided in Appendix E.

Table A-28

Industrial Energy Efficiency Cost 2020-2050

Year	Annual Cost ($/MMBtu)
2020	$ 183
2030	$ 202
2040	$ 223
2050	$ 247

Source: "Meeting the Challenge: Scenarios for Decarbonizing New York's Economy," Guidehouse Inc., February 19, 2021. Provided in Appendix E.

C. Scenario Inputs

The industrial energy efficiency decarbonization scenarios differ with respect to maximum participation rate assumptions. The SCE Scenario assumes a 0.5% participation rate annually starting in 2024 until a maximum of 5% is reached. The Aggressive Scenario and LTP assumes a 0.5% participation rate annually starting in 2024 until a maximum of 10% is reached.

X. Thermal Energy Networks

A. Methodology

The modeling focused on geothermal networks, one type of Thermal Energy Network ("TEN"). A geothermal network consists of a system of interconnected pipe that supports the use of ground source heat pumps to heat and cool homes or buildings. They are modeled to estimate potential reduction in gas usage and project cost assuming that each network has 50 customers. While a hypothetical geothermal network project is specified for modeling purposes, it does not fully capture the site-specific nature of these projects. Two types of geothermal network projects are modeled: newly constructed developments and existing neighborhoods. Emissions reduction estimates are based on ground source heat pump electric usage and average home gas consumption. Ground source heat pump and shared loop costs are used to calculate an average cost per home for both project types.

B. Assumptions, Inputs, Sources

A standard new construction project is defined as a 50-home new development comprised of 2,500 square foot homes that would have heated with gas forced air furnaces and cooled with central AC systems. A standard existing home project is defined as a 50-home existing neighborhood with 1,500 square foot homes that all heat with gas forced air furnaces. Table A-29 provides a description of both projects and the cost associated with the geothermal network loop as well as market saturation data for air conditioning and other gas appliances.

Table A-29

New Construction and Existing Home Standard Project Definitions

	New Construction	Existing Home
Number of Homes	50	50
Size (SQFT)	2,500	1,500
Heat Pump Size (ton)	5	3
Cost ($/Home)(1) $2022	$71,626	$54,431
Market Saturation (% of Homes)	**New Construction**	**Existing Home**
Gas Air Furnace	100%	100%
Central Air(2)	100%	50%
Window AC(2)	0%	7%
Gas Water Heater / Tank(2)	100%	69%
Gas Clothes Dryer(2)	55%	55%
Gas Range(2)	56%	56%

(1) Source: "Net Zero Community Study: National Fuel," Cadmus, August 5, 2021. ("Cadmus Geothermal Study.") Provided in Appendix I; Cost per home includes ground loop cost, indoor equipment cost, design cost, and thermal conductivity testing cost.

(2) Source for existing home estimate: JRB Residential Market Study

In calculating net installed costs, the cost of the geothermal loop and equipment are offset by the avoided cost of gas heating and air conditioning equipment. For new construction projects avoided costs include both the avoided gas equipment cost and gas infrastructure cost: main, service line, and meter. New construction projects also reflect a discount on the ground loop installation cost due to savings from working in open ground, unencumbered by other utilities, roads, and landscaping.

For existing neighborhood projects, avoided gas and central air conditioning equipment costs are reduced by 50% to reflect the likelihood that not all homes in an existing neighborhood will have appliances approaching end-of-life at time of heating system conversion to geothermal.

Table A-30

Geothermal Network: Baseline Natural Gas and Air Conditioning Equipment

Natural Gas Mains & Services, Appliances & Air Conditioners	Replacement Cost $2022/Unit		Annual Use per Unit	
	New Construction	Existing Home(1)	New Construction	Existing Home
Main	$2,114	n/a	n/a	n/a
Service	$1,512	n/a	n/a	n/a
Meter	$126	n/a	n/a	n/a
Natural Gas Furnace	$4,460	$2,230	112 Mcf	87 Mcf
Central Air	$3,500	$1,750	1,341 kWh	1,341 kWh
Window AC	n/a	$250	n/a	1,073 kWh
Natural Gas Water Heater w/ Tank	$2,101	$1,051	20 Mcf	20 Mcf
Natural Gas Clothes Dryer	$920	$460	4 Mcf	4 Mcf
Natural Gas Range	$1,000	$500	4 Mcf	4 Mcf

(1) Installed cost reduced by 50%.

Geothermal network installed cost and equipment annual kWh usage assumptions are shown in Table A-31 below. Ground loop costs include drilling piping, right of way, and central pumping station costs. Indoor equipment includes a 5-ton and 3-ton ground source heat pump ("GSHP") for new construction and existing home projects, respectively, and an assumption to reflect the cost of site-specific improvements. Additional costs include thermal conductivity test and design cost from the Cadmus Weatherization Study.

Table A-31

Thermal Energy Network: GSHP Cost Component and Annual Usage

GSHP & Electric Appliances	Cost $2022/Unit		kWh / Unit	
	New Construction	Existing Home	New Construction	Existing Home
Ground Loop Cost(1)	$35,444	$35,698	n/a	n/a
Indoor Equipment(1)	$28,221	$18,133	n/a	n/a
Additional Cost(1)	$600	$600	n/a	n/a
GSHP, Space Heating(1)	incl above	incl above	5,732	3,460
GSHP, Air Cooling(2)	incl above	incl above	555	335
Water Heating w/ Tank(3)	$5,350	$5,350	630	630
Electric Clothes Dryer(4)	$770	$770	821	821
Electric Range(4)	$750	$750	821	821

(1) Source: Values adjusted based on Cadmus Geothermal Study
(2) Cooling kwh estimated by multiplying space heating kwh by ratio developed using estimates from CJ Brown Study estimate for individual geothermal ground sourced heat pump cooling to heating kwh.
(3) Source: CJ Brown Study, Water heating WWHP kWh estimate.
(4) Source: CJ Brown Study

C. Scenario Inputs

The SCE Scenario and LTP assume one new construction geothermal network project will be placed into service per year beginning in 2027. The Aggressive Scenario assumes one new construction and one existing neighborhood geothermal network project will be placed into service per year beginning in 2027.

XI. Renewable Natural Gas

A. Methodology

Renewable Natural Gas ("RNG") is biogas that has been converted to pipeline-quality gas. The RNG model focuses on the anerobic digestion-based production of RNG from animal manure, food waste, landfill gas and wastewater feedstocks within National Fuel's New York service territory and its injection into the Company's distribution system. The model allows for specification of different timeline estimates of RNG supply availability and analyzes the resulting production cost premium and GHG emission reductions as compared to the natural gas it displaces.

B. Assumptions, Inputs, Sources

Table A-32

RNG Production Cost

Process	Feedstock	Production Cost $2022/ MMBtu[1]
Anaerobic Digestion	Landfill Gas	$11.29
	Animal Manure	$34.56
	Food Waste	$23.86
	Wastewater	$27.68

Source: "Potential of Renewable Natural Gas in New York State prepared for New York State Energy Research and Development Authority", ICF Resources, April 2022. NYSERDA Report Number 21-34, ("ICF NYSERDA RNG Study,") p 44. Production cost adjusted for inflation in modeling.

RNG life cycle CO2e emission rates are estimated based on 100-year GWP CO2e emission rates, which are converted to 20-year GWP rates to allow for comparison with other decarbonization measures included in this LTP and to comply with New York GHG accounting requirements. This conversion process is illustrated Tables A-33 and A-34.

Table A-33

GHG Emission Factor Conversion 100-Year GWP to 20-Year GWP

RNG Feedstock	CO2e Component (100-yr GWP) (lb/MMBtu)			
	Total CO2e[1] lb/MMBtu	Assumed[2] % CO2e from CH4	CO2e from CH4 lb/MMBtu	CO2e from CO2, N2O lb/MMBtu
Landfill Gas	21.0	45%	9.45	11.55
Animal Manure	(124.0)	60%	(74.40)	(49.60)
Food Waste	(9.9)	60%	(5.94)	(3.96)
Wastewater	16.6	60%	9.96	6.64

(1) Based on 100-year GWP. "Meeting the Challenge: Scenarios for Decarbonizing New York's Economy", Guidehouse Inc., February 19, 2021. Table A-1. Estimated RNG Production Potential and Emissions Rates for New York State. Scenarios for Decarbonizing New York's Economy | NFGDC Report | Guidehouse. Provided in Appendix E
(2) Landfill Gas: EPA Landfill Methane Outreach Program
Animal Manure: Michigan State University A Primer on Anerobic Digestion
Food Waste and Wastewater: Environmental and Energy Study Institute Biogas: Converting Waste to Energy

Table A-34

GHG Emission Factor Conversion 100-Year GWP to 20-Year GWP (Continued)

RNG Feedstock	Emission Rate (lb/Mcf)			
	CH4	CO2	N2O	20-yr GWP CO2e
Landfill Gas	0.35	11.93	0.00	41.22
Animal Manure	(2.74)	(51.24)	0.00	(281.80)
Food Waste	(0.22)	(4.09)	0.00	(22.50)
Wastewater	0.37	6.86	0.00	37.73

C. Scenario Inputs

Total RNG technical potential estimates by feedstock within National Fuel's service territory are based on an RNG study prepared for National Fuel.[11]

Annual 2040 RNG production estimates as percentage of total technical potential in New York are calculated from data published in the ICF NYSERDA RNG Study that reflect "achievable deployment" and "optimistic growth" levels. These percentages are then multiplied by the Company's estimated total RNG technical potential within its New York service territory to derive production levels.

The rate of RNG production implementation to reach 2040 achievable deployment and optimistic growth levels is based on information gathered from RNG projects within National Fuel's service territory that are already underway. The resulting 2023-2042 timelines of annual RNG production supply projected to be available within National Fuel's New York service territory are presented in Table A-35 and Figure A-3.

Table A-35

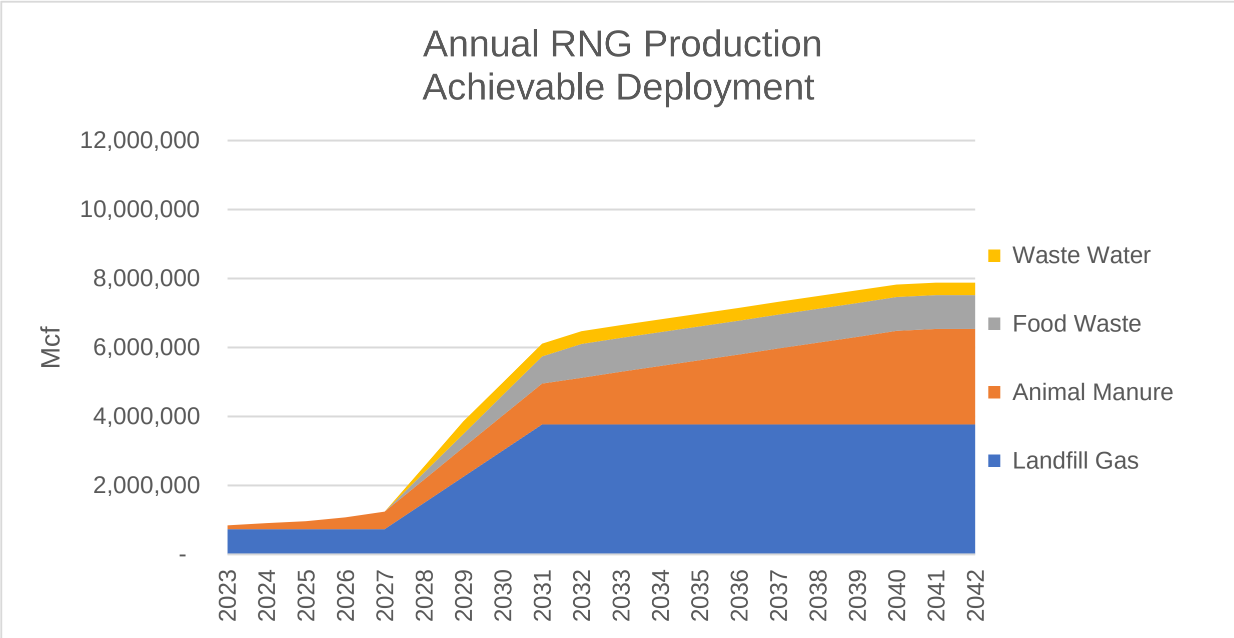
Available RNG Production in National Fuel's New York Service Territory

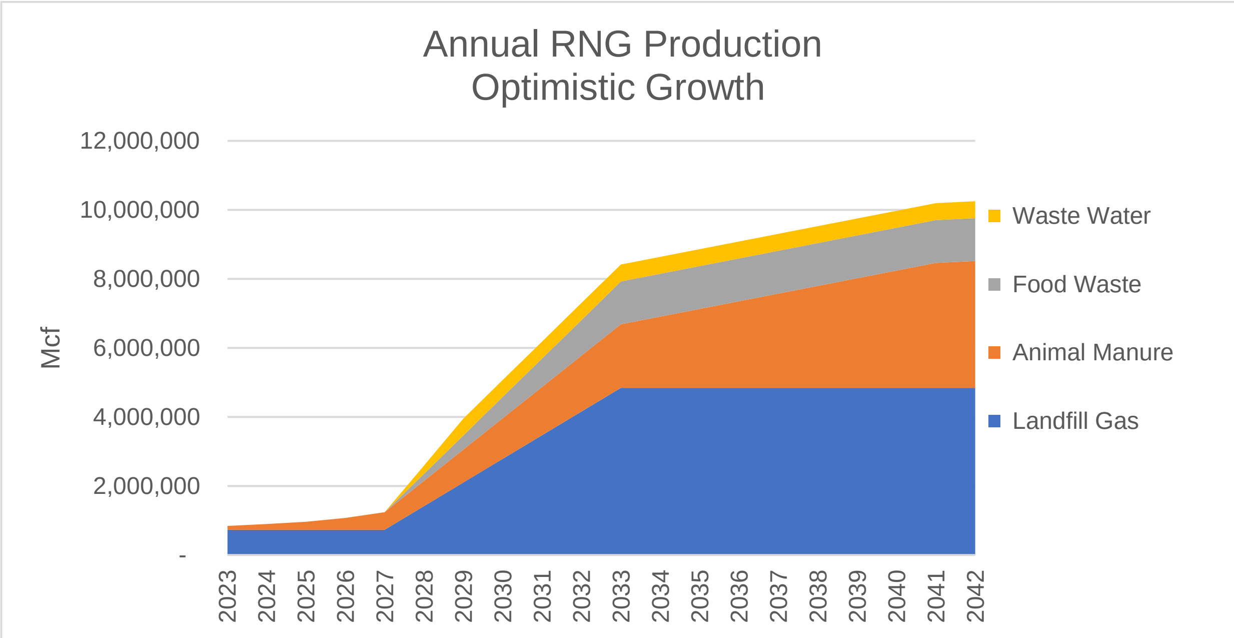
	Achievable Deployment (Mcf)				Optimistic Growth (Mcf)			
	Landfill Gas	Animal Manure	Food Waste	Waste Water	Landfill Gas	Animal Manure	Food Waste	Waste Water
2023	730,000	113,909	-	-	730,000	113,909	-	-
2024	730,000	170,289	-	-	730,000	169,550	-	-
2025	730,000	226,670	-	-	730,000	225,191	-	-
2026	730,000	339,431	-	-	730,000	336,473	-	-
2027	730,000	508,572	-	-	730,000	503,395	-	-
2028	1,489,569	677,713	196,308	184,563	1,415,356	725,959	206,893	246,085
2029	2,249,139	846,854	392,616	369,127	2,100,713	948,522	413,787	492,169
2030	3,008,708	1,015,995	588,925	369,127	2,786,069	1,171,086	620,680	492,169
2031	3,768,277	1,185,136	785,233	369,127	3,471,426	1,393,649	827,574	492,169
2032	3,768,277	1,354,277	981,541	369,127	4,156,782	1,616,213	1,034,467	492,169
2033	3,768,277	1,523,419	981,541	369,127	4,842,139	1,838,776	1,241,361	492,169
2034	3,768,277	1,692,560	981,541	369,127	4,842,139	2,061,340	1,241,361	492,169
2035	3,768,277	1,861,701	981,541	369,127	4,842,139	2,283,904	1,241,361	492,169
2036	3,768,277	2,030,842	981,541	369,127	4,842,139	2,506,467	1,241,361	492,169
2037	3,768,277	2,199,983	981,541	369,127	4,842,139	2,729,031	1,241,361	492,169
2038	3,768,277	2,369,124	981,541	369,127	4,842,139	2,951,594	1,241,361	492,169
2039	3,768,277	2,538,266	981,541	369,127	4,842,139	3,174,158	1,241,361	492,169
2040	3,768,277	2,707,407	981,541	369,127	4,842,139	3,396,721	1,241,361	492,169
2041	3,768,277	2,763,787	981,541	369,127	4,842,139	3,619,285	1,241,361	492,169
2042	3,768,277	2,763,787	981,541	369,127	4,842,139	3,674,926	1,241,361	492,169

[11] "RNG Potential in NY & NFGDC Territory," National Fuel, April 2020. Provided in Appendix J.

Figure A-3

Available RNG Production in National Fuel's New York Service Territory





The SCE Scenario assumes achievable deployment, while the Aggressive Scenario and LTP assume optimistic growth.

XII. Hydrogen

A. Methodology

Blending hydrogen into the natural gas distribution system can reduce emissions by eliminating emissions associated with end-use combustion. This analysis utilized assumptions from pilot programs and independent studies to determine hydrogen cost and safe blending percentages. These assumptions are used to model hydrogen blending potential within National Fuel's distribution system. The model computes costs and GHG emission reductions associated with a specified schedule of annual hydrogen blend as a percent of total throughput.

B. Assumptions, Inputs, Sources

Hydrogen cost data is sourced from ICF's 2021 hydrogen study. Green Hydrogen is assumed to be used in the blending process for all scenarios.

Table A-36

Cost Projection of Green Hydrogen 2023-2043

Year	Green Hydrogen ($2020/MMBtu)
2023	$24.02
2024	$23.26
2025	$22.50
2026	$21.46
2027	$20.42
2028	$19.38
2029	$18.34
2030	$17.30
2031	$16.76
2032	$16.22
2033	$15.68
2034	$15.14
2035	$14.60
2036	$14.18
2037	$13.76
2038	$13.34
2039	$12.92
2040	$12.50
2041	$12.18
2042	$11.86

Source: Cost data estimated from graph in "Examining the Current and Future Economics of Hydrogen Energy," ICF, August 13, 2021. Cost adjusted for inflation in modeling to nominal dollars.

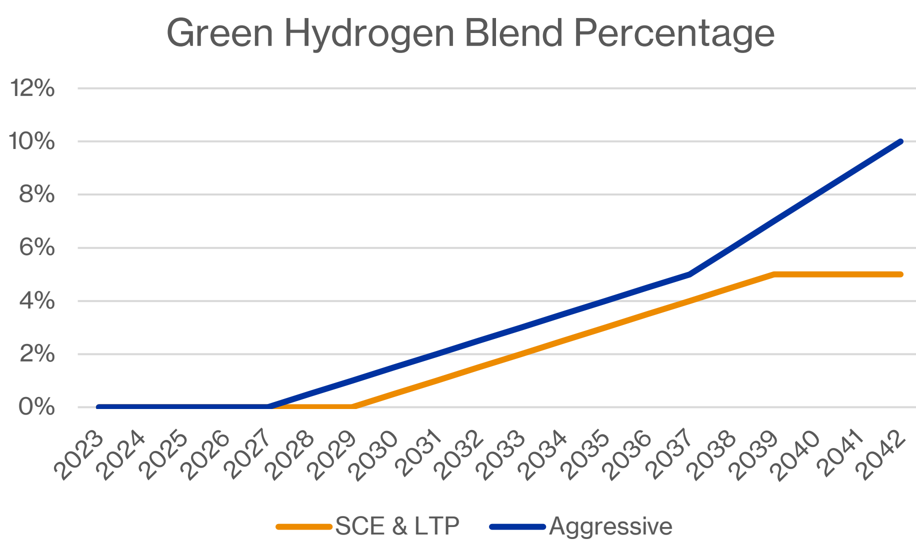
C. Scenario Inputs

The SCE and LTP scenarios both assume that the hydrogen blend as percentage of total throughput increases by 0.5% per year starting in 2030 with a max blend percentage of 5%. The

Aggressive Scenario increases hydrogen as percentage of total throughput by 0.5% per year starting in 2028, increasing to 1% per year starting in 2038 with a max blend percentage of 10% by 2042. Figure 16 depicts the start year, total blend percentage, and annual increase by scenario.

Figure A-4

Percent Hydrogen Blend by Scenario 2023-2024



Appendix B

National Fuel Gas Distribution Corporation

December 22, 2022

CONTENTS

Appendix B: Modeling of Scenarios

I. Modeling of Scenarios

A. Overview

The SCE Scenario, Aggressive Scenario and Long-Term Plan were developed using a bottom-up approach whereby per unit costs (e.g., incremental equipment cost and incremental energy bills per participating customer or incremental cost per unit of RNG or hydrogen) and benefits (e.g., decreased emissions per participating customer, decreased emissions per unit of RNG or hydrogen) were modeled for each Decarbonization Action on an annual basis over the 20-year planning period. Assumptions specific to each Decarbonization Action are discussed in Appendix A.

B. Cumulative Impacts

The scenario results incorporate the combined effects of the Decarbonization Actions included in the scenario. For example, the quantity of hydrogen that is blended into the system in each scenario depends on how much gas throughput remains after energy efficiency and electrification Decarbonization Actions reduce gas use.

The modeling of each Decarbonization Action produces the same annual outputs over the 20-year planning period, including the first (or one-time) incremental installation and/or implementation costs, associated gas usage reduction and net change in electric use. While participant installation costs for energy efficiency weatherization and electrification are one time first costs, the net change in gas and electric usage and associated GHG emission reductions occur year after year following each conversion.

The economic impact of reduced gas bills and increased electric bills depends on two major factors: the change in energy usage and the per unit energy price. Participants' cumulative change in gas and electric use is calculated by summing across all Decarbonization Actions in a scenario. The gas and electric prices used to calculate the economic impact of the change in usage under the scenarios are different from the Reference Case prices due to the impacts of decarbonization on electric and gas prices. The gas and electric price forecasts used to determine participant net operating costs are discussed in Sections II and III below.

II. Gas Prices

The gas price forecast will be multiplied by the change in gas usage under the scenarios to determine the economic benefits of reduced gas usage over the 20-year analysis period. The Company's Reference Case forecasted delivered natural gas prices (commodity cost of gas, storage and pipeline demand charges, and base gas distribution rates) are the starting point for all analyses. The gas prices used in each scenario are adjusted based on the combined effects the Decarbonization Actions associated with the scenario have on gas-related costs and gas billing determinants (i.e., both the numerator and denominator can be affected by the various Decarbonization Actions). The resulting scenario-specific gas prices are used to quantify the economic benefits of reduced gas usage.

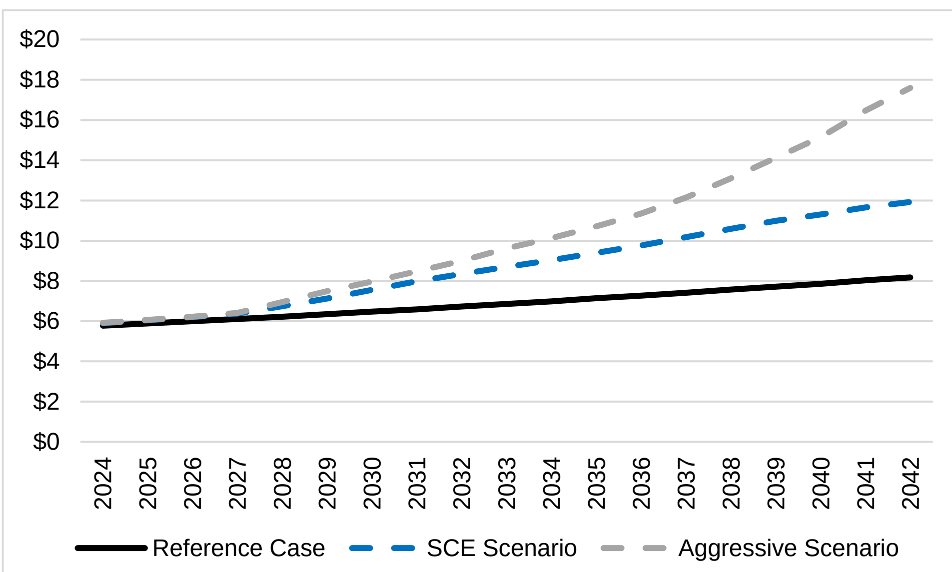
A. Cost of Gas – Commodity and Demand

The cost of gas is comprised of per unit commodity prices and demand charges. The Reference Case cost of gas is adjusted to incorporate the production cost premium of RNG and hydrogen supply. Since the amount of RNG and hydrogen differs across scenarios, the total effect the addition of these fuels has on the cost of gas differs across scenarios. The Reference Case cost of gas is also adjusted to reflect the increased per unit cost of storage and pipeline demand (i.e., reservation) charges as natural gas demand decreases.

The cost of gas in the Aggressive Scenario is higher than the cost of gas in the SCE scenario because: (1) the Aggressive Scenario includes more RNG and hydrogen than the SCE scenario, and these fuels have higher rates than existing natural gas supplies, and (2) the Aggressive Scenario has lower billing determinants than the SCE Scenario. The Reference Case, SCE Scenario and Aggressive Scenario cost of gas is illustrated in Figure B-1.

Figure B-1

Annual Cost of Gas by Scenario ($/MCF)



For each scenario, the average monthly gas commodity prices are weighted by HDDs and CDDs using the same winter, shoulder and summer seasonal definitions discussed in Appendix A, Table A-10 to develop seasonal average prices. These seasonal prices are then applied to the cumulative change in seasonal gas use for each Decarbonization Action within the scenario portfolio. Seasonal prices are required to estimate the economics of Decarbonization Actions that have different impacts throughout the year (e.g., electrification, weatherization).

B. Gas Base Distribution (Non-Gas) Rates

National Fuel developed a 20-year forecasted reference case distribution revenue requirement for its NY division, applying existing revenue requirements policies. For each scenario, the annual Home Energy Report Program costs are added to the Company's Reference Case revenue requirement forecast.

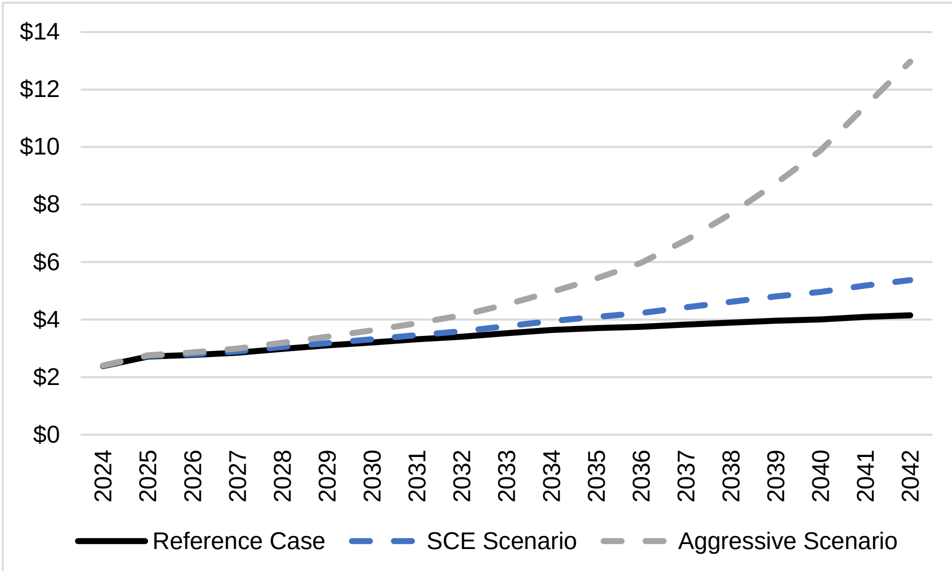
Illustrative gas base distribution non-gas costs are calculated for each rate class (i.e., SC1, SC3, TC1.1, TC2.0, TC3.0, TC4.0, TC4.1) using the Company's adjusted revenue requirement forecast and previously proposed class level revenues as approved in National Fuel's last rate case. For each forecasted year, the model calculates the cumulative percentage change in National Fuel's forecasted revenue requirement from its last approved revenue requirement of $272,375,000 in NYPSC Case 16-G-0257. These cumulative percentage changes are then applied to the base distribution non-gas cost revenues for each rate class as was approved in NYPSC Case 16-G-0257.

Customer charge revenues are calculated assuming a 2% per year increase in customer charge applied to National Fuel's 20-year forecasted reference case sales and transportation customer accounts, reduced for any reduction in customer accounts resulting from full electrification or thermal network systems. The resulting customer charge revenues are netted from base non-gas cost revenues to calculate volumetric revenues, which are then divided by National Fuel's 20-year forecasted reference case sales and transportation volumes, adjusted by the reduction in throughput volumes resulting from the scenario portfolio's Decarbonization Actions to derive a $/MCF base distribution non-gas volumetric rate.

Average gas base distribution non-gas costs are then calculated for each customer segment (i.e., residential, small commercial, industrial, large multi-family, and universities). The Reference Case, SCE Scenario and Aggressive Scenario base distribution rate for residential customers is illustrated in Figure B-2.

Figure B-2

Annual Residential Base Gas Distribution Rate by Scenario ($/MCF)



III. Electric Price Forecast and Adjustments for Electrification

The electric price forecast will be multiplied by the net change in electric usage under the scenarios to determine the economic benefits of increased usage over the 20-year analysis period.

A. Electric Price Base Forecast

National Fuel's service territory overlaps with three electric utilities: New York State Energy & Gas ("NYSEG"), Rochester Gas & Electric ("RG&E") and National Grid Niagara Mohawk ("NIMO"). Bundled all-in electric prices[1] are calculated for National Fuel's New York residential, commercial, and industrial segments by first calculating 2021 average $/kWh volumetric residential, commercial, and industrial rates for NYSEG, RG&E, and NIMO by dividing 2021 retail electric revenues by electric volumes for each customer segment as reported by S&P Capital IQ. For each of the three electric utilities, average volumetric $/kWh rates are calculated by removing customer charge revenues.

A population-weighted average 2021 $/kWh volumetric bundled all-in rate was calculated for residential, commercial, and industrial segments specific to National Fuel's New York service territory by weighting the volumetric rates calculated for NYSEG, RG&E and NIMO by 2020 zip code-level population census data. NYSEG represents 35% of National Fuel's service territory, NIMO represents 61%, and RG&E represents 4%. The resulting weighted average 2021 volumetric $/kWh bundled all-in rates for residential, commercial, and industrial segments are

1 Bundled all-in rates that include generation, transmission, and distribution charges

than escalated by the U.S. Energy Information Administration (EIA) 2022 Annual Energy Outlook (AEO) year-to-year forecasted change in its end-use Upstate New York $2021/kWh electric price. The resulting annual average $2021 real prices were then inflated to nominal dollars using inflation values shown in Appendix A, Table A-2.

Seasonal average all-in electric prices are calculated by adjusting the supply portion of the forecasted all-in electric prices based on seasonal price differentials observed historically in the New York Independent System Operator (NYISO) Day-Ahead locational-based market prices (LBMPs). Specifically, monthly average load-weighted 2021 LBMPs for NYISO Zones A, B, and C are weighted by HDDs and CDDs using the same winter, shoulder and summer seasonal definitions discussed in Appendix A, Table A-10 to develop seasonal average LBMPs for each Zone A, B, and C. Seasonal LBMP ratios are calculated by dividing the winter, shoulder and summer seasonal average LBMPs by the annual average LBMP. A single population weighted ratio that represents National Fuel's service territory was then calculated for each season by weighing Zone A, B, and C ratios by 2020 zip code-level population census data.

The allocation between the generation supply portion and delivery portion (i.e., transmission and distribution) of bundled all-in electric prices is estimated for residential, commercial and industrial segments using percentages calculated based on NIMO typical bill impacts provided in Case 20-E-0380 & 20-G-0381.[2]

B. Electric Price Adjustment for Electrification

The electric prices used in all scenarios are adjusted to account for the estimated impact of increased electric transmission, distribution, and generation infrastructure necessary to implement economy wide electrification.

NIMO's February 2022 Capital Investment Plan,[3] provides electric transmission and distribution capital investment cost estimates for FY 2023 through 2027 with a break-out of incremental distribution capital investments and transmission capital investments related to electric vehicles, the CLCPA Phase 1 Supplemental filing, and the Smart Path Connect program. These incremental decarbonization capital investments increase as a percentage of NIMO's base distribution and transmission capital investment levels at a compound annual growth rate of 5.3%. Therefore, for all scenarios, a compound annual growth rate of 5.3% was applied to the delivery (i.e., transmission and distribution) portion of the nominal electric price forecast.

The National Renewable Energy Laboratory ("NREL"), projects that by 2035 the U.S. average $/MWh generation system cost for its Accelerated Demand Electrification ("ADE") case will be 6% greater than the EIA AEO 2021 reference case.[4] NREL projects this increase to occur after

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2 Order Adopting Terms of Joint Proposal, Establishing Rate Plans and Reporting Requirements. Case 20-E-0380 & 20-G-0381, Appendix 2. Schedule 4.3.1. January 20, 2022.

3 National Grid. *Transmission and Distribution Capital Investment Plan*. Case 20-E-0380. February 1, 2022.

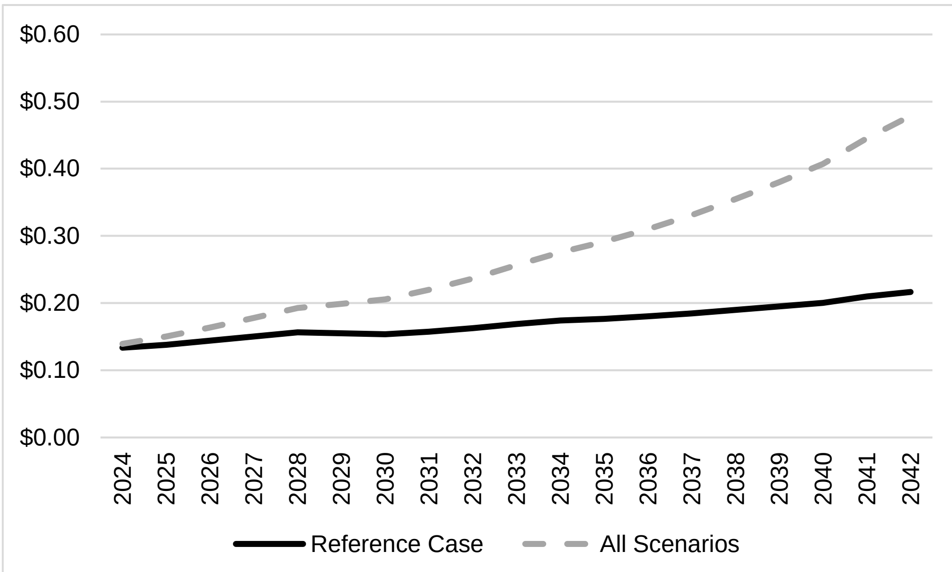
4 Denholm, Paul, Patrick Brown, Wesley Cole, et al. 2022. *Examining Supply-Side Options to Achieve 100% Clean Electricity by 2035*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A40-81644. https://www.nrel.gov/docs/fy22osti/81644.pdf

four years, which is equivalent to a 1.5% compound annual growth rate. Therefore, for all scenarios, a compound annual growth rate of 1.5% is applied to the supply portion of the nominal electric price forecast to reflect projected increases in electric generation capacity required to meet additional demand requirements resulting from electrification.

Figure B-3 shows the nominal residential Reference Case electric prices as well as the residential electric prices used for all scenarios.

Figure B-3

Annual Residential Electric Price ($/kWh)



IV. Calculation of NPV $/MT CO2e reduction

Comparison of the net present value ("NPV") $/MT CO2e metric across the scenarios as well as across the various individual Decarbonization Actions allows for a quantitative assessment of the trade-off between reductions in GHG emissions and cost impacts. To calculate this metric for a specific Decarbonization Action, the NPV of the projected annual costs and CO2e emission reductions are calculated for the Decarbonization Action.[5] The NPV $/MT CO2e metric is then calculated by dividing the NPV of costs by the NPV of the CO2e emission reductions for the Decarbonization Action. To calculate this metric for a scenario, the NPVs of costs and CO2e reductions are summed across all Decarbonization Actions that comprise the scenario. The NPV $/MT CO2e metric is then calculated by dividing the NPV of costs by the NPV of the CO2e emission reductions for the scenario in total.

5 All NPV calculations use National Fuel's weighted average cost of capital of 6.92% as approved by Commission in Docket C-16-G-0257.

V. Typical Residential Non-Participant Gas Bill Impact Calculation

Typical residential non-participant gas bill impacts are calculated for each year of the analysis. The analysis assumes a customer's typical use remains constant at 106 Mcf per year. Gas bill increases reflect incremental utility program costs and supply cost premiums for RNG and hydrogen, and the impact of reduced throughput resulting from the Decarbonization Actions.

Appendix C

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Appendix C: Benefit Cost Analysis

I. The Societal Cost Test ("SCT")

The Commission's Gas Planning Order[1] directs LDCs to apply benefit-cost analyses ("BCA") to long-term plans, adopting the methodology established in the BCA Framework Order.[2]

The BCA Framework Order provides guidance most directly applicable to electric utilities. LDCs have yet to develop a consistent BCA framework for gas utilities, and National Fuel, specifically, has not yet developed a BCA Handbook for Non-Pipeline Alternatives. In the absence of a consistent BCA framework for gas utilities, this analysis follows guidance previously provided in the BCA Framework Order and industry best practices. Care was taken to avoid double counting of monetized benefits or costs by defining each benefit and cost, following the cost and benefit streams resulting from multiple elements of each decarbonization action, and allowing for consideration of how the interconnected components interact.

The BCA Framework Order designated the SCT as the primary BCA method. By utilizing the SCT, National Fuel assesses the impact of its LTP from a holistic perspective that recognizes customer, utility, and societal impacts. The SCT attempts to identify, evaluate, and compare the net present value of all benefits and costs. A Benefit Cost Ratio ("BCR") greater than 1.0 is considered "passing".

The SCT was applied to National Fuel's LTP at the portfolio level (rather than evaluating individual decarbonization actions in isolation), allowing for a comprehensive, balancing of potential synergies and economies across the LTP and allowing the use of broader assumptions when more granular data is not readily available or quantifiable.

This Appendix contains a description of the LTP's benefit and cost streams included in the BCA and identifies the sources of values used to monetize them over the LTP's 20-year planning horizon.

II. LTP Benefit and Cost Categories

A. Definitions of Benefit Categories

The following categories of benefits are quantified and included in the SCT for the LTP:

- **Fixed and Variable Avoided Upstream Supply:** includes the commodity component associated with physical molecules of natural gas that are delivered to city-gate by pipeline and storage capacity. Avoided commodity costs are the result of displaced

[1] May 12, 2022 Order Adopting Gas System Planning Process.

[2] Case 14-M-0101, Reforming the Energy Vision, Order Establishing the Benefit Cost Analysis Framework (issued January 21, 2016).

natural gas supply by RNG and hydrogen or reduced throughput resulting from demand related decarbonization actions.

- **Avoided Distribution Capital Costs:** includes avoided mains, services and meters from thermal energy systems in new housing developments.
- **Avoided Electric Costs:** includes reduced electric costs due to lower air conditioning loads resulting from weatherization.
- **Avoided Emissions:** accounts for reduced CO2, CH4 and N20 emissions from reduced gas use.
- **Avoided Electric Generation Capital:** accounts for reduced generation installed capacity costs ("ICAP") due to lower air conditioning loads resulting from weatherization.

B. Definitions of Cost Categories

The following categories of costs are quantified and included in the SCT for the LTP:

- **Program Administration:** includes program administration costs for residential Home Energy Reports.
- **Incremental Electric Generation Capital Costs:** includes incremental installed capacity costs ("ICAP") required to incent the construction of generation capacity required to meet increase in electric demand resulting from electrification.
- **Incremental Participant Electricity Costs:** includes incremental participant electric costs for net increased electric use resulting from electrification decarbonization measures and thermal energy systems.
- **Incremental O&M Expense:** includes incremental supply cost of RNG and hydrogen.
- **Participant Costs:** includes energy efficiency and electrification net installed costs behind the meter. Installed costs are net of avoided replacement cost of retired (or new) appliance.
- **Increased GHG Emissions:** accounts for CO2, CH4, and N2O emissions from increased electricity use resulting from electrification and thermal energy systems. This includes emissions that occur during combustion at fossil plants and transportation of natural gas through pipelines to location of combustion.

III. Avoided and Incremental Cost Values for Monetizing Costs and Benefits

Avoided and Incremental cost values are used to monetize some of the benefits and costs listed above. For example, the social cost of carbon is an avoided cost, which, when multiplied by the amount of CO2 avoided by a decarbonization measure, provides a dollar value for the societal benefit of reduced CO2 for that measure. These avoided and incremental costs and associated assumptions are listed in Tables C-1, C-2 and C-3 below.

Table C-1
BCA Global Modeling Assumptions for LTP

Input	Description	Source	Value
Analysis Period	20-years (2023-2042)	Same as LTP	n/a
Inflation Rate	Inflation rate applied if forecasted data is not available.	Blue Chip Economic Indications ("BCEI"), GDP Chained Price Index, April 11, 2022 at 5 and BCEI Long-Range Consensus US Economic Projections at, GDP Chained Price Index, March 11, 2022 at 14.	2022: 7.3% 2023: 3.3% 2024: 2.2% 2025/27: 2.1% 2028/42: 2.0%
Company-retained gas	Gas lost between send-out and point of consumption; includes lost and unaccounted for gas (LAUF) and shrinkage.	NFG's 20-Year Reference Case	1.72%
Electric loss rate	Electricity lost between wholesale and retail	NYSEG and RG&E Secondary Voltage, Energy/UFE Loss Factor in Case 08-E-0751; Niagara Mohawk Power Corporation, Electric Service Tariff, PSC No. 220 Electricity, Leaf 216, Revision 2. Initial Effective Date: February 1, 2011. Weighted average loss factor calculated for NFG service territory using 2020 Census Population data by zip code.	7.95%
Discount Rate	National Fuel's Weighted Average Cost of Capital (WAAC)	As approved by Commission in Docket C-16-G-0257.	6.92%

Table C-2
Avoided Gas Supply and Capacity Benefits for LTP

Input	Description	Source
Gas Rate	Gas rate used to monetize reduced gas use resulting from decarbonization actions.	See Appendix B
Social Cost of Carbon (SCC)	Social cost of CO2 used to monetize gas and electric GHG emissions ($/MT)	NY DEC Social Cost of CO2 at 3% discount rate.[3]
Social Cost of Methane and Nitrous Oxide	Social cost of CH4 and N20 used to monetize avoid gas GHG emissions ($/MT)	NY DEC Social Cost of CO2 at 3% discount rate.[4]

[3] New York State Department of Conservation's report, "Establishing a Value of Carbon. Guidelines for use by State Agencies," May 2022. Available online at https://www.dec.ny.gov/docs/administration_pdf/vocapp22.pdf

[4] Ibid.

Table C-3
Increased Electric Supply and Capacity Costs

Input	Description	Source
Electric All-In Rate	Avoided or increased electricity costs	See Appendix B. Excludes electric generation supply cost adjustment for electrification (1.5% compounded annual growth rate) discussed in Appendix B, to avoid double counting of avoided cost of generating capacity which is monetized using ICAP payments.
Incremental cost of generating capacity	Incremental cost of capacity associated with generation	ICAP spreadsheet from DPS Staff published in 14-M-00581/14-M-0101.
Incremental cost of transmission	Incremental cost of electric transmission	Included in electric bundled full rate.
Incremental cost of distribution	Incremental cost of electric distribution	Included in electric bundled full rate.
Electric cost of carbon	Social cost of CO2 used to monetize increased electric GHG emissions ($/MT)	NY DEC Social Cost of CO2 at 3% discount rate[5] net of RGGI credit,[6] escalated by inflation forecast, multiplied by assumed electric emissions rate. Forecasted electric generation emission rates are provided in Appendix D, Table D-22. These emission rates are based on EPA's eGrid data[7] by fuel stock applied to EIA's 2022 AEO reference case forecasted generation mix.
Social Cost of Methane and Nitrous Oxide	Social cost of CH4 and N20 used to monetize avoid gas GHG emissions ($/MT)	NY DEC Social Cost of CO2 at 3% discount rate.

5 Ibid.

6 Most recent RGGI Auction 58 (12/7/2022) Clearing Price is $12.99 per Short Ton CO2 (Source: https://www.rggi.org/auctions/auction-results) The cost of CO2 collected through RGGI is already reflected in New York LBMPs component of forecasted fully bundled electric rates. The cost of CO2 collected via RGGI credits are subtracted from the social cost of carbon to avoid double counting.

7 United States Environmental Protection Agency. *Emissions & Generation Resource Integrated Database (eGrid), NPCC Upstate NY subregion year 2020 data (SRL20),* January 27, 2022.

Appendix D

National Fuel Gas Distribution Corporation

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Appendix D: Reference Case Documentation

I. Demand Forecast

Reference Case demand for residential, commercial, and public authority customers is forecast by multiplying an account forecast by a use per account forecast developed using regression analysis. Large industrial demand was forecast on a customer-by-customer basis based on information provided by account representatives. The small industrial demand forecast was held constant. All demand forecasts include retail sales and transportation customers. Tables D-1, D-2, and D-3 present the annual accounts, usage per account, and demand for each customer sector.

Table D-1

Reference Case Annual Account Projection by Sector[1]

	Residential	Commercial	Industrial	Public Authority	Total
FY 2023	506,539	33,268	447	2,436	542,690
FY 2024	508,683	33,359	446	2,454	544,942
FY 2025	510,682	33,450	444	2,472	547,048
FY 2026	513,168	33,542	442	2,490	549,642
FY 2027	514,695	33,633	440	2,507	551,275
FY 2028	516,228	33,725	438	2,525	552,916
FY 2029	517,764	33,817	436	2,543	554,560
FY 2030	519,306	33,909	434	2,561	556,210
FY 2031	520,852	34,001	432	2,579	557,864
FY 2032	522,402	34,094	431	2,597	559,524
FY 2033	523,957	34,187	429	2,616	561,189
FY 2034	525,517	34,280	427	2,634	562,858
FY 2035	527,082	34,374	425	2,653	564,534
FY 2036	528,651	34,467	423	2,671	566,212
FY 2037	530,224	34,561	421	2,690	567,896
FY 2038	531,803	34,655	420	2,709	569,587
FY 2039	533,386	34,750	418	2,728	571,282
FY 2040	534,974	34,845	416	2,748	572,983
FY 2041	536,566	34,940	414	2,767	574,687
FY 2042	538,164	35,035	412	2,787	576,398

1 Fiscal Year is defined as October through September of the following year.

Table D-2

Reference Case Annual Usage/Account Projection by Sector (MCF/Account)

	Residential	Commercial	Industrial	Public Authority
FY 2023	106	597	41,851	3,186
FY 2024	107	609	41,812	3,213
FY 2025	106	614	42,192	3,204
FY 2026	106	622	42,595	3,212
FY 2027	106	630	42,965	3,221
FY 2028	107	642	43,398	3,247
FY 2029	106	647	43,533	3,239
FY 2030	106	656	43,821	3,248
FY 2031	106	665	44,110	3,257
FY 2032	107	678	44,555	3,283
FY 2033	106	683	44,694	3,275
FY 2034	106	693	44,989	3,284
FY 2035	106	702	45,286	3,293
FY 2036	107	715	45,743	3,319
FY 2037	106	721	45,885	3,311
FY 2038	106	731	46,188	3,320
FY 2039	106	741	46,493	3,329
FY 2040	107	755	46,962	3,356
FY 2041	106	761	47,108	3,348
FY 2042	106	771	47,419	3,357

Table D-3

Reference Case Annual Demand Forecast by Sector (MCF)

	Residential	Commercial	Industrial	Public Authority	Company Use	Shrinkage*	Total
FY 2023	53,852,740	19,867,974	18,710,749	7,761,309	110,793	1,755,414	102,058,979
FY 2024	54,308,420	20,325,238	18,651,658	7,885,607	111,001	1,772,537	103,054,461
FY 2025	54,215,331	20,544,929	18,736,633	7,920,067	110,793	1,776,839	103,304,592
FY 2026	54,494,156	20,873,237	18,827,040	7,997,409	110,793	1,790,400	104,093,035
FY 2027	54,684,434	21,197,705	18,908,011	8,076,379	110,793	1,802,208	104,779,530
FY 2028	55,123,294	21,655,601	19,016,010	8,198,207	110,793	1,821,924	105,925,829
FY 2029	54,993,365	21,895,522	18,992,555	8,236,161	110,793	1,824,103	106,052,499
FY 2030	55,148,484	22,252,999	19,034,969	8,317,233	110,793	1,835,235	106,699,713
FY 2031	55,304,041	22,616,312	19,077,478	8,399,104	110,793	1,846,493	107,354,221
FY 2032	55,747,874	23,104,851	19,186,445	8,525,801	110,793	1,866,934	108,542,698
FY 2033	55,616,472	23,360,829	19,162,780	8,565,271	110,793	1,869,391	108,685,536
FY 2034	55,773,348	23,742,229	19,205,574	8,649,583	110,793	1,881,036	109,362,563
FY 2035	55,930,668	24,129,855	19,248,464	8,734,726	110,793	1,892,814	110,047,320
FY 2036	56,379,530	24,651,089	19,358,407	8,866,485	110,793	1,914,022	111,280,326
FY 2037	56,246,639	24,924,198	19,334,531	8,907,532	110,793	1,916,776	111,440,469
FY 2038	56,405,293	25,331,122	19,377,708	8,995,214	110,793	1,928,964	112,149,094
FY 2039	56,564,395	25,744,689	19,420,982	9,083,758	110,793	1,941,294	112,865,911
FY 2040	57,018,343	26,300,805	19,531,911	9,220,783	110,793	1,963,310	114,145,945
FY 2041	56,883,946	26,592,191	19,507,821	9,263,470	110,793	1,966,383	114,324,604
FY 2042	57,044,398	27,026,348	19,551,385	9,354,655	110,793	1,979,148	115,066,727

*Shrinkage is the difference between the amount of gas accepted into the distribution system at the citygate and the amount of gas delivered through customer meters and is assumed to be 1.72%.

Table D-4 presents the design day demand forecast.

Table D-4

Reference Case Annual Design Day Demand (Dth/Day)

	Design Day Demand (Dth/Day)
FY 2023	1,026,958
FY 2024	1,035,990
FY 2025	1,038,831
FY 2026	1,047,089
FY 2027	1,054,379
FY 2028	1,057,741
FY 2029	1,061,042
FY 2030	1,064,370
FY 2031	1,067,724
FY 2032	1,071,106
FY 2033	1,074,525
FY 2034	1,077,962
FY 2035	1,081,431
FY 2036	1,084,930
FY 2037	1,088,459
FY 2038	1,092,020
FY 2039	1,095,609
FY 2040	1,099,230
FY 2041	1,102,879
FY 2042	1,106,564

II. Supply Forecast

Table D-5 summarizes the contracts in National Fuel's gas supply portfolio into three major categories: upstream pipeline supplies, pipeline delivered citygate supplies, and storage delivery supplies. Supplies provided by other entities to serve transportation customer loads (i.e., ESCO provided supplies and large industrial delivered supplies) are also presented in Table D-5.

Table D-5

Reference Case Capacity by Source Forecast

	Contracted Upstream Pipeline Supplies	Contracted Pipeline Delivered Citygate Supplies	Contracted Storage Delivery Supplies	ESCO Provided Capacity Supplies	Large Industrial Delivered Supplies	Total
FY 2023	234,473	93,432	473,109	61,007	184,791	1,046,812
FY 2024	234,473	99,932	473,109	61,007	184,982	1,053,503
FY 2025	234,473	99,932	473,109	61,007	187,703	1,056,224
FY 2026	234,473	108,432	473,109	61,007	190,411	1,067,432
FY 2027	234,473	108,432	473,109	61,007	193,115	1,070,136
FY 2028	234,473	118,432	473,109	61,007	193,273	1,080,294
FY 2029	234,473	118,432	473,109	61,007	193,429	1,080,450
FY 2030	234,473	118,432	473,109	61,007	193,587	1,080,608
FY 2031	234,473	118,432	473,109	61,007	193,744	1,080,765
FY 2032	234,473	128,432	473,109	61,007	193,902	1,090,923
FY 2033	234,473	128,432	473,109	61,007	194,064	1,091,085
FY 2034	234,473	128,432	473,109	61,007	194,222	1,091,243
FY 2035	234,473	138,432	473,109	61,007	194,381	1,101,402
FY 2036	234,473	138,432	473,109	61,007	194,542	1,101,563
FY 2037	234,473	138,432	473,109	61,007	194,703	1,101,724
FY 2038	234,473	148,432	473,109	61,007	194,863	1,111,884
FY 2039	234,473	148,432	473,109	61,007	195,024	1,112,045
FY 2040	234,473	148,432	473,109	61,007	195,189	1,112,210
FY 2041	234,473	158,432	473,109	61,007	195,349	1,122,370
FY 2042	234,473	158,432	473,109	61,007	195,514	1,122,535

III. GHG Emissions

Greenhouse gases ("GHG") are gases in the earth's atmosphere that trap heat and contribute to rising temperatures on earth. Separate emissions calculations are performed for carbon dioxide, methane, and nitrous oxide. This analysis estimates Scope 1 emissions: direct emissions from company-owned and controlled resources, Scope 2 emissions: indirect emissions from consumption of purchased electricity, and Scope 3 emissions: indirect emissions from non-company owned upstream and downstream entities. Total emissions are the sum of Scope 1, 2, and 3 emissions.

Reference Case GHG emissions are calculated for the 20-year analysis period using the Reference Case demand, supply, and system characteristics forecast. GHG emissions are also reported for 1990 since 1990 levels of emissions are frequently referred to as the baseline from which reductions are measured. Many of the GHG emissions assumptions and results tables have values for 1990, as well as 2023-2042.

A. Global Warming Potential

A Global Warming Potential ("GWP") is used to weigh the global warming impact of different GHGs to calculate total emissions on a carbon dioxide equivalent basis because it is helpful to have a single measure of emissions rather than three separate measures for each GHG. Specifically, Global Warming Potential factors are used to convert carbon dioxide (CO_2) methane (CH_4), and nitrous oxide (N_2O) into carbon dioxide equivalents (CO_2e). All CO2e values calculated in the LTP analysis and presented in the report and appendices use the IPCC AR5 20-Year GWPs, as shown in Table D-6.

Formula:

$$(GWP(CO_2) * Mass\ of\ CO_2) + (GWP(CH_4) * Mass\ of\ CH_4) + (GWP(N_2O) * Mass\ of\ N_2O) = Mass\ of\ CO_2e$$

Table D-6

Global Warming Potential Factors

Gas	AR5 100-Year	AR5 20-Year
CO_2	1	1
CH_4	28	84
N_2O	265	264

Source: https://www.ipcc.ch/site/assets/uploads/2018/02/SYR_AR5_FINAL_full.pdf

B. Common Conversion Factors

The common conversion factors in Table D-7 are used throughout analysis to compute GHG emissions. Emissions presented in this analysis are computed in metric tons (MT).

Table D-7

Common Conversion Factors

1000	kg	=	1	MT
2204.62	lbs.	=	1	MT
1.033	MMBtu	=	1	MCF

C. Scope 1 Emissions

1. Methodology

Scope 1 emissions include emissions from operating National Fuel's distribution, transmission, and gathering segments. Included in these segments are mains, services, meters, and various other emission sources. Reference Case emissions are computed on a CO_2, CH_4, and N_2O basis for 1990 as well as for 2023-2042.

Mains and services related emissions were computed using a density and volumetric approach to derive the mass of emissions. Meter emissions were computed by multiplying the total number of meters by customer segment by the applicable emission factor. Emissions from other sources were calculated in a similar manner by applying appropriate emission factors to the appropriate quantities.

The tables below detail the methane and carbon dioxide calculations for mains and services. The tables display an input of one mile or service. The emission mass per mile is calculated by multiplying down the column. The general formulas for a mile of main or one service:

$$1.\ \boldsymbol{Methane\ (kg)} = Distance\ (miles) * Emission\ Factor\left(\frac{\frac{cf}{hr}}{mile\ or\ service}\right) * Time(hr) * Density\left(\frac{kg}{cf}\right)$$

$$2.\ \boldsymbol{Carbon\ Dioxide(kg)} = Distance(miles) * Emission\ Factor\ \left(\frac{\frac{cf}{hr}}{mile\ or\ service}\right) * Time\ (hr) * Mole\ Fraction\ (CO_2) * Density\left(\frac{kg}{cf}\right)$$

Tables D-8 and D-9 on the following page report emissions assumptions per mile of main by pipe material.

