Clean Heat Portfolio Analysis

Prepared for Public Service Company of Colorado

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Energy+Environmental Economics

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Introduction

Energy and Environmental Economics (E3), Inc. is a multi-disciplinary consulting firm focused on the clean energy transition. We have offices in San Francisco, California; Calgary, Alberta; Cambridge, Massachusetts; and New York City, New York. E3 supported the Colorado Energy Office in the development of the 2021 Greenhouse Gas Pollution Reduction Roadmap (2021 Roadmap), which provides an economy-wide vision for how the state of Colorado can meet its climate goals.

E3 was engaged by Public Service Company of Colorado (PSCo or the Company) to conduct portfolio modeling to support the development of the Company's Clean Heat Filing. The modeling work in this proceeding both builds on and is substantially different from that done for the for the 2021 Roadmap. The 2021 Roadmap was a higher level, non-optimized scenario modeling exercise designed to work backwards from the state's climate goals to identify a plausible transition pathway towards 2050. In contrast, the portfolio modeling approach used here is focused primarily on least-cost strategies for the Company to support achievement of the state's Clean Heat goals through 2030. Another key difference is that the portfolio modeling approach used here incorporates more granular data on both demand- and supply-side Clean Heat measures than the data that were used to create the economy-wide 2021 Roadmap.

Summary of Clean Heat Portfolio Analysis

Clean Heat Targets

Senate Bill 21-264 (SB 21-264) directed the Colorado Public Utilities Commission (CPUC) to establish rules that require utilities, including the Company, to file Clean Heat Plans to reduce greenhouse gas (GHG) emissions from their operations and customers. SB 21-264 established targets of a 4% reduction in GHG emissions by 2025 and a 22% reduction by 2030, both relative to a 2015 baseline.

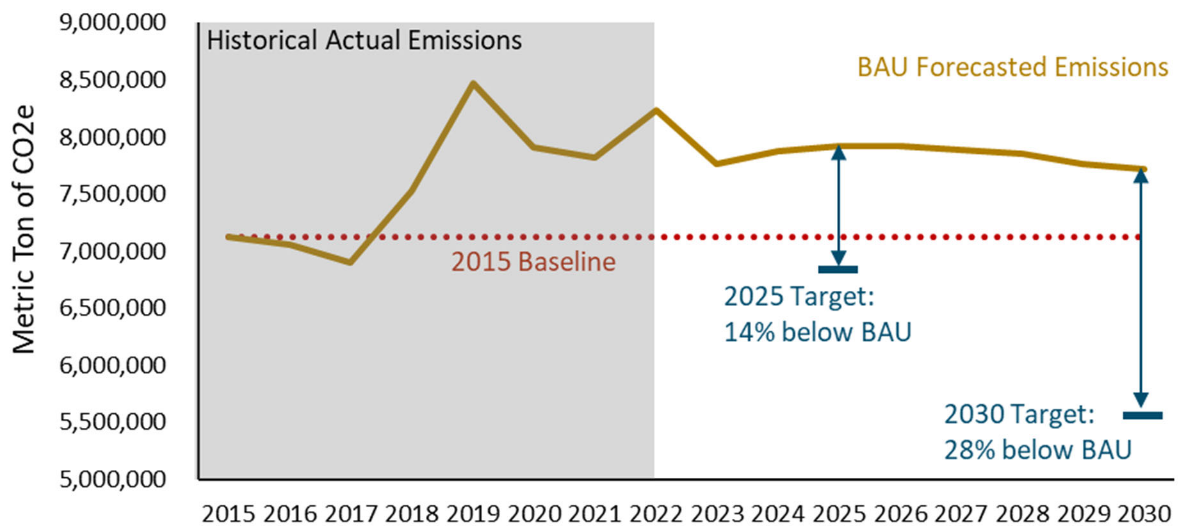
E3 notes that the Colorado Clean Heat Statute has set the most ambitious heating sector-specific GHG reduction targets in North America.[1] The language of SB 21-264 establishes GHG reduction targets of 4% by 2025 and 22% by 2030, relative to 2015. However, emissions have grown by 15% since 2015, as shown in Figure 1. The Company's GHG emissions have grown since 2015 for two primary reasons. First, 2015 was a warm year, and as a result the amount of gas the Company delivered was lower than in a typical year. The statute requires the Company to achieve emission reductions relative to actual emissions in 2015. In contrast, the 2021 Roadmap used a weather normalized level of emissions for 2015 to make its

[1] The only state policies that are comparable are economy-wide GHG reduction targets that include a declining share of free emissions for natural gas utilities. For example, Washington state provides gas utilities with free allowances under its cap-and-invest program. The share of free allowances falls by 7% per year, but utilities have the opportunity to purchase additional allowances at market prices.

projections. Second, the Company's system has seen customer growth with the number of full-service customers increasing from 1.35 million in 2015 to 1.47 million through 2022.

Figure 1 shows the historical emissions and business-as-usual forecasted emissions, which include the impacts of the Company's currently approved demand-side management (DSM) and building electrification (BE) programs. Under currently approved programs, the Company forecasts that its emissions will peak in 2025 and decline thereafter[2]. However, existing programs are not sufficient to achieve the Clean Heat targets and additional action will be needed. Since the statute uses 2015, a warm year, as the baseline for Clean Heat, and the customer base has grown since 2015, the Company will need to achieve a 14% emissions reduction by 2025 and a 28% reduction by 2030 compared to the business-as-usual forecast.

Figure 1. PSCo Historical and Forecasted Emissions



Clean Heat Plan Resource Options

SB 21-264 defines a set of Clean Heat Resources. Those resources and a high-level description of their treatment in E3's modeling is provided in Table 1.

Table 1. Clean Heat Resources

Resource Option	Modeling Treatment
Gas Demand Side Management (DSM)	Both approved and additional incremental DSM measures are included.
Recovered Methane	Landfill gas, municipal solid waste, manure, and coal bed methane feedstocks. Limited to 1% of 2025 target and 5% of 2030 target by statute.

[2]The Company's forecasted BAU emissions reflect both forecasted gas sales and estimated leakage from the transport and delivery of gas to customers.

Resource Option	Modeling Treatment
Hydrogen (H2)	Green and blue H2 production options with a maximum blend on the Company's system of 1% by volume in 2027 and 4% in 2030.
Beneficial Electrification (BE)	Heating, ventilation, and air conditioning (HVAC) and water heating with market saturation benchmarked to modified 2021 Colorado GHG Roadmap trajectories
Pyrolysis of Tires	Not considered

As discussed by Company witness Mr. Ihle, SB 21-264 allows for consideration of technologies that cost-effectively reduce emissions from natural gas end-uses. The Company identified additional resources that are included as part of a "Clean Heat Plus" scenario, which is described in more detail below. The additional resources are listed in Table 2.

Table 2. Additional Emissions Reduction Resources Included in Clean Heat Plus

Resource Option	Modeling Treatment
Certified Natural Gas	Natural gas that is produced in a manner that reduces upstream methane emissions
Offsets	GHG reductions from natural and working lands, destruction of hydrofluorocarbons (HFCs)

Clean Heat Portfolio Requirements

SB 21-264 requires the Company to present a portfolio that does not exceed a cost target of 2.5% of total annual revenue for all full-service customers. SB 21-264 also requires the Company to present a portfolio that meets the emissions targets, but that may not meet the cost target.

Modeling Approach

To support the Company in developing its Clean Heat Plan, E3 developed a portfolio analysis model that identifies least-cost combinations of supply- and demand-side resources that achieve Clean Heat targets. The model considers two types of costs: total resource costs and program administrator costs. The total resource cost metric is the basis of the model's cost minimization function, while the program administrator cost is used to assess the cost of Clean Heat compliance for the Company's gas customers. For supply side resources, program costs are equal to the cost premium of those resources relative to natural gas. Demand-side program costs are evaluated based on the incentives that the Company would pay its customers to support energy efficiency or electrification. Those incentives vary by measure type and are assumed to increase in size as the targeted level of market penetration of a given technology increases.

To the extent possible, E3 calibrated the model to existing Company data for resource costs, such as the Company's Technical Reference Manual (TRM) for DSM and BE. In addition, E3 worked with the Company to characterize resource costs and characteristics for options such as recovered methane and hydrogen.

A detailed discussion of the portfolio modeling framework and key assumptions used can be found in Exhibit A.

Clean Heat Scenarios

E3 modeled Clean Heat Portfolios across four core scenarios. In addition to those scenarios, E3 also conducted sensitivity analyses, which are discussed below. The core scenarios include:

+ **Cost Target:** least-cost portfolio of Clean Heat Resources, subject to the Clean Heat cost cap of 2.5% of annual gas bills for all full-service customers as a whole[3]. This scenario does not necessarily meet the emissions targets.
+ **Emissions Target**: This scenario includes a least-cost portfolio of Clean Heat Resources, subject to meeting the 2030 emissions reductions target. This scenario does not necessarily meet the cost cap.
+ **Clean Heat Plus**: This scenario achieves the 2030 emissions reduction target using both Clean Heat Resources and additional measures (i.e., CNG and Offsets), but does not necessarily meet the cost cap.
+ **Electrification Only**: This scenario relies solely on incremental DSM and electrification, not including hybrid heat pumps, to achieve the Clean Heat targets. This scenario is constrained to achieve the 2030 emissions target, provided that sufficient electrification resources are available.

Key scenario parameters are summarized in Table 3. A more detailed discussion of the scenario assumptions can be found in Exhibit A.

Table 3. Scenario Parameters

Scenario	Cost Target Enforced	Emissions Target Enforced*	Additional Measures Allowed
Cost Target	X		
Emissions Target		X	
Clean Heat Plus		X	X
Electrification Only		X	

**Achievement of the emissions target in each scenario is subject to resource availability. E3 considered several sensitivities on resource availability, which are discussed below.*

[3] In addition to the Clean Heat cost cap, the total cost cap modeled for the Cost Target scenario is inclusive of a $10.5 million rebate allowance budget estimated for two rebate programs authorized under the Inflation Reduction Act (IRA) of 2022. The two rebate programs available to the Company's customers who install qualified equipment are the High-Efficiency Electric Home Rebate Act (HEEHRA) program and the Home Owner Managing Energy Savings (HOMES) program. The $10.5 million total rebate estimate was provided by Guidehouse in the Company's Attachment NCM-5 Proceeding No. 22A-0309EG Hearing Exhibit 108.

Clean Heat Resource Constraints

Achieving the 2025 and 2030 Clean Heat targets will require implementing emissions reduction measures at an unprecedented pace, but those measures will face constraints. Key constraints E3 has reflected include:

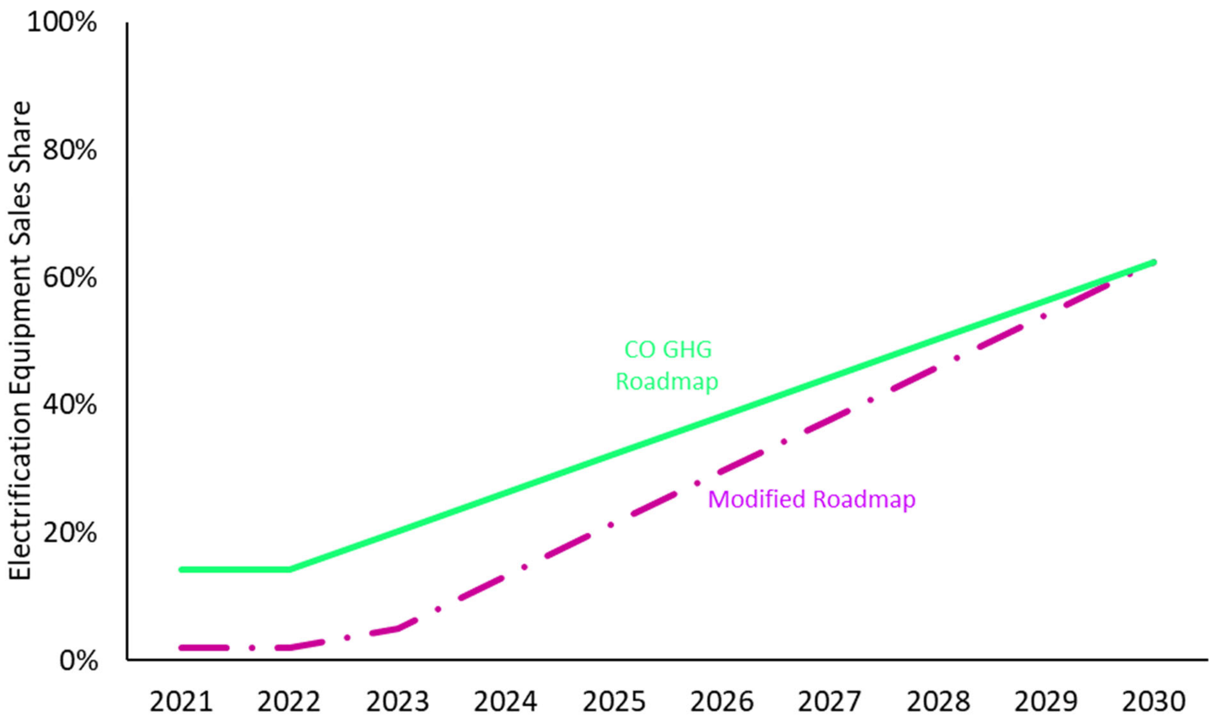
+ Statutory: SB 21-264 sets a cap on the share of emissions reductions that can be met by recovered methane credits in 2025 and 2030.
+ Physical: The Company indicated that hydrogen resources would not be available until 2027 and should not exceed more than a 4% blend by volume by 2030[4]. Emissions savings from certified natural gas are limited by the remaining gas throughput on the Company's system.
+ Stock Turnover: E3 assumes that the adoption of demand-side measures, including energy efficiency and building electrification, occurs upon equipment failure. This assumption sets a limit on the number of buildings eligible to adopt a heat pump or efficiency measure in each year.
+ Market Transformation: For the purposes of modeling, E3 stipulated a maximum pace of assumed market transformation for demand-side technologies. This pace is defined as the sales share of demand-side technologies that can be met by electrification or gas efficiency measures in any given year.

E3 began the Clean Heat portfolio modeling process by assuming that the maximum pace of electrification market transformation is equal to the sales share for appliances assumed in the 2021 Roadmap. However, E3 ultimately varied that pace across scenarios for two reasons:

+ First, the 2021 Roadmap assumed that electrification would begin in 2021, but in practice the Company will not be able to implement Clean Heat programs until 2024 at the earliest. Given that difference in timing, E3 developed a Modified Roadmap trajectory that shifts the start point of the 2021 Roadmap trajectory back by three years but achieves the same sales share by 2030. The Modified Roadmap trajectory is shown in Figure 2 relative to the 2021 CO GHG Roadmap.
+ Second, our analysis indicates that the 2030 emissions target is not achievable using Clean Heat Resources alone if electrification occurs at the pace of the Modified Roadmap. Given that finding, E3 ultimately treated the pace of electrification market transformation required to meet the 2030 Clean Heat target as a variable that our analysis solves for in the Emissions Target, Clean Heat Plus and Electrification Only scenarios.

[4] Note that E3 assumed a 4% blend by volume is achievable across both The Company's retail and transport sales.

Figure 2. CO GHG Roadmap and Modified Roadmap Electrification Sales Share Trajectories



Program Costs and Emissions

The program costs and emissions savings for each portfolio are summarized in Figure 3, and the composition of those program costs and emissions savings are shown in Figure 4. Key findings for each portfolio are discussed below. Program costs include the incremental cost of supply-side resources and the incentives the Company offers to support adoption of demand-side measures. Program costs are presented as annual averages from 2024 through 2030. In practice, these costs increase over time. A more detailed summary of program costs by resource type and year can be found in Exhibit A.

Figure 3. Program Costs and Emissions Savings for each Portfolio

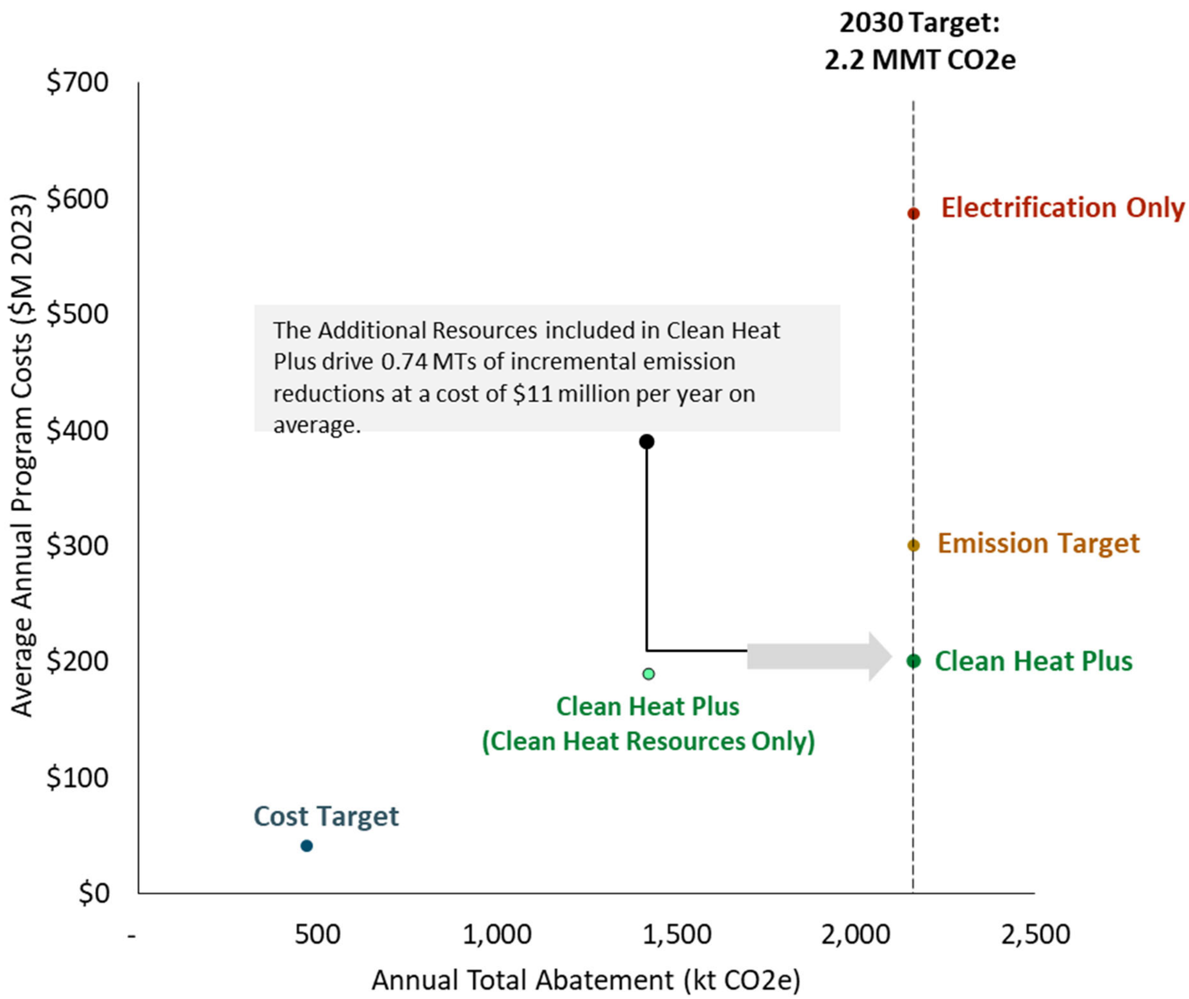
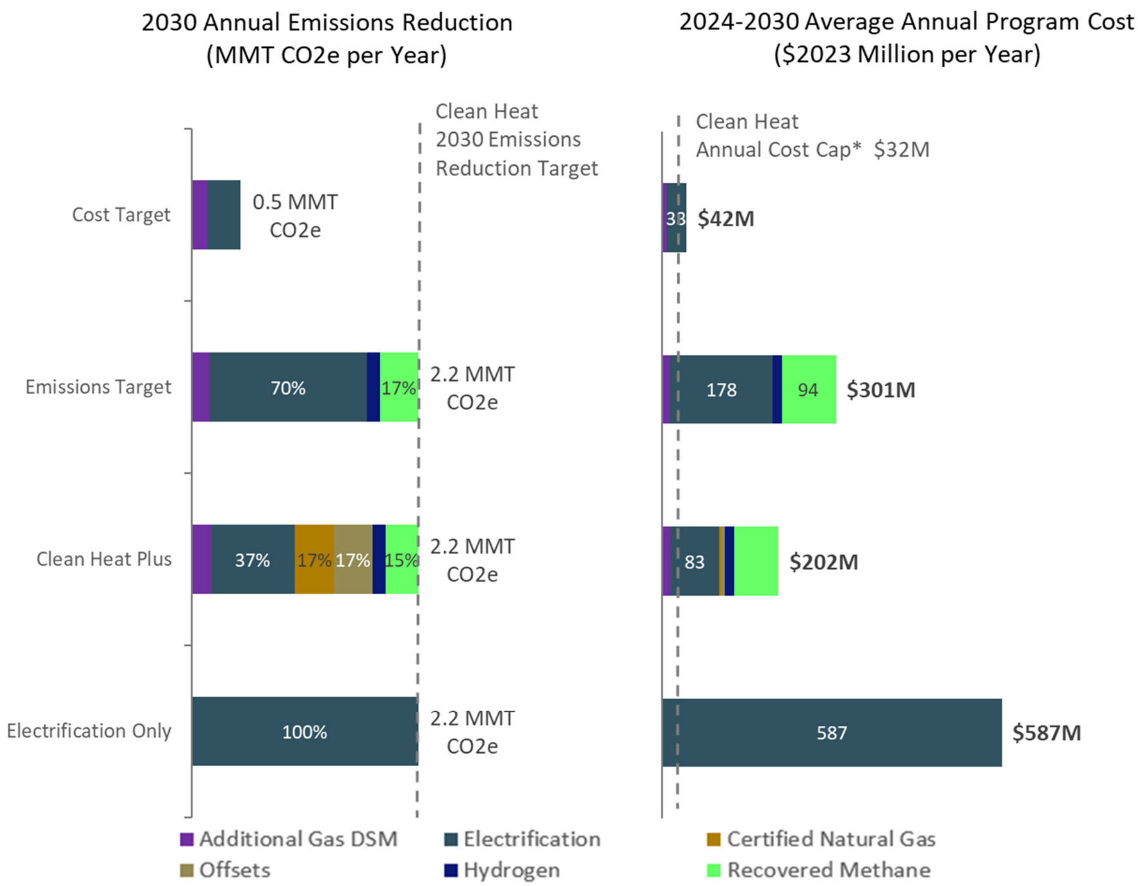


Figure 4. Program Costs and Emissions Savings by Portfolio and Resource Type



* Clean Heat Cost Cap is inclusive of a $10.5M rebate allowance budget estimated for two rebate programs authorized under the Inflation Reduction Act (IRA) of 2022
** Cost Target average annual costs include $33M of Electrification and $9M of Additional Gas DSM
*** The average annual cost cap is in $2023. It is around $34M per year in nominal dollars.

