Legislating heat pumps: Assessing the costs and carbon savings from a state heat pump standard

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ABSTRACT

The Colorado state legislature requested research on the impact of a statewide point-of-sale standard requiring new residential central air conditioners (CAC) serving one- and two-family dwelling units to be configured as heat pumps.

We interviewed equipment manufacturers, distributors, contractors, homebuilders, environmental justice groups, and utilities. Using this primary data, we conducted engineering and economic analyses to assess heat pump installation costs and operational savings. Our engineering analysis used loadshapes with a heat pump equipment performance model to estimate 8760 fossil fuel, electricity, cost, and GHG impacts.

We found the proposed Standard could reduce residential sector carbon emissions by 13% over the next 20 years. The Standard would result in an incremental upfront cost increase of equipment of $2,200. For 82% of impacted households, the legislation would result in an increase to total annualized costs including operating and equipment costs of $92 per year. However, the remaining 18% of households save an average of over $1,000 a year. The wide difference in costs is driven by heating system fuel types, differences in climate, and electricity and fossil fuel costs throughout the State.

In this presentation we explore the relationship between GHG savings and the potential cost burden it places on households. For households with increased annualized costs, replacing a CAC with a baseline efficiency heat pump, can result in a reduction in GHG emissions with an implied cost of $99 per metric ton of CO2e, indicating that baseline efficiency heat pumps could be a prime candidate for state or utility rebates.

Introduction

Heat pumps offer the potential to dramatically lower residential HVAC carbon emissions by switching from burning fossil fuels to using electricity, which can be generated through renewable sources (Wilson et al. 2024). However, the cost of switching from fossil fuel heating systems to heat pumps, especially in cold climates, is often higher than customer bill savings over the lifetime of the equipment (Wilson et al. 2024). The likely most cost-effective solution from a customer perspective is to purchase a heat pump that is sized to the cooling load at the time of adding new cooling or replacing failed cooling equipment and relying on their existing heating source. The reasons for this include:

1) At the time of new purchase, if the customer is not also in the market for a new heating source, a customer is choosing between the cost of a CAC or a heat pump, and thus the incremental cost is simply how much more expensive a heat pump is compared to a CAC.

2) A customer is less likely to require electric panel upgrades when the heat pump is sized to the cooling load rather than the full heating load.
3) A customer is less likely to require new, larger ducts, which could accommodate the required heat necessary at their maximum heating load.
4) The heat pump will operate at a higher heating coefficient of performance (COP) since, at colder temperatures, when the COP is low, the heating system will switch over from the heat pump to the existing heating system. A higher COP results in lower customer bills since every kWh purchased produces more heat.

For the reasons above, states and municipalities with goals to reduce emissions and provide cost savings for their residents have explored the option of legislation that would require new air conditioners to have the capability to operate as heat pumps. This is complicated by the Energy Policy and Conservation Act (EPCA) preemption provision that prohibits states and local governments from establishing their own energy conservation standards for products already covered by federal standards. The EPCA already includes standards for air conditioner efficiency, and thus any legislation that is likely to be robust against legal challenges will need to regulate something other than the unit's efficiency. Furthermore, as we found in our research, heat pumps are more expensive than CACs. Affordability is a key political issue that requires careful consideration and passing legislation that increases up-front costs to customers could be politically untenable. Table 1, below, shows states with requirements for heat pumps. In all three cases, the requirement only applies to new construction, not necessarily any failed equipment, as proposed in Colorado. However, some municipalities, such as Aspen, CO, have a requirement for heat pumps to be installed even for AC retrofit applications (City of Aspen 2023).