Table D-8

Methane Emissions Assumptions per Mile of Main by Pipe Material

Material	Unprotected Steel	Protected Steel	Plastic	Cast/Wrought Iron
Mile	1.000	1.000	1.000	1.000
Emission Factor (cf/hr./mile)	12.580	0.350	1.130	27.250
Time (hours)	8760.000	8760.000	8760.000	8760.000
Density CH4 (kg/cf)	0.019	0.019	0.019	0.019
CH4 (kg)	**2115.855**	**58.867**	**190.057**	**4583.232**
CH4 (MT)	**2.116**	**0.059**	**0.190**	**4.583**

Source: 40 CFR Part 98, Table W-7 ('Default Methane Emission Factors for Natural Gas Distribution')

Table D-9

Carbon Dioxide Emissions Assumptions per Mile of Main by Pipe Material

	Unprotected Steel	**Protected Steel**	**Plastic**	**Cast/Wrought Iron**
Mile	1.000	1.000	1.000	1.000
Emission Factor (cf/hr./mile)	12.580	0.350	1.130	27.250
Time (hours)	8760.000	8760.000	8760.000	8760.000
Mole Fraction (CO2)	0.011	0.011	0.011	0.011
Density CH4 (kg/cf)	0.053	0.053	0.053	0.053
CO2 (kg)	**63.762**	**1.774**	**5.727**	**138.118**
CO2 (MT)	**0.064**	**0.002**	**0.006**	**0.138**

Tables D-10 and D-11 report emissions assumptions per mile of main by pipe material.

Table D-10

Methane Emissions Assumptions Per Service by Pipe Material

Material	**Unprotected Steel**	**Protected Steel**	**Plastic**
Emission Factor (cf/hr/service)	0.190	0.020	0.001
Time(hours)	8760.000	8760.000	8760.000
Density CH4 (kg/cf)	0.019	0.019	0.019
CH4 (kg)	**31.956**	**3.364**	**0.168**
CH4 (MT)	**0.032**	**0.003**	**0.000**

Table D-11

Carbon Dioxide Emissions Calculation Per Service by Pipe Material

Material	Unprotected Steel	Protected Steel	Plastic
Emission Factor (cf/hr./service)	0.190	0.020	0.001
Time (hours)	8760.000	8760.000	8760.000
Mole Fraction (CO2)	0.011	0.011	0.011
Density CH4 (kg/cf)	0.053	0.053	0.053
CO2 (kg)	**0.963**	**0.101**	**0.005**
CO2 (MT)	**0.001**	**0.000**	**0.000**

Table D-12 reports emissions assumptions per meter by customer segment.

Table D-12

Emissions Factors for Meters by Type

Meter Type	Residential	Commercial	Industrial
Methane (kg/meter)	1.490	23.400	105.000
Carbon Dioxide (kg/meter)	0.040	0.690	3.100

2. Assumptions, Inputs, Sources – Mains, Services, Meters

Mains and services by type reflect expected changes in the composition of the Company's distribution system over time due to its leak prone pipe replacement program. Table D-13 on the following page reports the forecast of miles of mains by materials.

Table D-13

Number of Miles of Mains by Material

	Unprotected Steel	Protected Steel	Plastic	Cast / Wrought Iron	Total Main Miles
1990	3,753	2,201	2,397	710	9,061
2023	923	2,245	6,499	145	9,812
2024	830	2,247	6,619	128	9,824
2025	737	2,249	6,739	111	9,836
2026	644	2,251	6,859	94	9,848
2027	551	2,253	6,979	77	9,860
2028	458	2,255	7,099	60	9,872
2029	365	2,257	7,219	43	9,884
2030	272	2,259	7,339	26	9,896
2031	179	2,261	7,459	9	9,908
2032	86	2,263	7,554	-	9,903
2033	81	2,268	7,554	-	9,903
2034	76	2,273	7,554	-	9,903
2035	71	2,278	7,554	-	9,903
2036	66	2,283	7,554	-	9,903
2037	61	2,288	7,554	-	9,903
2038	56	2,293	7,554	-	9,903
2039	51	2,298	7,554	-	9,903
2040	46	2,303	7,554	-	9,903
2041	41	2,308	7,554	-	9,903
2042	-	2,313	7,554	-	9,867

Source: National Fuel Gas Distribution Corp. 2021 DOT reports and Modernization Emission Projections

Table D-14 presents the number of services by material.

Table D-14

Number of Services by Material

	Unprotected Steel	Protected Steel	Plastic	Total Services
1990	173,636	90,248	177,995	441,879
2023	28,236	40,882	395,229	464,347
2024	25,356	40,132	399,729	465,217
2025	22,476	39,382	404,229	466,087
2026	19,596	38,632	408,729	466,957
2027	16,716	37,882	413,229	467,827
2028	13,836	37,132	417,729	468,697
2029	10,956	36,382	422,229	469,567
2030	8,076	35,632	426,729	470,437
2031	5,196	34,882	431,229	471,307
2032	2,316	34,132	435,729	472,177
2033	2,299	33,757	436,104	472,160
2034	2,282	33,382	436,479	472,143
2035	2,265	33,007	436,854	472,126
2036	2,248	32,632	437,229	472,109
2037	2,231	32,257	437,604	472,092
2038	2,214	31,882	437,979	472,075
2039	2,197	31,507	438,354	472,058
2040	2,180	31,132	438,729	472,041
2041	2,163	30,757	439,104	472,024
2042	-	30,382	439,479	469,861

Source: National Fuel Gas Distribution Corp. 2021 DOT reports and Modernization Emission Projections

Table D-15 presents the number of meters by customer class.

Table D-15

Number of Meters by Type

	Number of Outdoor Residential Meters	Number of Commercial Meters	Number of Industrial Meters
1990	182,531	36,036	484
2023	432,077	33,268	447
2024	434,295	33,359	446
2025	436,368	33,450	444
2026	438,928	33,542	442
2027	440,529	33,633	440
2028	442,136	33,725	438
2029	443,746	33,817	436
2030	445,362	33,909	434
2031	446,981	34,001	432
2032	448,604	34,094	431
2033	450,232	34,187	429
2034	451,865	34,280	427
2035	453,503	34,374	425
2036	455,145	34,467	423
2037	456,791	34,561	421
2038	458,443	34,655	420
2039	460,099	34,750	418
2040	461,760	34,845	416
2041	463,425	34,940	414
2042	465,096	35,035	412

3. Results

The Scope 1 emissions estimates in Tables D-16, D-17, D-18, and D-19 are based on the Company's Reference Case forecast of demand, supply, and distribution system characteristics. CO2e estimates reflect the 20-year GWP.

Table D-16

Scope 1 Emissions – Mains (MT)

	CO2	CH4	CO2 e
1990	355	11,780	989,878
2023	120	3,985	334,847
2024	113	3,733	313,691
2025	105	3,481	292,535
2026	97	3,230	271,380
2027	90	2,978	250,223
2028	82	2,726	229,068
2029	75	2,474	207,912
2030	67	2,222	186,756
2031	59	1,971	165,600
2032	53	1,751	147,126
2033	52	1,741	146,262
2034	52	1,730	145,397
2035	52	1,720	144,534
2036	52	1,710	143,669
2037	51	1,699	142,805
2038	51	1,689	141,940
2039	51	1,679	141,077
2040	50	1,669	140,212
2041	50	1,658	139,348
2042	47	1,572	132,083

Table D-17

Scope 1 Emissions – Services (MT)

	CO2	CH4	CO2 e
1990	177	5,882	494,292
2023	33	1,106	92,964
2024	31	1,013	85,082
2025	28	919	77,200
2026	25	825	69,318
2027	22	731	61,436
2028	19	637	53,554
2029	16	544	45,672
2030	14	450	37,789
2031	11	356	29,907
2032	8	262	22,025
2033	8	260	21,879
2034	8	259	21,733
2035	8	257	21,586
2036	8	255	21,440
2037	8	253	21,294
2038	8	252	21,147
2039	8	250	21,001
2040	7	248	20,855
2041	7	246	20,708
2042	5	176	14,799

Table D-18

Scope 1 Emissions - Meters by Customer Segment (MT)

	Residential			Commercial			Industrial		
	CO2	CH4	CO2 e	CO2	CH4	CO2 e	CO2	CH4	CO2 e
1990	8	272	22,839	25	843	70,857	2	51	4,270
2023	19	643	54,063	23	778	65,415	1	47	3,944
2024	19	647	54,340	23	781	65,593	1	47	3,935
2025	19	650	54,600	23	783	65,772	1	47	3,917
2026	19	654	54,920	23	785	65,953	1	46	3,900
2027	19	656	55,120	23	787	66,132	1	46	3,882
2028	19	658	55,321	23	789	66,313	1	46	3,865
2029	19	661	55,523	23	791	66,494	1	46	3,847
2030	20	663	55,725	23	793	66,675	1	46	3,829
2031	20	666	55,927	23	796	66,856	1	45	3,812
2032	20	668	56,131	23	798	67,039	1	45	3,803
2033	20	670	56,334	24	800	67,222	1	45	3,785
2034	20	673	56,539	24	802	67,404	1	45	3,767
2035	20	675	56,744	24	804	67,589	1	45	3,750
2036	20	678	56,949	24	807	67,772	1	44	3,732
2037	20	680	57,155	24	809	67,957	1	44	3,715
2038	20	683	57,362	24	811	68,142	1	44	3,706
2039	20	685	57,569	24	813	68,329	1	44	3,688
2040	20	688	57,777	24	815	68,515	1	44	3,670
2041	20	690	57,985	24	818	68,702	1	43	3,653
2042	20	693	58,194	24	820	68,889	1	43	3,635

Table D-19

Scope 1 Other Emissions (all others) – (MT)[2]

	CO2	CH4	N2O	CO2 e
1990	6,961	506	0.04	49,512
2023	6,962	559	0.04	53,923
2024	6,962	560	0.04	53,980
2025	6,962	560	0.04	54,037
2026	6,962	561	0.04	54,094
2027	6,962	562	0.04	54,151
2028	6,963	562	0.04	54,208
2029	6,963	563	0.04	54,265
2030	6,963	564	0.04	54,322
2031	6,963	564	0.04	54,379
2032	6,963	564	0.04	54,391
2033	6,963	564	0.04	54,390
2034	6,963	564	0.04	54,390
2035	6,963	564	0.04	54,389
2036	6,963	564	0.04	54,389
2037	6,963	564	0.04	54,388
2038	6,963	564	0.04	54,388
2039	6,963	564	0.04	54,387
2040	6,963	564	0.04	54,387
2041	6,963	564	0.04	54,386
2042	6,963	563	0.04	54,228

[2] All other Scope 1 emissions include emissions associated with the transmission, gathering, and other segments. The transmission segment includes blowdowns, combustion, and pipeline leaks. The gathering segment includes pipeline leaks, blowdowns, dehydrator equipment, equipment leaks, and combustion. The other segment includes fleet, buildings, LDC M&R, and LDC small combustion.

Table D-20 presents total Scope 1 emissions by source.

Table D-20

Scope 1 Total Emissions (Sum of Mains, Services, Meters, and Other) – (MT)

	CO_2	CH_4	N_2O	CO_2 e
1990	7,527	19,334	0.04	1,631,648
2023	7,159	7,119	0.04	605,155
2024	7,149	6,779	0.04	576,621
2025	7,139	6,439	0.04	548,061
2026	7,128	6,100	0.04	519,564
2027	7,118	5,760	0.04	490,945
2028	7,108	5,419	0.04	462,328
2029	7,098	5,079	0.04	433,712
2030	7,087	4,738	0.04	405,096
2031	7,077	4,398	0.04	376,481
2032	7,068	4,089	0.04	350,514
2033	7,068	4,081	0.04	349,871
2034	7,067	4,073	0.04	349,230
2035	7,067	4,066	0.04	348,591
2036	7,067	4,058	0.04	347,951
2037	7,067	4,050	0.04	347,313
2038	7,066	4,043	0.04	346,684
2039	7,066	4,035	0.04	346,050
2040	7,066	4,028	0.04	345,415
2041	7,066	4,020	0.04	344,782
2042	7,061	3,866	0.04	331,828

D. Scope 2 Emissions

1. Methodology

Scope 2 emissions are indirect emissions from purchased electricity for Distribution, Supply, Empire, and Midstream operations. Electric usage was held constant over the 20-year period at 5,654 MWh/year. Annual CO_2, CH_4, and N_2O emissions were computed by multiplying electric usage by projected emissions factors based on EIA's forecasted generation mix for Upstate New York.[3] The projected emission factors as based off current factors provided by the EPA's Power Profiler as shown in Table D-21.

General Formula:

$$CO_2, CH_4, N_2O\ (lbs) = Electric\ Usage\ (MWh) * Emission\ Factor\ (CO_2, CH_4, N_2O)$$

2. Assumptions, Inputs, Sources

Table D-21 presents electric emissions factor for the upstate New York subregion.

Table D-21

2022 Electric Emission Factors – NYUP Subregion – (lbs/MWH)

CO_2	CH_4	N_2O
233.5	0.016	0.002

Source: Power Profiler | US EPA

[3] Sources: 2021: U.S. Energy Information Administration (EIA), Short-Term Energy Outlook, November 2021 and EIA, AEO2022 National Energy Modeling System run ref2022.d011222a. Projections: EIA, AEO2022 National Energy Modeling System run ref2022.d011222a.

Table D-22 presents the emissions factor based over the LTP period based on a projection of the electric generation fuel mix.

Table D-22

Electric Emission Factor for Projected Fuel Mix in Upstate New York – (lbs/MWH)

Electric Generation, Upstate NY (lb/MWh)(2)	CO2	CH4	N2O	CO2e
1990	234	0.02	0.002	235
2023	282	0.56	0.003	330
2024	259	0.51	0.002	302
2025	221	0.44	0.002	258
2026	170	0.33	0.002	199
2027	144	0.28	0.002	168
2028	140	0.27	0.002	163
2029	137	0.26	0.002	159
2030	207	0.41	0.002	242
2031	211	0.41	0.002	246
2032	195	0.38	0.002	228
2033	191	0.37	0.002	223
2034	176	0.34	0.002	206
2035	162	0.32	0.002	190
2036	153	0.30	0.002	178
2037	150	0.29	0.002	175
2038	153	0.30	0.002	178
2039	151	0.29	0.002	176
2040	153	0.30	0.002	178
2041	154	0.30	0.002	180
2042	155	0.30	0.002	181

Source: US EPA eGrid 2020, EIA AEO 2022 Generation Fuel Mix for Upstate NY. Includes emissions associated with imported gas.

3. Results

Table D-22 presents the total Scope 2 emissions.

Table D-23

Scope 2 Total Emissions – (MT)

Electric Generation, Upstate NY (lb/MWh)(2)	CO2	CH4	N20	CO2 e
1990	599	0.04	0.01	604
2023	724	1.44	0.01	847
2024	663	1.32	0.01	775
2025	567	1.12	0.01	662
2026	437	0.85	0.01	510
2027	369	0.71	0.01	431
2028	359	0.69	0.01	418
2029	351	0.67	0.01	409
2030	532	1.05	0.01	621
2031	540	1.06	0.01	631
2032	500	0.98	0.01	584
2033	490	0.96	0.01	572
2034	452	0.88	0.01	528
2035	417	0.81	0.01	486
2036	392	0.76	0.01	457
2037	384	0.74	0.01	448
2038	391	0.76	0.01	456
2039	388	0.75	0.01	453
2040	391	0.76	0.01	456
2041	396	0.77	0.01	462
2042	397	0.77	0.01	464

E. Scope 3 Emissions

Scope 3 emissions are indirect emissions resulting from assets not owned or controlled by National Fuel but related to National Fuel's operations. Scope 3 emissions are comprised of emissions associated with end user combustion and gas imported into National Fuel's distribution system ("imported gas").[4]

1. End User Emissions

a. Methodology

Scope 3 end user emissions result from the combustion of natural gas by the Company's end-use customers. End user emissions are estimated using the 40 CFR Part 98, Subpart NN methodology with adjustments to include methane and nitrous oxide components. Emissions are calculated by multiplying total throughput by applicable emission factors.

Formula:

$$CO_2, CH_4, N_2O\ (kg) = Volume\ (Mcf) * Heating\ Value\ \left(\frac{MMBTu}{Mcf}\right) * Emission\ Factor\left(kg\,\frac{CO_2, CH_4, N_2O}{MMBtu}\right)$$

[4] Note that the term "imported gas" refers to gas imports into National Fuel's distribution system, not gas imports from other countries.

b. Assumptions, Inputs, Sources

Tables D-24 through D-26 present the assumptions and results that result in a forecast of Scope 3 end-user emissions.

Table D-24

Total Throughput

	Volume (Mcf)
1990	109,730,930
2023	100,303,565
2024	101,281,923
2025	101,527,753
2026	102,302,635
2027	102,977,322
2028	104,103,906
2029	104,228,397
2030	104,864,479
2031	105,507,728
2032	106,675,764
2033	106,816,145
2034	107,481,528
2035	108,154,506
2036	109,366,305
2037	109,523,693
2038	110,220,130
2039	110,924,618
2040	112,182,635
2041	112,358,221
2042	113,087,579

Table D-25

End User Emission Factors

CO_2 (kg CO_2/MMBtu)	CH_4 (kg CH_4/MMBtu)	N_2O (kg N_2O/MMBtu)
53.06	0.001	0.0001

Source: Greenhouse Gas Inventory Guidance: Direct Emissions from Stationary Combustion Sources Appendix A-Table A-3

c. Results

Table D-26

Scope 3 End User Emissions (MT)

	CO_2	CH_2	N_2O	CO_2 e
1990	6,014,460	115	12	6,027,197
2023	5,497,737	104	10	5,509,176
2024	5,551,361	105	10	5,562,912
2025	5,564,836	105	10	5,576,414
2026	5,607,308	106	11	5,618,975
2027	5,644,288	106	11	5,656,032
2028	5,706,037	108	11	5,717,909
2029	5,712,861	108	11	5,724,747
2030	5,747,725	108	11	5,759,684
2031	5,782,982	109	11	5,795,014
2032	5,847,003	110	11	5,859,169
2033	5,854,698	110	11	5,866,879
2034	5,891,168	111	11	5,903,425
2035	5,928,054	112	11	5,940,389
2036	5,994,474	113	11	6,006,947
2037	6,003,101	113	11	6,015,591
2038	6,041,273	114	11	6,053,843
2039	6,079,887	115	11	6,092,537
2040	6,148,840	116	12	6,161,634
2041	6,158,464	116	12	6,171,278
2042	6,198,441	117	12	6,211,338

2. Imported Gas

a. Methodology

Imported Gas emissions are indirect emissions related to producing and transporting gas to National Fuel's distribution system. These emissions are categorized as local and upstream gas. These two segments are computed using the same methodology but different emission factors. Out-of-state upstream production and transmission has much higher emission factors than in-state local production. In addition, Gulf Coast production and transmission has much higher emissions factors than Appalachian Shale production and transmission. It was assumed that all 1990 out-of-state gas was Gulf Coast conventional production and 2023-2042 out-of-state gas was Appalachian shale production. The emission factors were converted from the NETL Lifecyle Assessment to account for the use of the 20-Year GWP, and an estimate of gas distribution emissions were removed from the NETL Lifecycle Assessment emissions factors because distribution-related emissions are captured in Scope 1 emissions above.

Formula:

$$CO_2, CH_4, N_2O\ (kg) = Volume\ (Mcf) * Heating\ Value\ \left(\frac{MMBTu}{Mcf}\right) * Emission\ Factor\ \left(kg\,\frac{CO_2, CH_4, N_2O}{MMBtu}\right)$$

b. Assumptions/Inputs/Sources

As presented in Table D-27, total Reference Case forecasted throughput was allocated into upstream and local gas on a monthly basis using historical upstream vs local gas ratios.

Table D-27

Annual Out-of-State Upstream and In-State Local Gas

	Upstream Gas (Mcf)	Local Gas (Mcf)	Total (Mcf)
1990	106,969,010	4,716,530	111,685,540
2023	97,614,247	4,444,630	102,058,877
2024	98,568,380	4,485,977	103,054,358
2025	98,805,071	4,499,419	103,304,490
2026	99,560,427	4,532,506	104,092,932
2027	100,218,003	4,561,422	104,779,425
2028	101,321,587	4,604,137	105,925,724
2029	101,438,554	4,613,841	106,052,395
2030	102,059,128	4,640,480	106,699,607
2031	102,686,702	4,667,412	107,354,114
2032	103,830,874	4,711,717	108,542,591
2033	103,963,259	4,722,170	108,685,429
2034	104,612,451	4,750,004	109,362,455
2035	105,269,062	4,778,148	110,047,210
2036	106,456,080	4,824,132	111,280,212
2037	106,604,975	4,835,384	111,440,359
2038	107,284,497	4,864,485	112,148,982
2039	107,971,884	4,893,914	112,865,798
2040	109,204,160	4,941,671	114,145,831
2041	109,370,713	4,953,775	114,324,489
2042	110,082,394	4,984,218	115,066,613

Table D-28

Imported Gas Emission Factors

	Appalachian Shale Basin (Kg/MMBtu)	Gulf-Conventional Basin (Kg/MMBtu)	In-State Local Gas (Kg/MMBtu)
CO_2	11.2777	11.3832	0.0020
CH_4	0.1311	0.3033	0.0680
N_2O	0.0001	0.0001	N/A

Source: NETL Lifecyle Assessment 2019 Exhibit E-32; Source: 2021 Statewide GHG Emissions Report: Summary Report, Table A3

c. Results

Table D-29 presents the forecast of Scope 3 emissions.

Table D-29

Scope 3 Imported Gas Emissions 2023-2042 (MT)

	CO2	CH4	N2O	CO2 e
1990	1,257,846	33,846	15	4,104,811
2023	1,137,206	13,533	14	2,277,550
2024	1,148,321	13,665	14	2,299,800
2025	1,151,079	13,698	14	2,305,338
2026	1,159,879	13,802	14	2,322,954
2027	1,167,540	13,893	14	2,338,291
2028	1,180,396	14,046	14	2,363,996
2029	1,181,759	14,062	14	2,366,750
2030	1,188,989	14,148	14	2,381,220
2031	1,196,300	14,235	14	2,395,853
2032	1,209,629	14,393	15	2,422,503
2033	1,211,172	14,412	15	2,425,618
2034	1,218,735	14,502	15	2,440,755
2035	1,226,384	14,593	15	2,456,065
2036	1,240,213	14,757	15	2,483,713
2037	1,241,948	14,778	15	2,487,213
2038	1,249,864	14,872	15	2,503,057
2039	1,257,872	14,967	15	2,519,084
2040	1,272,228	15,137	15	2,547,787
2041	1,274,169	15,161	15	2,551,699
2042	1,282,460	15,259	15	2,568,293

Appendix E

National Fuel Gas Distribution Corporation

December 22, 2022

National Fuel®

Guidehouse

Meeting the Challenge: Scenarios for Decarbonizing New York's Economy

Provided to:

National Fuel Gas Distribution Corporation

Provided by:
Guidehouse Inc.
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February 19, 2021

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National Fuel

National Fuel is a utility that provides natural gas service to more than 740,000 customers in western New York and northwestern Pennsylvania.

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Executive Summary

When the *Climate Leadership and Community Protection Act* (the Climate Act)[1] was passed in 2019, it placed New York State at the forefront of ambitious climate legislation. This commitment generated numerous questions about what the Climate Act's targets will mean for the state, including:

- **How will the state meet these goals for dramatic greenhouse gas (GHG) emissions reductions?** What actions are required today and in the future? Which technologies will be central to achieving the Climate Act's goals?
- **What is the economic impact of meeting the Climate Act's goals?** What capital investments are required to facilitate various emissions reduction options that achieve the state's targets?
- **How will New York's energy utilities and power generators meet the requirements for this transition?** These companies and their customers contributed more than 40%[2] of New York State's GHG emissions reductions from 1990 to 2016, and their involvement is critical to the state's ability to achieve its goals. How will this energy transition occur?
- **How does the NFGDC energy network, as part of the broader energy system, participate in the transition to a decarbonized future state?** How can the NFGDC infrastructure support decarbonization while maintaining energy system reliability and resiliency?

To assess the Climate Act's impacts on the energy system and the communities it serves, NFGDC engaged Guidehouse to evaluate potential scenarios for meeting 2050 GHG reduction goals and implications for its service territory. This report describes the findings of this analysis.

The Scenarios

To test the impacts of achieving the Climate Act's goals, we constructed three potential future scenarios. Our scenarios, as Figure 1 details, consider the interplay of electrification and low carbon gas adoption in the achievement of the Climate Act's targets.

[1] Available at: https://climate.ny.gov/

[2] The New York State Energy Research and Development Authority (2019). "New York State Greenhouse Gas Inventory 1990-2016." Available at: https://www.nyserda.ny.gov/-/media/Files/EDPPP/Energy-Prices/Energy-Statistics/greenhouse-gas-inventory.pdf

Figure 1. Decarbonization Scenarios

	Reference Case	High Electrification	Selective Electrification
Assumptions	The Climate Act was not promulgated, and New York targets the 2016 Clean Energy Standard goals. (Defined by the Energy Information Administration's [EIA's] *Annual Energy Outlook 2019* reference case)	The Climate Act's targets are achieved almost exclusively through electrification without consideration of cost, and fuel sources are phased out to the greatest extent feasible.	The Climate Act's targets are achieved by balancing electrification with low carbon fuels, when fuels represent a more cost-effective option from a $/GHG reduction perspective.
Purpose	Provides a benchmark against which to compare the actions associated with meeting the Climate Act's targets.	Portrays a future vision that has been presented by many stakeholders in the Northeast.	Provides a vision for decarbonization that includes leveraging existing energy infrastructure and the element of customer choice.

Evaluating the Scenarios

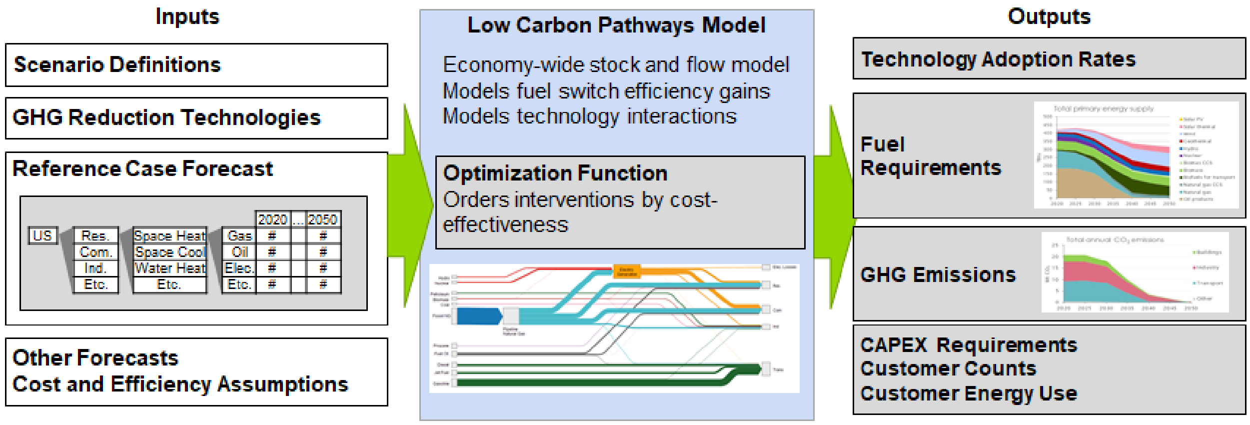
We used Guidehouse's low carbon pathways (LCP) analytical model to evaluate the scenarios. The LCP model determines the least-cost combination of technologies from a capital investment perspective to achieve a GHG emissions reduction target, given the constraints of each modeled scenario, by:

- Estimating the energy consumption and demand, capital costs, and emissions impacts of deploying different technologies to decarbonize the energy system.
- Accounting for interactions between the technologies and ranking the available GHG emissions reduction technologies in order of cost-effectiveness, in terms of dollars of capital investment per ton of GHG emissions abated.
- Considering region-specific factors—including policy, energy demand, electric generation, renewable natural gas (RNG) potential, hydrogen, HVAC equipment saturations, and vehicle usage.

The decarbonization targets set out in the Climate Act are technically achievable through various pathways.

Figure 2 provides a schematic of the LCP model and illustrates the inputs, operations, and outputs of the model.

Figure 2. Schematic of LCP Model Inputs and Outputs



Key Findings

Multiple pathways can achieve the decarbonization targets set out in the Climate Act, but a pathway that is more inclusive can do so in a way that provides solutions for hard to electrify sectors and results in crucial resilience and reliability benefits. Our analysis led to the following three key findings.

#1 Achieving the Climate Act's targets requires accelerating efficiency improvements for transportation, buildings, and appliances.

Decarbonization of the transportation sector is critical to achieving the Climate Act's emissions reduction targets. Emissions from transportation increased 25% from 1990 to 2016, and the transportation sector currently produces over one-third of New York State's GHG emissions.[3] Energy efficiency (from building shell improvements and high efficiency heat pumps and appliances) is another critical element for reducing GHG emissions. The *Reference Case* scenario assumes significant gains in energy efficiency[4] due to updated building codes, appliance standards, and utility energy efficiency rebates. Additionally, automobile fuel economy standards increase in the *Reference Case*. The *High Electrification* and *Selective Electrification* scenarios each assume that further efficiency improvements reduce building envelope and appliance energy consumption by an additional 10% due to improvements in building codes and standards. Further, switching gasoline to electric vehicles, coupled with 10% more efficiency from additional technology improvements results in energy intensity reductions in the residential (32% overall), commercial (23% overall), and transportation (42% overall) sectors.[5]

[3] The New York State Energy Research and Development Authority (2019). "New York State Greenhouse Gas Inventory 1990-2016." Available at: https://www.nyserda.ny.gov/-/media/Files/EDPPP/Energy-Prices/Energy-Statistics/greenhouse-gas-inventory.pdf

[4] The *Reference Case* scenario is based on the EIA's *Annual Energy Outlook 2019*, which projects that from 2018 to 2050, increases in energy efficiency will cause energy intensity to decline by 22% in the residential sector, 13% in the commercial sector, and 32% in the transportation sector.

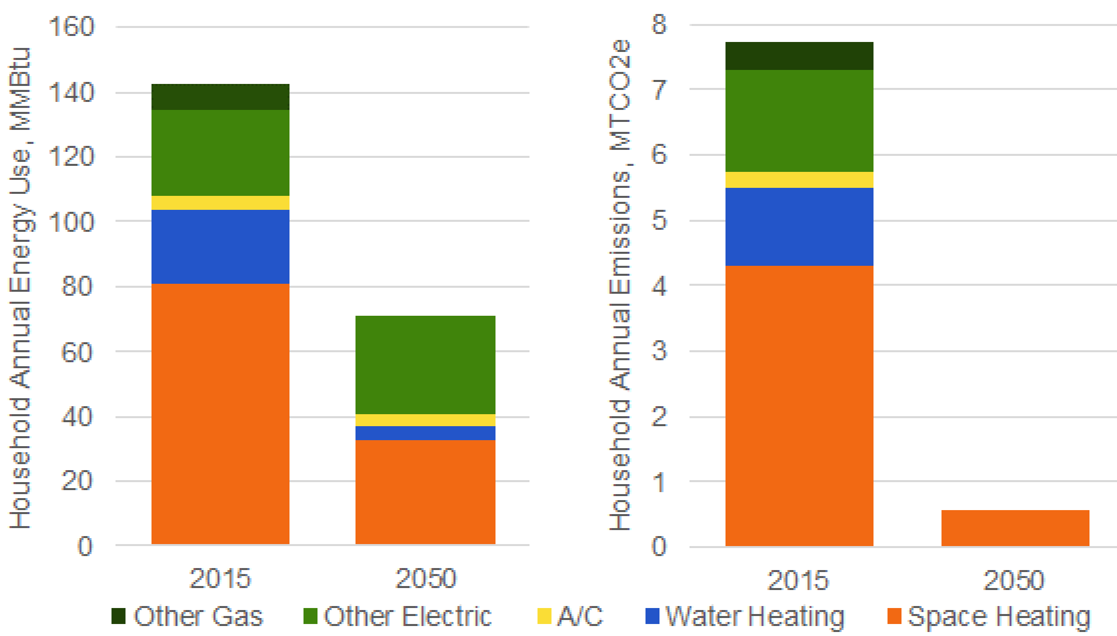
[5] "Energy intensity" is measured by the quantity of energy required per unit output or activity. For buildings, energy intensity is usually expressed in energy use per sq.ft of building space; for transportation, it is expressed as energy use per vehicle mile.

#2 The *Selective Electrification* scenario demonstrates the critical importance of including all options in developing an effective decarbonization pathway.

The *Selective Electrification* scenario accomplishes the Climate Act's GHG emission reduction targets using a variety of technologies, with each providing significant GHG reductions. For typical residential customer energy use, energy consumption and GHG emissions are assumed to decrease through building envelope and appliance energy efficiency measures, and through the use of high efficiency heat pumps (whether whole-home electric or dual-fuel), as Figure 3 illustrates. An individual customer's GHG footprint will be further reduced by decarbonization measures implemented upstream of the customer. Renewable power generation will reduce the emissions from customers' electric consumption, and RNG and hydrogen enriched natural gas (HENG) will reduce the emissions from customers' pipeline gas consumption. The dual-fuel heating option available in the *Selective Electrification* scenario will also mitigate growth in winter peak demand and improve system resilience in cold climate regions. This finding demonstrates the value of allowing all emissions reduction options to play a role in achieving New York State's emissions reduction targets.

Figure 3. Reduction in Energy Use and GHG Emissions from Selective Electrification

Example: Single-family home, NFGDC territory, switching from natural gas to dual-fuel heat



Intervention	Energy Savings	Emissions Reduction
Building Shell Efficiency	15%	14%
Heat Electrification & Dual Fuel Systems	30%	30%
Appliance Efficiency	5%	4%
Renewable Elec. Generation	n/a	27%
Carbon Capture & Storage	n/a	10%
Low-Carbon Fuels (RNG, Hydrogen)	n/a	7%
Total	**50%**	**93%**

#3 The *Selective Electrification* scenario offers an effective pathway to decarbonize high temperature industrial processes and heavy-duty trucking.

> *The Selective Electrification scenario offers additional benefits, particularly related to the crucial elements of the reliability and resilience of the energy system.*

The *Selective Electrification* scenario assumes greater use of the existing gas pipeline infrastructure, relative to the *High Electrification* scenario. The *Selective Electrification* scenario retains clearer pathways for the utilization of low carbon gases, which will be critical to decarbonizing hard-to-electrify industrial and transportation end uses. Not only does the *Selective Electrification* scenario offer a pathway to further decarbonize these end uses, it also mitigates the risk of disproportionately burdening other market sectors with deeper decarbonization requirements to offset limited pathways for the industrial sector.

Summary

The study findings illustrate the value of the *Selective Electrification* scenario for effectively meeting the Climate Act's GHG emissions reduction targets. The *Selective Electrification* scenario leverages existing infrastructure to provide a comprehensive solution to achieving the Climate Act's decarbonization targets. In addition, it offers an important pathway for decarbonization of the industrial and transportation end uses, which are the most difficult to electrify.

> An American Gas Foundation study published in January 2021 demonstrates that "Utilities, system operators, regulators, and policymakers need to recognize that resilience will be achieved through a diverse set of integrated assets … policies need to focus on optimizing the characteristics of both the gas and electric systems."

Beyond the findings of the analysis completed for this study and discussed in detail in this report, the energy system envisioned through the *Selective Electrification* scenario offers additional benefits, particularly related to the crucial elements of energy system reliability and resilience.[6] As an example in cold weather climates like western NY, the American Gas Foundation report demonstrated that in a 2019 polar vortex case study the gas utility delivered 3.5 times the energy that was delivered by the overlapping electric utility. Significant growth in energy production from intermittent renewable resources, such as wind and solar, requires energy storage and dispatchable electricity generation capabilities to ensure that energy system resilience can be maintained. Batteries will provide some energy storage capacity, but batteries are currently not a viable solution for longer duration and seasonal storage, which are foundational elements of the existing natural gas system. An American Gas Foundation study published in January 2021 demonstrates that "Utilities, system operators, regulators, and policymakers need to recognize that resilience will be achieved through a diverse set of integrated assets … policies need to focus on optimizing the characteristics of both the gas and electric systems."[7]

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[6] This study did not analyze these issues in depth since they are treated in prior studies, including Guidehouse's *2020 Gas Decarbonisation Pathways* study: Guidehouse (2020). "Gas Decarbonisation Pathways 2020-2025." Available at: https://gasforclimate2050.eu/publications/

[7] American Gas Foundation (2021). "Building a Resilient Energy Future: How the Gas System Contributes to US Energy System Resilience" Available at: https://gasfoundation.org/2021/01/13/building-a-resilient-energy-future/

How to Use the Results of this Study

This study's analysis demonstrates various pathways to achieving the Climate Act's goals. Policy makers and regulators would benefit from further evaluation of how to use our existing energy infrastructure and optimize future investments to decarbonize the New York economy.

Illustrating the technical and financial viability of the *Selective Electrification* scenario is the first step to understanding the alternative pathways on the road to decarbonizing New York's energy system and meeting the Climate Act's targets. This study's results illustrate the benefits to maintaining robust pipeline transmission and distribution networks across the state and investing in low carbon gas technologies as part of New York's decarbonization plan. However, the policies, regulations, and incentives in place at the state and federal level are insufficient to encourage the required investment in a decarbonized gas system and equitable distribution of the associated costs. The State of New York should encourage specific levels of production for low carbon renewable fuels such as RNG and HENG by setting achievable milestones.

Delivering on the vision of the energy system outlined in the *Selective Electrification* scenario will require engagement from policymakers, regulators, utilities, and stakeholders across New York. Table 1 lists strategies and associated actions that can support the creation of the energy system envisioned in the *Selective Electrification* scenario.

Table 1. Strategies and Actions to Support Delivery of the *Selective Electrification* Scenario

Strategy	Key Actions
Increase the supply of RNG and hydrogen in the gas system and the use of these low carbon fuels in downstream sectors to deliver a pathway for near-term GHG emissions reductions and a viable pathway for decarbonizing the most challenging market sectors.	• Develop and support state and federal policies consistent with those that have supported the development of solar and wind generation. • Offer encouragement and targets for RNG and hydrogen and the regulatory compact to support implementation.
Support investments to develop renewable and low carbon gas, technologies that will be required to deliver more cost-effective emissions reductions for consumers achieved in the *Selective Electrification* scenario.	• Design regulatory policies to provide long-term consistency for investors around targets and market mechanisms associated with low carbon fuels and the risks of embracing new technologies. • Encourage and facilitate research, development, and demonstration through statewide platforms, to fill gaps and drive the development of technologies with the greatest potential for the state.

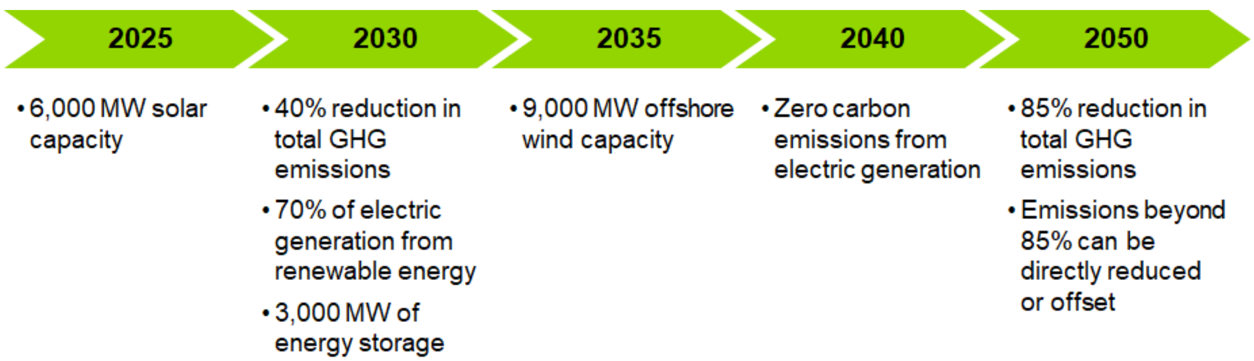
Strategy	Key Actions
Ensure energy system resilience, which will become increasingly important with the growth of intermittent renewables on the grid and the potential for increasing severity and impacts of climate-related events. Natural gas, RNG, and hydrogen can provide the required seasonal storage capacity to support the development of a resilient grid, but currently are not adequately encouraged to be developed as resilience assets. Continue to support investments that yield safe and reliable system operations.	• Identify metrics for evaluating resilience. • Require the consideration of system resilience as a part of all utility planning efforts. • Develop regulatory structures that value energy system resilience and support the amortization of resilience assets over the largest array of market segments as benefits accrue to all system users. Policies that foster complementary operations of electric and pipeline systems for resilience will reduce risks to local economies and communities.
Embed equity in the process, considering all emissions reduction technology pathways, to avoid picking winners and losers in New York's energy transition. While there will be winners and losers in the development of new technologies and solutions to power the transition, residential and commercial customers should not be penalized because they do not have the means to be early adopters of new technologies.	• Encourage policies that leverage existing infrastructure and prioritize pathways that limit costs, such as using existing infrastructure to transport renewable gas and hydrogen. • Support disadvantaged communities to ensure they can participate in decarbonizing their communities.

1. Introduction and Background

Many countries have announced pledges and proposed legislation to reduce greenhouse gas (GHG) emissions, but few jurisdictions have enacted laws to follow through on these commitments. On July 18, 2019, New York Governor Andrew M. Cuomo signed the Climate Leadership and Community Protection Act (the Climate Act) into law.[8] Among the most ambitious climate regulations in the world,[9] the Climate Act requires New York State to reduce economywide GHG emissions 40% by 2030 and 85% by 2050 from 1990 levels. It also sets interim requirements (see Figure 1-1) that the state's power sector must meet prior to 2050.

This report considers several pathways to reach the Climate Act's emissions targets and their associated costs, with varying degrees of electrification, low carbon fuels, and natural gas usage. Guidehouse analyzed these pathways on behalf of National Fuel Gas Distribution Corporation (NFGDC).

Figure 1-1. Requirements of New York Climate Leadership and Community Protection Act



The Climate Act specifies requirements for energy storage capacity and for electric generation capacity from solar and offshore wind technologies. Aside from these requirements, the Climate Act does not specify which technologies should be implemented to reduce GHG emissions.

All sectors of New York's economy contribute to the state's GHG emissions. As Figure 1-2 indicates, New York reduced economywide GHG emissions by 13% between 1990 and 2016.[10] Changes in the commercial, industrial, and power sectors drove these reductions. In the power sector, New York replaced older coal-fired power plants with lower emissions natural gas plants. GHG emissions from the commercial and industrial sectors dropped by about 34% from 1990 to 2016[10] due to investments in efficiency, improvements in building codes, and customers converting their heating systems from oil to natural gas. Meanwhile, transportation sector emissions *rose* significantly by about 25% from 1990 to 2016.

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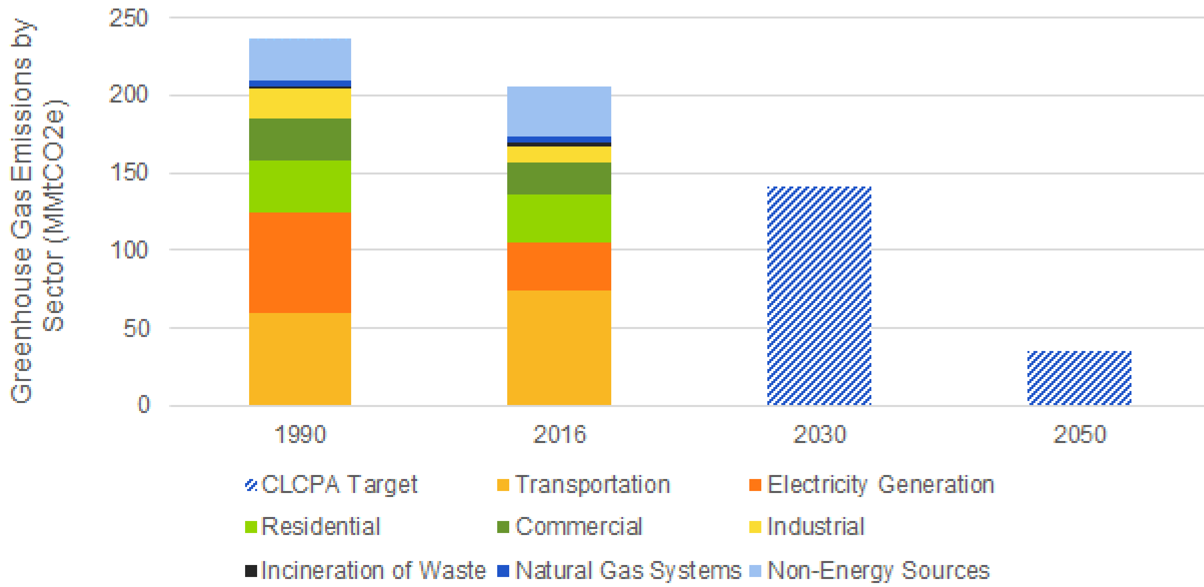
[8] New York State Senate (2019). "S.B. S6599." Available at: https://www.nysenate.gov/legislation/bills/2019/s6599

[9] As of January 2021, only eight countries and eight US states (including New York) have enacted laws requiring net zero carbon dioxide emissions by 2050. Source: Energy & Climate Intelligence Unit, Net Zero Tracker CSV data files, available at: https://eciu.net/netzerotracker/map

[10] The New York State Energy Research and Development Authority (2019). "New York State Greenhouse Gas Inventory 1990-2016." Between 1990 and 2016, economywide GHG emissions dropped from 236 to 206 $MMtCO_2e$, and GHG emissions from commercial and industrial sectors dropped from 47 to 31 $MMtCO_2e$. Available at: https://www.nyserda.ny.gov/-/media/Files/EDPPP/Energy-Prices/Energy-Statistics/greenhouse-gas-inventory.pdf

Figure 1-2. New York State Greenhouse Gas Inventory and Climate Act Targets



The power sector will need to retain a significant share of gas-fired generation to deliver baseload capacity when intermittent renewable sources of power are unavailable.

Figure 1-2 also depicts the Climate Act targets for GHG emissions reduction in 2030 and 2050.[11] To achieve the Climate Act's targets, all sectors of New York's economy must deploy GHG mitigation technologies. As of 2015, 91% of households in New York used fossil fuel as their primary source of space heating (66% of New York households use natural gas, 24% use fuel oil, and 1% use propane).[12] At present, 40% of the utility-scale electricity produced in New York is generated by burning fossil fuels, and fossil fuels provide 68% of summer peak capacity.[13] Compliance with Climate Act targets will require the state to displace its consumption of high-carbon fuels, and this reduction will impact electric utilities and natural gas utilities.

The Climate Act sets interim targets for decarbonizing the power sector (see Figure 1-1). It requires installation of new solar and wind generation capacity; these new renewables likely will displace a portion of the state's natural gas-fired electric generation. Guidehouse forecasts the power sector will need to retain a significant share of gas-fired generation to deliver baseload capacity when intermittent renewable sources of power are unavailable. Compared to other

[11] The New York Department of Environmental Conservation adopted 6 NYCRR Part 496, Statewide Greenhouse Gas Emission Limits, that sets limits on GHG emissions in 2030 and 2050, as a percentage of 1990 emissions, per the requirements of the Climate Act. The values in Figure 1-2 correspond to NYSERDA's "New York State Greenhouse Gas Inventory 1990-2016," which correspond to the GHG emissions associated with fuel combustion, presented in Table 4 of the rule's regulatory impact statement, available at: https://www.dec.ny.gov/docs/administration_pdf/revisedris496.pdf

[12] The New York State Energy Research and Development Authority (2019). "Patterns and Trends: New York Energy Profiles 2002–2016." Table B-2. Available at: https://www.nyserda.ny.gov/-/media/Files/Publications/Energy-Analysis/2002-2016-Patterns-and-Trends.pdf

[13] New York Independent System Operator (2020). "Power Trends 2020." Figures 13 & 14. Available at: https://www.nyiso.com/documents/20142/2223020/2020-Power-Trends-Report.pdf/dd91ce25-11fe-a14f-52c8-f1a9bd9085c2

technologies that promote grid reliability (such as battery storage), gas-fired generation is significantly less expensive and can meet reliability needs over a longer period. Since the Climate Act requires that power generation be carbon free by 2040, gas-fired generators will be required to mitigate their carbon emissions by applying carbon capture and storage (CCS) or other technologies.

A shift from fuel-fired heating to electric heating will largely drive the decarbonization of building heat. Investment in electric transmission and distribution infrastructure is required to achieve the electrification of building heating and other end uses.[14] Mass electrification of building heat will lead to a requirement for substantially more electric generation capacity during the winter heating season. The New York power grid is currently a summer peaking system, but the New York Independent System Operator (NYISO) projects New York may become winter peaking around 2039.[15] Deployment of air-source heat pumps and EVs could accelerate New York's transition from summer peaking to winter peaking. In addition, electrification of building space and water heating will result in declining natural gas demand and reduced gas customer counts, leading to higher distribution costs for the remaining natural gas customers.

There are varying perspectives regarding the role of natural gas in a low carbon economy. Climate advocates have opposed the construction of new gas transmission infrastructure in New York, and municipalities in New York and elsewhere have proposed banning natural gas connections to new construction.[16] On January 28, 2021, New York City Mayor Bill de Blasio announced his administration will ban fossil fuel connections in new construction by 2030.[17] Continued investment in resilient pipeline infrastructure creates options for future pathways. An approach that retains natural gas for selective end uses and introduces low carbon alternatives such as renewable natural gas (RNG)[18] and hydrogen could achieve New York's emission targets at a lower total capital cost than an approach that focuses solely on electrification.

An approach that retains natural gas for selective end uses and introduces low-carbon alternatives such as renewable natural gas (RNG) and hydrogen could achieve New York's emission targets at a lower total capital cost than an approach focused solely on electrification.

[14] In response to a NY Public Service Commission order, the New York utilities filed a working group report on November 2, 2020 that estimated between $16.6 billion and $17.2 billion of investment in transmission and distribution upgrades will be needed by 2030 to comply with the Climate Act's renewable capacity requirements. Available at: http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={2794FC7E-D2A6-4C79-8834-4B60FA25ED1F}

[15] New York Independent System Operator (NYISO) 2020. "2020 Load & Capacity Data." Figure I-4. Available at: https://www.nyiso.com/documents/20142/2226333/2020-Gold-Book-Final-Public.pdf

[16] The city of Ithaca adopted a building policy that calls for a 2030 ban on fossil fuels in new construction, with an exception for commercial cooking. Source: Politico (2020). Available at: https://www.politico.com/states/new-york/albany/story/2020/02/25/new-york-slow-to-curb-natural-gas-in-new-construction-1263585

[17] City of New York (Jan 28, 2021). "Transcript: Mayor de Blasio Delivers 2021 State of the City Address." Available at: https://www1.nyc.gov/office-of-the-mayor/news/063-21/transcript-mayor-de-blasio-delivers-2021-state-the-city-address

[18] RNG is a gaseous fuel with lower carbon intensity and similar operational and performance characteristics to natural gas. RNG can be produced through several production technologies, including landfill gas collection, anaerobic digestion, and thermal gasification systems

1.1 Study Goals

The study evaluates pathways for decarbonizing the New York State energy system by mid-century. Many policy and technology options can contribute to accomplishing the economywide decarbonization goals enacted by policymakers. Our report examines several plausible scenarios driven by market fundamentals that can achieve net zero carbon emissions by mid-century. The study addresses the following questions:

- What are the optimal pathways for achieving the Climate Act's goals?
- How will electric and natural gas loads evolve as decarbonization is implemented?
- How can the natural gas system facilitate achievement of the Climate Act's objectives?

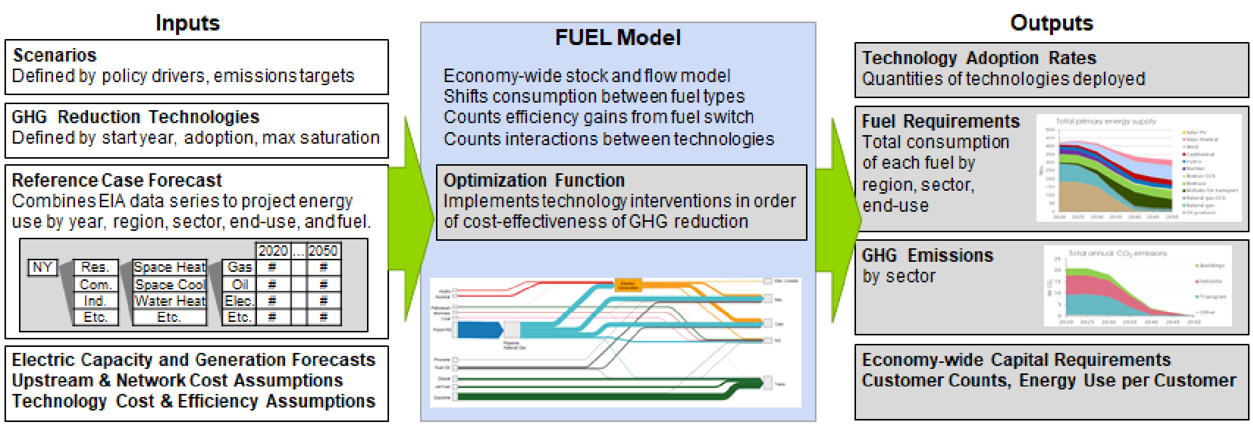
2. Methodology

2.1 Economywide Energy and Emissions Modeling

Guidehouse used its low carbon pathways (LCP) analytical model to evaluate different GHG reductions scenarios. Our economywide energy and emissions accounting model forecasts any changes in energy consumption across all sectors of the economy by fuel type and by end use. The model accounts for energy used upstream to generate electricity and energy used downstream by customers. We used the model to examine the application of carbon-reducing technologies in specific geographies. For this study, Guidehouse tailored the model to examine energy consumption and emissions for New York State and for NFGDC's territory in New York, as Section 2.3 describes.

Our LCP model compares different decarbonization scenarios to a reference case, described in Section 2.2. Each scenario is defined by a GHG emissions reduction target and an array of decarbonization technologies that are deployed to meet the emissions target. The model introduces these decarbonization technologies as deviations from the reference case. The model forecasts the extent to which each technology is deployed to meet the scenario targets and then calculates the collective energy and emissions impacts of each scenario's technology bundle. Figure 2-1 summarizes the LCP model's inputs, operations, and outputs.

Figure 2-1. Schematic of Low Carbon Pathways Model Inputs and Outputs



A key feature of our model is that it accounts for interactions between technologies and it quantifies the GHG reductions that result when technologies are deployed in tandem. For example, the emissions reductions from replacing fuel-fired heating equipment with electric heat pumps depend on the carbon intensity of the electricity supplied to power the heat pumps. By concurrently tracking upstream and downstream technology interventions, the model represents the GHG reductions that may be achieved in different scenarios.

Our LCP model also uses an optimization function to rank the available GHG reduction technologies by cost-effectiveness in terms of dollars of capital investment per ton of GHG emissions abated. To determine the pathway that meets each scenario's GHG reduction target in the least capital-intensive way possible, the model deploys the most cost-effective technologies first.

2.2 Scenario Definitions

Our analysis considers the following three scenarios, which are referenced throughout this report. These scenarios are defined around plausible future visions, including fundamental drivers such as policy/regulatory impacts, economic development, social acceptance of technology changes, and energy supply/use developments. Table 2-2 (see page 22) presents the technologies included in each scenario.

