Maryland Clean Heat Standard Model

Methodology Documentation

Prepared by Current Energy Group for Evergreen Action

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1. Executive Summary

This document describes the structure, data sources, and assumptions of a model developed by Current Energy Group (CEG) to estimate the effects of a clean heat standard on Maryland's residential and commercial building stocks. The model projects how a policy that progressively reduces building-sector greenhouse gas emissions would reshape the building stock, energy consumption, emissions, and costs over the 2027–2045 period, in support of Evergreen Action's policy engagements in Maryland.

The model compares two scenarios: a business-as-usual (BAU) reference case, representing how the building stock would evolve absent new policy, and a policy case, representing the stock as clean heat measures are deployed to meet a target of a 90% reduction in building-sector emissions by 2045 (consistent with Maryland's statutory economy-wide net-zero-by-2045 requirement). Every reported value expresses the policy case against the BAU reference, isolating the incremental effect of the standard. The model draws building stock, consumption, and hourly load data from the National Laboratory of the Rockies' (NLR, formerly the National Renewable Energy Laboratory, NREL) ResStock and ComStock datasets; layers U.S. Environmental Protection Agency (EPA) and Maryland Department of the Environment (MDE) emissions factors over that data (EPA combustion factors for on-site fuels and an hourly marginal-emissions trajectory for electricity that declines to net zero by 2045); and passes the resulting per-measure emissions reductions along with measure costs to a selection model that deploys measures on a least-cost basis to meet the target.

The model's results should be read as scenario estimates rather than forecasts. Reported emissions are direct combustion and electric grid emissions only, excluding upstream and lifecycle emissions. The model assumes an exogenous electric grid decarbonization trajectory that is based on Maryland Department of the Environment (MDE) projections and Maryland's climate goals. The underlying building-stock datasets represent a statistical sample of the building stock, with known coverage limitations in the commercial sector that CEG addresses through documented adjustments (Section 3). The sections that follow document each of these elements in detail.

2. Purpose & Scope

Purpose

This model estimates the effects of a clean heat standard on Maryland's residential and commercial building stocks. A clean heat standard is a policy mechanism that obligates gas utilities and delivered-fuel providers to progressively reduce the greenhouse gas emissions associated with building energy use, generally through a tradeable credit system. The model projects four linked outcomes under such a policy: turnover of the building stock as heating and water-heating equipment is replaced, changes in energy consumption across fuels, reductions in emissions, and the costs of the transition.

The model supports Evergreen Action's policy engagements in Maryland, and its geographic scope, timeframe, and building-type coverage are set accordingly. All results are expressed as a policy scenario measured against a business-as-usual (BAU) reference case.

Scope

The model covers the 2027–2045 timeframe. This horizon aligns with Maryland's statutory requirement of economy-wide net-zero greenhouse gas emissions by 2045. Within the buildings sector, the model operationalizes that requirement as a 90% reduction in building-sector emissions by 2045, consistent with the design of Maryland's forthcoming clean heat standard as currently understood.

On the emissions side, the model accounts for space heating, water heating, and other miscellaneous building fossil energy consumption (for example, cooking and commercial process loads) across both the residential and commercial sectors.

Boundaries

The model is bounded to the buildings sector and does not model the electricity system. It does not simulate generation dispatch, capacity expansion, or transmission. Where electrification increases electricity demand, the model estimates the added consumption and its associated emissions using an exogenous per-kWh marginal emissions trajectory supplied as an input assumption (documented in Section 3). The model does not select or provide incentives for electric resistance to electric heat pump conversions, though it does model the change in consumption as resistance stock ages out and is replaced with heat pumps (see section 5 discussion on user inputs).

Consistent with Maryland's net-zero target, this trajectory assumes the electricity sector reaches net-zero emissions by 2045. The electricity grid is therefore treated as an input to the model rather than a modeled outcome, and no analysis of the electricity sector is performed beyond these demand-driven changes.

3. Data Inputs

The model draws on two categories of inputs: publicly available datasets and projections (used as provided, with critical assumptions summarized here and full documentation referred to the original source), and inputs developed or adjusted by CEG for this analysis (documented in full below). Table 1 summarizes all inputs; the narrative elaborates only those requiring explanation.

Input	Provides	Source / vintage	Type
ResStock	2018 residential stock, consumption, characteristics; 15-min load timeseries	NLR ResStock 2025 Release 1	Public[1]
ComStock	2018 commercial stock, consumption, characteristics; 15-min load timeseries	NLR ComStock 2025 Release 3	Public[2]
Marginal grid emissions trajectory	Hourly marginal electricity emissions intensity	Maryland Department of the Environment	Public

[1] ResStock's Technical Reference Guide available from the National Laboratory of the Rockies' website at https://resstock.nlr.gov/datasets.
[2] ComStock's documentation available from the National Laboratory of the Rockies' website at https://comstock.nlr.gov/.

Input	Provides	Source / vintage	Type
AEO reference projections	Building stock and energy consumption growth	EIA Annual Energy Outlook 2025 (Reference case)	Public[3]
Fossil fuel emissions factors	Emissions intensity of natural gas, propane, fuel oil	EPA GHG Emission Factors Hub	Public[4]
Incentive levels	Program cost benchmarks	CEG analysis of comparable state programs	CEG-developed
Low-carbon fuel supply/cost	RNG and hydrogen availability and cost per ton	AGF & WGL (RNG); DOE Liftoff (hydrogen)	Public[5] [6] [7]

Table 1. Model inputs.

Building stock and load data (ResStock and ComStock)

Residential and commercial building characteristics, baseline energy consumption, and hourly load shapes are drawn from NLR's ResStock and ComStock datasets. Both are statistical representations of the U.S. building stock: they model large samples of representative buildings, weighted to reproduce stock-level totals. For example, ComStock 2025 Release 3 comprises roughly 350,000 building energy models representing approximately 6 million commercial buildings. Both datasets represent the building stock circa 2018 and are simulated on 2018 actual-meteorological-year (AMY) weather data. This model uses each dataset's building-characteristic metadata (baseline stock, consumption, and building details) together with the 15-minute time series results (load shapes and hourly emissions analysis).

Importantly, the model uses ResStock and ComStock for stock, consumption, and load-shape data only — it does *not* use their built-in emissions outputs. All emissions in this model are calculated by CEG by applying independent emissions factors to modeled consumption (electricity via the modified MDE projected trajectory described below; fossil fuels via EPA emissions factors). Use of MDE emissions factors for electricity enables the model to account for projected changes in the electricity mix in the PJM region as well as Maryland emissions policies.

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[3] Annual Energy Outlook 2025, U.S. Energy Information Administration, April 15, 2025, https://www.eia.gov/outlooks/archive/aeo25/.
[4] GHG Emission Factors Hub, U.S. Environmental Protection Agency, accessed July 23, 2026, https://www.epa.gov/climateleadership/ghg-emission-factors-hub.
[5] 2019 Renewable Natural Gas Supply Assessment, American Gas Foundation and ICF, 2019, https://gasfoundation.org/2019/12/18/renewable-sources-of-natural-gas/.
[6] Study on the Use of Biofuels (Renewable Natural Gas) in the Greater Washington, D.C. Metropolitan Area, ICF, submitted to Washington Gas and Light Company, March 2020, https://washingtongasdcclimatebusinessplan.com/wp-content/uploads/2020/04/200316-WGL-RNG-Report-FINAL.pdf and https://washingtongasdcclimatebusinessplan.com/wp-content/uploads/2020/04/Technical-Study-Report-Opportunities-for-Evolving-the-Natural-Gas-Distribution-Business-to-Support-DCs-Climate-Goals-April-2.pdf.
[7] Pathways to Commercial Liftoff: Clean Hydrogen Update 2024, U.S. Department of Energy, December 2024, https://climateprogramportal.org/wp-content/uploads/2025/02/Pathways-to-Commercial-Liftoff_Clean-Hydrogen_December-2024-Update.pdf.

Full methodology for both ResStock and ComStock datasets is documented by NLR and not reproduced here. See the ComStock 2025 Reference Documentation[8] and the ResStock's Technical Reference Guide.[9]

From each dataset, the model uses a specific subset of upgrade packages. Upgrade 0 is the baseline (no measures applied) and serves as the reference against which all other packages are compared.

ID	Measure
0	Baseline (no measures) — reference case
4	Cold Climate Air-Source Heat Pump
5	Dual Fuel Heat Pump
9	Heat Pump Water Heater
11	Advanced Air Sealing
16	Advanced Air Sealing + Drill-and-Fill Wall Insulation + Attic Floor Insulation + Duct Sealing and Insulation

Table 2. ResStock upgrade packages used.