Table 1. States Requiring Heat Pumps

Jurisdiction	Legislation	Heat Pump Requirements
New York	All-Electric Buildings Act	All new buildings seven stories and lower will have to be built without any fossil fuel-burning equipment starting 1/1/2026 (New York State Legislature 2023)
California	Title 24	Heat pumps are required for prescriptive compliance in all climate zones for single-family new construction starting 1/1/2026 (California Energy Commission 2024)
Oregon	2026 Oregon Residential Specialty Code, Section N1105.8.	New home with split-system cooling must be a heat pump that can provide both cooling and the first stage of heating starting October 1, 2026 (Oregon Building Code Division 2026)

Colorado has established statewide emission targets to reduce greenhouse gas (GHG) emissions based on the levels that existed in 2005, including a 50% reduction by 2030, a 65% reduction by 2035, and net zero emissions by 2050. In 2021, the Colorado Greenhouse Gas

Pollution Reduction Roadmap (Colorado Energy Office 2021) identified that electrification and decarbonization of space heating in residential buildings will be important for Colorado to meet its 2050 climate goal. Increased adoption of electric heat pump technology is likely to be a key contributor to the residential building electrification and GHG reduction effort because heat pumps operate at much higher efficiency than electric resistance heating technologies.

In 2024, the Colorado General Assembly passed SB24-214 directing the Colorado Energy Office (CEO) (Colorado General Assembly 2024) to conduct an analysis of a potential statewide point-of-sale standard requiring new residential central air conditioners (CACs) serving one- and two- family dwelling units and townhouses to be configured as heat pumps (this point-of-sale standard will hereafter be referred to as the "Residential CAC Standard"). As outlined in statute, the primary objective of this directive was to assess factors likely to affect the impacts of a Residential CAC Standard in Colorado including but not limited to: assessing heat pump technical viability, examining heat pump installation and operating costs, evaluating heat pump workforce readiness, and estimating the statewide economic and greenhouse gas (GHG) emission impacts of such a standard.

Ultimately, the Colorado legislature did not pass a bill that would require new residential CACs to be configured as heat pumps. While several utility rebate programs and federal programs offer incentives or tax rebates for high-efficiency heat pumps[1], incentives are largely unavailable for lower-cost standard efficiency units. Furthermore, utilities may have a challenging time continuing to offer incentives for equipment that is required by a statewide standard due to lack of available funding or pressure to not incentivize equipment that is already required. However, legislation like this provides environmental carbon reduction benefits at a cost (if incentives were provided at equipment incremental cost) that is on par with other interventions being taken at the utility, state, and federal levels. For example, Xcel Energy's most recent 2025 DSM filing shows a portfolio level cost of $102 per metric ton of CO2e and a beneficial electrification cost of $146 per metric ton of CO2e (Public Service Company of Colorado 2026).

This paper discusses our analysis methodology, results for individual households and the state of Colorado, as well as conclusions on the implications of statewide standards that require heat pump adoption.

Methodology

To analyze the impacts of a Residential CAC Standard in Colorado, our team conducted research interviews with 22 stakeholders, including HVAC equipment manufacturers and distributors, HVAC contractors, heat pump experts, green homebuilders, environmental justice groups, and utilities. Using the data collected through this primary research, the team conducted engineering and economic analyses to assess upfront heat pump installation costs and operational costs under a variety of scenarios.

To start the analysis, the team utilized the NREL Restock Database (Present et al. 2024) to estimate the number of households that would be impacted by the Residential CAC Standard. The population impacted by the standard includes residential one- and two-family dwelling units and townhouses with CACs installed or future new construction projects that are expected to

[1] At the time of this research high efficiency heat pumps had rebates in at least 9 utility territories covering the majority of the state population, the state of Colorado had an additional $500-$1,500 incentive, and there was a federal $2,000 tax credit available. Almost of all of these rebates had a minimum efficiency requirement.

install CACs. Out of the existing 2,377,943 households in Colorado, 1,147,720 households would have been impacted by the standard.