Cost Target

A notable finding of E3's analysis is that the Clean Heat cost target of 2.5% of full-service retail sales is not sufficient to achieve either the 2025 or 2030 targets. With that cap enforced, the modeling results indicate that the Company achieves approximately 22% of the 2030 emissions target in the Cost Target scenario (0.47 $MMTCO_2e$ achieved vs. target of 2.16 $MMTCO_2e$). The primary resource types selected in this scenario are DSM and building electrification.

Emissions Target

In order for the Emissions Target scenario to achieve the 2030 Clean Heat emissions target, E3 found that the pace of electrification adoption needs to exceed the Modified Roadmap pace by 85% in each year. In addition to high levels of electrification, the Emissions Target scenario relies on a portfolio of hydrogen, recovered methane, and gas efficiency strategies to achieve the 2030 target. The average annual program costs of the Emissions Target scenario are $301 million per year, or almost nine times the Clean Heat cost cap. Relative to the Cost Target scenario, the program costs in the Emissions Target scenario are driven by higher overall levels of resource procurement, higher cost resources, and increases in the per-unit cost of building electrification incentives.

Electrification Only

The Electrification Only scenario achieves the 2030 Clean Heat emissions target using only all-electric technologies and non-device DSM resources. To achieve the target, this scenario requires electrification to proceed at a pace that exceeds the pace of the Modified Roadmap by 195% in each year. Put differently, the Electrification Only scenario requires that nearly half of all space heating and water heater sales in the Company's service territory be all-electric by 2025, with 100% all-electric sales by 2027. E3 identified an average annual program cost of $587 million per year for this scenario. The higher costs in the Electrification Only scenario are driven by the exclusion of lower cost tranches of renewable fuels and hybrid heating. In addition, because this scenario includes a near-complete transformation of the building heating market, it includes the highest escalation in the per-unit cost of building electrification incentives that are included in program costs.

One notable outcome in Electrification Only is that no additional gas DSM is selected. This outcome occurs because the $/tCO2 abated costs, the metric used for resource selection by E3's model, are lower for electrification measures compared to building shell upgrades, the primary incremental non-device measure considered. This outcome occurs because the incremental cost of a heat pump and shell measure are similar, but a shell measure only reduces 5-20% of a building's space heating related gas consumption and corresponding emissions, whereas a fully electric heat pump would fully avoid that gas consumption.

Clean Heat Plus

The Clean Heat Plus scenario achieves the 2030 Clean Heat emissions target at an average annual cost of $202 million per year, or approximately 33% lower than the Emissions Target scenario and 66% lower than the Electrification Only scenario.

In terms of resource selection, Clean Heat Plus relies on high levels of electrification, though at a moderated pace that matches the Modified Roadmap trajectory (exceeds the roadmap trajectory by 0%). The cost reductions in Clean Heat Plus relative to the Emissions Target scenario are achieved primarily by replacing more expensive tranches of both demand- and supply-side resources with certified natural gas and offsets. By 2030, 66% of emissions reductions are achieved with Clean Heat Resources and 34% are achieved by additional resources.

Clean Heat Scenario Sensitivities

E3 modeled the following sensitivities that vary resource availability or cost:

+ Limited Electrification: The pace of market transformation required to achieve the emissions targets using enumerated Clean Heat Resources represents a rapid, and likely unprecedented, shift in how the Company's customers choose to heat their homes and businesses. Under Clean Heat, the Company has the ability to offer these customers incentives to support adoption of electrification technologies, but the company does not have direct control over its customers' decisions. As a result, E3 also assessed each scenario under a Limited Electrification sensitivity that assumes 50% of the Modified Roadmap market transformation trajectory in each year.

+ Optimistic Fuels: E3's base assumptions for recovered methane were derived based on specific projects identified by the Company. E3 evaluated the emissions reductions of those projects using project-specific data under the Colorado Department of Public Health and Environment (CDPHE) recovered methane protocols. Given the nascent state of the recovered methane market in Colorado, E3 worked with the Company to develop an Optimistic sensitivity for recovered methane that considers additional plausible project types. However, the maximum share of recovered methane is still limited per SB 21-264. In addition, for Clean Heat Plus only, the Optimistic Fuels case reflects plausible additional offset projects that the Company believes could become available over time.

Table 4 shows the results of these sensitivities in terms of average annual portfolio costs and emissions compared to the core scenarios. Under the Limited Electrification sensitivity, neither the Emissions Target nor the Electrification Only scenario come close to achieving the 2030 emissions target. In contrast, Clean Heat Plus is able to meet the 2030 target in the Limited Electrification sensitivity, though at higher cost due to a need to leverage more costly tranches of recovered methane. The Optimistic Fuels sensitivity lowers the cost of the Emissions Target and Clean Heat Plus scenarios.

Table 4. Emissions Savings and Costs for Sensitivities

Scenario	2030 Emissions Savings (kt CO2e)			2024-2030 Average Annual Cost ($M 2023)		
	Limited Electrification	Base Assumption	Optimistic Fuels	Limited Electrification	Base Assumption	Optimistic Fuels
Cost Target	506	471	538	42	42	42
Emissions Target	1,028	2,162	2,162	160	301	221
Electrification Only	507	2,162	N/A	63	587	N/A
Clean Heat Plus	1,790	2,162	2,162	178	202	140

Discussion of Clean Heat Resource Characteristics

Building Electrification

E3 leveraged the 2021 Colorado GHG Roadmap as a starting point to assess the maximum pace of electrification adoption that can occur in each scenario. As discussed above, the Modified Roadmap pace is not sufficient to achieve the 2030 Clean Heat target using only Clean Heat Resources. As a result, E3 treated the level of electrification required to meet the 2030 target as a variable the model solved for. Figure 4 compares each scenario's pace of electrification in single-family buildings to the pace assumed in the 2021 Roadmap. The pace of electrification in the Cost Target scenario falls well below that of the Modified Roadmap because the cost cap becomes binding before the Roadmap level of adoption is achieved. The Clean Heat Plus scenario follows a trajectory that is most similar to the Roadmap, while the Emissions Target and High Electrification scenarios must exceed the trajectory in the Roadmap by a significant margin to achieve the 2030 target as indicated by Figure 4

Figure 4. Single Family HVAC Electrification Sales Share by Scenario

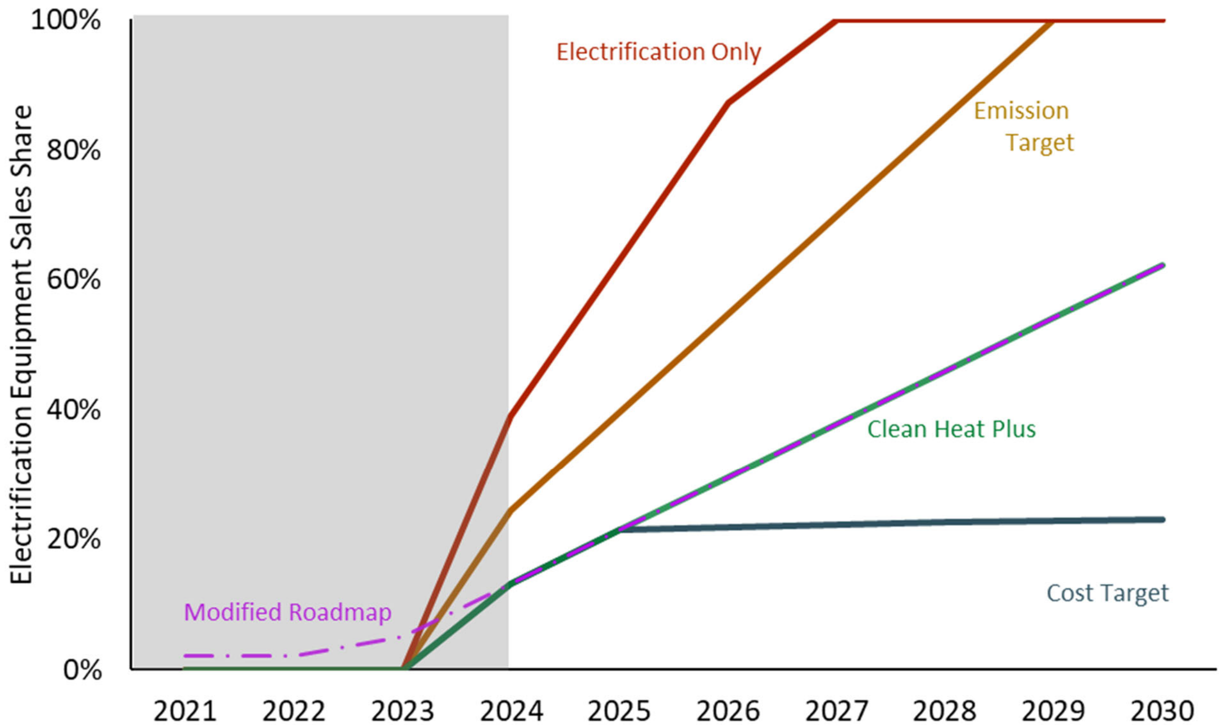


Table 5. Electrification Sales Share Trajectories Relative to the Modified Roadmap Trajectory

Scenario	Electrification Sales Share as Percent of Modified Roadmap Trajectory	Exceeds Modified Roadmap Trajectory by X%
Cost Target	**Does not reach Modified Roadmap**	**Does not reach Modified Roadmap**
Clean Heat Plus	**100%**	**0%**
Emissions Target	**185%**	**85%**
Electrification Only	**295%**	**195%**

Most portfolios include both all-electric and hybrid HVAC systems, as well as a significant role for heat pump water heaters. E3's model selected a diverse portfolio of building electrification measures in all scenarios except the Electrification Only scenario where hybrid heat pumps are not allowed. Table 6 provides the 2030 stock share of building electrification technologies across different market segments in each scenario.

Table 6. 2030 Stock Share of BE Technologies by Market Segment in each Scenario

Market Segment	Technology	Equipment Stock Share (%)			Equipment Stock Share (Quantity)		
		Emissions Target	Clean Heat Plus	Electrification Only	Emissions Target	Clean Heat Plus	Electrification Only
Single Family	Electric	10.8%	6.0%	32.7%	128,645	71,786	391,496
	Hybrid	15.5%	8.7%	0.0%	185,920	103,747	0
	HPWH	35.4%	20.6%	42.9%	423,202	246,976	512,958
Multi-Family	Electric	16.4%	9.4%	31.8%	30,418	17,338	58,819
	Hybrid	10.4%	5.9%	0.0%	19,216	10,952	0
	HPWH	35.1%	20.5%	42.6%	64,999	37,931	78,811
Commercial	Electric	16.9%	9.9%	33.3%	1,763	1,028	3,473
	Hybrid	10.6%	6.2%	0.0%	1,104	644	0
	HWPH	22.7%	12.5%	28.8%	1,755	948	2,392

All scenarios that achieve or approach achievement of the 2030 Clean Heat target rely on high levels of building electrification. However, the pace of electrification envisioned in those scenarios entails rapid market transformation in the building heating sector. The Company may have the ability to influence the market via its programs and incentives but does not have direct control over customer decisions to electrify, nor can they alone ensure there is a sufficient number of skilled contractors to deliver electrification measures at the scales envisioned here. For those reasons, additional policy support beyond incentives may be needed to meet the Clean Heat targets.

In terms of customer decision-making, E3's analysis suggests that building electrification in retrofit applications continues to carry a capital cost premium over conventional gas technologies throughout the study period. The Inflation Reduction Act (IRA) reduces, but does not close, that cost gap. Figure 5 shows the cumulative investment required on the premises of the Company's customers. E3 estimates that the total demand-side investment exceeds $8 billion between 2024 and 2030 in the Electrification Only scenario.

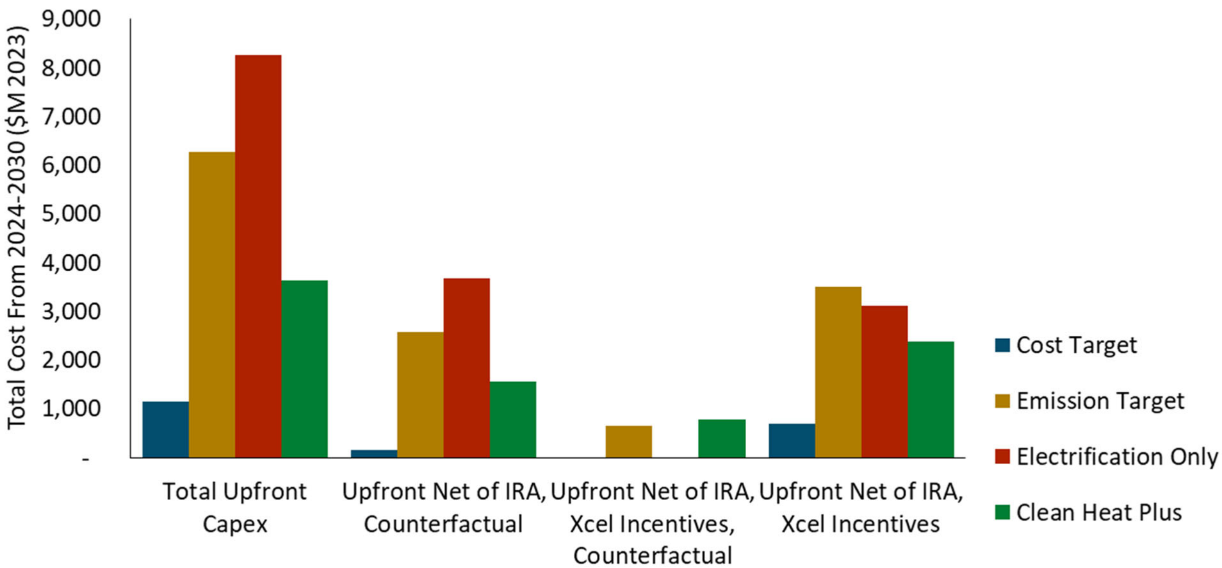
The incremental costs customers must pay to electrify are lower, however, because E3 assumes that electrification occurs upon the failure of existing equipment. For example, the cost of electrifying a home is the incremental cost of a heat pump relative to a counterfactual installation of a new furnace paired with an air conditioner. The assumption to include the full cost of an air conditioner unit yields a lower incremental cost, and this may be an optimistic assumption for customers who would be replacing air conditioners with remaining useful life, or customers currently without air conditioning that did not intend to get air conditioning. Incremental costs, net of the IRA and the cost of counterfactual heating and cooling systems customers would have installed anyway, are over $3 billion in the Electrification Only scenario.

The Clean Heat incentives modeled by E3, when paired with IRA incentives, are sufficient to cover the remaining "missing money"[5] from an upfront cost perspective in Cost Target and Electrification Only, while a small cost premium remains in Emissions Target and Clean Heat Plus. This outcome occurs because E3 assumes that electrification incentives scale as a function of the sales share of devices that are targeted

[5] "Missing Money" in this case refers to the incremental cost of a heat pump system over the counterfactual furnace/AC system.

each year. A key source of uncertainty in this analysis is the extent to which the Company's customers will respond to the incentive levels assumed here. Customers may not choose to adopt electrification technologies based on non-cost factors or preferences. Additionally, given current electric and gas rates, E3 expects most customers to see bill increases due to electrification. These findings underscore that driving sufficient building decarbonization on the timeline of Clean Heat will be a substantial challenge, even after accounting for the impact of the IRA and the Company's Clean Heat incentives.

Figure 5. Participant Upfront Costs and Funding Needed for each Scenario[6].



Gas DSM

E3 leveraged the Company's existing gas DSM plans to characterize the emissions savings and costs of measures ranging from insulation to more efficient appliances. In addition, E3 modeled additional DSM savings that are incremental to the Company's existing plans. Table 7 summarizes the relative contribution of incremental gas DSM measures in each scenario.

Table 7. Cumulative Reductions (Dekatherms) from Incremental DSM by Year

Scenario	2024	2025	2026	2027	2028	2029	2030
Cost Target	755,149	1,389,006	1,977,319	2,547,824	2,706,278	2,847,518	2,969,353
Emissions Target	649,275	1,269,596	1,840,247	2,323,533	2,676,086	2,971,319	3,210,795
Clean Heat Plus	673,897	1,294,470	1,865,128	2,396,232	2,869,616	3,274,791	3,530,019
Electrification Only	0	0	0	0	0	0	0

[6] Note that this figure does not include costs such as secondary distribution upgrades that participants might incur as part of an electrification project.

Recovered Methane

Recovered methane resources are selected in the Emissions Target and Clean Heat Plus scenarios, but are limited in supply and carry a wide variation in costs across resources.[7] E3 worked with the Company to develop a set of representative recovered methane project types that vary across factors including feedstock and baseline emissions. E3 assessed the emissions savings of these projects under the recovered methane protocols established by CDPHE. Under those protocols, E3 found a wide variation in the GHG emissions savings from recovered methane projects, in part because the outcomes of the protocols depend heavily on existing methane management practices and do not account for biogenic emissions reductions.

Table 8 shows the total quantities of Recovered Methane selected in each scenario. A more detailed of Recovered Methane resources by type is provided in the appendix.

Table 8. Cumulative Recovered Methane Quantities by Year (Dth)

Scenario	2024	2025	2026	2027	2028	2029	2030
Cost Target	0	0	0	0	0	0	0
Emissions Target	512,512	2,658,481	3,287,481	3,287,481	3,287,481	3,287,481	3,428,152
Clean Heat Plus	512,512	2,192,289	2,821,289	2,821,289	2,821,289	2,821,289	2,794,161
Electrification Only	0	0	0	0	0	0	0

Hydrogen

Blue and green hydrogen resources are selected in the Emissions Target and Clean Heat Plus scenarios. However, hydrogen is limited in the quantity that can be blended into the Company's system. The green hydrogen resource modeled is assumed to be zero GHG emissions using renewable energy. The blue hydrogen resource is assumed to have lifecycle emissions due to both incomplete capture of CO_2 at the point of production and electric system emissions associated with the production process. In addition, based on input from the Company, E3 assumed that hydrogen blends in the Company's system can begin at 1% by volume in 2027 and increase to 4% by 2030. These blend volumes are based on the total volume for both retail and transport customers. After consulting with the Company, E3 assumed that retail customers would pay for the lower-GHG attributes of hydrogen delivered to the entire system and the Company would credit those attributes against its Clean Heat targets.

Table 8 shows the amount of hydrogen selected in each scenario. Both Clean Heat Plus and Emissions Target include a similar amount of hydrogen because that resource is lower cost than certain recovered methane resources[8]. There is no hydrogen in Cost Target because of lower cost demand-side options, nor in Electrification Only because hydrogen was excluded from that scenario by design.