ID	Measure
0	Baseline (no measures) — reference case
2	Heat Pump RTU with original-fuel backup
15	Air-Source Heat Pump Boiler
16	Air-Source Heat Pump Boiler with natural gas boiler backup
54	Package: wall & roof insulation and new windows
56	Package: wall & roof insulation, new windows, and LED lighting, with an HP-RTU or ASHP-boiler
58	Package: HP-RTU or ASHP-boiler with demand-control ventilation, heat/energy recovery, and economizers

Table 3. ComStock upgrade packages used. Packages 56 and 58 are each modeled as boiler and RTU variants.[10]

ComStock Data Limitations and CEG Responses

Comstock data presents three major gaps requiring CEG adjustments.

1. Building Stock Coverage. ComStock does not model the entire commercial building sector, instead covering only a subset of commercial building types. Per NLR's ComStock reference documentation and correspondence with NLR staff, ComStock represents approximately 63% of the U.S. commercial building stock relative to the U.S. Energy Information Administration's (EIA) 2018 Commercial Building Energy

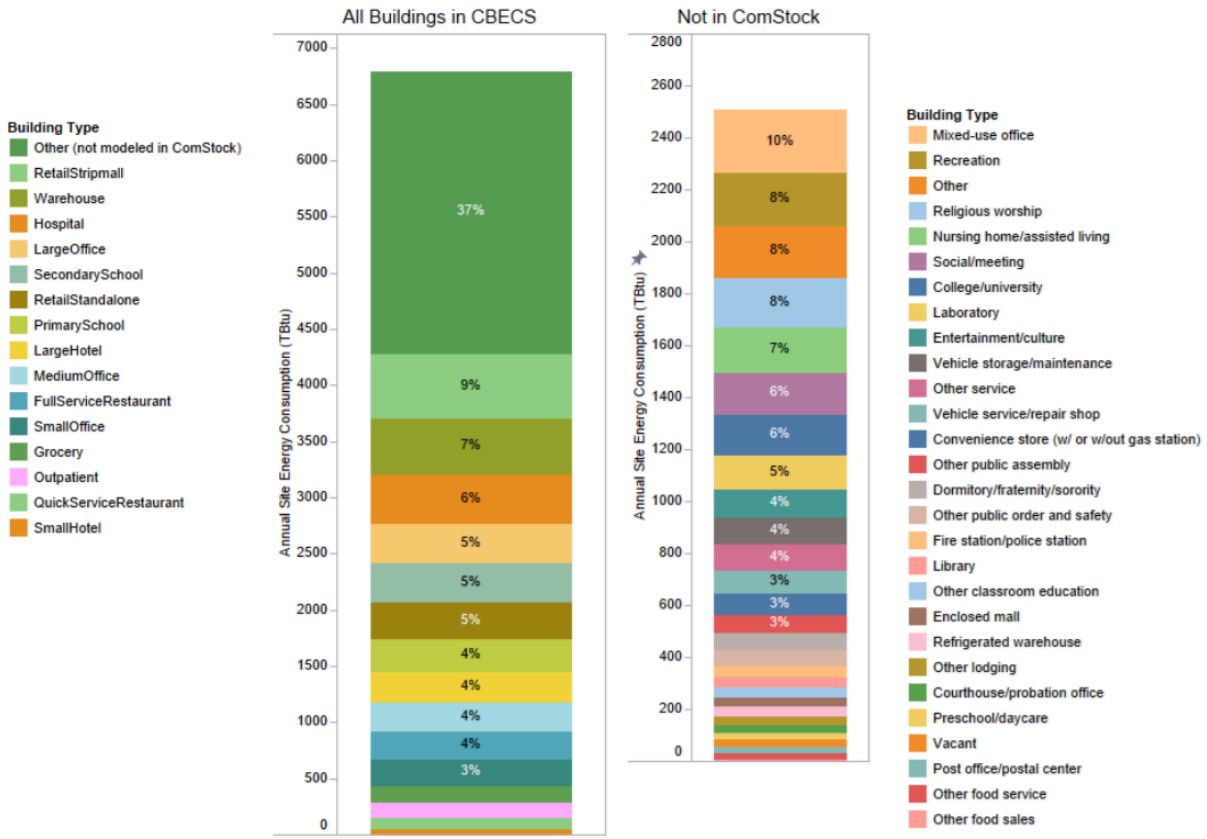
[8] ComStock's documentation available from the National Laboratory of the Rockies' website at https://comstock.nlr.gov/.

[9] ResStock's Technical Reference Guide available from the National Laboratory of the Rockies' website at https://resstock.nlr.gov/datasets.

[10] Packages 56 and 58 each convert space heating through one of two pathways — a heat-pump rooftop unit (HP-RTU) or an air-source heat-pump boiler (ASHP-boiler) — and are therefore modeled as two variants each (56_rtu / 56_boiler and 58_rtu / 58_boiler); a given building receives one pathway. The difference between the two packages is the accompanying efficiency bundle: Package 56 pairs the heat pump with envelope measures (wall and roof insulation, new windows, LED lighting), while Package 58 pairs it with systems and ventilation measures (demand-control ventilation, heat/energy recovery, and economizers). The table lists the measures as applied across the stock; in practice a building receives one heating pathway plus the associated efficiency measures.

Consumption Survey (CBECS) 2018 — by both total floor area and total annual energy — leaving roughly 37% of floorspace and energy use unrepresented. Figure 1 below shows this discrepancy.

Figure 1: Comparison of energy consumption in building types represented in ComStock (left) vs. unrepresented in ComStock (right) created by NLR.[11]



To remedy this issue, CEG created a "Commercial-Other" building category to account for the commercial buildings not represented in ComStock. To impute the square footage of "Commercial-Other" buildings and their associated consumption, CEG scaled up the space and water heating consumption of ComStock-modeled buildings by dividing the "known" square footage and consumption by 0.63, then multiplying that quantity by 0.37 (1 minus 0.63). While it is possible the unmodeled buildings may have a higher natural gas energy-use intensity than those modeled in ComStock, CEG made no further adjustments to this category, as further consumption gaps were addressed elsewhere (see below).

The 63% figure describes ComStock's national stock representation across all U.S. building types and end uses. Maryland could have better or worse representation within ComStock than the U.S. average.[12]

[11] See figure 57 in ComStock's documentation, available at https://comstock.nlr.gov/.

[12] CEG contacted NLR staff for clarification on this discrepancy. For the South Atlantic division (which contains Maryland), NLR staff clarified that the ComStock estimate falls near the low end of the uncertainty range for total gas consumption and high for total floor area. NLR staff further advised against local re-weighting to align with top-down delivery data and noted that no public state-level commercial floor-area data are available, hence CEG's decision to scale the data based on known limitations.

Given the lack of publicly available state-level commercial floorspace data, CEG used the 63% national figure provided in the documentation rather than a Maryland-specific percentage of floorspace represented.

2. Consumption Coverage. In addition to underrepresenting actual building stock, ComStock also underestimates consumption in the commercial buildings sector when compared to Maryland Greenhouse Gas Inventory data by as much as 75% for particular fuels, even after adjusting for the building coverage gap above. Based on our communications with NLR, it is our understanding that part of this coverage gap is due to differing definitions of "commercial" customers or end uses. For example, combined heat and power facilities owned by commercial entities may be included in the "commercial" sector according to statewide consumption data, but ComStock does not model gas consumption by commercial combined heat and power. Additionally, ComStock does not model certain commercial building end uses like cooking.

Figures X and Y below, which CEG obtained through email communication with NLR, illustrate the magnitude of the issue. The first chart compares ComStock modeled energy consumption with total gas consumption reported through the EIA State Energy Data System (SEDS) database, and the second chart provides a ratio of SEDS to ComStock consumption by state. The ratio of SEDS commercial gas consumption to ComStock modeled consumption in Maryland is approximately 4, much larger than can be explained solely through the 37% of commercial building types that are not modeled.