While the total potential population that could be impacted by the Residential CAC Standard is 1,147,720 households, only those households that are purchasing new CACs in any given year are impacted each year. The number of CAC installations in retrofit scenarios that happen each year is estimated by multiplying the total impacted population by the estimated yearly turnover rate of residential CAC equipment. A 20-year equipment lifetime was assumed for CAC equipment. In addition to retrofit installations, new residential construction projects that will include space cooling equipment are also impacted by the standard. To estimate the number of new construction units that will be impacted each year, the team added the forecasted county-level increase in housing units from the Colorado Department of Local Affairs (DOLA 2024) to the estimated demolition rate from the HUD User Office of Policy Development and Research (HUD 2020) to produce an estimate of total new constructed housing units. The team then multiplied total new construction housing units by the percent of homes with CACs per county from the 2000-2020 vintage from the ResStock database to estimate the number of newly constructed homes with CAC installed each year. The team estimated 81,696 households would be impacted by the Residential CAC Standard each year.

Next, the team assigned each household to a geographic region based on a combination of climate, gas utility, and electric utility. Climate informs the consumption of the heat pump, and the utility is needed to understand gas rates, electric rates, and ultimately customer economics. The team then gathered the electric and gas rates for each utility (retrieved between December 2024 and January 2025)[2]. Since this research focused on a legislative requirement that would only apply to CACs, the team did not consider cases where customers choose to size the unit to the heating load, fully electrify, and eliminate fixed charges for natural gas service. When multiple electric rates were available to households, the team analyzed the two most common rate options and utilized results from the rate structure that provided the lowest heating and cooling bills after heat pump installation, our assumption being that customers would act economically rationally. For propane rates, the team used the statewide propane rate estimate assumed in the ResStock database.

Finally, the team used a heating system operation model to estimate the impacts of customers for each geographic region analyzed. The team aggregated 15-minute interval data from ResStock into hourly heating and cooling load shapes for each region. These load shapes include data on energy usage and GHG impacts. The electric grid emissions used are marginal emissions averaged over a 15-year time horizon under Cambium's mid-case forecast scenario. The hourly emission values in this dataset are provided at the month-hour level, i.e., the forecasted emissions in each month are averaged for each hour of the day in that month. This methodology captures monthly and daily changes in electric grid GHG emissions but does not allow for a direct comparison between temperature and emission rates. Emission intensity for natural gas and propane was sourced from ResStock and includes methane leakage from the natural gas system, expressed in CO2e.

For all modeling, heat pumps were sized to cover cooling design loads typical of the Front Range region of Colorado (e.g. 2 to 3 tons cooling capacity). For households in climate zones 6B and 7, sizing for design cooling load according to standard sizing procedures (Manual J

[2] Heat pump specific rates are available for Fort Collins and Wheatland Electric, covering less than 5% of Colorado residents. SB24-214 requires investor-owned utilities to provide heat pump rates by August 1, 2027, which could improve customer economics, though utilities are directed to avoid cross subsidies with these rates.

and Manual S) often results in the selection of very small heat pumps (smaller than is typically available for purchase). The number of households with CAC systems that are located in climate zones 6B and 7 is not very high, and the team assumes these homes are likely large in size, with above-average cooling load requirements. Thus, the team assumed households with CACs in climate zones 6B and 7 would also utilize heat pumps sized to cover typical Front Range cooling loads. Note that sizing a heat pump to cover cooling loads will typically result in a heat pump installation that is not capable of meeting the home's full heating requirements. Thus, we assume all households retain their existing heating systems and use them for backup or supplemental heat in dual fuel configurations (in homes with natural gas or propane furnaces) or all-electric heating systems (in homes with electric resistance heating systems).

The regional 8760 energy and emission load shapes (data corresponding to annual data available at an hourly granularity) were paired with a minimum efficiency heat pump (meHP) and cold-climate heat pump (ccHP) performance models to estimate energy consumption, annual heating costs, and GHG emissions of the heat pumps when operated in dual fuel systems with differing switchover temperatures. The switchover temperature is the temperature at which the thermostat is programmed to switch from heating with the heat pump to heating with the natural gas or propane furnace in dual fuel heating systems. Heat pump performance and economics in households with existing electric resistance space heating systems were modeled without any heat pump switchover temperature and without setback-induced increases in electric resistance heating. As a result, in these all-electric heating systems, the heat pump was assumed to operate whenever it could output heat (down to -5 degrees F for meHPs and -15 degrees F for ccHPs). The electric resistance heating system was modeled to supplement the heat pump when the heat pump's heating output was lower than the building's heat load.