[7] The Electrification Only scenario intentionally excludes recovered methane and other supply side resources, while the Cost Target scenario allows recovered methane, but the model does not select it due to relative cost effectiveness of other emission reductions.

[8] The amount of hydrogen in these scenarios varies slightly due to variation in overall gas throughput, which the total amount of hydrogen allowable is a percentage of.

Table 9. Cumulative Hydrogen Quantities by Year (Dekatherms)

Scenario	2024	2025	2026	2027	2028	2029	2030
Cost Target	0	0	0	0	0	0	0
Emissions Target	0	0	0	669,890	1,725,658	2,878,064	3,664,305
Clean Heat Plus	0	0	0	669,890	1,725,658	2,874,623	3,711,888
Electrification Only	0	0	0	0	0	0	0

Discussion of Clean Heat Plus Emissions Reduction Measures

Certified natural gas and offsets are selected by the model in the Clean Heat Plus scenario. In that scenario, these resources represent approximately 34% of 2030 emissions reductions, with the remaining 66% coming from Clean Heat resources. The maximum amount of certified natural gas in each year is selected such that by 2030, 100% of remaining natural gas is certified natural gas in the Clean Heat Plus scenario.

Table 10. Cumulative Certified Natural Gas Quantities by Year (Dekatherms)

	2024	2025	2026	2027	2028	2029	2030
Certified Natural Gas Quantities	0	20,000	35,735,961	71,168,913	100,421,249	117,265,928	116,868,077

Offsets in Clean Heat Plus include a variety of project types including avoided grassland conversion, improved forest management (IFM) and hydrofluorocarbon (HFC) reclamation. Total emissions savings by offset project type are summarized in Table 11.

Table 11. Cumulative GHG Savings from Offsets (tCO2e)

Feedstock Type	2024	2025	2026	2027	2028	2029	2030
Avoided Grassland Conversion	30,000	52,174	78,261	95,217	95,217	95,217	95,217
HFC Reclaim	25,000	43,478	65,217	79,348	79,348	79,348	79,348
IFM - Reduction	50,000	86,957	130,435	158,696	158,696	158,696	158,696
IFM - Removal	10,000	17,391	26,087	31,739	31,739	31,739	31,739

Impacts on Company Gas Sales

All Clean Heat scenarios rely on a high level of demand-side transformations that reduce gas sales on the Company's system, as shown in Figure 6. The Cost Target scenario has the least impact on gas sales, with a reduction of 2% relative to the business-as-usual case in 2030. The Electrification Only scenario has the greatest impact on gas sales, with a reduction of 26% by 2030. The Emissions Target and Clean Heat Plus scenarios result in a 23% and 13% reductions, respectively, in 2030.

Figure 6. Gas Sales by Scenario

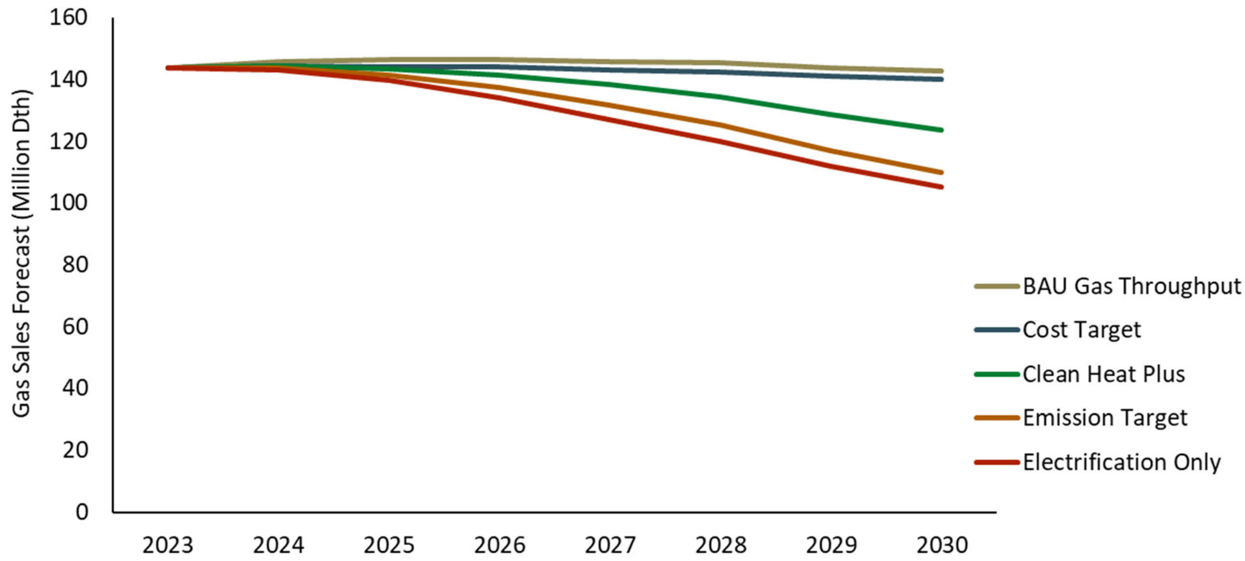


Exhibit A Methodology

Portfolio Analysis Model

E3 developed a portfolio analysis model to assess the cost and availability of resources for achieving the Clean Heat emissions reduction targets through 2030. The model incorporates both demand-side and supply-side emissions reduction resources:

+ Demand-side resources are modeled with details specific to individual building typologies representing various building types, building vintages, and climate zones in the Company's service territory. E3 assessed each building typology with multiple electrification and efficiency measure package alternatives based on building simulations from the National Renewable Energy Laboratory (NREL) ResStock and ComStock Analysis Database and the Company's energy data (e.g., PSCo 2023 DSM & BE Plan Technical Reference Manual, Company 2022 Home Energy Use Study).
+ Supply-side resources are represented with a diverse set of specific projects the Company has identified as well as plausible project archetypes. The resources fall into five broad categories: recovered methane, hydrogen, certified natural gas, and offsets. In addition to supply-side resources enumerated in the Clean Heat Statute, additional resources are also modeled in specific scenarios for cost and feasibility considerations.

The portfolio analysis model conducts four key steps to construct a portfolio for a specific year (see Figure 7):

1. **Apply cost tests to each resource.** The model is equipped to calculate costs and benefits from various perspectives commonly used for assessment of energy efficiency and electrification measures. This step calculates the total resource costs and program costs for demand-side resources. In the following steps, total resources costs are used as a metric for ranking the resources and program costs are applied towards the relevant constraints for each portfolio.
2. **Sort demand- and supply-side measures in the order of cost ($/ton).** In this step, the model constructs a combined supply curve for all resources including both costs and potential of each resource. This step sets the dispatch order for portfolio selection.
3. **Select least-cost portfolios subject to constraints.** Based on the resource supply curve constructed in the previous step, the model applies further constraints for portfolio selection including annual emissions reduction target, annual program cost cap, maximum emissions reduction allowed by certain resources and resource availability and eligibility specific to scenario assumptions.
4. **Output the selected portfolio with key metrics**. Key metrics including sales of efficient and electric appliances, blend of natural gas, recovered methane and hydrogen, emissions reductions achieved, and program costs are reported out for a portfolio constructed for a specific model year. In addition, results of the specific resources and quantities selected for that portfolio are applied to update resource availability and constraints for the following model year.

The model is iterative. That is, each model year in the portfolio analysis builds on results from the previous year as the model selects portfolios annually from 2024 through 2030 (see Figure 8). After the model solves for a specific scenario, E3 further conducts a refinement for interim years based on the resources selected for 2030. The purpose of the refinement is to remove any high-cost resources that were selected in interim years, but that are not needed to meet the 2030 Clean Heat emissions target.

Figure 7. Schematic diagram of key steps in the portfolio analysis model

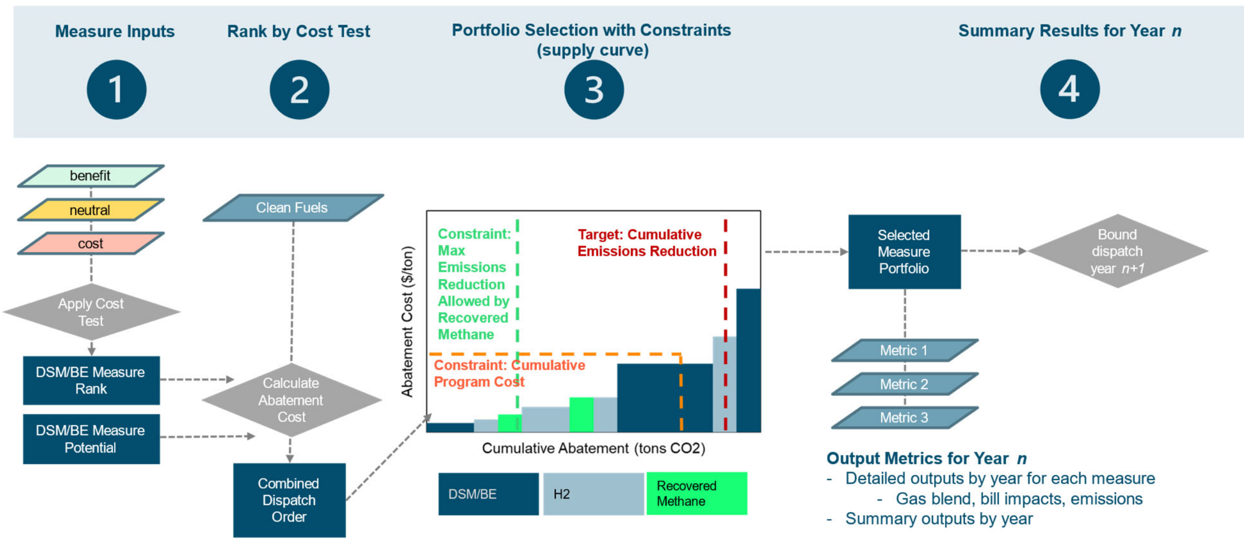
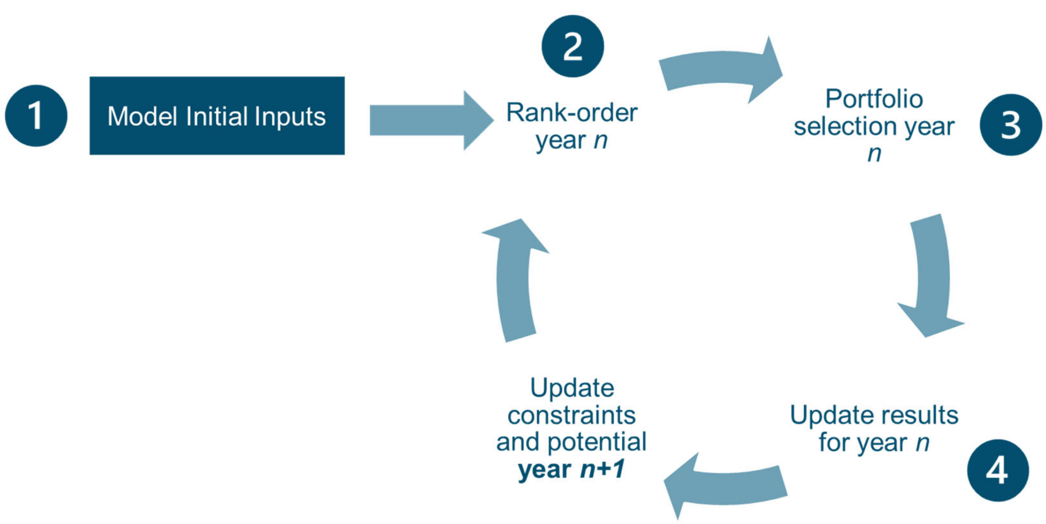


Figure 8. Illustration of the year-over-year modeling process in the portfolio analysis model



Cost Metrics and Selection Criteria

The portfolio analysis model conducts multiple cost tests to resources to reflect multiple perspectives of measure cost and benefit to participants, non-participating ratepayers, the utility and the society as a whole. Among those, two cost metrics are applied in portfolio selection:

+ Total Resource Cost (or TRC) metric is applied to rank resources from lowest to highest abatement cost in the supply curve for portfolio selection. Using TRC as the criteria to rank and select resources minimizes energy system cost impacts of the portfolios. TRC is calculated as the incremental cost of a resource relative to a baseline. For demand-side resources, a baseline resource is assumed to be a like-for-like replacement of an existing piece of equipment in buildings. TRCs of demand-side resources are calculated considering five major components as shown in Table 12. On the cost side, incremental installed cost of equipment, incremental electric system cost impact and administrative cost for running a program to encourage the adoption of the resources are modeled. On the benefit side, avoided gas cost and federal incentives for installing certain equipment are modeled. For supply-side resources as shown in Table 13, TRCs are inclusive of incremental supply costs of resources, federal incentives and avoided gas fuels cost.
+ Program Cost metric is applied to assess the programmatic costs of the Clean Heat portfolios to utility customers and to compare those portfolios against the cost cap. For demand-side resources, Portfolio Cost includes utility incentives and administrative overhead (see Table 12). For supply-side resources, Portfolio Cost reflects incremental commodity costs of clean fuels resources, methane abatement and offsets net of avoided fuels costs and any federal incentives provided to certain resources (see Table 13).

Table 12. Components of the Two Cost Metrics Used in Portfolio Selection for Demand-side Resources

Measure Attributes	Total Resource Cost	Program Cost
Incremental Installed Equipment Cost	**Cost**	
Incremental Electric System Cost (Energy, Generating Capacity, T&D)	**Cost**	
Program Administrative Cost	**Cost**	**Cost**
Avoided Gas Cost	**Benefit**	
Federal Incentives	**Benefit**	
Utility Incentives		**Cost**

Table 13. Components of the Two Cost Metrics Used in Portfolio Selection for Supply-side Resources

Measure Attributes	Total Resource Cost	Program Cost
Costs of Clean Fuels Resources, Methane Abatement and Offsets	**Cost**	**Cost**
Avoided Gas Fuels	**Benefit**	**Benefit**
Federal Incentives	**Benefit**	**Benefit**

Model Capability and Limitations

The portfolio analysis model is well equipped for modeling a least-cost portfolio of resources to meet the Clean Heat emissions target subject to cost constraints (see first column of Table 14). The model defines and tracks key metrics for resource planning such as changes in gas sales, transformation of gas supply, and deployment of electrification measures. The granularity of the resources allows the model to capture heterogeneity in both supply- and demand-side options, such as different clean fuel supplies and various measures specific to a building typology. Given a range of alternative assumptions , the model can also provide a reasonable range of cost impacts for any selected portfolio.

The model does come with limitations (see second column of Table 14). Although both costs and availability of the various resources are considered in the analysis, those are not necessarily a forecast of what levels of deployment are feasible for each resource. Non-cost factors, such as customers' willingness to adopt electric equipment or the constructability of supply-side project projects, are not modeled and such risks should be considered in addition to the direct modeling outputs produced by E3. Another limitation is that the model does not comprehensively capture the impact of building electrification measures on the electric system. For example, a system-level simulation would be needed to capture the diversified peak impact from electrifying a large number of different buildings. Such diversified impact is not fully captured in the bottom-up approach applied in this model where one building prototype is modeled at a time.

Additionally, the model calculates its TRC metric in the context of the Company's current avoided costs, which are largely consistent with a summer peaking system. This means that, over the course of the Clean Heat period, building electrification measures have lower impacts on the Company's electric system. Given the high levels of electrification in all scenarios, E3 expects that the Company's system will shift to winter peaking by or shortly after 2030. At that point, building electrification could impose substantial new generation, transmission and distribution capacity requirements on the Company's electric system. Potential load impacts of electrification through mid-century are discussed in the 2050 decarbonization scenario analysis, described in further detail in Exhibit 2.

Table 14. Strengths and Limitations of the Portfolio Analysis Model

Strengths	Limitations
+ Select a least-cost portfolio of resources subject to emissions or cost constraints + Define key metrics such as changes in gas sales, transformation of gas supply, and deployment of electrification measures + Capture heterogeneity in both supply- and demand-side options + Provide a reasonable range of cost impacts under alternative assumptions	– Cannot determine what levels of resource deployment are feasible – Does not comprehensively capture the electric sector impacts of building electrification measures

The least-cost structure of the portfolio analysis model also has limitations with potential program design and portfolio construction of Building Electrification measures. For some tranches of building sector, only the single most cost-effective measure is selected, based on lifecycle $/t$CO_2$. Further heterogeneity of the building stock within the tranches of buildings represented in this model may have slightly different $/t$CO_2$

levels, and different rank ordering of measure cost effectiveness. Non-selected measures may still be cost effective, and perhaps better suited to a more specific application (ex. employing a dual fuel heat pump to avoid a panel upgrade). A pragmatic program may present several options of HVAC technology (standard, cold climate, hybrid, etc.) to better suit the needs of a specific building or customer. Further, the portfolio analysis model has a limited representation of conditions that may yield more expensive electrification retrofits, for example from more complicated electrical circuits, panel upgrades, upgraded secondary distribution, etc. This results in a generally optimistic view of potential market-wide electrification costs.

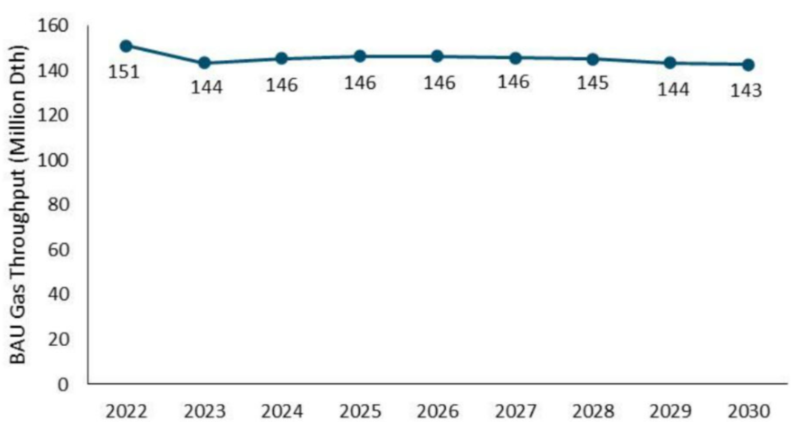
Resource Options and Assumptions

Scenario Assumptions

Base Gas Sales Forecast

The base gas sales forecast developed by the Company serves as the starting point of all resources modeled in the portfolio analysis. The base forecast assumes that the Company's DSM Strategic Issues[9] and DSM Plan Goals are achieved. It also reflects a limited amount of organic adoption of building electrification, along with the impacts of current municipal codes and standards for new construction.

Figure 9. Base Gas Sales Forecast Developed by PSCo



Weather Year Assumptions

The energy impacts modeled for demand-side measures represent those under an average weather condition. Typical Meteorology Year weather data were used to generate the energy impacts used in the portfolio analysis, both from NREL ResStock and ComStock simulation database and The Company's program data.

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[9] Note that because the Strategic Issues proceeding has not been finalized, E3 used the levels of electrification assumed in the Company's rebuttal testimony.

Electrification

To model electrification resources, E3 started by considering data from the Technical Reference Manual (TRM) of The Company's 2023 Demand Side Management and Beneficial Electrification Plan[10]. E3 leveraged these materials as the basis for our assumptions, but made selected modifications to them in order to better capture heterogeneity in building electrification costs.

Upon review, E3 determined that the heat pump water heater data from the TRM was available at a sufficient level of detail for our portfolio model. For HVAC measures, however, given the heterogeneity of HVAC applications across The Company's service territory and potentially significant penetration of building electrification measures, E3 determined that additional granularity was needed to fully capture the distribution of HVAC electrification opportunities. In particular, E3 determined that it is critical to represent a broader distribution of energy consumption profiles, technology configurations, heat pump equipment sizing, and corresponding incremental capital costs across the full building stock, with consideration of different building vintages, climate zones and building types. Table 15 shows where data was sourced from for this analysis.

Table 15. Building Electrification Measures and Data Sources

Sector	Measure	Energy Data Source	Incremental Cost Data Source
Residential Single Family	Water Heating	Company TRM	Company TRM
	Space Heating	E3 Modeling	E3 Cost Database
	Shell Improvements	Company TRM	Company TRM
Residential Multifamily	Water Heating	Company TRM	Company TRM
	Space Heating	E3 Modeling	E3 Cost Database
	Shell Improvements	Company TRM	Company TRM
Commercial	Water Heating	Company TRM	Company TRM
	Space Heating	E3 Modeling	E3 Cost Database
	Shell Improvements	Company TRM	Company TRM

To generate data for measure energy impacts electrifying space heating across The Company's service territory, E3 took the following steps, based on public datasets:

1. Define The Company's residential building stock based on data from EIA's 2020 Residential Energy Consumption Survey (RECS) database[11], supplemented with data from The Company's 2022 Home Energy Use Study.
2. Define The Company's commercial building stock based on data from EIA's 2018 Commercial Energy Consumption Survey (CBECS) database[12]

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[10] The Company. 2023 Demand Side Management and Beneficial Electrification Plan: 22A-0315EG_2023 DSM & BE Plan.pdf (xcelenergy.com)

[11] US Energy Information Administration, YEAR. Residential Energy Consumption Survey: Residential Energy Consumption Survey (RECS) - Energy Information Administration (eia.gov)

[12] US Energy Information Administration, 2018. Commercial Building Energy Consumption Survey: Energy Information Administration (EIA)- Commercial Buildings Energy Consumption Survey (CBECS)

3. Pull baseline residential building end use energy profiles from NREL's ResStock[13] database
4. Pull baseline commercial building end use energy profiles from NREL's ComStock[14] database

This data was then segmented by E3 based on defined building stock characteristics, and processed to create measure specific data for a selected list of technology configurations and sizing criteria. The combination of these parameters was used to create a database of candidate measures for the model to select from.