Figure X. ComStock vs. SEDS Total Commercial Natural Gas Consumption by State

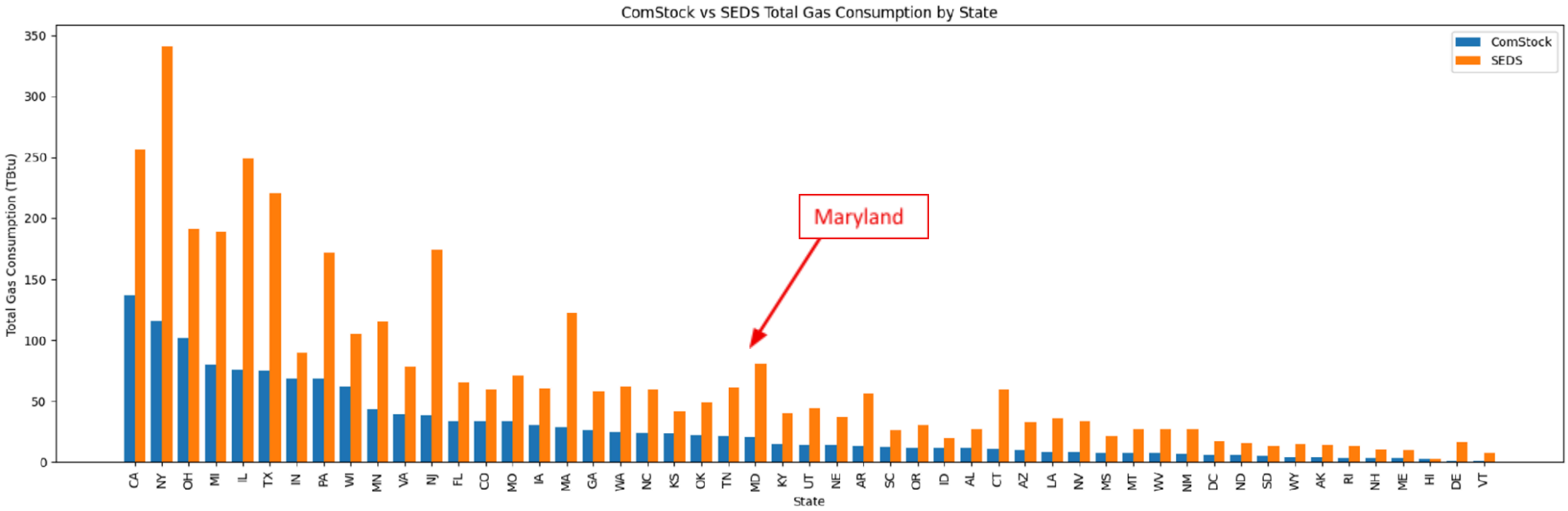
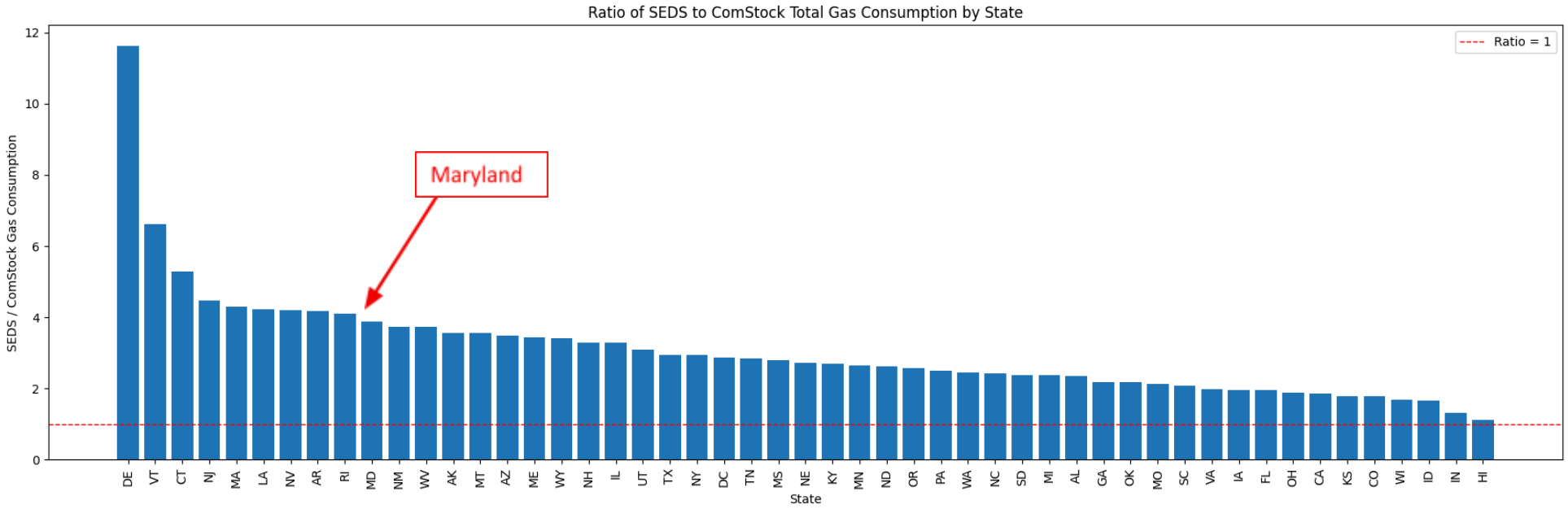


Figure Y. Ratio of SEDS to ComStock Total Commercial Natural Gas Consumption by State



CEG created a proxy category to account for commercial end uses not modeled by ComStock, "Commercial Other Consumption." To estimate the magnitude of Commercial Other Consumption, CEG assumes that the true statewide commercial space- and water-heating consumption equals the commercial deliveries in the 2020 Maryland greenhouse gas inventory for each fuel, scaled by an assumed space-and-water-heating share of commercial use. The ComStock capture fraction is then the ComStock-modeled Maryland space- and water-heating consumption for that fuel divided by the larger Maryland GHG Inventory estimate. For example, ComStock models 196 million kWh or 669 billion BTU of propane consumption for space and water heating in the Maryland commercial building sector. This consumption is 24.6% of the propane consumption in the commercial sector presented in Maryland's 2020 greenhouse gas inventory.[13] In other words, ComStock captures roughly a quarter of the estimated true statewide consumption of propane in the commercial sector. Therefore, Commercial Other Consumption is estimated by dividing ComStock's modeled space and water heating consumption by the capture fraction (0.246) and then multiplying that quantity by (1 minus 0.246). The same top-down comparison yields capture fractions of 0.406 for fuel oil and 0.344 for natural gas.[14]

This methodology is borrowed from the EIA National Energy Modeling System (NEMS) Commercial Module, which handles a similar difference between CBECS modeled end-use consumption and SEDS reported consumption in an identical way. NEMS creates an "unspecified" end use to account for fuel consumption for non-building commercial end uses. NEMS assumes that "unspecified" consumption grows at the same rate as commercial floorspace through 2050.[15]

CEG then created the simulated upgrade package "Upgrade 99" to provide a separate upgrade measure to electrify "Commercial Other Consumption" from fossil fuels. To create the package, we follow the same method used to calculate the reductions from other electrification measures: calculating the fossil emissions intensities, calculating the post-upgrade emissions (i.e., from electricity), and the difference between the two for deployment in the selection model.

- To calculate the fossil fuel (or not upgraded) emissions per square foot, we first divided the imputed "Commercial Other" fossil fuel consumption by the space heating square footage for that fuel to calculate the energy use intensity (EUI). The EUI is then multiplied by the emissions intensity for the fuel in question to calculate emissions per square foot for "Commercial Other Consumption."

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[13] Maryland 2020 GHG Inventory, Maryland Department of the Environment, September 24, 2022, https://mde.maryland.gov/programs/air/climatechange/pages/greenhousegasinventory.aspx.

[14] There are multiple potential reasons for discrepancies of this magnitude, but CEG was unable to ascertain what factors are most likely at play in Maryland. NLR staff confirmed our unit conversions were correct and noted that reported fuel deliveries in the State Energy Data System (SEDS) also vary substantially from ComStock estimates. This suggests potential definitional inconsistencies (e.g., defining what is a commercial vs. industrial facility) exist or anomalous usage in the Maryland commercial building sector not modeled in ComStock.

[15] U.S. Energy Information Administration, 2025, "Commercial Demand Module of the National Energy Modeling System," pages 56-57, available at https://www.eia.gov/outlooks/aeo/nems/documentation/commercial/pdf/CDM_AEO2025.pdf.

- To calculate the post upgrade emissions from electricity for Upgrade 99, we multiply the natural gas "Other Consumption" EUIs by 0.33 and calculate the associated emissions using annual average electricity emissions factors projected by MDE. The factor of 0.33 assumes that electric end-use equipment has an efficiency three times higher than natural gas. This efficiency assumption in turn assumes that fossil fuel end uses not modeled by ComStock are largely replaced with efficient electric equipment such as induction (for cooking), heat pumps, or renewable electricity generation (for combined heat and power).[16]
- The difference between the no-upgrade fossil emissions and post-upgrade electricity emissions (i.e., the emissions reductions from upgrading) is then calculated in ComStock Combined in tab *DSM--Comm Emis Measure 1 y*.

We model "Other Consumption" for the commercial sector only. Because ResStock modeled emissions are similar in magnitude to the emissions reported in the 2020 Maryland GHG inventory, we do not represent other end uses in the residential sector.