For meHPs, the range of switchover temperature examined was 20 to 50 degrees F. For ccHPs, switchover temperatures between 5 and 50 degrees F were examined. Below these minimum temperatures, a heat pump installed in a CAC-replacement scenario with no ductwork modifications or electrical infrastructure upgrades will likely have insufficient heating capacity to meet the building heating load. Thus, the team assumed the existing gas or propane furnace supplies all heating when the outdoor temperature is below the switchover temperature.

The team then determined the economically optimal switchover temperature for each heating system type in each Geographic Analysis Region, where the economically optimal switchover temperature is defined as the switchover temperature within the allowed range that provided the lowest annual heating utility bill. The Residential CAC Standard analyzed does not require that households operate their heat pump heating systems with any particular switchover temperature and does not explicitly require that the household utilize the heat pump for heating. The standard simply requires that a heat pump be installed instead of a CAC. That said, the team believes it is fair to assume that households will operate their heat pump system in an economically optimal manner that reduces heating utility bills.

In addition to the impact on heating utility bills, the team calculated cooling utility bill savings based on the higher federal minimum efficiency standard for heat pumps compared to air conditioners. A minimum seasonal energy efficiency ratio (SEER2) value of 14.3 was used for heat pumps, and a minimum SEER2 value of 13.4 was used for CACs.

After calculating the economics and GHG emission impacts for each CAC installation type at the Geographic Analysis Region level, the team used the distribution of households with each heating system efficiency level and fuel type from ResStock to weigh the average per household impacts for each region to a statewide level.

Results

Stakeholder Interviews

The team conducted interviews with 22 different stakeholders. Interviewees included national policy and market technology experts, environmental and business stakeholders, equity-focused stakeholders, and local government and utility employees.

From the perspective of environmental advocates, policy experts, and local government staff, there was a general consensus that a statewide standard would likely be an effective mechanism for achieving GHG emission reductions in the state. Compared to local code advancements, stakeholders generally viewed the standard as more enforceable. However, the team repeatedly heard concerns that the standard could violate the EPCA preemption clause, place financial burdens on residents, and risk long-term success of heat pump adoption in Colorado if the market was unable to deliver high-quality installations.

From the perspective of the 15 HVAC contractors that we interviewed, we heard mixed enthusiasm for the proposed standard. Roughly half of the interviewed contractors supported a standard and felt that it would have a positive impact on their business and the market. Some of the supporting contractors cited existing municipal codes driving the majority of their heat pump installations (including one contractor who thought Denver had already implemented such a mandate) and believed these codes had already transformed their regional markets. Other contractors differentiated themselves as heat pump specialists and described how they would thrive under a mandate: "I would love it. I can put them in, and a lot of people can't." As contractors benefited from existing heat pump incentives, some felt that regulation driving further heat pump business would only be positive for contractors: "I would think that would be a boon to our industry."

Other contractors expressed market concerns about the impact of standardizing their specialty across HVAC projects, especially for smaller businesses. Several contractors felt that the current incentive-based approach was effective in driving market transformation toward heat pumps. Just under half of the contractors preferred a market-driven evolution heavily supported by incentives (with a few contractors feeling neutral about the mandate). These contractors stated that the current system allows educated contractors to naturally guide homeowners toward the best heat pump solution for the home. Some contractors were concerned that broadening the pool of contractors offering heat pump equipment may hurt smaller HVAC businesses that have specialized in heat pump installation and built expertise around available incentives.

All stakeholders agreed that heat pumps cost more than a CAC, whether for new construction or replacement projects; however, incentives have the potential to offset much of the upfront costs, especially for low-income households. Explaining cost differences, one manufacturer noted that federal minimum efficiency requirements differ between air conditioners and heat pumps, and, as a result, they do not expect the price differences of minimum efficiency models to narrow significantly in the next five years without incentives.