1. **Reference Case:** We established a reference case for evaluation based on the US Energy Information Administration's (EIA's) *Annual Energy Outlook 2019* reference case,[19] prior to New York's enactment of the Climate Act. In this scenario, early century decarbonization trends continue but renewable energy, energy efficiency, and electrification activities are limited. Trends proceed at a pace to meet New York's Clean Energy Standard, but emissions reductions do not meet the Climate Act's requirements. Customers continue to maintain current fuel and system choices. The existing pipeline infrastructure is fully utilized, and companies continue to invest in system enhancements to provide safe, reliable, and resilient operations. Many of these investments will increase the integrity of the system and reduce methane emissions. Shale development continues to provide low cost supply to support growing demand. Gas-fired generation complements growing renewables generation.
2. **High Electrification Scenario:[20]** In this scenario, we assume that every end use that is technically possible to electrify will be electrified by mid-century. This scenario is motivated by recent efforts to curtail or eliminate natural gas supplies—such as natural gas bans proposed by some jurisdictions—and achieves the Climate Act's emissions targets. It assumes that policies including incentives, penalties, or mandates will limit customer choice to all-electric systems. Downstream fossil fuel use will be nearly eliminated, and electricity generation will be 100% carbon free. Most natural gas infrastructure will be retired, and extensive build out of electric infrastructure will be required to maintain reliable electric supply during peak heating periods.
3. **Selective Electrification Scenario:** In this scenario, we assume that some market segments fully electrify their energy needs. However, demand components that are not cost-effective to electrify may shift to non-fossil decarbonized gas (*i.e.*, biogas, hydrogen). Electricity generation will be fully decarbonized, and the natural gas pipeline infrastructure will continue to serve market segments that were challenged in the *High Electrification* scenario. Together, the pipeline infrastructure and electric systems decarbonize and achieve Climate Act emissions targets. Customers will maintain some choice in their energy supply and natural gas infrastructure will provide resilience. While natural gas use will be reduced, it will not be eliminated, due to the availability of dual-fuel heating options that combine heat pumps with gas-fired heating systems. Much of existing pipeline infrastructure can be used to transport RNG and hydrogen-enhanced natural gas (HENG), and some standalone hydrogen systems for industrial processes are implemented. System resiliency and reliability will be similar to the *Reference Case* scenario.

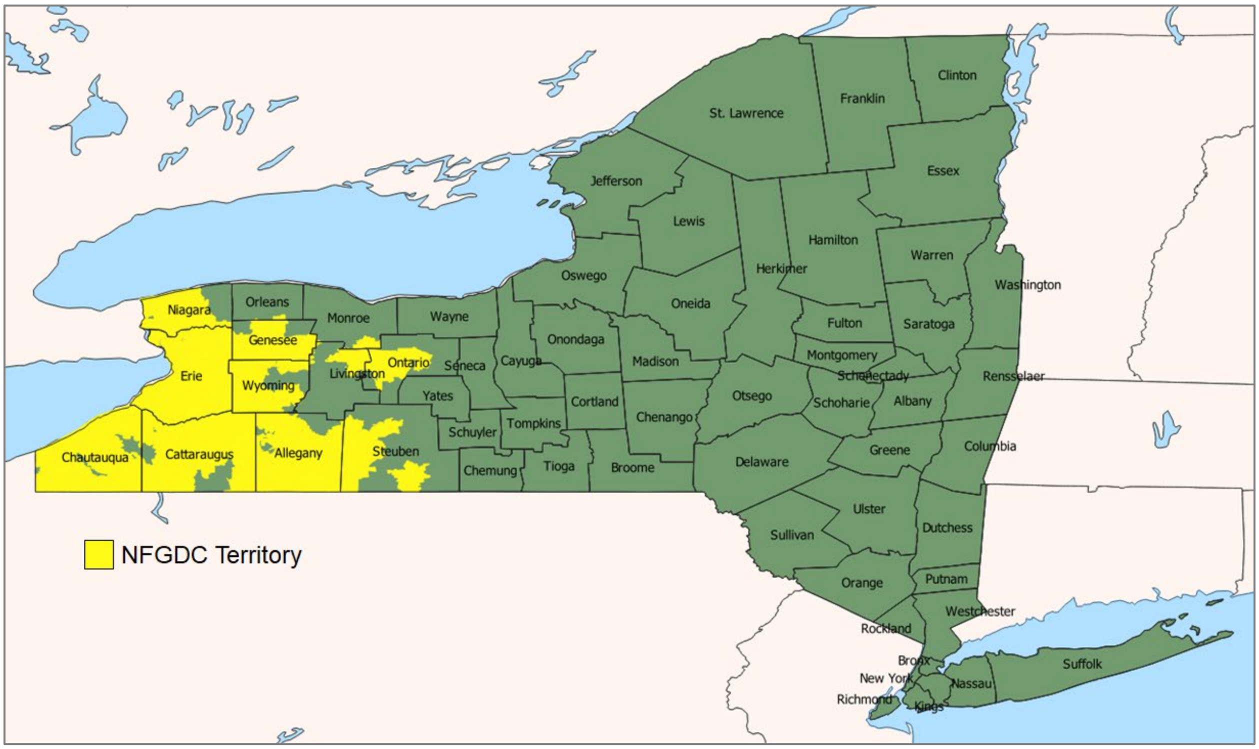
[19] US Energy Information Administration (2019). "Annual Energy Outlook 2019." Available at: https://www.eia.gov/outlooks/archive/aeo19/pdf/aeo2019.pdf

[20] Studies of decarbonization pathways often model high electrification scenarios as described here, but recent reports use different nomenclature for this scenario. Gas for Climate (2018) defines this as an "Electricity Only" scenario. E3 (2020) uses the term "Limited Non-Energy Pathway." The Brattle Group (2020) analyzed a comparable "ASHP Bookend Scenario."

2.3 Region Definitions

To account for regional differences in factors like power generation mix and fuel consumption, Guidehouse separately analyzed New York State as a whole and NFGDC's territory in New York. Figure 2-2 illustrates these regions. Appendix A describes our treatment of regional definitions in more detail.

Figure 2-2. New York State Regions Modeled



2.4 Scope of this Study

There are issues outside the scope of this analysis that will be critical to achieving mid-century GHG reduction requirements. Guidehouse recommends further analysis of the following issues:

- **Resilience:** Resilience is a set of energy system abilities that allows an energy system to prevent, withstand, adapt to, and quickly recover from damage or operational disruption.[21] Resiliency is distinct from reliability and is characterized by a response to high impact, low probability events such as extreme weather and cyberattacks. As the energy system moves toward mid-century with significant renewable and distributed generation, resiliency becomes ever more important. Further, energy system investments that enhance resilience will likely be required. In the *Selective Electrification* scenario, the pipeline infrastructure can be utilized to enhance future resilience requirements.

[21] American Gas Foundation (2021). "Building a Resilient Energy Future: How the Gas System Contributes to US Energy System Resilience" Available at: https://gasfoundation.org/2021/01/13/building-a-resilient-energy-future/

- **Reliability:** Reliability is the ability of the energy system to deliver services in the quantity and with the quality demanded by end users. Reliability differs from resiliency in that investments and maintenance are focused on low impact, high probability events, such as power surges and sudden changes in demand or supply. In every scenario, utilities with oversight by regulators will need to continue making capital and maintenance investments in certain assets to provide a reliable energy system. Our analysis modeled a future mix of electric generation and storage that meets reliability requirements, but we did not attempt to quantify system reliability or optimize our model around reliability.

- **Retirement of Infrastructure Assets:** The natural gas distribution industry has a positive safety track record. In the past, there has been strong policy and regulatory support for utilities to invest in safe and reliable infrastructure. As an example, in 2015 the New York Public Service Commission (NYPSC) issued an order instituting a proceeding for a recovery mechanism to Accelerate Replacement of Infrastructure on the Natural Gas System.[22] Utilities have made significant capital investments in these long-lived assets in support of this order. In the *High Electrification* scenario, these assets would primarily be retired long before the end of their useful life. The capital deployed by the utility companies and their respective stakeholders would need to be recovered. In this scenario, these stranded costs would be material and require amortization beyond those end users who remain on the system. Such stranded costs were not included in the current study's economic analysis. Policymakers need to recognize that a wide array of stakeholders would need to bear these costs.

- **Equity**: Without targeted incentives or rate relief programs focused on economically disadvantaged customers, it is likely that some customer groups will be unable to afford the upgrades to their homes and businesses that are required to meet GHG emissions targets. The Climate Act stresses the importance of avoiding burdens on disadvantaged communities. Section 7.3 of the Climate Act states:

  > *In considering and issuing permits, licenses, and other administrative approvals and decisions, including but not limited to the execution of grants, loans, and contracts, pursuant to article 75 of the environmental conservation law, all state agencies, offices, authorities, and divisions shall not disproportionately burden disadvantaged communities as identified pursuant to subdivision 5 of section 75-0101 of the environmental conservation law.*[23]

  Higher income customers have fewer, though still significant, barriers to electrify, while low income households are unable to electrify without substantial targeted incentives to help them overcome the additional costs of both installing and running their electric systems. However, these costs are not the only concern. As many customers electrify their homes and leave the gas grid, it is expected that gas rates and total energy costs will increase for those that remain. The issue of who pays and how costs are equitably managed across the system was not considered as part of this study.

[22] New York Public Service Commission. Case 15-G-0151. "Order Instituting Proceeding for Recovery Mechanism to Accelerate the Replacement of Leak Prone Pipe." Available at: http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={7A1320F6-3972-4F09-9CB6-ECB2F902F67B}

[23] New York State Senate (2019). "Senate Bill S6599." Available at: https://www.nysenate.gov/legislation/bills/2019/s6599

2.5 Decarbonization Opportunities

Each of the scenarios in our analysis includes a different combination of decarbonization technologies that could be deployed over the 2020-2050 analysis period. These range from upstream technologies associated with power generation and fuel supply (e.g., low carbon fuels, carbon capture, and renewable generation) to downstream technologies that are tied to specific end uses of energy (e.g., EVs, space and water heating, and energy efficiency). Table 2-1 describes each of the technologies considered in the LCP model. Appendix B discusses each of these technologies in more depth.

Table 2-1. Summary of Technologies Considered in the Low Carbon Pathways Model

Technology	Description
Renewable natural gas (RNG)	RNG is a gaseous fuel with lower carbon intensity and similar operational and performance characteristics to natural gas and can reduce GHG emissions in applications that currently use natural gas and other fossil fuels. The GHG reduction potential of RNG depends on the feedstock and production technology. We consider separate RNG production streams using anaerobic digestion and thermal gasification.
Hydrogen-enhanced natural gas (HENG)	Hydrogen can be produced through electrolysis using dedicated renewable electric generation or curtailed renewable electric generation systems (power-to-gas or green hydrogen) and through natural gas reformation with carbon capture (blue hydrogen). It can then be blended into existing natural gas pipelines to reduce GHG emissions.
Solar generation	Solar PV generation capacity will increase to meet the Climate Act's requirements and will displace natural gas-fired generation.
Wind generation	Wind generation capacity (onshore and offshore) will increase to meet the Climate Act's requirements and will displace natural gas-fired generation.
Post- and pre-combustion carbon capture power generation	Carbon capture technologies reduce the GHG emissions from natural gas, RNG, or hydrogen fuels by capturing CO_2 exhaust gas for sequestration, storage, or utilization.
Natural gas heavy duty vehicles	CNG- and liquefied natural gas-powered heavy duty vehicles are a mature technology that could be a cost-effective alternative to traditional diesel-powered vehicles.
Electric heavy duty vehicles	Different classes of passenger vehicles and trucks may be decarbonized by a transition from gasoline- and diesel-powered vehicles to EVs.
Electric medium duty vehicles	
Electric light duty vehicles	
Biofuel production for aviation	Conventional jet fuel can be displaced by biofuels to reduce the GHG impact of aviation fuels.
Industrial local green hydrogen	Hydrogen may be delivered to customers through dedicated distribution systems designed for 100% hydrogen gas, known as hydrogen clusters or districts.
Heating oil to electric heat pump conversions	Residential customers using fuel oil for heating may convert their heating systems to use electric heat pumps.
Transport efficiency	The energy efficiency of the transportation sector may be further improved beyond the federal vehicle fuel economy requirements that are currently in place.

Technology	Description
Industrial efficiency	The energy efficiency of the industrial sector may be improved by measures that target process efficiency.
The following technologies apply to both the Residential and Commercial sectors	
Heat pump water heaters (HPWHs)	HPWHs use electricity to transfer heat from ambient air to a stored water tank and are an energy efficient alternative to electric resistance water heaters and fuel-fired water heaters.
District water-loop heating and cooling	In a district energy system, a central plant or plants produce steam, hot water, or chilled water that is then pumped through a network of insulated pipes to provide space heating, cooling, or hot water for nearby connected customer buildings.
Air-source heat pumps (ASHPs)	ASHPs provide space heating and space cooling by using electricity to move heat from the outdoor space to the indoor space, and by using electric resistance heat during periods of low outdoor temperatures.
Geothermal heat pumps (GSHPs)	Similar to ASHPs, GSHPs use electricity to move heat in and out of a building's conditioned space. GSHPs exchange heat with the ground via a buried pipe loop and are more efficient than ASHPs.
Dual-fuel heating - furnace/boiler plus HP	A dual-fuel HVAC system pairs an electric ASHP with a high efficiency, gas-fired heating appliance and alternates between the two sources depending on ambient outdoor air conditions.
Building efficiency, non-insulation	High efficiency options are available for most residential and commercial building technologies, including water heating, lighting, kitchen and laundry appliances, and electronics.
Space conditioning efficiency, retrofit and new buildings	The efficiency of building envelope technologies (e.g., wall, floor, and ceiling insulation and windows) may be improved beyond current building code requirements.

Each of the technologies in Table 2-1 is limited in terms of how quickly it can be adopted and its maximum level of saturation. To develop a realistic forecast of a potential future state, our model limits the annual adoption rate and the maximum saturation of each technology. Guidehouse analyzed market trends, forecasts, and pilot-level program data to estimate the costs, typical adoption rates, and saturation limits associated with each technology. For example, the adoption rate of EVs is limited by the natural turnover rate of vehicle stock. As another example, the total saturation of HENG is limited to the proportion of pipeline natural gas that can be safely displaced by hydrogen. Table 2-2 summarizes the limitations we set for each technology in each of the modeled scenarios. Appendix B details the analysis and assumptions that inform these limits.

As Section 2.1 describes, our LCP model uses an optimization function to deploy technologies in order of cost-effectiveness. In practice, the model deploys the most cost-effective technologies first, up to the individual technology's saturation limit. The model then selects and deploys less cost-effective technologies until the economywide decarbonization target is met. Some amount of technology adoption is included in the *Reference Case* scenario, and the limits in Table 2-2 describe incremental activity beyond the reference case assumptions. For example, the *Reference Case* assumes a steady increase in transportation and building sector efficiency due to federal vehicle fuel economy standards, appliance efficiency standards, and building codes. The efficiency measures in Table 2-2 describe efficiency improvements beyond the reference case that may be spurred by more aggressive efficiency programs.

Table 2-2. Summary of Technologies Specified in the Low Carbon Pathways Model

	Technology	Unit Basis	Max Annual Saturation Increase HE*	Max Annual Saturation Increase SE*	Maximum Saturation Allowed in Model HE*	Maximum Saturation Allowed in Model SE*
	RNG - anaerobic digestion	Billion Btu per year	N/A	4,200	N/A	95,000
	RNG - thermal gasification	Billion Btu per year	N/A	7,700	N/A	153,800
	HENG	H_2 as a % of natural gas supply, by energy	N/A	1.0%	N/A	4.9%
	Solar generation	% of electric supply, except nuclear and hydro	5.5%		41.0%	
	Wind generation	% of electric supply, except nuclear and hydro	4.0%		45.0%	
	Post- and pre-combustion capture power generation	% of fossil electric generation	7.5%		100.0%	
	Natural gas heavy duty vehicles	% of heavy duty (diesel) load switched	N/A	6.3%	N/A	30%
	Electric heavy duty vehicles	% of heavy duty (diesel) load switched	6.3%		100%	70%
	Electric medium duty vehicles	% of medium duty (diesel) load switched	5.0%		100.0%	
	Electric light duty vehicles	% of gasoline load switched	4.5%		100.0%	
	Biofuel production for aviation	% of jet fuel switched	3.5%		100.0%	
	Industrial local green hydrogen	% of industrial load switched	N/A	5.0%	N/A	75.0%
Residential	Heat pump water heaters	% of carbon load switched	5.0%		100.0%	
Residential	Heating oil-to-heat pump	% of fuel oil load switched	3.0%	3.0%	100.0%	100.0%
Residential	Air-source heat pumps	% of carbon load switched	5.0%		99%	70%
Residential	Geothermal heat pumps	% of carbon load switched	1.0%		30%	
Residential	Dual-fuel heating - furnace/boiler plus HP	% of carbon load switched	N/A	3.5%	N/A	70%
Commercial	Heat pump water heaters	% of carbon load switched	5.0%		100.0%	
Commercial	District heating and cooling	% of carbon load switched	1.0%		10%	
Commercial	Air-source heat pumps	% of carbon load switched	5.0%		98%	70%
Commercial	Geothermal heat pumps	% of carbon load switched	1.0%		30%	
Commercial	Dual-fuel heating - furnace/boiler plus HP	% of carbon load switched	N/A	3.5%	N/A	70%
	Transport efficiency	Entire sector consumption	0.8%		10.0%	
	Industrial efficiency	Entire sector consumption	1.0%		10.0%	
	Residential building efficiency, non-insulation	Entire sector consumption (except space conditioning)	1.0%		10.0%	
	Commercial building efficiency, non-insulation	Entire sector consumption (except space conditioning)	1.0%		10.0%	
	Residential space conditioning efficiency, retrofit	Entire sector space conditioning load	1.0%		10.0%	
	Residential space conditioning efficiency, new buildings	Entire sector space conditioning load	1.0%		10.0%	
	Commercial space conditioning efficiency, retrofit	Entire sector space conditioning load	1.0%		10.0%	
	Commercial space conditioning efficiency, new buildings	Entire sector space conditioning load	1.0%		10.0%	

* Note: HE stands for *High Electrification* scenario, and SE stands for *Selective Electrification* scenario.

2.6 Investment Requirements

Guidehouse estimated the total investment CAPEX associated with technology deployment in each of the scenarios. For end-use technologies, we calculated the incremental installed costs as the cost of a new unit of that technology minus the cost of a new unit of the baseline technology. For example, the incremental cost of a whole-home heat pump is calculated relative to the cost of a natural gas heating and electric A/C system that customers would install in the absence of electrification programs. Our analysis accounts for the fact that whole-building cold climate ASHPs are substantially more expensive than conventional heat pumps that could be used in a dual fuel heating system.

For upstream technologies, we calculated absolute costs of retrofit technologies. For example, the cost of installing CCS technology is estimated relative to a zero-cost baseline where CCS is not installed. Guidehouse developed a time series of costs for each technology based on expected innovation. Our analysis of investment requirements does not include costs associated with retiring existing infrastructure.

3. Results

The following subsections describe the effects that the technologies discussed in Section 2.5 will have on overall GHG reductions and energy use.

3.1 GHG Emissions Reductions

With high technology adoption, both the High Electrification and Selective Electrification scenarios can achieve the Climate Act's emissions reduction requirements.

The Climate Act's emissions reduction requirement can be achieved in the *High Electrification* and *Selective Electrification* scenarios. In both cases, high adoption of GHG mitigation technologies will be necessary to achieve the target.

Figure 3-1 compares the GHG emissions by sector for each scenario in NFGDC's New York territory. The GHG reductions are based on an 85% reduction in emissions relative to 1990 levels. Both scenarios meet the Climate Act's requirement of 40% GHG reductions from 1990 to 2030. In both scenarios, the power sector is a major driver of decarbonization, since the Climate Act requires eliminating power sector emissions by 2040. The *Selective Electrification* scenario shows lower GHG contribution from the industrial sector, since it allows adoption of industrial green hydrogen.

Figure 3-1. Emissions in Each Scenario as a Function of Time, National Fuel Territory

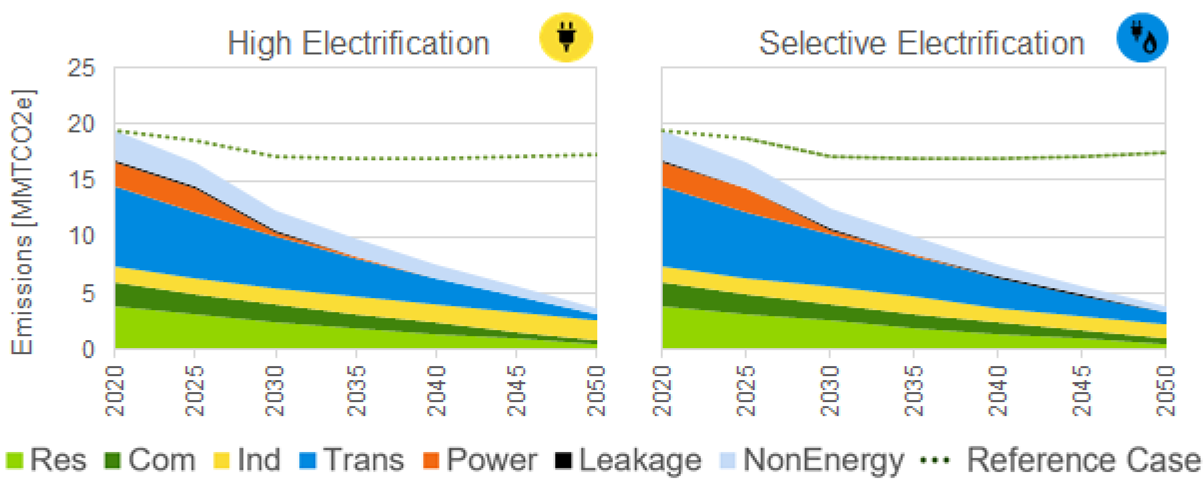


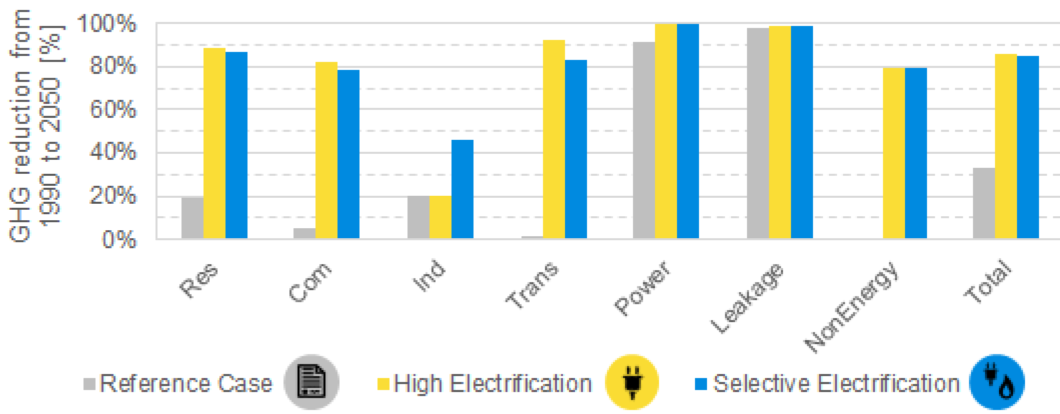
Figure 3-2 shows the proportional emissions reduction from 1990 to 2050 from different sectors in National Fuel's New York territory. The *Reference Case* shows high GHG reduction in the power sector due to New York's Clean Energy Standard and in the leakage category due to ongoing replacement of aging pipelines.[24] Compared to the *Selective Electrification* scenario, the *High Electrification* scenario shows significantly smaller emissions reductions in the industrial sector and larger emissions reductions in the non-industry sectors (Res, Com, Trans).[25] This is because the *High Electrification* scenario does not allow for the development of

[24] The Leakage category of GHG emissions shows greater emissions reduction in the *Selective Electrification* and *Customer Choice* scenarios due to the displacement of some pipeline natural gas with HENG.

[25] For the industrial sector, the *Selective Electrification* scenario shows higher GHG reductions than the *High Electrification* scenario, because the *Selective Electrification* scenario includes the industrial green hydrogen technology.

low carbon fuel infrastructure that will enable heavy industry to decarbonize. This finding points to a concern around the equitable distribution of the burden of decarbonization within the *High Electrification* scenario. Because the scenario does not provide a pathway for the decarbonization of the industrial sector, residential and commercial customers will bear a greater burden of decarbonization.

Figure 3-2. Emissions Reduction from 1990 to 2050, by Sector, NFGDC Territory



3.2 Energy Consumption

If NFGDC's territory is to decarbonize by mid-century, electricity consumption will increase, and pipeline natural gas consumption will decrease. In the *High Electrification* and *Selective Electrification* scenarios, we project that nearly all commercial customers and over 85% of residential customers will either partially or fully switch from fuel-fired heating to electric heat sources. The *High Electrification* scenario assumes that customers who electrify their heat will do so by installing whole-building heat pumps, while the *Selective Electrification* scenario allows for a high degree of hybrid dual-fuel heating systems (see Section 2.5).

In both scenarios, the steady electrification of heating will not increase residential and commercial electricity consumption as drastically as might be expected due to three factors:

1. Building improvements will increase shell efficiency and reduce heating and cooling loads over time
2. Some electric heat pump systems will replace less efficient electric resistance heating systems in use today[26]
3. Other electric end uses such as lighting, appliances, and space cooling will become more efficient over time due to increased efficiency standards and building codes

Section 3.4 provides more detail on our findings related to building energy consumption.

[26] In 2015, 10.6% of occupied households in New York used electricity as their primary heat source. Source: NYSERDA (2017). "Patterns and Trends New York State Energy Profiles: 2001–2015 Final Report", Appendix D-1. Available at: https://www.nyserda.ny.gov/-/media/Files/Publications/Energy-Analysis/2001-2015-patterns-and-trends.pdf

In 2015, 10.5% of homes in the Northeast U.S. used low efficiency electric resistance heating equipment as their primary heat source. Source: U.S. Energy Information Administration (2018). "Residential Energy Consumption Survey, Table HC6.7" Available at: https://www.eia.gov/consumption/residential/data/2015/#sh

Figure 3-3. Annual Electricity and Pipeline Gas Consumption, by Sector, NFGDC Territory

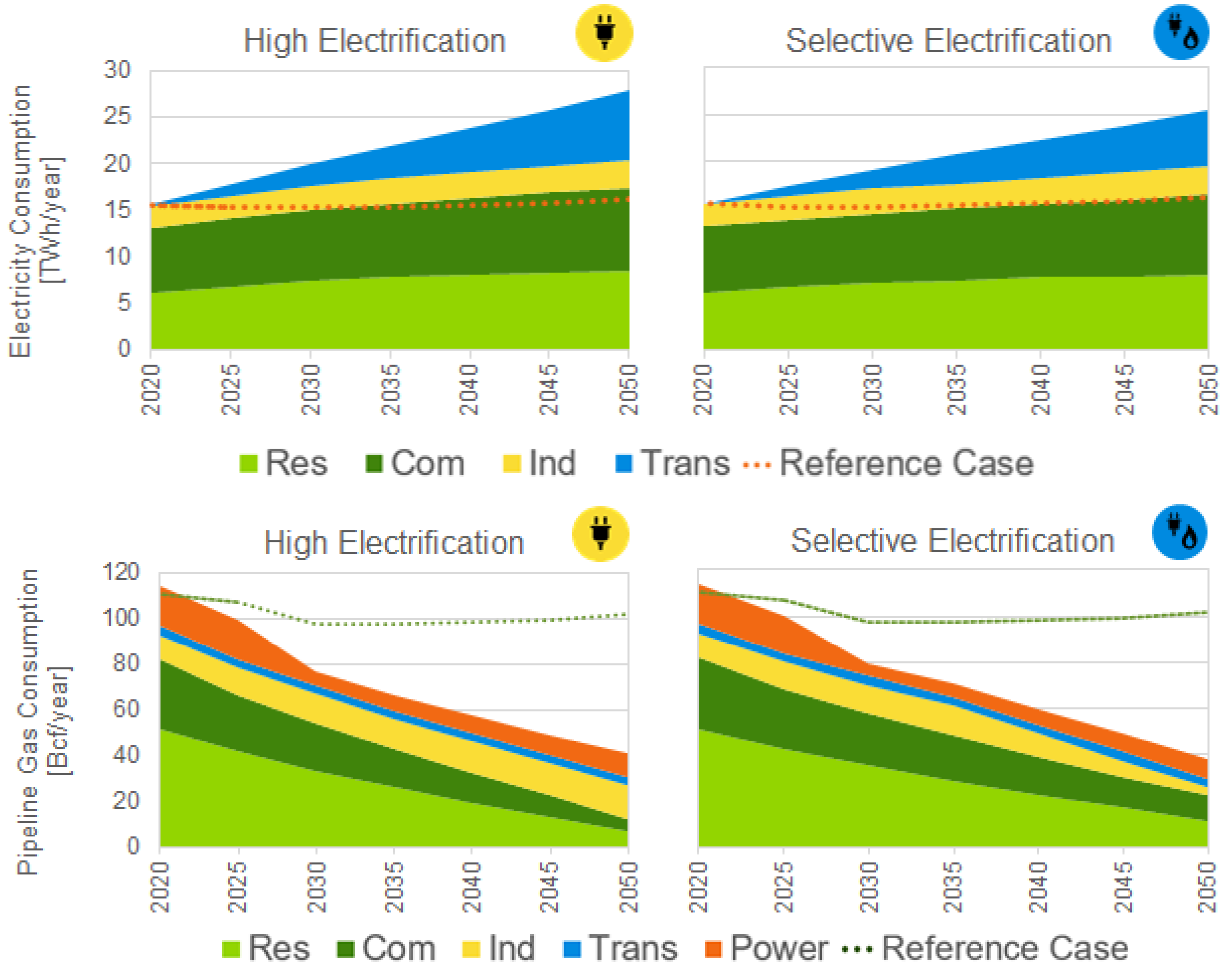


Figure 3-3 shows electricity and pipeline natural gas (including fossil gas, RNG, and HENG) consumption in NFGDC's New York territory by sector over time for each scenario. Both scenarios show increased electricity consumption in the transportation sector, driven by the introduction of light, medium, and heavy duty EVs. Electricity consumption would be greatest in the *High Electrification* scenario, while the *Selective Electrification* scenario shows more moderate growth in electric consumption over time due to its use of low carbon gaseous fuels (RNG and HENG).

The Climate Act's power sector requirements drive a reduction in power sector gas consumption from 2020 to 2030. To meet the Climate Act's renewable generation requirement, the power sector must rapidly displace natural gas-fired generation with generation from renewable sources. The residential and commercial sectors also see reduced pipeline gas consumption due to increased adoption of electric heat pumps. Energy efficiency measures reduce the overall energy needs of each sector and contribute to the downward trend in pipeline gas consumption.

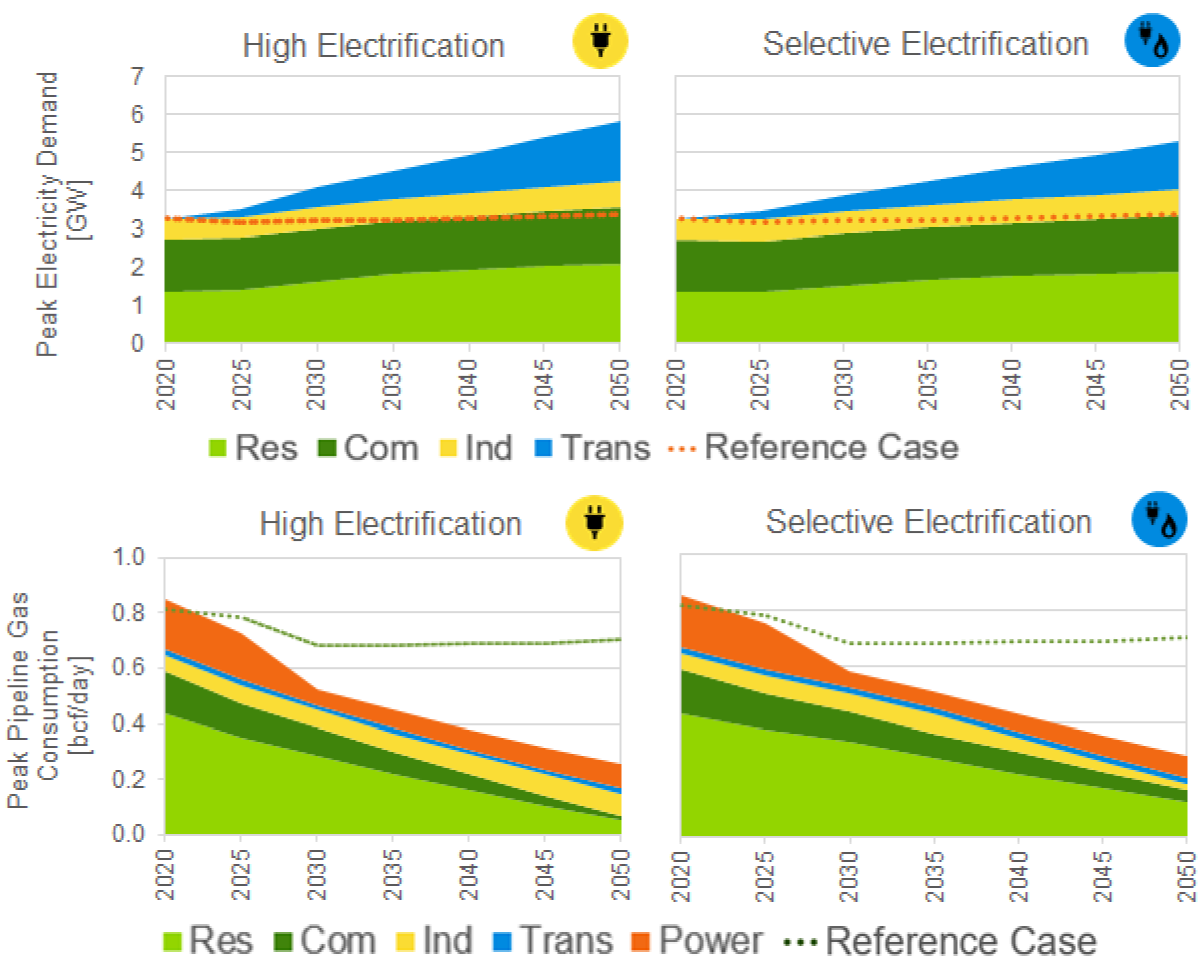
The *High Electrification* scenario shows little reduction in industrial pipeline gas consumption, while the *Selective Electrification* scenario creates a greater reduction in pipeline gas consumption because it permits the offset of industrial natural gas use with industrial local green hydrogen (a technology that is excluded from the *High Electrification* scenario).

3.3 Energy Demand

Figure 3-4 shows the peak electric demand and peak pipeline gas consumption by scenario and sector, respectively, in NFGDC's New York territory. The *High Electrification* scenario shows peak demand in National Fuel's territory increasing 2.6 GW by 2050, compared to 2.0 GW of peak demand increase for the *Selective Electrification* scenario.[27] Those scenarios show a similar decrease in peak pipeline gas consumption, but with different allocation across sectors in 2050. The *Selective Electrification* scenario shows higher gas consumption in the residential and commercial sectors and lower gas demand in the industrial sector because the *Selective Electrification* scenario includes the industrial green hydrogen technology and assumes that 50% of pipeline gas is composed of non-fossil fuels such as RNG and HENG.

The High Electrification scenario shows a statewide electric peak demand increase of 75% in 2050 relative to 2020, compared to a 60% increase in the Selective Electrification scenario.

Figure 3-4. Forecast of Peak Electric and Pipeline Gas Demand, by Scenario and Sector



[27] At a statewide level, the *High Electrification* scenario shows peak demand increasing 23.2 GW by 2050, compared to 18.9 GW of peak demand increase for the *Selective Electrification* scenario

3.4 Residential and Commercial Buildings

Figure 3-5 and Figure 3-6 show changes in residential and commercial space heating consumption over time for each scenario in NFGDC's New York territory. Energy efficiency (from the building shell improvements and the inherent efficiency advantages of heat pumps) is a key driver for reducing energy consumption and GHG emissions in all scenarios. The *High Electrification* scenario relies more heavily on electric technologies, while *Selective Electrification* uses RNG, hydrogen, and dual-fuel heating to reduce GHG emissions. Both scenarios show efficiency gains from converting fuel-fired heating to electric heat pumps. These efficiency gains are slightly higher in the *High Electrification* scenario because it assumes a higher proportion of customers fully electrify their space heating needs.

Figure 3-5. Residential Space Heating Consumption, by Scenario and Fuel Type

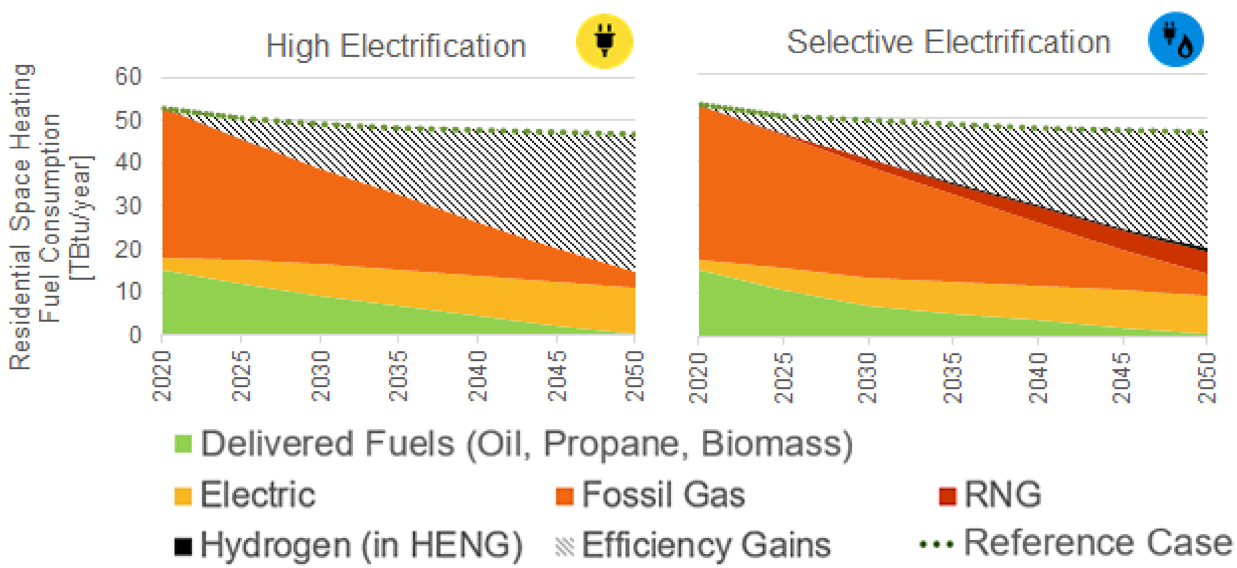


Figure 3-6. Commercial Sector Space Heating Consumption, by Scenario and Fuel Type

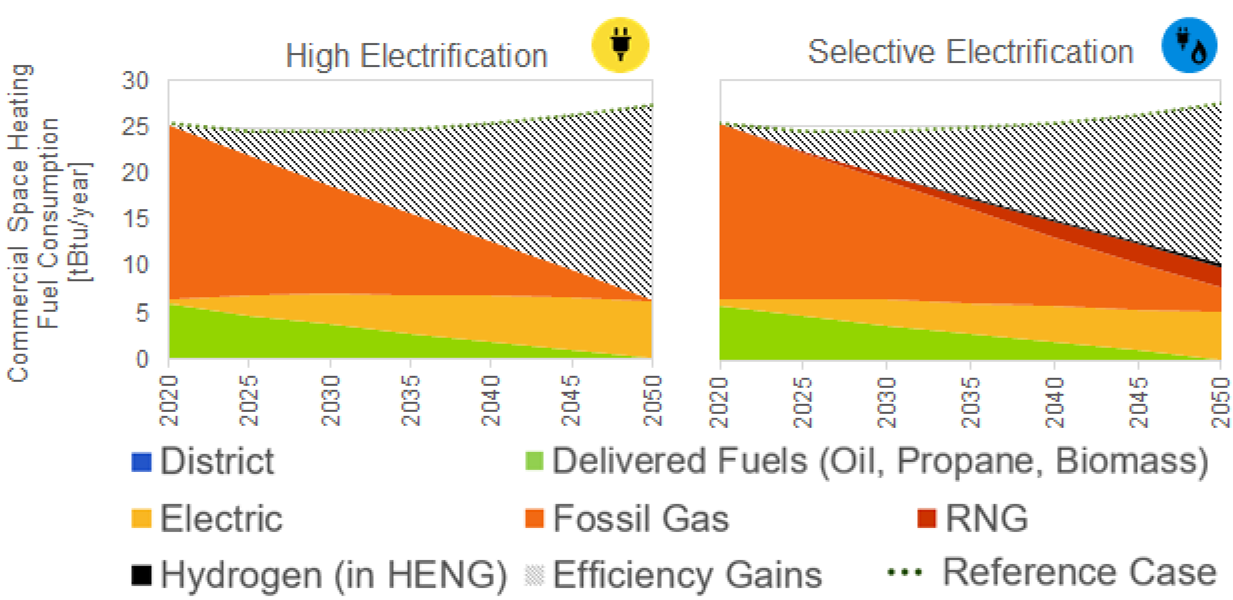
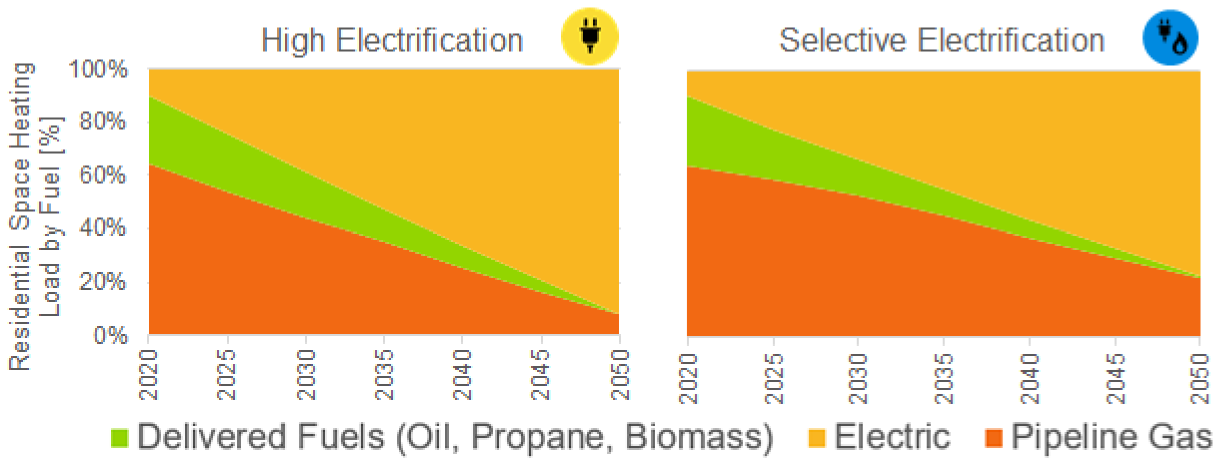


Figure 3-7 shows how the proportion of statewide residential space heating load met by each fuel type would evolve over time in both scenarios. The *High Electrification* sees a greater increase in electric space heating. The *Selective Electrification* scenario allows for a greater proportion of heating from low carbon pipeline gas, made up of a mixture of RNG, hydrogen, and fossil natural gas. Both scenarios show a gradual elimination of propane and fuel oil.

Figure 3-7. Residential Space Heating Load Met by Each Fuel Type



Guidehouse also modeled the impacts that interventions in the *Selective Electrification* scenario would have on a typical single family household in NFGDC's New York territory. Figure 3-8 shows how different residential end uses contribute to household energy consumption and associated GHG emissions in 2015 (prior to intervention) and in 2050 (after intervention). In 2015, the typical single family household consumes natural gas for space heating and water heating.[28] In the *Selective Electrification* scenario, we assume that by 2050, the typical household takes steps to improve building shell and appliance efficiency and switches to electric water heating and dual-fuel space heating.

In NFGDC's territory, an individual household's GHG footprint will be further reduced by decarbonization measures implemented upstream. Renewable power generation and CCS will reduce emissions from customers' electric consumption and in the *Selective Electrification* scenario, RNG and HENG will reduce emissions from customers' pipeline gas consumption. For this illustration, we estimate GHG emissions per household as product of energy use and emissions factors.[29] As Figure 3-8 illustrates, interventions in the *Selective Electrification* scenario can more than halve a typical household's energy consumption and reduce household GHG emissions by greater than 90%. We found that similar reductions are possible for typical homes in New York State, as described in Appendix C.3.

[28] Annual energy use in 2015 from NYSERDA (2019) Patterns and Trends, New York Energy Profiles: 2002–2016, Appendix B, representing single-family homes in New York State. Available at: https://www.eia.gov/consumption/residential/data/2015/

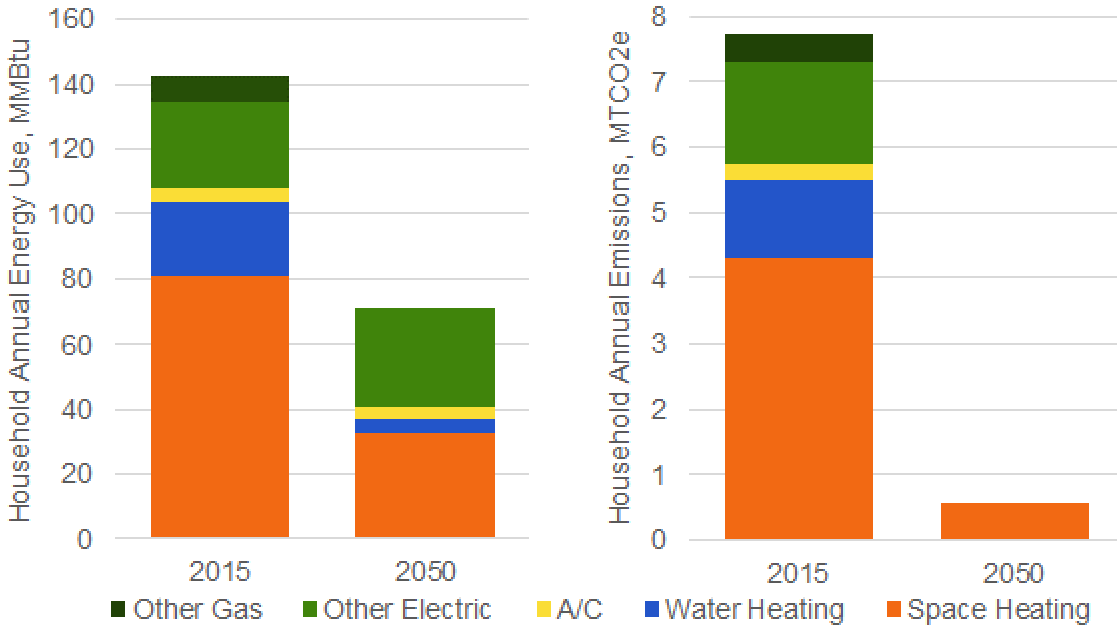
[29] Natural gas consumption has emissions factor of 53.1 kg CO_2 per MMBtu, from U.S. EPA.

U.S. Environmental Protection Agency (2014). "Emission Factors for Greenhouse Gas Inventories." Available at: https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf

Electric consumption in 2020 has emissions factor of 58.7 kg CO_2 per MMBtu, from NYISO. Electric consumption in 2050 has zero emissions due to interventions that decarbonize the electric generation sector.

NY ISO. "2018 Power Trends." Figure 23 shows 0.20 tons CO_2 per net MWh, equivalent to 58.7 kg CO_2 per MMBtu. Available at: https://www.nyiso.com/documents/20142/2223020/2018-Power-Trends.pdf/4cd3a2a6-838a-bb54-f631-8982a7bdfa7a

Figure 3-8. Reduction in Energy Use and GHG Emissions from Selective Electrification
Example: Single-family home, NFGDC territory, switching from natural gas to dual-fuel heat

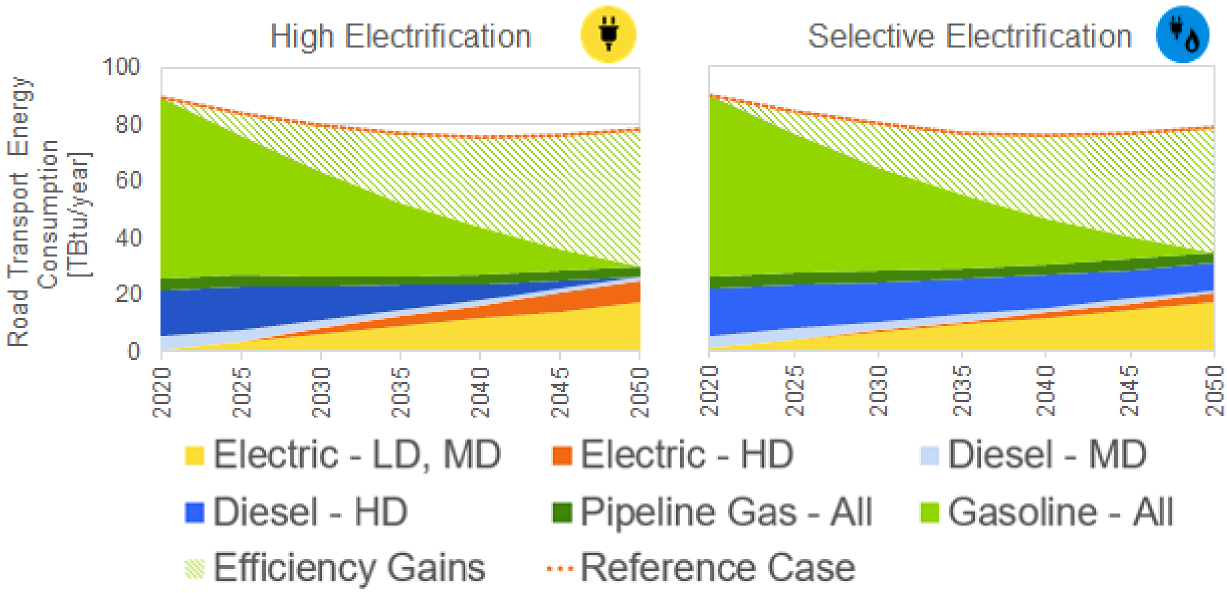


Intervention	Energy Savings	Emissions Reduction
Building Shell Efficiency	15%	14%
Heat Electrification & Dual Fuel Systems	30%	30%
Appliance Efficiency	5%	4%
Renewable Elec. Generation	n/a	27%
Carbon Capture & Storage	n/a	10%
Low-Carbon Fuels (RNG, Hydrogen)	n/a	7%
Total	**50%**	**93%**

3.5 Transportation Sector

Figure 3-9 shows the forecast vehicle energy consumption in NFGDC's New York territory for each scenario and vehicle type, and the energy consumption reduction deriving from efficiency improvements. Efficiency is a key driver of emission reductions in the transportation sector for all scenarios, and the improvement comes from two sources: general improvements in transportation efficiency and the inherent efficiency gains in switching from internal combustion engines to electric motors.

Figure 3-9. Forecast of Vehicle Energy Consumption, by Scenario and Vehicle Type



3.6 Power Sector

> *Natural gas-fired generation will decrease over time but will not be eliminated; it serves an essential role in addressing reliability challenges associated with intermittent renewable resources.*

The Climate Act's requirements will force major changes in the power sector. Electrification of customers' end use consumption will increase electric demand and annual electric generation. The Climate Act also requires 70% of electric generation to come from renewables by 2030 and that electric generation be 100% zero emissions by 2040. We modeled scenarios to comply with the Climate Act's interim requirements for the power sector; the act requires 6,000 MW of solar capacity by 2025 and 9,000 MW of offshore wind capacity by 2035. Guidehouse's LCP model also accounts for the Climate Act requirement that 3,000 MW of energy storage capacity be installed by 2030.[30]

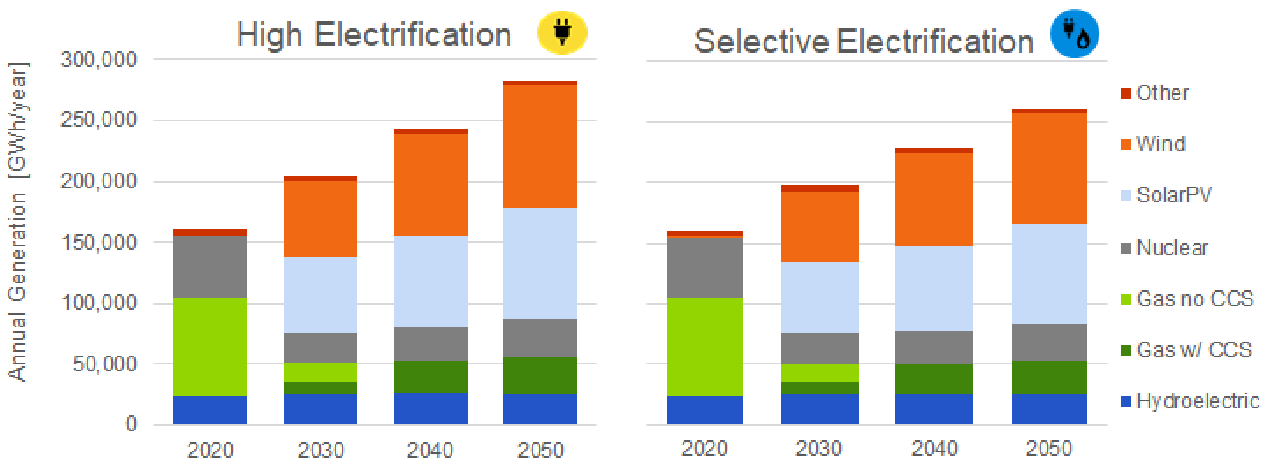
For all scenarios, we expect new solar and wind capacity to increase from 2020 to 2030 to replace retired nuclear generators and some gas-fired generators. Natural gas-fired generation will be reduced over time but not eliminated; it serves an essential role in addressing reliability challenges associated with intermittent renewable resources. To achieve the requirement of carbon-free generation by 2040, we anticipate that gas-fired generators will begin deploying CCS technology in 2030 and that CCS deployment will steadily increase until all gas-fired generators use CCS in 2040. New York has many options for carbon capture within the state

[30] Assuming linear adoption of wind, solar and energy storage capacities, the Climate Act implies the need for energy storage capacity equivalent to one-sixth of the total wind and solar (i.e., intermittent renewable) capacity. We assume that for every 6 MW of intermittent renewables installed, 1 MW of energy storage must be available. We assume that this is a necessary requirement for all levels of adoption of intermittent renewables and our LCP model includes energy storage costs as part of the cost to install intermittent renewables. The cost of storage is assumed to be the cost of utility-scale Li-ion batteries according to Guidehouse Insights forecasts (Market Data: Energy Storage Pricing Trends, Guidehouse Insights, 2Q 2020).

and surrounding areas, including oil and natural gas reservoirs, un-mineable coal seams, saline formations, offshore sandstone formations, shale basins, and basalt-rich areas. In all scenarios, our analysis accounts for the expected retirement of two Indian Point nuclear generators before 2025.

Figure 3-10 illustrates the amount of electricity generated from different energy sources for each scenario. The amount of electric generation exceeds the amount of electric consumption reported in Figure 3-3 due to transmission and distribution losses, which are assumed to be 8% of supplied electricity. In all scenarios, other fuels (coal, oil, biomass, and hydrogen) make up less than 3% of total generation throughout the 2020-2050 study period.

Figure 3-10. New York State Annual Electric Generation, by Energy Source and Scenario



3.7 Industrial Sector

The EIA's *AEO 2019* Reference Case projects that industrial energy consumption will increase 31% between 2018 and 2050, driven by economic growth and affected by low prices and resource availability.[31] This growth in energy consumption accounts for improvements in energy efficiency that are projected to reduce the energy intensity of most industrial activities by about 10%.[32]

Guidehouse found that hydrogen can play a key role in offsetting natural gas emissions in the industrial sector. The difference is material.