To create a representative view of The Company's building stock, E3 aggregated simulations from ResStock and ComStock across Building Type, Building Vintage, and Climate Zone as shown in Table 16.

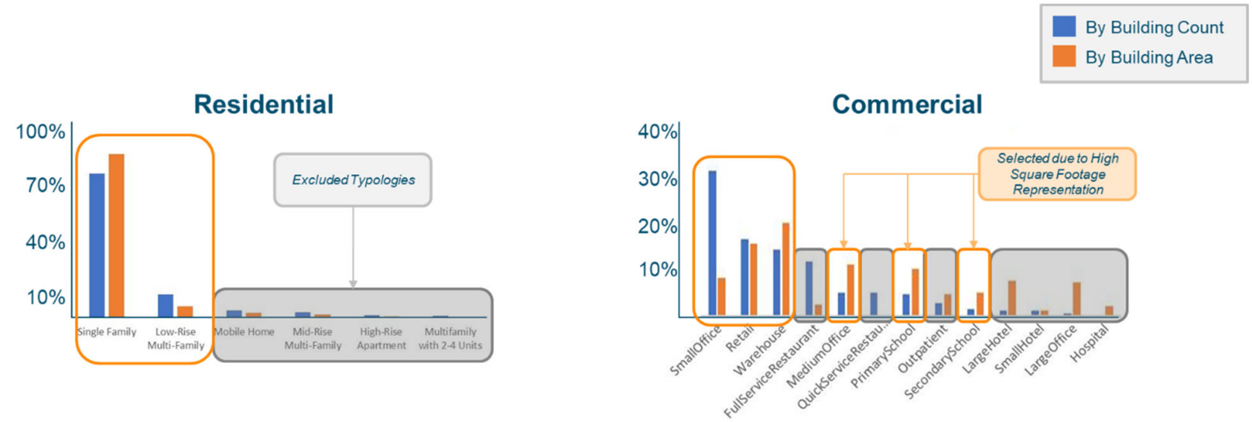
Table 16. Building Types, Building Vintages, and Climate Zones Modeled

Sector	Building Types Modeled	Building Vintages Modeled	IECC Climate Zones Modeled
Residential	Single Family Low-Rise Multi-Family	Pre-1945 1945-1980 1980-present New Construction (IECC 2021)	5B 6B 7B
Commercial	School Retail Small Office	Pre-1980 1980-present New Construction (IECC 2018)	5B 6B 7B

These building types were selected by E3 based the highest amount of representative stock served; for example, mobile homes, and high-rise multifamily did not make up a substantial portion of The Company's residential building stock. On the commercial side, smaller building typologies were selected, as they have higher coincidence with packaged and rooftop units, which have more straight-forward heat pump retrofit options. Existing large commercial buildings, for example, have more complex HVAC systems, and higher prevalence of boiler-driven heat hot water systems, which create the need for high cost retrofit solutions; these building types were excluded from the candidate sites for building electrification retrofits.

[13] NREL, 2022. ResStock. [ResStock - NREL]
[14] NREL, 2022. ComStock. [ComStock - NREL]

Figure 10. Coverage of Building Stock by Market Segment



In aggregate, these sites represent annual consumption, displayed in Table 17. Total sites and average consumption by fuel type are also included. Candidate BE measures are applied to this level of building stock.

Table 17. Summary Metrics for Building Types

Building Type	Total Building Area (Million sq.ft.)	Annual Electricity (GWh)	Annual Gas (MMBtu)	Total Sites	Average Electricity (kWh)	Average Gas (Therms)
All Units	**3,054**	**14,366**	**1,159**	**1,209,484**	**11,878**	**959**
SF	2,423	7,945	968	1,043,100	7,617	928
MF	135	668	47	152,300	4,389	307
Com	497	5,752	145	14,083	408,442	10,293
Office	*162*	*1,835*	*205*	*6,480*	*283,265*	*3,162*
Retail	*165*	*2,556*	*689*	*5,486*	*465,944*	*12,554*
School	*170*	*1,361*	*556*	*2,118*	*642,465*	*26,256*

For residential new construction, the following growth trajectories were used, based on new growth estimates provided to E3 by the Company. For commercial new construction, E3 used a 1% annual growth rate, taken from EIA's 2022 Annual Energy Outlook[15].

Table 18. Assumed Residential Annual New Construction Rates

Housing Sector	Climate Zone	New Housing Units/yr
Single Family Homes	5B	9,501
	6B	418
	7B	360
Multi-Family Homes	5B	2,773
	6B	75
	7B	70

[15] U.S. Energy Information Administration, Annual Energy Outlook 2022 (AEO2022). https://www.eia.gov/outlooks/aeo/

Table 19. Modeled Baseline Space Heating Gas Consumption for Residential Buildings and Table 20 show the baseline space heating gas consumption for the Residential and Commercial representative buildings included in this analysis.

Table 19. Modeled Baseline Space Heating Gas Consumption for Residential Buildings

Building Type	Climate Zone	Vintage	Baseline Space Heating Gas Consumption (Dth)
Multi Family	IECC-5B	New Construction	14.06
		post-1980	15.57
		pre-1980	23.81
		pre-war	21.20
	IECC-6B	New Construction	17.81
		post-1980	9.95
		pre-1980	16.01
		pre-war	19.10
	IECC-7B	New Construction	12.18
		post-1980	9.90
		pre-1980	15.19
		pre-war	57.52
Single Family	IECC-5B	New Construction	45.99
		post-1980	54.56
		pre-1980	72.72
		pre-war	80.72
	IECC-6B	New Construction	56.38
		post-1980	41.54
		pre-1980	60.82
		pre-war	80.65
	IECC-7B	New Construction	44.42
		post-1980	50.40
		pre-1980	81.08
		pre-war	108.66

Table 20. Modeled Baseline Space Heating Gas Consumption for Commercial Buildings

Building Type	Climate Zone	Vintage	Baseline Space Heating Load (Dth)
Retail	IECC-5B	New Construction	571
		post-1980	1,485
		pre-1980	1,619
	IECC-6B	New Construction	690
		post-1980	963
		pre-1980	780
	IECC-7B	New Construction	692
		post-1980	1,008
		pre-1980	935
School	IECC-5B	post-1980	5,207
		pre-1980	7,294

Building Type	Climate Zone	Vintage	Baseline Space Heating Load (Dth)
	IECC-6B	post-1980	5,805
		pre-1980	2,053
	IECC-7B	pre-1980	8,975
Small Office	IECC-5B	New Construction	23
		post-1980	408
		pre-1980	521
	IECC-6B	New Construction	28
		post-1980	439
		pre-1980	651
		New Construction	25
		post-1980	512
		pre-1980	532

For each combination of building type, vintage, and climate zone, the following measures were modeled, shown in Table 21. This suite of measures includes high performance cold climate heat pumps, along with air source heat pumps with electric resistance backup, and hybrid systems with gas backup. The modeling also considered different sizing conventions; a hybrid system with gas backup may typically be sized to cover peak air conditioning loads, to minimize ancillary electrical work, and make AC replacements as straight-forward as possible. From that sizing starting point, additional emissions reductions can be obtained by sizing the heat pump slightly larger, covering typical cold temperatures, without the need for significant oversizing for the absolute coldest day. Cutover temperatures in this context are meant to represent the design temperature of the heat pump, which sets how large the system is. A system designed with enough capacity to meet peak cooling loads in air conditioning mode will typically need to include supplemental heat from electric resistance strip heat, or a backup gas furnace below outdoor air temperatures of 20-30 degrees Fahrenheit. As an alternate to supplemental heat, a variable speed heat pump could be sized large enough to meet all space heating needs in space heating mode, without the need for supplemental heat, even at Colorado’s subzero heating design temperature.

For single family homes, on top of the heat pump measures, shell measures were also modeled for additional energy savings impacts. To capture interactive effects, shell measure impacts were modeled before heat pump sizing and performance calculations.

For commercial measures, heat pump retrofits were centered around packaged and rooftop units, as this is the most straight-forward system to replace with a heat pump, whether it be hybrid or all-electric with electric resistance backup.

To aggregate results to a representative datapoint for a given building type, building vintage, and climate zone, measures were applied individually to each building simulation that fit that category from the ResStock or ComStock database.

Table 21. Measures Modeled by Sector and Building Type

Sector	Building Type	Measure Type	Measure Description
Residential	SF and MF	HVAC Baseline	Gas Furnace + Dx Cooling
		Air Source Heat Pump	High Performance CC-ASHP Minisplit, Full load
			High Performance CC-ASHP Minisplit, 10F Cutover Temp
			High Performance CC-ASHP Minisplit, 20F Cutover Temp
			High Performance CC-ASHP Minisplit, sized to AC load
			CC-ASHP Ducted w/ ER Backup, 10F Cutover Temp
			CC-ASHP Ducted w/ ER Backup, 20F Cutover Temp
			CC-ASHP Ducted w/ ER Backup, sized to AC load
			ASHP w/ ER Backup, 10F Cutover Temp
			ASHP w/ ER Backup, 20F Cutover Temp
			ASHP w/ ER Backup, sized to AC load
			Hybrid ASHP w/ Gas Backup, 10F Cutover Temp
			Hybrid ASHP w/ Gas Backup, 20F Cutover Temp
			Hybrid ASHP w/ Gas Backup, sized to AC load
	SF Only	GSHP	Ground source Heat Pump
		Shell	Air Sealing + Attic Insulation
			Air Sealing + Attic and Wall Insulation
			Air Sealing + Attic and Wall Insulation, windows
Commercial	Small Office	Baseline	Gas Furnace + DX Cooling
		Air Source Heat Pump	Rooftop Unit ASHP w/ ER Backup, -15F Cutover
			Rooftop Unit ASHP w/ ER Backup, 10F Cutover
			Rooftop Unit ASHP w/ ER Backup, 20F Cutover
			Rooftop Unit ASHP w/ ER Backup, sized to AC load
			Rooftop Unit ASHP w/ Gas Backup, 10F Cutover
			Rooftop Unit ASHP w/ Gas Backup, 20F Cutover
			Rooftop Unit ASHP w/ Gas Backup, sized to AC load
	Retail	Baseline	Gas Furnace + DX Cooling (CAV dist.)
		Air Source Heat Pump	Rooftop Unit ASHP w/ ER Backup, -15F Cutover
			Rooftop Unit ASHP w/ ER Backup, 10F Cutover
			Rooftop Unit ASHP w/ ER Backup, 20F Cutover
			Rooftop Unit ASHP w/ ER Backup, sized to AC load
	School	Baseline	Gas Furnace + DX Cooling (CAV dist.)
		Air Source Heat Pump	Rooftop Unit ASHP w/ ER Backup, -15F Cutover
			Rooftop Unit ASHP w/ ER Backup, 10F Cutover
			Rooftop Unit ASHP w/ ER Backup, 20F Cutover
			Rooftop Unit ASHP w/ ER Backup, sized to AC load

To inform hourly heat pump efficiency, and corresponding hourly energy consumption, E3 developed heat pump efficiency curves for different technologies and sectors, as shown in **Error! Reference source not found.** These efficiency curves were also used by E3 to determine appropriate heat pump sizing, to cover building heating needs at the specified design temperature or cutover temperature. The minimum value for coefficient of performance was assumed by E3 to be 1, as that is the efficiency of electric resistance heating.

Figure 11. Assumed Heat Pump Coefficient of Performance as a Function of Outside Air Temperature

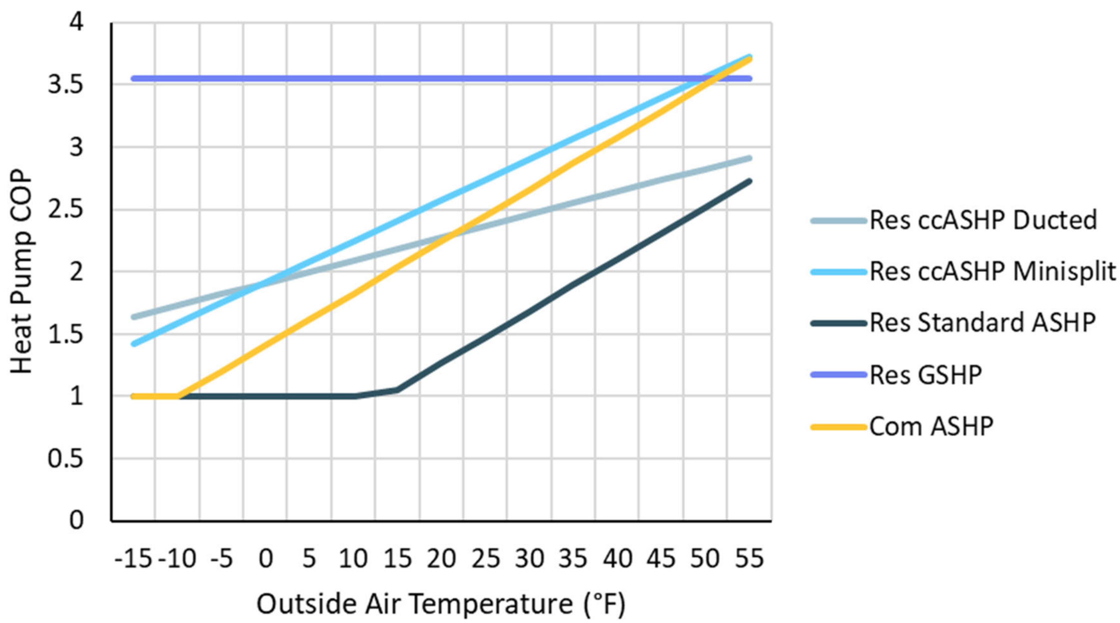


Table 22 shows energy performance/impact results for HVAC BE measures for an example building type: Pre-1980s vintage single family home in Climate Zone 5B. This set of calculations was performed by E3 for combinations of building types, climate zones, and measures.

Table 22. Energy Impact Calculation for Pre-1980s Vintage Single Family Home in Climate Zone 5B for Select Measures

CZ 5B Pre-1980s SFH HVAC Measure	Increase in Electricity Consumption (kWh)	Decrease in Gas Consumption (th)	% Decrease in Gas Consumption	Annual Average Heating COP
High Performance CC-ASHP Minisplit, Full Load	6,501	727	100%	2.33
CC-ASHP Ducted w/ ER Backup, 10F Cutover Temp	7,800	727	100%	1.76
ASHP w/ ER Backup, sized to AC load	12,879	727	100%	1.06
Hybrid ASHP w/ Gas Backup, 20F Cutover Temp	8,130	586	81%	1.14
Hybrid ASHP w/ Gas Backup, sized to AC load	5,096	395	54%	1.00
Ground source Heat Pump	10,903	727	100%	1.95

Beyond HVAC system performance, these measures were paired with three combinations of shell measures. The following assumptions were included for the energy reduction impact of shell measures.

Shell measure impacts were by E3 modeled upstream of HVAC system sizing, and building energy consumption calculations.

Table 23. Energy Reduction Impact of Shell Measures

Measure	Assumed Reduction in Energy
Air Sealing + Attic Insulation	5%
Air Sealing + Attic and Wall Insulation	15%
Air Sealing + Attic and Wall Insulation, Windows	20%

Heat pump water heater energy impact data was derived from The Company's 2023 Demand Side Management Plan, as shown in Table 24.

Table 24. Water Heater Energy Impacts

Sector	Measure	Annual Electricity Savings (kWh)	Annual Gas Savings (Dth)
Single Family	Heat Pump Water Heater	-1,409	210
	Efficient Gas WH	0	52
Multi-Family Low-rise	Heat Pump Water Heater	-1,638	133
	Efficient Gas WH	0	33.3

The next step in developing candidate heat pump measures is to assign capital costs to each measure, to compare to a counterfactual measure. Capital costs were informed by two key data sources:

+ Total $/ton[16] was taken from the Technical Reference Manual of The Company's 2023 Demand Side Management and Beneficial Electrification Plan
+ Splits between $/unit fixed cost and $/ton capacity variable cost were informed by cost data from E3's 2019 study, Residential Building Electrification in California[17]

Data in the Company's Technical Reference Manual are reported in $/ton capacity, which means that total installed cost scales linearly with heat pump capacity. E3 modified this approach because, in our view, delineating data between fixed costs per unit and variable costs based on heat pump system capacity is critical to accurately model the cost implications of both hybrid systems and all-electric systems designed to cover more of the annual space heating needs via the heat pump. A significant portion of total installation cost is driven by line items like labor, electrical wiring work, and other on-site demolition/infrastructure work that have little dependence on system capacity. In this framework, for example, the total installed cost of a 5-ton heat pump is not 66% more than a 3-ton system with the same form factor. E3 assumed that a new electrical circuit would be required in buildings without air conditioning along with all buildings with pre-1980s vintages; this cost does not cover panel upgrade costs or costs of upgrading other secondary electrical distribution infrastructure.

[16] In this context $/ton_capacity refers to dollars per ton of heating capacity. This should not be confused with $/ton_CO2 – the cost of abating CO2 emissions – which is a metric used in other parts of this report

[17] Energy and Environmental Economics, Inc, 2019. Residential Building Electrification in California
E3_Residential_Building_Electrification_in_California_April_2019.pdf (ethree.com)

To merge the two datasets together E3 developed a linear cost equation for fixed costs and variable cost based on data from E3's Residential Building Electrification in California study. To align with The Company's TRM, E3 applied a scalar such that the results of the linear equation equaled total project cost from TRM data at a typical heat pump size (ex. 5 tons for a residential system).