3. No Water Heater Upgrade. Unlike ResStock, ComStock does not provide a heat pump water heater upgrade package for commercial buildings. To account for the lack of a commercial heat pump water heater upgrade package, CEG created a package to represent commercial HPWH adoption. Referred to in the model as "Upgrade 98," the CEG-created package assumes a coefficient of performance (COP) of 3.5. This value is comparable to the efficiency of ResStock's residential heat pump hot water upgrade package[17] and conservative relative to commercially available commercial HPWH products from Trane[18] (COP of 4.1) and Rheem[19] (COP of 4.0 at 80°F). To create this package, we divided ComStock water heating electricity consumption data (which ComStock states is assumed to be entirely electric resistance, with a COP of 1.0)[20] by 3.5. The 3.5 assumption was selected to remain defensibly conservative given the absence of any commercial water-heating heat pump package in ComStock.

Marginal grid emissions trajectory

Hourly marginal electricity emissions intensity is provided by MDE projections. CEG adjusted this trajectory so that emissions intensity declines to zero by 2045, applying a linear decline between 2035 and 2045, consistent with the net-zero-by-2045 requirement in the Climate Solutions Now Act of 2022[21]

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[16] According to the Department of Energy, induction stoves are about three times more efficient than natural gas stoves. *See* Energy.gov, 2023, "Making the Switch to Induction Stoves or Cooktops," https://www.energy.gov/articles/making-switch-induction-stoves-or-cooktops. For natural gas heating end uses replaced with heat pumps, we likewise assume a COP of around 3.0.

[17] See ResStock's Technical Reference Guide, available from the National Laboratory of the Rockies' website at https://resstock.nlr.gov/datasets.

[18] See "Model Specifications" at https://www.trane.com/commercial/north-america/us/en/products-systems/heat-pumps/domestic-hot-water-heat-pump.html

[19] See "Documentation" at https://www.rheem.com/commercialheatpumpwaterheater/?utm_source=/commercialheatpumpwaterheater&utm_medium=vanityURL&utm_campaign=vanityURL#

[20] See section 4.7 in ComStock's Reference Documentation, available from the National Laboratory of the Rockies' website at https://comstock.nlr.gov/.

[21] SB 0528, available at https://mgaleg.maryland.gov/mgawebsite/Legislation/Details/sb0528?ys=2022RS.

and Climate Pollution Reduction Plan.[22] The hourly resolution allows electrification emissions to reflect *when* electricity is consumed rather than relying on an annual average.

Growth projections (AEO)

The EIA Annual Energy Outlook 2025, Reference case,[23] provides projections of building stock and energy consumption growth, used to build the reference (BAU) case forward from the 2018 base year. Growth is applied at the census-division level (Census Division 5, South Atlantic, which contains Maryland).

Fossil fuel emissions factors, incentives, and renewable fuels

Emissions intensities for non-electricity fuels (natural gas, propane, fuel oil) are taken from EPA's GHG Emission Factors Hub,[24] which reflects direct combustion emissions. CEG uses the following emissions intensities.

Fuel	Emissions Intensity (kg/MMbtu)	Emissions Intensity (metric ton/kWh)
Natural Gas	53.06	0.00018104
Propane	62.87	0.00021451
Fuel Oil	73.96	0.00025235
Kerosene	75.20	0.00025658
Wood	93.80	0.000320046

Renewable fuels

Renewable fuel inputs, including available Maryland supply, prices, and emissions intensities come from two sources: an American Gas Foundation (AGF) study[25] and a Washington Gas and Light regional analysis[26] adapting that study. With these inputs, CEG produced a low and high cost estimate in the LCF Data workbook, to reflect the varying emissions intensities and costs of renewable fuel feedstocks. CEG also completed an analysis of Hydrogen costs by adapting data from the Department of Energy Clean

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[22] Maryland's Climate Pollution Reduction Plan, Maryland Department of the Environment, December 28, 2023, https://mde.maryland.gov/programs/air/ClimateChange/Maryland%20Climate%20Reduction%20Plan/Maryland%27s%20Climate%20Pollution%20Reduction%20Plan%20-%20Final%20-%20Dec%2028%202023.pdf.

[23] Annual Energy Outlook 2025, U.S. Energy Information Administration, April 15, 2025, https://www.eia.gov/outlooks/archive/aeo25/.

[24] GHG Emission Factors Hub, U.S. Environmental Protection Agency, accessed July 23, 2026, https://www.epa.gov/climateleadership/ghg-emission-factors-hub.

[25] 2019 Renewable Natural Gas Supply Assessment, American Gas Foundation and ICF, 2019, https://gasfoundation.org/2019/12/18/renewable-sources-of-natural-gas/.

[26] Study on the Use of Biofuels (Renewable Natural Gas) in the Greater Washington, D.C. Metropolitan Area, ICF, submitted to Washington Gas and Light Company, March 2020, https://washingtongasdcclimatebusinessplan.com/wp-content/uploads/2020/04/200316-WGL-RNG-Report-FINAL.pdf and https://washingtongasdcclimatebusinessplan.com/wp-content/uploads/2020/04/Technical-Study-Report-Opportunities-for-Evolving-the-Natural-Gas-Distribution-Business-to-Support-DCs-Climate-Goals-April-2.pdf.

Hydrogen Liftoff report,[27] but opted to not include this fuel as an option given a lack of existing or foreseeable clean hydrogen supply in state, very high costs, and blending limitations that make the fuel impractical for widespread buildings use.

The model does not represent liquid biofuels separately from renewable natural gas. The Vermont Public Utilities Commission studying the state's clean heat standard proposal found that liquid biofuels costs are a similar magnitude to and somewhat higher than renewable natural gas (RNG), at $30 to 39 per MMBtu compared with RNG at $20 per MMBtu.[28] The model therefore captures RNG and liquid biofuels under a single "renewable fuels" designation, with lower-cost and higher-cost tranches available for selection in the model.

Incentives Data

CEG completed a benchmarking analysis of comparable clean heat programs and fuel switching incentives in Washington, D.C.,[29] Massachusetts,[30] Maine,[31] and Colorado[32] in the Incentives Data file. The results of this analysis are presented below.

Incentives	Low	Average	Average (per ton)	High	Income Qualified
Air Source Heat Pump	$2,500	$4,167	$1,342	$8,500	$16,000
Heat Pump Water Heaters	$750	$1,300	n/a	$2,250	$22,600

The model assumes that beneficial electrification has an increasing marginal cost. In other words, faster growth of beneficial electrification requires a higher incentive. The model enables the user to set a "base" incentive level, which is the incentive required to encourage 100% year-over-year sales growth in heat pumps. Based on other constraints and user inputs, the model scales the incentives based on the year-over-year growth rate, using the ratios below. To achieve greater than 100% growth, the model assumes that an incentive higher than the base incentive is required; conversely, the model scales down

[27] Pathways to Commercial Liftoff: Clean Hydrogen Update 2024, U.S. Department of Energy, December 2024, https://climateprogramportal.org/wp-content/uploads/2025/02/Pathways-to-Commercial-Liftoff_Clean-Hydrogen_December-2024-Update.pdf.

[28] Vermont Public Utilities Commission, 2025, "Second Checkback Report on the Clean Heat Standard Under Act 18 of 2023, Section 6(i)", available at https://puc.vermont.gov/sites/psbnew/files/documents/second-checkback-report-on-clean-heat-standard-act-18-011525.pdf.

[29] Residential Heating & Cooling Rebates, District of Columbia Sustainable Energy Utility, https://www.dcseu.com/residential-rebates/heating-cooling.

[30] Heating and Cooling, Mass Save, https://www.masssave.com/residential/rebates-offers-services/heating-and-cooling/.

[31] Residential Heat Pump Rebates , Efficiency Maine, https://www.efficiencymaine.com/at-home/residential-heat-pump-rebates/.

[32] Proceeding 23A-0392EG, Colorado Public Utilities Commission, https://puc.colorado.gov/cleanheatplans.

the incentive required to achieve growth rates lower than 100%. The model assumes S-shaped growth in heat pump sales consistent with a Bass diffusion curve, with sales starting at low levels, accelerating as market familiarity increases, then decelerating as the market begins saturating in later years.[33] As we noted above, incentives are only available for fuel switching measures; they are not modeled for electric resistance to heat pump conversions. The model applies additional multipliers to provide higher incentives for low- and moderate- income residential ratepayers.

Year on Year (YoY) Growth Rate	Space Heating Ratio	Water Heating Ratio
>100%	1.166667	1.25
100%	1	1
75%	0.833333	0.875
50%	0.666667	0.75
40%	0.5	0.6
30%	0.333333	0.5
20%	0.25	0.4
10%	0.166667	0.3
0%	0.083333	0.2

Model files and data flow

The analysis is operationalized across five Excel workbooks: one model and four preprocessor workbooks. The model — the Cost Curve Template — performs the selection and accounting described in Section 4 and generates every output described in Section 5. The four preprocessor workbooks prepare the per-measure emissions, consumption, and stock inputs to the model from NLR's ResStock and ComStock 15-minute timeseries data files and building metadata (see "Building stock and load data" above). Table 4 maps each workbook to its role.