In our contractor and manufacturer interviews, we asked participants about the cost of meHPs and ccHPs compared to CACs. Based on the feedback from these groups, as well as secondary data research, the team determined an incremental equipment cost of $2,200 for meHPs and $6,600 for ccHPs compared to standard efficiency CACs. Since the units analyzed are those impacted by the standard and thus sized to the cooling load of the home, the team did not include the cost of existing heating equipment in the incremental cost analysis. Table 2 and Table 3, below, show incremental costs from several sources for meHPs and ccHPs, respectively.

Table 2. Data and Sources Used to Estimate the Incremental Cost of Installing a meHP

Source	meCAC Cost 13-14 SEER2	meHP Cost 14-15 SEER2	Incremental Cost of meHP
Heat Pumps in the Northeast and Mid-Atlantic (Energy Solutions 2024)	$4,140	$7,200	$3,060
TECH Clean California Incremental Cost Study (Opinion Dynamics 2024)	$9,777	$11,201	$1,424
Cool Way to Heat Homes (Building Decarbonization Alliance 2024)	$6,546	$8,503	$1,957
Heat pumps for all? Distributions of the costs and benefits of residential air-source heat pumps in the United States (Wilson et al. 2024)	$5,891	$8,562	$2,671
Xcel 2024-2026 Demand-Side Management & Beneficial Electrification Plan (Public Service Company of Colorado 2023)	$7,522	$9,195	$1,673
Investigation of Air Source Heat Pumps as a Replacement of Central Air Conditioning (Center for Energy and Environment 2022)	N/A	N/A	$1,350
EIA – Technology Forecast Updates – Residential and Commercial Building Technologies – Advanced Case (EIA 2023)	$5,310	$6,810	$1,500
The Cost of Decarbonization and Energy Upgrade Retrofits for US Homes (Walker et al. 2021)	$6,000	$7,443	$1,443
Illinois Statewide Technical Reference Manual, V11.0 (Il Energy Efficiency Stakeholder Advisory Group 2023)	$2,960	$8,485	$5,525
Wholesale equipment price data (RMI 2024)	$4,302	$6,018	$1,717

Table 3. Data and Sources Used to Estimate the Incremental Cost of Installing a ccHP

Source	meCAC Cost 13-14 SEER2	ccHP Cost 15-20 SEER2	Incremental Cost of ccHP
Xcel 2024-2026 Demand-Side Management & Beneficial Electrification Plan (Public Service Company of Colorado 2023)	$7,522	$17,739	$10,217
Heat pumps for all? Distributions of the costs and benefits of residential air-source heat pumps in the United States (Wilson et al. 2024)	$5,891	$12,900	$7,009
Heat Pumps Pay Off, Unlocking lower-cost heating and cooling in Canada (Canadian Climate Institute 2023)	$4,913	$13,200	$8,287

Investigation of Air Source Heat Pumps as a Replacement of Central Air Conditioning, 2022 (Center for Energy and Environment 2022)	N/A	N/A	$7,860
EIA – Technology Forecast Updates – Residential and Commercial Building Technologies – Advanced Case (EIA 2023)	$5,310	$6,940	$1,630
Wholesale equipment price data (RMI 2024)	$4,302	$8,902	$4,600

Household-Level Impacts

Differences in the electricity-to-fuel price ratio determine heat pump economics, which in turn affects the economically optimal switchover temperature for a dual fuel heating system. How frequently a heat pump is utilized for heating plays a primary role in determining how large the energy saving and GHG emission reduction impacts will be.