Table 25. Assumed HVAC System Costs for Retrofit Applications (2023$)

Building Type	Tech	HP/AC Equipment Fixed Cost	HP/AC Equipment Variable Cost	Furnace Fixed Cost	Furnace Variable Cost	Labor	Misc	Electrical Circuit Cost (pre-1980s vintages)
		$/unit	$/ton (HVAC)	$/unit	$/ton (HVAC)	$/unit	$/unit	$/unit
Single Family	Gas Furnace + DX cooling	$502	$389	$1,212	$182	$5,027	$735	$0
Multifamily Low-rise	Gas Furnace + DX cooling	$0	$659	$1,212	$182	$3,910	$2,058	$0
Small Office	Gas Furnace + DX cooling	$0	$265	$0	$0	$21,168	$3,675	$0
Retail	Gas Furnace + DX cooling	$0	$96	$0	$0	$19,757	$5,145	$0
School	Gas Furnace + DX cooling	$0	$265	$0	$0	$21,168	$3,675	$0
Single Family	CC-ASHP Ducted - ER Backup	$1,933	$939	$0	$0	$6,145	$1,029	$3,557
	CC-ASHP Minisplit	$14,418	$939	$0	$0	$6,145	$1,029	$3,557
	ASHP - ER Backup	$3,995	$144	$0	$0	$6,145	$1,029	$3,557
	ASHP - Gas Backup	$2,996	$144	$1,212	$182	$6,145	$1,029	$0
	GSHP	$7,526	$2,452	$0	$0	$11,541	$1,029	$3,557

Building Type	Tech	HP/AC Equipment Fixed Cost	HP/AC Equipment Variable Cost	Furnace Fixed Cost	Furnace Variable Cost	Labor	Misc	Electrical Circuit Cost (pre-1980s vintages)
		$/unit	$/ton (HVAC)	$/unit	$/ton (HVAC)	$/unit	$/unit	$/unit
Multifamily Low-rise	CC-ASHP Ducted - ER Backup	$916	$939	$0	$0	$5,027	$2,352	$583
	CC-ASHP Minisplit	$6,830	$939	$0	$0	$5,027	$2,352	$583
	ASHP - ER Backup	$1,046	$480	$0	$0	$5,027	$2,352	$583
	ASHP - Gas Backup	$1,081	$480	$1,212	$182	$5,027	$2,352	$0
Small Office	RTU - ASHP - ER Backup	$12,715	$631	$0	$0	$24,696	$5,145	$14,406
	ASHP - ER Backup	$17,018	$581	$0	$0	$24,696	$5,145	$14,406
	ASHP - Gas Backup	$13,614	$581	$0	$0	$24,696	$5,145	$0
Retail	RTU - ASHP - ER Backup	$70,705	$713	$0	$0	$22,579	$8,085	$24,990
School	ASHP - ER Backup	$17,018	$581	$0	$0	$24,696	$5,145	$14,406

Table 26. Assumed HVAC System Costs in New Construction Applications (2023$)

Building Type	Technology	Gas Line Cost $/unit	HP/AC Equipment Fixed Cost $/unit	HP/AC Equipment Variable Cost $/ton (HVAC)	Furnace Fixed Cost $/unit	Furnace Variable Cost $/ton (HVAC)	Labor $/unit	Misc $/unit	Add'l Elec Circuit Cost $/unit
Single Family	Gas Furnace + DX cooling	$2,440	$502	$389	$1,212	$182	$3,357	$9,555	$0
Multifamily Low-rise	Gas Furnace + DX cooling	$7,350	$0	$659	$1,212	$182	$1,794	$4,275	$0
Small Office	Gas Furnace + DX cooling		$0	$265	$0	$0	$14,125	$81,229	$0
Retail	Gas Furnace + DX cooling		$0	$96	$0	$0	$16,948	$82,699	$0
School	Gas Furnace + DX cooling		$0	$265	$0	$0	$14,125	$81,229	$0
Single Family	CC-ASHP Ducted - ER Backup		$1,933	$939	$0	$0	$4,463	$0	$0
	CC-ASHP Minisplit		$14,418	$939	$0	$0	$4,463	$0	$0
	ASHP - ER Backup		$3,995	$144	$0	$0	$4,463	$0	$0
	ASHP - Gas Backup	$2,440	$2,996	$144	$1,212	$182	$4,463	$9,555	$0
	GSHP		$7,526	$2,452	$0	$0	$9,859	$0	$0
Multifamily Low-rise	CC-ASHP Ducted - ER Backup		$610	$939	$0	$0	$2,911	$1,323	$0
	CC-ASHP Minisplit		$4,553	$939	$0	$0	$2,911	$1,323	$0
	ASHP - ER Backup		$1,046	$480	$0	$0	$2,911	$1,323	$0
	ASHP - Gas Backup	$7,350	$1,046	$480	$1,212	$182	$2,911	$4,275	$0
Small Office	RTU - ASHP - ER Backup		$12,715	$631	$0	$0	$17,640	$0	$0
	ASHP - ER Backup		$17,018	$581	$0	$0	$17,640	$0	$0
	ASHP - Gas Backup		$13,614	$581	$0	$0	$17,640	$30,870	$0
Retail	RTU - ASHP - ER Backup		$70,705	$713	$0	$0	$19,757	$1,470	$0

Building Type	Technology	Gas Line Cost $/unit	HP/AC Equipment Fixed Cost $/unit	HP/AC Equipment Variable Cost $/ton (HVAC)	Furnace Fixed Cost $/unit	Furnace Variable Cost $/ton (HVAC)	Labor $/unit	Misc $/unit	Add'l Elec Circuit Cost $/unit
School	ASHP - ER Backup		$17,018	$581	$0	$0	$17,640	$0	$0

These costs are applied as seen in Table 27. The tonnage included in this table is representative – each site has a tonnage calculated for it. In retrofit (RF) applications, heat pumps typically have a cost premium over counterfactual. In new construction (NC), counterfactual systems, which include a gas furnace and an air conditioning unit have a cost premium over heat pumps.

Table 27. Example Total System Costs, based on above cost assumptions

Note: System sizes in this chart are meant to be representative to demonstrate methodology and may not reflect actual system sizing determined in the model.

Sector		System	HP/AC (tons)	Furnace (tons)	Intercon-nection Cost	Misc. Cost	HP/AC Cost	Furnace Cost	Labor Cost	New Circuit (Pre-1980) Cost	Total Cost
RF	SF	ccASHP	5.00	-	$0	$1,029	$6,630	$0	$6,145	$3,557	$17,361
		ASHP	4.00	-	$0	$1,029	$4,572	$0	$6,145	$3,557	$15,303
		DFHP	3.00	4.00	$0	$1,029	$3,429	$2,352	$6,145		$12,955
		CF	4.00	4.10	$0	$735	$2,060	$2,411	$5,027		$10,233
	LR MF	ccASHP	3.50	-	$0	$2,352	$4,203	$0	$5,027	$645	$12,228
		ASHP	1.58	-	$0	$2,352	$1,805	$0	$5,027	$645	$9,829
		DFHP	1.63	1.63	$0	$2,352	$1,865	$959	$5,027		$10,204
		CF	1.50	1.27	$0	$2,058	$773	$748	$3,910		$7,489
NC	SF	ccASHP	5.00	-	$0	$0	$6,630	$0	$4,463		$11,093
		ASHP	4.00	-	$0	$0	$4,572	$0	$4,463		$9,035
		DFHP	3.00	4.00	$7,350	$2,205	$3,429	$2,352	$4,463		$19,799
		CF	4.00	4.10	$7,350	$2,205	$2,060	$2,411	$3,357		$17,383
	LR MF	ccASHP	1.58	-	$0	$1,323	$2,094	$0	$2,911		$6,327
		ASHP	1.58	-	$0	$1,323	$1,805	$0	$2,911		$6,038
		DFHP	1.58	1.58	$2,440	$1,835	$1,805	$928	$2,911		$9,919
		CF	1.50	1.27	$2,440	$1,835	$773	$748	$1,794		$7,590

Table 28 displays the assumed per-unit water heater costs for heat pump water heaters, efficient gas water heaters (as would be eligible for an Energy Efficiency program), and counterfactual standard gas water heaters.

Table 28. Assumed Water Heater Costs

Building Type	Equipment	2023$/unit
Single Family	Heat Pump Water Heater	$4,124
	Efficient Gas WH	$1,091
	Standard Gas WH	$1,014
Multifamily Low-rise	Heat Pump Water Heater	$4,124
	Efficient Gas WH	$1,091
	Standard Gas WH	$1,014

Assumptions for Effective Useful Life (EUL) are taken from the Technical Reference Manual of The Company's 2023 Demand Side Management and Beneficial Electrification Plan[18].

Table 29. Assumed Effective Useful Life for HVAC and Water Heater Measures

Measure	Assumed EUL (yrs)
HVAC (Furnace, Heat Pump)	18
Water Heater	12

Table 30 shows assumed costs per square foot for building shell measures.

Table 30. Assumed Shell Measure Costs

Measure	EUL (yrs)	Assumed Cost ($/sqft)
Air Sealing + Attic Insulation	10	$2.76
Air Sealing + Attic and Wall Insulation	20	$4.31
Air Sealing + Attic and Wall Insulation, Windows	20	$7.17

The costs described above are augmented by incentives and tax credits offered through the Inflation Reduction Act, displayed in Table 31. General consumers are eligible for tax credits under the Inflation Reduction Act. These offset the incremental capital cost for modeled measures. E3 assumed that these incentives could be stacked across different measure which, in practice, would mean that an individual customer would need to electrify one appliance per year given annual limitation on IRA incentives.

Based on state and population-level scaling, E3 assumes that $10.5 Million in annual High-Efficiency Electric Home Rebate Act (HEEHRA) rebate funding will be allocated to the Company's service territory.

[18] The Company. 2023 Demand Side Management and Beneficial Electrification Plan: 22A-0315EG_2023 DSM & BE Plan.pdf (xcelenergy.com)

Table 31. Inflation Reduction Act Tax Credits

Measure	IRA Code	Incentive	
Res ASHP or CCASHP	25C	30% of project cost, capped at $2,000	Tax Credit
Res HPWH	25C	30% of project cost, capped at $2,000	Tax Credit
Res Shell upgrades	25C	30% of project cost, capped at $1,200	Tax Credit
Res SFH, New Construction (All)	45L	$2500/unit	Tax Credit
Res MFH, New Construction (All)	45L	$500/unit	Tax Credit
Comm Retrofit (All)	179D	$0.50/sqft	Tax Credit
Low/Moderate Income Res ASHP or CCASHP	HEEHRA	$8,000/unit, capped at 50% of Capex for moderate income	Tax Rebate
Low/Moderate Income Res HPWH	HEEHRA	$1,750/unit, capped at 50% of Capex for moderate income	Tax Rebate
Low/Moderate Income Res Shell	HEEHRA	$1,800/unit, capped at 50% of Capex for moderate income	Tax Rebate

Assumed program incentives, which flow into the total program cost, are structured to be consistent with incentives in The Company's existing DSM programs. Program incentives are a function of first year gas savings, measure type, and market segment. Hybrid heat pump measure incentives are initially set at $2.56/therm and all-electric measure incentives are set at $3.20/therm. The difference in costs between these incentives are meant to reflect the higher level of complexity and upfront capital cost associated with an all-electric retrofit relative to a hybrid project.

In addition to these base levels, at the direction of the Company, E3's model assumes that electrification incentives scale as a function of sales share. This approach is intended to reflect that achieving transformative levels of heat pump adoption will require higher incentives to encourage broad, rather than just early adopter, electrification. For example, based on the chart below, to reach 60% sales share for all electric heat pumps, the base incentive would need to be multiplied by a factor of two. E3 worked in partnership with the Company to develop these incentive scalars.

Table 32. Program Incentives

Rebate / Gross Therm Savings					Incentive Scalar Tranches by Market Penetration					
Sector	**Measure Type**	**Construction**	**Fuel Group**	**Base Incentive**	**0%**	**20%**	**40%**	**60%**	**80%**	**100%**
Residential	Efficient Gas WH	New Construction		$3.97	1.00	1.00	1.00	1.00	1.00	1.00
Residential	HP + Shell	New Construction	Electric	$3.20	1.00	1.50	1.50	2.00	4.00	6.00
Residential	HP + Shell	New Construction	Hybrid	$2.56	1.00	1.20	1.20	1.40	1.70	2.00
Residential	HPWH	New Construction		$3.97	1.00	1.00	1.00	1.00	1.00	1.00
Residential	Improved HVAC + Shell	New Construction		$3.97	1.00	1.00	1.00	1.00	1.00	1.00

Rebate / Gross Therm Savings					Incentive Scalar Tranches by Market Penetration					
Sector	Measure Type	Construction	Fuel Group	Base Incentive	0%	20%	40%	60%	80%	100%
Residential	Other	New Construction		$1.12	1.00	1.00	1.00	1.00	1.00	1.00
Residential	Showerhead	New Construction		$0.35	1.00	1.00	1.00	1.00	1.00	1.00
Residential	Efficient Gas WH	Existing		$2.56	1.00	1.00	1.00	1.00	1.00	1.00
Residential	HP + Shell	Existing	Electric	$3.20	1.00	1.50	1.50	2.00	4.00	6.00
Residential	HP + Shell	Existing	Hybrid	$2.56	1.00	1.20	1.20	1.40	1.70	2.00
Residential	HPWH	Existing		$2.56	1.00	1.00	1.00	1.00	1.00	1.00
Residential	Improved HVAC	Existing		$2.56	1.00	1.00	1.00	1.00	1.00	1.00
Residential	Improved HVAC + Shell	Existing		$2.56	1.00	1.00	1.00	1.00	1.00	1.00
Residential	Other	Existing		$1.12	1.00	1.00	1.00	1.00	1.00	1.00
Residential	Shell only	Existing		$1.92	1.00	1.00	1.00	1.00	1.00	1.00
Residential	Showerhead	Existing		$0.35	1.00	1.00	1.00	1.00	1.00	1.00
Commercial	Efficient Gas WH	New Construction		$0.86	1.00	1.00	1.00	1.00	1.00	1.00
Commercial	HP only	New Construction	Electric	$3.20	1.00	1.50	1.50	2.00	4.00	6.00
Commercial	HP only	New Construction	Hybrid	$2.56	1.00	1.20	1.20	1.40	1.70	2.00
Commercial	HPWH	New Construction		$0.86	1.00	1.00	1.00	1.00	1.00	1.00
Commercial	Improved HVAC	New Construction		$0.86	1.00	1.00	1.00	1.00	1.00	1.00
Commercial	Efficient Gas WH	Existing		$0.94	1.00	1.00	1.00	1.00	1.00	1.00
Commercial	HP only	Existing	Electric	$3.20	1.00	1.50	1.50	2.00	4.00	6.00
Commercial	HP only	Existing	Hybrid	$2.56	1.00	1.20	1.20	1.40	1.70	2.00
Commercial	HPWH	Existing		$0.94	1.00	1.00	1.00	1.00	1.00	1.00
Commercial	Improved HVAC	Existing		$0.94	1.00	1.00	1.00	1.00	1.00	1.00

In addition to incentives, administrative costs on a per participant basis are included in total program costs, per Table 33.

Table 33. Administrative Costs ($/unit)

Sector	Measure Type	Retrofit	New Construction
Residential	HPWH	$14.05	$12.71
	Efficient Gas WH	$14.05	$12.71

	Improved HVAC	$14.05	$12.71
	Improved HVAC + Shell	$14.05	$12.71
	HP only	$14.05	$12.71
	CF_Furnace_DX	$0.00	$0.00
	Showerhead	$3.03	$3.03
	Other	$44.94	$44.94
	Shell only	$42.19	$0.00
	HP + Shell	$12.71	$12.71
Commercial	HPWH	$2,096.00	$1,565.32
	Efficient Gas WH	$2,096.00	$1,565.32
	Improved HVAC	$2,096.00	$1,565.32
	HP only	$2,096.00	$1,565.32
	CF_Furnace_DX	$0.00	$0.00

Assumed rebates were escalated at the rates shown in Table 34.

Table 34. Rebate Escalation Rates

Rebate Escalation Rate	Escalation Rate – Nominal	Escalation Rate – Real
Commercial	7.5%	5.4%
Residential	5.8%	3.7%

Next, E3 leveraged modeled hourly energy impacts to calculate hourly avoided costs and hourly emissions, for each measure. To calculate avoided costs, avoided costs were provided by the Company, consistent with the 2023 Demand Side Management and Beneficial Electrification plan, as shown in Table 35.

Table 35. Avoided Cost Data Sources

Cost Component	Data Source
Avoided Energy Costs	Hourly marginal energy price forecast
Avoided Losses	6.38% from DSM Plan
Avoided Distribution Costs	$3.50/kW-mo applied to gross load peak
Avoided Generation	7.89 $2023/kW-mo from Company 2021 ERP for CT applied to net load
Avoided Ancillary Services	$0.6882 $/kW-mo at 55% load factor from OATT
Avoided Transmission Costs	$0/kW-mo

These avoided cost streams were projected over the lifetime of each measure, with the financial assumptions outlined in Table 36. Effective Useful Life data and discount rate input assumptions were taken from the Company's 2023 Demand Side Management and Beneficial Electrification plan.

Table 36. Financial Assumptions

Metric	Value
Inflation Rate	2%

Metric	Value
Nominal WACC	6.7%
Real WACC	4.6%

Next, lifetime emissions were calculated using hourly grid emissions factors supplied by the Company, consistent with hourly wholesale electricity prices. Natural gas consumption was converted to emissions based on the carbon intensity of combusting natural gas.

Table 37. Sources of Emissions Factors

Emissions Component	Data Source
Electric Emissions	Hourly marginal emissions consistent with hourly electricity prices
Natural Gas Carbon Content	0.0528 tonnes/MMBtu[19]

In order to calculate lifecycle $/ton_CO2 of emissions abatement, annualized lifecycle TRC (in dollars) is divided by annualized lifecycle emissions reductions. Table 38, below shows the components of the $/ton calculation for select measures, including annualized capex, federal incentives, and annualized electric and gas system avoided costs, along with annual emissions reductions. In this example, a hybrid solution with a heat pump large enough to cover heating loads at 20F is the most cost effective measure on a $/ton basis, although other configurations and cold climate systems are not significantly more expensive.

[19] EIA (https://www.eia.gov/environment/emissions/co2_vol_mass.php)

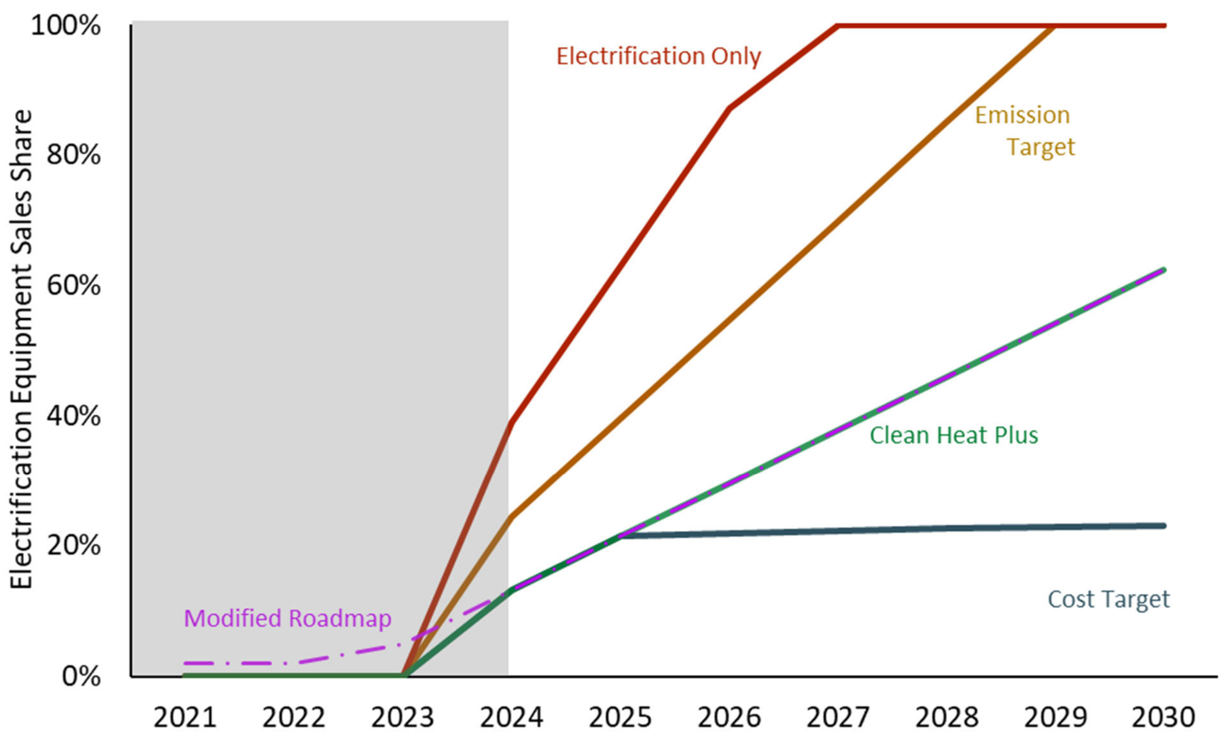
Table 38. $/tCO2 Calculation for select candidate BE measures for the Pre-1980s Single Family home prototypical building in Climate Zone 5B

CZ 5B Pre-1980s SFH HVAC Measure	System Size (tons)	CF Capex	Measure Capex	Incremental Capex	Annualized Capex	IRA Incentive	Annualized IRA Incentive	Annualized Avoided Costs	Annualized Total Resource Cost	Annual Emissions Reduced	$/tCO2 for Ranking
CC-ASHP Minisplit, Full Load	5	$7,967	$29,014	$21,047	$1,746	$2,000	$166	$35	$1,545	3.84	$402
CC-ASHP Ducted w/ ER Backup, 10F C/O Temp	3.5	$7,967	$15,378	$7,411	$615	$2,000	$166	$25	$448	3.84	$117
ASHP w/ ER Backup, sized to AC load	2.5	$7,967	$13,877	$5,910	$490	$2,000	$166	-$143	$468	3.84	$122
Hybrid ASHP w/ Gas Backup, 20F C/O Temp	3	$7,967	$11,374	$3,407	$283	$2,000	$166	-$73	$190	3.09	$61
Hybrid ASHP w/ Gas Backup, AC load	2.5	$7,967	$11,235	$3,268	$271	$2,000	$166	-$61	$166	2.09	$79
Ground source Heat Pump	2	$7,967	$27,419	$19,452	$1,613	$2,000	$166	-$70	$1,518	3.84	$395

As the last component of incorporating building modeling into this portfolio generation framework, annual BE adoption is limited based on a maximum share of annual sales, given an assumed adoption curve. Sales share represents the percentage of equipment sold in each that are heat pumps. This analysis assumes stock rollover is equal to 1/EUL for a given equipment category. For example, E3 assumed that space heating equipment, on average, has an 18 year lifespan, therefore in a given year, 1/18 or 5.6% of space heating *stock* is turned over. A 50% sales share for a given year would mean that 2.8% of space heating equipment stock is converted to heat pumps in that year.