File	Role	What it produces	Outputs to
ComStock Electricity Load Curve and Emissions	Commercial preprocessor — electricity (per unit estimates)	Hourly commercial electricity load by upgrade × building type, multiplied by the marginal grid trajectory to give per-square-foot electricity emissions and EUI for each measure	ComStock Combined
ComStock Fossil Estimates	Commercial preprocessor — fossil and electricity (overall consumption estimates)	Commercial natural gas, fuel oil, and propane consumption and combustion emissions per square foot, including the Upgrade 99 fuel-by-fuel gross-up and the Commercial-Other adjustment, plus AEO commercial growth inputs	ComStock Combined
ComStock Combined Fossil_Elec	Commercial integrator	Merges the electricity and fossil results into per-measure emissions deltas vs. the Upgrade 0 reference (space heating by starting fuel, water	Cost Curve

[33] See, e.g., Mahajan, Muller, and Bass, 1990, "New Product Diffusion Models in Marketing: A Review and Directions for Research," *Journal of Marketing* 54:1-26.

File	Role	What it produces	Outputs to
		heating, and Other), plus the commercial reference case and appliance starting values	
ResStock Combined Fossil_Elec	Residential integrator (electricity + fossil)	Per-appliance emissions deltas by measure for residential space and water heating; the residential reference case and stock estimates; the marginal electricity trajectory; low-carbon-fuel (RNG, H_2) supply and cost; and residential AEO growth and incentive data	Cost Curve
Cost Curve Template (v8)	The model	Consumes the per-measure deltas, reference cases, starting values, LCF supply, and growth/saturation limits; performs the merit-order selection and physical accounting; produces every headline output in Table 5	N/a (final)

Table 4. Model files and data flow.

The commercial and residential analyses of the source ComStock and ResStock 15-minute data and metadata are built separately but ultimately produce the same core results (described in the table above and in section 5).

For residential data, a single workbook (ResStock Combined) analyzes both the electricity and fossil appliance data. For electricity, the per appliance emissions are calculated from hourly load data rather than annual averages.

- For electricity appliances, the workbook builds load curves across the representative year for each hour using the ResStock and ComStock 15-minute time series. This is done by converting the 15-minute time series into hourly data, normalizing the consumption over year (i.e., calculating what percent of consumption falls in a given hour over the ResStock modeled year), then multiplying the ResStock-modeled annual consumption for a given electric appliance across the normalized hourly consumption, creating hourly load curves in kWh. Then, we multiplied the electricity load in that hour (in kWh) by the corresponding hourly marginal emissions intensity through 2045 (e.g., the consumption in the 7th hour on January 8th by the emissions intensity of grid electricity in the 7th hour on January 8th of the year in question). The hourly emissions are then summed over each year, providing the electricity emissions per appliance for each year through 2045.[34] [35] These calculations are primarily completed via Power Query in the workbook.[36] This hourly approach captures the effect of *when* electricity is used, which matters increasingly as the grid decarbonizes and emissions intensity varies across hours. Hourly electricity emissions load curves for each appliance are used as an input into both the Reference and the Policy case.

[34] We assume that the overall magnitude and load curve in ResStock's 2018 model year is fixed through 2045.
[35] As discussed in "Marginal grid emissions trajectory" above, we assume that, grid emission decline linearly to zero by 2045 starting in 2035.
[36] A note for users, the data loaded into Power Query from the ResStock 15-minute data and marginal emissions relies on links to external workbooks. The data will remain loaded into the ResStock file and remain directly stable, but errors could emerge if not connected to the internet.

- For fossil appliances, the per-appliance emissions are calculated directly in the workbook by dividing the AEO- and ResStock-projected consumption by the projected number of appliances, multiplied by the emissions intensity of the fuel. Together, the per unit emissions reductions from upgrading from a fossil appliance to a heat pump are calculated and consolidated in tab *DSM--Res Emis Measur 1 y* in the *ResStock Combined* workbook for simple copy and pasting into the model's *DSM--Emis Red p Meas 1y Start* tab in the *Cost Curve* workbook.

For commercial data, the processing described above for residential data is completed via two intermediate workbooks, "ComStock Fossil Estimates" and "ComStock Electricity Load Curve and Emissions." Rather than producing the estimates for overall consumption, emissions, stock estimates, energy use intensities, and emission intensities in a single file, these calculations were separated. ComStock Fossil Estimates provides the overall consumption, emissions, and stocks estimates, as well as the reference case per square foot emissions for fossil appliances. ComStock Electricity Load Curve and Emissions calculates the per square foot emissions for electricity appliances for both the reference stock and for the heat pump upgrade packages. This analysis relied in part on a simple Python script to replace the Power Query analysis described (to incorporate the hourly grid emissions intensity), with the results statically copied and pasted into the file.

Then, the core outputs of the ComStock Fossil Estimates and ComStock Electricity Load Curve and Emissions spreadsheets (described in the table above and in section 5) are brought into a third workbook, ComStock Combined. This workbook integrates the overall consumption, emissions, stock estimates, energy use intensities, and emission intensities in a format that can be more easily brought into the model. This workbook also calculates the emissions reductions on a per square foot basis from the deployment of an upgrade package (that is, the difference in emissions per square foot between a reference case fossil appliance and an upgraded heat pump), consolidates these values in tab *DSM--Comm Emis Measur 1 y* for simple copy and pasting into the model's "*DSM--Emis Red p Meas 1y Start*" tab in the *Cost Curve* workbook.

Apart from that Power Query step, the workbooks are not connected by live external references. Values are copied and pasted statically at each hand-off between workbooks to avoid broken links when files are moved or shared. The data flow is therefore largely manual; a change upstream requires re-running the affected preprocessor workbook and re-pasting its results downstream.

4. Methodology

The model produces two scenarios — a business-as-usual (BAU) reference case and a policy case — and reports the difference between them. The reference case establishes how Maryland's building stock, energy consumption, and emissions would evolve absent the clean heat standard. The policy case reflects the stock as measures are deployed to meet the emissions target. This section describes the analytical workflow in sequence.

Model timeline

The model incorporates several distinct year baselines and targets:

- **2018** — the vintage of the ResStock and ComStock building-stock and load data.
- **2025** — the reference year: the baseline against which the emissions-reduction target is measured. This value is fixed in the model. A "90% reduction by 2045" means 2045 building-sector emissions at least 90% below their 2025 level. Emissions baselines and targets are calculated with respect to buildings' natural gas, fuel oil, and propane consumption; they do not incorporate emissions from electricity generated to serve buildings.
- **2027** — the implied starting year of the model: the year to which the 2018 stock is aged (via AEO growth, see Step 2) and at which appliance starting values are set. This value is also fixed.
- **2028** — the first year in which the model makes deployment decisions, i.e., the first year the policy and reference cases diverge.
- **2045** — the target year and the end of the model's projection period. This value can be changed by the user. If the user designates a target that is sooner than 2045, the model assumes that incentive and deployment levels continue on a constant basis after the target year through the end of 2045.

The model is designed around a 90% reduction target by 2045. The target percentage, target year, and start year are user-editable inputs. However, the model may fail to produce results if the target is not feasible given the model's assumptions about measure availability.

Although MDE intends to set annual targets, requiring covered entities to retire credits in each year,[37] the CEG model optimizes measure selection and deployment around a single, terminal target year. We found that when we attempted to model separate cost curves and measure selection for interim-year targets, the model would deploy measures along an inconsistent and unrealistic pathway, abruptly starting and stopping the deployment of measures at the margin in consecutive years. This approach did not result in the development of a mature market for marginal or higher-cost demand-side management (DSM) measures that would be required to hit a 90% by 2045 target. Therefore, we modified the model's selection method to choose measures that would meet the end-year target at lowest cumulative cost over the full projection period. The policy implication for MDE is that it is imperative for Maryland to support robust, cost-effective DSM and beneficial electrification programs from the outset of the clean heat standard (via the EMPOWER program, third-party default delivery agents, etc.) , to ensure sufficient market growth in DSM and electrification to decarbonize the buildings sector by 2045.

How CEG Constructed the Reference Case

The following steps were used to construct reference case projections for overall consumption, emissions, stock, energy use intensities, and emission intensities.

1. **CEG established the 2018 baseline.** Baseline stock and consumption for space heating and water heating were taken from the ResStock and ComStock reference-case (Upgrade 0) metadata. Because both datasets model weighted samples rather than individual buildings, the modeled values were

[37] Maryland Department of the Environment, July 16, 2026 Webinar on Clean Heat Standard Development—Credit Retirements, available at https://www.youtube.com/watch?v=l41RgM5c2pM.

scaled up by the appropriate NLR determined weight to create an estimate of the actual Maryland building stock and its energy consumption.

