Climate Business Plan
Supplemental Data and Assumptions

(2020)

End Use

Details on Hybrid Systems and Gas Consumption

For the purposes of estimating natural gas consumption - and associated GHG emission impacts, the portion of buildings that convert to hybrid heating systems are assumed to see a 60% reduction in their total annual natural gas consumption.

The share of natural gas vs. electric operation to meet heating requirements varies by month, with electric heat pumps assumed to operate more in periods when it is not as cold, while natural gas meets a higher portion of requirements during the coldest periods of winter.

On the peak day (which drives electrification impacts) the assumption for hybrid systems is that overall, an average of 34% of peak day heating requirements would be met with electric heat pump operation, and 66% would be met with natural gas heating options. This reflects an average across the range of installations.

There is not a single changeover temperature for hybrid heat pump systems. Differences in installations, including unit size per building square foot and operational settings means that there will be a diversity of changeover temperatures in different installations.

Normalization of Weather Data

For 2017 emissions results (i.e. the 'Change Between 2006 and 2017' emissions listed in Table 1 of the report) the actual 2017 emissions were used, consistent with the District's Greenhouse Gas (GHG) Inventory.

Weather normalized usage was assumed for natural gas consumption per residential and commercial customer in 2018 and onwards.

Due to temperature shifts (2017 was warmer than 2018), the 2018 per customer residential consumption was 8.3% higher than 2017, and 2018 per customer commercial consumption was 3.5% higher than 2017. That average 2018 per customer consumption was assumed to apply to the rest of the years of the study, driving the reference case for consumption (along with the growth in number of customers and further BAU efficiency improvement, addressed below).

Gas Sales Under Business as Usual (BAU) Scenario

ICF projected the BAU gas sales trajectory based on projections of gas system customer growth and efficiency improvements out to 2050.

From 24.4 million MMBtu of natural gas consumption in the District in 2020 (14.8 million MMBtu residential and 9.6 million MMBtu commercial), the BAU forecast sees annual natural gas consumption drop to 22.0 million MMBtu in 2050 (13.2 million MMBtu residential and 8.8 million MMBtu commercial). This is driven by annual growth in the number of residential / commercial customers of 0.25%* / 0.03%, offset by an annual BAU efficiency trend (% change in use per customer) in average residential / commercial customers of -0.6% / -0.3%.

*The annual residential customer growth rate is the only one of these values to change over the study period. With growth rates of 0.9%/year in 2018 and 2019, 0.6%/year in 2020 and 2021, 0.5%/year in 2022, 0.4%/year in 2023, 0.3%/year in 2024 to 2032, and 0.1%/year in 2033 to 2050. Simple average of annual values is 0.25%.

Residential Sector Gas Use

For the residential sector roughly 75% of the non-space heating load is water heating, and 25% cooking and other end-uses (we did not differentiate between cooking and other uses in calculating electrification impacts).

Energy Efficiency Equipment Performance Factors

The values used to model the average efficiency of cumulative electrified heating equipment (new units are more efficient than this average of converted stock by milestone) are shown in the table below. The average efficiency of cumulative gas-electric hybrid heating systems is also shown.

The same efficiencies were used for both residential and commercial sectors.

We have assumed the annual COP for new ASHPs improves from current levels to 4.0 by 2050, the average of new electrified equipment installed due to the electrification policy over the time period from 2020 through 2050 is 3.25.

District of Columbia's Building Sector Average of Cumulative Converted Stock - Equipment Performance Assumptions

	ASHP Space Heating		Water Heating	Other Demand	Gas-Electric Hybrid Space Heating	
	COP - Annual	COP - Peak Day	Efficiency Annual	Efficiency Annual	COP - Annual	COP - Peak Day
2020	1.93	1.20	1.66	1.00		
2025	2.20	1.71	1.75	1.00	2.58	1.87
2030	2.47	1.79	1.84	1.00	2.90	1.95
2040	3.01	1.85	2.00	1.00	3.54	2.02
2050	3.25	1.90	2.00	1.00	3.82	2.08

All-electric case values are shown in left two columns, hybrid case values shown in right two columns. Note the hybrids include higher COPs than similar ASHPs in the all-electric case because the ASHPs in hybrids units are not operating as much in the colder (least efficient) portions of the year.