While it is uncertain what level of adoption growth is achievable, this analysis uses the 2030 CO GHG Roadmap sales share target as a benchmark point. In most scenarios, starting from today's market share for heat pumps in Colorado, this analysis assumes a straight-line trajectory to the 2030 target sales share. For the Emissions Target, this analysis assumes a sales share trajectory that yields a Clean Heat compliant plan for 2030; this corresponds with achieving 100% sales share for heat pumps, starting 2028. The high electrification sensitivity, also assumes this adoption trajectory, reaching 100% sales share in 2028.

Figure 12. Single Family HVAC Sales Share by Scenario



Other DSM

Beyond building electrification, this analysis assumes impacts from embedded DSM and planned DSM. Embedded DSM refers to DSM plans that have already been approved and funded for future years, but have not yet taken place. Planned DSM refers to DSM plans that have been filed already, but as of the onset of this analysis, had not yet reached final approval. Emissions reductions from these plans count towards the Company meeting its Clean Heat targets, but do not count against its Clean Heat program cost cap, as the embedded DSM plans leverage a different funding mechanism. In general, this analysis assumes that this level of reductions will occur outside of the Clean Heat Plan; the emissions target presented in this report is the emissions target, after the impacts of these programs. To the extent that these reductions do not take place, the Company will need to factor that into its accounting for emissions reductions that it needs to achieve to meet Clean Heat Plan targets.

As there is some overlap in target customers between these DSM plans and the building electrification and additional DSM modeled in this analysis, it is assumed that 60% of the Planned Gas EE and BE measures and customers overlap with the measures and customers eligible for modeled BE/DSM measures. The extent of planned EE and BE do not change, so in effect, this limits the number of eligible customers that can implement a newly modeled BE or EE measure in the model. Table 39 shows the annual incremental reductions in gas consumption for a given year. As DSM measures have an assumed measure life, the impacts from each year persist into future years; the total impact of these programs in 2030, for example, would be the sum of the incremental impact from all of the preceding years in this table.

Table 39. Embedded and Planned DSM achieved in each year, as assumed in this analysis (DTh/yr)

	2023	2024	2025	2026	2027	2028	2029	2030
Embedded DSM	800,000	800,000	800,000	800,000	800,000	800,000	800,000	800,000
Planned Gas EE	*98,487*	*150,000*	*200,000*	*250,000*	*250,000*	*250,000*	*250,000*	*250,000*
Planned BE	*0*	*200,000*	*465,000*	*840,000*	*840,000*	*840,000*	*840,000*	*840,000*

Beyond embedded DSM, the portfolio analysis model allows additional gas energy efficiency measures beyond existing plans. This analysis assumes energy and cost data for these measures from the Company's 2023 Demand Side Management and Beneficial Electrification plan, shown in the tables below. Shell measures independent of HVAC system, along with efficient gas water heaters and efficient gas furnaces are included in this category, with cost and energy impact data listed in the section above.

Table 40. Additional Residential Gas EE Assumptions

Measure	Gas Savings (Dth)/yr/unit	Cost (2023$/unit)
Energy Star Gas Dryer	3.8	$120
Showerhead	1.2	$8

Recovered Methane

To qualify as a Clean Heat Resource, recovered methane projects must be located in Colorado and meet a recovered methane protocol approved by the Air Quality Control Commission. Recovered methane resource types with an approved protocol include methane recovered from livestock manure management systems, methane derived from municipal solid waste (landfills) and wastewater treatment (agro-industrial or domestic), and methane from coal mines. The following protocols include the emissions accounting methodology for each type of project:

+ Livestock manure management systems: California Air Resources Board (CARB) Compliance Offset Protocol Livestock Projects
+ Methane from municipal solid waste: American Carbon Registry (ACR) Landfill Gas Destruction and Beneficial Use Projects
+ Methane from agro-industrial wastewater treatment: Climate Action Reserve (CAR) Organic Waste Digestion Project Protocol
+ Methane from domestic wastewater treatment: division-developed protocol that relies on calculation methodologies and requirements described in Subpart NN of 40 Code of Federal Regulations (CFR) Part 98
+ Coal mine methane: American Carbon Registry (ACR) Capturing and Destroying Methane from U.S. Coal and Trona Mines

The recovered methane supply curves developed by E3 include both specific project proposals identified by The Company as well as generic project archetypes. These project types include landfill gas, livestock, coal mine methane, agro-industrial wastewater treatment, and gasification. E3 evaluated the emissions reductions for the gasification project using the CAR Organic Waste Digestion Project Protocol with adjustments in the feedstock type and assumptions determining the methane generation potential. Under the recovered methane protocols, E3 found a wide variation in the GHG emissions savings from recovered methane projects, in part because the outcomes of the protocols depend heavily on existing methane management practices and do not account for biogenic emissions reductions.

Some of the recovered methane projects include a range of expected volumes and/or costs. To reflect these ranges, the model includes both a conservative and optimistic outlook for recovered methane, where the optimistic outlook results in lower marginal abatement costs and higher avoided emissions from recovered methane. The optimistic and conservative supply curves in 2030 are shown in Figure 13. Recovered methane gross costs range from $12-62/MMBtu in the optimistic outlook and $18-62/MMBtu in the conservative outlook.

Figure 13. Optimistic and Conservative Recovered Methane Supply Curves

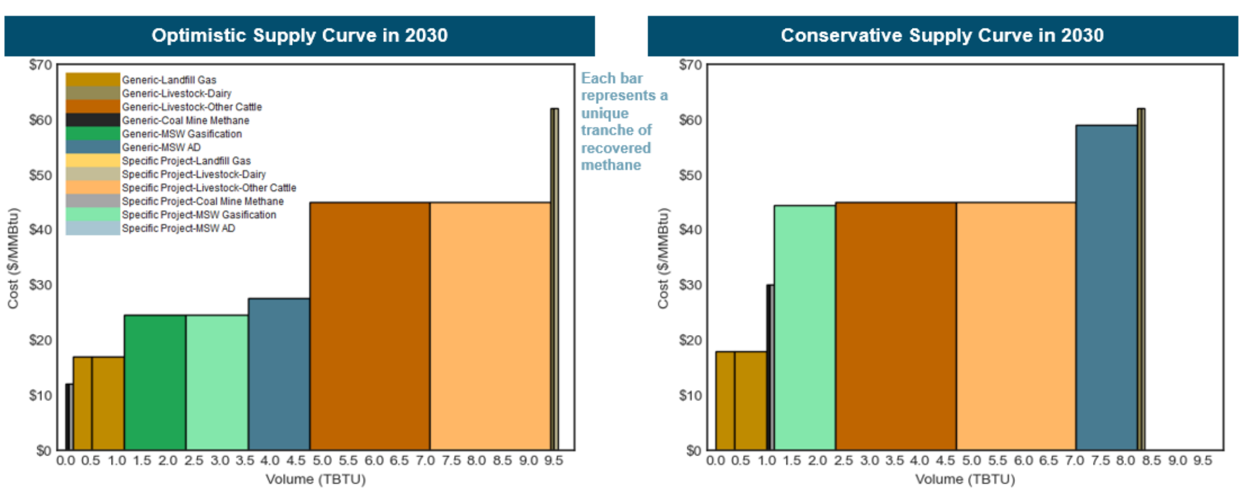
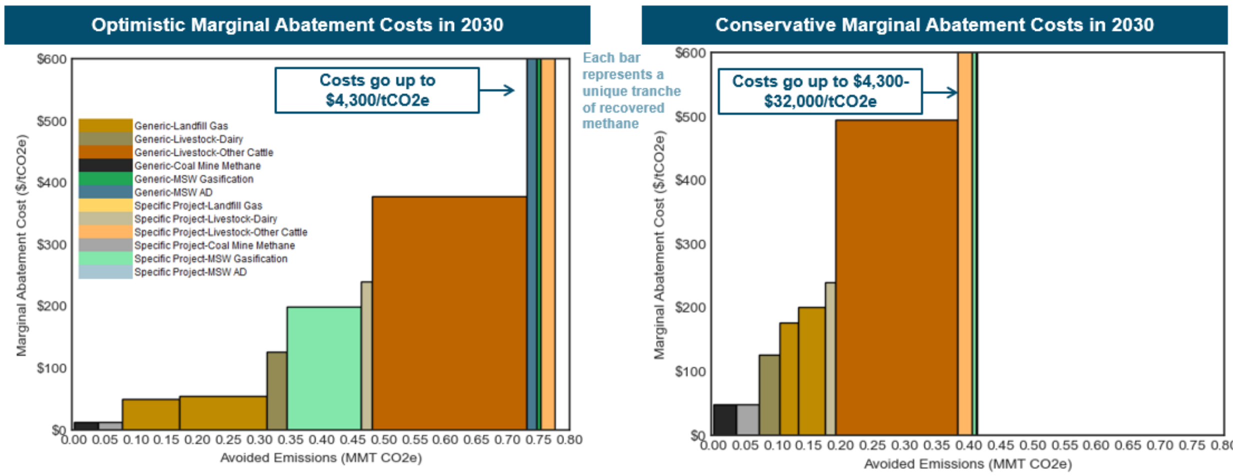


Figure 14 shows the optimistic and conservative marginal abatement costs in 2030. In the optimistic and conservative outlooks, recovered methane could mitigate up to 0.78 MMT CO2e and 0.41 MMT CO2e, respectively.

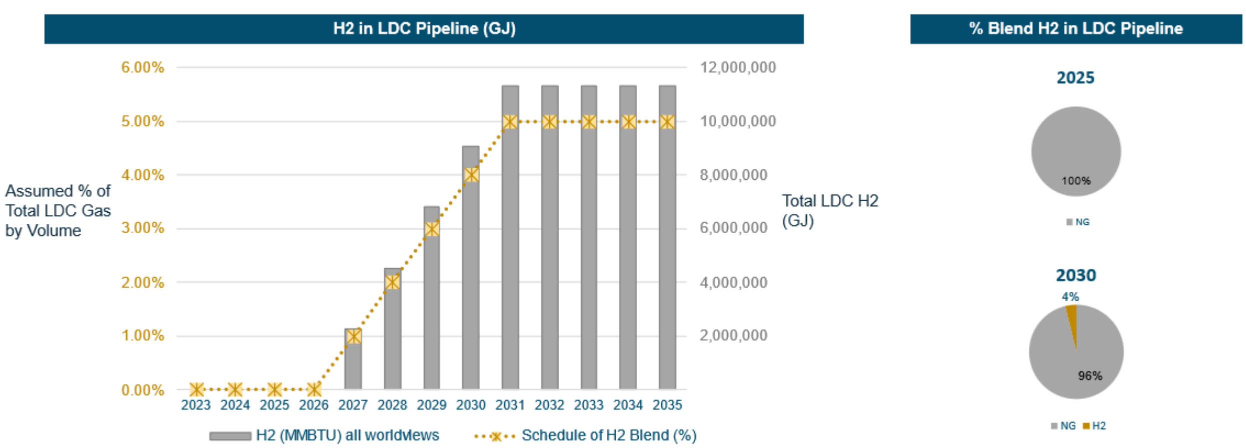
Figure 14. Optimistic and Conservative Recovered Methane Marginal Abatement Costs



Hydrogen

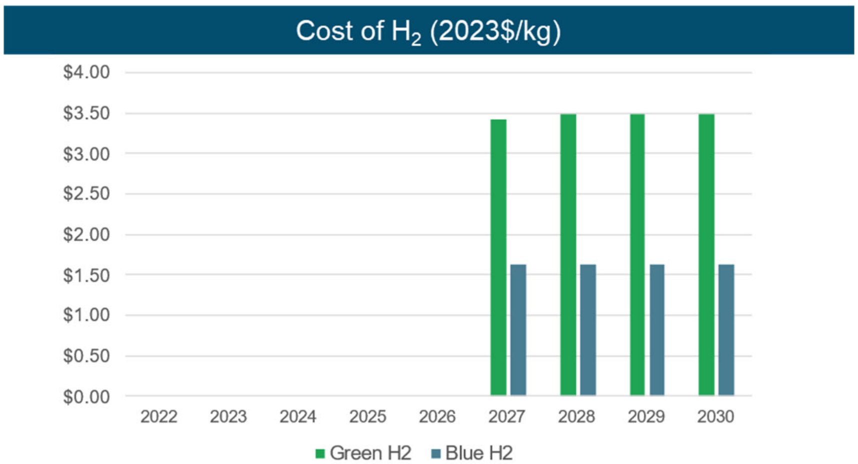
The hydrogen blend limit for the Company's entire system is assumed to be 1% by volume starting in 2027 and ramps up linearly to 4% by volume in 2030. The hydrogen blend in the Company's LDC pipeline over time is shown in Figure 15. The blend volume is based on the total volume for both retail and transport customers. The upper bound for the hydrogen resource in the model was set from assumed blend limits on the LDC pipeline by energy, assuming no fuel switching or efficiency beyond The Company's throughput projections. The maximum blend volume decreases within E3's modeling framework as demand-side measures further reduce the Company's geologic gas throughput.

Figure 15. Hydrogen Blend in LDC Pipeline



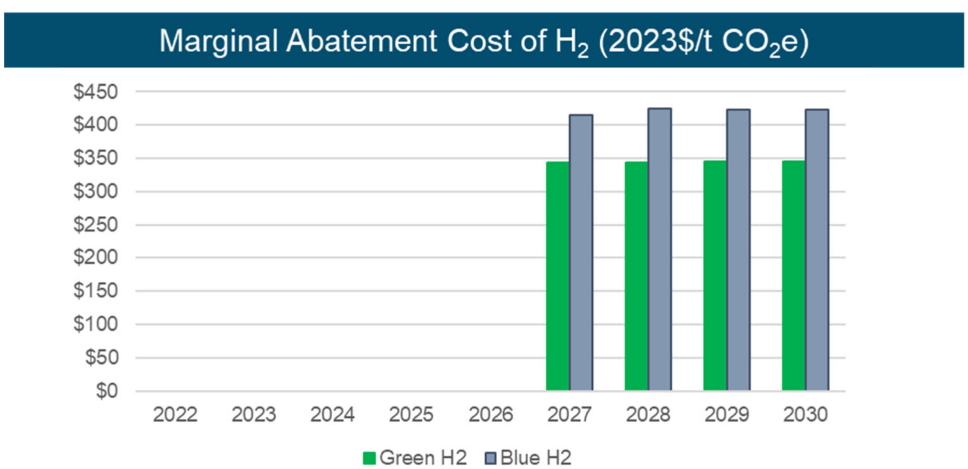
The hydrogen resource includes both blue and green hydrogen. Figure 16 shows the estimated costs for blue and green hydrogen provided by the Company. Green hydrogen costs include electrolyzer costs and dedicated pipeline costs. E3 also completed an independent analysis of costs for benchmarking. For blue hydrogen, E3 estimated costs using capital, fixed, and variable costs from Case 3 of NETL 2022 Comparison of Commercial, State-of-the-Art, Fossil-Based Hydrogen Production Technologies. Additional costs include pipeline costs and feedstock costs. For green hydrogen, E3 benchmarked the Company's costs against green hydrogen costs with various sensitivities for wind resource capacity factors and electrolyzer types.

Figure 16. Blue and Green Hydrogen Costs



For blue hydrogen, E3 used an estimated emissions factor of 3.80 kg CO2/kg H2, accounting for electricity use and fugitive emissions from carbon capture and sequestration. For green hydrogen, E3 used a lifecycle emissions factor of 0 kg CO2/kg H2. The resulting marginal abatement costs for green and blue hydrogen are shown in Figure 17.

Figure 17. Hydrogen Marginal Abatement Costs



Certified Natural Gas

The Company provided assumptions for CNG volumes, baseline leakage rates, CNG leakage rates, and cost premiums. CNG blending by volume starts at 25% in 2025 and increases to 100% in 2030. The counterfactual leakage rate assumption is 1.11% in 2025 and decreases to 0.69% in 2030[20]. The CNG leakage rate assumption is 0.23% in 2025 and decreases to 0.21% in 2030. The model includes a conservative and optimistic outlook for CNG based on a cost premium range of $0.05-0.10/MMBtu. Table 41 shows the CNG price premiums, volumes, and marginal abatement cost assumptions.

Table 41. Certified Natural Gas Costs, Volumes, and Marginal Abatement Costs

Outlook	Year	Price Premium ($/MMBtu)	Incremental Volume (MMBtu)	Cumulative Volume (TBTU)	Avoided Emissions (tCO2e)	Marginal Abatement Cost ($/tCO2e)
Conservative	2025	$0.10	20,000	0.02	87	$33.36
	2026	$0.10	35,715,961	36	133,652	$36.16
	2027	$0.10	35,432,952	71	111,091	$38.41
	2028	$0.10	29,252,336	100	84,317	$39.74
	2029	$0.10	28,065,553	128	75,219	$40.68
	2030	$0.10	16,722,337	145	40,590	$41.24
Optimistic	2025	$0.05	20,000	0.02	87	$16.68
	2026	$0.05	35,715,961	36	133,652	$18.08
	2027	$0.05	35,432,952	71	111,091	$19.20
	2028	$0.05	29,252,336	100	84,317	$19.87
	2029	$0.05	28,065,553	128	75,219	$20.34
	2030	$0.05	16,722,337	145	40,590	$20.62

Offsets

Offsets projects include GHG reductions from project types including avoided grassland conversion, HFC reclaim, and improved forest management (IFM). The model uses project volumes and cost estimates provided by the Company, with both volumes and costs increasing over time. Offsets projects become available in 2024 and ramp up in volume through 2027, at which point the volumes remain constant through 2030. The model includes both a conservative and optimistic outlook to reflect a range of expected project volumes. The optimistic and conservative marginal abatement costs are shown in Figure 18. Under the optimistic outlook, offset volumes reach 0.365 MMT CO2e each year. Table 42 shows the avoided emissions and marginal abatement costs in 2024 and 2030.

[20] Note that the counterfactual and certified gas upstream emissions factors are reduced over time by policies such as CDPHE Regulation Number 7.

Figure 18. Offsets Marginal Abatement Costs

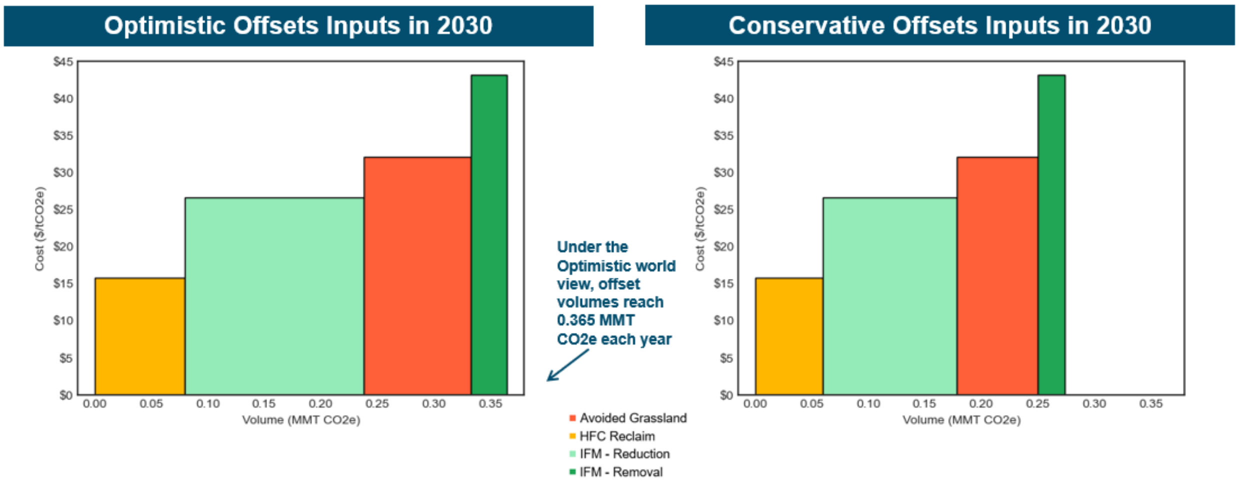


Table 42. Offsets Avoided Emissions and Marginal Abatement Costs

Feedstock Type	Outlook	Avoided Emissions (tCO2e)		Marginal Abatement Cost ($/tCO2e)	
		2024	2030	2024	2030
Avoided Grassland Conversion	Conservative	30,000	71,413	20.50	32.07
HFC Reclaim	Conservative	25,000	59,511	11.81	15.83
IFM - Reduction	Conservative	50,000	119,022	22.00	26.57
IFM - Removal	Conservative	10,000	23,804	33.00	43.12
Avoided Grassland Conversion	Optimistic	30,000	95,217	20.50	32.07
HFC Reclaim	Optimistic	25,000	79,348	11.81	15.83
IFM - Reduction	Optimistic	50,000	158,696	22.00	26.57
IFM - Removal	Optimistic	10,000	31,739	33.00	43.12

Scenarios

E3 modeled Clean Heat Portfolios across four core scenarios. In addition to those scenarios, E3 also conducted sensitivity analyses, which are discussed below. The core scenarios include:

- **Cost Target**: This scenario includes a least-cost portfolio of Clean Heat Resources, subject to the Clean Heat cost cap of 2.5% of annual gas bills for all full-service customers as a whole. The scenario does not necessarily meet the emissions targets.
- **Emissions Target**: This scenario includes least-cost portfolio of enumerated resources, subject to meeting the 2025 and 2030 emissions reductions targets. The scenario does not meet the cost cap.
- **Clean Heat Plus**: This scenario achieves the 2025 and 2030 emissions reduction targets using both enumerated and non-enumerated resources, but does not meet the cost cap.