2. **CEG projected the 2018 baseline forward.** The 2018 baseline of stock and consumption is aged to the 2027 starting year and continued annually through 2045 using EIA Annual Energy Outlook (AEO) 2025 (Reference case) growth rates for Census Division 5 (South Atlantic), which contains Maryland. The percentage growth rate for the Census Division is calculated based on AEO projections and applied to the Maryland-specific values from ResStock and ComStock, for both energy consumption and total appliance stock.[38] Emissions were derived from the projected fuel consumption.

3. **CEG derived the reference-case metrics.** Steps 1 and 2 together produced reference-case projections, for each year from 2027 through 2045, of consumption, appliance stock, energy use intensity (EUI), total emissions, and emissions intensity (metric tons CO_2 per appliance for residential; metric tons CO_2 per square foot for commercial). Together, these values constitute the reference case against which the policy case is measured. As described in section 3, hourly electricity emissions load curves for each appliance are used as an input into both the Reference and the Policy case.

How CEG Constructed the Policy Case

The following steps were used to construct reference case projections for overall consumption, emissions, stock, energy use intensities, and emission intensities for the policy case.

1. **CEG estimated post-upgrade emissions.** The policy case represents the stock after clean heat measures ("upgrades") are installed. For each upgrade package, post-upgrade electricity emissions are calculated from the ResStock and ComStock upgrade files using the same hourly method as the reference case (Step 3): the post-upgrade hourly electricity load is multiplied by the MDE marginal emissions intensity for that hour and summed across the year. Because a heat pump shifts an end use from fossil fuel to electricity, this step captures both the new electricity load and its associated emissions.

ID	Measure
0	Baseline (no measures) — reference case
4	Cold Climate Air-Source Heat Pump
5	Dual Fuel Heat Pump
9	Heat Pump Water Heater
11	Advanced Air Sealing
16	Advanced Air Sealing + Drill-and-Fill Wall Insulation + Attic Floor Insulation + Duct Sealing and Insulation

Table 2. ResStock upgrade packages used.

ID	Measure
0	Baseline (no measures) — reference case

[38] EIA's AEO reference case projects consumption and emissions to decline over time due to projected efficiency improvements in appliances, building envelopes, and commercial building sensors and controls. These results carry through to CEG's reference case.

ID	Measure
2	Heat Pump RTU with original-fuel backup
15	Air-Source Heat Pump Boiler
16	Air-Source Heat Pump Boiler with natural gas boiler backup
54	Package: wall & roof insulation and new windows
56	Package: wall & roof insulation, new windows, and LED lighting, with an HP-RTU or ASHP-boiler
58	Package: HP-RTU or ASHP-boiler with demand-control ventilation, heat/energy recovery, and economizers
98	Commercial Heat Pump Water Heater with COP of 3.5, CEG-created
99	Other Electrification Measures to electrify "Commercial Other Consumption," CEG-created

Table 3. ComStock upgrade packages used. Packages 56 and 58 are each modeled as boiler and RTU variants.[39]

The model assumes no residual on-site fossil fuel emissions for an end use once it receives an electrification upgrade of the corresponding type. E.g., a home that installs a heat pump for space heating is treated as having no remaining fossil fuel consumption for space heating.[40] Space heating and water heating are treated independently, so a building may be electrified for one end use while retaining fossil fuel for the other. As described in section 3, hourly electricity emissions load curves for each appliance are used as an input into both the Reference and the Policy case.

5. CEG derived the effect of each measure. Comparing the reference-case values (Step 3) against the post-upgrade values (Step 4) gives the change in energy use intensity and emissions intensity attributable to each measure — the per-unit fossil fuel and emissions savings from switching a given appliance or building to a heat pump or other upgrade, and the additional electricity consumption from the upgrade. These deltas are expressed per appliance for residential measures and per square foot for commercial measures, consistent with the reference-case metrics.

6. Measures are deployed via the selection model. The per-measure emissions savings from Step 5 are passed to a selection model that deploys measures in least-cost (merit) order to meet the emissions target at the target year (e.g., a 90% reduction in building-sector emissions by 2045). Deployment is subject to limits on how quickly each measure can scale:

- Growth in heat pumps is limited by pace of stock turnover with an assumed 15-year lifetime and does not allow for early retirements. Therefore, only 1/15 of fossil fuel appliances can be replaced with heat pumps in any given year.

[39]Packages 56 and 58 each convert space heating through one of two pathways — a heat-pump rooftop unit (HP-RTU) or an air-source heat-pump boiler (ASHP-boiler) — and are therefore modeled as two variants each (56_rtu / 56_boiler and 58_rtu / 58_boiler); a given building receives one pathway. The difference between the two packages is the accompanying efficiency bundle: Package 56 pairs the heat pump with envelope measures (wall and roof insulation, new windows, LED lighting), while Package 58 pairs it with systems and ventilation measures (demand-control ventilation, heat/energy recovery, and economizers). The table lists the measures as applied across the stock; in practice a building receives one heating pathway plus the associated efficiency measures.

[40] CEG opted to not include a dual fuel upgrade package in the model despite completing an analysis of the ResStock- and ComStock-modeled dual fuel upgrade package. CEG determined that the dual fuel heat pumps are modeled in ResStock and ComStock to have very similar consumption and emissions profiles to all-electric upgrades and thus inclusion was of limited benefit.

- The model assumes S-shaped growth in heat pump sales consistent with a Bass diffusion curve, with sales starting at low levels, accelerating as penetration increases, then decelerating as the market begins saturating in later years.

- These limits are set through year-over-year market growth-rate scenarios (i.e., scenarios for year-over-year growth in heat pump sales as a percentage of appliance stocks being replaced) that differ by measure category (residential space heating, residential water heating, residential insulation, commercial space heating, commercial water heating, and commercial other). The model offers several fixed, pre-built growth scenarios (e.g., slower and more rapid ramps, scenarios that minimize cumulative or peak cost) plus a user-defined scenario in which year-over-year limits can be entered directly

- As we noted above, the selection model models for fuel switching measures only, as no incentives are modeled as being provided for electric resistance to heat pump conversions.

- The model does not represent incentives provided through other programs, such as EmPOWER or forthcoming federal rebate programs, separately from incentives provided as part of Clean Heat offerings. Rather, the model projects the *total* amount of incentives and program spending that will be required to achieve the emissions targets.

Additional information regarding the cost curves model is provided in "The Cost Curve selection model in detail" below.

7. CEG aggregated results. The selection model's deployment schedule is then aggregated to produce the model's headline outputs over the 2027–2045 study period: appliance stocks by fuel and technology, energy consumption by fuel, emissions, and program costs — each reported for the policy case against the BAU reference established in Steps 1–3.

The Cost Curve selection model in detail

The Cost Curve Template file is the model. The model relies on several inputs from earlier preprocessing steps (see section 3), including:

- The per-unit change in emissions relative to the Upgrade 0 reference (per appliance for residential measures, per square foot for commercial) calculated in the ResStock and ComStock combined workbooks and statically copied and pasted into the *DSM--Emis Red p Meas 1y Start* tab.

- The modeled incentive levels, based on the benchmarking analysis completed in the Incentives Data workbook and used in the *DSM Subsidy Curve* tab (in addition to user inputs).

- The 2027 starting stock by fuel and/or appliance type derived from ResStock and ComStock data and projected forward to 2027 in the ResStock and ComStock Combined workbooks, and statically pasted into the *Appliance Starting Values* tab.

- Each measure's lifetime, assumed to be 15 years for all appliances in the *Appliance Starting Values* and *Resistance Stocks* tabs.

- The energy use intensity (EUI) and unit energy consumption (UEC) calculations derived from ResStock and ComStock data, processed in the midstream workbooks, and statically pasted into tab *UEC-EUI*.
- The low-carbon-fuel availability and cost estimates (derived in LCF Data workbook and statically pasted in the *LCF Supply* tab).