Electric heat pump water heater conversions are only included in the Policy-driven Electrification Case.

For natural gas energy efficiency measures, the space and water heating technologies assumed change over the study period, and the assumed efficiency improvements are as follows:

> **2020-2025:** Roughly 11% of customers are assumed to participate in the program in this period, and all of these residential program participants install high efficiency furnaces (10.53% savings based on going from 85% to 95% efficiency), while all commercial program participants are assumed to install a basket of measures (20.83% savings based on going from 80% to 96%). These program participants also install high efficiency water heaters (assumed to have same percentage savings as space heating).
>
> **2026-2039:** Roughly 31% of customers are assumed to participate in the program in this period, of these participants 50% include retrofits as indicated for the previous period (10.53% savings or 20.83%), while the other 50% install natural gas heat pumps (35.7% savings based on going from 90% efficiency to 140% efficiency).
>
> **2040-2050:** Roughly 25% of customers are assumed to participate in the program in this period, and all of these participants include natural gas heat pumps, with the efficiency gains from heat pumps listed in the previous period. Water heating savings assumed to be the same percentage as space heating here as well.

Only reference case improvements in the efficiency of existing electric equipment were modeled.

Dollar Values and Capital Costs

Plan, scenarios and models use 2018 dollars. The only values that were discounted were for the Emission Reduction Costs (ICF Technical Study, Figure 29). All other dollar figures are undiscounted $2018 real (simple sums).

The capital costs used for residential Air Source Heat Pumps in the study are presented in the table below. These same ASHP costs are used for both stand-alone heat pumps in the Policy-Driven Electrification Case and for Hybrid Heating systems (in addition to gas furnace costs) in the Fuel Neutral Case. Costs for installation, also important to the analysis, are presented below.

Year	ASHP Capital Cost
2020	$3,568
2025	$3,457
2030	$3,345
2035	$3,212
2040	$3,078
2045	$2,922
2050	$2,766

The average baseline and upgrade cost values assumed across the study period for other electrification equipment categories are presented in the tables below.

The next set of tables focuses on the residential sector and provides an average of the different Single-Family Home (SFH) archetypes considered, where costs differ mainly in terms of the difficulty and requirements to install the new systems.

The 'Total System Costs' in the top portion of the table adds up the upfront costs for space heating / AC systems, water heating systems, and other systems, from the tables below, as well as the non-energy operating costs for those different units. The 'Annualized – Total System Costs' divide each of the aforementioned cost components by the appropriate product lifetime, to account for differences in expected measure lives. The 'Total System Product Life Difference' is based on the annualized values over an 18-year period.

Construction	Household Type	Baseline HVAC Building Category	Current Fuel	Fuel Choice	Household Size	Total System Product Life Difference	Annualized - Total System Costs	Total System Costs
New	Single Family			Natural Gas	2250 sq. ft.	$9,202	$511	$10,174
Existing	Single Family	Average of Forced Air Furnace / Non-Forced Air Systems, AC / No-AC SFHs	Natural Gas	Natural Gas	2250 sq. ft.	$8,942	$497	$9,828
New	Single Family			Electric System	2250 sq. ft.	$10,228	$568	$9,333
Existing	Single Family	Average of Forced Air Furnace / Non-Forced Air Systems, AC / No-AC SFHs	Natural Gas	Electric System	2250 sq. ft.	$11,422	$635	$10,526

Construction	Household Type	Baseline HVAC Building Category	Current Fuel	Fuel Choice	Household Size	Furnace Unit Size	Space Heating/AC Upfront Cost	2050 Heating Equipment Costs	A/C Unit Costs	HVAC Installation Costs	HVAC Annual Operating Cost ($)	HVAC - Product Lifetime
New	Single Family			Natural Gas	2250 sq. ft.	90,000 Btu	$6,683	$1,973	$2,522	$2,188	$45	24
Existing	Single Family	Average of Forced Air Furnace / Non-Forced Air Systems, AC / No-AC SFHs	Natural Gas	Natural Gas	2250 sq. ft.	90,000 Btu	$6,337	$1,745	$2,522	$2,070	$45	24
New	Single Family			Electric System	2250 sq. ft.	3 Ton	$4,854	$2,766	$0	$2,088	$76	18
Existing	Single Family	Average of Forced Air Furnace / Non-Forced Air Systems, AC / No-AC SFHs	Natural Gas	Electric System	2250 sq. ft.	3 Ton	$6,047	$2,766	$0	$3,281	$76	18