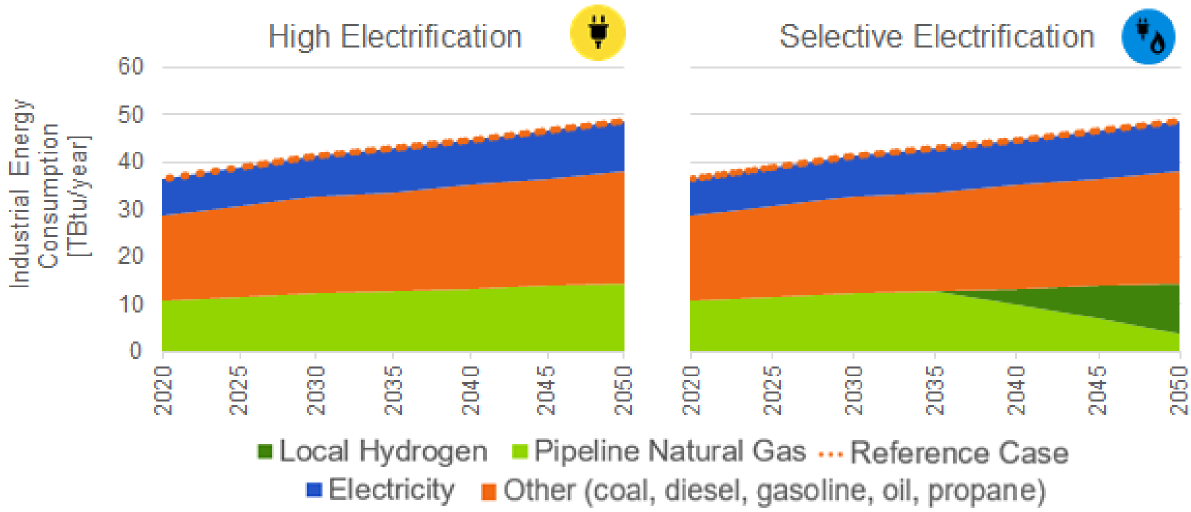
Guidehouse's LCP model includes three technologies that can affect industrial emissions: additional industrial energy efficiency beyond the reference case assumptions, RNG, and local green hydrogen as a natural gas replacement. Guidehouse found that hydrogen can play a key role in offsetting natural gas emissions in the industrial sector. The difference is material; in Figure 3-2 (page 25), the *Selective Electrification* scenario shows greater reductions in industry emissions than the *High Electrification* scenario that excludes it.

[31] US Energy Information Administration (2019). "Annual Energy Outlook 2019." Slides 149-153. Available at: https://www.eia.gov/outlooks/archive/aeo19/pdf/aeo2019.pdf

[32] *Ibid.* slides 153-154.

Figure 3-11 shows the industrial energy use by fuel and scenario. In the *Selective Electrification* scenario, pipeline gas includes RNG and HENG, as Appendix C describes. Our analysis assumed that hydrogen displaces industrial natural gas use but does not impact consumption of other fuels (e.g., diesel, coal, gasoline).[33] Further decarbonization of the industrial sector would likely require additional technologies that can replace other fuels or prevent emissions that stem from the use of those fuels.

Figure 3-11. Industrial Energy Use, by Fuel and Scenario, National Fuel Territory[34]



3.8 Non-Combustion GHGs

In addition to the emissions associated with fuel use, Guidehouse's LCP model also tracks emissions from natural gas leakage and from non-energy sources such as refrigerant leakage (globally referred to as non-combustion GHGs). The model treats these streams as follows:

1. Leakage emissions are calculated based on the makeup of the gas pipelines. The model accounts for planned pipeline replacements and replacements required for the use of HENG (in the *Selective Electrification* scenario where it is included). As Figure 3-1 and Figure 3-2 show, leakage is a small part of the state's total emissions. In all scenarios, we assume that pipeline replacement programs and system upgrades lead to a 90% reduction in natural gas leakage in 2050 relative to 1990 levels.
2. Non-energy emissions do not pertain to the energy system and so are considered out of scope for this study. For example, New York has committed to regulatory action to phase out the use of hydrofluorocarbon refrigerants, a major contributor to non-energy emissions. We assume that new programs and initiatives will reduce non-energy emissions to meet the same target imposed for the entire economy. That is, we assume that non-energy emissions decrease by 85% in both scenarios.

[33] The aggregate energy consumption data referenced in this analysis does not specify how "other" fuels are being used in the industrial sector. We assume these fuels are used in a variety of process-specific equipment and/or high-temperature applications, and that the electrification of these end uses would be less cost-effective than the other decarbonization options considered in this analysis. Based on this assumption, our analysis does not consider the electrification of "other" fuel use in the industrial sector.

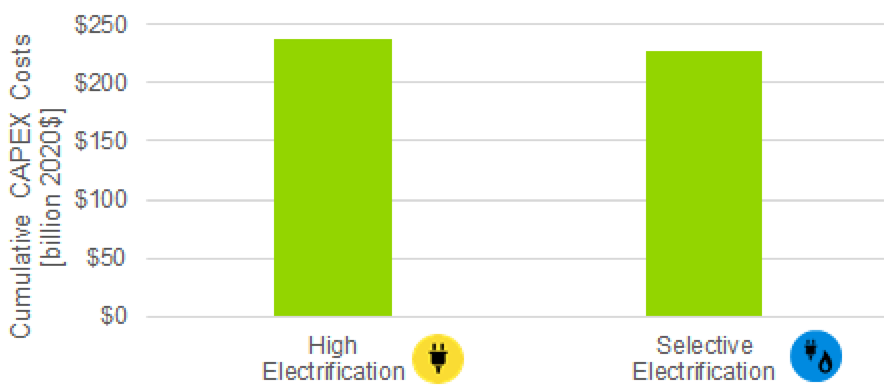
[34] Electricity emissions are counted in the power sector, but electricity consumption is assigned to each sector as exemplified in this figure.

3.9 Costs by Scenario

Figure 3-12 shows the cumulative statewide costs of each scenario from 2020 to 2050, reported in nominal 2020 dollars. All costs are incremental relative to the *Reference Case* scenario. The *High Electrification* and *Selective Electrification* scenarios are likely to require similar CAPEX over the analyzed period. However, *Selective Electrification* offers more technology options and a more diversified energy system so it preserves options to provide a more resilient system in the future; such details may impact costs in ways that are not captured by the CAPEX metric provided in Figure 3-12. Utilizing the existing pipeline infrastructure will allow stakeholders to continue to benefit from the reliability that gas utility systems provide. Additionally, the inherent characteristics of pipeline infrastructure and storage which is mostly underground support a resilient energy system.

The Selective Electrification *scenario offers more technology options and a more diversified energy system, so it preserves options to provide a more resilient system in the future.*

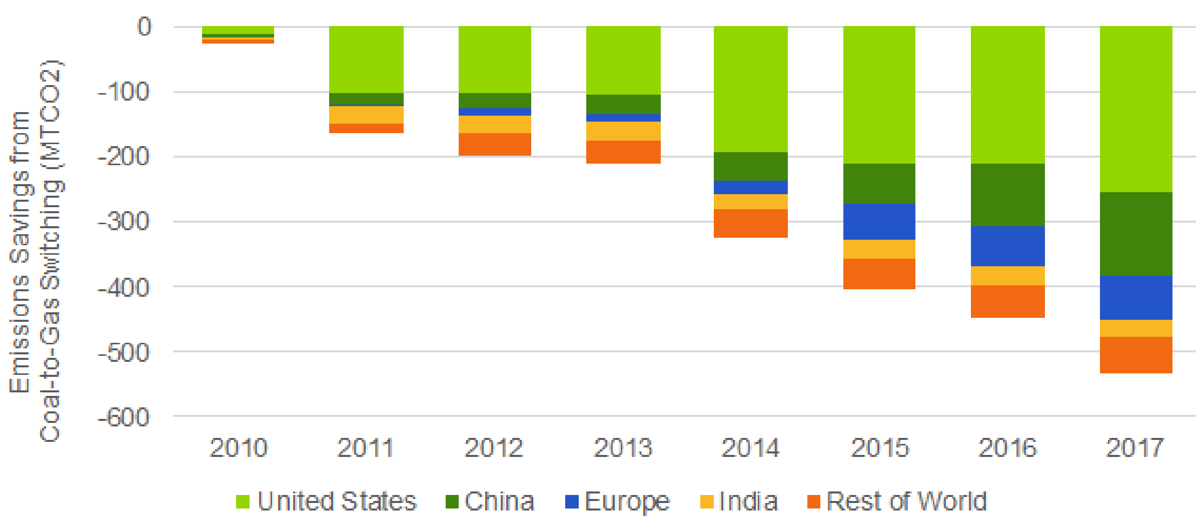
Figure 3-12. Cumulative Statewide CAPEX, Incremental to Reference Case



4. Conclusions

Many stakeholders see the natural gas system as a transitional state along the decarbonization pathway—one that has already contributed to GHG emissions reductions and whose future role will be to reduce reliance on coal-fired electric power generation, the most carbon-intensive source of electricity generation. As of 2018, the transition from coal to natural gas has resulted in a reduction of over 500 $MTCO_2$ globally and over 255 $MTCO_2$ in the US as compared to a 2010 baseline (Figure 4-1). Further CO_2 savings will result when natural gas use is reduced by renewable fuels and electricity.

Figure 4-1. CO_2 Savings from Coal-to-Gas Switching in Selected Regions, 2010-2018[35]



New York has already benefited from the use of natural gas as a lower carbon energy source, resulting in one of the most energy efficient economies in the nation. As of 2017, "New Yorkers use less energy per capita than the residents of any other state except Rhode Island."[36] However, as the state moves toward the Climate Act's mid-century decarbonization targets, additional emissions reductions will be necessary. This study shows there are viable pathways to achieving the Climate Act targets and New York's gas system can play a significant role in decarbonizing New York's energy system.

4.1 Study Results

To demonstrate the different pathways to decarbonization, Guidehouse explored two scenarios that achieve the Climate Act target of 85% decarbonization by 2050. A *High Electrification* scenario would nearly eliminate natural gas use in buildings, while a *Selective Electrification* scenario would substantially reduce natural gas use in buildings and modify the natural gas

[35] International Energy Agency (2019). "The Role of Gas in Today's Energy Transitions." Available at: https://www.iea.org/data-and-statistics/charts/co2-savings-from-coal-to-gas-switching-in-selected-regions-compared-with-2010-2018

[36] US Energy Information Administration, State Profile and Energy Estimates, New York: https://www.eia.gov/state/analysis.php?sid=NY#11

economy to include low carbon fuels such as RNG and HENG.[37] Our analysis led to the following key findings.

#1 Achieving the Climate Act's targets requires accelerating the advancement of efficiencies related to transportation, buildings, and appliances.

Decarbonization of the transportation sector is critical to achieving the Climate Act's emissions reduction targets. Emissions from transportation increased 25% from 1990 to 2016, and the transportation sector currently produces over one-third of New York State's GHG emissions.[38] Energy efficiency (from building shell improvements and high efficiency heat pumps and appliances) is another critical element for reducing GHG emissions. The *Reference Case* scenario assumes significant gains in energy efficiency[39] due to updated building codes, appliance standards, and utility energy efficiency rebates. Additionally, automobile fuel economy standards increase in the *Reference Case*. The *High Electrification* and *Selective Electrification* scenarios each assume that further efficiency improvements reduce building envelope and appliance energy consumption by an additional 10% due to improvements in building codes and standards. Further, switching gasoline to electric vehicles, coupled with 10% more efficiency from additional technology improvements results in energy intensity reductions in the residential (32% overall), commercial (23% overall), and transportation (42% overall) sectors.[40]

#2 The *Selective Electrification* scenario demonstrates the critical importance of including all options in developing an effective decarbonization pathway

The *Selective Electrification* scenario accomplishes the Climate Act's GHG emissions reductions targets using a variety of technologies, with each providing significant GHG reductions. For typical *residential* customer energy use, GHG emissions were reduced through building envelope and appliance energy efficiency measures, and through the use of high efficiency heat pumps (whether whole-home or dual-fuel). An individual customer's GHG footprint will be further reduced by decarbonization measures implemented upstream of the customer. Renewable power generation will reduce the emissions from customers' electric consumption, and RNG and HENG will reduce the emissions from customers' pipeline gas consumption. The dual-fuel heating option available in the *Selective Electrification* scenario

[37] By exploring the scenarios included in this study, we identified various pathways to a decarbonized future. There are many ways to achieve these goals, and we do not forecast that these specific scenarios are the only viable means to achieve the Climate Act's requirements. However, scenario modeling helps identify challenges associated with the current state and opportunities to develop policies and regulatory structures that will enable the execution of the legislation. The study's conclusions are specific to New York and should not be extrapolated to other regions. In particular, regions with milder climates than New York or regions with different gas and electric rates might reach different conclusions.

[38] The New York State Energy Research and Development Authority (2019). "New York State Greenhouse Gas Inventory 1990-2016." Available at: https://www.nyserda.ny.gov/-/media/Files/EDPPP/Energy-Prices/Energy-Statistics/greenhouse-gas-inventory.pdf

[39] The *Reference Case* scenario is based on the EIA's *Annual Energy Outlook 2019*, which projects that from 2018 to 2050, increases in energy efficiency will cause energy intensity to decline by 22% in the residential sector, 13% in the commercial sector, and 32% in the transportation sector.

[40] "Energy intensity" is measured by the quantity of energy required per unit output or activity. For buildings, energy intensity is usually expressed in energy use per sq.ft of building space; for transportation, it is expressed as energy use per vehicle mile.

will also mitigate growth in winter peak demand and improve system resilience in cold climate regions. This finding demonstrates the value of allowing all emissions reduction options to play a role in achieving the state's emissions reduction targets.

#3 The *Selective Electrification* scenario offers an effective pathway to decarbonize high temperature industrial processes and heavy duty trucking.

The *Selective Electrification* scenario assumes greater use of the existing gas pipeline infrastructure relative to the *High Electrification* scenario. The *Selective Electrification* scenario retains clearer pathways for the utilization of low carbon gases, which will be critical to decarbonizing hard-to-electrify industrial and transportation end uses. The *Selective Electrification* scenario offers a pathway to further decarbonize these end uses. It also mitigates the risk of disproportionately burdening other market sectors with deeper decarbonization requirements to offset limited pathways for the industrial sector.

4.2 Additional Considerations

Achieving the Climate Act's mid-century target will require extensive decarbonization of the energy sector at an unprecedented speed. The gas system could support this transition by:

- **Providing a complementary asset to battery storage.** Strong growth in energy production from wind and solar PV requires dispatchable electricity production by biomass and low carbon gas and storage options in times of excess electricity production. Seasonal battery storage is challenging even at substantially reduced costs.

- **Providing a pathway to decarbonize high temperature industrial processes.** Full decarbonization of high temperature industrial heating processes is currently not feasible through electric solutions. Low carbon gases (such as RNG and green or blue hydrogen) can meet the heating needs of high temperature processes while reducing the processes' GHG emissions.[41]

- **Mitigating the growth in electric peak demand.** Dual-fuel heating systems contribute less to winter electric peak demand than whole-home ASHPs do during cold periods, because at low temperatures they rely on gas-fired heating with low electric demand.

- **Ensuring the reliability and resiliency of the energy system.** In a decarbonized future, gas infrastructure will continue to support a broader energy system reliability and resiliency when it is used to transport and distribute low carbon gas and hydrogen.

[41] European Commission Joint Research Centre (2020). "Global Energy and Climate Outlook 2019: Electrification for the low-carbon transition." p.50. Available at: https://publications.jrc.ec.europa.eu/repository/bitstream/JRC119619/kjna30053enn_geco2019.pdf

This study did not analyze these issues in depth since they are treated in prior studies, including Guidehouse's *2020 Gas Decarbonisation Pathways* study[42] and the American Gas Foundation's 2021 study on *Building a Resilient Energy Future*.[43]

4.3 Issues for Policymakers and Regulators

Demonstrating the technical and financial viability of a *Selective Electrification* pathway is only the first step on the long road to decarbonize New York's energy system to meet the Climate Act goals. Significant policy and regulatory barriers impede the reality of this future if the future framework does not support the investment needed for a safe, reliable natural gas delivery infrastructure providing added optionality for achieving the decarbonization objectives.

Over the last century, natural gas utilities have successfully built reliable, safe, and affordable energy delivery systems. Transforming this system will require investment that must be evaluated differently from previous investments. The policies, regulations, and economic frameworks that exist at the state and federal level are inadequate to encourage gas utilities to embrace the risks of new technologies, business models, and structural change required to realize a decarbonized future where gas infrastructure and supply play a significant role.

We present considerations around the policy and regulatory changes that may be required to accomplish the goals of the Climate Act by leveraging this analysis and similar work Guidehouse has performed regarding the transition to a lower carbon economy. Table 4-1 includes some of the barriers that may be encountered and some of the actions that should be taken to overcome them.

Table 4-1. Policy Issues and Opportunities

Issue 1: Regional policies and regulations should be structured to increase the supply of RNG and green or blue hydrogen in gas grids and to increase the use of these low carbon fuels in downstream sectors.

- State and federal policies similar to those that supported the development of solar and wind renewable generation will be helpful to build this market.
- New York State should mandate or encourage specific levels of production for both RNG and decarbonized hydrogen. Policymakers and regulators must understand that to achieve these production goals, utilities and private investors will likely need to undertake interstate transactions. Although many sources are available in New York, other suitable development sites may lie outside New York's borders.

[42] Guidehouse (2020). "Gas Decarbonisation Pathways 2020-2025." Available at: https://gasforclimate2050.eu/publications/

[43] 2021 . "Building a Resilient Energy Future: How the Gas System Contributes to US Energy System Resilience" Available at: https://gasfoundation.org/2021/01/13/building-a-resilient-energy-future/

Issue 2: Consumers would benefit from regulatory structures that support the development of resiliency assets and compensate investors for providing those services.

- Low carbon solutions like RNG and green or blue hydrogen can be readily stored to supplement supply for intermittent and peaking generation. This storage capability supports the development of resilient systems.
- RNG and hydrogen are excellent sources of feedstock for long duration and seasonal storage. These attributes are especially important in cold weather climates with extreme seasonal winter demand, such as those in New York.
- Regulatory policy should directly reward investments in system resiliency and (similar to stranded costs) should be amortized over the largest array of market segments as the benefits accrue to all energy users. Failure to construct policies that foster complementary operations of electric and pipeline systems and associated resiliency will create material risks to local economies and their communities.

Issue 3: There is too much long-term uncertainty in the low carbon fuel and infrastructure market to drive the required investment from private investors.

- Investments in renewable and low carbon gases and gas infrastructure require long-term certainty provided by encouragement to energy-using sectors, investors, and project developers. Current policies fall short in providing such a framework, even though the Climate Act and the increasing focus on decarbonization demonstrate the need.
- To encourage private investment, regulatory policy should be designed to provide long-term consistency in targets associated with low carbon fuels.

List of Acronyms

This section defines key terms and acronyms used throughout this report.

AC	Air Conditioning
ASHP	Air-Source Heat Pump
Bcf	Billion cubic feet (a measure of volume)
CAPEX	Capital Expenditures
CCS	Carbon Capture and Storage
CNG	Compressed Natural Gas
CO_2e	Carbon Dioxide Equivalent
EIA	US Energy Information Administration
EPRI	Electric Power Research Institute
EV	Electric Vehicle
GHG	Greenhouse Gas
GSHP	Ground-Source Heat Pump
HE	High Electrification (scenario)
HENG	Hydrogen-Enhanced Natural Gas
HP	Heat Pump
HPWH	Heat Pump Water Heater
HVAC	Heating, Ventilation, and Air Conditioning
LCP	Low Carbon Pathways
MMBtu	Million British Thermal Units (a measure of energy)
MMTCO2e	Million metric tons of carbon dioxide equivalent (a measure of GHG)
MW	Megawatts (a measure of power)
NFGDC	National Fuel Gas Distribution Corporation
NYISO	New York Independent System Operator
NYSERDA	New York State Energy Research and Development Authority
Solar PV	Solar Photovoltaics (a means of power generation)
RNG	Renewable Natural Gas
TBtu	Trillion British Thermal Units (a measure of energy)
TWh	Terawatt-hours (a measure of energy)
US	United States

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Appendix A. Definition of Geographic Study Regions

As described in Section 2.3, our analysis studied New York State as a whole and NFGDC's service territory in New York. Many of the inputs to Guidehouse's LCP model are based on state-level energy consumption information provided by the EIA, which was then scaled to the regional level with sector-specific scaling factors developed from data available at the county and ZIP code level. Regional statistics used for scaling include population, energy consumption, vehicle registration, and commercial and industrial employment statistics. For example, we used county level energy consumption data from the Open NY program to scale residential and commercial energy consumption and GHG emissions, and we used ZIP code level vehicle registration data to scale energy consumption and emissions in the transportation sector. Table A-1 presents summary statistics for the regions modeled in this analysis.

Table A-1. Summary Statistics for Regions Modeled

Region	Population (millions)	Total Monthly Energy Consumption (TBtu)	Total Vehicle Registrations (millions)	Commercial Employment (millions)
NFGDC Territory	1.54 (7.9%)	123.4 (10.8%)	1.09 (10.6%)	0.62 (7.0%)
Total (NY State)*	19.38 (100%)	1,144 (100%)	10.26 (100%)	8.82 (100%)

Appendix B. Decarbonization Opportunities

The scenarios considered in this analysis include different combinations of decarbonization technologies that could be deployed over the 2020-2050 analysis period. The following sections detail the opportunities and limitations of each technology we considered

B.1 Upstream Technologies

B.1.1 Renewable Natural Gas

RNG is a gaseous fuel with lower carbon intensity and similar operational and performance characteristics to natural gas, and RNG can reduce GHG emissions in applications that use natural gas and other fossil fuels. RNG reduces systemwide GHG emissions by avoiding the release of methane into the atmosphere from the natural breakdown of organic materials. Combusted natural gas has a much lower carbon intensity than pure methane when released to the atmosphere; eliminating methane emissions provides the majority of avoided GHG emissions. The specific carbon intensity of RNG is a complex calculation that depends on feedstock, production technology, and location, among other factors.

RNG or biomethane can be produced through several production technologies, including landfill gas collection, anaerobic digestion, and thermal gasification systems. Common RNG feedstocks include landfill gases, livestock waste, food waste, agricultural residues, and woody biomass. RNG facilities can use the produced gas onsite for electricity generation, boiler heating, and transportation refueling, or facilities can inject the RNG into the natural gas grid for use by gas utility customers. When distributed to these end-use customers, RNG can reduce the GHG emissions of gas appliances in buildings, gas-fired combined heat and power systems at industrial sites, or through compressed natural gas (CNG) vehicle fleets. RNG is a valuable low carbon resource for applications that are difficult or expensive to electrify.

Table B-1 highlights the RNG production potentials for each feedstock assumed for New York State, along with the applicable emissions rates. In recent years, RNG development has increased in support of federal and state decarbonization goals in the transportation and gas utility sectors. New York State has an estimated in-state RNG production technical potential of roughly 94 trillion Btu per year from available landfill, animal manure, wastewater treatment, and food waste resources through anaerobic digestion technologies. In future years, thermal gasification production technologies could increase in-state RNG technical potential by about 177 trillion Btu per year using available agricultural residues, forest residue, municipal solid waste resources, and energy crops. In 2017, New York consumed 1,394 trillion Btu of natural gas.[44] Our analysis assumes that the state's total natural gas consumption will decline over time while the state's total RNG potential will remain stable. Based on these trends, we estimate that the RNG technical potential represents about 16% of total natural gas consumption in 2020 and about 42% of total natural gas consumption in 2050.

RNG currently has a price premium over conventional natural gas, with the premium varying depending on the commercial structure of offtake agreements and whether credits are bundled

[44] U.S. Energy Information Administration. State Energy Data System, Table C1. Available at: https://www.eia.gov/state/seds/data.php?incfile=/state/seds/sep_sum/html/sum_btu_1.html&sid=NY

with the commodity. Per-unit RNG prices may decline over time as the market matures and production technologies improve.

Table B-1. Estimated RNG Production Potential and Emissions Rates for New York State

Process	Feedstock	Potential (Trillion Btu/Year)* Low	High	Average High-Technical	Technical	Emissions Rate (lbs CO_2e per MMBtu)**
Anaerobic Digestion	Landfill gas	19.7	32.8	41.6	50.5	21.0
	Animal manure	4.5	9.0	12.1	15.1	-124.0
	Water resource recovery facilities	2.5	3.3	5.3	7.2	16.6
	Food waste	2.4	4.2	12.9	21.6	-9.9
Thermal Gasification	Agricultural waste	2.0	5.0	14.7	24.3	12.3
	Forestry and forest product residue	2.0	4.0	7.1	10.2	10.4
	Energy crops	0.6	3.0	18.1	33.2	9.7
	Municipal solid waste	19.3	43.5	76.3	109.0	6.4
	Total	**53.0**	**104.9**	**188.0**	**271.1**	

* Low, High, and Technical potentials from ICF (2019), "Renewable Sources of Natural Gas: Supply and Emissions Reduction Assessment." The ICF report claims that the provided potentials are conservative, so Guidehouse calculated an average of the High and Technical cases from ICF (2019).

** Emissions rates are based on relevant Low Carbon Fuel Standard projects; data available at: https://ww2.arb.ca.gov/resources/documents/lcfs-pathway-certified-carbon-intensities

B.1.2 Hydrogen-Enhanced Natural Gas

In sectors currently using natural gas and other fossil fuels, hydrogen offers another low carbon gas solution to reduce GHG emissions. Hydrogen can be produced through electrolysis using dedicated renewable generation or curtailed renewable generation systems (power-to-gas or green hydrogen) and through natural gas reformation with carbon capture (blue hydrogen). It can be blended into existing natural gas pipelines using a strategy known as HENG. If implemented with low concentrations, this strategy appears to be viable without increasing risks in end-use devices (such as household appliances), overall public safety, or the durability and integrity of the existing natural gas pipeline network. Our research and interviews with heating technology experts indicate that hydrogen may be blended with natural gas at a maximum concentration of 15% hydrogen by volume, which could displace about 5% of natural gas supplied in HENG pipelines.[45,46] Our findings indicate that HENG technology is unlikely to be available beyond the pilot scale until 2030.

[45] GRTgaz et al. (2019). "Technical and economic conditions for injecting hydrogen into natural gas networks." Available at: http://www.grtgaz.com/fileadmin/plaquettes/en/2019/Technical-economic-conditions-for-injecting-hydrogen-into-natural-gas-networks-report2019.pdf

[46] Melaina, Antonio and Penev (2013). "Blending Hydrogen into Natural Gas Pipeline Networks: A Review of Key Issues." Available at: https://www.nrel.gov/docs/fy13osti/51995.pdf

B.1.3 Carbon Capture and Storage

Carbon capture technologies reduce the GHG emissions from natural gas, RNG, or hydrogen fuels by capturing CO_2 exhaust gas for sequestration, storage, or utilization. Carbon capture would generally occur at large centralized facilities such as gas-fired generation facilities or natural gas reformation systems.

New York has many options for carbon capture within the state and surrounding areas, including oil and natural gas reservoirs, un-mineable coal seams, saline formations, offshore sandstone formations, shale basins, and basalt-rich areas. Areas such as the Marcellus Shale and the Great Stone Dome could store enough carbon to offset several decades (and possibly centuries) of stationary emissions, so sequestration availability is not expected to be a major hurdle within the period of study and subsequent decades.[47,48] The model assumes that carbon capture and storage (CCS)-based power generation could meet all of New York's generation requirements. Wide commercialization of carbon capture technology will require additional R&D, pilot projects, and policy support to achieve wide commercialization. Given these requirements, our LCP model assumes that deployment of CCS will not begin prior to 2030.

In the model, CCS-based power generation competes with non-CCS natural gas combined cycle plants, solar generation, and wind generation. CCS-based power generation is assumed to include a combination of post-combustion capture retrofit plants and purpose-built pre-combustion plants; purpose-built plants are assumed to be phased in as plants available for retrofit become less common. Table B-2 summarizes these assumptions.

Table B-2. Assumed Share of Capture Technologies and Associated CAPEX Costs

Variable	Technology	2030	2040	2050
Share of capture technologies deployed per period†	Post-combustion, retrofit	100%	75%	50%
	Pre-combustion, new	0%	25%	50%
Cost to install power generation with carbon capture, per Unit of Power Generation Capacity ($/kBtu/h)‡	Post-combustion, retrofit	$578	$561	$544
	Pre-combustion, new	$1,296	$1,215	$1,134
	Combined cost	**$578**	**$725**	**$839**

† These values indicate the share of CCS-based power generation capacity that is assigned to each technology in each time period. For example, 100% post-combustion retrofit in 2030 means that 100% of the power plants with carbon capture built in 2030 will use post-combustion retrofit. The values pertain only to power plants with carbon capture; other power plant types (such as wind, solar, non-CCS combined cycle, etc.) are not accounted for in this ratio. The proportions are Guidehouse assumptions.
‡ Capture costs based on Rubin et al. (2015), "The cost of CO_2 capture and storage." Available at: https://www.cmu.edu/epp/iecm/rubin/PDF%20files/2015/Rubin_et_al_ThecostofCCS_IJGGC_2015.pdf

[47] NTEL (2016). "U.S. DOE NETL methodology for estimating the prospective CO_2 storage resource of shales at the national and regional scale." Available at: https://www.osti.gov/biblio/1275480

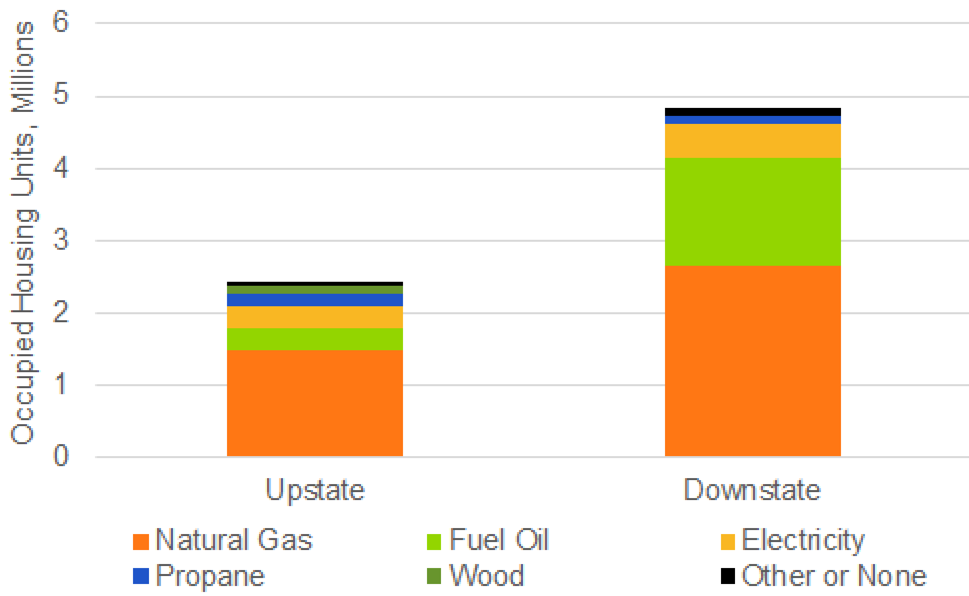
[48] Cumming et al. (2016). "Mid-Atlantic U.S. Offshore Carbon Storage Resource Assessment." Available at: https://www.sciencedirect.com/science/article/pii/S1876610217317848

Guidehouse forecasts the electric generation fuel mix from 2020 through 2050. For each of the non-reference case scenarios, we assume that the power sector achieves the Climate Act requirements that 70% of electric generation come from renewables by 2030 and that generation be 100% carbon free by 2040. Natural gas-fired generation is projected to decrease over time but will not be eliminated since it serves an essential role providing reliable electric supply compared to intermittent renewable sources. To achieve the Climate Act requirement of carbon-free generation by 2040, CCS deployment is expected to begin in earnest in 2030 and will steadily increase over time through 2040, when all remaining gas-fired generators employ CCS.

B.2 Building Heat and Hot Water

In 2018, 84% of homes in New York used fossil fuels as their primary heating source.[49] Figure B-1 describes the number of households that use different heating fuels in Upstate and Downstate New York. According to NYSERDA, thermal energy use for space heating, space cooling, and hot water in New York State's residential and commercial sector constitutes approximately 37% of statewide net energy consumption.[50] The sector's reliance on fossil fuel sources results in about 32% of the state's GHG emissions coming from space and water heating.[51]

Figure B-1. Occupied Housing Units in New York, by Space Heating Fuel, 2011-2015[52]



[49] US Energy Information Administration (2020). "State Profile and Energy Estimates: New York." Available at: https://www.eia.gov/state/data.php?sid=NY#ConsumptionExpenditures

[50] The New York State Energy Research and Development Authority (2017). Renewable Heating and Cooling Policy Framework. Available at: https://www.nyserda.ny.gov/-/media/Files/Publications/PPSER/NYSERDA/RHC-Framework.pdf

[51] *Ibid.*

[52] Source: NYSERDA (2017). "Patterns and Trends New York State Energy Profiles: 2001–2015 Final Report", Appendix D-1. Available at: https://www.nyserda.ny.gov/-/media/Files/Publications/Energy-Analysis/2001-2015-patterns-and-trends.pdf

Technologies available today can be used to fully electrify the heating and hot water needs of New York's buildings. However, the *High Electrification* scenario will require electric capacity upgrades to supply roughly 30% higher peak electric demand (see Section 3.3). *High Electrification* will also require substantial expenditures by consumers to purchase and install heat pumps suitable for New York's climate. Guidehouse tested whether a more selective approach to building electrification can meet the Climate Act targets in a more cost-effective manner.

Guidehouse focused on four technologies to electrify buildings' space heating needs: whole-building heat pumps, dual-fuel heating (heat pump plus gas heat), ground-source heat pumps (GSHPs), and district heating/cooling. The subsections that follow describe these technologies in more detail. Table B-3 lists the proportion of the total space heating load assigned to each technology in the modeled scenarios. These proportions were selected to represent the fundamental definitions of the scenarios in our model. For water heating technologies, Guidehouse assumes that installed stock of fuel-fired water heaters in New York will be completely replaced by electric heat pump water heaters (HPWHs) by the year 2050.

Table B-3. Saturation Limits of Space Heating Technologies, by Scenario, 2050

Space Heating Technologies by Sector	Proportion of Heating Load Met by Technology	
	High Electrification	Selective Electrification
Residential		
Whole-Building Heat Pumps	99%	70%
Dual-Fuel Heating (ASHP plus Gas Heat)	0%	70%
Ground-Source Heat Pumps	30%	30%
Commercial		
Whole-Building Heat Pumps	98%	70%
Dual-Fuel Heating (ASHP plus Gas Heat)	0%	70%
Ground-Source Heat Pumps	30%	30%
District Water-Loop Heating and Cooling	10%	10%

B.2.1 Whole-Building Heat Pumps

Electric heat pumps provide space heating and space cooling by using electricity to move heat from the outdoor space to the indoor space and vice versa. Recent advances in cold climate air-source heat pump (ASHP) technology make it possible to use heat pumps for space heating when outdoor ambient temperatures are as low as -13ºF.[53] With these systems, most buildings in New York State could feasibly electrify their heating systems. Complete electrification of building heating loads allows the natural gas consumption of the residential and commercial sectors to be reduced to near zero, which aligns with the policy drivers of the *High Electrification* scenario. Our analysis assumed that whole-building heat pumps must be capable of cold

[53] A sample of heat pump products capable of continuous operation at -13ºF include Daikin's Aurora, Mitsubishi's Hyper-Heat, Fujitsu's Halcyon, and Lennox's MLA product lines.
https://daikincomfort.com/go/aurora/
https://www.mitsubishicomfort.com/benefits/hyper-heating
https://www.fujitsugeneral.com/us/residential/technology/xlth-low-temp-heating.html
https://www.lennox.com/products/heating-cooling/mini-split-systems/mla

climate operation, meaning that they continue to use vapor compression cycle down to 5ºF, and use electric resistance heating below 5ºF.

Whole-building cold climate ASHPs are substantially more expensive than conventional heat pumps and, at present energy rates, they are considerably more expensive to operate compared to conventional gas-fired equipment. An additional challenge is that high electrification of building heat will greatly increase peak electric demand during peak heating periods. To meet the peak electric demands of regions with fully electrified building heat, significant investments in electric distribution infrastructure will be needed. Guidehouse accounts for infrastructure investments upstream of the customer's electric meter (to increase transmission and distribution capacity) and investments downstream of the meter (to upgrade electrical panels and add circuits for customers who did not previously have a central AC system).

B.2.2 Ground-Source Heat Pumps

GSHPs (also called geothermal heat pumps) are similar to ASHPs in that they use electricity to move heat in and out of a building's conditioned space. While ASHPs gather heat from ambient outdoor air, GSHPs exchange heat with the ground via a buried pipe loop. GSHPs are typically more efficient than ASHPs because they exchange heat with their surroundings more efficiently, and because ground temperatures fluctuate less than ambient air temperatures. However, GSHPs have a much higher upfront cost that ASHPs due to the cost associated with installing a ground loop.

On balance, GSHPs are less cost-effective than ASHPs in terms of customer payback period and in terms of cost per GHG emissions reduction. GSHPs are expected to play a role in New York's decarbonization. Utilities in New York are experimenting with new ownership models that could facilitate wider adoption of GSHP technology, and Guidehouse projects that a small portion of customers will continue to invest in GSHP systems. Due to the high upfront costs associated with GSHPs, Guidehouse assumes that adoption of GSHP technology will be limited.

B.2.3 Dual-Fuel Space Heating

A dual-fuel HVAC system pairs an electric heat pump with a gas-fired heating appliance and alternates between the two sources depending on ambient outdoor air conditions. Our analysis assumed that dual-fuel systems use a switchover temperature of 30ºF. Above 30ºF, the system uses the heat pump, and below 30ºF, the system uses gas-fired heating. In effect, users of dual-fuel systems electrify a portion (but not all) of their space heating energy consumption. Our analysis assumed that dual-fuel heating systems use conventional ASHPs, which are typically less expensive than cold climate capable heat pumps.

Dual-fuel heating systems address three major shortfalls of whole-home ASHPs:

1. Dual-fuel systems use heat pumps when they are most efficient, and switch to gas-fired heating at low temperatures where heat pumps are less efficient.

2. Dual-fuel systems contribute less to winter electric peak demand than whole-home ASHPs do during cold periods, because at low temperatures they rely on gas-fired heating with low electric demand.

3. Dual-fuel systems are typically less expensive to install and less expensive for customers to operate compared to whole-building cold climate heat pumps.

Dual-fuel systems contribute less to winter electric peak demand than whole-home ASHPs do during cold periods, because at low temperatures they rely on gas-fired heating with low electric demand.

It is important that analyses distinguish between conventional heat pumps that have been widely used in moderate climates for many years and the more advanced and expensive cold climate heat pumps that are required to meet the low ambient temperatures common in New York. We expect that upstate customers can electrify 60% of their heating load with a dual-fuel system, and downstate customers can electrify 80% of their heating load.[54] We assume that dual-fuel customers' non-electrified heating load will be met using natural gas-fired heating. To deliver the GHG emissions reductions mandated by the Climate Act, a pathway that uses dual-fuel heating will also need to implement technologies such as RNG or HENG that reduce the carbon intensity of pipeline natural gas.

Our analysis deploys dual-fuel heating in tandem with RNG technologies in the *Selective Electrification* scenario, but not in the *High Electrification* scenario. The incremental cost of dual-fuel systems is calculated assuming that dual-fuel heating is a replace-on-failure measure. That is, we assume that dual-fuel systems are installed to replace a prior HVAC system that is taken out of service, and they are not retrofit on to existing HVAC system. From this assumption, we calculate the incremental cost of a dual-fuel system relative to the cost of a baseline gas furnace and central AC system.

B.2.4 Heat Pump Water Heaters

HPWHs use electricity to transfer heat from ambient air to a stored water tank and are an energy efficient alternative to electric resistance water heaters and fuel-fired water heaters. The adoption of HPWHs has been limited by a variety of factors, including cost, product availability, and installation constraints. Guidehouse projects that the market for HPWHs will overcome these barriers and that nearly all New York buildings will use HPWH technology for water heating by 2050.

Depending on the specifics of the building, HPWHs may or may not require electrical upgrades for installation. Buildings that previously had an electric resistance water heater are unlikely to need upgrades as the HPWH can simply replace the previous water heater in the electrical circuit. However, buildings that had a fuel-powered water heater are likely to need upgrades as the existing circuits probably cannot handle the HPWH current rating. In modeling HPWHs, we assumed that electrical upgrades would not be necessary.

[54] To estimate the portion of heating load that may be electrified using dual-fuel heating, our analysis examined the heating degree days for representative weather stations in upstate and downstate New York, assuming that a dual-fuel heating system will use an electric heat pump to meet heating needs when the outdoor ambient dry bulb temperature is 30ºF or higher.

B.2.5 District Energy

In a district energy system, a central plant (or plants) produce steam, hot water, or chilled water that is then pumped through a network of insulated pipes to provide space heating, cooling, or hot water for nearby connected customer buildings. District heating plants can provide higher efficiencies than local heat generation with smaller-scale equipment. Con Edison operates the New York City steam system that provides district heat to a large portion of Manhattan Island and to several other systems across New York State, serving campuses and building clusters. A recent market characterization by ICF International prepared for the US EIA forecasts that district heating systems may see limited long-term growth from 2020 to 2050.[55] Guidehouse anticipates that district energy systems currently installed in New York will continue to operate but that installation of new district energy systems will be limited.

B.3 Transportation

The transportation sector is the largest contributor to GHG emissions in New York. Reducing GHG emissions to a level in compliance with Climate Act targets requires significant adoption of low and zero emissions alternative fuel transportation technologies.

B.3.1 EVs

Our LCP model considers the electrification of light duty passenger vehicles, the electrification and emergence of natural gas in medium and heavy-duty commercial vehicles, and the adoption of low emissions bio-jet fuel in commercial aviation.

The decarbonization of light duty passenger vehicles are modeled as a transition from gasoline-powered vehicles to EVs. The projected advancements in battery technology provide a pathway for reduced incremental costs of EVs over traditional gasoline alternatives. Guidehouse references market projections showing that light duty EVs will have only a small cost premium over gasoline vehicles by 2050. For medium and heavy-duty applications where electrification is more difficult, the model considers the availability of natural gas-powered vehicle technologies. These CNG- and liquefied natural gas-powered medium and heavy-duty vehicles are a relatively mature technology that could be cost-effective alternatives to traditional diesel-powered vehicles in scenarios where natural gas fuel costs remain low.

B.3.2 Low Carbon Aviation Fuel

To further decarbonize the transportation sector, sustainable aviation fuels such as aviation biofuels are considered as a technology option. While procurement of aviation biofuels was limited to about 15 million liters in 2018 (less than 0.1% of total aviation consumption), IEA estimates that scaling procurement to levels meeting 2% of international aviation demand could provide the cost reductions needed for a self-sustaining aviation biofuel market.[56] Guidehouse's LCP model considers CAPEX costs associated with this initial investment on a $/MMBtu basis.

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[55] ICF and IDEA (2018). "U.S. District Energy Services Market Characterization." Available at: https://www.eia.gov/analysis/studies/buildings/districtservices/pdf/districtservices.pdf

[56] International Energy Agency (2019). "Are aviation biofuels ready for take off?". Available at: https://www.iea.org/commentaries/are-aviation-biofuels-ready-for-take-off

B.4 Industrial

Many industrial processes are difficult to decarbonize, such as the manufacture of chemicals, steel, and cement. However, there is potential for reducing GHG emissions from these processes through adoption of RNG and green hydrogen. RNG may be used to displace a portion of the fossil natural gas supplied to industrial customers, and Section B.1.1 describes our assumptions regarding RNG deployment. Section C.2 describes how the proportion of RNG and HENG in the pipeline gas mix may increase over time in a scenario that is favorable to low carbon fuels.

Green hydrogen is a term used to describe hydrogen that is separated from water and converted to a viable fuel source through a renewables-powered electrolysis process. Recent studies that have demonstrated the feasibility of using green hydrogen in the steel industry[57] and the cement-making process.[58] Many of these technologies will not be cost-effective during this study period unless significant carbon taxes or other cost-leveling measures are applied. Separate from the HENG strategy (Section B.1.2), hydrogen may be delivered to customers through dedicated distribution systems designed for 100% hydrogen gas, known as hydrogen clusters or districts. Guidehouse's LCP model calculates the energy use and emissions impacts associated with switching a portion of the industrial sector's energy consumption from pipeline gas sources to locally produced hydrogen.

B.5 Efficiency Improvements

New York State has a variety of policies and programs that encourage the adoption of higher efficiency technologies and operational practices. Federal appliance standards and building codes by state and city agencies improve the energy efficiency of building stock over time through new building construction and replacement of existing systems at end of life. The *Reference Case* scenario is based on the EIA's Annual Energy Outlook 2019, which projects that from 2018 to 2050, energy efficiency in different sectors will be improved through building codes, appliance standards, vehicle fuel economy standards, and other actions. The EIA forecasts that increases in energy efficiency will cause energy intensity to decline by 22% in the residential sector, 13% in the commercial sector, and 32% in the transportation sector.

The baseline *Reference Case* scenario assumes the energy efficiency of buildings and transportation will increase about 15% due to current building codes, appliance standards, and vehicle fuel economy standards. Additional energy efficiency opportunities are available to further reduce energy consumption in the residential, commercial, and industrial sectors. New York State utilities and public organizations also encourage the adoption of above-code building technologies through energy efficiency incentive programs. These programs provide incremental energy savings above those already forecasted for future years from today's codes and standards.

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[57] See, for instance, Hybrit Steel in Sweden, at: http://www.hybritdevelopment.com/ ;
Voestalpine Hydrogen Production Facility in Austria, at: https://www.voestalpine.com/group/en/media/press-releases/2019-11-11-h2future-worlds-largest-green-hydrogen-pilot-facility-successfully-commences-operation/ ;
Thyssenkrupp Steel Europe's partnership for green hydrogen production, at: https://www.thyssenkrupp.com/en/newsroom/press-releases/pressdetailpage/green-hydrogen-for-steel-production--rwe-and-thyssenkrupp-plan-partnership-82841 ;
[58] Doyle, Amanda (2019). "Producing cement using electrolysis". Available at: https://www.thechemicalengineer.com/news/producing-cement-using-electrolysis/

- Building envelope technologies (wall, floor, and ceiling insulation and windows) are a core component of most buildings and carry long lifetimes, leading to infrequent retrofits or replacements. Consequently, most buildings have an existing building shell that performs well below today's building code requirements for new construction. Upgrading the insulation, windows, and air sealing of existing buildings to code or above-code performance would reduce the HVAC energy consumption of the building. In our model, we capture those potential improvements through technologies that reduce the space conditioning load in new and existing residential and commercial buildings.

- High efficiency options are available for most residential and commercial building technologies, including water heating, lighting, kitchen and laundry appliances, electronics, and industrial processes. However, higher efficiency products or control systems that reduce energy consumption for major equipment typically have an incremental cost premium over baseline options. We capture those potential improvements through the general efficiency improvement technologies for residential and commercial buildings.

- Like residential and commercial buildings, industrial facilities can benefit from the various efficiency improvements described previously. They also can benefit from improvements to process efficiency. We capture those potential improvements via the industrial efficiency measures technology.

- Transportation sector efficiency improvements can come from various sources, such as improved logistics, self-driving vehicles, increased reliance on public transportation, among others. Those potential improvements are captured by the transport efficiency improvements technology.

Recent reports from the Electric Power Research Institute (EPRI) and NYSERDA estimate that energy efficiency measures could result in a 35% reduction in energy use and a 30% reduction in GHG emissions.[59,60] The *Reference Case* scenario accounts for efficiency improvements that will result from codes and standards that have already been enacted. NYISO's *2019 Load & Capacity Data* report forecasts that building codes and efficiency programs will reduce end-use electricity consumption by 15% in 2050.[61] Guidehouse's LCP model assumes that further energy and GHG savings are possible through more aggressive action by efficiency programs, and that these activities could increase energy efficiency by another 10% in the residential, commercial, industrial, and transportation sectors. The potential improvements in efficiency are shown in Table 2-2 under the appropriate technology. The unit cost of those improvements in shown in Table B-4.

[59] The New York State Energy Research and Development Authority (2018). "New Efficiency New York." p.2 Available at: https://www.nyserda.ny.gov/-/media/Files/Publications/New-Efficiency-New-York.pdf

[60] Electric Power Research Institute (2020). "Electrification Scenarios for New York's Energy Future. " p.5. Available at: https://www.epri.com/research/products/3002017940

[61] New York Independent System Operator (2019). "2019 Load & Capacity Data Report." Table I-1b. Available at: https://www.nyiso.com/documents/20142/2226333/2019-Gold-Book-Final-Public.pdf/

Table B-4. Estimated Incremental Energy Efficiency Costs for New York State[62]

Technology	Cost [$ per MMBtu saved/year]			
	2020	2030	2040	2050
Residential space conditioning efficiency, retrofit	282	311	344	380
Residential space conditioning efficiency, new buildings	282	311	344	380
Commercial space conditioning efficiency, retrofit	104	115	127	140
Commercial space conditioning efficiency, new buildings	104	115	127	140
Residential building efficiency, non-insulation	226	250	276	305
Commercial building efficiency, non-insulation	177	196	216	239
Transport efficiency	43	43	43	43
Industrial efficiency	183	202	223	247

[62] To estimate the cost per annual energy savings associated with energy efficiency upgrades, we reviewed the benefit-cost models of several utilities in the Northeast U.S. These benefit-cost models contain data on the customer cost and energy savings for individual measures, based on historical program spending and studies that evaluate energy savings.

Appendix C. Detailed Results

Detailed results tables regarding technology adoption, pipeline fuel mix, and figure data are provided in the following sections.

C.1 Technology Adoption

As Section 2.1 describes, Guidehouse's LCP model uses an optimization function to model the deployment of decarbonization technologies in order of the technologies' cost-effectiveness. The model assumes that technologies with the lowest cost per GHG abated will be adopted first and technologies with a high cost per GHG abated will be adopted last. For each scenario, our model increases the amounts of technology adoption until the scenario's GHG emissions target is achieved. The outcome is that cost-effective technologies are deployed to the maximum extent possible, while higher cost technologies may see more moderate adoption or may not be adopted at all.

The scenario definitions influence the adoption rates of different technologies. Compared to other scenarios that allow RNG, HENG, and dual-fuel building heat, the *High Electrification* scenario requires higher adoption of whole-building heat pumps to meet the Climate Act's emissions targets. Table C-1 presents the adoption rates assigned to each technology in the LCP model, as a result of the model's optimization function. These results are distinct from the model inputs presented in Table B-3, which describe the saturation limits imposed on the model.

Table C-1. Technology Adoption Rates Modeled in National Fuel Territory

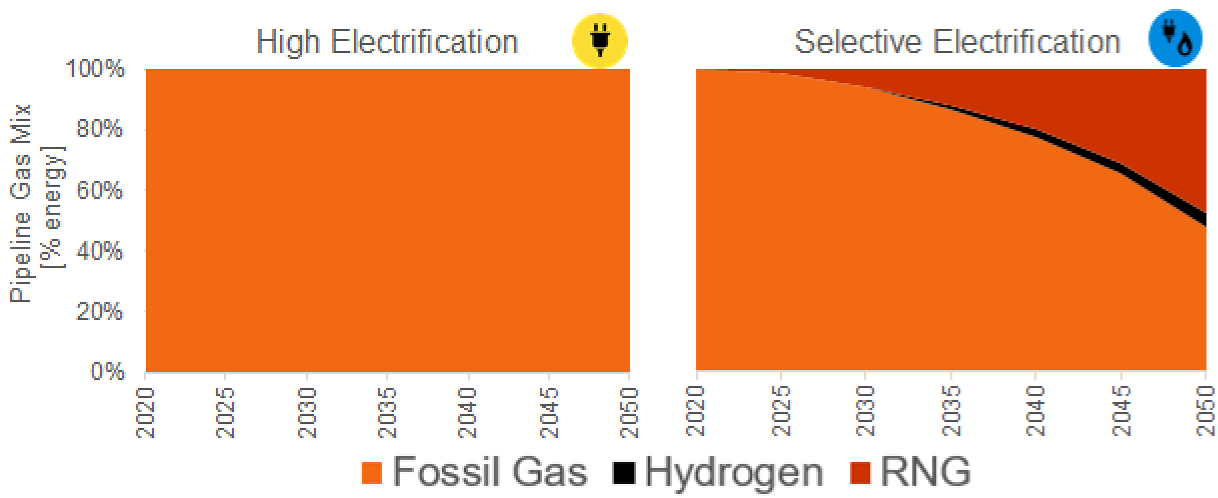
Technology	Unit Basis	Technology Adoption Rate in 2050 HE*	SE*
RNG - Anaerobic digestion	Billion Btu per year	N/A	8,500
RNG - Thermal gasification	Billion Btu per year	N/A	13,800
Hydrogen-enhanced natural gas	H_2 % of natural gas supply by energy	N/A	5%
Solar generation	% of elec. supply, except nuclear and hydro	41%	41%
Wind generation	% of elec. supply, except nuclear and hydro	45%	45%
Post- and pre-combustion capture power generation	% of fossil electric	100%	100%
Natural gas heavy duty vehicles	% of heavy duty (diesel) load switched	N/A	2%
Electric heavy duty vehicles	% of heavy duty (diesel) load switched	100%	37%
Electric medium duty vehicles	% of medium duty (diesel) load switched	2%	2%
Electric light duty vehicles	% of gasoline load switched	100%	100%
Biofuel production for aviation	% of jet fuel switched	100%	100%
Industrial local green hydrogen	% of industrial load switched	N/A	75%
Heat pump water heaters (HPWH), residential	% of carbon load switched	100%	100%
Heating oil to heat pump conversions, residential	% of fuel oil load switched	100%	100%
District water-loop heating and cooling, residential	% of carbon load switched	0%	0%
ASHP Whole-building, residential	% of carbon load switched	87%	30%
Geothermal heat pumps, whole-building, residential	% of carbon load switched	0.4%	0.4%
Dual-fuel heating - furnace/boiler plus HP, residential	% of carbon load switched	N/A	69%
Heat pump water heaters (HPWH), commercial	% of carbon load switched	100%	100%
District water-loop heating and cooling, commercial	% of carbon load switched	0.4%	0.4%
ASHP, Whole-building, commercial	% of carbon load switched	98%	30%
Geothermal heat pumps, whole-building, commercial	% of carbon load switched	1%	1%
Dual-fuel heating - furnace/boiler plus HP, commercial	% of carbon load switched	N/A	68%
Transport efficiency	Entire Sector Consumption	10%	10%
Industrial efficiency	Entire Sector Consumption	0.4%	0.4%
Residential building efficiency, non-insulation	Entire Sector Consumption (non-space conditioning)	0.4%	0.4%
Commercial building efficiency, non-insulation	Entire Sector Consumption (non-space conditioning)	10%	10%
Residential space conditioning efficiency, retrofit & new	Entire Sector Space Conditioning Load	10%	10%
Commercial space conditioning efficiency, retrofit & new	Entire Sector Space Conditioning Load	10%	10%

* Note: HE stands for High Electrification scenario, and SE stands for Selective Electrification scenario

C.2 Pipeline Gas Mix

Figure C-1 shows the pipeline gas mix for each scenario in terms of energy. The *High Electrification* scenario does not include RNG and hydrogen, so the pipeline gas is composed entirely of fossil gas. In the *Selective Electrification* scenario, RNG and hydrogen are available. The *Selective Electrification* scenario assumes that in 2050, 50% of pipeline gas is composed of non-fossil fuels. The adoption of hydrogen is limited by the expected safety limit of 5% by energy, which is achieved in the *Selective Electrification* scenario. The RNG adoption is limited to 45% of the pipeline gas supply by the absolute RNG potential in the region.

Figure C-1. Pipeline Gas Mix for Each Scenario



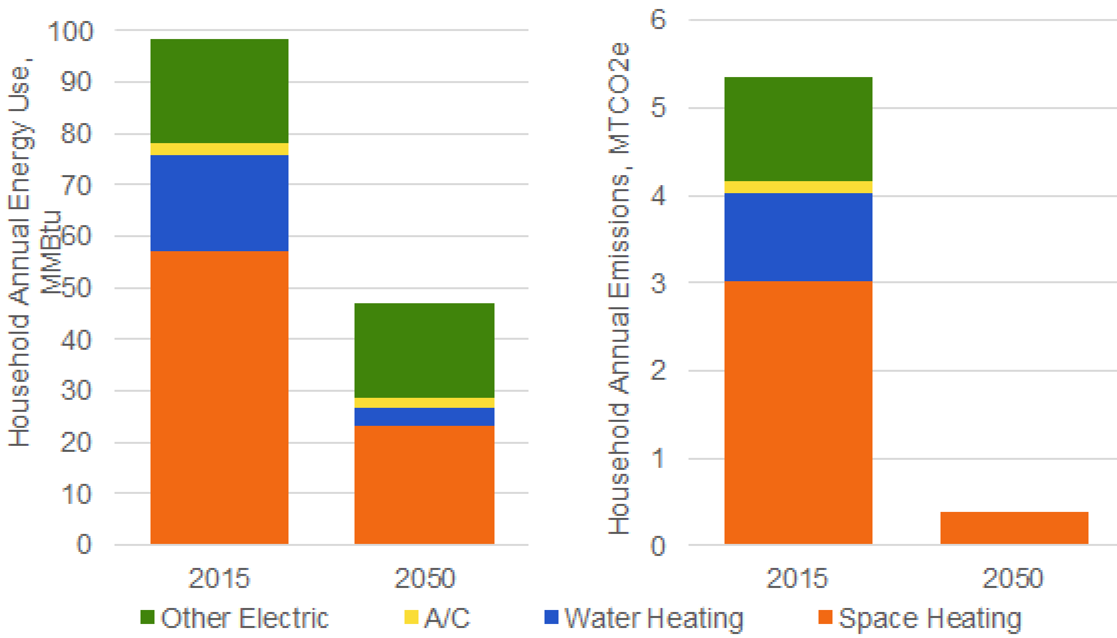
C.3 Reductions in Household Energy Use and Associated Emissions

Guidehouse also modeled the impacts that interventions in the *Selective Electrification* scenario would have on a typical household in New York State. Figure C-2 shows how different residential end uses contribute to household energy consumption and associated GHG emissions in 2015 (prior to intervention) and in 2050 (after intervention). In 2015, the typical single family household consumes natural gas for space heating and water heating.[63] In the *Selective Electrification* scenario, we assume that by 2050, the typical household takes steps to improve building shell and appliance efficiency and switches to electric water heating and dual-fuel space heating.