The model also provides a series of user selections (see *User Inputs* tab), including:

- Target year: The year the model is solving for.
- Emissions reduction target: The level of emissions reductions that the model solves for in the target year.
- Baseline incentive amount.: The amount required to cause 100% year-over-year heat pump sales rate growth. This amount is then scaled up or down based on the needed growth as discussed in section 3- Incentives Data.
- Low- and moderate-income multipliers for the baseline incentive: The factors that will be multiplied by the baseline incentive level to calculate low- and moderate-income residential customer incentives. For example, if the baseline incentive is $3,000, and the low-income multiplier is 2, the low-income incentive will be $6,000.
- Incentive decay limits: Selects whether incentives decline purely in line with heat pump deployment sales growth rates or whether the decline is limited year over year. This control was added because tying incentive level to market growth can lead to significant shifts in incentive levels between years once heat pumps reach market saturation (e.g., declining from ~$7,000 to $500 in 2-3 years). Actual policy design and market conditions will likely lead to less dramatic shifts, hence the addition of this limiting factor as a user input. This input acts as "brake" on the incentive decline, with the model formulas choosing the slower decline of the market driven change or the decay limit. For example, if the model would otherwise have a 65% decrease in incentive levels between years, and the decay limit is set at 45%, the incentive level will decay at 45%.
- Heat pump sales rate growth scenario: The scenarios for year-over-year growth in heat pump sales as a percentage of appliance stocks being replaced. CEG developed 5 scenarios to represent different potential market development trajectories or outcomes and one scenario in which the user can define their own YoY growth rates.[41]
- Insulation deployment levels and costs: CEG opted to not include a separate insulation upgrade package in the model despite completing an analysis of the ResStock- and ComStock-modeled insulation packages. CEG determined that the insulation measures were generally not cost effective on a $/ton basis compared with full electrification. However, given the other benefits of efficiency measures (e.g., home comfort) and their likelihood of being included in Maryland policy, we wanted to represent the effects of efficiency measures in the model.

[41] See *YoY Growth Scenarios* tab in the Cost Curves workbook, rows 67-75.

- The share of electric resistance stock turnover replaced by heat pumps: Using the assumed 15-year lifespan for HVAC appliances, 1/15 of current electric resistance stock ages out. This input allows the user to determine what share of that aging stock is replaced with a heat pump (e.g., a user input of 75% means 75% of electric heaters are replaced with heat pumps at their end of lifespan). This is particularly impactful for electric water heating consumption and emissions, given the predominance of resistance water heaters, and heat pump water heaters are ~3.5x efficient.
- The share of new electric construction receiving electric resistance or heat pump: CEG assumes that the building stock grows by 1.2% per year, in line with AEO2025 population projections. This input allows the user to determine what share of that new electric stock is deployed with a heat pump (e.g., a user input of 75% means 75% of the new electric stock comes with a heat pump with the remaining 25% having the default electric resistance heat).

Using the inputs from the ComStock and ResStock Combined files, the heat pump deployment constraints (see Section 4, step 6), and the user selections, the model determines, for each measure, how much to deploy so that building-sector emissions reach the target at the lowest achievable cost within those limits.

The model's core is a least-cost selection evaluated at the target year in tab *Target Year 1*, relying on the inputs and selections above. The first step is assigning a cost per metric ton of CO_2 abated for each measure and ranking the measures based on said cost. The cost (numerator) is not the cost of the appliance itself, instead focusing on the projected utility program incentive cost (or via other programs participating in the clean heat standard credit system). For appliances, this is the incentive that the utility provides in the year the appliance is deployed divided by the lifetime emissions reductions. For renewable fuels, this is the cost per MMBtu of the fuel divided by the emissions reductions from the fuel relative to natural gas. As we noted above, only fuel switching measures are modeled as receiving incentives (and thus being eligible for selections); they are not modeled for electric resistance to heat pump conversions, or for heat pumps that replace electric resistance in new buildings. The model calculates the cost of each measure based on the *average* cost per ton of deployment across the projection period.

As discussed in Section 3, Incentive Data, the utility program incentive cost for DSM measures depends on the year-over-year sales growth rate; a higher incentive level results in faster growth. Annual incentives offered for each appliance are shown in the *Incentives per Year* tab and are calculated based on the inputs in *DSM Subsidy Curve* tab, which correlates incentive levels with growth rates, and the *Max HP %* tab, which specifies sales of electric appliances as a percentage of fossil appliances reaching end of life for measures that are selected.

The tons of CO2 abated (denominator) is determined from the analysis completed in the ComStock Combined and ResStock Combined files and brought into the Cost Curves file in the *DSM--Emis Red p Meas 1 y Start* tab, summed over the assumed 15-year lifetime of the appliance in the *DSM--Emis Redux p Measur Life* tab. Future emissions reductions are assumed to have the same value with no discount rate applied for the value of credits for future emissions.

The measures are then ranked from cheapest to most expensive on that basis in tab *Target Year 1*. The model then computes, for each measure, the maximum abatement it could contribute by the target year given its constraints, and accumulates reductions down the ranked list, selecting the cheapest measures first (thus minimizing costs), until the cumulative reduction meets the target. The target itself is expressed against the 2025 reference year: a reduction of X% by the target year means target-year emissions at or below (1 − X%) of the 2025 level. The last, most expensive measure required to close the gap is the marginal resource, and its cost per ton sets the clean heat credit clearing price.

Once the measures are ranked and selected, the model then translates the needed emissions reductions into needed measure deployment in tab *DSM Sales*. As previously mentioned, deployment is bounded below by natural stock turnover and measure lifetime since equipment is generally replaced only at end of life (in addition to user inputs on assumed YoY sales growth limits). The maximum a measure can contribute by the target year is therefore the joint product of its growth ramp, its saturation ceiling, and available turnover, with the model selecting among measures within that feasible region.

The model's selection is binary; a measure is either selected and deployed, or not selected and not deployed. If a measure is selected and deployed, its deployment proceeds along one of the pre-set year-over-year growth scenarios specified in the *YOY Growth Scenarios* tab. Users can select the growth scenario using the drop-down menu in the *Inputs* tab. The growth rates in the selected scenario are then applied to assumed 2027 starting values in the *Max HP %* tab. These starting values are projected in the *Max HP % Scratch* tab based on BGE's and Pepco's annualized 2025 Empower electrification program achievements. The *Max HP % Scratch* tab assumes that these programs grow between 2025 and 2027 in line with growth rates achieved by other nascent electrification programs in the U.S. For example, a comparison between our assumed early-stage growth rates and growth rates in Xcel Colorado's beneficial electrification programs is shown in Table X below.

Table X. Assumed Maryland Empower vs. Xcel Colorado Heat Pump Incentive Growth[42]

	Maryland		Xcel Colorado	
Program Year	Calendar Year	Growth % (assumed)	Calendar Year	Growth % (actual)
Year 1	2025 (start of EmPOWER fuel switching incentives)	Base	2021 (start of BE program)	Base
Year 2	2026	100%	2022	110%
Year 3	2027	50%	2023	52%
Year 4	2028 (start of Clean Heat program)	Determined by model	2024	45%
Year 5	2029	Determined by model	2025 (start of Clean Heat program; incentives increased)	154%

[42] Citation for Maryland assumptions: *Max HP % Scratch* tab. Citation for Xcel Colorado actuals: Colorado PUC Proceeding No. 26A-0263EG, Hrg. Ex. 103, PSCo 2028-2030 Clean Heat Plan, at page 50.

The model then sums heat pumps deployed, fossil and resistance appliances displaced in a given year to calculate the next year's stock in tabs *Heat Pump Stocks, Resistance Stocks,* and *Fossil Fuel Stocks,* then summed into *Stocks-Summary*.

Based on these stock deployment decisions, the model then uses the energy use intensities calculated in the ResStock and ComStock Combined (and statically carried into the model into tab *UEC-EUI)* to calculate the consumption by appliance type.[43] Several tabs aggregate these results by consumption by fuel, sector, and end use (*Fuel Consumption-Measure*, *Fuel Consumption-Building Type, Fuel Consumption-Summary* tabs). Using the assumed fuel emissions intensities, the emissions are then calculated for the policy case.[44]

Finally, the results are aggregated into several summary tables which show stocks, consumption, and emissions in a variety of formats for the policy and reference cases in the *Stocks Summary Table, Consumption Summary Table,* and *Emissions Summary Table* tabs. The amount of deployed stock in the *DSM Sales* tab is multiplied by the incentive level to calculate the total program cost (see *Program Costs* tab). These values are visualized in the *Charts* tab. We also provide a high-level comparison of program costs to existing used bills in the *Bill Impact Estimate* tab, estimating cost increase from program costs on a per MMBTU and per stock basis.

5. Key Assumptions

Emissions. Emissions are calculated by CEG using two sources: EPA's GHG Emission Factors Hub for on-site fossil fuels (natural gas, propane, fuel oil) and the MDE hourly marginal trajectory for electricity. CEG modified the MDE hourly electricity trajectory so that emissions decline linearly to zero between 2035 and 2045, consistent with Maryland's economy-wide net-zero-by-2045 target. This adjustment is applied within the per-measure emissions calculations (Section 3). Fossil fuel emissions are direct combustion emissions only, with upstream and pre-combustion emissions (e.g., methane leakage) excluded, consistent with the EPA fuel emissions intensity data. The model further assumes no residual on-site fossil emissions for an end use once it is electrified (Section 4, Step 4).