Construction	Household Type	Baseline HVAC Building Category	Current Fuel	Fuel Choice	Household Size	Water Heater Size	Water Heater Cost	Water System Annual Operating Cost ($)	Water Heating - Product Lifetime	Other Systems Costs	Cooking Range	Clothes Dryer	Other Product Lifetime
New	Single Family			Natural Gas	2250 sq. ft.	50 Gallons	$1,392	$14	15	$1,214	$525	$689	15
Existing	Single Family	Average of Forced Air Furnace / Non-Forced Air Systems, AC / No-AC SFHs	Natural Gas	Natural Gas	2250 sq. ft.	50 Gallons	$1,392	$14	15	$1,214	$525	$689	15
New	Single Family			Electric System	2250 sq. ft.	50 Gallons	$1,651	$16	15	$1,448	$799	$649	15
Existing	Single Family	Average of Forced Air Furnace / Non-Forced Air Systems, AC / No-AC SFHs	Natural Gas	Electric System	2250 sq. ft.	50 Gallons	$1,651	$16	15	$1,448	$799	$649	15

The table below provides similar information for multi-family buildings being electrified.

Construction	Household Type	Current Fuel	Fuel Choice	Household Size	Total System Product Life Difference	Annualized - Total System Costs	Total System Costs
New	Apartment		Natural Gas	1000 sq. ft.	$6,671	$371	$6,800
Existing	Apartment	Natural Gas	Natural Gas	1000 sq. ft.	$6,815	$379	$6,991
New	Apartment		Electric System	1000 sq. ft.	$8,622	$479	$7,726
Existing	Apartment	Natural Gas	Electric System	1000 sq. ft.	$9,233	$513	$8,331

Construction	Household Type	Current Fuel	Fuel Choice	Household Size	Furnace Unit Size	Space Heating/AC Upfront Cost	2050 Heating Equipment Costs	A/C Unit Costs	HVAC Installation Costs	HVAC Annual Operating Cost ($)	HVAC - Product Lifetime
New	Apartment		Natural Gas	1000 sq. ft.	30,000 Btu	$3,309	$1,243	$1,222	$844	$45	24
Existing	Apartment	Natural Gas	Natural Gas	1000 sq. ft.	30,000 Btu	$3,500	$1,243	$2,522	$1,035	$45	24
New	Apartment		Electric System	1000 sq. ft.	1 Ton	$3,247	$2,203	$0	$1,044	$76	18
Existing	Apartment	Natural Gas	Electric System	1000 sq. ft.	1 Ton	$3,825	$2,203	$0	$1,622	$76	18

Construction	Household Type	Current Fuel	Fuel Choice	Household Size	Water Heater Size	Water Heater Cost	Water System Annual Operating Cost ($)	Water Heating - Product Lifetime	Other Systems Costs	Cooking Range	Clothes Dryer	Other Product Lifetime
New	Apartment		Natural Gas	1000 sq. ft.	50 Gallons	$1,392	$14	15	$1,214	$525	$689	15
Existing	Apartment	Natural Gas	Natural Gas	1000 sq. ft.	50 Gallons	$1,392	$14	15	$1,214	$525	$689	15
New	Apartment		Electric System	1000 sq. ft.	50 Gallons	$1,651	$16	15	$1,448	$799	$649	15
Existing	Apartment	Natural Gas	Electric System	1000 sq. ft.	50 Gallons	$1,651	$16	15	$1,448	$799	$649	15

The table below provides the assumed baseline and upgrade costs for commercial buildings being electrified (incremental cost used in the analysis). In some cases, the upgrade equipment assumed to be used differed between retrofits and new construction, resulting in differences in incremental costs.