Similar to our analysis of single-family homes in NFGDC's territory (see Section 3.4), interventions in the *Selective Electrification* scenario can more than halve a typical New York household's energy consumption and reduce household GHG emissions by greater than 90%.

[63] Annual energy use in 2015 from NYSERDA (2019) Patterns and Trends, New York Energy Profiles: 2002–2016, Appendix B, representing single-family homes in New York State. Available at: https://www.eia.gov/consumption/residential/data/2015/

Figure C-2. Reduction in Energy Use and GHG Emissions from Selective Electrification
Example: Average household in New York State



Intervention	Energy Savings	Emissions Reduction
Building Shell Efficiency	15%	15%
End Use Electrification	33%	32%
Appliance Efficiency	4%	4%
Renewable Elec. Generation	n/a	25%
Carbon Capture & Storage	n/a	9%
Low-Carbon Fuels (RNG, Hydrogen)	n/a	7%
Total	**52%**	**93%**

C.4 Figure Data

Table C-2 shows the underlying data for selected figures in this report.

Table C-2. Data for Selected Figures

Variable	Scenario	Data Series	2020	2025	2030	2035	2040	2045	2050
Figure 3-1: GHG Emissions [MMTCO2]	High Electrification	NonEnergy	2.6	2.3	1.9	1.5	1.2	0.8	0.4
		Leakage	0.2	0.1	0.1	0.0	0.0	0.0	0.0
		Power	2.2	2.1	0.5	0.2	0.0	0.0	0.0
		Trans	7.2	5.8	4.5	3.3	2.3	1.4	0.5
		Ind	1.3	1.4	1.5	1.6	1.6	1.7	1.8
		Com	2.1	1.7	1.5	1.2	0.9	0.7	0.4
		Res	3.9	3.1	2.5	1.9	1.4	0.9	0.4
	Selective Electrification	NonEnergy	2.6	2.3	1.9	1.5	1.2	0.8	0.4
		Leakage	0.2	0.1	0.1	0.0	0.0	0.0	0.0
		Power	2.1	2.0	0.4	0.2	0.0	0.0	0.0
		Trans	7.2	5.8	4.6	3.6	2.7	1.9	1.1
		Ind	1.3	1.4	1.5	1.5	1.3	1.2	1.2
		Com	2.1	1.8	1.5	1.2	0.9	0.7	0.4
		Res	3.9	3.1	2.5	1.9	1.4	0.9	0.4
	Reference	Total	19.4	18.6	17.2	16.9	16.9	17.1	17.4
Figure 3-3: Electricity Consumption [TWh/year]	High Electrification	Trans	0.2	1.1	2.4	3.6	4.8	6.1	7.4
		Ind	2.3	2.4	2.6	2.7	2.8	2.9	3.0
		Com	7.1	7.3	7.6	7.9	8.2	8.5	8.9
		Res	6.0	6.8	7.4	7.8	8.1	8.4	8.5
	Selective Electrification	Trans	0.2	1.1	2.1	3.0	3.9	4.9	5.9
		Ind	2.3	2.4	2.6	2.7	2.8	2.9	3.0
		Com	7.1	7.2	7.4	7.7	7.9	8.2	8.6
		Res	6.0	6.7	7.1	7.4	7.7	7.9	8.0
	Reference	Total	15.5	15.2	15.2	15.3	15.5	15.8	16.2
Figure 3-3: Pipeline Gas Consumption [Bcf/year]	High Electrification	Power	16.9	16.9	6.0	6.9	7.8	8.9	10.0
		Trans	4.3	3.9	3.7	3.5	3.4	3.3	3.4
		Ind	11.0	11.8	12.6	13.0	13.5	14.1	14.8
		Com	30.4	25.1	20.7	16.8	13.1	9.4	5.6
		Res	51.2	41.4	33.4	26.2	19.4	13.0	6.9
	Selective Electrification	Power	16.9	16.2	5.6	6.3	7.0	7.8	8.7
		Trans	4.3	4.0	3.8	3.7	3.7	3.7	3.8
		Ind	11.0	11.8	12.6	13.0	10.1	7.1	3.7
		Com	30.4	25.9	22.4	19.3	16.4	13.5	10.7
		Res	51.2	44.0	38.2	31.5	25.4	19.5	13.9
	Reference	Total	110.4	106.7	97.4	97.4	98.3	99.6	101.5
Figure 3-4: Peak Electricity [GW]	High Electrification	Trans	0.0	0.2	0.5	0.8	1.0	1.3	1.6
		Ind	0.5	0.5	0.6	0.6	0.6	0.6	0.7
		Com	1.4	1.4	1.4	1.4	1.4	1.4	1.5
		Res	1.3	1.4	1.7	1.8	2.0	2.0	2.1
	Selective Electrification	Trans	0.0	0.2	0.5	0.6	0.8	1.0	1.3
		Ind	0.5	0.5	0.6	0.6	0.6	0.6	0.7
		Com	1.4	1.4	1.4	1.4	1.4	1.4	1.5
		Res	1.3	1.3	1.5	1.7	1.8	1.8	1.9
	Reference	Total	3.3	3.2	3.2	3.2	3.3	3.3	3.4

Variable	Scenario	Data Series	2020	2025	2030	2035	2040	2045	2050
Figure 3-4: Peak Pipeline Gas Consumption [Bcf/day]	High Electrification	Power	0.18	0.17	0.06	0.06	0.07	0.08	0.09
		Trans	0.02	0.02	0.02	0.02	0.02	0.02	0.02
		Ind	0.06	0.06	0.07	0.07	0.07	0.07	0.08
		Com	0.15	0.12	0.10	0.08	0.06	0.04	0.02
		Res	0.44	0.35	0.28	0.22	0.16	0.10	0.05
	Selective Electrification	Power	0.18	0.16	0.05	0.06	0.07	0.07	0.08
		Trans	0.02	0.02	0.02	0.02	0.02	0.02	0.02
		Ind	0.06	0.06	0.07	0.07	0.05	0.04	0.02
		Com	0.15	0.13	0.11	0.09	0.07	0.06	0.04
		Res	0.44	0.38	0.33	0.27	0.22	0.17	0.12
	Reference	Total	0.82	0.79	0.68	0.68	0.69	0.69	0.70
Figure 3-5: Residential Space Heating Fuel Consumption [tBtu/year]	High Electrification	Efficiency Gains	0.0	4.9	10.3	15.8	21.4	26.9	32.2
		Hydrogen (HENG)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		RNG	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Fossil Gas	35.2	28.2	22.5	17.3	12.4	7.9	3.6
		Electric	2.6	5.5	7.3	8.6	9.5	10.2	10.6
		Biomass	1.4	1.1	0.9	0.7	0.5	0.3	0.1
		Delivered Fuels	13.7	10.7	8.3	6.0	4.0	2.0	0.2
	Selective Electrification	Efficiency Gains	0.0	4.1	8.6	13.1	17.8	22.3	26.8
		Hydrogen (HENG)	0.0	0.0	0.0	0.3	0.4	0.5	0.5
		RNG	0.0	0.4	1.6	2.7	3.6	4.4	5.0
		Fossil Gas	35.2	30.4	25.5	19.5	14.2	9.3	5.0
		Electric	2.6	4.9	6.3	7.3	8.0	8.5	8.9
		Biomass	1.4	1.1	1.0	0.8	0.6	0.5	0.3
		Delivered Fuels	13.4	9.3	6.1	4.5	3.0	1.6	0.3
	Reference	Total	53.0	50.5	49.3	48.5	47.9	47.3	46.9
Figure 3-6: Commercial Space Heating Fuel Consumption [tBtu/year]	High Electrification	Efficiency Gains	0.0	2.7	5.7	9.0	12.6	16.6	21.0
		Hydrogen HENG	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		RNG	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Fossil Gas	18.9	15.0	11.8	8.8	6.0	3.1	0.1
		Electric	0.5	2.1	3.3	4.1	4.9	5.5	6.2
		Biomass	0.5	0.4	0.3	0.2	0.1	0.1	0.0
		Petroleum	5.5	4.4	3.4	2.6	1.7	0.9	0.0
		District	0.0	0.0	0.0	0.0	0.1	0.1	0.1
	Selective Electrification	Efficiency Gains	0.0	2.2	4.6	7.3	10.3	13.5	17.1
		Hydrogen HENG	0.0	0.0	0.0	0.1	0.2	0.3	0.3
		RNG	0.0	0.2	0.7	1.2	1.6	2.0	2.2
		Fossil Gas	18.9	15.7	12.7	9.9	7.3	4.9	2.6
		Electric	0.5	1.8	2.7	3.3	3.9	4.4	4.9
		Biomass	0.5	0.4	0.3	0.3	0.2	0.2	0.1
		Petroleum	5.5	4.4	3.4	2.6	1.7	0.9	0.0
		District	0.0	0.0	0.0	0.0	0.1	0.1	0.1
	Reference	Total	25.3	24.6	24.5	24.8	25.4	26.3	27.4

Variable	Scenario	Data Series	2020	2025	2030	2035	2040	2045	2050
Figure 3-9: Road Transport Energy Consumption [Trillion Btu/year]	High Electrification	Efficiency Gains	0.0	8.0	16.3	24.0	31.6	39.8	48.6
		Gasoline - All	63.9	49.1	36.6	26.0	16.7	8.3	0.0
		Natural Gas - All	4.2	3.8	3.6	3.4	3.3	3.3	3.3
		Diesel - HD	16.5	15.7	12.3	9.0	5.9	3.0	0.0
		Diesel - MD	4.7	3.9	2.9	2.3	1.8	1.5	1.2
		Electric - HD	0.0	0.0	1.6	3.2	4.7	6.4	8.2
		Electric - MD	0.0	0.0	0.1	0.1	0.1	0.1	0.1
		Electric - LD	0.5	3.7	6.5	9.0	11.5	14.2	17.0
	Selective Electrification	Efficiency Gains	0.0	7.9	15.4	22.2	28.8	36.1	43.9
		Gasoline - All	63.9	49.1	36.6	26.0	16.7	8.3	0.0
		Natural Gas - All	4.2	3.9	3.7	3.6	3.6	3.6	3.7
		Diesel - HD	16.5	15.7	14.1	12.6	11.4	10.4	9.5
		Diesel - MD	4.7	3.9	2.9	2.3	1.8	1.5	1.2
		Electric - HD	0.0	0.0	0.6	1.2	1.7	2.3	3.0
		Electric - MD	0.0	0.0	0.1	0.1	0.1	0.1	0.1
		Electric - LD	0.5	3.7	6.5	9.0	11.5	14.2	17.0
	Reference	Total	89.8	84.3	79.9	76.9	75.7	76.6	78.4
Figure 3-11: Industrial Energy Consumption [Trillion Btu/year]	High Electrification	Electricity	7.7	8.2	8.8	9.1	9.4	9.9	10.3
		Other	17.8	19.0	20.3	21.0	21.8	22.8	23.8
		Local Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Natural Gas	10.7	11.5	12.3	12.7	13.2	13.7	14.4
	Selective Electrification	Electricity	7.7	8.2	8.8	9.1	9.4	9.9	10.3
		Other	17.8	19.0	20.3	21.0	21.8	22.8	23.8
		Local Hydrogen	0.0	0.0	0.0	0.0	3.3	6.9	10.8
		Natural Gas	10.7	11.5	12.3	12.7	9.9	6.9	3.6
	Reference	Total	36.3	38.7	41.4	42.9	44.5	46.5	48.7

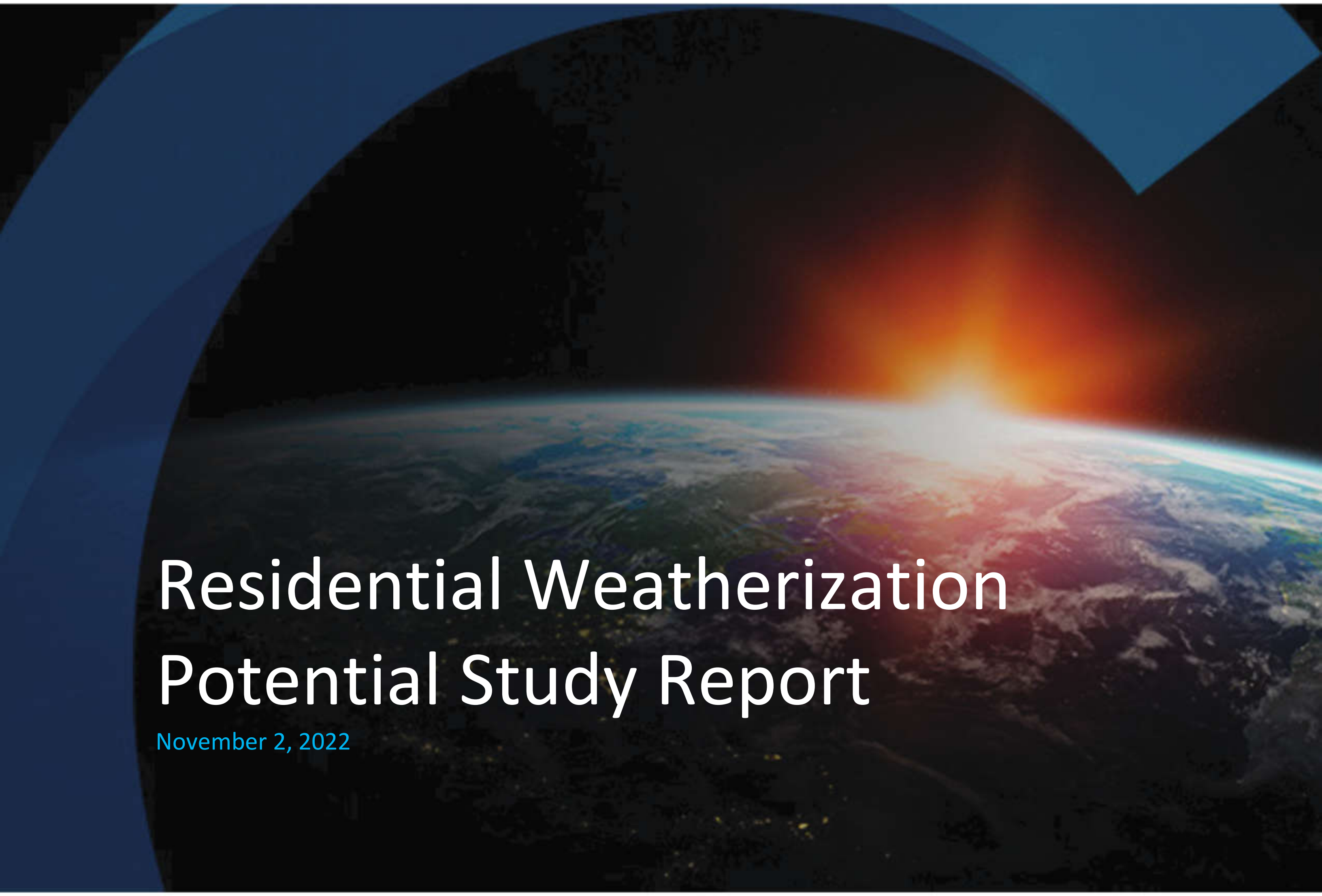
Appendix F

National Fuel Gas Distribution Corporation

December 22, 2022

National Fuel®

CADMUS



Residential Weatherization Potential Study Report

November 2, 2022

Prepared for:

National Fuel Gas Distribution Corporation

6363 Main Street

Williamsville, NY 14221

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Executive Summary

National Fuel Gas Distribution Corporation (Distribution) asked Cadmus to conduct a potential assessment of natural gas energy efficiency from residential weatherization measures within its New York service territory. Cadmus developed a model with a 20-year planning horizon (2023 through 2042) of residential retrofit weatherization measures to estimate technical potential and examine three market potential scenarios.

Distribution's New York service territory extends from the Pennsylvania boarder with Cattaraugus and Allegany counties, north to Niagara county.[1] In fiscal year 2022, Distribution delivered 55,630,000 Mcf of natural gas to 511,900 residential New York customers.

Objectives and Approach

There were four primary objectives for this residential weatherization potential study:

- Estimate residential weatherization potential
- Identify key measures, or measure combinations, for delivering weatherization savings for Distribution's residential customers
- Outline program offerings that could support Distribution in meeting the goals of New York State's Climate Leadership and Community Protection Act
- Identify budget requirements for a program that would support the Climate Leadership and Community Protection Act goals

The study provided energy efficiency estimates for three residential segments:

SINGLE FAMILY (1-4 UNITS)	**MULTIFAMILY (5+ UNITS)**	**MANUFACTURED HOMES**

Cadmus estimated technical potential based on natural gas end-use and energy conservation weatherization measure engineering calculations, accounting for fuel shares, current market saturations, and technical feasibility considerations. Calculations and input assumptions are based on Distribution's account and sales forecasts, Distribution's 2021 residential survey, NYSERDA's 2019 single-family *Residential Building Stock Assessment* (RBSA),[2] the *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs - Residential, Multi-Family, and Commercial/Industrial*,

1 National Fuel Gas Distribution Corporation. Updated February 19, 2019. "National Fuel Gas Supply Corporation System Map." https://informationalpostings.natfuel.com/supply/market/MktgNews/Presentations/documents/NFGSC_SYSTEM_MAP.pdf

2 New York State Energy Research and Development Authority. 2019. *Residential Building Stock Assessment.* https://www.nyserda.ny.gov/About/Publications/Building-Stock-and-Potential-Studies/Residential-Building-Stock-Assessment

known as the *New York Technical Resource Manual* (TRM),[3] regional U.S. Census Bureau data from the American Community Survey,[4] and supplemental Cadmus data from prior potential assessments. Cadmus estimated end-use and savings in three existing residential construction segments[5] (single family, multifamily, and manufactured homes), in three customer program pathways (market rate [standard income], moderate income, and low income), and based on natural gas end-use components (furnaces, boilers, and other natural gas heat sources such as wall units).

TECHNICAL POTENTIAL represents the theoretical maximum available savings opportunities. It assumes that all technically feasible energy efficiency weatherization measures available at the time of the study will be implemented, regardless of their costs or of any market barriers.

Cadmus modeled three market scenarios, described below. The aggressive savings scenario program costs were driven by achieving the savings target while the high and moderate budget scenario savings were constrained by available budget. Budget assumptions are based on projected measure incentives that covered a portion or all of the installed measure costs depending on customer pathway (market rate, moderate income, or low income) and on the estimated budget to administer the measure or program. Administration budgets were informed by benchmarking similar programs offered by NYSERDA and other regional utilities.

AGGRESSIVE SAVINGS represent a savings rate and investment designed to capture total achievable technical potential savings by 2050. Achievable technical potential is assumed to be 85% of the total technical potential and represents presumed voluntary participation with all cost barriers removed. In this scenario, costs are determined by the savings target.

HIGH BUDGET represents a scenario where savings are constrained by the available budget, with a year-1 budget of approximately $5 million, a year-2 budget of approximately $10 million, a year-3 budget of approximately $15 million, and a year-4 budget of approximately $20 million, and budgets growing at an 18% rate from years 5 through 10 and then leveling off.

MODERATE BUDGET represents a scenario where savings are constrained by the available budget, with a year-1 budget of approximately $4 million, a year-2 budget of approximately $6 million, a year-3 budget of approximately $8 million, and a year-4 budget of approximately $10 million, and budgets growing at an 18% rate from years 5 through 10 and then leveling off.

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3 New York State Joint Utilities. August 30, 2021. *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs – Residential, Multi-Family, and Commercial/Industrial Measures*, Version 9. https://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/72c23decff52920a85257f1100671bdd/$FILE/NYS%20TRM%20V9.pdf

4 U.S. Census Bureau. Last revised November 23, 2021. *American Community Survey*. https://www.census.gov/programs-surveys/acs/data.html

5 Cadmus did not assess the potential for new construction buildings in this study scope.

Refer to the *Methodology* section for a more comprehensive discussion of Cadmus' methodology.

Results

Potential estimate results are shown in Table 1 through Table 6. For additional discussion of Cadmus' results, refer to the *Analysis Results* section of this report.

Table 1. 2042 Residential Forecast Sales (Final Year Baseline Sales)

	NATURAL GAS ENERGY	**58,266,499 Mcf in 2042**

Table 2. Cumulative 20-Year Residential Weatherization Potential Savings Estimates, 2023–2042

Natural Gas Potential in Mcf	Technical Potential	Aggressive Savings Potential	High Budget Potential	Moderate Budget Potential
Natural Gas Energy Efficiency	**7,961,299**	**5,898,069**	**2,685,966**	**1,429,124**
(Percentage of Baseline Sales)	(14%)	(10%)	(5%)	(2%)

Table 3. Cumulative 20-Year Residential Weatherization Potential Savings Estimates by Segment, 2023–2042

Natural Gas Energy Efficiency by Segment in Mcf	Technical Potential	Aggressive Savings Potential	High Budget Potential	Moderate Budget Potential
Single Family	7,220,706	5,321,089	2,625,821	1,398,025
Multifamily	508,438	408,847	39,630	20,518
Manufactured Home	232,155	168,133	20,515	10,581

Table 4. Cumulative Residential Weatherization Potential Savings by Scenario and Customer Program, 2 Year, 5 Year, 10 Year, and 20 Year

Natural Gas Energy Efficiency by Scenario and Customer Program Pathway in Mcf	2 Year	5 Year	10 Year	20 Year
Aggressive Savings Scenario				
Low Income	66,225	263,631	948,011	3,453,588
Moderate Income	17,461	69,511	249,960	910,601
Market Rate	29,413	117,089	421,050	1,533,879
Aggressive Savings Total	**113,099**	**450,232**	**1,619,021**	**5,898,069**
High Budget Scenario				
Low Income	18,483	129,656	521,171	1,583,405
Moderate Income	9,228	64,734	219,760	537,967
Market Rate	21,241	82,235	240,164	564,594
High Budget Total	**48,952**	**276,625**	**981,095**	**2,685,966**
Moderate Budget Scenario				
Low Income	10,230	58,911	224,226	678,893
Moderate Income	5,115	29,456	112,113	339,446
Market Rate	8,122	36,783	136,268	410,786
Moderate Budget Total	**23,467**	**125,150**	**472,607**	**1,429,124**

Table 5. Cumulative Residential Weatherization Potential Budget by Scenario and Customer Program, 2 Year, 5 Year, 10 Year, and 20 Year

Budget by Scenario and Customer Program Pathway in $ (Millions)	2 Year	5 Year	10 Year	20 Year
Aggressive Savings Scenario				
Low Income	$29.9M	$116.7M	$413.3M	$1,492.8M
Moderate Income	$8.6M	$31.9M	$108.5M	$382.4M
Market Rate	$6.0M	$20.6M	$64.8M	$217.1M
Aggressive Savings Total	**$44.5M**	**$169.2M**	**$586.6M**	**$2,092.3M**
High Budget Scenario				
Low Income	$7.0M	$42.2M	$162.2M	$485.8M
Moderate Income	$3.9M	$20.4M	$64.0M	$154.4M
Market Rate	$4.6M	$15.2M	$39.9M	$91.8M
High Budget Total	**$15.5M**	**$77.8M**	**$266.1M**	**$732.0M**
Moderate Budget Scenario				
Low Income	$4.4M	$20.6M	$71.8M	$210.5M
Moderate Income	$2.7M	$11M	$35.3M	$100.2M
Market Rate	$3.0M	$9.5M	$27.0M	$72.2M
Moderate Budget Total	**$10.1M**	**$41.1M**	**$134.0M**	**$382.9M**

Budget totals may not sum due to rounding.

Table 6. Cost-Effectiveness Five-Year Results by Scenario and Test, 2023–2027

Scenario and Customer Program Pathway	Societal Cost Test (SCT)			Utility Cost Test (UCT)		
	Benefits	Costs	Benefit/Cost Ratio	Benefits	Costs	Benefit/Cost Ratio
Aggressive Savings Scenario						
Low Income	$54,585,861	$118,098,453	0.46	$29,831,156	$116,698,764	0.26
Moderate Income	$14,415,811	$33,146,190	0.43	$7,882,088	$30,156,040	0.26
Market Rate	$24,261,970	$50,888,635	0.48	$13,153,366	$20,589,477	0.64
Portfolio Total	**$93,263,642**	**$202,133,278**	**0.46**	**$50,866,610**	**$167,444,280**	**0.30**
High Budget Scenario						
Low Income	$26,922,274	$37,157,659	0.72	$14,525,834	$37,093,721	0.39
Moderate Income	$13,454,096	$19,775,425	0.68	$7,263,372	$18,330,885	0.40
Market Rate	$16,372,479	$34,323,960	0.48	$8,906,497	$15,213,901	0.59
Portfolio Total	**$56,748,849**	**$91,257,044**	**0.62**	**$30,695,704**	**$70,638,507**	**0.43**
Moderate Budget Scenario						
Low Income	$12,129,838	$18,401,033	0.66	$6,561,945	$18,373,884	0.36
Moderate Income	$6,069,403	$10,759,483	0.56	$3,285,456	$10,127,538	0.32
Market Rate	$7,302,116	$18,078,592	0.40	$3,963,963	$9,534,478	0.42
Portfolio Total	**$25,501,357**	**$47,239,107**	**0.54**	**$13,811,365**	**$38,035,900**	**0.36**

Introduction

National Fuel Gas Distribution Corporation (Distribution) asked Cadmus to conduct a potential assessment of natural gas energy efficiency from residential weatherization measures within its New York service territory. In light of recent legislation within New York State, Distribution wanted to understand the extent of available savings within the residential sector and the cost implications for capturing those savings.

In 2019 New York State passed the Climate Leadership and Community Protection Act, which set aggressive greenhouse gas reduction targets[6] and required New York to reduce economy-wide greenhouse gas emissions by 40% by 2030 and by no less than 85% by 2050 from 1990 levels. The law created a Climate Action Council charged with developing the pathway for meeting these targets. The *Draft Scoping Plan,*[7] filed in 2021, identified six key sectors, with buildings as one of these sectors. The recommended strategies for existing buildings is focused on improving the building envelope and converting to emissions-free systems within buildings. Specifically relating to weatherization, the *Draft Scoping Plan* called for "…energy efficiency improvements in all buildings, with the emphasis on improvements to building envelopes (air sealing, insulation, and replacing poorly performing windows) to reduce energy demand by 30% to 50%."[8]

The estimates developed by a potential study can help to inform program goals and planning. Cadmus conducted a 20-year planning horizon potential study (2023 through 2042) of retrofit residential

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6 New York State. Accessed in August 2022. "Climate Leadership and Community Protection Act." https://climate.ny.gov/Our-Climate-Act

7 New York State. Accessed in August 2022. *Climate Action Council Draft Scoping Plan.* https://climate.ny.gov/Our-Climate-Act/Draft-Scoping-Plan

8 The *Draft Scoping Plan* does not offer details for this target. This analysis found a technical potential from residential weatherization measures that represents 14% of baseline sales; however, savings at the individual project level ranged from 11% to 24% of average customer natural gas usage, depending on the customer segment and program pathway. Given as a percentage of home heating natural gas usage, savings ranged from 14% to 30%, approaching the lower range of the percentage stated in the *Draft Scoping Plan*.

weatherization measures in Distribution's territory, including improvements to building envelopes, such as air sealing, insulation, and window upgrades. Cadmus followed five steps for this study:

STEP 1	Conduct a weatherization program review of New York and other regional utility programs to inform best practice program design, weatherization measures to be included in this study, and budgets.
STEP 2	Collect additional data to inform measure characterization and as assessment of potential. This includes Distribution data, TRM data assumptions, U.S. Census data, and supplemental Cadmus data.
STEP 3	Estimate technical potential, which is the theoretical maximum available savings if all residential existing buildings participate and install weatherization improvement measures over a 20-year study horizon.
STEP 4	Develop program design scenarios and estimates of potential for aggressive, high budget, and moderate budget weatherization savings and budget projections (over 20-years).
STEP 5	Conduct a benefit/cost assessment (BCA) for each scenario and customer program pathway over five years (2023 through 2027) following the New York State BCA Framework.[9]

9 New York State Public Service Commission. Issued January 21, 2016. *Case 14-M-0101, Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision, Order Establishing the Benefit Cost Analysis Framework.*

Analysis Results

The results in this section represents the culmination of steps 1 through 5 (outlined in the *Introduction*). Refer to the *Methodology* section for a more comprehensive discussion of Cadmus' methodology.

Residential Weatherization Potential

While this potential study does not provide a specific weatherization target for program planning, the research was timed to provide input on future Distribution program planning. Results from the study provide foundational information for Distribution in assessing the appropriate goals, priorities, and program budgets.

Cadmus estimated four types of potential, outlined below: technical potential and three scenarios that represent a subset of the technical potential.

TECHNICAL POTENTIAL represents the theoretical maximum available savings opportunities. It assumes that all technically feasible energy efficiency weatherization measures available at the time of the study will be implemented, regardless of their costs or of any market barriers.

AGGRESSIVE SAVINGS is a scenario that represents a savings rate and investment designed to capture total achievable technical potential savings by 2050. Achievable technical potential is assumed to be 85% of total technical potential and represents presumed voluntary participation with all cost barriers removed. In this scenario, costs are determined by the savings target.

HIGH BUDGET is a scenario where savings are constrained by the available budget, with a year-1 budget of approximately $5 million, a year-2 budget of approximately $10 million, a year-3 budget of approximately $15 million, and a year-4 budget of approximately $20 million, and with the budget growing at an 18% rate from years 5 to 10 and then leveling off.

MODERATE BUDGET is a scenario where savings are constrained by the available budget, with a year-1 budget of approximately $4 million, a year-2 budget of approximately $6 million, a year-3 budget of approximately $8 million, and a year-4 budget of approximately $10 million, and with the budget growing at an 18% rate from years 5 to 10 and then leveling off.

For each type of potential, Cadmus segmented savings estimates into three building types (single family one to four units, multifamily five or more units, and manufactured homes), three customer program pathways (market rate, moderate income, and low income), and three natural gas end uses (furnaces, boilers, and other natural gas heat sources). Cadmus characterized nine measure categories for a combination of building type, customer pathway, and end use to estimate potential savings:

- Air leakage sealing
- Insulation - attic
- Insulation - rim and band joist
- Insulation - wall
- Insulation - floor
- Window - upgrade

- Window - low-E storm
- Insulation - boiler hot water and steam pipe
- Duct sealing and insulation

Cadmus estimated potential for existing construction only and did not assess the potential for new construction buildings (which were excluded from the study scope). New construction weatherization potential is relatively small due to New York State building energy codes and the number of new construction customers is small in comparison to Distribution's existing residential customer base.

The three scenarios included three pathways for customers to participate in energy efficiency programs (market rate, moderate income, and low income). Cadmus designed these pathways to expand upon existing NYSERDA-based programs for these customer types. For example, market-rate eligible customers can currently participate in NYSERDA's Comfort Homes program, which provides "good," "better," and "best" customer options based on different weatherization improvement criteria. For this study, Cadmus expanded these options by adding more eligible measures to create a "gold" customer option. In addition, Cadmus leveraged NYSERDA's EmPower program data to inform Distribution's moderate- and low-income customer pathways. Similar to the EmPower program offerings, Cadmus included budget for home audits, energy education, and health and safety. Cadmus focused on weatherization measures and did not include direct install measures.

The technical potential and the scenario results are presented below.

Technical Potential

The residential cumulative potential of weatherization measures for natural gas sales in 2042 is 14% over the 20-year horizon, as shown in Table 7.

Table 7. Residential Weatherization Cumulative Technical Potential Compared to Sales, 2042

Distribution 2042 Residential Forecasted Sales	2042 Weatherization Technical Potential	Percentage of Sales
58,266,499 Mcf	7,961,299 Mcf	14%

With the technical potential broken down by segment and customer pathway, single family–low income and single family–market rate represent the majority of the potential savings with a combined 79%, as shown in Table 8. The low-income pathways represent about 51% of the overall potential, with market rate representing 36% and moderate income representing 13%. The low-income segment has higher technical potential than the market-rate segment because of the high population of low-income customers in the Distribution service area, the higher number of low-income customers who have not weatherized their homes (per NYSERDA's 2019 RBSA), and the TRM weatherization assumptions (which specify a lower existing insulation R-value for low-income customers).

Table 8. Residential Weatherization Cumulative Technical Potential by Segment, 2042

Segment	Pathway	Weatherization Technical Potential 2042 (Mcf)	Percentage of Total Technical Potential (Mcf)
Single family (1-4 units)	Low income	3,583,453	45%
	Moderate income	968,501	12%
	Market rate	2,668,752	34%
Multifamily (5+ units)	Low income	383,287	5%
	Moderate income	76,657	1%
	Market rate	48,493	1%
Manufactured homes	Low income	112,838	1%
	Moderate income	30,497	0%
	Market rate	88,820	1%

The residential weatherization cumulative 20-year technical potential by end use results in 76% of the potential coming from natural gas furnaces, as shown in Table 9. This expected result is primarily driven by the Distribution 2021 residential survey where 71% of surveyed customers said they use central furnace heating.

Table 9. Residential Weatherization Cumulative Technical Potential by End Use, 2042

Natural Gas End-Use	Weatherization Technical Potential 2042 (Mcf)	Percentage of Total Technical Potential (Mcf)
Furnace	6,086,160	76%
Boiler	1,773,615	22%
Other Natural Gas Heat	101,524	1%

Table 10 shows the cumulative 20-year technical potential by measure. While window upgrades have the highest individual cumulative technical potential (32%), shell insulation measures combined represent 46% of potential for all the weatherization measures.

Table 10. Residential Weatherization Cumulative Technical Potential by Measure, 2042

Measure	Weatherization Technical Potential 2042 (Mcf)	Percentage of Total Technical Potential (Mcf)
Air Leakage Sealing	1,170,326	15%
Insulation - Attic	1,264,249	16%
Insulation - Rim and Band Joist	395,138	5%
Insulation - Wall	1,328,507	17%
Insulation - Floor	665,892	8%
Window - Upgrades	2,582,581	32%
Window - Low-E Storm	455,068	6%
Insulation - Boiler Hot Water and Steam Pipe	82,497	1%
Duct Sealing and Insulation	17,042	0%

Aggressive Savings Scenario Potential

The aggressive savings scenario is a subset of the technical potential that represents presumed voluntary participation with all cost barriers removed. For this scenario, Cadmus applied an 85%

maximum achievability factor to the total technical potential. Cadmus also applied a ramp rate over the 20-year study period to account for program acquisition ramp time in the early years and ramp down in the later years as the market gets more saturated. Figure 1 shows the annual (incremental) savings and annual budgets for each customer program pathway.

Figure 1. Aggressive Savings Scenario Annual Savings and Budgets by Customer Program Pathway

Table 11 shows savings for the first five years (annually) for the aggressive savings scenario by customer pathway. In 2027, the estimated savings is 132,220 Mcf, with the low-income segment representing 59% of the total.

Table 11. Aggressive Savings Scenario Residential Annual Weatherization Potential Savings and Customer Program Pathway, 2023–2027

Savings and Customer Program Pathway in Mcf	2023	2024	2025	2026	2027
Low Income - Aggressive Savings	19,126	47,098	55,009	64,977	77,421
Moderate Income - Aggressive Savings	5,043	12,418	14,504	17,132	20,413
Market Rate - Aggressive Savings	8,495	20,918	24,432	28,859	34,386
Aggressive Savings Total	**32,664**	**80,435**	**93,945**	**110,969**	**132,220**

As shown in Table 12, the estimated annual budget for the aggressive savings scenario by customer pathway totals roughly $169 million over the five-year period. The low-income and moderate-income segments cost more to implement (per Mcf) than the market-rate segment due the higher incentives and implementation costs.

Table 12. Aggressive Savings Scenario Residential Annual Weatherization Potential Budget and Customer Program Pathway, 2023–2027

Budget and Customer Program Pathway in $ (Millions)	2023	2024	2025	2026	2027
Low Income - Aggressive Savings	$9.0M	$20.9M	$24.3M	$28.6M	$33.9M
Moderate Income - Aggressive Savings	$2.8M	$5.8M	$6.6M	$7.7M	$9.0M
Market Rate - Aggressive Savings	$2.2M	$3.8M	$4.2M	$4.8M	$5.5M
Aggressive Savings Total	**$14M**	**$30.5M**	**$35.2M**	**$41.1M**	**$48.4M**

Budget totals may not sum due to rounding.

High Budget Scenario Potential

The high budget scenario, a subset of the technical potential, is based on budget constraints ranging from $5 million in 2023 to $20 million in 2026. After 2026, the budgets grow at an 18% rate from years 5 through 10 and then level off as the custom programs reach maturity. Figure 2 shows the annual (incremental) savings and annual budgets for each customer program pathway.

Figure 2. High Budget Scenario Annual Savings and Budgets by Customer Program Pathway

Table 13 shows the high budget scenario savings for the first five years (annually) by customer pathway. The estimated savings is 12,478 Mcf in 2023 and 93,093 Mcf in 2027, with the majority of savings coming from low-income eligible customers.

Table 13. High Budget Scenario Residential Annual Weatherization Potential Savings and Customer Program Pathway, 2023–2027

Savings and Customer Program Pathway in Mcf	2023	2024	2025	2026	2027
Low Income - High Budget	4,143	14,340	25,494	39,303	46,377
Moderate Income - High Budget	2,068	7,160	12,728	19,623	23,155
Market Rate - High Budget	6,267	14,974	17,469	19,965	23,560
High Budget Total	**12,478**	**36,474**	**55,691**	**78,890**	**93,092**

The estimated annual budget for the high budget scenario by customer pathway totals roughly $78 million over the five-year period, as shown in Table 14.

Table 14. High Budget Scenario Residential Annual Weatherization Potential Budget and Customer Program Pathway, 2023–2027

Budget and Customer Program Pathway in $ (Millions)	2023	2024	2025	2026	2027
Low Income - High Budget	$2.0M	$5.0M	$8.3M	$12.4M	$14.5M
Moderate Income - High Budget	$1.3M	$2.6M	$4.0M	$5.8M	$6.7M
Market Rate - High Budget	$1.8M	$2.8M	$3.2M	$3.5M	$3.9M
High Budget Total	**$5.1M**	**$10.4M**	**$15.5M**	**$21.7M**	**$25.1M**

Budget totals may not sum due to rounding.

Table 15 shows the high budget scenario broken down to show the customer savings, cost, and incentive per average project. The per-customer amounts represent a 20-year average of the total savings, cost, or incentive by the total number of installed projects. This average is across all building segments, where most projects occur within single-family homes. Table 15 also shows the retail rate program design, similar to NYSERDA's Comfort Homes program, broken out by measure installation option (good, better, best, and gold). Under the best and gold options, the project cost includes windows and is notably expensive.

Table 15. High Budget Scenario Average Per Customer Savings, Project Cost, and Incentive

Customer Program Pathway	Average Savings Per Customer (Mcf)	Average Cost Per Project ($)	Average Incentive Per Customer ($)
Low Income	20.02	$5,172	$5,158
Moderate Income	19.99	$5,067	$4,548
Market Rate	15.68	$5,185	$1,543
Market Rate - Good	12.00	$3,018	$921
Market Rate - Better	20.78	$4,432	$2,231
Market Rate - Best	26.33	$17,000	$3,420
Market Rate - Gold	26.78	$17,583	$4,195
Total Average	**18.92**	**$5,156**	**$4,126**

Moderate Budget Scenario Potential

Similar to the high budget scenario, the moderate budget scenario is based on budget constraints ranging from $4 million in 2023 to $10 million in 2026. After 2026, the budgets grow at an 18% rate from years 5 to 10 and then level off as the custom programs reach maturity. Figure 3 shows the annual (incremental) savings and annual budgets for each customer program pathway.

Figure 3. Moderate Budget Scenario Annual Savings and Budgets by Customer Program Pathway

Table 16 shows the moderate budget scenario savings for the first five years (annually) by customer pathway. The estimated savings is 7,270 Mcf in 2023 and 41,179 Mcf in 2027.

Table 16. Moderate Budget Scenario Residential Annual Weatherization Potential Savings and Customer Program Pathway, 2023–2027

Savings and Customer Program Pathway In Mcf	2023	2024	2025	2026	2027
Low Income - Moderate Budget	3,183	7,047	12,503	16,595	19,582
Moderate Income - Moderate Budget	1,591	3,524	6,252	8,298	9,791
Market Rate - Moderate Budget	2,496	5,626	6,874	9,982	11,805
Moderate Budget Total	**7,270**	**16,197**	**25,629**	**34,875**	**41,179**

The estimated annual budget for the moderate budget scenario by customer pathway totals roughly $41 million over the five-year period, as shown in Table 17.

Table 17. Moderate Budget Scenario Cumulative Residential Weatherization Potential Budget and Customer Program Pathway, 2023–2027

Budget and Customer Program Pathway in $ (Millions)	2023	2024	2025	2026	2027
Low Income - Moderate Budget	$1.6M	$2.8M	$4.3M	$5.5M	$6.4M
Moderate Income - Moderate Budget	$1.1M	$1.6M	$2.3M	$2.8M	$3.2M
Market Rate - Moderate Budget	$1.3M	$1.7M	$1.9M	$2.2M	$2.5M
Moderate Budget Total	**$4.0M**	**$6.0M**	**$8.5M**	**$10.5M**	**$12.0M**

Budget totals may not sum due rounding.

Table 18 shows the customer savings, cost, and incentive per average project for the moderate budget scenario. The per-customer values are similar to the high budget scenario but vary slightly due to differences in annual program participation estimates for each customer pathway. The average cost per project varies between low income and moderate income by $100. This slight difference is driven by additional heathy and safety funds for the low-income customer pathway. Details on the input assumptions within this study can be found in the *Methodology* section.

Table 18. Program-Level Moderate Budget

Customer Program Pathway	Average Savings Per Customer (Mcf)	Average Cost Per Project ($)	Average Incentive Per Customer ($)
Low Income	21.43	$5,298	$5,284
Moderate Income	21.43	$5,198	$4,665
Market Rate	15.68	$5,185	$1,543
Market Rate - Good	12.00	$3,018	$921
Market Rate - Better	20.78	$4,432	$2,231
Market Rate - Best	26.33	$17,000	$3,420
Market Rate - Gold	26.78	$17,583	$4,195
Total Average	**19.39**	**$5,237**	**$3,822**

Benefit/Cost Analysis

This section presents the results of the BCA for each scenario (aggressive savings, high budget, and moderate budget). Cadmus calculated the BCA following the New York State BCA Framework, *CE-07 Utility-Administered Energy Efficiency BCA Filing Requirement Guidance*,[10] and used specific Distribution economic assumptions consistent with NYSERDA's recent 2022 *Statewide Low- to Moderate-Income Portfolio Implementation Plan*.[11] The BCA results for the societal cost test (SCT) include the added benefits associated with reduced carbon emissions. The BCA results presented within this study show the first five years of the 20-year study period to better reflect Distribution's near-term program planning timeframe. Table 19 shows the BCA results for each customer program pathway for both the SCT and utility cost test (UCT) cost-effectiveness perspectives over the five years (2023 through 2027). Overall, the SCT is higher than the UCT, in part due to the inclusion of the carbon emission benefits. However, none of the customer program pathways passed the BCA for either the SCT or the UCT. The weatherization measures Cadmus assessed have high costs and are not expected to pass the BCA.

10 New York State Department of Public Service, Office of Clean Energy. May 14, 2018. *Benefit Cost Analysis Filing Requirement Guidance*. https://www3.dps.ny.gov/Utility-Administered%20Energy%20Efficiency%20Portfolio_5.14.2018.pdf

11 New York State Energy Research and Development Authority. *Statewide Low- to Moderate-Income Portfolio Implementation Plan*, Version 2. Case 18-M-0084 and Case 14-M-0094. p. 94. https://www.nyserda.ny.gov/All-Programs/Low-to-moderate-Income-Programs/LMI-Stakeholder-Resources-New-Efficiency-New-York

Table 19. Cost-Effectiveness Five-Year Results by Scenario and Test, 2023–2027

Scenario and Customer Program Pathway	Societal Cost Test (SCT)			Utility Cost Test (UCT)		
	Benefits	Costs	Benefit/Cost Ratio	Benefits	Costs	Benefit/Cost Ratio
Aggressive Savings Scenario						
Low Income	$54,585,861	$118,098,453	0.46	$29,831,156	$116,698,764	0.26
Moderate Income	$14,415,811	$33,146,190	0.43	$7,882,088	$30,156,040	0.26
Market Rate	$24,261,970	$50,888,635	0.48	$13,153,366	$20,589,477	0.64
Portfolio Total	**$93,263,642**	**$202,133,278**	**0.46**	**$50,866,610**	**$167,444,280**	**0.30**
High Budget Scenario						
Low Income	$26,922,274	$37,157,659	0.72	$14,525,834	$37,093,721	0.39
Moderate Income	$13,454,096	$19,775,425	0.68	$7,263,372	$18,330,885	0.40
Market Rate	$16,372,479	$34,323,960	0.48	$8,906,497	$15,213,901	0.59
Portfolio Total	**$56,748,849**	**$91,257,044**	**0.62**	**$30,695,704**	**$70,638,507**	**0.43**
Moderate Budget Scenario						
Low Income	$12,129,838	$18,401,033	0.66	$6,561,945	$18,373,884	0.36
Moderate Income	$6,069,403	$10,759,483	0.56	$3,285,456	$10,127,538	0.32
Market Rate	$7,302,116	$18,078,592	0.40	$3,963,963	$9,534,478	0.42
Portfolio Total	**$25,501,357**	**$47,239,107**	**0.54**	**$13,811,365**	**$38,035,900**	**0.36**

Table 20 shows the results by scenario for each installation year.

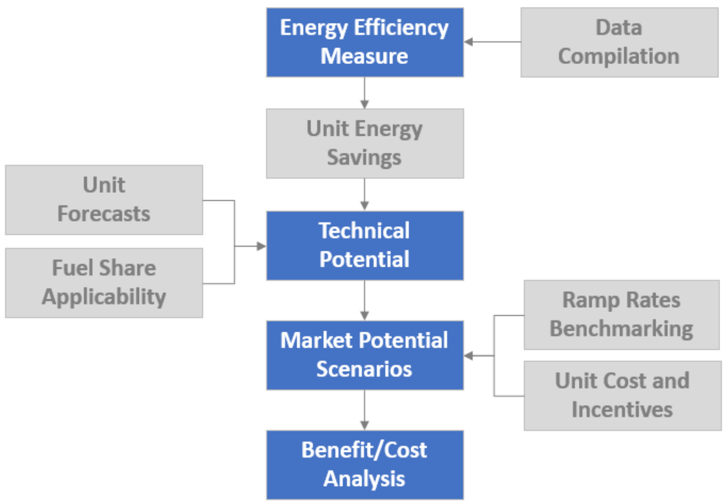
Table 20. Cost-Effectiveness Portfolio Results by Installation Year, Scenario, and Test, 2023–2027

Scenario and Year	Societal Cost Test (SCT)			Utility Cost Test (UCT)		
	Benefits	Costs	Benefit/Cost Ratio	Benefits	Costs	Benefit/Cost Ratio
Aggressive Savings Scenario						
2023	$6,904,457	$16,401,462	0.42	$3,864,012	$13,884,806	0.28
2024	$17,441,585	$36,371,661	0.48	$9,863,945	$30,174,394	0.33
2025	$19,462,512	$42,054,142	0.46	$10,507,673	$34,815,976	0.30
2026	$22,818,483	$49,199,920	0.46	$12,113,389	$40,650,127	0.30
2027	$26,636,605	$58,106,093	0.46	$14,517,592	$47,918,977	0.30
5 Year Portfolio Total	**$93,263,642**	**$202,133,278**	**0.46**	**$50,866,610**	**$167,444,280**	**0.30**
High Budget Scenario						
2023	$2,655,364	$6,346,750	0.42	$1,505,846	$4,835,149	0.31
2024	$7,646,263	$13,300,017	0.57	$4,229,626	$9,655,345	0.44
2025	$11,628,876	$18,442,900	0.63	$6,323,990	$14,088,825	0.45
2026	$16,140,306	$24,589,951	0.66	$8,511,553	$19,495,577	0.44
2027	$18,678,041	$28,577,427	0.65	$10,124,688	$22,563,611	0.45
5 Year Portfolio Total	**$56,748,849**	**$91,257,044**	**0.62**	**$30,695,704**	**$70,638,507**	**0.43**
Moderate Budget Scenario						
2023	$1,541,752	$4,499,309	0.34	$871,837	$3,884,062	0.22
2024	$3,377,737	$7,060,380	0.48	$1,867,294	$5,676,130	0.33
2025	$5,334,656	$9,541,818	0.56	$2,908,793	$7,806,809	0.37
2026	$7,064,118	$12,176,762	0.58	$3,725,706	$9,672,540	0.39
2027	$8,183,093	$13,960,839	0.59	$4,437,735	$10,996,359	0.40
5 Year Portfolio Total	**$25,501,357**	**$47,239,107**	**0.54**	**$13,811,365**	**$38,035,900**	**0.36**

Methodology

For this study, Cadmus estimated the natural gas energy efficiency potential of residential weatherization measures for Distribution customers over a 20-year time horizon (2023 through 2042). For each year, the number of estimated household installations influenced the total annual natural gas savings and cost for each measure combination. Figure 4 provides a general overview of the process and inputs required to estimate technical potential and conduct market potential scenarios.

Figure 4. Overview of Energy Efficiency Potential Study Approach



Cadmus first compiled data to inform the natural gas end-use and energy conservation weatherization measure engineering calculations:

- Distribution's account and sales forecast
- Distribution's 2021 residential survey
- NYSERDA's 2019 single-family building assessment (RBSA) and potential study
- *New York Technical Resource Manual*
- U.S. Census Bureau *American Community Survey*
- Cadmus' review of regional weatherization programs
- Supplemental data from Cadmus' prior potential assessments

Energy efficiency reductions are dependent on the segment, measures installed, and heating end use. The combinations of all these variables influence and are used to determine energy savings, costs to the utility, and costs to the customer. Table 21 shows each variable, with each unique measure combination having a differing amount of energy savings and costs for each year modeled.

Table 21. Modeling Variations by Variable

Customer Program Pathway	Segment	Measure	Heating End Use
• Low Income • Moderate Income • Market Rate ▪ Market Rate - Good ▪ Market Rate - Better ▪ Market Rate - Best ▪ Market Rate - Gold	• Single Family (1-4 units) • Multifamily (5+ units) • Manufactured Homes	• Air Leakage Sealing • Insulation - Attic • Insulation - Rim and Band Joist • Insulation - Wall • Insulation - Floor • Window • Window - Low-E Storm • Insulation - Boiler Hot Water and Steam Pipe • Duct Sealing and Insulation	• Furnace • Boiler • Other Natural Gas Heat

Table 22 shows key inputs and data sources.

Table 22. Key Measure Data Sources

Input	Residential Weatherization Measures
Sector Unit Forecast	Distribution's account and sales forecast, Distribution's 2021 residential survey, NYSERDA's 2019 RBSA, U.S Census Bureau data from the American Community Survey, Cadmus research
Saturation and Fuel Shares	Distribution's 2021 residential survey, NYSERDA's 2019 RBSA, Cadmus research
Energy Savings	New York TRM v9, NYSERDA's 2019 RBSA, other statewide TRMs (Wisconsin and Iowa), Cadmus research
Equipment and Labor Costs	NREL's "National Residential Efficiency Measures Database," [a] RSMeans cost data, [b] Regional Technical Forum data, other statewide TRMs (Wisconsin and Iowa), Cadmus research
Program Administration Budgets	Review of regional weatherization programs (NYSERDA, Mass Save)
Measure Life	New York TRM v9
Applicability Factors	Distribution's 2021 residential survey, NYSERDA's 2019 RBSA, Cadmus research

[a] National Renewable Energy Laboratory. "National Residential Efficiency Measures Database." https://remdb.nrel.gov/
[b] RSMeans. Cost Data. https://www.rsmeans.com/products/online

Cadmus developed unit forecasts for the retrofit weatherization measures. Retrofit measures encompass existing building upgrades (weatherization measures) that can theoretically be completed any time over the study forecast. Unlike natural replacement measures (such as natural gas furnaces), the timing of retrofit savings is not determined by turnover rates (such as a natural gas furnace being replaced on failure based on equipment life).

To determine measure-specific unit forecasts (used to estimate technical potential), Cadmus considered four factors:

- ***Sector unit forecasts*** are estimates of the number of residential homes derived from Distribution's customer database and load forecast data.
- ***Measure saturations (units per sector unit)*** are estimates of the number of units per home or per square foot in Distribution's natural gas service territories.

- ***Applicability factors (technical feasibility percentage and measure competition share)*** are the percentage of homes or buildings that can feasibly receive the measure and the percentage of eligible installations, after accounting for competition with similar measures.
- ***Turnover rates (for natural replacement measures)*** are used to determine the percentage of units that can be installed in each year for natural replacement measures. The turnover rate equals 1 divided by the measure's effective useful life.

Figure 5 illustrates the general equation Cadmus used to determine the number of units for each measure over the study forecast horizon. By default, the turnover rate for retrofit measures is 100% (so turnover is not accounted for in these permutations.)

Figure 5. Unit Forecast Equation

Weatherization Program Review

To inform the potential assessment, Cadmus reviewed best practices for implementing successful residential energy efficiency weatherization programs that surround Distribution within the Northeast. Cadmus reviewed weatherization programs such as NYSERDA's Assisted Home Performance with ENERGY STAR program, NYSERDA's EmPower New York program, NYSERDA's Comfort Homes program, Mass Save's weatherization programs (offering home insulation and windows), Efficiency Maine Trust's Home Energy Savings program, and Connecticut utilities' Home Energy Solution programs (offered to market-rate and income-qualified customers). From this benchmarking, Cadmus identified common natural gas weatherization measures to assess along with the differing pathways (market rate, moderate income, and low income).

In addition, Cadmus collected program budget data for each customer program pathway. Cadmus leveraged data from NYSERDA's EmPower program for low-income and moderate-income customers and from Mass Save's weatherization program to inform the market-rate customer program pathway.

Building on the benchmarking data, Cadmus characterized the three pathways, as discussed below.

Market Rate

Market-rate (or standard-income) eligible customers can currently participate in NYSERDA's Comfort Homes program, which provides "good," "better," and "best" customer options based on different weatherization improvement criteria. For this study, Cadmus expanded these options by adding more eligible measures to create a "gold" customer option, as shown in Table 23. This pathway assumes that the customer will pay a majority portion of the project costs (50% to 80%). Cadmus prorated multifamily incentives to account for the decrease in savings compared to single-family applications.

Table 23. Market-Rate Measure Pathway Criteria

Market-Rate Measure	Good	Better	Best	Gold
Air Leakage Sealing	X	X	X	X
Insulation - Attic	X	X	X	X
Insulation - Rim and Band Joist	X	X	X	X
Insulation - Wall	-	X	X	X
Insulation - Floor	-	X	X	X
Window Upgrade	-	-	X	X
Window - Low-E Storm	-	-	X	X
Insulation - Boiler Hot Water and Steam Pipe	-	-	-	X
Duct Sealing and Insulation	-	-	-	X
Single Family and Manufactured Homes – Incentive (up to)	**$1,000**	**$2,500**	**$4,000**	**$5,000**
Multifamily per Apartment – Incentive (up to)	**$250**	**$550**	**$1,000**	**$1,250**

Low Income

Cadmus leveraged NYSERDA's EmPower program data to inform Distribution's low-income customer pathway. The low-income pathway would ideally follow the EmPower New York income eligibility guidelines.[12] Cadmus did include budget for home audits and energy education ($300 per home) and for health and safety ($500 per home)—we focused on weatherization measures and did not include direct install measures. Cadmus assumed that 10% of the multifamily audit/educational services, health and safety, and measure installation costs will be covered by the building owner. We also assumed that 100% of project costs for single family and manufactured homes would be covered by the utility.