+ **Electrification Only**: This scenario relies on existing DSM and electrification, not including hybrid heat pumps, to achieve the Clean Heat targets. The scenario is constrained to achieve the emissions targets, provided that sufficient electrification resources are available.

Key scenario parameters are summarized in Table 43.

Table 43. Scenario Parameters

Scenario	Cost Target Enforced	Emissions Target Enforced	Additional Resources Allowed
Cost Target	X		
Emissions Target		X	
Clean Heat Plus		X	X
High Electrification		X	

Portfolio Results

Cost Target Scenario Results

To achieve emissions reductions, the Cost Target Scenario adopts measures and resources displayed in Table 44 through Table 48, below.

Table 44. Buildings Adopting Full HVAC Electrification (units/year) - Cost Target Scenario

Measure	2024	2025	2026	2027	2028	2029	2030	Total	% of Stock Electrified
Residential Single Family	3,583	5,807	7,252	9,595	11,676	11,013	15,285	64,212	5.37%
Residential Multi Family	854	1,188	1,586	2,056	2,505	2,954	3,403	14,547	7.87%
Commercial	47	67	21	27	33	0	4	200	1.91%

Table 45. Buildings Adopting Hybrid HVAC Electrification (units/year) - Cost Target Scenario

Measure	2024	2025	2026	2027	2028	2029	2030	Total	% of Stock Electrified
Residential Single Family	5,178	8,392	0	1,176	3,398	0	0	18,145	1.52%
Residential Multi Family	538	507	0	0	0	0	0	1,045	0.56%
Commercial	30	50	1	2	2	2	3	89	0.86%

Table 46. Buildings Adopting Heat Pump Water Heaters (units/year) - Cost Target Scenario

Measure	2024	2025	2026	2027	2028	2029	2030	Total	% of Stock Electrified
Residential	15,908	0	0	0	0	0	0	15,908	1.15%
Commercial	75	0	0	0	0	0	0	75	0.72%

Table 47. Incremental Gas DSM (Dth/year) - Cost Target Scenario

Measure	2024	2025	2026	2027	2028	2029	2030
Incremental Gas DSM	755,149	633,856	588,313	570,506	158,453	141,240	121,835

Table 48. Supply Side Resource Procurement (Dth/year) - Cost Target Scenario

Measure	2024	2025	2026	2027	2028	2029	2030
Certified Natural Gas	0	0	0	0	0	0	0
Recovered Methane	0	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0	0

To procure these resource, annual program costs for the Cost Target Scenario are displayed in Table 49 below.

Table 49. Annual Program Costs ($ Millions) - Cost Target Scenario

Measure	2024	2025	2026	2027	2028	2029	2030	Portfolio Average
Additional Gas DSM	16.1	13.0	12.8	13.6	1.9	1.9	1.9	8.7
Electrification	27.8	30.9	28.5	28.4	39.8	38.7	38.1	33.2
Certified Natural Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Offsets	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Recovered Methane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	43.9	43.9	41.3	41.9	41.8	40.6	40.0	41.9

In the Cost Target Scenario, the portfolio of resources creates the incremental annual abatement displayed in Table 50. Table 51 has the total annual abatement, which accounts for the persisting impacts from Building Electrification and Demand Side Management Measures, and represents the progress towards the Clean Heat Plan emissions reductions.

Table 50. Annual Incremental Abatement (tCO2/year) - Cost Target Scenario

Measure	2024	2025	2026	2027	2028	2029	2030
Additional Gas DSM	40,076	33,639	31,222	30,277	8,409	7,496	6,466
BE	49,584	52,895	28,756	41,756	58,133	33,993	48,244
CNG	0	0	0	0	0	0	0
Offsets	0	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0	0
Recovered Methane	0	0	0	0	0	0	0
Total	89,660	86,534	59,978	72,033	66,542	41,488	54,710

Table 51. Annual Total Abatement (tCO2/year) - Cost Target Scenario

Measure	2024	2025	2026	2027	2028	2029	2030
Additional Gas DSM	40,076	73,715	104,937	135,214	143,623	151,119	157,585
BE	49,584	102,478	131,235	172,990	231,123	265,116	313,360
CNG	0	0	0	0	0	0	0
Offsets	0	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0	0
Recovered Methane	0	0	0	0	0	0	0
Total	89,660	176,193	236,172	308,204	374,746	416,235	470,945

Resources procured in the Cost Target Scenario have impacts on gas throughput and retail gas sales, shown in Table 52

Table 52. Gas Throughput at Year End (Dekatherms/year) – Cost Target Scenario

Measure	2024	2025	2026	2027	2028	2029	2030
Certified Natural Gas	0	0	0	0	0	0	0
Recovered Methane	0	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0	0
Natural Gas	144,288,688	144,155,123	144,023,697	143,025,104	142,227,708	140,825,691	140,015,345
Electrification	951,660	1,953,411	2,498,015	3,288,811	4,389,764	5,033,540	5,947,219
Additional DSM	784,244	1,454,548	2,107,025	2,784,045	2,990,037	3,195,463	3,396,812

Emissions Target Scenario Results

To achieve emissions reductions, the Emissions Target Scenario adopts measures and resources displayed in Table 53 through Table 58, below.

Table 53. Buildings Adopting Full HVAC Electrification (units/year) - Emissions Target Scenario

Measure	2024	2025	2026	2027	2028	2029	2030	Total	% of Stock Electrified
Residential Single Family	6,629	10,743	14,858	18,972	23,087	27,179	27,179	128,645	10.75%
Residential Multi Family	1,580	2,580	3,581	4,582	5,583	6,256	6,256	30,418	16.45%
Commercial	88	149	210	272	333	356	356	1,763	16.89%

Table 54. Buildings Adopting Hybrid HVAC Electrification (units/years) - Emissions Target Scenario

Measure	2024	2025	2026	2027	2028	2029	2030	Total	% of Stock Electrified
Residential Single Family	9,580	15,526	21,472	27,419	33,365	39,279	39,279	185,920	15.54%
Residential Multi Family	999	1,631	2,264	2,897	3,529	3,955	3,941	19,216	10.39%
Commercial	55	93	132	170	209	223	223	1,104	10.58%

Table 55. Buildings Adopting Heat Pump Water Heaters (units/year) - Emissions Target Scenario

Measure	2024	2025	2026	2027	2028	2029	2030	Total	% of Stock Electrified
Residential	29,671	52,959	76,180	99,387	115,002	115,002	99,686	587,887	42.56%
Commercial	140	245	351	457	562	610	0	2,364	22.65%

Table 56. Incremental Gas DSM (Dth/year) - Emissions Target Scenario

Measure	2024	2025	2026	2027	2028	2029	2030
Incremental Gas DSM	649,275	620,322	570,651	483,286	352,552	295,233	239,476

Table 57. Supply Side Resource Procurement (Dth/year) - Emissions Target Scenario

Measure	2024	2025	2026	2027	2028	2029	2030
Certified Natural Gas	0	0	0	0	0	0	0
Recovered Methane	512,512	2,658,481	3,287,481	3,287,481	3,287,481	3,287,481	3,428,152
Hydrogen	-	-	-	669,890	1,725,658	2,878,064	3,664,305

To procure these resource, annual program costs for the Emissions Target Scenario are displayed in Table 58 below.

Table 58. Annual Program Costs ($ Millions) - Emissions Target Scenario

Measure	2024	2025	2026	2027	2028	2029	2030	Portfolio Average
Additional Gas DSM	14.7	15.4	16.1	14.9	11.6	9.7	9.9	13.2
Electrification	47.5	73.4	106.7	155.1	217.3	323.9	324.0	178.3
Certified Natural Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Offsets	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydrogen	0.0	0.0	0.0	5.7	20.1	36.7	45.2	15.4
Recovered Methane	13.2	100.3	108.7	108.7	108.7	108.7	109.0	93.9
Total	75.4	189.2	231.5	284.4	357.7	479.0	488.0	300.7

In the Emissions Target Scenario, the portfolio of resources creates the incremental annual abatement displayed in Table 59. Table 60 has the total annual abatement, which accounts for the persisting impacts from Building Electrification and Demand Side Management Measures, and represents the progress towards the Clean Heat Plan emissions reductions.

Table 59. Annual Incremental Abatement (tCO2/year) – Emissions Target Scenario

Measure	2024	2025	2026	2027	2028	2029	2030
Additional Gas DSM	34,457	32,921	30,285	25,648	18,710	15,668	12,709
BE	85,525	137,694	183,102	234,811	277,824	301,889	285,056
CNG	0	0	0	0	0	0	0
Offsets	0	0	0	0	0	0	0
Hydrogen	0	0	0	16,622	53,723	95,952	118,749
Recovered Methane	77,716	252,988	294,514	294,514	294,514	294,514	366,796
Total	197,697	423,602	507,901	571,596	644,771	708,024	783,309

Table 60. Annual Total Abatement (tCO2/year) - Emissions Target Scenario

Measure	2024	2025	2026	2027	2028	2029	2030
Additional Gas DSM	34,457	67,378	97,663	123,311	142,021	157,689	170,398
BE	85,525	223,218	406,320	641,131	918,955	1,220,843	1,505,899
CNG	0	0	0	0	0	0	0
Offsets	0	0	0	0	0	0	0
Hydrogen	0	0	0	16,622	53,723	95,952	118,749
Recovered Methane	77,716	252,988	294,514	294,514	294,514	294,514	366,796
Total	197,697	543,584	798,497	1,075,578	1,409,213	1,768,999	2,161,842

Resources procured in the Emissions Target Scenario have impacts on gas throughput and retail gas sales, shown in Table 61.

Table 61. Gas Throughput at Year End (Dekatherms/year) – Emissions Target Scenario

Measure	2024	2025	2026	2027	2028	2029	2030
Certified Natural Gas	0	0	0	0	0	0	0
Recovered Methane	512,512	2,658,481	3,287,481	3,287,481	3,287,481	3,287,481	3,428,152
Hydrogen	0	0	0	669,890	1,725,658	2,878,064	3,664,305
Natural Gas	142,987,700	138,604,764	134,055,113	127,735,977	120,129,072	110,734,913	102,736,113
Electrification	1,763,786	4,736,957	8,918,228	14,283,269	20,699,123	27,750,686	34,569,424
Additional DSM	760,593	1,547,329	2,352,363	3,105,792	3,750,623	4,387,999	5,025,376

Clean Heat Plus Scenario Results

To achieve emissions reductions, the Clean Heat Plus Scenario adopts measures and resources displayed in Table 62 through Table 66, below.

Table 62. Buildings Adopting Full HVAC Electrification (units/year) – Clean Heat Plus Scenario

Measure	2024	2025	2026	2027	2028	2029	2030	Total	% of Stock Electrified
Residential Single Family	3,583	5,807	8,031	10,255	12,479	14,703	16,927	71,786	6.00%
Residential Multi Family	854	1,395	1,936	2,477	3,018	3,559	4,100	17,338	9.37%
Commercial	47	81	114	147	180	213	246	1,028	9.85%

Table 63. Buildings Adopting Hybrid HVAC Electrification (units/years) – Clean Heat Plus Scenario

Measure	2024	2025	2026	2027	2028	2029	2030	Total	% of Stock Electrified
Residential Single Family	5,178	8,392	11,607	14,821	18,035	21,250	24,464	103,747	8.67%
Residential Multi Family	540	882	1,224	1,566	1,908	2,250	2,583	10,952	5.92%
Commercial	30	50	71	92	113	134	154	644	6.17%

Table 64. Buildings Adopting Heat Pump Water Heaters (units/year) – Clean Heat Plus Scenario

Measure	2024	2025	2026	2027	2028	2029	2030	Total	% of Stock Electrified
Residential	16,038	28,626	41,214	53,803	66,375	78,850	79,198	364,104	26.36%
Commercial	75	133	190	247	304	361	0	1,310	12.55%

Table 65. Incremental Gas DSM (Dth/year) – Clean Heat Plus Scenario

Measure	2024	2025	2026	2027	2028	2029	2030
Incremental Gas DSM	673,897	620,572	570,659	531,103	473,384	405,175	55,228

Table 66. Supply Side Resource Procurement (Dth/year) – Clean Heat Plus Scenario

Measure	2024	2025	2026	2027	2028	2029	2030
Certified Natural Gas	0	20,000	35,735,961	71,168,913	100,421,249	117,265,928	116,868,077
Recovered Methane	512,512	2,192,289	2,821,289	2,821,289	2,821,289	2,821,289	2,794,161
Hydrogen	0	0	0	669,890	1,725,658	2,874,623	3,711,888

To procure these resource, annual program costs for the Clean Heat Plus Scenario are displayed in Table 67 below.

Table 67. Annual Program Costs ($ Millions) - Clean Heat Plus Scenario

Measure	2024	2025	2026	2027	2028	2029	2030	Portfolio Average
Additional Gas DSM	15.6	15.4	16.2	16.8	17.1	16.7	10.0	15.4
Electrification	19.9	35.0	57.7	83.9	106.2	129.3	147.2	82.8
Certified Natural Gas	0.0	0.0	2.4	4.6	6.2	7.1	7.1	3.9
Offsets	2.3	4.2	6.7	8.7	9.3	9.6	9.9	7.3
Hydrogen	0.0	0.0	0.0	5.7	20.1	36.7	46.2	15.5
Recovered Methane	13.2	80.9	89.2	89.2	89.2	89.2	86.0	76.7
Total	51.1	136.2	172.8	209.6	248.8	289.3	303.8	201.7

In the Clean Heat Plus Scenario, the portfolio of resources creates the incremental annual abatement displayed in Table 68. Table 69 has the total annual abatement, which accounts for the persisting impacts from Building Electrification and Demand Side Management Measures, and represents the progress towards the Clean Heat Plan emissions reductions.

Table 68. Annual Incremental Abatement (tCO2/year) – Clean Heat Plus Scenario

Measure	2024	2025	2026	2027	2028	2029	2030
Additional Gas DSM	35,764	32,934	30,285	28,186	25,123	21,503	13,545
BE	43,303	67,626	86,716	114,700	141,090	165,140	181,412
CNG	0	87	133,739	244,830	329,147	374,293	373,226
Offsets	115,000	200,000	300,000	365,000	365,000	365,000	365,000
Hydrogen	0	0	0	16,622	53,723	95,769	121,274
Recovered Methane	77,716	214,912	256,438	256,438	256,438	256,438	315,014
Total	271,783	515,559	807,178	1,025,776	1,170,520	1,278,143	1,369,472

Table 69. Annual Total Abatement (tCO2/year) - Clean Heat Plus Scenario

Measure	2024	2025	2026	2027	2028	2029	2030
Additional Gas DSM	35,764	68,698	98,983	127,169	152,292	173,794	187,339
BE	43,303	110,929	197,646	312,346	453,436	618,576	799,987
CNG	0	87	133,739	244,830	329,147	374,293	373,226
Offsets	115,000	200,000	300,000	365,000	365,000	365,000	365,000
Hydrogen	0	0	0	16,622	53,723	95,769	121,274
Recovered Methane	77,716	214,912	256,438	256,438	256,438	256,438	315,014
Total	271,783	594,626	986,805	1,322,405	1,610,035	1,883,870	2,161,842

Resources procured in the Clean Heat Plus Scenario have impacts on gas throughput and retail gas sales, shown in Table 70

Table 70. Gas Throughput at Year End (Dth/year) – Clean Heat Plus Scenario

Measure	2024	2025	2026	2027	2028	2029	2030
Certified Natural Gas	0	20,000	35,735,961	71,168,913	100,421,249	117,265,928	116,868,077
Recovered Methane	512,512	2,192,289	2,821,289	2,821,289	2,821,289	2,821,289	2,794,161
Hydrogen	0	0	0	669,890	1,725,658	2,874,623	3,711,888
Natural Gas	143,765,072	141,194,020	102,848,826	63,496,768	29,324,533	5,758,511	387,918
Electrification	953,398	2,560,518	4,821,358	7,722,923	11,275,095	15,475,724	20,143,816
Additional DSM	793,610	1,580,705	2,385,751	3,202,626	4,024,134	4,843,069	5,517,510

Electrification Only Scenario Results

To achieve emissions reductions, the Electrification Only Scenario adopts measures and resources displayed in Table 71 through Table 75, below.

Table 71. Buildings Adopting Full HVAC Electrification (units/year) – Electrification Only Scenario

Measure	2024	2025	2026	2027	2028	2029	2030	Total	% of Stock Electrified
Residential Single Family	25,846	41,889	57,932	66,458	66,458	66,458	66,458	391,496	32.73%
Residential Multi Family	4,111	6,716	9,321	10,211	10,211	10,211	8,039	58,819	31.80%
Commercial	227	386	546	578	578	578	578	3,473	33.27%

Table 72. Buildings Adopting Hybrid HVAC Electrification (units/years) – Electrification Only Scenario

Measure	2024	2025	2026	2027	2028	2029	2030	Total	% of Stock Electrified
Residential Single Family	0	0	0	0	0	0	0	0	0.00%
Residential Multi Family	0	0	0	0	0	0	0	0	0.00%
Commercial	0	0	0	0	0	0	0	0	0.00%

Table 73. Buildings Adopting Heat Pump Water Heaters (units/year) – Electrification Only Scenario

Measure	2024	2025	2026	2027	2028	2029	2030	Total	% of Stock Electrified
Residential	47,313	84,448	115,002	115,002	115,002	115,002	99,686	691,455	50.06%
Commercial	222	391	560	610	610	610	99	3,101	29.71%

Table 74. Incremental Gas DSM (Dth/year) – Electrification Only Scenario

Measure	2024	2025	2026	2027	2028	2029	2030
Incremental Gas DSM	0	0	0	0	0	0	0

Table 75. Supply Side Resource Procurement (Dth/year) – Electrification Only Scenario

Measure	2024	2025	2026	2027	2028	2029	2030

Certified Natural Gas	0	0	0	0	0	0	0
Recovered Methane	0	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0	0

To procure these resource, annual program costs for the Electrification Only Scenario are displayed in Table 76 below.

Table 76. Annual Program Costs ($ Millions) – Electrification Only Scenario

Measure	2024	2025	2026	2027	2028	2029	2030	Portfolio Average
Additional Gas DSM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Electrification	93.3	217.0	388.5	816.0	842.6	869.9	883.1	587.2
Certified Natural Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Offsets	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Recovered Methane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	93.3	217.0	388.5	816.0	842.6	869.9	883.1	587.2

In the Electrification Only Scenario, the portfolio of resources creates the incremental annual abatement displayed in Table 77. Table 78Table 51 has the total annual abatement, which accounts for the persisting impacts from Building Electrification and Demand Side Management Measures, and represents the progress towards the Clean Heat Plan emissions reductions.

Table 77. Annual Incremental Abatement (tCO2/year) – Electrification Only Scenario

Measure	2024	2025	2026	2027	2028	2029	2030
Additional Gas DSM	0	0	0	0	0	0	0
BE	153,938	255,196	345,346	368,010	358,958	349,489	330,906
CNG	0	0	0	0	0	0	0
Offsets	0	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0	0
Recovered Methane	0	0	0	0	0	0	0
Total	153,938	255,196	345,346	368,010	358,958	349,489	330,906

Table 78. Annual Total Abatement (tCO2/year) – Electrification Only Scenario

Measure	2024	2025	2026	2027	2028	2029	2030
Additional Gas DSM	0	0	0	0	0	0	0
BE	153,938	409,134	754,479	1,122,489	1,481,447	1,830,936	2,161,842
CNG	0	0	0	0	0	0	0
Offsets	0	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0	0
Recovered Methane	0	0	0	0	0	0	0
Total	153,938	409,134	754,479	1,122,489	1,481,447	1,830,936	2,161,842

Resources procured in the Electrification Only Scenario have impacts on gas throughput and retail gas sales, shown in Table 79.