Building Type	Vintage	End Use	Baseline Equipment	Upgrade Equipment	Base Case Cost ($/ft2)	Upgrade Cost ($/ft2)	Incremental Cost ($/ft2)
Federal Building	New Construction	HVAC	(2) 1,000 MBH boiler & (1) 50 ton water cooled chiller	180 ton VRF ASHP	$7.59	$8.00	$0.41
Federal Building	New Construction	DHW	400 MBH boiler	400 MBH equ. HP	$0.13	$0.27	$0.13
Institutional	New Construction	HVAC	(2) 1,500 MBH boiler & (1) 75 ton water cooled chiller	300 ton VRF ASHP	$5.75	$8.00	$2.25
Institutional	New Construction	DHW	600 MBH boiler	600 MBH equ. HP	$0.13	$0.27	$0.13
Large Commercial	New Construction	HVAC	(2) 750 MBH boiler & (1) 30 ton air cooled chiller	120 ton VRF ASHP	$6.08	$9.60	$3.52
Large Commercial	New Construction	DHW	200 MBH boiler	200 MBH equ. HP	$0.16	$0.33	$0.16
Small Commercial	New Construction	HVAC	(3) 5 ton, 112MBH gas fired RTU	(3) 5 ton ASHP RTUs	$2.68	$3.21	$0.54
Small Commercial	New Construction	DHW	(2) 60 gallon tank	19 MBH ASHP	$0.48	$0.81	$0.33
Federal Building	Retrofit (EOL)	HVAC	(2) 1,000 MBH boiler & (1) 50 ton water cooled chiller	(15) 12 ton ASHP	$1.23	$2.68	$1.44
Federal Building	Retrofit (EOL)	DHW	400 MBH boiler	400 MBH equ. HP	$0.13	$0.27	$0.13
Institutional	Retrofit (EOL)	HVAC	(2) 1,500 MBH boiler & (1) 75 ton water cooled chiller	(25) 12 ton ASHP	$0.99	$2.68	$1.68
Institutional	Retrofit (EOL)	DHW	600 MBH boiler	600 MBH equ. HP	$0.13	$0.27	$0.13
Large Commercial	Retrofit (EOL)	HVAC	(2) 750 MBH boiler & (1) 30 ton air cooled chiller	(10) 12 ton ASHP	$1.32	$3.21	$1.89
Large Commercial	Retrofit (EOL)	DHW	200 MBH boiler	200 MBH equ. HP	$0.16	$0.33	$0.16
Small Commercial	Retrofit (EOL)	HVAC	(3) 5 ton, 112MBH gas fired RTU	(3) 5 ton ASHP RTUs	$2.68	$3.21	$0.54
Small Commercial	Retrofit (EOL)	DHW	(2) 60 gallon tank	19 MBH ASHP	$0.48	$0.81	$0.33

Details regarding Combined Heat & Power (CHP)

Incremental natural gas consumption, electricity generation, and usable thermal output from CHP are provided on tab 'CHP Information' of the accompanying Excel file. A CHP installation is modeled as having an average of 7,500 full-load hours per year of operation, and in practice would run 24/7 except for maintenance downtime.

We also offer additional guidance with respect to calculations on costs for CHP energy consumption shown in Table 15 of the ICF Technical Study Report (page 74).
The net effects of gas consumption and electric generation from CHP are included in the lines "natural gas purchases" and "incremental electricity purchases." They capture, among other changes in costs, both the increased costs to purchase natural gas and the decreased expenditures on grid-electricity purchases for CHP owners.

With respect to the $766 million CHP cost estimate, (ICF Technical Study, p. 74), this represents the total of (non-energy) CHP costs for the 2020 to 2050 study horizon.

Impact of Changes in Natural Gas and Electricity Consumption on Cost of Energy Purchases

In connection with Table 15, referenced above, and the lines "natural gas purchases" and "incremental electricity purchases," these two lines show the impact of changes in natural gas and electricity consumption to the cost of energy purchases for customers, based on the reference case forecast of residential and commercial electricity and natural gas rates (i.e. not capturing here any potential impacts of the demand scenarios on energy prices).