Moderate Income

Cadmus leveraged NYSERDA's EmPower program and Assisted Home Performance with ENERGY STAR program data to inform Distribution's moderate-income customer pathway. Similar to the low-income pathway, the moderate-income pathway would ideally follow NYSERDA's eligibility criteria for moderate-income homes.[13] Cadmus did include budget for home audits and energy education ($300 per home) and for health and safety ($400 per home). We assumed that single family and manufactured homeowners would pay 10% of the project costs (excluding the audit and health and safety costs). For multifamily homes, Cadmus assumed that 20% of the project costs would be covered by the building owner.

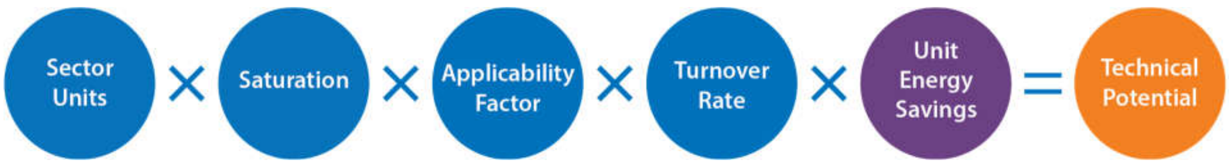
[12] New York State Energy Research and Development Authority. Accessed in August 2022. "EmPower New York Income Eligibility Guidelines 2021-2022." https://www.nyserda.ny.gov/All-Programs/empower-new-york/eligibility-guidelines

[13] New York State Energy Research and Development Authority. Accessed in August 2022. "Income Guidelines for Assisted Home Performance with ENERGY STAR 2021-2022." https://www.nyserda.ny.gov/All-Programs/Assisted-Home-Performance-with-ENERGY-STAR/Income-Guidelines

Technical Potential

Technical potential represents the available weatherization savings if 100% of customers participate and savings are only limited by technical constraints, regardless of their costs or of any market barriers. After Cadmus estimated the unit energy savings for each weatherization measure and developed sector unit forecasts for each permutation of each energy efficiency measure, we multiplied the two to create 20-year estimates of the technical potential beginning in 2023. Figure 6 shows the equation for calculating technical potential. Blue components make up the measure unit calculation (shown previously in Figure 5.).

Figure 6. Technical Potential Equation



Scenario Modeling

Using the same methodology as applied to calculate technical potential, Cadmus modeled three separate scenarios, shown in Table 24. We used the same measure-level savings and incremental costs for all three scenarios.

Table 24. Market Potential Scenarios

Scenario	Goal	Criteria
Aggressive Savings	Meets a specified savings target, regardless of budget	Achievable technical potential (85% of technical) by 2050
High Budget	Maximizes savings given a high program budget	Budget parameters: year 1: approx. $5 million, year 2: approx. $10 million, year 3: approx. $15 million, year 4: approx. $20 million, year 5–year 20: 18% annual increase, year 11–year 20: flat budget
Moderate Budget	Maximizes savings given a moderate program budget	Budget parameters: year 1: approx. $4 million, year 2: approx. $6 million, year 3: approx. $8 million, year 4: approx. $10 million, year 5–year 10: 18% annual increase, year 11–year 20: flat budget

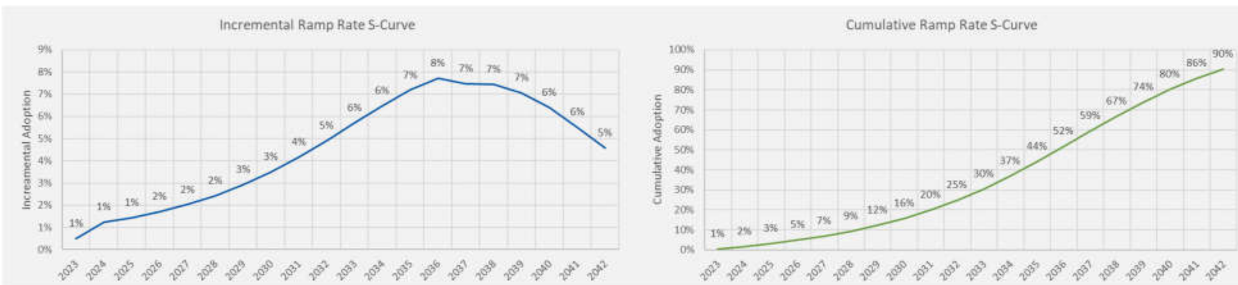
Aggressive Savings

The aggressive savings scenario is a subset of the technical potential. Cadmus used two key inputs to estimate aggressive potential from technical potential for a measure: the ramp rate and a maximum achievability percentage.

This scenario applies an 85% maximum achievability percentage to the total technical potential and represents presumed voluntary participation with all cost barriers removed. The 85% maximum achievability factor has been used in other jurisdictions, including in the Northwest where the use of maximum achievability factors has been applied to energy efficiency measures as part of the planning process.[14]

Cadmus applied a ramp rate over the 20-year study period to account for program acquisition ramp time in the early years and ramp down in the later years as the market becomes saturated. We used ramp rates to determine the incremental, year-to-year aggressive savings potential for an energy efficiency weatherization measure. Ramp rates are not sector-specific; rather, they are generalized S-curves that assume an initial saturation rate in the study's first year (2023) before progressing to the maximum achievability percentage on an incremental basis. Cadmus applied a retrofit curve for the weatherization measures, as shown in Figure 7.

Figure 7. Aggressive Ramp Rate S-Curves



Cadmus applied budget assumptions to the aggressive savings scenario. To estimate the budget for each customer pathway, we allocated budgets into four categories: implementation, administration, marketing, and evaluation services. Cadmus created the base budget assumptions from our program review and then adjusted these to account for differences between each scenario. We applied several assumptions for each budget category to the aggressive savings scenario. All budget estimates included an annual 2% inflation adder.

IMPLEMENTATION	Variable cost assumption ($/Mcf) dependent on the amount of annual savings. The variable cost estimate varied by customer pathway.
ADMINISTRATION	Fix cost assumption to operate the customer program pathway.
MARKETING	Fix cost assumption to market the customer program pathway. For the aggressive savings scenario Cadmus applied a 75% increase to the marketing budget to support the increased savings under this scenario.
EVALUATION SERVICES	Fix cost assumption to operate the customer program pathway.

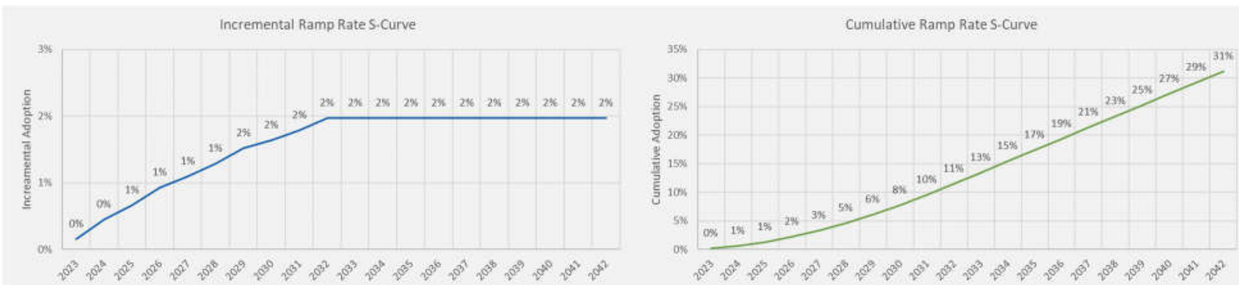
[14] Northwest Power and Conversation Council. Accessed in August 2022. *2021 Power Plan*. "Achievable Technical Potential Overview." https://www.nwcouncil.org/2021powerplan_conservation-methodologies/#_AchTechPot

High Budget

The high budget scenario is a subset of the technical potential and is based on budget constraints ranging from approximately $5 million in 2023 to approximately $20 million in 2026. After 2026, the budget grows at an 18% rate from year 5 through year 10 and then levels off as the custom programs reach maturity. Cadmus created the high budget scenario showing the cumulative potential for each year for the number of household installations, savings, incentives, and total project budgets. Participation was limited by the 2023 through 2026 budgets' criteria.

Cadmus applied a retrofit curve for the weatherization measures, as shown in Figure 8.

Figure 8. High Ramp Rate S-Curves



Cadmus applied budget assumptions by category to the high budget scenario. All budget estimates included an annual 2% inflation adder.

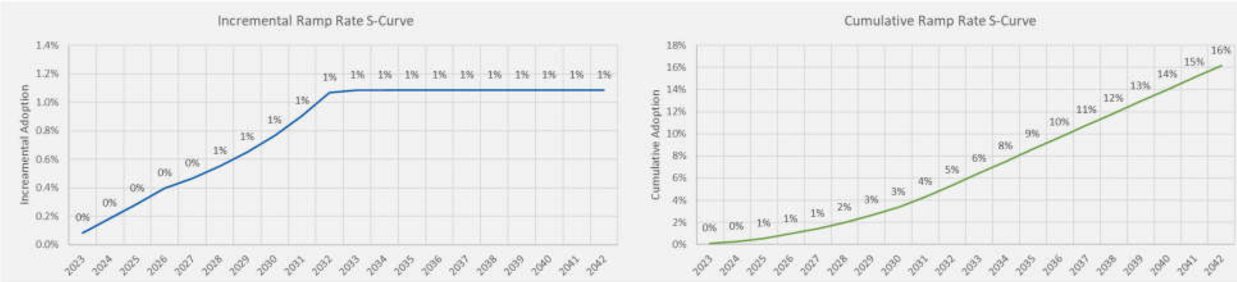
IMPLEMENTATION	Variable cost assumption ($/Mcf) dependent on the amount of annual savings. The variable cost estimate varied by customer pathway.
ADMINISTRATION	Fix cost assumption to operate the customer program pathway.
MARKETING	Fix cost assumption to market the customer program pathway. For the high budget scenario Cadmus applied a 25% increase to the marketing budget to support the increased savings under this scenario.
EVALUATION SERVICES	Fix cost assumption to operate the customer program pathway.

Moderate Budget

The moderate budget scenario is a subset of the technical potential and is based on budget constraints ranging from approximately $4 million in 2023 to approximately $10 million in 2026. After 2026, the budget grows at an 18% rate from year 5 through year 10 and then levels off as the custom programs reach maturity. Similar to the high budget scenario, Cadmus created the moderate budget scenario showing the cumulative potential for each year for number of household installations, savings, incentives, and total project budgets.

Cadmus applied a retrofit curve for the weatherization measures, as shown in Figure 9.

Figure 9. Moderate Ramp Rate S-Curves



Cadmus applied budget assumptions by category to the moderate budget scenario. All budget estimates included an annual 2% inflation adder.

IMPLEMENTATION	Variable cost assumption ($/Mcf) dependent on the amount of annual savings. The variable cost estimate varied by customer pathway.
ADMINISTRATION	Fix cost assumption to operate the customer program pathway.
MARKETING	Fix cost assumption to market the customer program pathway (Cadmus did not apply a marketing adder).
EVALUATION SERVICES	Fix cost assumption to operate the customer program pathway.

Benefit/Cost Analysis

To assess the cost-effectiveness of Distribution's weatherization program plan, Cadmus calculated two benefit-cost tests—the SCT and the UCT—following the New York State BCA framework[15] and subsequent New York Department of Public Service guidance.[16] The primary BCA test in New York State is the SCT, which includes several components:

- The cost and benefits experienced by program administrators
- The costs and benefits to program participants
- Valuing of the benefits associated with avoided carbon dioxide emissions

A benefit/cost ratio that is equal to or greater than 1.0 indicates that a portfolio is cost-effective from the test perspective. Table 25 lists the benefits and costs considered in calculating benefit/cost ratios using the SCT for the weatherization portfolio.

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[15] New York State Public Service Commission. January 21, 2016. "Order Establishing the Benefit Cost Analysis Framework." Case 14-M-0101, supra.

[16] New York State Department of Public Service, Office of Clean Energy. May 14, 2018. "Utility-Administered Energy Efficiency BCA Filing Requirement Guidance." Clean Energy Guidance CE-07.

Table 25. Summary of Costs and Benefit Components of the Societal Cost Test

Type	Component
Costs	Measure equipment and installation (labor) costs
	Program administrator costs (for program administration including marketing, implementation contractor, and evaluation, measurement, and verification)
Benefits	Avoided energy costs (natural gas and fuel oil)
	Deferred capacity costs for natural gas (generation, transmission, and distribution)
	Reduced carbon dioxide emissions

In addition to the SCT, Cadmus also calculated the UCT to provide additional context. The UCT is similar to the SCT but considers only costs and benefits applicable to the program administrators, including direct incentives paid by program administrators. Participants' contribution to measure costs and reduced carbon dioxide emissions are not included in the UCT. In addition to each benefit and cost detailed below, Cadmus used a discount rate of 6.48% based on Distribution's weighted average cost of capital and consistent with Distribution's economic assumptions used in NYSERDA's recent 2022 *Statewide Low- to Moderate-Income Portfolio Implementation Plan*.

- **Incremental measure equipment costs** include equipment and labor required to purchase a measure and sustain savings over each measure's effective useful life. These are the total measure costs borne by participants and/or program administrators (such as program administrator incentives offsetting all or some of the participants' cost).
- **Program administrator costs** include forecasted estimates from program administrators for each weatherization scenario and include administration, marketing, implementation, and evaluation, measurement, and verification costs.
- **Avoided energy costs** reflect the direct (primary) and secondary energy savings from installing energy efficiency measures. Avoided natural gas energy costs are based on the 2018 Congestion Assessment and Resource Integration Study 2 forecasted natural gas prices. Cadmus assigned an end-use load shape to each energy efficiency measure based on the U.S. Department of Energy's Building America energy simulations.[17]
- **Avoided and deferred capacity costs** include the deferred natural gas distribution costs, relying on the most recently filed data from Distribution's marginal cost of service studies.
- **Reduced carbon dioxide emissions** reflect the economic value of avoided carbon dioxide emissions consistent with the New York State Department of Environmental Conservation's social cost of carbon.[18]

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17 National Renewable Energy Laboratory. Accessed in August 2022. "Commercial and Residential Hourly Load Profiles for All TMY3 Locations in the United States." https://data.openei.org/submissions/153

18 New York State Department of Environmental Conservation. Accessed in August 2022. "Appendix: NYS Social Cost Values." https://www.dec.ny.gov/docs/administration_pdf/vocapp22.pdf

Appendix G

National Fuel Gas Distribution Corporation

December 22, 2022

National Fuel®

NATIONAL FUEL GAS DISTRIBUTION CORP.
NEW YORK DIVISION

RESIDENTIAL HOME ENERGY ANALYSIS
May 2021 cost updates by CJ Brown 8/2022

Baseline - Typical WNY Home

End Use	Energy Type	Equipment	First Cost	Annual Usage		Annual Cost
I. ENTIRE HOME ENERGY						
Space Heating	Gas	Furnace	$ 4,060	819	ccf	$ 643
Fans & Pumps	Electric	Fans		552	kWh	$ 69
Space Cooling	Electric	Central AC	$ 3,500	1,341	kWh	$ 168
Water Heating	Gas	Storage Tank	$ 2,026	200	ccf	$ 157
Cooking	Gas	Range	$ 1,000	35	ccf	$ 27
Clothes Drying	Gas	Dryer	$ 870	35	ccf	$ 27
Refrigerator	Electric			846	kWh	$ 106
Other Plug Loads	Electric			6,364	kWh	$ 796
Total Gas			$ 7,956	1,089	ccf	$ 855
Total Electric			$ 3,500	8,551	kWh	$ 1,069
Total Home			**$ 11,456**			**$ 1,924**
II. SPACE HEATING & COOLING ONLY						
Space Heating	Gas	Furnace	$ 4,060	819	ccf	$ 643
Fans & Pumps	Electric	Fans		552	kWh	$ 69
Space Cooling	Electric	Central AC	$ 3,500	1,341	kWh	$ 168
Total Gas			$ 4,060	819	ccf	$ 643
Total Electric			$ 3,500	1,893	kWh	$ 237
Total Home			**$ 7,560**			**$ 880**

III. ASSUMPTIONS

First Costs include Rebates/Incentives from:

National Fuel (Gas)	Furnace	$ 400
	Storage Tank	$ 75
	Dryer	$ 50
		$ 525
National Grid (Electric)		

Annual Costs based on:

National Fuel Gas Cost	$ 0.785	per ccf
National Grid Electric Cost	$ 0.125	per kWh

NATIONAL FUEL GAS DISTRIBU
NEW YORK DIVISION

RESIDENTIAL HOME ENERGY A
May 2021

Option 1: 100% Electrification with Air Source Heat Pump

End Use	Energy Type	Equipment	First Cost	Annual Usage		Annual Cost
I. ENTIRE HOME ENERGY						
Space Heating	Electric	Cold Climate ASHP	$ 17,500	10,527	kWh	$ 1,316
Fans & Pumps	Electric	Fans		494	kWh	$ 62
Space Cooling	Electric	Cold Climate ASHP		969	kWh	$ 121
Water Heating	Electric	ASHP Storage Tank	$ 2,800	1,077	kWh	$ 135
Cooking	Electric	Range	$ 750	821	kWh	$ 103
Clothes Drying	Electric	Dryer	$ 770	821	kWh	$ 103
Refrigerator	Electric			846	kWh	$ 106
Other Plug Loads	Electric			6,364	kWh	$ 796
Total Gas						
Total Electric			$ 21,820	21,919	kWh	$ 2,740
Total Home			**$ 21,820**			**$ 2,740**
II. SPACE HEATING & COOLING						
Space Heating	Electric	Cold Climate ASHP	$ 17,500	10,527	kWh	$ 1,316
Fans & Pumps		Fans		494	kWh	$ 62
Space Cooling	Electric	Cold Climate ASHP		969	kWh	$ 121
Total Gas						
Total Electric			$ 17,500	11,990	kWh	$ 1,499
Total Home			**$ 17,500**			**$ 1,499**

ASHP - Air Source Heat Pump

III. ASSUMPTIONS

First Costs include Rebates/Inc

National Fuel (Gas)

National Grid (Electric)	Cold Climate ASHP	$ 4,700
	ASHP Storage Tank	$ 700
		$ 5,400

Annual Costs based on:

National Fuel Gas Cost	$ 0.785	per ccf
National Grid Electric Cost	$ 0.125	per kWh

NATIONAL FUEL GAS DISTRIBU
NEW YORK DIVISION

RESIDENTIAL HOME ENERGY A
May 2021

Option 2: 100% Electrification with Geothermal Heat Pump

End Use	Energy Type	Equipment	First Cost	Annual Usage		Annual Cost
I. ENTIRE HOME ENERGY						
Space Heating	Electric	GSHP	$ 41,000	4,645	kWh	$ 581
Fans & Pumps	Electric	Fans & Pumps		1404	kWh	$ 176
Space Cooling	Electric	GSHP		458	kWh	$ 57
Water Heating	Electric	WWHP	$ 5,000	630	kWh	$ 79
Cooking	Electric	Range	$ 750	821	kWh	$ 103
Clothes Drying	Electric	Dryer	$ 770	821	kWh	$ 103
Refrigerator	Electric			846	kWh	$ 106
Other Plug Loads	Electric			6,364	kWh	$ 796
Total Gas						
Total Electric			$ 47,520	15,989	kWh	$ 1,999
Total Home			**$ 47,520**			**$ 1,999**
II. SPACE HEATING & COOLING						
Space Heating	Electric	GSHP	$ 41,000	4,645	kWh	$ 581
Fans & Pumps	Electric	Fans & Pumps		1404	kWh	$ 176
Space Cooling	Electric	GSHP		458	kWh	$ 57
Total Gas						
Total Electric			$ 41,000	6,507	kWh	$ 813
Total Home			**$ 41,000**			**$ 813**

GSHP - Ground Source Heat Pump

III. ASSUMPTIONS

First Costs include Rebates/Inc

National Fuel (Gas)

National Grid (Electric)	GSHP	$ 7,050	
	WWHP	$ 350	
		$ 7,400	

Annual Costs based on:

National Fuel Gas Cost	$ 0.785	per ccf
National Grid Electric Cost	$ 0.125	per kWh

NATIONAL FUEL GAS DISTRIBU
NEW YORK DIVISION

RESIDENTIAL HOME ENERGY A
May 2021

Option 3: Hybrid Gas/Electric HVAC System

End Use	Energy Type	Equipment	First Cost	Annual Usage		Annual Cost
I. ENTIRE HOME ENERGY						
Space Heating	Gas	Furnace	$ 4,060	393	*ccf*	$ 309
Fans & Pumps	Electric	ASHP & Fans	$ 5,040	3,988	*kWh*	$ 499
Space Cooling	Electric	Standard ASHP	$ -	1,341	*kWh*	$ 168
Water Heating	Gas	Tankless	$ 3,800	148	*ccf*	$ 116
Cooking	Gas	Range	$ 1,000	35	*ccf*	$ 27
Clothes Drying	Gas	Dryer	$ 870	35	*ccf*	$ 27
Refrigerator	Electric			846	*kWh*	$ 106
Other Plug Loads	Electric			6,364	*kWh*	$ 796
Total Gas			$ 9,730	611	*ccf*	$ 480
Total Electric			$ 5,040	12,539	*kWh*	$ 1,567
Total Home			**$ 14,770**			**$ 2,047**
II. SPACE HEATING & COOLING						
Space Heating	Gas	Furnace	$ 4,060	393	*ccf*	$ 309
Fans & Pumps	Electric	ASHP & Fans	$ 5,040	3,988	*kWh*	$ 499
Space Cooling	Electric	Standard ASHP	$ -	1,341	*kWh*	$ 168
Total Gas			$ 4,060	393	*ccf*	$ 309
Total Electric			$ 5,040	5,329	*kWh*	$ 666
Total Home			**$ 9,100**			**$ 975**

ASHP - Air Source Heat Pump

III. ASSUMPTIONS

First Costs include Rebates/Inc

National Fuel (Gas)	Furnace	$ 1,000
	Tankless	$ 200
	Dryer	$ 50
		$ 1,250
National Grid (Electric)	Standard ASHP	$ -

Annual Costs based on:

National Fuel Gas Cost	$ 0.785	per ccf
National Grid Electric Cost	$ 0.125	per kWh

Heating and cooling energy use were modeled in Carrier HAP 5.11

Fan and pump energy was included for all cases. Furnace blowers are included here also.

Baseline - Typical WNY Home

The gas use of 820 ccf indicates an 80% AFUE furnace.

The hybrid heat pump model has a 95% AFUE furnace.

Do we want the baseline to represent the an old baseline or the current tehnology (95% AFUE)
A fleet average of 85% to 90% is another possibility.
We have simulations of each of these AFUE points.

		85% AFUE			
Space Heating	Gas	Furnace	$ 3,000	771	*ccf*
Fans & Pumps	Electric	Fans		552	*kWh*
Space Cooling	Electric	Central AC	$ 4,000	1,341	*kWh*

		90% AFUE			
Space Heating	Gas	Furnace	$ 3,000	728	*ccf*
Fans & Pumps	Electric	Fans		552	*kWh*
Space Cooling	Electric	Central AC	$ 4,000	1,341	*kWh*

		95% AFUE			
Space Heating	Gas	Furnace	$ 3,000	690	*ccf*
Fans & Pumps	Electric	Fans		552	*kWh*
Space Cooling	Electric	Central AC	$ 4,000	1,341	*kWh*

The ground source heat pump includes a domestic water heater.
In cooling mode, the GSHP rejects heat to the DHW system.
In heating mode, DHW is heated at the 4.1 avg. COP of the GSHP

Appendix H

National Fuel Gas Distribution Corporation

December 22, 2022

National Fuel

2021 Residential Market Study

August 5, 2021

JRB INSIGHTS
Market Research Services

Table of Contents

Introduction

National Fuel's Energy Services Department identified the need to conduct a follow-up to the market study last conducted in 2016.

The study goals were to obtain updated statistics regarding National Fuel's potential market, available market, served market, and penetrated market through all of National Fuel's service territory in western New York and northwestern Pennsylvania.

Additional study objectives included:

- Current and preferred energy source, equipment replacement intent and purchase factors considered for the following:
    - Home heating
    - Water heating
    - Cooking
    - Clothes drying
- Air conditioner ownership
- Fireplace ownership and energy source used
- Outdoor natural gas appliance ownership
- Emergency/Backup generator ownership
- Awareness and attitudes towards carbon footprint reduction/renewable energy programs and systems
- Household dwelling characteristics

Methodology

A mixed mode methodology was used to accomplish the objectives of this study as follows:

- A total of 800 surveys were completed (400 in New York and 400 in Pennsylvania).
- To ensure the surveys were completed proportionate to customer counts within each state, the following county quotas were established:

New York Counties	Sample Size
Allegany	8
Cattaraugus	11
Chautauqua	33
Erie	287
Genesee	8
Livingston	1
Monroe	1
Niagara	41
Ontario	2
Steuben	5
Wyoming	3
Total	400

Pennsylvania Counties	Sample Size
Armstrong	1
Butler	5
Cameron	3
Clarion	7
Clearfield	14
Crawford	36
Elk	15
Erie	185
Forest	2
Jefferson	13
McKean	13
Mercer	55
Venango	30
Warren	21
Total	400

- A sample size of 800 for the overall service territory including western New York and northwestern Pennsylvania provides a sampling error of ± 3.5% at a 95% confidence level. A sample size of 400 for each state provides a sampling error of ± 5.0% at a 95% confidence level.
- In addition to county quotas, household income quotas were established to ensure a representative sampling of the market was achieved according to household income census data for National Fuel's service territory.

Methodology

- Respondents were qualified for participation in this study by determining that they met the following qualifications:
  - Make or share in utility decisions for their household including selection of appliances, utilities, and payment of monthly utility bills including gas and electric.
  - Resident of one of the counties in National Fuel's service territory.
  - Resident of select towns within each county. National Fuel provided JRB Insights with a list of towns within each county that were within their service territory (see appendix).
  - For security purposes and to eliminate any study bias, anyone employed in market research, the media including online social media, advertising, or by a utility or energy related company will not be eligible to participate in this study.
- 775 online surveys were completed with residents who were part of an online research panel who met the required qualifications. 25 telephone surveys were completed from a purchased telephone sample of listed, unlisted and cell phone telephone numbers.
- The surveys were completed June 14-July 17, 2021.
- The survey was developed by representatives of JRB Insights in conjunction with representatives of National Fuel to generate responses pertaining to the objectives listed on the Introduction slide. The survey was 10 minutes in length. JRB Insights programmed and hosted the survey.

Data Analysis

The Total Service Territory survey results have been weighted to account for the greater number of customers in the New York Service Territory (506,690) compared to the Pennsylvania Territory (187,640). The Total survey results have been weighted so New York respondents account for 73% of the total and Pennsylvania respondents represent 27% of the total. Results within each state have not been weighted.

The study results have been analyzed by State, Household Income and whether the respondents use natural gas for any end use including heating, cooking and drying their clothes. Significant findings from this analysis are noted in the report. The results have also been compared to the 2016 results.

Tables that provide detailed results for each question by these variables are included as a separate document. When reviewing the tables, please be aware of the following:

- In some tables, percentages will add up to slightly more than 100% due to rounding, or percentages will exceed 100% if multiple answers were provided for a specific question.
- The tables feature significance testing to help identify key areas of difference within each segment.

Management Summary

Management Summary

The results from this study indicates National Fuel continues to have a stronger Available Market (95.2%) and Served Market (92.5%) in New York compared to Pennsylvania (87.8% and 83.5% respectively). These market metrics are statistically similar to the 2016 Residential Survey results.

	New York		Pennsylvania		Total Territory *	
	2016	2021	2016	2021	2016	2021
Available Market	96.2%	95.2%	88.8%	87.8%	94.1	93.2%
Served Market/Market Share	94.0%	92.5%	82.0%	83.5%	90.6	90.1%

* The Total Service Territory was weighted to reflect higher number of customers in New York Service. Results within each state have not been weighted.

Market Share

National Fuel's overall market share of 92.5% in New York is significantly higher than their Market Share in Pennsylvania (83.5%). The New York Market share is particularly high for Home Heating (83.3%), while the market share for Water Heating decreased significantly from 84.8% in 2016 to 73.0% in 2021. The share of market for these end uses is much lower in Pennsylvania (Home Heating: 72.8% and Water Heating: 61.3%). The largest Market Share gap between the service territories continues to be Clothes Drying where New York's Market Share was 50.8% compared to 33.3% in Pennsylvania.

Market Penetration

National Fuel's Market Penetration (percent of households in the available market on or near National Fuel's mainline who use natural gas) is slightly higher in New York (97.1%) than in Pennsylvania (95.2%). The New York Market Penetration by end use is highest for Home Heating (87.4%) and Water Heating (76.6%). Market Penetration for these end uses is significantly lower in Pennsylvania (Home Heating: 82.9% and Water Heating: 69.8%). The market penetration for Water Heating in New York decreased significantly from 88.1% in 2016 to 76.6% in 2021.

Market Saturation

National Fuel's Market Saturation (percent of households using natural gas for specific end use among National Fuel households) was comparable between New York and Pennsylvania for all but one of the end uses. The Market Saturation was significantly higher in New York for Clothes Drying (54.9%) than in Pennsylvania (39.8%). Home Heating Market Saturation was comparable between New York (90.0%) and Pennsylvania (87.1%). The market saturation for Water Heating in New York decreased significantly from 90.2% in 2016 to 78.9 in 2021.

Management Summary

Planned Replacement of End Uses

11%-15% of the 2021 respondents were planning to replace the following end uses within the next 12 months. A significantly higher percent of the respondents in 2021 stated they are planning to replace their water heater. Planned replacement of end uses did not vary significantly by state.

Planning To Replace Within The Next 12 Months

	2016	2021
Primary Heating	11%	15%
Water Heating	8%	**13%** [1]
Ranges, Cooktop or Oven	10%	13%
Clothes Dryers	10%	11%

[1] Significantly higher than 2016

End Use Purchase Factors

Cost-based factors continue to be mentioned most frequently in the purchase of new end use appliances. *Improved efficiency-lower energy costs* and *Purchase, installation costs* were the factors mentioned most often across all of the end uses.

Renewable Energy

While there was lower awareness of government initiatives to lower emissions and lower interest in air or ground source heat pumps; there was moderate interest in paying more in their monthly utility bills to reduce their carbon footprint.

- 69% were not aware of government energy plans or policies that set emission goals to address climate change
- There was low interest in air source heat pumps (11% likely to purchase in next 3-5 years) or ground source heat pumps (5% likely to purchase in next 3-5 years).
- There was low current use of renewable energy sources (14% use solar energy or wind power on-site or as part of a network).
- 63% would be willing to pay $10-$50 more in their utility bills to reduce their home’s carbon footprint
- 62% would be willing to pay $5-$15 more in their utility bills to use low-carbon electric power alternatives

Market Statistics

Potential Market / Available Market / Served Market

		Total Service Territory *	
		2016	2021
Potential Market	**The total number of households within National Fuel's service territory** *(All survey respondents)*	100.0%	100.0%
Available Market	**The number of gas customers and non-customers on or near National Fuel's main line** *(Have a natural gas furnace, water heater, clothes dryer, range, cooktop, oven, fireplace or grill in home OR natural gas service is available within the immediate vicinity of home)*	94.1%	93.2%
Served Market/ Market Share	**The total number of National Fuel customers** *(Have a natural gas furnace, water heater, clothes dryer, range, cooktop, oven, fireplace or grill in home)*	90.6%	90.1%
	N	800	800

* The Total Service Territory has been weighted to account for the greater number of customers in the New York Service Territory. Results within each state have not been weighted.

	New York		Pennsylvania	
	2016	2021	2016	2021
Potential Market	100.0%	100.0%	100.0%	100.0%
Available Market	**96.2%** $_P$	**95.2%** $_P$	88.8%	87.8%
Served Market/Market Share	**94.0%** $_P$	**92.5%** $_P$	82.0%	83.5%
N	400	400	400	400

$_P$ Significantly higher than PA

Market Statistics: Market Share

The percentage of households in the Potential Market* who use natural gas for the specific end use

	Total		New York		Pennsylvania	
	2016	2021	2016	2021	2016	2021
Market Share Overall	90.6%	90.1%	**94.0%** P	**92.5%** P	82.0%	83.5%
Market Share by End Use:						
Heating	83.0%	80.4%	**86.8%** P	**83.3%** P	73.8%	72.8%
Water Heating	**79.4%** 1	69.9%	**84.8%** P1	73.0% P	65.8%	61.3%
Ranges	52.9%	54.4%	54.3%	56.0%	49.3%	50.0%
Cooktops	4.1%	6.1%	4.5%	6.5%	3.0%	5.3%
Oven	1.8%	3.3%	2.0%	3.3%	1.0%	3.3%
Clothes Dryer	48.8%	46.0%	**56.5%** P	**50.8%** P	29.5%	33.3%
Fireplaces	18.8%	18.3%	**20.5%** P	**20.0%** P	14.3%	13.5%
Grills	24.5%	25.6%	**26.3%** P	25.8%	20.3%	25.5%
N	800	800	400	400	400	400

* Potential Market=The total number of households within National Fuel's service territory

1 Significantly higher than 2021
P Significantly higher than PA

Market Statistics: Market Penetration

The percentage of households in the Available Market* who use natural gas for the specific end use

	Total		New York		Pennsylvania	
	2016	2021	2016	2021	2016	2021
Market Penetration Overall	96.3%	96.6%	**97.7%** P	97.1%	92.4%	95.2%
Market Penetration by End Use:						
Heating	88.2%	86.2%	**90.1%** P	87.4%	83.1%	82.9%
Water Heating	**84.3%** 1	74.9%	**88.1%** P1	76.6% P	74.1%	69.8%
Ranges	56.2%	58.3%	56.4%	58.8%	55.5%	57.0%
Cooktops	4.4%	6.6%	4.7%	6.8%	3.4%	6.0%
Oven	1.9%	3.5%	2.1%	3.4%	1.1%	**3.7%** 2
Clothes Dryer	51.8%	49.3%	**58.7%** P	**53.3%** P	33.2%	37.9%
Fireplaces	19.9%	19.6%	21.3%	21.0%	16.1%	15.4%
Grills	26.0%	27.5%	27.3%	27.0%	22.8%	29.1%
N	753	746	385	381	355	351

* Available Market=The total number of gas customers and non-customers on or near National Fuel's mainline

1 Significantly higher than 2021
2 Significantly higher than 2016
P Significantly higher than PA

Market Statistics: Market Saturation

The percentage of households in the Served Market* who use natural gas for the specific end use

	Total		New York		Pennsylvania	
	2016	2021	2016	2021	2016	2021
Market Saturation by End Use:						
Heating	91.6%	89.2%	92.3%	90.0%	89.9%	87.1%
Water Heating	**87.6%** 1	**77.5%**	**90.2%** P1	**78.9%**	**80.2%** 1	**73.4%**
Ranges	58.3%	60.3%	57.7%	60.5%	60.1%	59.9%
Cooktops	4.6%	6.8%	4.8%	7.0%	3.7%	6.3%
Oven	1.9%	**3.6%** 2	2.1%	3.5%	1.2%	**3.9%** 2
Clothes Dryer	53.8%	51.0%	**60.1%** P	**54.9%** P	36.0%	39.8%
Fireplaces	20.7%	20.2%	21.8%	21.6%	17.4%	16.2%
Grills	27.0%	28.4%	27.9%	27.8%	24.7%	30.5%
N	725	721	376	370	328	334

* Served Market=The total number of National Fuel customers

1 Significantly higher than 2021
2 Significantly higher than 2016
P Significantly higher than PA

Market Statistics Summary

Total Service Territory (Combined New York and Pennsylvania)*

	Market Share		Market Penetration		Market Saturation	
	2016	2021	2016	2021	2016	2021
Overall	90.6%	90.1%	96.3%	96.6%		
Primary Heating	83.0%	80.4%	88.2%	86.2%	91.6%	89.2%
Water Heating	**79.4%** [1]	69.9%	**84.3%** [1]	74.9%	**87.6%** [1]	77.5%
Ranges	52.9%	54.4%	56.2%	58.3%	58.3%	60.3%
Cooktops	4.1%	6.1%	4.4%	6.6%	4.6%	6.8%
Ovens	1.8%	3.3%	1.9%	3.5%	1.9%	**3.6%** [2]
Clothes Dryers	48.8%	46.0%	51.8%	49.3%	53.8%	51.0%
Fireplaces	18.8%	18.3%	19.9%	19.6%	20.7%	20.2%
Grills	24.5%	25.6%	26.0%	27.5%	27.0%	28.4%
N	800	800	753	746	725	721

* The Total Service Territory has been weighted to account for the greater number of customers in the New York Service Territory.

[1] Significantly higher than 2021
[2] Significantly higher than 2016

Market Statistics Summary

New York Service Territory

	Market Share		Market Penetration		Market Saturation	
	2016	2021	2016	2021	2016	2021
Overall	94.0%	92.5%	97.7%	97.1%		
Primary Heating	86.8%	83.3%	90.1%	87.4%	92.3%	90.0%
Water Heating	**84.8%** [1]	**73.0%**	**88.1%** [1]	**76.6%**	**90.2%** [1]	**78.9%**
Ranges	54.3%	56.0%	56.4%	58.8%	57.7%	60.5%
Cooktops	4.5%	6.5%	4.7%	6.8%	4.8%	7.0%
Ovens	2.0%	3.3%	2.1%	3.4%	2.1%	3.5%
Clothes Dryers	56.5%	50.8%	58.7%	53.3%	60.1%	54.9%
Fireplaces	20.5%	20.0%	21.3%	21.0%	21.8%	21.6%
Grills	26.3%	25.8%	27.3%	27.0%	27.9%	27.8%
N	400	400	385	381	376	370

[1] Significantly higher than 2021

Market Statistics Summary

Pennsylvania Service Territory

	Market Share		Market Penetration		Market Saturation	
	2016	2021	2016	2021	2016	2021
Overall	82.0%	83.5%	92.4%	95.2%		
Primary Heating	73.8%	72.8%	83.1%	82.9%	89.9%	87.1%
Water Heating	65.8%	61.3%	74.1%	69.8%	**80.2%** [1]	73.4%
Ranges	49.3%	50.0%	55.5%	57.0%	60.1%	59.9%
Cooktops	3.0%	5.3%	3.4%	6.0%	3.7%	6.3%
Ovens	1.0%	3.3%	1.1%	**3.7%** [2]	1.2%	**3.9%** [2]
Clothes Dryers	29.5%	33.3%	33.2%	37.9%	36.0%	39.8%
Fireplaces	14.3%	13.5%	16.1%	15.4%	17.4%	16.2%
Grills	20.3%	25.5%	22.8%	29.1%	24.7%	30.5%
N	400	400	355	351	328	334

[1] Significantly higher than 2021
[2] Significantly higher than 2016

Detailed Survey Findings

Natural Gas Customers

Natural Gas Customers

- 90.1% of the respondents have a natural gas furnace, water heater, clothes dryer, range, cooktop or oven in their home (customers) and 3.2% stated natural gas service is available within the immediate vicinity of their home (non-customers).
- The percent of respondents who are customers was significantly higher in New York (92.5%) compared to Pennsylvania (83.5%).
- The results were statistically unchanged compared to 2016.

Do you have a natural gas furnace, water heater, clothes dryer, range, cooktop or oven in your home?

	Total		New York		Pennsylvania	
	2016	2021	2016	2021	2016	2021
Yes (Served Market)	90.6%	90.1%	**94.0%** P	**92.5%** P	82.0%	83.5%
No	9.4%	9.9%	6.0%	7.5%	**18.0%** N	**16.5%** N
N	800	800	400	400	400	400

Is natural gas service available within the immediate vicinity of your home? By immediate vicinity we mean within approximately 100-300 feet from your home.

	Total		New York		Pennsylvania	
	2016	2021	2016	2021	2016	2021
Yes (Served Market)	3.5%	3.2%	2.2%	2.8%	**6.8%** N	4.2%
No	5.0%	4.7%	3.2%	2.8%	**9.2%** N	**10.0%** N
Don't know	0.9%	2.1%	0.5%	2.0%	2.0%	2.2%
N	800	800	400	400	400	400

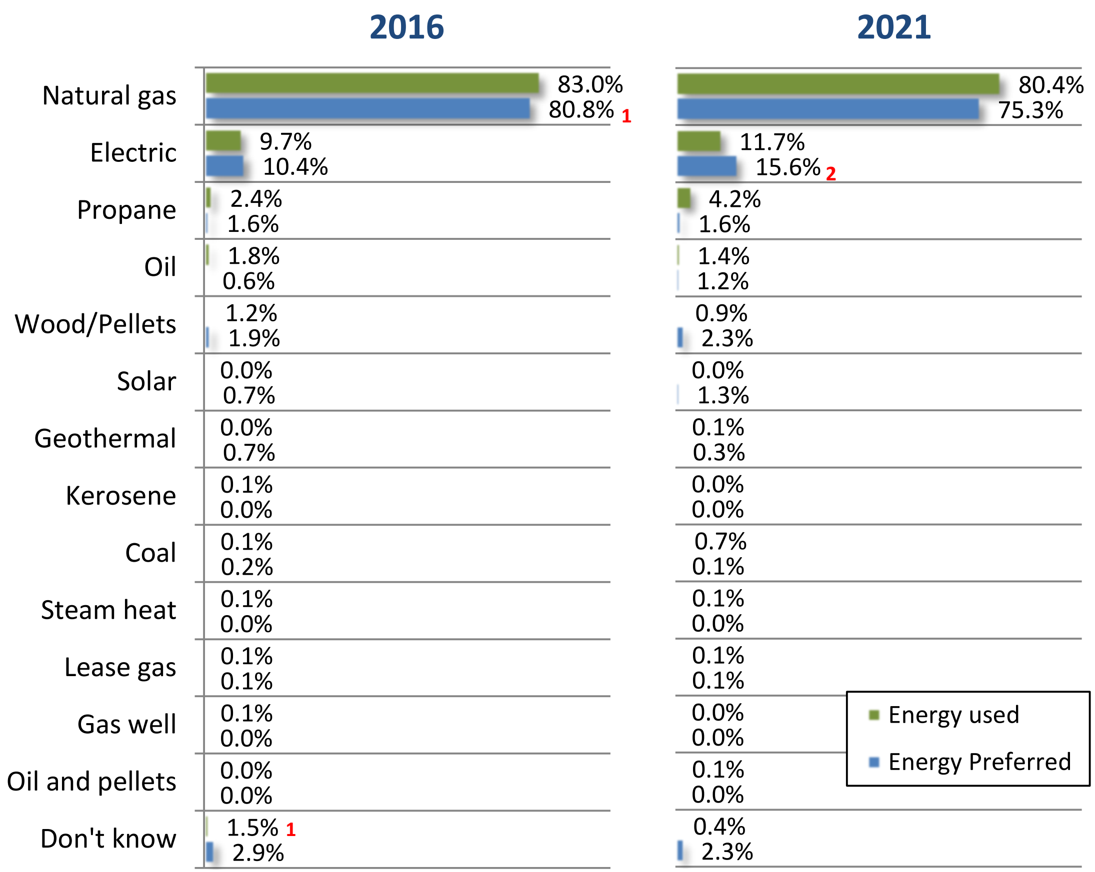
N Significantly higher than NY
P Significantly higher than PA

Home Heating

Home Heating: Current and Preferred Energy Source

What type of energy does your main heating system use?
Assuming all energy sources were available at equal installation cost, which energy source would you prefer for heating?

Total Service Territory
(N=800 each year)



[1] Significantly higher than 2021
[2] Significantly higher than 2016

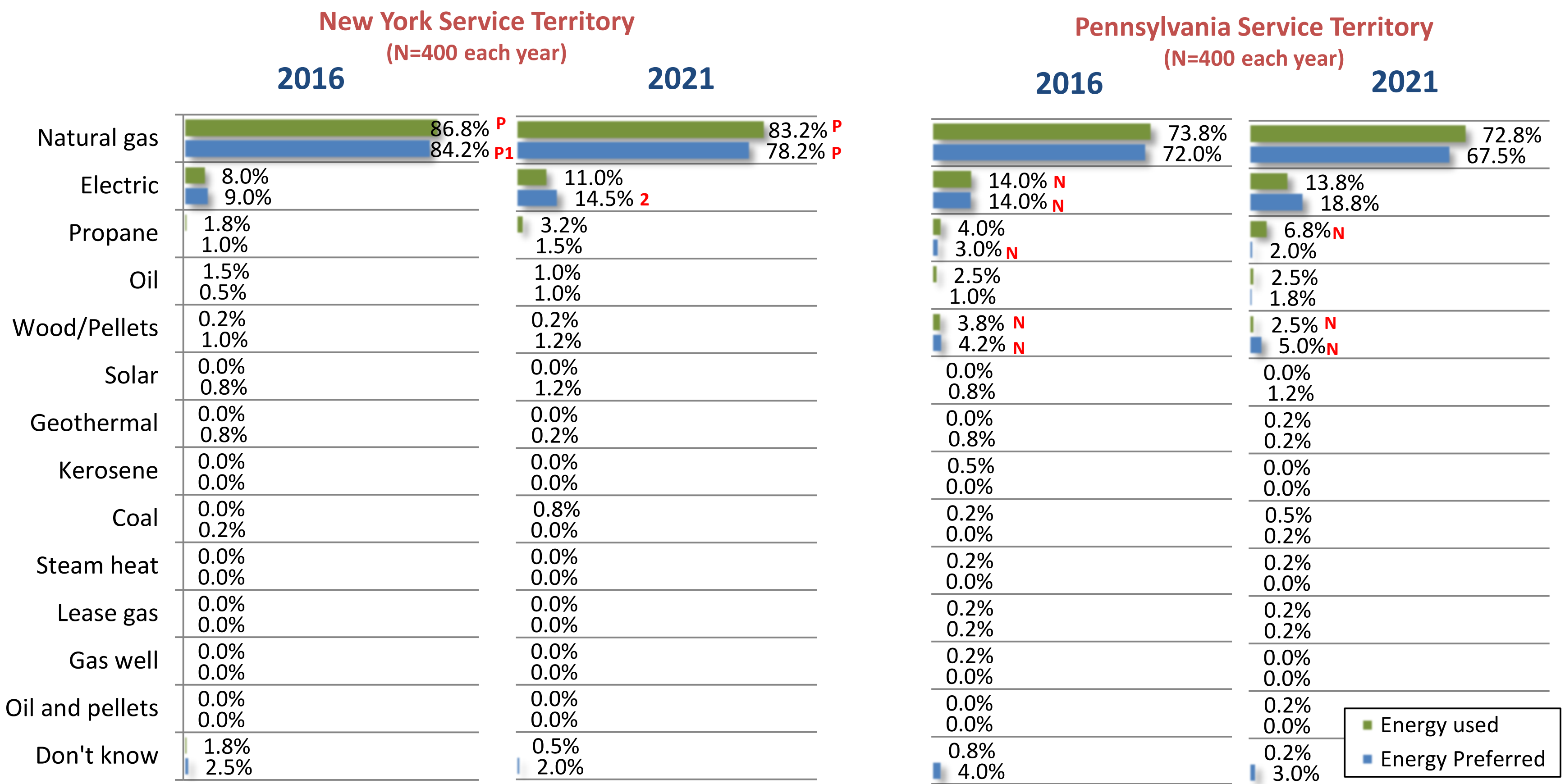
- 80.4% of the Total respondents indicated their main heating system used natural gas.
- 75.3% would prefer to use natural gas for heating which was statistically lower than 2016 (80.8%).
- Preference for electric heating increased by 5.2 points to 15.6%.

Home Heating: Current and Preferred Energy Source

- Similar to 2016, a significantly higher percent (83.2%) of the New York respondents indicated their heating system used natural gas and 78.2% preferred natural gas compared to those in Pennsylvania (72.8% and 67.5% respectively).

What type of energy does your main heating system use?

Assuming all energy sources were available at equal installation cost, which energy source would you prefer for heating?



1 Significantly higher than 2021
2 Significantly higher than 2016
N Significantly higher than NY
P Significantly higher than PA

Home Heating: Type of Heating System

- The respondents were shown heating system descriptions and images and asked what type of heating system they have.
- The percent of the respondents indicating they have a forced air furnace dropped from 75% in 2016 to 70% in 2021 (see chart next page).
- 22% of the 2021 respondents stated they had a boiler.

Heating System Descriptions Included in Survey

- Forced Air Furnace. This heats the air, and then a blower motor moves the warmed air through the home's duct system
- Boiler (baseboard, radiator). This heats water, which then flows through a network of pipes in the home.
- Space/Strip Heaters. This is a stand-alone unit, usually electric, for heating an enclosed room.
- Ground Source (geothermal) Heat Pump. This is a central heating system that transfers heat from the ground.
- Air to Air Heat Pump. This uses the outside air to heat a home.
- Stove

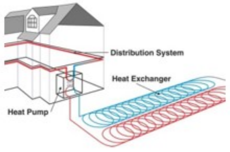
Heating System Images Included in Survey

Forced Air Furnace

Boiler Baseboard or Radiator

Space/Strip Heaters

Ground Source Heat Pump



Air Source Heat Pump

Stove

Home Heating: Type of Heating System

What type of main heating system do you have?

	Total		New York		Pennsylvania	
	2016	2021	2016	2021	2016	2021
Forced Air Furnace. This heats the air, and then a blower motor moves the warmed air through the home's duct system	**75%** 1	70%	75%	69%	76%	72%
Boiler (baseboard, radiator). This heats water, which then flows through a network of pipes in the home.	20%	22%	**22%** P	23%	16%	18%
Space/Strip Heaters. This is a stand-alone unit, usually electric, for heating an enclosed room.	2%	2%	2%	2%	3%	3%
Stove	1%	2%	1%	1%	**4%** N	**5%** N
Air to Air Heat Pump. This uses the outside air to heat a home.	1%	1%	<1%	1%	**2%** N	1%
Ground Source (geothermal) Heat Pump. This is a central heating system that transfers heat from the ground.	1%	1%	1%	2%	1%	1%
Wall mounted gas heater	0%	<1%	0%	1%	0%	0%
Gravity fed	0%	<1%	0%	0%	0%	<1%
Ventless gas heater	0%	<1%	0%	0%	0%	<1%
Don't know	1%	2%	1%	2%	1%	1%
N	800	800	400	400	400	400

N Significantly higher than NY
P Significantly higher than PA
1 Significantly higher than 2021

Home Heating: Efficiency/Age

- Similar to 2016, a nearly equal percent of the Total respondents indicated the efficiency of their furnace was High (43%) or Standard (44%).
- Ownership of a high efficiency heating system appears to be somewhat correlated with household income. Those with incomes above $75,000 were more likely to have a high efficiency heating system compared to lower income households.

What is the efficiency of your main heating system?

	Total		New York		Pennsylvania	
	2016	2021	2016	2021	2016	2021
High	43%	43%	44%	44%	38%	40%
Standard	42%	44%	41%	43%	45%	46%
Don't know	15%	13%	15%	13%	17%	14%
N	800	800	400	400	400	400

2021 Respondents	Household Income			
	Under $30k	$30k-$49.9k	$50k-$74.9k	$75k or higher
High	26%	**45%** [1]	**45%** [1]	**54%** [1]
Standard	**53%** [2]	39%	42%	40%
Don't know	**22%** [3]	**16%** [4]	13%	6%
N	211	142	142	305

[1] Significantly higher than Under $30k
[2] Significantly higher than $30k-$49.9k and $75k or higher
[3] Significantly higher than $50k-$74.9k and $75k or higher
[4] Significantly higher than $75k or higher

Home Heating: Perceived Costs

- A significantly higher percent (42%) of the 2021 respondents felt their energy costs were higher than they were 10 years ago (34% in 2016).
- A significantly higher percent (49%) of the Pennsylvania respondents felt their energy costs were higher compared to the New York respondents (40%).

Are your energy costs to heat your home higher or lower than they were 10 years ago?

	Total		New York		Pennsylvania	
	2016	2021	2016	2021	2016	2021
Higher	34%	**42%** 1	31%	**40%** 1	**40%** N	**49%** N1
Lower	**32%** 2	20%	**35%** N2	21%	**26%** 2	17%
The same	20%	**26%** 1	20%	**27%** 1	21%	24%
Not sure	14%	12%	15%	12%	13%	10%
N	800	800	400	400	400	400

N Significantly higher than NY
P Significantly higher than PA
1 Significantly higher than 2016
2 Significantly higher than 2021

Home Heating: Age of Heating System

- A higher percent (29%) of the New York respondents indicated their main heating system was less than 5 years old compared to 22% of the Pennsylvania respondents. Conversely, a higher percent (27%) of the Pennsylvania respondents stated their main heating system was more than 15 years old.

How old is your main heating system?

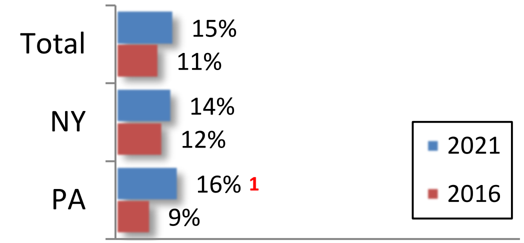
	Total		New York		Pennsylvania	
	2016	2021	2016	2021	2016	2021
Less than 5 years	26%	27%	28%	**29%** P	23%	22%
5-10 years	28%	32%	28%	32%	28%	33%
11-15 years	16%	16%	15%	16%	16%	16%
More than 15 years	23%	21%	23%	18%	24%	**27%** N
Don't know	**7%** 1	4%	6%	**5%** P	**9%** 1	2%
N	800	800	400	400	400	400

N Significantly higher than NY
P Significantly higher than PA
1 Significantly higher than 2021

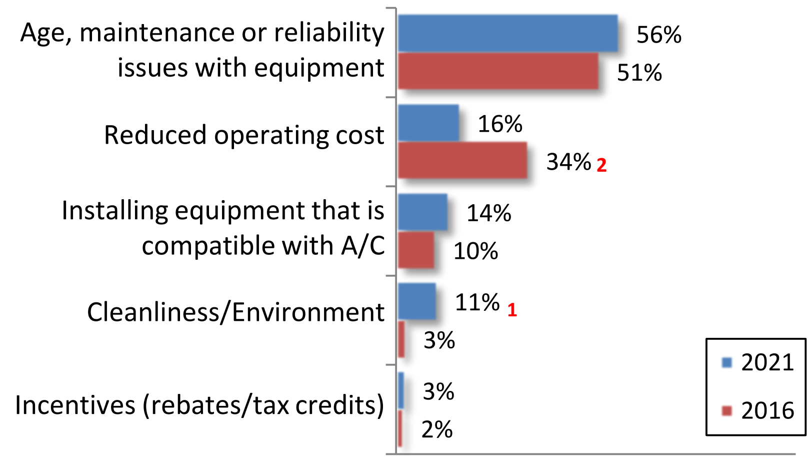
Home Heating: Replacement

- A significantly higher percent (16%) of the Pennsylvania respondents are planning to replace their main heating system within the next 12 months compared to 9% in 2016.
- *Age, maintenance or reliability issues with equipment* was mentioned most frequently by 59% of the respondents as the primary reason why they will be replacing their heating equipment.

Are you planning to replace your main heating system within the next twelve months?
% Yes
(Total N=800 / Each State N=400)



What is the primary reason you are planning to replace your main heating system?
(2021 N=117 / 2016 N=92) *



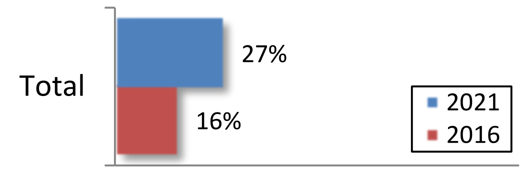
* Results did not differ significantly by state.

1 Significantly higher than 2016
2 Significantly higher than 2021

Home Heating: Replacement

- A slightly higher percent (27%) of the 2021 respondents who are replacing their main heating system indicated they are planning to change their energy source.
- 36% of those planning to replace the energy source stated they are planning on switching to electric and 28% are switching to natural gas. Note this is based on a small sample size.

Are you planning to change the energy source for your main heating system?
% Yes
(2021 N=117 / 2016 N=92) *



What energy source are you planning on switching to?