Units. ResStock and ComStock report all consumption in kWh, so the electricity marginal-emissions factor (published in metric tons CO_2 per MWh) is converted to metric tons per kWh in the ResStock Combined and ComStock Electricity Load Curve and Emissions files. Consumption is expressed in kWh throughout the intermediate steps and converted to MMBtu only in the final cost-curves model, while emissions are expressed in metric tons CO_2 throughout.

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[43] Simplified, this means we are recalculating the total consumption and emissions for the policy case. Per unit consumption (and emissions) are first calculated in upstream workbooks using estimates of statewide consumption and stocks. Appliances are then deployed based on the modeled costs and emissions reductions. Then, the original per unit consumptions estimates are multiplied by the stock values, creating the policy case consumption.

[44] While per appliance electricity emissions and differences between a heat pump upgrade and fossil appliance are calculated using hourly load curves (e.g., in the DSM tabs), we rely on average grid intensities for translating the modeled electricity consumption into emissions in the summary tables.

Consumption. Reference case consumption patterns are held constant and grown forward using AEO 2025 (Reference case) growth rates for Census Division 5 (South Atlantic). The reference case does not assume changes in underlying consumption behavior over the study period beyond the assumptions in the AEO 2025 reference case.[45]

Stock. The composition of the building stock is likewise held broadly constant — building-type shares are not assumed to shift over time — with overall growth applied from the same AEO division-level projections.

ComStock treatment. Beyond the native ComStock assumptions adopted as-is, [46] CEG applies three distinct treatments for different gaps in ComStock's commercial coverage: Commercial-Other adjusts for commercial building stock not represented in ComStock (the ~37% of floor area from excluded building types, see Section 7), Upgrade 99 ("Other Measures") addresses the consumption shortfall in modeled space and water heating through the fuel-by-fuel gross-up, treating the uncaptured remainder as a fully electrifiable catchall, and "Other heat pump" represents known commercial loads for which ComStock offers no corresponding modeled upgrade package (e.g., certain RTU or boiler configurations).

ResStock treatment. Native ResStock upgrade-package assumptions and generic modeling assumptions are adopted as-is.[47]

Weather. ResStock and ComStock source data is simulated on 2018 actual-meteorological-year weather. Results therefore reflect 2018 weather patterns and are not adjusted for future climate or for a typical-year normalization.

Configuration and fragility. The model is built around the 90%-reduction-by-2045 target measured from the 2025 reference year. Target percentage, target year, and start year are user-editable, but the grid-decarbonization trajectory's linear-to-zero segment is fixed to a 2035–2045 window and does not move with the target year. While the model can be run with other target years and percentage emissions reductions, it may fail to produce results if the user inputs a target that cannot be achieved by the target year given the measures available in the model.

Renewable fuels. Renewable natural gas availability and cost are treated as inputs (Section 3), not modeled endogenously.

6. Outputs & Metrics

All outputs are reported annually across the 2027–2045 study period and, unless noted, are expressed for the policy scenario against the business-as-usual (BAU) reference case, so that each value isolates the

[45] EIA's AEO reference case projects consumption and emissions to decline over time due to projected efficiency improvements in appliances, building envelopes, and commercial building sensors and controls. These results carry through to CEG's reference case.
[46] ComStock's documentation available from the National Laboratory of the Rockies' website at https://comstock.nlr.gov/.
[47] ResStock's Technical Reference Guide available from the National Laboratory of the Rockies' website at https://resstock.nlr.gov/datasets.

incremental effect of the clean heat standard. Where relevant, outputs are broken out by sector (residential, commercial, and total buildings). The model's outputs span the following families:

- **Emissions.** Annual building-sector greenhouse gas emissions, policy vs. BAU, reported for residential, commercial, and total buildings.
- **Energy consumption by fuel.** Annual consumption of natural gas, propane, fuel oil, renewable fuels, and electricity, policy vs. BAU, by sector and total.
- **Measure deployment.** Annual and cumulative deployment of clean heat measures by category — residential space heating, residential water heating, commercial space heating, commercial water heating, commercial other, and alternative fuels. Residential measures are reported as installs and commercial measures as floor area (thousands of square feet).
- **Fuel shares of stock.** The share of stock using each heating fuel (propane, fuel oil, natural gas, electricity) by year, reported separately for space heating and water heating, and separately for the residential (share of homes) and commercial (share of floor area) sectors.
- **Program costs and investments.** Annual and cumulative clean heat investments (incentive/program dollars), reported by the same measure categories as deployment.
- **Policy-mechanism outputs.** Outputs specific to the clean heat credit (CHC) market: the CHC requirement placed on each obligated utility, derived from the state emissions target, total CHC revenue generated from credit sales per year, the marginal cost of emissions reductions (the CHC clearing price), and a greenhouse gas abatement cost curve.
- **Compliance and rate impacts.** Total cost of compliance for each investor-owned utility and for delivered-fuel providers, and the resulting impact on gas rates and on delivered-fuel costs ($/MMBtu).

These outputs are intended to provide a comprehensive but deliberately simplified view of the building-energy system — sufficient to characterize the policy's effects on stock, consumption, emissions, and cost while remaining a tractable representation rather than a full systems model. The framework can be extended to produce more granular estimates where needed. For example, the hourly electricity results could support a more detailed treatment of electricity-system impacts than the consumption- and emissions-focused analysis completed here. Table 5 summarizes the full output set.

#	Output	Unit
1	Annual GHG emissions, policy vs. BAU	metric tons CO_2e
2	Annual consumption by fuel	MMBtu
3	Annual measure deployment	appliances (residential) or 1,000 sqft (commercial)
4	Cumulative measure deployment	Appliances or 1,000 sqft
5	Residential fuel shares	% of homes
6	Commercial fuel shares	% of floor area
7	Annual clean heat investments	$

#	Output	Unit
8	Cumulative clean heat investments	$
9	Marginal cost of reductions (CHC clearing price)	$/ton
10	GHG abatement cost curve	$/ton vs. cumulative tons
11	Compliance cost	$
12	Rate & fuel-cost impact	rate impacts on $ / MMBtu and $ / stock basis

Table 5. Model outputs.

7. Other Limitations & Known Gaps

ResStock limitations. No residential-specific limitations of the same significance as the ComStock coverage gaps were identified for this analysis. Users should nonetheless be aware of the general limitations of the ResStock dataset as documented by NLR (see the ResStock 2025 Release 1 Technical Reference Guide), which apply here as they would to any ResStock-based analysis.

Selection / cost-curve model. The model does not represent economy-wide changes beyond what AEO assumes — notably, it does not endogenously model large emergent loads such as data centers. Deployment and cost relationships are treated as linear, and growth is constrained by the year-over-year growth-rate schedules described in Section 4 rather than by a more granular market-adoption model.

Emissions scope. Because fossil fuel factors are combustion-based, the analysis does not capture upstream methane leakage or other lifecycle emissions. Electricity emissions depend entirely on the exogenous MDE trajectory, so results are sensitive to that trajectory's zero-by-2045 assumption.

8. Appendix: Data Sources

Source	Used for	Reference
NLR ResStock 2025 Release 1	Residential stock, consumption, load shapes	https://resstock.nlr.gov/datasets.
NLR ComStock 2025 Release 3	Commercial stock, consumption, load shapes	https://comstock.nlr.gov/.
EIA Annual Energy Outlook 2025 (Reference case)	Stock/consumption growth (Census Division 5)	https://www.eia.gov/outlooks/archive/aeo25/.
EPA GHG Emission Factors Hub	Fossil fuel combustion emissions factors	https://www.epa.gov/climateleadership/ghg-emission-factors-hub.
Maryland Department of the Environment grid trajectory	Hourly marginal electricity emissions (→ net zero 2045)	Provided by Evergreen Action; adjusted by CEG
Maryland GHG emissions inventory	Emissions benchmarking	https://mde.maryland.gov/programs/air/climatechange/pages/greenhousegasinventory.aspx.

Source	Used for	Reference
American Gas Foundation 2019 Supply Estimate	RNG supply and cost	https://gasfoundation.org/2019/12/18/renewable-sources-of-natural-gas/.
ICF regional analysis for Washington Gas and Light	RNG supply and cost	https://washingtongasdcclimatebusinessplan.com/wp-content/uploads/2020/04/200316-WGL-RNG-Report-FINAL.pdf and https://washingtongasdcclimatebusinessplan.com/wp-content/uploads/2020/04/Technical-Study-Report-Opportunities-for-Evolving-the-Natural-Gas-Distribution-Business-to-Support-DCs-Climate-Goals-April-2.pdf.
DOE Liftoff report	Hydrogen supply and cost	https://climateprogramportal.org/wp-content/uploads/2025/02/Pathways-to-Commercial-Liftoff_Clean-Hydrogen_December-2024-Update.pdf.

Table 8. Data sources.