Savings from natural gas purchases would include the gas cost savings to customers from net natural gas demand reductions including energy efficiency, hybrid-heat pumps, and CHP (an increase). Changes from electricity purchases would include the net cost impact to customers from any increases to electricity consumption from electrification in the buildings sector and CHP (a decrease in purchased electricity).

The equipment and retrofit costs included in the study cost results are incremental to BAU costs.

Breakdown of Residential and Commercial Energy Efficiency Programs

The Residential and Commercial Energy Efficiency Programs costs cited on page 74, ($763 million and $227 million, in Case 4) are built up from the full cost or full incremental cost of these measures (varies by measure).

Residential energy efficiency – the total cost provided can be broken down between types of measures as follows:

- 75% space heating measures
- 20% water heating measures
- 4% as behavioral measures, and
- 1% other/building envelope measures (shower heads, weather stripping, faucet aerators, door sweeps, etc.).

Commercial energy efficiency – the cost analysis used an average $/MMBtu total cost (total cost of measures / first year savings) from a basket of measures in existing gas commercial-sector energy efficiency programs. This cost was increased overtime to reflect the incremental cost of the more aggressive commercial measures included in the projection.

Delivered Natural Gas Volumes over Time

The impact of the scenarios on natural gas volumes is illustrated, numerically and graphically, in the Tab 'WGL Delivered Gas Volumes' in the accompanying Excel document.

Sourcing and Supply

Renewable Natural Gas Details on Sourcing

Table 40. Lifecycle GHG Emission Factor Ranges for RNG Feedstocks by Region, gCO_2e/MJ

Fuel	New England	Mid-Atlantic	East North Central	West North Central	East South Central	West South Central	Mountain	Pacific
LFG	18 – 26	15 – 21	28 – 34	28 – 32	26 – 28	26 – 31	21 – 32	13 – 29
Animal Manure								
Dairy	-304 – -294	-308 – -300	-292 – -285	-292 – -286	-294 – -292	-294 – -288	-300 – -286	-310 – -290
Swine	-404 – -394	-408 – -400	-392 – -385	-392 – -386	-394 – -392	-394 – -388	-400 – -386	-410 – -390
Beef/Poultry	36 – 36	31 – 31	46 – 46	44 – 44	38 – 38	42 – 42	44 – 44	41 – 41
WRRF	18 – 26	15 – 21	28 – 34	28 – 32	26 – 28	26 – 31	21 – 32	13 – 29
Food Waste	-97 – -82	-104 – -91	-79 – -68	-79 – -70	-83 – -79	-83 – -73	-91 – -70	-108 – -76
Agricultural Res.	25 – 55	25 – 55	25 – 55	25 – 55	25 – 55	25 – 55	25 – 55	25 – 55
Forestry Res.	25 – 55	25 – 55	25 – 55	25 – 55	25 – 55	25 – 55	25 – 55	25 – 55
Energy Crops	25 – 55	25 – 55	25 – 55	25 – 55	25 – 55	25 – 55	25 – 55	25 – 55
MSW	25 – 55	25 – 55	25 – 55	25 – 55	25 – 55	25 – 55	25 – 55	25 – 55
P2G	0	0	0	0	0	0	0	0
Natural Gas	65	65	65	65	65	65	65	65

Table 40, above, is excerpted from the Renewable Natural Gas Study (page 88).

Peak Load and Weather Assumptions

Peak loads consider electrification of both transportation and buildings, however the overall peak hour load does *not* include the full transportation peak demand, as the peak charging hours for the transportation sector are assumed to have been shifted away from peak periods through time of use rates. The assumptions surrounding widespread off-peak charging of electric vehicles result in very little contribution to the winter peak demand from the transportation sector.

Transportation sector – The same 24-hour breakdown of load impacts is assumed to apply each day of the year (i.e. not assuming different summer and winter peak loads from transportation electrification).

Building sector – The winter peak load is based on a 'Design Day' with an HDD of 54.5 based on the coldest average daily temperature from the last 30 years of historical data, which occurred in the District of Columbia on January 19, 1994. This Design Day HDD is used for planning purposes by gas utilities to estimate the maximum expected daily load, while average monthly demand profiles were used for all other days and months.