	2016	2021
Natural gas	14%	28%
Electric	21%	36%
Propane	23%	11%
Wood/Pellets	10%	8%
Oil	4%	5%
Solar	0%	5%
Don't know	29%	8%
N*	15**	32

* Results did not differ significantly by state
** Small sample size; caution interpreting results

Home Heating: Purchase Factors

- When asked what is the primary factor considered in the purchase of a new main heating system, "Purchase and installation cost" and "Improved efficiency-lower monthly energy costs" continue to be mentioned most frequently by 36% and 35% respectively.

What is the primary factor you would consider/are considering in the purchase of a new main heating system?

	Total		New York		Pennsylvania	
	2016	2021	2016	2021	2016	2021
Improved efficiency-lower monthly energy costs	**45%** 1	35%	**47%** P1	35%	40%	38%
Purchase and installation cost	32%	36%	32%	36%	34%	36%
Type of energy source already in home	9%	10%	9%	11%	10%	10%
Preferred type of energy (i.e. gas, electric, oil, etc.)	6%	**10%** 2	5%	**10%** 2	7%	10%
Environmental benefits	2%	4%	2%	4%	2%	3%
Decision up to landlord/owner/managers	2%	1%	2%	2%	**2%** 1	1%
Size, appearance, features	1%	2%	1%	2%	1%	2%
Comfort	<1%	0%	0%	0%	<1%	0%
Don't know	**3%** 1	1%	3%	1%	**4%** 1	1%
N	800	800	400	400	400	400

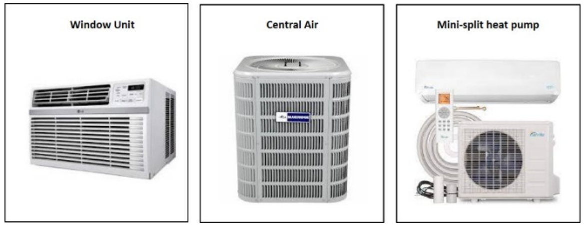
1 Significantly higher than 2021
2 Significantly higher than 2016
P Significantly higher than PA

Air Conditioning

Air Conditioning

Do you have air conditioning in your home?
Question added 2021
% Yes
(Total N=800 / Each State N=400)

- 73% of the Total respondents stated they have an air conditioner in their home.
- The respondents were shown air conditioner images and asked what type they have.



- A significantly higher percent of the New York respondents (67%) have central air compared to 56% in Pennsylvania.

Is it a window unit, central air conditioning, or a mini-split heat pump?
Question added 2021

	Total	NY	PA
Central Air	64%	**67%** P	56%
Window	28%	25%	**36%** N
Min-Split heat pump	7%	7%	7%
Don't know	1%	1%	1%
N	581	295	279

N Significantly higher than NY
P Significantly higher than PA

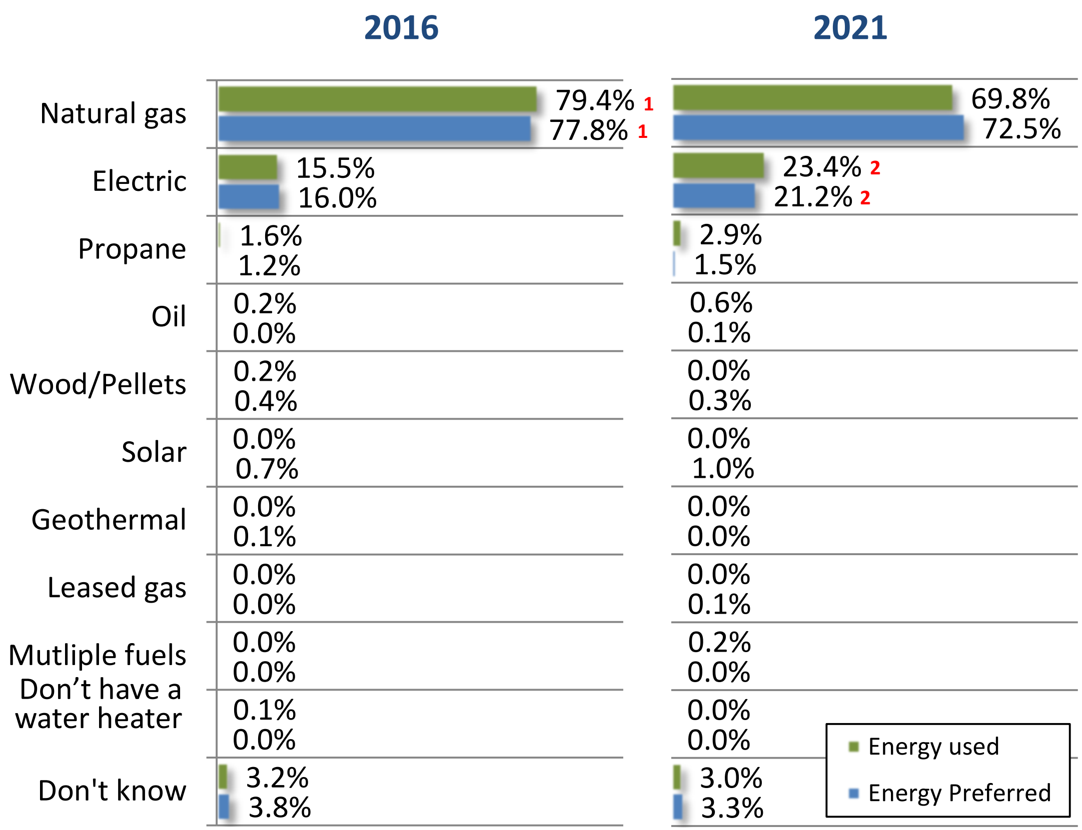
Water Heater

Water Heater : Current and Preferred Energy Source

What energy source does the water heater in your home use?

Assuming all energy sources were available at equal installation cost, which energy source would you prefer for water heating?

Total Service Territory
(N=800 each year)



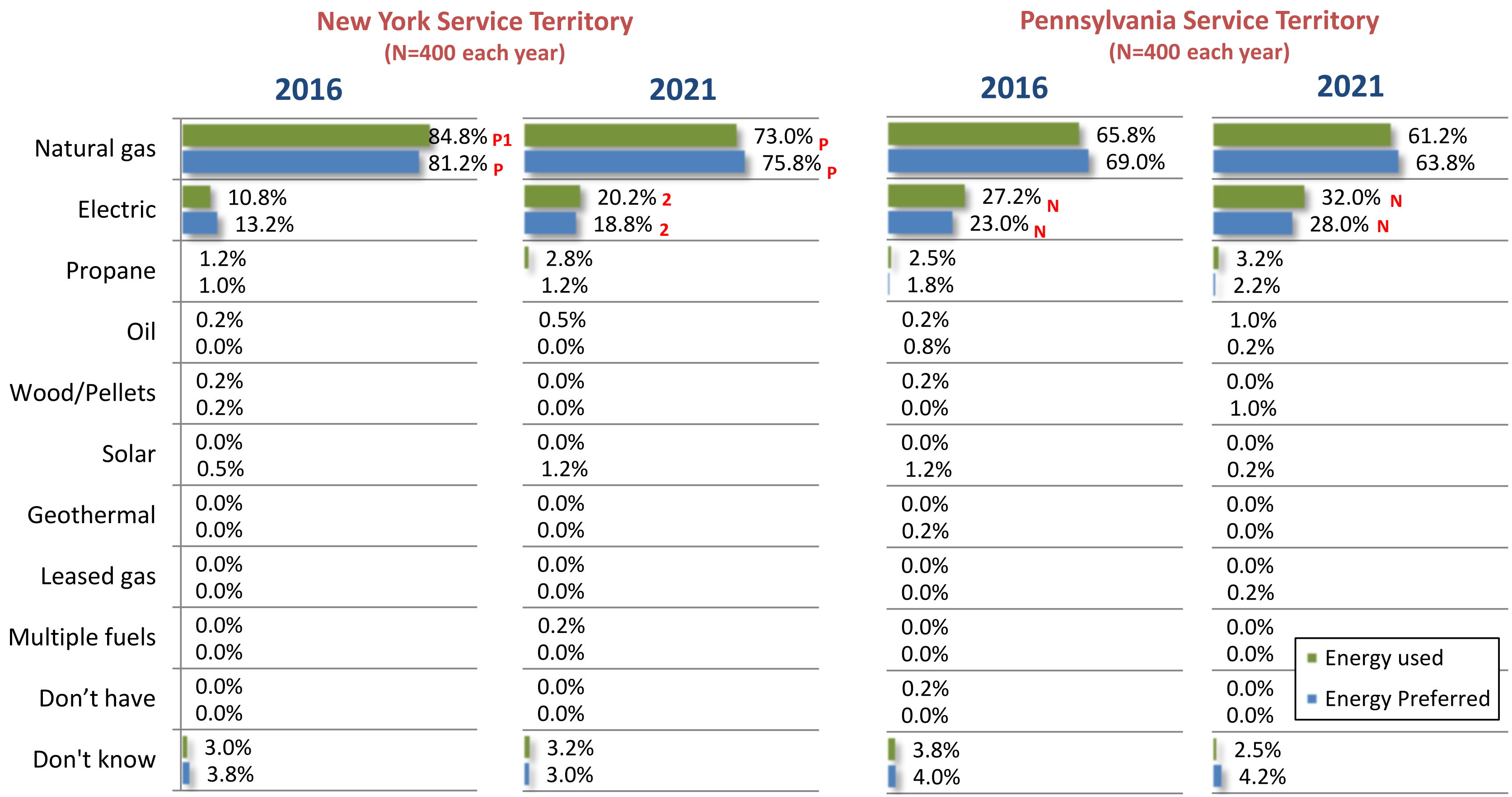
1 Significantly higher than 2021
2 Significantly higher than 2016

- A significantly lower percent (69.8%) of the 2021 Total respondents stated their water heater used natural gas (79.4% in 2016).
- A lower percent (72.5%) would prefer to use natural gas for water heating (77.8% in 2016).
- Use and preference for natural gas as a water heating source decreased significantly in New York compared to the 2016 study (see chart next page).
- A significantly higher percent (73.0%) of the New York respondents indicated their water heater used natural gas and 75.8% would prefer natural gas compared to those in Pennsylvania (61.2% and 63.8% respectively).

Water Heater : Current and Preferred Energy Source

What energy source does the water heater in your home use?

Assuming all energy sources were available at equal installation cost, which energy source would you prefer for water heating?



1 Significantly higher than 2021
2 Significantly higher than 2016
N Significantly higher than NY
P Significantly higher than PA

Water Heater: Type

- The respondents were shown water heater descriptions and images and asked what type of water heater they have.
- 88% of the Total respondents indicated they have a storage tank and 10% have a tankless water heater (see chart next page).
- The percent who had a tankless water heater increased by 6 points from 4% in 2016 while the percent who had a storage tank dropped by 6 points.
- Tankless ownership was higher among those with household incomes above $75,000 (16%).

Water Heater Descriptions Included in Survey

- Storage Tank. This stores and preheats 30-50 gallons of water in a tank. That preheated water is used whenever someone showers, does the laundry or washes dishes. The tank then refills to be reheated once again.
- Tankless. This uses a heat source (electric or gas) to warm up cool water whenever needed rather than storing hot water in a tank.

Heating System Images Included in Survey

Storage Tank

Tankless

Water Heater: Type

What type of water heater do you have?

	Total		New York		Pennsylvania	
	2016	2021	2016	2021	2016	2021
Storage Tank	**94%** [1]	88%	**94%** [1]	88%	**95%** [1]	90%
Tankless	4%	**10%** [2]	**5%** [P]	**11%** [2]	2%	**8%** [2]
Hybrid tankless with small tank	<1%	<1%	<1%	0%	<1%	<1%
Boiler with recycling	0%	<1%	0%	0%	0%	<1%
Boiler Mate	0%	<1%	0%	0%	0%	<1%
Don't have a water heater	<1%	0%	0%	0%	<1%	0%
Don't know	2%	2%	1%	1%	3%	2%
N	800	800	400	400	400	400

[1] Significantly higher than 2021
[2] Significantly higher than 2016
[P] Significantly higher than PA

2021 Respondents	Household Income			
	Under $30k	$30k-$49.9k	$50k-$74.9k	$75k or higher
Storage Tanks	**92%** [1]	**91%** [1]	**92%** [1]	83%
Tankless	5%	8%	8%	**16%** [2]
N	211	142	142	305

[1] Significantly higher than $75k or higher
[2] Significantly higher than Under $30k, $30k-$49.9k and $50k-$74.9k

Water Heater: Age

- 34% of the Total respondents indicated their water heater was less than 5 years old and 40% stated their water heater was 5-10 years old.

How old is your water heater?

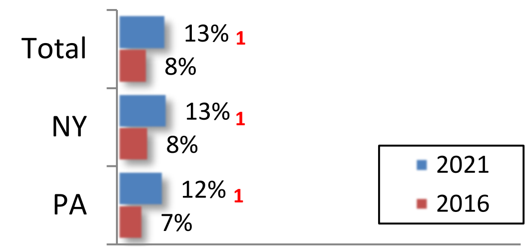
	Total		New York		Pennsylvania	
	2016	2021	2016	2021	2016	2021
Less than 5 years	32%	34%	30%	35%	**38%** $_{N}$	33%
5-10 years	36%	40%	**39%** $_{P}$	39%	30%	**41%** $_{2}$
11-15 years	13%	13%	13%	13%	13%	12%
More than 15 years	9%	10%	10%	8%	7%	**13%** $_{N2}$
Don't know	**10%** $_{1}$	4%	**9%** $_{1}$	**5%** $_{P}$	**13%** $_{1}$	1%
Don't have a water heater	<1%	0%	0%	0%	<1%	0%
N	800	800	400	400	400	400

$_{1}$ Significantly higher than 2021
$_{2}$ Significantly higher than 2016
$_{N}$ Significantly higher than NY
$_{P}$ Significantly higher than PA

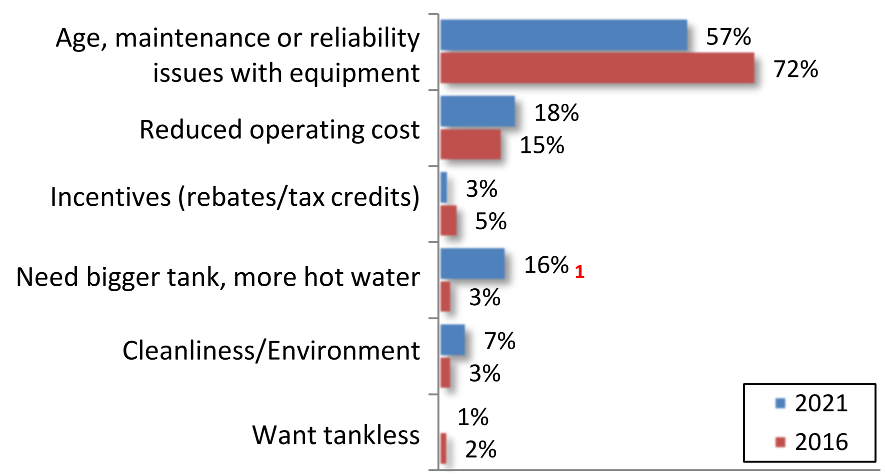
Water Heater: Replacement

- Water heater replacement intent increased significantly overall to 13% and in both states (13% New York; 12% Pennsylvania).
- *Age, maintenance or reliability issues with equipment* was mentioned most frequently by 57% of the respondents as the primary reason why they will be replacing their water heater.

Are you planning to replace your water heater within the next twelve months?
% Yes
(Total N=800 / Each State N=400)



What is the primary reason you are planning to replace your water heater?
(2021 N=100 / 2016 N=63) *



1 Significantly higher than 2016

* Results did not differ significantly by state.

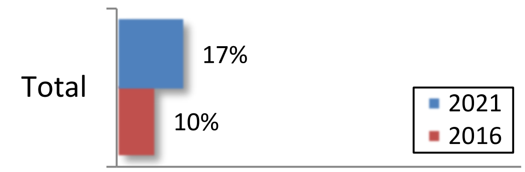
Water Heater: Replacement

- 17% of those replacing their water heater are planning on changing the energy source.
- 30% of those planning to replace the energy source stated they are switching to electric and 27% are switching to natural gas. Note this is based on a small sample size.

Are you planning to change the energy source for your water heater?

% Yes

(2021 N=100 / 2016 N=63) *



What energy source are you planning on switching to?

	2016	2021
Natural gas	18%	27%
Electric	32%	30%
Propane	23%	17%
Wood/Pellets	9%	0%
Oil	9%	15%
Solar	9%	0%
Don't know	0%	12%
N*	6**	17**

* Results did not differ significantly by state
** Small sample size; caution interpreting results

[1] Significantly higher than 2016

Water Heater: Purchase Factors

- When asked what is the primary factor considered in the purchase of a new water heater, "Improved efficiency-lower monthly energy costs" and "Purchase and installation cost" continue to be mentioned most frequently.

What is the primary factor you would consider/are considering in the purchase of a new water heater?

	Total		New York		Pennsylvania	
	2016	2021	2016	2021	2016	2021
Improved efficiency-lower monthly energy costs	**42%** 1	36%	**43%** 1	34%	40%	39%
Purchase and installation cost	31%	**36%** 2	32%	37%	29%	35%
Type of energy source already at appliance connection	12%	9%	11%	9%	**14%** 1	9%
Preferred type of energy (i.e. gas, electric, oil, etc.)	6%	7%	6%	7%	7%	8%
Size, appearance, features	2%	**6%** 2	3%	**7%** 2	2%	**6%** 2
Decision up to landlord/owner/managers	2%	1%	2%	2%	2%	1%
Environmental benefits	1%	3%	2%	2%	1%	3%
Don't know	3%	2%	3%	**3%** P	**5%** N1	1%
N	800	800	400	400	400	400

1 Significantly higher than 2021
2 Significantly higher than 2016
N Significantly higher than NY
P Significantly higher than PA

Cooking

Cooking: Type of Appliance

- The respondents were shown cooking appliance descriptions and images and asked what type of cooking appliance they have.
- 88% of the respondents indicated they have a range and 11% have a separate cooktop and 11% have an oven (see chart next page).
- Oven ownership is up 5 points to 11% compared to 2016.
- Separate cooktop and oven ownership was significantly higher among respondents with household incomes of $75,000 or higher.

Cooking Appliance Descriptions Included in Survey

- Range. This is an appliance that includes a cooktop and oven together
- Separate Cooktop. This is a cooktop that is on a countertop or an island in your kitchen and not on top of an oven
- Oven. This is a stand-alone appliance without a cooktop (i.e. in a wall)

Cooking Appliance Images Included in Survey

Range

Cooktop

Oven

Cooking: Type of Appliance

What type of cooking appliance do you have in your home?

	Total		New York		Pennsylvania	
	2016	2021	2016	2021	2016	2021
Range. This is an appliance that includes a cooktop and oven together	91%	88%	90%	88%	92%	88%
Separate Cooktop. This is a cooktop that is on a countertop or an island in your kitchen and not on top of an oven	9%	11%	10%	11%	8%	12%
Oven. This is a stand-alone appliance without a cooktop (i.e. in a wall)	6%	**11%** [1]	7%	**11%** [1]	5%	**12%** [1]
Other						
Microwave	<1%	<1%	<1%	0%	<1%	<1%
Hot plate	<1%	0%	0%	0%	<1%	0%
Do not have a stove/cooking appliance	<1%	0%	<1%	0%	0%	0%
Don't know	<1%	<1%	<1%	<1%	<1%	0%
N	800	800	400	400	400	400

[1] Significantly higher than 2016

2021 Respondent Cooking Appliance Ownership By Household Income

	Under $50k	$50k-$74.9k	$75k or higher
Range	**95%** [1]	**91%** [1]	79%
Separate Cooktop	4%	7%	**21%** [2]
Oven	4%	12%	**20%** [3]
N	353	142	305

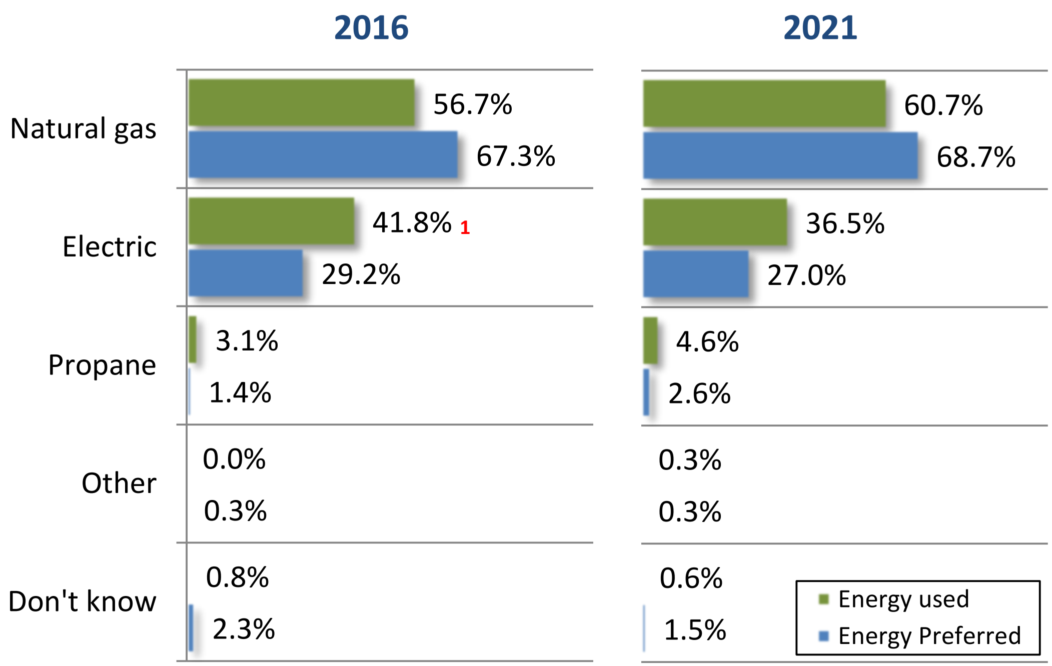
[1] Significantly higher than $75k or higher
[2] Significantly higher than Under $50k and $50k-$74.9k
[3] Significantly higher than Under $50k

Cooking: Current and Preferred Energy Source

What type of energy does your range, cooktop or oven use?

Assuming all energy sources were available at equal installation cost, which energy source would you prefer for cooking?

Total Service Territory
(N=800 each year)



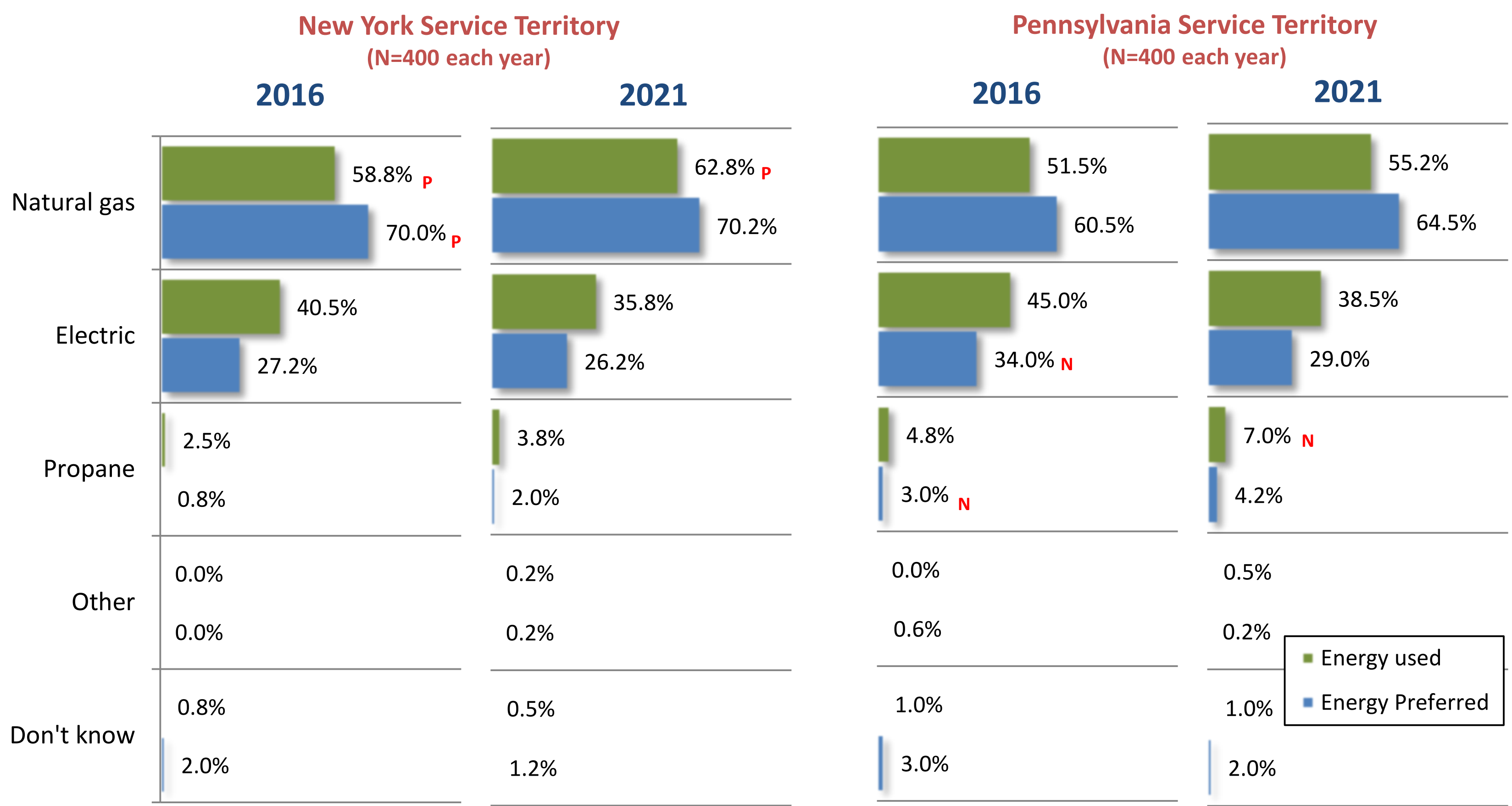
[1] Significantly higher than 2021

- 60.7% of the Total respondents stated their range, cooktop or oven used natural gas and a higher percent (68.7%) would prefer to use natural gas for cooking.
- A significantly higher percent (62.8%) of the New York respondents indicated their range, cooktop or oven used natural gas compared to 55.2% in Pennsylvania (see chart next page).

Cooking: Current and Preferred Energy Source

What type of energy does your range, cooktop or oven use?

Assuming all energy sources were available at equal installation cost, which energy source would you prefer for cooking?



N Significantly higher than NY
P Significantly higher than PA

Cooking: Energy Used

What type of energy does your range, cooktop and oven use?

2021

	Range			Cooktop			Oven		
	Total	NY	PA	Total	NY	PA	Total	NY	PA
Natural gas	62%	64%	57%	56%	59%	47%	29%	29%	28%
Electric	33%	32%	35%	40%	39%	42%	67%	64%	72%
Propane	5%	4%	7%	4%	2%	9%	5%	7%	0%
Multiple fuels	<1%	<1%	1%	0%	0%	0%	0%	0%	0%
Don't know	<1%	<1%	<1%	1%	0%	2%	0%	0%	0%
N	705	352	353	89	44	45	91	45	47

2016

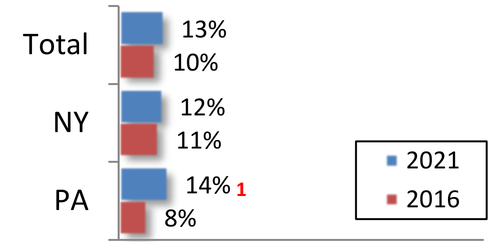
	Range			Cooktop			Oven		
	Total	NY	PA	Total	NY	PA	Total	NY	PA
Natural gas	58%	60%	54%	45%	47%	38%	27%	30%	20%
Electric	**40%** [1]	38%	**43%** [1]	47%	45%	53%	73%	70%	80%
Propane	3%	2%	4%	8%	8%	9%	0%	0%	0%
Don't know	<1%	<1%	0%	0%	0%	0%	0%	0%	0%
N	726	361	368	73	38 *	32 *	50	27 *	20 *

1 Significantly higher than 2021
* Small sample size; caution interpreting results

Cooking Appliance: Replacement

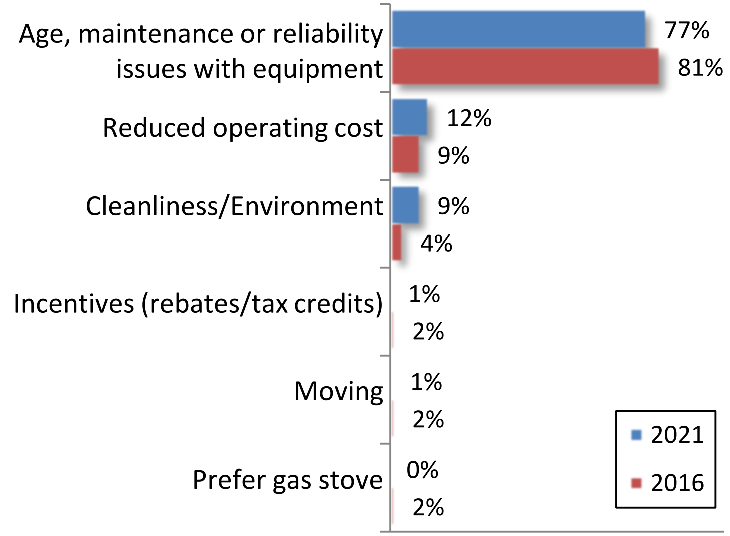
- 13% of the respondents are planning to replace their range, cooktop or oven within the next 12 months.
- *Age, maintenance or reliability issues with equipment* was mentioned most frequently by 77% of the respondents as the primary reason why they will be replacing their range, cooktop or oven.

Are you planning to replace your range, cooktop or oven within the next twelve months?
% Yes
2021 N=799 (NY=399/PA=400) / 2016 N=795 (NY=398/PA=396)



1 Significantly higher than 2016

What is the primary reason you are planning to replace your range, cooktop or oven?
(2021 N=101 / 2016 N=83) *



* 2021 results did not differ significantly by state.

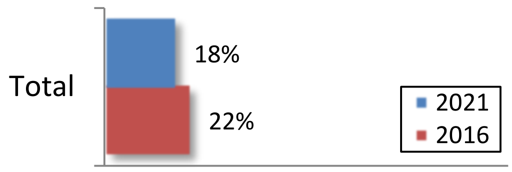
Cooking Appliance: Replacement

- 18% of those replacing their range, cooktop or oven are planning on changing the energy source.
- 57% of those planning to replace the energy source stated they are switching to electric and 33% are switching to natural gas. Note this is based on a small sample size.

Are you planning to change the energy source for your range, cooktop or oven?

% Yes

(2021 N=101 / 2016 N=83) *



What energy source are you planning on switching to?

	2016	2021
Electric	54%	57%
Natural gas	46%	33%
Propane	3%	11%
N*	18**	18**

* Results did not differ significantly by state
** Small sample size; caution interpreting results

1 Significantly higher than 2016

Cooking Appliance: Purchase Factors

- When asked what is the primary factor considered in the purchase of a new cooktop, range or oven, "Purchase and installation cost" was mentioned significantly more frequently by 34% of the Total respondents followed by "Improved efficiency-lower monthly energy costs" (23%).

What is the primary factor you would consider/are considering in the purchase of a new cooktop, range or oven?

	Total		New York		Pennsylvania	
	2016	2021	2016	2021	2016	2021
Purchase and installation cost	28%	**34%** [2]	28%	**35%** [2]	27%	30%
Improved efficiency-lower monthly energy costs	23%	23%	23%	23%	22%	24%
Size, appearance, features	18%	15%	**19%** [1]	13%	16%	**19%** [N]
Type of energy source already at appliance connection	13%	12%	12%	12%	15%	13%
Preferred type of energy (i.e. gas, electric, oil, etc.)	13%	12%	13%	12%	14%	11%
Decision up to landlord/owner/managers	1%	1%	1%	1%	**2%** [1]	<1%
Environmental benefits	1%	1%	1%	2%	<1%	1%
Don't know	3%	2%	3%	2%	4%	2%
N	795	799	398	399	396	400

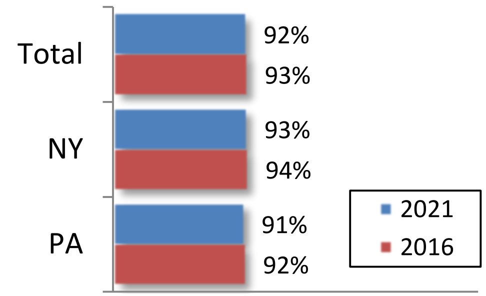
[1] Significantly higher than 2021
[2] Significantly higher than 2016
[N] Significantly higher than NY

Clothes Dryer

Clothes Dryer: Use/Energy Source

- 92% of the Total respondents stated they have a clothes dryer.
- The respondents were shown descriptions and images and asked what energy source their clothes dryer used. Overall, 50% of the respondents indicated they have a natural gas dryer and 43% have an electric dryer.
- A significantly higher percent of the New York respondents (55%) have a natural gas dryer and 56% of the Pennsylvania respondents have an electric dryer.

Do you have a clothes dryer in your home?
% Yes
(Total N=800 / Each State N=400)



Dryer Descriptions Included in Survey

- Natural gas. A natural gas dryer requires a 120-volt outlet and a gas hookup.
- Propane gas. A propane gas dryer requires a 120-volt outlet and a gas hookup.
- Electric. An electric dryer requires a 220-volt outlet.

Dryer Images Included in Survey

120 volt outlet and gas hookup for gas dryer

220 volt outlet for electric dryer

What energy source does your clothes dryer use?

	Total		New York		Pennsylvania	
	2016	2021	2016	2021	2016	2021
Natural gas	53%	50%	**60%** $_{P}$	**55%** $_{P}$	32%	37%
Electric	45%	43%	37%	39%	**66%** $_{N1}$	**56%** $_{N}$
Propane gas	1%	2%	1%	1%	1%	3%
Don't know	2%	**5%** $_{2}$	2%	**5%** $_{2}$	1%	**4%** $_{2}$
N	744	738	374	371	367	363

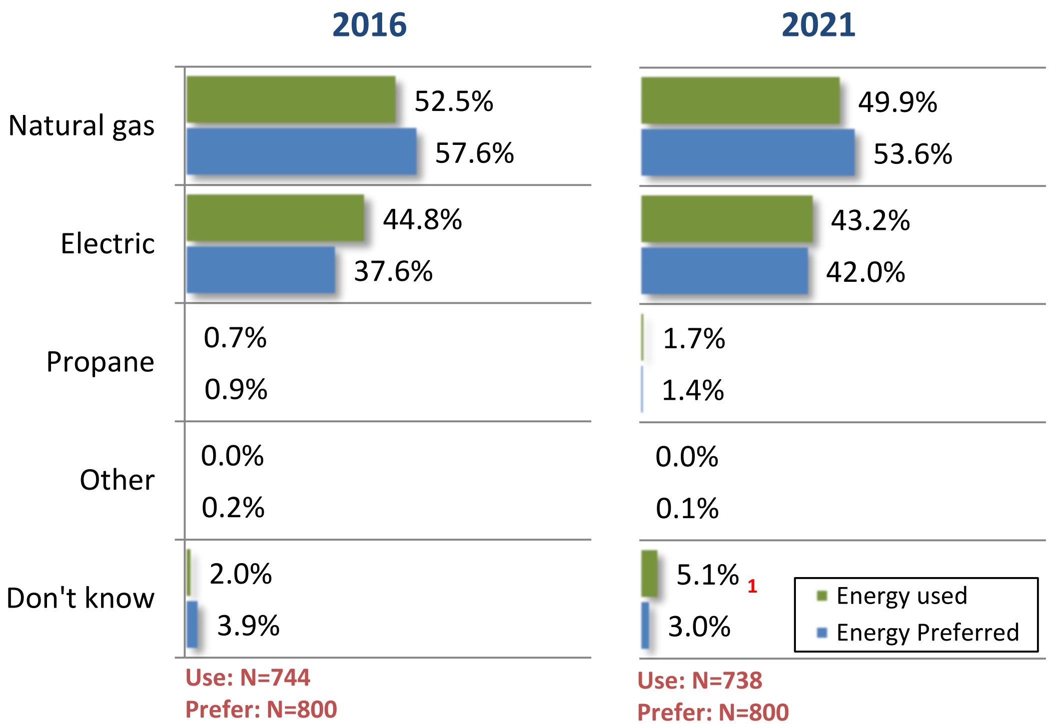
$_{1}$ Significantly higher than 2021 $_{N}$ Significantly higher than NY
$_{2}$ Significantly higher than 2016 $_{P}$ Significantly higher than PA

Clothes Dryer: Current and Preferred Energy Source

What energy source does your clothes dryer use?

Assuming all energy sources were available at equal installation cost, which energy source would you prefer for clothes drying?

Total Service Territory



- 49.9% of the Total respondents stated their clothes dryer used natural gas and (53.6%) would prefer to use natural gas for clothes drying.

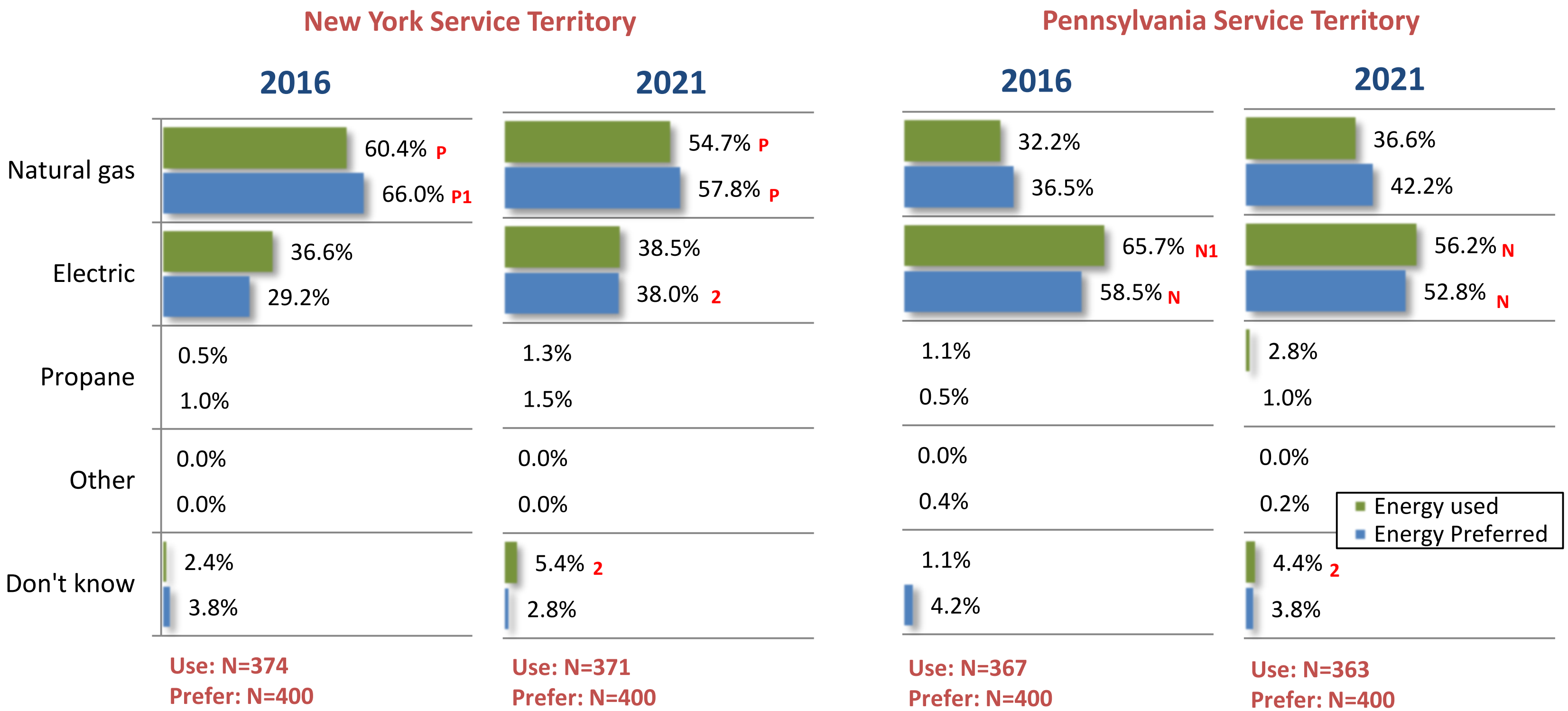
[1] Significantly higher than 2016

Clothes Dryer: Current and Preferred Energy Source

- A significantly higher percent (54.7%) of the New York respondents indicated their clothes dryer used natural gas and 57.8% would prefer natural gas for clothes drying compared to those in Pennsylvania (36.6% and 42.2% respectively). Use and preference of electric as a clothes dryer energy source was significantly higher in Pennsylvania.

What energy source does your clothes dryer use?

Assuming all energy sources were available at equal installation cost, which energy source would you prefer for clothes drying?



N Significantly higher than NY
P Significantly higher than PA
1 Significantly higher than 2021
2 Significantly higher than 2016

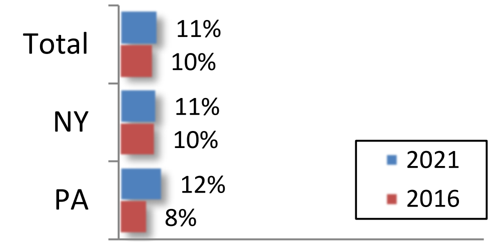
Clothes Dryer: Replacement

- 11% of the respondents are planning to replace their clothes dryer within the next 12 months. This result did not vary significantly by state.
- *Age, maintenance or reliability issues with equipment* was mentioned most frequently by 79% of the respondents as the primary reason why they will be replacing their clothes dryer.

Are you planning to replace your clothes dryer within the next twelve months?

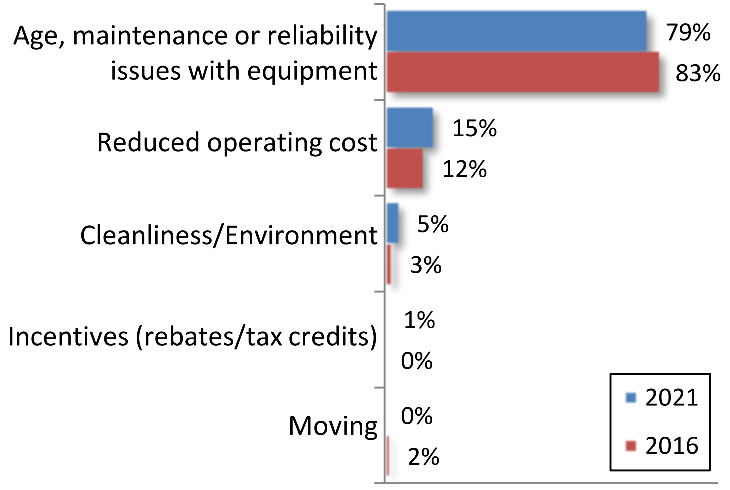
% Yes

2021 N=738 (NY=371/PA=363) / 2016 N=744 (NY=374/PA=367)



What is the primary reason you are planning to replace your dryer?

(2021 N=83 / 2016 N=73) *



* Results did not differ significantly by state.

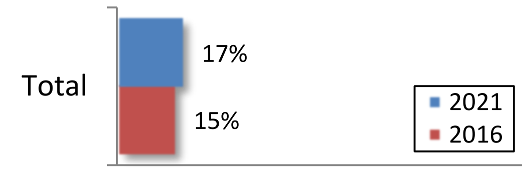
Clothes Dryer: Replacement

- 17% of those replacing their clothes dryer are planning on changing the energy source.
- 44% of those planning to replace the energy source stated they are switching to electric and 42% are switching to natural gas. Note this is based on a small sample size.

Are you planning to change the energy source for your clothes dryer?

% Yes

(2021 N=83 / 2016 N=73) *



What energy source are you planning on switching to?

	2016	2021
Electric	0%	44%
Natural gas	63%	42%
Propane	37%	14%
N*	11**	14**

* Results did not differ significantly by state
** Small sample size; caution interpreting results

Clothes Dryer: Purchase Factors

- When asked what is the primary factor considered in the purchase of a new clothes dryer, "Purchase and installation cost" was mentioned most frequently by 34% of the Total respondents followed by "Improved efficiency-lower monthly energy costs" (27%).

What is the primary factor you would consider/are considering in the purchase of a new clothes dryer?

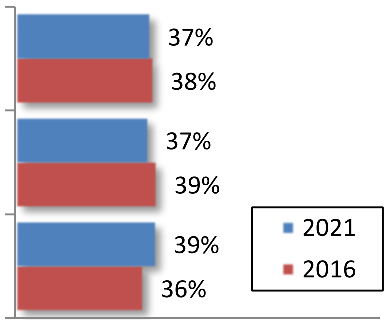
	Total		New York		Pennsylvania	
	2016	2021	2016	2021	2016	2021
Purchase and installation cost	30%	34%	30%	35%	30%	31%
Improved efficiency-lower monthly energy costs	**33%** 1	27%	**35%** P1	25%	27%	**33%** N
Type of energy source already at appliance connection	13%	13%	13%	13%	13%	12%
Size, appearance, features	11%	12%	11%	13%	14%	11%
Preferred type of energy (i.e. gas, electric, oil, etc.)	9%	9%	8%	9%	11%	9%
Environmental benefits	1%	3%	2%	3%	1%	**3%** 2
Decision up to landlord/owner/managers	<1%	<1%	0%	1%	1%	<1%
Don't know	3%	2%	3%	3%	**4%** 1	1%
N	800	800	400	400	400	400

1 Significantly higher than 2021
2 Significantly higher than 2016
N Significantly higher than NY
P Significantly higher than PA

Fireplace

Fireplace: Ownership/Energy Source

- 37% of the Total respondents stated they have a fireplace.
- 49% of the respondents who have a fireplace indicated they have either a natural gas fireplace or a wood burning fireplace with a natural gas starter.



What type of fireplace do you have?

	Total		New York		Pennsylvania	
	2016	2021	2016	2021	2016	2021
Wood burning	41%	39%	39%	35%	49%	**48%** N
Natural gas	38%	35%	41%	**39%** P	32%	24%
Wood burning with natural gas starter	11%	14%	12%	16%	9%	10%
Electric	8%	11%	8%	10%	9%	13%
Propane	1%	1%	1%	1%	1%	3%
Pellet stove/Gel canisters	<1%	<1%	0%	0%	1%	1%
Don't know	1%	1%	1%	1%	1%	1%
N	305	299	157	147	142	156

N Significantly higher than NY
P Significantly higher than PA

Outdoor Appliances

Outdoor Appliances

- 37% of the New York respondents and 31% of the Pennsylvania respondents own one or more outdoor natural gas appliances with Grills mentioned most frequently.

Which of the following outdoor natural gas (not propane) appliances and/or equipment do you own?

	Total		New York		Pennsylvania	
	2016	2021	2016	2021	2016	2021
Grill	25%	26%	**26%** P	26%	20%	26%
Fire pit or fireplace	4%	**10%** 2	4%	**10%** 2	4%	**11%** 2
Emergency/Backup generator	3%	**6%** 2	**5%** P	7%	1%	**4%** 2
Pool heater	2%	**5%** 2	2%	**5%** 2	2%	4%
Gaslights	1%	**3%** 2	1%	**3%** 2	1%	2%
Patio heater	1%	**2%** 2	1%	**3%** 2	1%	2%
I do not own any natural gas outdoor appliances and/or equipment	**70%** 1	65%	68%	63%	**77%** N1	69%
N	800	800	400	400	400	400

1 Significantly higher than 2021
2 Significantly higher than 2016
N Significantly higher than NY
P Significantly higher than PA

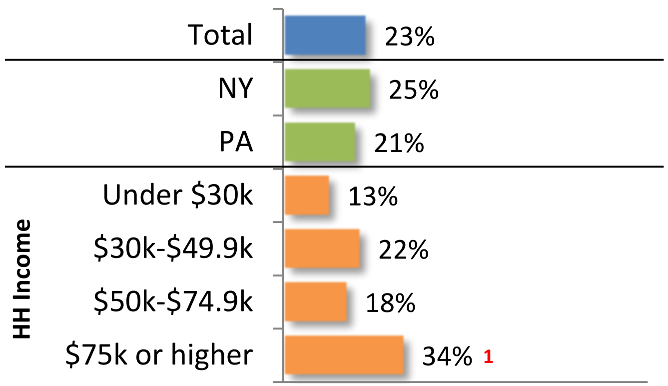
Emergency/Backup Generator

Emergency/Backup Generator

Questions added 2021

Do you own an emergency/backup generator?

% Yes

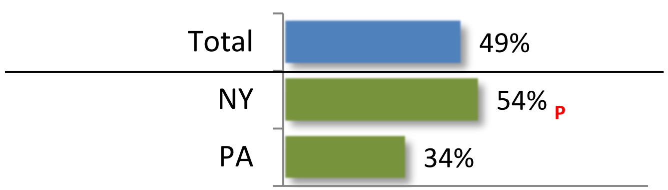


N
800
400
400
211
142
142
305

- 23% of the Total respondents own an emergency/backup generator. Ownership was highest among the $75k+ household income respondents.
- Nearly half (49%) of those who own a backup generator indicated it was a whole house natural gas backup generator.
- 12% of the Total respondent plan to purchase a whole house natural gas backup generator in the next 12 months with intent higher among the $50k+ household income respondents.

Is your emergency/backup generator a whole house natural gas backup generator? This is a permanently installed generator that is supplied with natural gas from your local utility company.

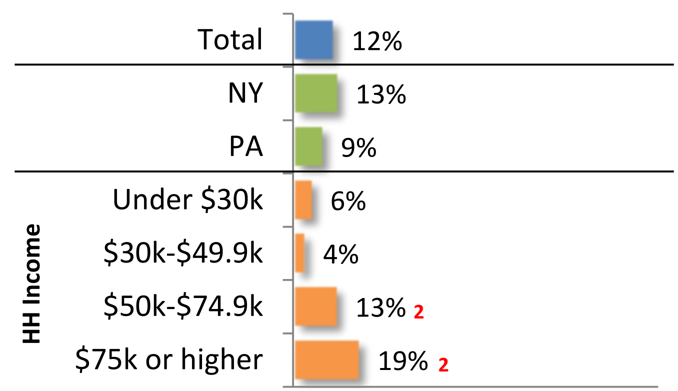
% Yes



N
187
98
82

Do you plan to purchase a whole house natural gas generator in the next 12 months? This is a permanently installed generator that is supplied with natural gas from your local utility company.

% Yes



N
800
400
400
211
142
142
305

1 Significantly higher than Under $30k, $30k-$49.9k and $50k-$74.9k
2 Significantly higher than Under $30k and $30k-$49.9k
P Significantly higher than PA

Renewable Energy

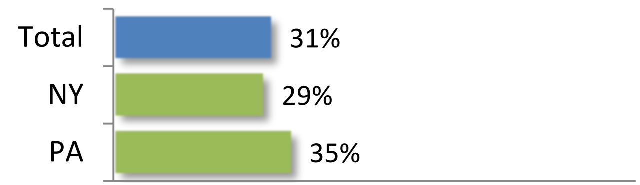
Renewable Energy: Plan/Policy Awareness

Questions added 2021

- Less than a third (31%) of the Total respondents indicated they were aware of government energy plans or policies that set emission reduction goals to address climate change.
- When asked what plans they were aware of (see chart next page), 36% could not recall a specific plan. Increased use of renewable energy (12%), reduced emissions (11%) and use of incentives (11%) were the plans mentioned most frequently.
- Only 16% of the New York respondents aware of plan or policies stated they were aware of New York state's Climate Leadership and Community Protection Act.

New York Respondents:
Are you aware of New York state government energy plans or policies that set emission reduction goals to address climate change?
(N=400)

Pennsylvania Respondents:
Are you aware of federal government energy plans or policies that set emission goals to address climate change?
(N=400)
% Yes



New York Residents Aware of Plans/Policies:
Are you aware of New York state's Climate Leadership and Community Protection Act?
% Yes
(N=117)

Renewable Energy: Plan/Policy Awareness

Question added 2021

What plans are you aware of?

Open ended question asked of respondents who stated they were aware of plans/policies that set emission goals

	Total	NY	PA
Don't recall specific plans	36%	**39%** P	28%
Increase use of renewable energy (solar/wind)/Green energy	12%	13%	12%
Lower/reduce emissions, reduce carbon footprint/reduce greenhouse gases	11%	8%	**20%** N
Incentives/rebates/credits/grants to invest in high efficiency equipment, appliances	11%	12%	9%
Update appliances/High efficiency appliances	9%	**11%** P	4%
Decreased/eliminate use of fossil fuels	7%	6%	9%
More electric cars in the future/All electric cars by 2030-2035	6%	4%	9%
Zero emission goals/Eliminate carbon by 2030-2050/Carbon neutral by 2025-2035	5%	5%	3%
Reduce climate change/Global warming/Save the environment	3%	3%	4%
Become more energy efficient/Energy efficient goals	3%	3%	2%
Stricter controls/Fines/Restrictions	2%	1%	**5%** N
N	245	117	138

N Significantly higher than NY
P Significantly higher than PA

Other Mentions

(less than 1% of Total respondents)

- Cheaper gas/Affordable energy/Lower costs
- Clean, safe energy system
- Close coal power plants/Close pipelines
- HEAP
- Energy efficiency help for low income
- Carbon tax
- Clean Air Act/Clean Air Bill/Green New Deal
- Reduction of electric costs by weatherization
- Updating systems
- Paris Agreement

Renewable Energy: Likely To Pay More To Reduce Carbon Footprint

Question added 2021

- There was moderate interest in paying more per month to reduce a home's carbon footprint.
- Nearly a third of the respondents (31%) indicated they would be very or somewhat likely to pay $50 more to reduce their home's carbon footprint and 32% would be likely to pay $10-$25 more per month.
- 37% were unlikely to pay $10 more per month.

New York Residents: ***The Climate Leadership and Community Protection Act establishes a set of measures to reduce New York's carbon footprint with emissions reduction targets starting in 2030. By carbon footprint we mean the amount of carbon dioxide and other carbon compounds that are emitted due to the consumption of fossil fuels. As part of this act, residents will need to reduce their own carbon footprint.***

Pennsylvania Residents: ***The Federal government is looking to establishes a set of measures to reduce United States carbon footprint. By carbon footprint we mean the amount of carbon dioxide and other carbon compounds that are emitted due to the consumption of fossil fuels. As part of these measures, residents will need to reduce their own carbon footprint.***

***Let's assume you pay an average of $200 a month for your heating and electric bills.
How likely would you be to pay $50-$10 more per month to reduce your home's carbon footprint?***

	Total	NY	PA
Very somewhat likely to pay $50 more per month	31%	30%	35%
Very somewhat likely to pay $25 more per month	14%	13%	16%
Very somewhat likely to pay $10 more per month	18%	19%	16%
Very somewhat unlikely/unsure to pay $10 more per month	37%	38%	33%
N	800	400	400

Renewable Energy: Air Source Heat Pump

Question added 2021

- Respondents who owned their home and had a forced air furnace were presented with an image and description of an air source heat pump and asked about their likelihood to replace their current system within the next 3-5 years.
- There was low interest in this pump with only 11% rating their likelihood a 5 (very likely) or a 4.

Asked of respondents who owned their home and had a forced air furnace

There are different ways to heat and cool your home to reduce your home's carbon footprint. Please read the following description and rate your interest.

Air Source Heat Pump

Description	An air source heat pump is an electric heating and cooling system which operates like an air conditioning unit. It cools and heats your home using the outside air.
Installation Cost	The approximate installed cost for an air source heat pump is $6,500. (note: the approximate installed cost for a new gas furnace and electric air conditioner is $7,000)
Operating Cost	The approximate annual operating cost for an air source heat pump is $1,500. (note: the approximate annual operating cost for a gas furnace and electric air conditioner is $900)
Benefit	Use of this system would result in a lower carbon footprint for your home.

How likely would you be to change out your current heating/cooling system and purchase an air source heat pump within the next 3-5 years?

	Total	NY	PA
5=Very likely	4%	2%	**7%** N
4	7%	9%	5%
3	25%	24%	27%
2	18%	18%	17%
1=Not at all likely	46%	47%	44%
I already own an air source heat pump	<1%	<1%	<1%
N	454	224	236

N Significantly higher than NY

Renewable Energy: Ground Source Heat Pump

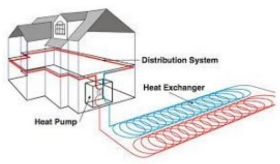
Question added 2021

- Respondents who owned their home and had a forced air furnace were presented with an image and description of a ground source heat pump and asked about their likelihood to replace their current system within the next 3-5 years.
- There was very low interest in this pump with only 5% rating their likelihood a 5 (very likely) or a 4.
- There was significantly higher interest in Pennsylvania (10%) compared to New York (3%).