Table 79. Gas Throughput at Year End (Dth/year) – Electrification Only Scenario

Measure	2024	2025	2026	2027	2028	2029	2030
Certified Natural Gas	0	0	0	0	0	0	0
Recovered Methane	0	0	0	0	0	0	0
Hydrogen	0	0	0	0	0	0	0
Natural Gas	143,071,814	139,641,665	133,854,256	126,876,994	119,940,057	111,940,758	105,058,839
Electrification	2,952,778	7,921,418	14,774,481	22,220,966	29,667,451	37,113,937	44,300,537
Additional DSM	0	0	0	0	0	0	0

Scenario Results Summarized by Resource

Building Electrification and Demand Side Measures

Table 80. Residential Full HVAC Electrification by Scenario (Devices Installed/year)

Scenario	2024	2025	2026	2027	2028	2029	2030	Total
Cost Target	4,437	6,995	8,838	11,651	14,181	13,967	18,689	78,759
Emissions Target	8,208	13,323	18,439	23,554	28,670	33,434	33,434	159,062
Clean Heat Plus	4,437	7,202	9,967	12,732	15,497	18,262	21,027	89,124
Electrification Only	29,957	48,604	67,252	76,668	76,668	76,668	74,497	450,315

Table 81. Residential Hybrid HVAC Electrification by Scenario (Devices Installed/year)

Scenario	2024	2025	2026	2027	2028	2029	2030	Total
Cost Target	5,716	8,899	0	1,176	3,398	0	0	19,190
Emissions Target	10,578	17,157	23,736	30,316	36,895	43,234	43,220	205,137
Clean Heat Plus	5,718	9,274	12,831	16,387	19,943	23,499	27,047	114,699
Electrification Only	0	0	0	0	0	0	0	0

Table 82. Residential Heat Pump Water Heater Installations by Scenario (Devices Installed/year)

Scenario	2024	2025	2026	2027	2028	2029	2030	Total
Cost Target	15,908	0	0	0	0	0	0	15,908
Emissions Target	29,671	52,959	76,180	99,387	115,002	115,002	99,686	587,887
Clean Heat Plus	16,038	28,626	41,214	53,803	66,375	78,850	79,198	364,104
Electrification Only	47,313	84,448	115,002	115,002	115,002	115,002	99,686	691,455

Table 83. Incremental Gas DSM by Scenario (Therms/year)

Scenario	2024	2025	2026	2027	2028	2029	2030
Cost Target	755,149	633,856	588,313	570,506	158,453	141,240	121,835
Emissions Target	649,275	620,322	570,651	483,286	352,552	295,233	239,476

Clean Heat Plus	673,897	620,572	570,659	531,103	473,384	405,175	255,228
Electrification Only	0	0	0	0	0	0	0

Supply Side and Fuels Measures

Table 84. Recovered Methane Procured by Scenario (Dth/year)

Scenario	2024	2025	2026	2027	2028	2029	2030
Cost Target	0	0	0	0	0	0	0
Emissions Target	512,512	2,658,481	3,287,481	3,287,481	3,287,481	3,287,481	3,428,152
Clean Heat Plus	512,512	2,192,289	2,821,289	2,821,289	2,821,289	2,821,289	2,794,161
Electrification Only	0	0	0	0	0	0	0

Table 85. Hydrogen Procured by Scenario (Dth/year)

Scenario	2024	2025	2026	2027	2028	2029	2030
Cost Target	0	0	0	0	0	0	0
Emissions Target	0	0	0	669,890	1,725,658	2,878,064	3,664,305
Clean Heat Plus	0	0	0	669,890	1,725,658	2,874,623	3,711,888
Electrification Only	0	0	0	0	0	0	0

Clean Heat Plus Emissions Reduction Measures

Table 86. Certified Natural Gas Procured by Scenario (Dth/year)

	2024	2025	2026	2027	2028	2029	2030
Certified Natural Gas	0	20,000	35,735,961	71,168,913	100,421,249	117,265,928	116,868,077

Table 87. GHG Offsets Procured in Clean Heat Plus Scenario (tCO2/year)

Feedstock Type	2024	2025	2026	2027	2028	2029	2030
Avoided Grassland Conversion	30,000	52,174	78,261	95,217	95,217	95,217	95,217
HFC Reclaim	25,000	43,478	65,217	79,348	79,348	79,348	79,348
IFM - Reduction	50,000	86,957	130,435	158,696	158,696	158,696	158,696
IFM - Removal	10,000	17,391	26,087	31,739	31,739	31,739	31,739

A.1. Comparison of Clean Heat Targets to Other State Policy

Decarbonizing the heating sector is an area of active investigation across several US states. Several states have opened “future of gas” proceedings at their public utility commissions, a handful of states are actively considering sectoral “clean heat” policies and other states have implemented economy-wide emissions cap-and-reduce policies that could spur emissions reductions from natural gas end-uses.

Among those states, none have established policies as ambitious as the Colorado Clean Heat targets. The closest corollary E3 identified in terms of percentage emissions reductions is the Washington state cap-and-reduce program, which requires reduces the number of allowances freely allocated to natural gas utilities by 7% per year, starting from 100% free allowances in 2023. That policy differs from Clean Heat in that utilities have the option to purchase permits rather than pursue direct emissions reductions in order to meet their emissions obligations. In addition, Washington State’s cap-and-trade policy allows for limited provision of offsets to meet obligated entities’ GHG reduction requirements.

Other states have also committed substantial rate-payer funding for electrification. For example, Massachusetts rate-payer funded programs are slated to offer $4 billion over three years with a “significant portion” of those funds dedicated to support electrification[21]. California has also committed rate-payer funds to support electrification, including funds for to support electrification in disadvantaged communities[22].

State such as California and Massachusetts have committed high levels of incentives funds towards electrification, but those efforts are not yet accompanied by enforceable sector specific emissions reduction targets. In California, electrification is supported by a combination of rate-payer surcharges, the state budget and forthcoming IRA funding. In Massachusetts, electrification is primarily supported by rate-payer funds the IRA.

A.2. Comparison of Clean Heat Portfolios to the 2021 Roadmap

E3 leveraged the 2021 Roadmap as a starting point for certain assumptions and as a point of comparison for the selected portfolios. E3 recognizes that an update of the Roadmap is currently underway, which may include different assumptions and outcomes than the previous iteration.

Key points of comparison to the Roadmap include:

+ Methodology
+ The pace, scale and composition of electrification
+ The pace and scale of gas DSM measures
+ Availability and use of low-carbon fuels
+ Role of non-enumerated emissions reduction measures

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Methodology

The 2021 Roadmap was developed by the Colorado Energy Office, with support by E3 using the PATHWAYS modeling framework. PATHWAYS is an economy-wide emissions and energy infrastructure accounting model. It includes a high-level representation of each sector, including device by device treatment of certain end-uses. Its outcomes are largely user defined and the model's general purpose is work backwards from 2050 to identify plausible pathways towards decarbonization.

The modeling approach E3 used to support the Company's Clean Heat Plan filling offers an enhanced level of detail on both demand- and supply-side resources. That level of detail allows the model to differentiate between higher and lower-cost opportunities across different building types and fuels. Using a supply-curve based approach, E3's model can then select cost-minimized portfolios of resources.

Each approach has its advantages. A PATHWAYS style framework is well suited to exploratory analysis that helps to identify the building blocks of economy-wide decarbonization. However, that framework is not well suited to identifying portfolios of decarbonization options. E3's modeling approach in Clean Heat better captures the heterogeneity of heating decarbonization options and leverages that to identify portfolios of solutions. However, the model is currently best suited to evaluate more near-term trade-offs between resources given the inherent uncertainties for the cost, performance and availability of resources in the long-run.

Pace, Scale, and Composition of Electrification

E3 leveraged the HB 1261 Scenario from the 2021 Roadmap as a starting point for a maximum reasonable pace of electrification for each Clean Heat Portfolio. However, E3 ultimately modified the roadmap trajectory for two reasons.

1. The Roadmap envisioned a transition towards electrification beginning in 2021, where the earliest the Company will be able to execute on Clean Heat funded project will be 2024. Given that, E3 assumed that electrification does not begin to gain market share until 2024.
2. Considering the later starting date for electrification, E3 found that the pace at which electrification gains market share in the Roadmap is insufficient to achieve the 2030 goal in all scenarios except Clean Heat Plus.

A further point of comparison between the Clean Heat portfolios and the Roadmap is the composition of HVAC technologies adopted. The Roadmap assumed that 50% of residential heat pump HVAC systems are all-electric and the remaining 50% are hybrid systems. In E3's Clean Heat Scenarios, the share of hybrid vs all-electric systems varies by scenario. However, E3's model selected a higher share of hybrid systems relative to all-electric systems in scenarios that meet the 2030 Clean Heat Target. This outcome is primarily driven by the lower overall installation costs of these systems and their lower overall impact on electric system costs.

Availability and Use of Low-Carbon Fuels

The Roadmap assumes limited blends of biogas and no hydrogen serving residential and commercial buildings through 2030. However, post-2030 the share of biogas increases rapidly, rising to 25% by 2035, over 50% by 2041 and 95% by 2050. In the Roadmap, hydrogen blends begin in 2031 at 0.2% by energy and rise to 5% by energy by 2050. Those blends occur in the context of decreasing gas throughput, with sales having fallen by 70% in 2040 and 95% in 2050.

Appendix B: 2050 Scenarios

Clean Heat Portfolios in the Context of Mid-Century Decarbonization Goals

E3 modeled Clean Heat portfolios from 2024 through 2030. To explore the implications of Clean Heat portfolios over a longer time horizon, E3 developed a set of indicative mid-century decarbonization scenarios for the Company's gas business. Outcomes through 2030 reflect the cost-based scenario modeling described above, while outcomes after 2030 leverage a higher-level scenario analysis framework similar to the PATHWAYS model used in the 2021 Roadmap.

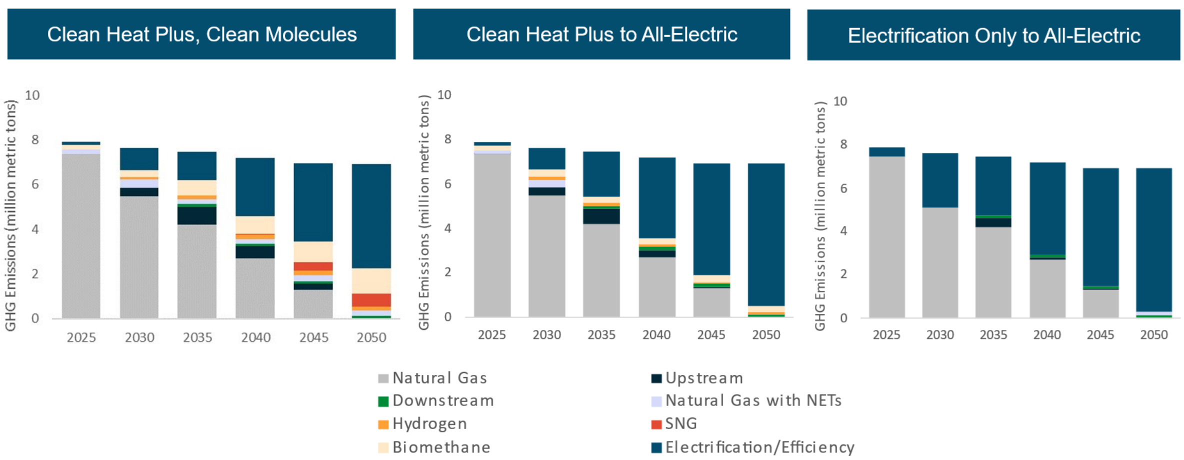
The mid-century analysis branches from two scenarios: Electrification Only and Clean Heat Plus. By 2050, the Electrification Only scenario is assumed to result in complete elimination of the usage of the Company's gas system. For Clean Heat Plus, E3 and the Company developed two alternative trajectories post-2030. The first is Clean Heat Plus with Clean Molecules, while the second is Clean Heat Plus, Pivot to All-Electric. The mid-century scenarios and their mappings to the Clean Heat Portfolio analysis are summarized in Table 88.

Table 88. Mid-Century and Clean Heat Scenario Mapping

2030 Clean Heat Scenario	Mid-Century Scenario	Key Assumptions
Electrification Only	Electrification Only, to All Electric	+ All-electric technologies, 100% sales share by 2028 + Building shell improvements + No fuels measures
Clean Heat Plus	Clean Heat Plus with Clean Molecules	+ Mixture of all-electric and hybrid. + Some traditional gas customers remain. + Biomethane produced via gasification and synthetic natural gas available post-2030. + H2 blends increase to 20% by volume after 2030
Clean Heat Plus	Clean Heat Plus, Pivot to All-Electric	+ Mixture of all-electric and hybrid in the near-term. + Hybrid customers go all-electric in subsequent equipment replacements. + Fuels measures phased out by 2050.

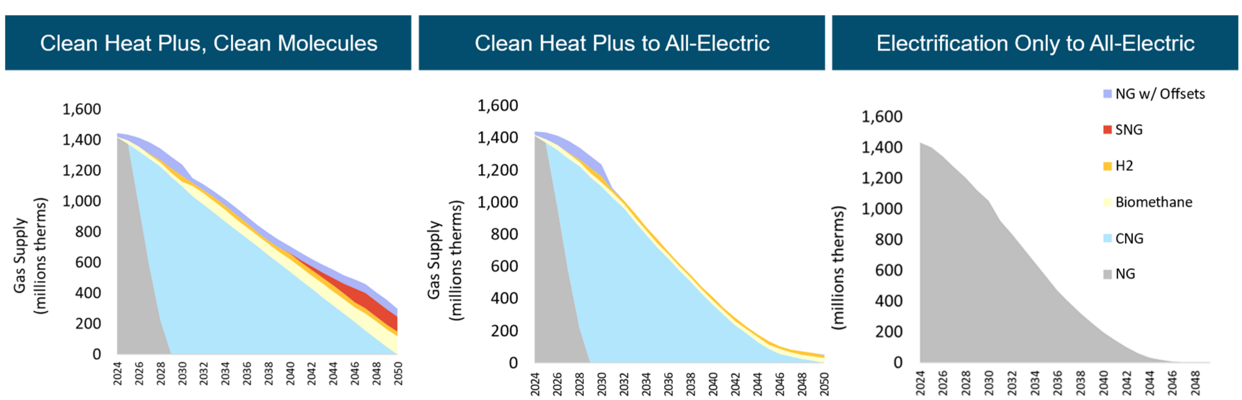
The total emissions and portfolio of emissions reduction strategies for each scenario are shown in Figure 19. A key conclusion from this analysis is that the Clean Heat Plus scenario can plausibly transition to either a pathway with higher levels of clean molecules or an all-electric future. Consistent with the 2024 through 2030 Clean Heat portfolio analysis, this scenario exercise also illustrates the central role of electrification in decarbonizing natural gas end-uses in the Company's territory.

Figure 19: Mid-Century Decarbonization Portfolios



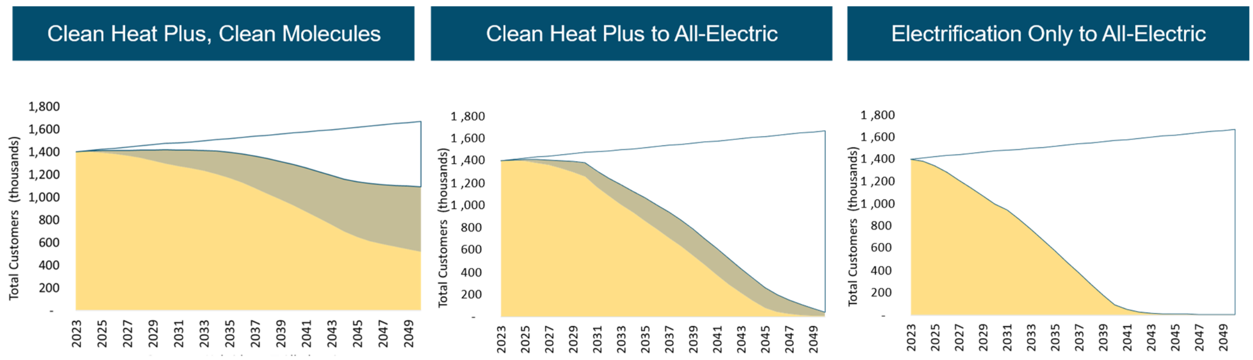
The trajectory of gas system sales is shown in Figure 20. Consistent with the 2030 Clean Heat Portfolios, gas sales continue to fall in all scenarios post 2030 as both all-electric and hybrid electrification solutions reduce annual throughput. The composition of gas supplied by the Company also change. Consistent with Clean Heat Plus, all natural gas is assumed to be certified by 2030. Additionally, the two Clean Heat Plus scenarios envision an ongoing role for a small amount of hydrogen and biomethane. The Clean Molecules branch of Clean Heat Plus has the highest overall gas throughput, and as a result requires use of synthetic natural gas and higher amounts of biomethane.

Figure 20: Gas Sales and Supply



The total number of customers Xcel Energy serves also falls in each scenario as shown in Figure 21. Customer declines occur most rapidly in Electrification Only, with the system reaching zero remaining customers by the mid-2040s. Clean Heat Plus, Clean Molecules has the most customers remaining such that by 2050 1/3 of the Company's customers maintain gas equipment as their primary heating source, 1/3 are hybrid electrification customers and 1/3 have gone all-electric.

Figure 21: Gas Customers



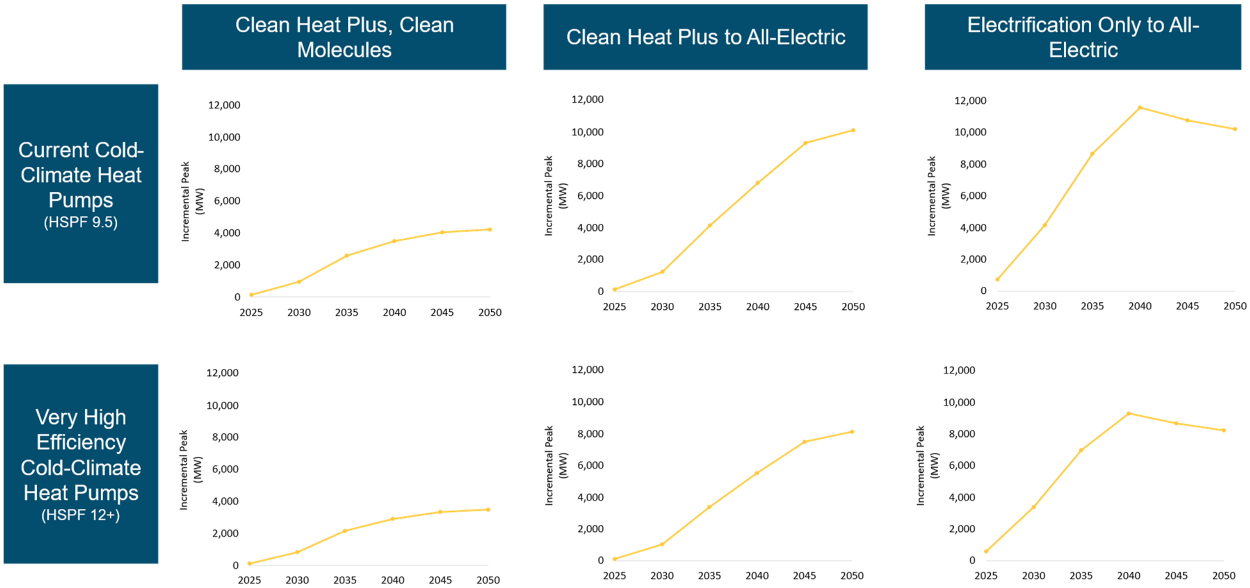
Increasing levels of electrification drive increases in electric sales and peak demands. Annual sales of electricity for heating purposes increase by between 5.5 and 12 TWh by 2050, compared to current annual sales which have averaged approximately 30 TWh over the past three years[23]. Increases in annual sales of electricity due to heating electrification implicates the scale of zero-GHG generation that The Company will need to add to its system.

The scenarios differ substantially in their impacts on peak demand (Figure 22) which implicates the scale of electric transmission and distribution upgrades, as well as firm generation capacity, required. Clean Heat Plus with Clean Molecules has the lowest peak demand impacts due to usage of hybrid heating. Electrification Only has the most rapid increase in peak demands, likely pushing the Company's electric system to winter peaking by 2030. Both Electrification and Clean Heat Plus, Pivot to All-Electric lead to peak demand impacts of between 9,200 MW and 12,000 MW by 2040, with that range depending on heat pump performance assumptions[24].

[23] The Company, 2022 Electric and Gas Statistics, https://s25.q4cdn.com/680186029/files/doc_downloads/2023/03/2022-electric-and-natural-gas-statistics.pdf

[24] Demand falls post-2040 because electrification has reached 100% stock share and ongoing efficiency improvements.

Figure 22: Electric Peak Demand Impacts



Figures show incremental winter peak demands at 6am during a 90th percentile cold-snap

These mid-century scenarios are meant to provide an initial, indicative view for how Clean Heat portfolios could translate into long-term decarbonization pathways. The results identify significant implications for both the Company's electric and gas infrastructure. Additional study is needed to identify the implications of electrification loads for the Company's electric transmission and distribution systems, as well as electric resource planning and reliability. Additional study is also needed to assess the regulatory and business model implications of significant declines in gas system utilization across all scenarios.