Asked of respondents who owned their home and had a forced air furnace

There are different ways to heat and cool your home to reduce your home's carbon footprint. Please read the following description and rate your interest.

Ground Source Heat Pump



Description	A ground source heat pump system acts much like an air source heat pump, and will also heat or cool a home, but this system exchanges heat with the ground, not the surrounding air.
Installation Cost	The approximate installed cost for a ground source heat pump is $25,000. (note: the approximate installed cost for a new gas furnace and electric air conditioner is $7,000)
Operating Cost	The approximate annual operating cost for a ground source heat pump is $800. (note: the approximate annual operating cost for a gas furnace and electric air conditioner is $900)
Benefit	Use of this system would result in a lower carbon footprint for your home.

How likely would you be to change out your current heating/cooling system and purchase a ground source heat pump within the next 3-5 years?

	Total	NY	PA
5=Very likely	2%	1%	**5%** N
4	3%	2%	5%
3	9%	10%	8%
2	15%	15%	14%
1=Not at all likely	71%	72%	68%
I already own an air source heat pump	<1%	0%	<1%
N	454	224	236

N Significantly higher than NY

Renewable Energy: Renewable Energy Sources Used

Question added 2021

- 14% of the Total respondents use a renewable energy source. New York respondents had a higher usage rate (15%) compared to the Pennsylvania respondent (9%).
- Solar energy as part of an energy network was used significantly more by the New York respondents (8%) compared to the Pennsylvania respondents (3%).

Which of the following renewable energy sources do you currently use?

	Total	NY	PA
Solar energy as part of energy network	7%	**8%** P	3%
Solar on-site at your home	5%	5%	5%
Wind power as part of energy network	2%	2%	2%
Wind on-site at your home	2%	2%	2%
None of these	83%	82%	**87%** N
Don't know	3%	3%	4%
N	800	400	400

N Significantly higher than NY
P Significantly higher than PA

Renewable Energy: Likely To Pay More To Reduce Carbon Footprint

Question added 2021

- There was moderate interest in paying more per month to use low-carbon electric power alternatives such as solar, or wind among respondents who do not currently use renewable energy sources.
- 40% of these respondents indicated they would be very or somewhat likely to pay $15 more to use lower-carbon alternatives and 22% would be likely to pay $5-$10 more per month.
- 38% were unlikely to pay $5 more per month.

How likely would you be to pay $15-$5 more per month to use low-carbon electric power alternatives such as solar, or wind to reduce your carbon footprint?

Asked of respondents who do not currently use renewable energy sources

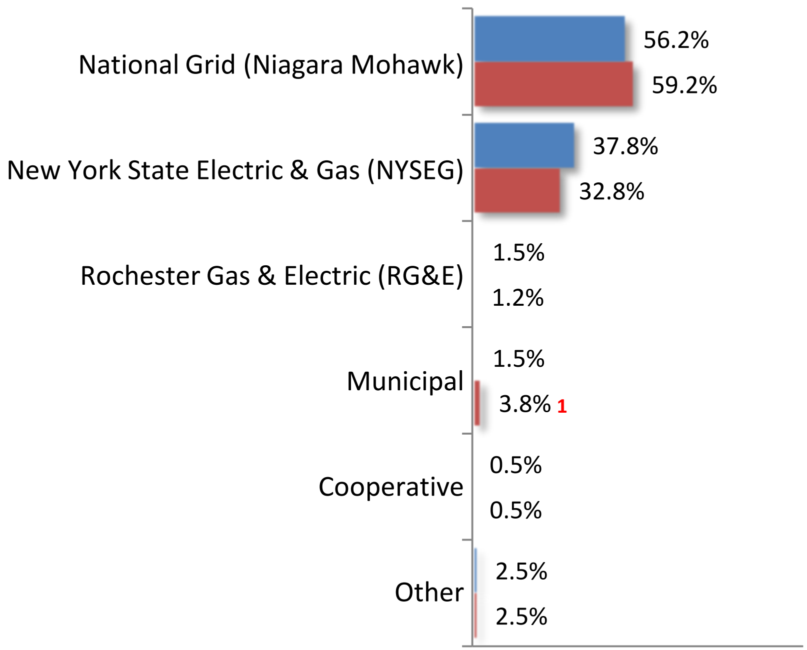
	Total	NY	PA
Very somewhat likely to pay $15 more per month	40%	39%	44%
Very somewhat likely to pay $10 more per month	12%	13%	10%
Very somewhat likely to pay $5 more per month	10%	9%	11%
Very somewhat unlikely/unsure to pay $5 more per month	38%	39%	35%
N	693	339	366

Housing Profile

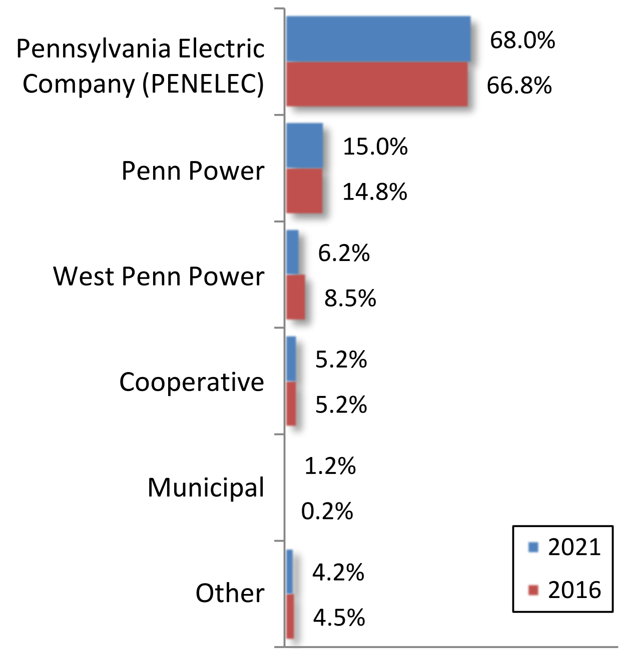
Housing Profile: Electric Utility

- National Grid (Niagara Mohawk) and New York State Electric & Gas (NYSEG) are the leading electric utility providers in the New York service territory.
- Pennsylvania Electric Company (PENELEC) is the leading electric utility provider in the Pennsylvania service territory.

NEW YORK
What is the name of your electric utility?
(N=400)



PENNSYLVANIA
What is the name of your electric utility?
(N=400)



[1] Significantly higher than 2021

Housing Profile: Own/Rent

- Home ownership was higher among those with household incomes above $30,000 and among those who use natural gas in their household.

Do you own or rent your home, apartment or condominium?

	Total		New York		Pennsylvania	
	2016	2021	2016	2021	2016	2021
Own	81%	77%	81%	77%	83%	78%
Rent	19%	23%	19%	23%	17%	22%
N	800	800	400	400	400	400

2021 Respondents	Household Income				Use Natural Gas In Household	
	Under $30k	$30k-$49.9k	$50k-$74.9k	$75k or higher	Yes	No
Own	48%	**75%** [1]	**86%** [2]	**95%** [3]	**79%** [7]	59%
Rent	**52%** [4]	**25%** [5]	**14%** [6]	5%	21%	**41%** [8]
N	211	142	142	305	721	79

[1] Significantly higher than Under $30k
[2] Significantly higher than Under $30k and $30k-$49.9k
[3] Significantly higher than Under $30k, $30k-$49.9k and $50k-$74.9k
[4] Significantly higher than $30k-$49.9k, $50k-$74.9k and $75k or higher
[5] Significantly higher than $50k-$74.9k and $75k or higher
[6] Significantly higher than $75k or higher
[7] Significantly higher than Do Not Use Natural Gas in HH
[8] Significantly higher than Use Natural Gas in HH

Housing Profile: Type/Size/Age

- Respondents living in a single-family home was significantly higher in Pennsylvania (91%) compared to New York (78%).
- 44% of the Total respondents stated the area of their home was 1,500 square feet or less and 44% indicated the size of their home was more than 1,500 square feet.

Is the home you live in built for a single family, two families, or multi-families?

	Total		New York		Pennsylvania	
	2016	2021	2016	2021	2016	2021
Single family	83%	82%	81%	78%	**90%** N	**91%** N
Two families	9%	7%	**10%** P	**9%** P	4%	5%
Multi-family (3 or more families)	8%	10%	9%	**12%** P	5%	3%
Don't know	<1%	1%	<1%	1%	1%	1%
N	800	800	400	400	400	400

What is the area of your home or apartment in square feet?

	Total		New York		Pennsylvania	
	2016	2021	2016	2021	2016	2021
Less than 1,000 square feet	11%	**15%** 2	12%	16%	10%	12%
1,001-1,500 square feet	27%	29%	**29%** P	30%	22%	26%
1,501-2,000 square feet	21%	23%	21%	22%	21%	24%
More than 2,000 square feet	25%	21%	25%	22%	24%	21%
Don't know	**16%** 1	12%	13%	10%	**23%** N1	**17%** N
N	800	800	400	400	400	400

1 Significantly higher than 2021
2 Significantly higher than 2016
N Significantly higher than NY
P Significantly higher than PA

Housing Profile: Type/Size/Age

- A majority (75%) of the Total respondents indicated their home or apartment/condominium building was more than 30 years old.

What is the approximate age of your home or apartment/condominium building?

	Total		New York		Pennsylvania	
	2016	2021	2016	2021	2016	2021
Less than 5 years	1%	2%	2%	2%	1%	<1%
5-10 years	3%	4%	3%	5%	3%	3%
11-20 years	8%	9%	7%	8%	9%	11%
21-30 years	10%	10%	10%	10%	11%	9%
More than 30 years	74%	75%	75%	75%	71%	77%
Don't know	4%	0%	3%	0%	5%	0%
N	800	800	400	400	400	400

Demographic Profile

Demographic Profile

Gender

	Total		New York		Pennsylvania	
	2016	2021	2016	2021	2016	2021
Female	**65%** 1	59%	64%	58%	66%	64%
Male	35%	**41%** 2	36%	42%	34%	36%
N	800	800	400	400	400	400

Age

	Total		New York		Pennsylvania	
	2016	2021	2016	2021	2016	2021
Under 25	1%	**4%** 2	1%	3%	1%	**5%** 2
25-34	9%	12%	9%	12%	8%	**12%** 2
35-44	11%	**16%** 2	11%	15%	13%	**19%** 2
45-54	**19%** 1	14%	**19%** 1	13%	20%	16%
55-64	**30%** 1	17%	**31%** 1	17%	**29%** 1	18%
65 and older	29%	**37%** 2	29%	**40%** P2	30%	30%
N	800	800	400	400	400	400

1 Significantly higher than 2021
2 Significantly higher than 2016
N Significantly higher than NY
P Significantly higher than PA

Demographic Profile

Education

	Total		New York		Pennsylvania	
	2016	2021	2016	2021	2016	2021
Some high school	1%	1%	1%	1%	2%	2%
High school graduate	23%	20%	21%	17%	**28%** N	**28%** N
Some college/Technical school	25%	27%	24%	26%	29%	31%
College graduate	33%	34%	**35%** P	**37%** P	26%	25%
Post graduate	18%	18%	19%	19%	15%	14%
N	800	800	400	400	400	400

How many people live in household

	Total		New York		Pennsylvania	
	2016	2021	2016	2021	2016	2021
1	24%	21%	24%	**22%** P	**23%** 1	16%
2	47%	44%	46%	46%	**48%** 1	39%
3	15%	16%	15%	14%	15%	**20%** N2
4	9%	11%	10%	10%	9%	**14%** 2
5 or more	5%	8%	5%	8%	5%	**11%** 2
N	800	800	400	400	400	400

1 Significantly higher than 2021
2 Significantly higher than 2016
N Significantly higher than NY
P Significantly higher than PA

Demographic Profile

Household Income

	Total		New York		Pennsylvania	
	2016	2021	2016	2021	2016	2021
Under $30,000	30%	26%	30%	26%	32%	28%
$30,000 to $49,999	20%	18%	20%	17%	19%	19%
$50,000 to $74,999	17%	18%	15%	17%	**22%** N	19%
$75,000 to $124,999	20%	22%	21%	22%	20%	22%
$125,000 or more	12%	**16%** 1	**14%** P	**18%** P	7%	**13%** 1
N	800	800	400	400	400	400

1 Significantly higher than 2016
N Significantly higher than NY
P Significantly higher than PA

Appendix

Cities, Towns, Villages, Boroughs, Townships In Service Territory Counties

Cities, Towns, Villages In New York Service Territory Counties

Allegany County
Alfred
Alma
Almond
Amity
Andover
Angelica
Belfast
Belmont
Bolivar
Caneadea
Centerville
Clarksville
Cuba
Friendship
Genesee
Independence
Richburg
Scio
Wellsville
Willing
Wirt

Cattaraugus
Ashford
Carrolton
Cattaraugus
Cold Spring
Delevan
East Otto
East Randolph
Ellicottville
Farmersville
Franklinville
Freedom
Gowanda
Great Valley
Little Valley
Machias
Mansfield
Napoli
New Albion
Olean
Otto
Perrysburg
Persia
Portville
Randolph
Red House
Salamanca
Yorkshire

Chautauqua
Arkwright
Bemus Point
Brocton
Busti
Carroll
Cassadaga
Celoron
Charlotte
Chautauqua
Clymer
Dunkirk
Ellery
Ellicott
Falconer
Forestville
Fredonia
Gerry
Hanover
Harmony
Jamestown
Kiantone
Lakewood
Mayville
North Harmony
Panama
Poland
Pomfret
Portland
Ripley
Sheridan
Sherman
Silver Creek
Sinclairville
Stockton
Westfield

Erie
Akron
Alden
Amherst
Angola
Aurora
Blasdell
Boston
Brant
Buffalo
Cheektowaga
Clarence
Colden
Collins
Collins Center
Concord
Depew
East Amherst
East Aurora
Eden
Elma
Evans
Farnham
Getzville
Gowanda
Grand Island
Hamburg
Holland
Kenmore
Lackawanna
Lancaster
Marilla
Newstead
North Collins
Orchard Park
Sardinia
Sloan
Springville
Tonawanda
Wales
West Seneca
Williamsville

Genesee
Alabama
Alexander
Attica
Batavia
Bethany
Corfu
Darien
Elba
Oakfield
Pavilion
Pembroke
Stafford

Livingston
Lima

Monroe
Honeoye Falls
Mendon

Niagara
Cambria
Lewiston
Niagara
Niagara Falls
North Tonawanda
Porter
Wheatfield
Wilson
Youngstown

Ontario
Bristol
East Bloomfield
Holcomb
Richmond
West Bloomfield

Steuben
Almond
Arkport
Canisteo
Fremont
Greenwood

Hornell
Hornellsville
Howard
North Hornell
West Union

Wyoming
Arcade
Attica
Bennington
Castile
Covington
Eagle
Gainesville
Genesee Falls
Java
Middlebury
Orangeville
Pike
Sheldon
Silver Springs
Wyoming

Villages, Boroughs, Townships In Pennsylvania Territory Counties

Armstrong
Bradys Bend
East Franklin
Perry
Sugarcreek
Washington
West Franklin

Butler
Adams
Allegheny
Center
Chicora
Concord
Donegal
Fairview
Forward
Karns City
Mars
Oakland
Parker
Penn
Petrolia
Summit
Venango
Washington

Cameron
Emporium
Shippen

Clarion
Ashland
Beaver
Brady
Clarion
East Brady
Elk
Farmington
Highland
Knox
Limestone
Madison
Millcreek
Monroe
Paint
Perry
Salem
Strattanville
Washington

Clearfield
Brady
DuBois
Falls Creek
Huston
Sandy

Crawford
Blooming Valley
Cambridge
Cambridge Springs
Cochranton
Conneaut
Conneaut Lake
Conneautville
East Fairfield
East Mead
Fairfield
Greenwood
Hayfield
Hydetown
Linesville
Meadville
Oil Creek
Pine
Randolph
Richmond
Sadsbury
Saegertown
South Shenango
Spring
Springboro
Steuben
Summerhill
Summit
Titusville
Townville
Venango
Vernon
Wayne
West Mead
Woodcock

Elk
Fox
Highland
Horton
Jay
Johnsonburg
Jones
Millstone
Ridgway
Spring Creek
St. Marys

Erie
Albion
Amity
Concord
Conneaut
Corry
Cranesville
East Springfield
Edinboro
Elgin
Elk Creek
Erie City
Fairview
Franklin
Girard
Greene
Greenfield
Harborcreek
Lake City
Lawrence Park
LeBoeuf
McKean
Middleboro
Mill Village
Millcreek
North East
Platea
Springfield
Summit
Union
Union City
Venango
Washington
Waterford
Wattsburg
Wayne
Wesleyville

Forest
Barnett
Green
Harmony
Hickory
Howe
Jenks
Kingsley

Jefferson
Barnett
Beaver
Brockway
Brookville
Clover
Corsica
Eldred
Falls Creek
Heath
Knox
Pinecreek
Polk
Reynoldsville
Rose
Snyder
Sykesville
Union
Warsaw
Washington
Winslow

McKean
Bradford
Eldred
Foster
Hamilton
Hamlin
Keating
Lafayette
Lewis Run
Norwich
Otto
Sergeant
Smethport
Wetmore

Mercer
Clarksville
Coolspring
Delaware
East Lackawannock
Fairview
Farrell
Findley
Fredonia
French Creek
Greene
Greenville
Hempfield
Hermitage
Hickory
Jackson
Jackson Center
Jamestown
Jefferson
Lackawannock
Lake
Mercer
Perry
Pine
Pymatuning
Sandy Creek
Sandy Lake
Sharon
Sharpsville
Sheakleyville
Shenango
South Pymatuning
Sugar Grove
West Middlesex
West Salem
Wheatland
Worth

Venango
Canal
Cherrytree
Clinton
Cooperstown
Cornplanter
Cranberry
Franklin
Frenchcreek
Irwin
Jackson
Mineral
Oakland
Oil City
Oilcreek
Pinegrove
Pleasantville
Polk
President
Richland
Rockland
Rouseville
Sandycreek
Scrubgrass
Sugarcreek
Utica

Warren
Brokenstraw
Clarendon
Columbus
Conewango
Deerfield
Farmington
Freehold
Glade
Limestone
Mead
Pine Grove
Pittsfield
Pleasant
Sheffield
Sugar Grove
Tidioute
Triumph
Warren
Youngsville

Appendix I

National Fuel Gas Distribution Corporation

December 22, 2022

National Fuel®

CADMUS

Memorandum

To: Brian Welsch; National Fuel Gas Company

From: Jeremy Koo, Sean Brennan, and Elissa Slocum; Cadmus

Subject: Net-Zero Community Model with Networked Geothermal Heat Pumps

Date: November 9, 2022

Background

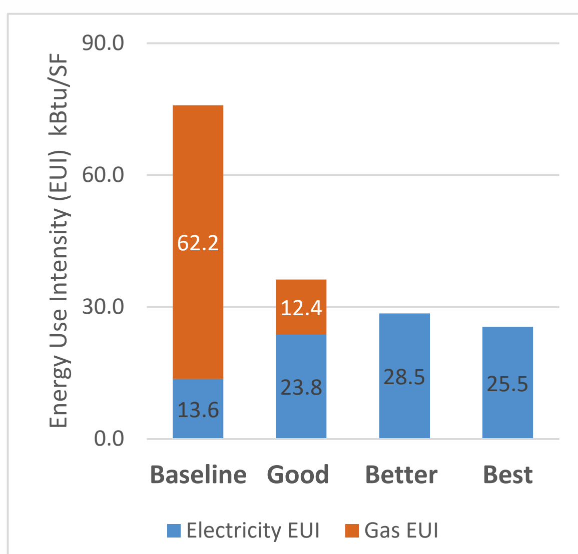
National Fuel Gas Distribution Corporation (Distribution) asked Cadmus to develop a model showing the costs, energy savings, and carbon dioxide emissions of a neighborhood in Batavia, New York, if it were to adopt measures to achieve net-zero annual building emissions. While the modeled net-zero scenario is hypothetical, it uses the building characteristics and energy bills of a neighborhood of 33 homes selected by Distribution in a disadvantaged community (as defined by New York State) as the model baseline.

As a result of the recently passed Utility Thermal Energy Network and Jobs Act, the Public Service Commission directed Distribution, along with other investor-owned utilities in New York, to propose pilots for networked geothermal projects. In parallel with the memo we previously submitted focused on hybrid natural gas and air-source heat pump (ASHP) systems, Cadmus explored a third scenario using networked district geothermal heat pumps for providing space heating and cooling (and potentially domestic hot water). We assessed the *best package* of measures referenced in the previous memo to achieve a net-zero profile for the homes within the modeled neighborhood; this included (1) a basic package of weatherization measures, (2) networked geothermal heat pumps, (3) hot water heat pumps, (4) electric appliances, and (5) renewable electricity.

Results

The Batavia neighborhood homes are relatively modest in size, with a median area of 1,410 square feet, and modest in energy use, with a median site energy use intensity (EUI) of 76 kBtu per square foot (shown as the baseline in Figure 1). Compared to the hybrid ASHP scenario (*good package*), the networked geothermal scenario is all-electric, requiring no offsets for the remaining natural gas loads and only renewable energy certificates (RECs) to offset the added electrical loads from whole-home electrification. The networked geothermal scenario significantly reduces the all-electric site EUI to 25.5 kBtu per square foot.

Figure 1. Baseline, Good, Better, and Best Package Comparison



In this scenario we only looked at a single package, representing the *best package* referenced in the previous memo. This package is estimated to cost approximately $83,200 per home, with an ongoing cost of $244 per year to purchase RECs to achieve net-zero carbon. In comparison, this is significantly higher than the costs of $34,400 for the *good package* using hybrid ASHPs and the cost of $53,200 per home for the *better package* using whole-building ASHPs, though ongoing costs will be lower due to lower energy costs and REC purchases, as detailed further in this memo. The summary of measures included, first costs, and annual costs for each package is shown in Table 1.

Table 1. Summary of Good, Better, and Best Package First and Annual Costs

Energy Conservation Measure		Description	Costs		
			Good	Better	Best
1a	Envelope Upgrades	Blower door, air sealing, attic insulation, wall insulation, storm windows	$11,009	$11,009	$11,009
1b		New windows per energy code	-	$13,753	-
2a	Hybrid HVAC	Replace furnace with dual-fuel heat pump	$12,125	-	-
2b	Full ASHP	Replace furnace with cold-climate ASHP (multi-split)	-	$17,200	-
2c	Geothermal Network	Install ground wells for neighborhood thermal energy network and indoor equipment for homes	-	-	$60,945
3	Hot Water Heat Pump	Replace hot water tank with heat pump	$4,651	$4,651	$4,651
4a	Electric Panel Upgrade	Increase panel capacity to at least 200 amps	$3,000	$3,000	$3,000
4b	ENERGY STAR Electric Appliances	Replace cooking and laundry with electric	$3,595	$3,595	$3,595
Total First Costs			**$34,380**	**$53,208**	**$83,200**
Annual Utility Costs			**$1,690**	**$1,841**	**$1,669**
Utility Cost Savings Compared to Baseline			**-$31**	**-$182**	**-$353**
Annual Costs Compared to Baseline with RECs/Carbon Offsets			**$316**	**$99**	**-$103**

The additional co-benefits associated with electrification and eliminating fossil fuel combustion were summarized in the previous memo.

Methodology

The methodology for utility energy and property data analysis for the 33 homes in the Batavia neighborhood was detailed in the previous memo. As discussed in that previous memo, Cadmus modeled a series of energy upgrades on top of these baseline models of energy use. We grouped the results into three packages—good, better, and best—as detailed in Table 1. The envelope measures include air sealing, wall and roof insulation, window treatments, and new windows. The heating and cooling systems would be replaced by ASHPs—either a hybrid dual-fuel ducted system (COP=3) in the *good package* or a full multi-split cold-climate ASHP system (COP=2.5) in the *better package*. Both packages used a hot water heat pump (COP=3.25) to supply domestic hot water. The *best package* discussed here uses networked geothermal heat pumps for space heating and cooling (COP=3.6). As shown in Table 2, each successive package of upgrades increases the carbon emission reduction (and thus the degree of RECs and offsets needed to achieve net zero carbon emissions).

Table 2. Results of Energy Upgrades on Baseline Models

Energy Conservation Measure		Description	Good	Better	Best
1a	Envelope Upgrades	Blower door, air sealing, attic insulation, wall insulation, storm windows	●	●	●
1b		New windows per energy code	-	●	-
2a	Hybrid HVAC	Replace furnace with dual-fuel heat pump	●	-	-
2b	Full ASHP	Replace furnace with cold-climate ASHP (multi-split)	-	●	-
2c	Geothermal Network	Install ground wells for neighborhood thermal energy network and indoor equipment for homes	-	-	●
3	Hot Water Heat Pump	Replace hot water tank with heat pump	●	●	●
4a	Electric Panel Upgrade	Increase panel capacity to at least 200 amps	●	●	●
4b	ENERGY STAR Electric Appliances	Replace cooking and laundry with electric	●	●	●
		Aggregate Carbon Emission Reduction	**62%**	**76%**	**79%**
5	RECs and Carbon Offsets	Offset all emissions—RECs and carbon credits	●	●	●
		Aggregate Carbon Emission Reduction	**100%**	**100%**	**100%**

Finally, Cadmus estimated the costs of implementing these energy upgrades and projected future utility costs for these homes. The methodology and sources for all non-HVAC measures were described in the previous memo. We developed a bottom-up approach for the networked geothermal heat pump construction costs of the district ground loop and indoor equipment. We consulted many sources to assess the system design and estimate costs, including Distribution staff, RSMeans, NYSERDA's Ground Source Heat Pump Rebate program data, National Grid's *Geothermal Gas REV Demonstration Project* (2020),[1] and the Home Energy Efficiency Team's *Geo Micro District Feasibility Study* (2019).[2] Additionally, we interviewed John Ciovacco of Aztech Geothermal and Zachary Fink of ZBF Geothermal, two New York–based geothermal installers actively involved with ongoing utility-led networked geothermal pilots in New York and Massachusetts.

The following sections describe the components of the networked geothermal system as well as our approach for designing the system and estimating its costs. In general, we took a conservative approach to making cost estimates, given the lack of maturity of the utility-developed networked geothermal market. The experts we interviewed noted that it might be possible over time—with greater economies of scale, streamlining, and increased learning and familiarity—to reduce the cost per ton from this estimate by 20% to 30%.

District Ground Loop and System Design

In typical residential geothermal systems, the ground loop (most commonly vertical closed loop boreholes) is contained within the property lines and serves a single home. Many homes in New York face feasibility constraints with installing vertical boreholes for geothermal systems: boreholes must be

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1 National Grid. April 3, 2020. *Geothermal Gas REV Demonstration Project, Long Island, New York: Final Report*. NY DPS Case 16-G-0058. https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={2511B9E5-F94E-451E-BD27-BB9535BEA596}

2 Home Energy Efficiency Team and BuroHappold Engineering. 2019. *Geo Micro District Feasibility Study.* https://heet.org/energy-shift/geomicrodistrict-feasibility-study/

spaced at least 20 feet apart to prevent thermal interference and at least 15 feet from the property to avoid potential damage to the foundation. As shown in the Google Maps screenshot of the Batavia neighborhood (Figure 2), many of the targeted homes may lack sufficient yard area for geothermal drilling or have existing fencing and other obstacles that will make it difficult for drill rigs to access backyards.

Figure 2. Map of Section of Batavia Neighborhood

The district ground loop is the primary component of the networked geothermal system that differs from individual geothermal heat pump systems: a networked geothermal system serves multiple homes and combines all boreholes into a single communal, district loopfield. In this scenario, we assume that Distribution will own and operate a communal loopfield that is drilled into the street, using the right-of-way established in its franchise agreement with the City of Batavia to install and maintain the required geothermal infrastructure. We assumed that boreholes would be drilled along the east side of the street, connected with a central horizontal loop trenched approximately 6 feet underground (below the local frost line).

There are several specifications of this central loop:

- ***System size.*** We estimate that **92.3 tons of ground loop capacity** will be needed for the system, based on aggregating the estimated peak heating demand from an analysis of annual natural gas demand from billing data. While the lack of differentiated load shapes limits the ability to reduce the size of the ground loop significantly below the aggregated peak load, we estimate a peak coincidence of 90%.[3] A detailed system design or feasibility study would establish actual system sizing based on heating load calculations of all connected homes.
- ***Vertical boreholes.*** Using an estimate of **170 feet of vertical bore depth per ton**,[4] we estimate that 55 boreholes averaging 285 feet in depth will be needed for the system. These boreholes would be drilled in a single line along the east side of the street, spaced 20 feet to 25 feet apart. An assessment of thermal conductivity following the drilling of a test bore would establish actual total bore depth necessary to serve the combined loads. We assume that 1¼-inch high density polyethylene (HDPE) piping grouted with a thermally conductive grout (1.2 Btu per hour foot conductivity) would be used for each borehole.
- ***Communal loop.*** Based on a visual analysis of Google Maps, we estimate that approximately **1,200 linear feet** of communal loop will connect the boreholes and feed piping to individual homes. We assume that the communal loop will use 3-inch HDPE supply and return piping as a one-pipe system, which reduces the total piping length but requires a central pumping station to operate.
- ***Individual home connections.*** Based on a visual analysis of Google Maps, the nearest exterior walls of the 31 buildings[5] range from approximately 40 feet to 60 feet from the street. In total, we estimate that **1,520 linear feet** of connections will be required from the communal loop to each home. We assume that each home will be connected to the communal loop using 1¼-inch HDPE piping trenched to a depth of 6 feet.

The installation of the district ground loop accounts for more than 60% of the overall system costs. The key cost components of the ground loop are summarized in Table 3. All costs include a 15% contingency. In addition to these costs, we estimate a cost of approximately $30,000 for system design and thermal conductivity testing as part of overall construction.

3 National Grid 2020; Interviews with John Ciovacco (Aztech Geothermal) and Zachary Fink (ZBF Geothermal).

4 Westchester GeoPossibilities Screening Tool; National Grid 2020.

5 Two of the buildings have two housings units.

Table 3. Networked Geothermal Ground Loop Cost Components

Ground Loop Component	Description	Estimated Cost
Vertical Boreholes	Estimate includes drilling, thermally conductive grouting (1.2 Btu per hour foot), 40-feet of casing, 1¼-inch HDPE piping per borehole (one U-bend), filling all piping with antifreeze, and 15,690 feet of total vertical bore depth (National Grid 2020; interviews with John Ciovacco and Zachary Fink)	$793,936
Communal Loop	Estimate includes trenching up to 6-feet and installing 3-inch HDPE supply/return piping and manifold, demolition of existing pavement and repavement, costs for traffic control, and 1,200 linear feet of excavation and piping installation (Distribution costs for natural gas main installation) [a]	$110,400
Central Pumping Station	Central pumping is required to circulate heat transfer fluid through the ground loop and throughout the system (interview with Zachary Fink)	$345,000
Connections to Individual Homes	Estimate includes trenching up to 6-feet, 1¼-inch HDPE piping, and 1,520 linear feet of excavation and piping installation (Distribution costs for natural gas line installation) [a]	$43,700
	Total	**$1,293,036**

[a] We initially developed bottom-up costs for construction and excavation of the communal ground loop and connections to individual homes. Cadmus then revised those estimates based on values provided by Distribution for actual typical costs for natural gas main and line installations, which are comparable to HDPE piping installed costs.

We explored the possibility of using the district loop to also provide domestic hot water to each home. Based on an analysis of the *New York Technical Reference Manual* for heat pump water heaters and interviews with installers, we estimated this would add approximately 135 feet to 140 feet of vertical bore depth per home, increasing the total installation cost by nearly $220,000. In conjunction with the cost of the indoor dedicated water-to-water system, we expect that the cost per home will be significantly higher to design the networked geothermal system to provide domestic hot water compared to using individual hybrid electric heat pump water heaters. Thus, the *best package* assessed here uses hybrid heat pump water heaters instead of a networked geothermal approach to provide domestic hot water.

Individual Home Components

In a networked geothermal system, a geothermal heat pump system is installed in each unit and connected to piping branched off from the communal loop. As all homes in the study use forced hot air furnaces, we assumes the installation of 3-ton, dual-stage, packaged water-to-air systems with electric resistance auxiliary heat to serve each unit. Based on an analysis of NYSERDA rebate data and the National Grid study (adjusted for inflation), we estimate that each heat pump will cost approximately **$15,132**.

Additionally, we assumed approximately **$5,700** per home of additional site-specific work to facilitate the installation of the geothermal heat pump. This is expected to include the cost of bringing lines into the home and could also include the cost of ductwork modifications, the use of split instead of packaged systems, building enclosures, more challenging location of existing mechanical space, and other site-specific work that may increase material or labor costs associated with installation. This increases the individual cost for each home to **$20,852**.

In total, the cost of individual components for the 33 homes is estimated at **$688,109**. In other neighborhoods, many more homes may use hydronic or steam distribution. Given that geothermal heat pumps produce hot water at lower temperatures than most hydronic/steam systems are designed for, retrofitting these homes will require either significant modification to the existing distribution system or the installation of new ductwork, greatly increasing the cost of installation.

Utility Cost Impacts

Using natural gas and electricity rates derived from Distribution natural gas rate summaries and National Grid electricity rate summaries from October 2021 to September 2022, we estimated the changes in operating costs from the baseline to the *best package* for the average home.

In summary, utility costs were reduced by 17% ($353) per home, prior to the cost of REC purchases, which reduce annual savings to 5% ($103). The low cost savings are due to the relatively high price of electricity and low price of natural gas. Table 4 shows first costs for the *best package* and Table 5 shows utility costs for the *best package*.

Notably, we do not include estimates for potential energy cost changes related to cooling. High-efficiency ASHPs and geothermal heat pumps meet or exceed the efficiency of central and window air conditioners and could deliver further electricity savings. However, we lack information about the presence of AC, the type of equipment, and usage in each home: while homes with existing central AC would likely see cooling energy savings, homes with window ACs may see more limited savings (or cost increases) if cooling usage increases due to greater convenience and increased coverage of space conditioned. Other homes without prior AC could experience load building. As a result, we have excluded potential cooling energy changes from our analysis.

Additionally, we have not included a potential geothermal customer charge in these estimates. Utilities exploring networked geothermal installations have discussed options for cost recovery in the case of a utility-owned geothermal system. Many utilities are exploring the use of a monthly geothermal customer charge (fixed or relative to the heat pump capacity) as opposed to metering flow rates to each home, given the added cost of metering. As Distribution explores the networked geothermal concept further, it will need to balance establishing a monthly geothermal customer charge (or similar billing mechanism) that allows for cost recovery and an adequate rate of return against the potential customer savings to manage bill impacts.

Table 4. Best Package Average First Costs Per Home

Energy Conservation Measure		Description	First Cost
1	Envelope Upgrades	Blower door, air sealing, attic and wall insulation, storm windows	$11,009.39
2c-1	Networked Ground Loop	Installation of district ground loop (divided across homes)	$34,072.10
2c-2	Geothermal Heat Pump	Installation of dual-stage, 3-ton water-to-air heat pump with $3,000 allowance for additional modifications	$20,851.79
2c-3	Networked Geothermal Design and Contingency	Design and thermal conductivity costs and 15% ground loop construction contingency (divided across number of homes)	$6,020.61
3	Hot Water Heat Pump	Replace hot water tank with heat pump	$4,651.00
4a	Electric Panel Upgrade	Increase panel capacity to 200 amps	$3,000.00
4b	ENERGY STAR Electric Appliances	Replace cooking and laundry with electric	$3,595.05
		Total	**$83,199.94**

Table 5. Best Package Average Utility Costs Per Home

Energy Conservation Measure		Gas EUI (kBtu/SF)	Elec EUI (kWh/SF)	Annual Utility Cost	Utility Cost Change	Proportional Cost Change
	BASELINE	62.2	4.0	$2,022.73	-	-
1	Envelope Upgrades	52.9	3.9	$1,899.97	($122.77)	-6%
2	Networked Geothermal	15.2	6.4	$1,941.43	($81.31)	-4%
3	Hot Water Heat Pump	1.9	7.1	$1,866.35	($156.38) [a]	-8%
4	Electric Panel and Appliances	0.0	7.5	$1,669.49	($353.24) [b]	-17%
5	RECs	0.0	7.5	$1,919.76	($102.97)	-5%

[a] Based on Distribution's rate structure, reducing Mcf consumed when monthly usage is under 5 Mcf yields significantly greater cost savings—increasing savings for the hot water heat pump retrofit compared to the geothermal retrofit despite lower COP.

[b] While converting from natural gas cooking and laundry to electric appliances increases electricity costs relative to gas costs, this measure eliminates the monthly cost associated with maintaining a natural gas connection to the home, which is retained until appliances are electrified. The utility savings associated with measure 4 thus appear to be significantly greater than what would be expected from a direct fuel switch from a natural gas to an electric resistance appliance.

Appendix J

National Fuel Gas Distribution Corporation

December 22, 2022

National Fuel Gas Company

RNG Potential in NY & NFGDC Territory

April 2020

Objective

Determine what percentage of the residential natural gas load renewable natural gas (RNG) can displace in both:

(1) New York State

(2) NFGDC NY Service Territory

National Fuel

Agenda

1) RNG Potential in NY State

2) RNG Potential in NFGDC Service Territory

3) Ability of RNG to Displace Residential Natural Gas Load

RNG Potential in NY State

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New York RNG Potential

	Landfill Gas	Animal Manure	Waste Water	Food Waste	Agri. Residue	Forest Residues	Energy Crops	Municipal Solid Waste	Total RNG (Bcf)
Low Resource Scenario	19.739	4.522	2.472	2.388	2.015	1.980	0.598	19.307	**53.021**
High Resource Scenario	32.753	9.044	3.304	4.179	5.038	3.959	3.041	43.536	**104.854**
Technical Potential In NYS	50.489	15.073	7.197	21.554	24.327	10.152	33.219	109.106	**271.117**

Source: AGF – Renewable Sources of Natural Gas: Supply and Emissions Reduction Assessment (2019)

RNG Potential in NFGDC NY Territory

Methodology

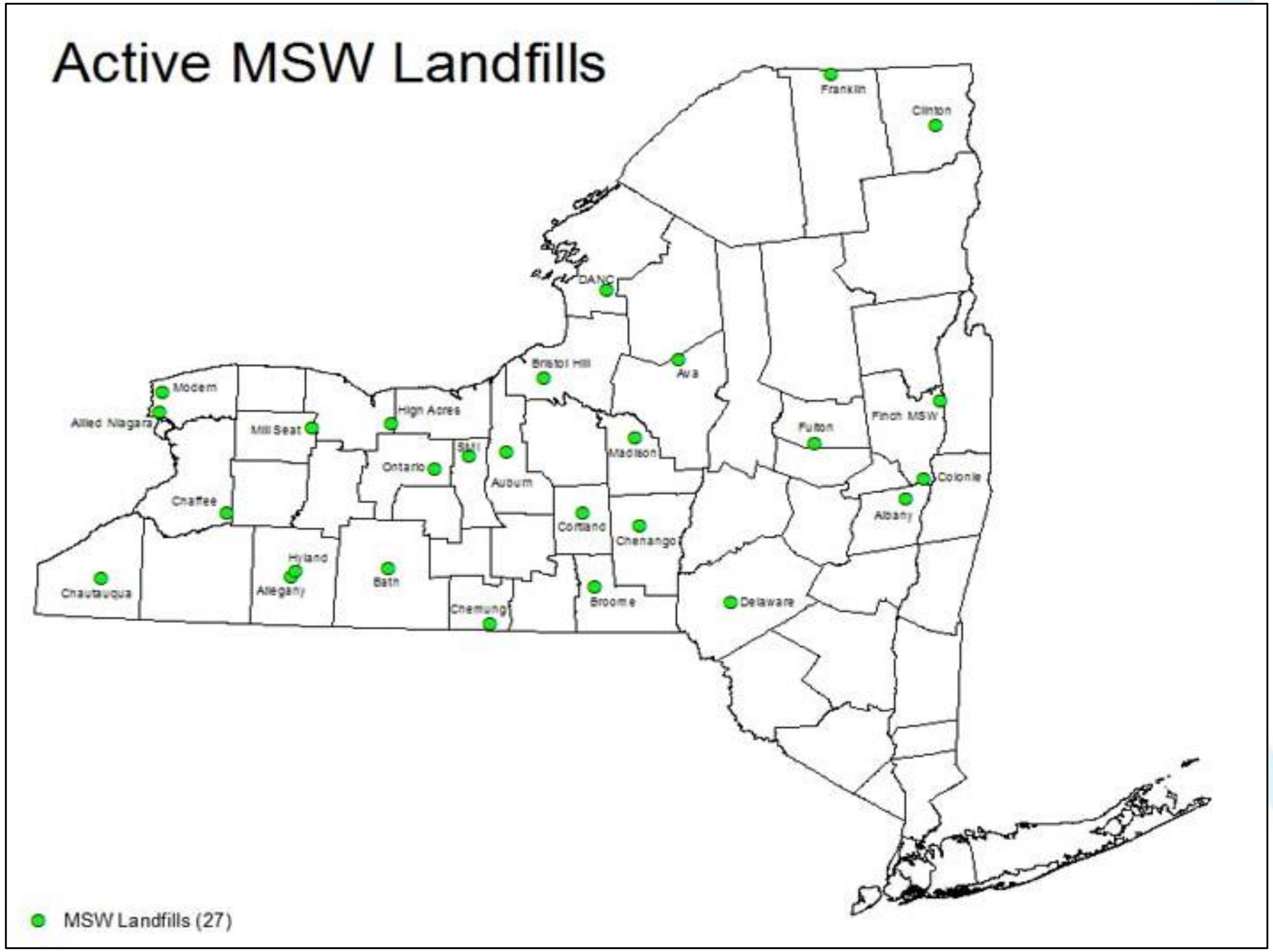
The NFG CLCPA Research Team utilized information and methodology from the AGF study *Renewable Sources of Natural Gas: Supply and Emissions Reduction Assessment* released in December 2019 to develop estimates of the RNG potential in National Fuel's NY service territory.

The following RNG resources were examined:

- Landfill Gas
- Animal Manure
- Waste Water Treatment
- Food Waste
- Agricultural Residue
- Forest Residues
- Energy Crops
- Municipal Solid Waste

Landfill Gas

Active Landfills in NYS



Active MSW Landfills in NFG NY Territory

- Waste Management: Chaffee, NY
- Chautauqua County Landfill
- Hyland Landfill: Angelica, NY
- Modern Landfill: Youngstown, NY
- Niagara Falls Landfill: Niagara, NY

NFGDC NY Division Landfill Gas Potential

Facility Name	County	2018 Emissions (mtCO2e)	RNG Potential 100% Recovery	High Resource 80% Facilities	Low Resource 50% Facilities
Allied/BFI Niagara Falls Landfill	Niagara	70,683	1,285,145	706,830	321,286
Waste Management Chaffee Landfill	Erie	60,704	1,103,709	607,040	275,927
Chautauqua Landfill	Chautauqua	38,953	708,236	389,530	177,059
Hyland Landfill	Allegany	67,519	1,227,618	675,190	306,905
Modern Landfill	Niagara	304,411	5,534,745	3,044,110	1,383,686
Total (Mcf)			**9,859,453**	**5,422,700**	**2,464,864**

Source: https://ghgdata.epa.gov/ghgp/main.do#

Animal Manure

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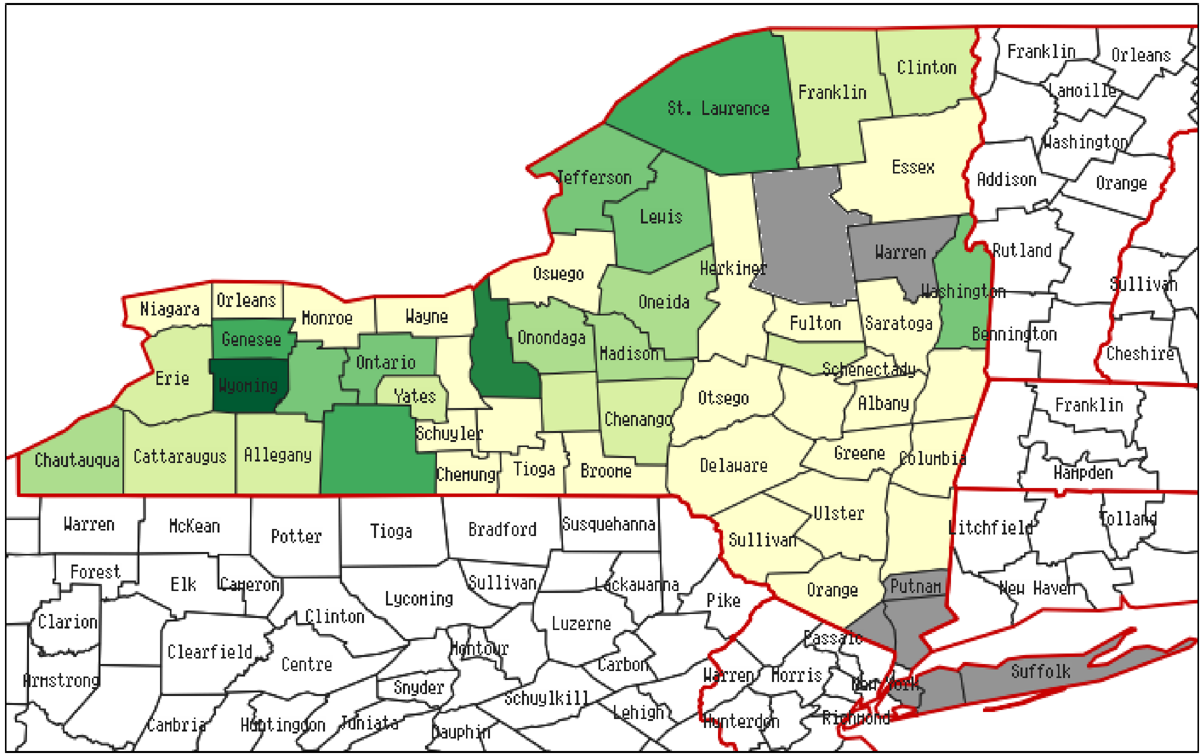
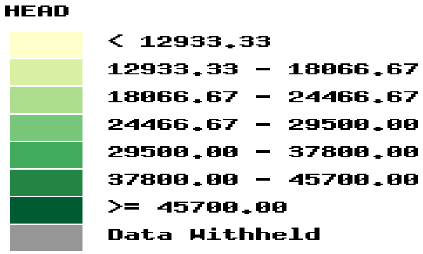
Location of Animal Manure Sources

Heads per County (Dairy, Swine, Beef, Poultry)



Source: US Department of Agriculture



County	Cattle / Calves	Hogs & Pigs	Total
Erie	**27,100**	740	27,840
Wyoming	**103,228**	365	103,593
Niagara	**21,190**	3,065	24,255
Chautauqua	**43,922**	526	44,448
Allegany	**29,319**	891	30,210
Cattaraugus	**36,651**	502	37,153
Genesee	**60,205**	294	60,499
Steuben	**75,923**	N/A	75,923

Source: 2017 NYS Census of Agriculture

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RNG Animal Waste Methodology

Three dairy cow projects from Brightmark Energy:

Yellowjacket Upstate NY	Augean Yakima County, WA	Larson Florida
• Headcount: 15,000 • MMBtu per Year: 260,000 • **MMBtu/yr/cow: 17.33** • GHG Reductions: 108,000 mtCO2e	• Headcount: 7,000 • MMBtu per Year: 160,000 • **MMBtu/yr/cow: 22.86** • GHG Reductions: 50,000 mtCO2e	• Headcount: 9,900 • MMBtu per Year: 171,000 • **MMBtu/yr/cow: 22.86** • GHG Reductions: 57,500 mtCO2e

- Boxler Dairy Farm – Varysburg, Wyoming County*
- Lamb Lakeshore Dairy – Wilson, Niagara County*
- Lamb Farms – Oakfield, Genesee County*
- Lawnhurst – Stanley, Ontario County
- Swiss Valley Farms – Warsaw, Wyoming County*
- Zuber Farms – Byron, Genesee County*

*Project coming online in 2020

National Fuel

RNG Potential From Animal Waste

County	Cattle Count	MMBtu per year per cow	100% Recovery	High Resource 60% Recovery	Low Resource 30% Recovery
Wyoming	103,228	17.33	1,754,876	1,052,926	526,463
Steuben	75,923	17.33	1,290,691	774,415	387,207
Genesee	60,205	17.33	1,023,485	614,091	307,046
Chautauqua	43,922	17.33	746,674	448,004	224,002
Allegany	29,319	17.33	498,423	299,054	149,527
Erie	27,100	17.33	460,700	276,420	138,210
Niagara	21,190	17.33	360,230	216,138	108,069
Total MCF:			**6,135,079**	**3,681,047**	**1,840,524**

Waste Water Treatment

National Fuel

RNG Potential From Waste Water Treatment

Facility Name	Design Flow (MGD)	Population Served	Technical Potential 100% Resource Capture	High Resource 50% of WRRF's >3.25 MGD	Low Resource 30% of WRRF's >7.25 MGD
BSA BIRD ISLAND WASTWATER TREATMENT PLAN	180	600,000	505,890	252,945	151,767
NIAGARA FALLS (C) WASTEWATER TRTMNT PLNT	48	61,840	134,904	67,452	40,471
AMHERST (T) SD #16 STP	36	115,000	101,178	50,589	30,353
TONAWANDA (T) WASTEWATER TREATMENT PL #2	30	110,000	84,315	42,158	25,295
LOCKPORT (C) WASTEWATER TREATMENT PLANT	22	35,000	61,831	30,916	18,549
ERIE COUNTY SOUTHTOWNS STP	16	85,404	44,968	22,484	13,490
NIAGARA COUNTY SEWER DIST #1	14.08	40,000	39,572	19,786	11,872
NORTH TONAWANDA (C) WASTEWATER TRT PLANT	13	35,000	36,537	18,268	10,961
OLEAN (C) WASTEWATER TREATMENT PLANT	7	17,500	19,674	9,837	5,902
BATAVIA (C) SEWAGE TREATMENT PLANT	7	17,500	19,674	9,837	5,902
ERIE COUNTY SEWER DIST #2	4.5	35,420	12,647	6,324	-
ERIE CO SD #6 LACKAWANDA (C)	4.5	22,000	12,647	6,324	-
GRAND ISLAND (T) SEWER DIST #2 WWTP	3.5	15,000	9,837	4,918	-
EAST AURORA (V) SEWAGE TREATMENT PLANT	3.14	7,311	8,825	4,412	-
Total MCF			**1,092,498**	**546,249**	**327,749**

Food Waste

RNG Potential From Food Waste

According to the 2019 AGF Study, Food Waste is defined as: Food that can be diverted from landfills to a composting or processing facility where it can be treated in an anaerobic digester.

NFG Methodology for calculating the resource scenarios is based on:

- NFGDC Service Territory Population vs. total New York State Population
- **NFGDC's service territory population is 8.17% of the state total**

	Technical Potential	High Resource Scenario	Low Resource Scenario
NY State	21.554	4.179	2.388
NFGDC Territory @ 8.14%	1.761	0.341	0.195

Agricultural Residue

RNG Potential From Agricultural Residues

According to the 2019 AGF Study, Agricultural Residues are defined as: agricultural crop residues, which include the stalks and leaves, are abundant, diverse, and widely distributed across the United States. Examples include corn stover (stalks, leaves, husks, and cobs), wheat straw, oat straw, barley straw, and rice straw.)

NFG Methodology for calculating the resource scenarios is based on:

- The total corn silage in NFGDC's service territory vs the total corn silage in New York State
- **NFGDC's service territory estimate is 29.06% of the states resource potential**

	Technical Potential	High Resource Scenario	Low Resource Scenario
NY State	24.327	5.038	2.015
NFGDC Territory @ 29.06%	7.069	1.464	.586

Forest Residues

RNG Potential From Forest Residues

According to the 2019 AGF Study, Forest Residues are: Forest Biomass generated from logging, forest and fire management activities, and milling. Inclusive of logging residues (e.g., bark, stems, leaves), forest thinnings (e.g., removal of small trees to reduce fire danger), and mill residues (e.g., slabs, sawdust). This includes materials from public forestlands, but not specially designated forests.

NFG Methodology for calculating the resource scenarios is based on:

- Forested acres of land in NFGDC's service territory vs the total state forested acres in New York State
- **NFGDC's service territory estimate is 14.45% of the states resource potential**

	Technical Potential	High Resource Scenario	Low Resource Scenario
NY State	10.152	3.959	1.980
NFGDC Territory @ 14.45%	1.467	0.572	0.286

Energy Crops

National Fuel

RNG Potential From Energy Crops

According to the 2019 AGF Study, Energy Crops are defined as: perennial grasses, trees, and some annual crops that can be grown specifically to supply large volumes of uniform, consistent quality feedstocks for energy production

NFG Methodology for calculating the resource scenarios is based on:

- The total agricultural crop land harvested in NFGDC's service territory vs the total agricultural crop land harvested in New York State
- **NFGDC's service territory estimate 25.23% of the states resource potential**

	Technical Potential	High Resource Scenario	Low Resource Scenario
NY State	33.219	3.041	0.598
NFGDC Territory @ 25.23%	8.381	0.767	0.151

Municipal Solid Waste

National Fuel

RNG Potential From Municipal Solid Waste

According to the 2019 AGF Study, MSW is defined as: trash and various items that household, commercial, and industrial consumers throw away—including materials such as glass, construction and demolition (C&D) debris, food waste, paper and paperboard, plastics, rubber and leather, textiles, wood, and yard trimmings.

NFG Methodology for calculating the resource scenarios is based on:

- NFGDC Service Territory Population vs. the total New York State Population
- **NFGDC's service territory estimate 8.17% of the states resource potential**

	Technical Potential	High Resource Scenario	Low Resource Scenario
NY State	109.106	43.536	19.307
NFGDC Territory @ 8.17%	8.914	3.557	1.577

Ability of RNG to Displace Residential Natural Gas Load

National Fuel

RNG Potential in NY & NFGDC NY Territory

	Landfill Gas	Animal Manure	Waste Water	Food Waste	Agri. Residue	Forest Residues	Energy Crops	Municipal Solid Waste	Total RNG (Bcf)
Low									
NYS	19.739	4.522	2.472	2.388	2.015	1.980	0.598	19.307	**53.021**
NFG	**2.465**	**1.841**	**.328**	**0.195**	**0.586**	**0.286**	**0.151**	**1.577**	**7.429**
% of NYS	12.49%	40.70%	13.26%	8.17%	29.06%	14.45%	25.23%	8.17%	**14.01%**
High									
NYS	32.753	9.044	3.304	4.179	5.038	3.959	3.041	43.536	**104.854**
NFG	**5.423**	**3.681**	**0.546**	**0.341**	**1.464**	**.572**	**0.767**	**3.557**	**16.351**
% of NYS	16.56%	40.70%	16.53%	8.17%	29.06%	14.45%	25.23%	8.17%	**15.59%**
Technical									
NYS	50.489	15.073	7.197	21.554	24.327	10.152	33.219	109.106	**271.117**
NFG	**9.86**	**6.135**	**1.092**	**1.761**	**7.069**	**1.467**	**8.381**	**8.914**	**44.679**
% of NYS	19.53%	40.70%	15.18%	8.17%	29.06%	14.45%	25.23%	8.17%	**16.48%**

Source: AGF – Renewable Sources of Natural Gas: Supply and Emissions Reduction Assessment (2019)

National Fuel

RNG & Residential Gas Consumption – NY State Wide

	Technical Potential	High Resource Scenario	Low Resource Scenario
NY State RNG (Bcf)	271.117	104.854	53.021
Residential Natural Gas Consumption (Bcf)	485.69	485.69	485.69
% of Residential Load Displaced by RNG	**56%**	**22%**	**11%**

RNG & Residential Gas Consumption – NFDGC Territory

	Technical Potential	High Resource Scenario	Low Resource Scenario
NFGDC Territory RNG (Bcf)	44.679	16.351	7.429
Residential Natural Gas Consumption (Bcf)	48.795	48.795	48.795
% of Residential Load Displaced by RNG	91.56%	33.51%	15.22%
Emission Reductions (MMTCO2e)	2.4	0.9	0.4
Equivalent # of homes' energy use for one year	282,881	103,525	47,036
Equivalent 2.32MW wind turbines running for 1 year	529	194	88

Questions?