Figure 1 below shows the estimated annual heating cost for a dual fuel heating system composed of a meHP and 80% annual fuel utilization efficiency (AFUE) natural gas furnace for a range of switchover temperatures for various Geographic Analysis Regions. Regions with high natural gas costs (e.g. climate zone 6B-Mountains, Morgan County Area) have lower heating costs at lower switchover temperatures, while regions with low natural gas costs (e.g. El Paso County) have lower heating costs with higher switchover temperatures. The switchover temperature for natural gas dual fuel heating systems varies significantly between Geographic Analysis Regions, showing that there is geographic variation for when it is more economical to operate a heat pump or a natural gas furnace. On the other hand, propane dual fuel systems have switchover temperatures of 20 degrees F and 5 degrees F for meHPs and ccHPs, respectively, in 15 out of 16 regions, showing that it is nearly always economically optimal to operate a heat pump instead of a propane furnace. ccHPs generally have lower economically optimal switchover temperatures when compared to meHPs, because ccHPs are frequently more efficient than meHPs, especially at temperatures below 20 degrees F. In addition, homes with 80% efficient furnaces have lower switchover temperatures, because the heat pump provides higher natural gas savings when paired with lower efficiency furnaces.

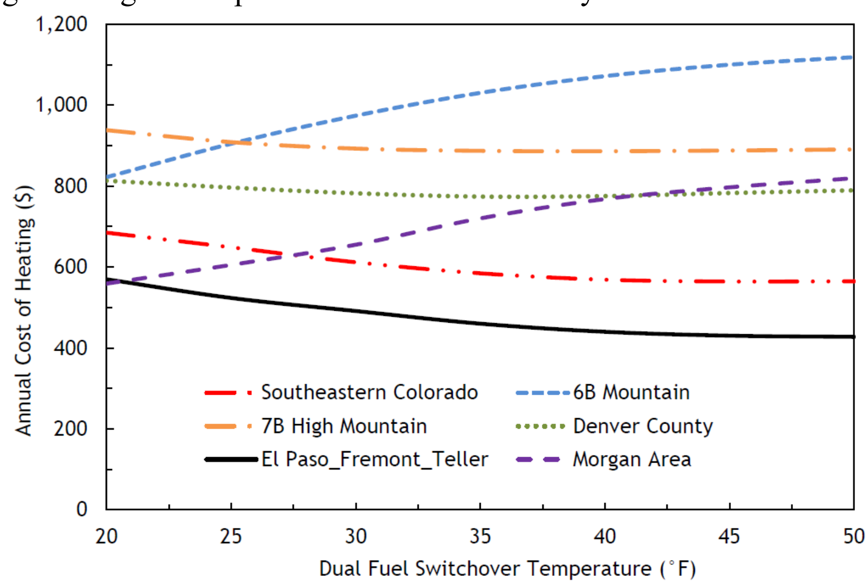

Figure 1. Impact of Switchover Temperature on Annual Heating Costs

Space heating and cooling system operating costs, energy use, and GHG emissions were calculated for each equipment scenario in each Geographic Analysis Region. All households in Colorado are found to realize annual heating and cooling bill savings after installation of a meHP or ccHP instead of a meCAC (when the meHP is operated in an economically optimal manner). That said, the specific amount of utility bill savings is not evenly distributed across households. An estimated 82% of households realize annual utility bill savings of $50 or less after installing a meHP, as shown in Figure 2. The other 18% of Colorado households see much more significant utility bill savings after installing a meHP, with 3% of households saving between $50 and $500 per year, 2% of households saving between $500 and $1,000 per year, and 13% of households saving over $1,000 per year.

When the annualized incremental meHP cost of $122/year is added to the annual utility bill savings, the resulting annual total savings are negative (an added cost) for 82% of households and positive (savings) for the other 18% of households. The primary conclusion from this data is that the annual total savings potential after a heat pump installation is divided into two primary cohorts. One cohort of Colorado households (≈80% of households) sees a modest annual total cost increase after installing a meHP instead of a meCAC, and the other cohort (≈20% of households) sees large annual savings after installing a meHP. Decreasing the upfront incremental cost of installing a heat pump would play a large role in improving heat pump economics and making the installation of a meHP economically positive for all Colorado households.

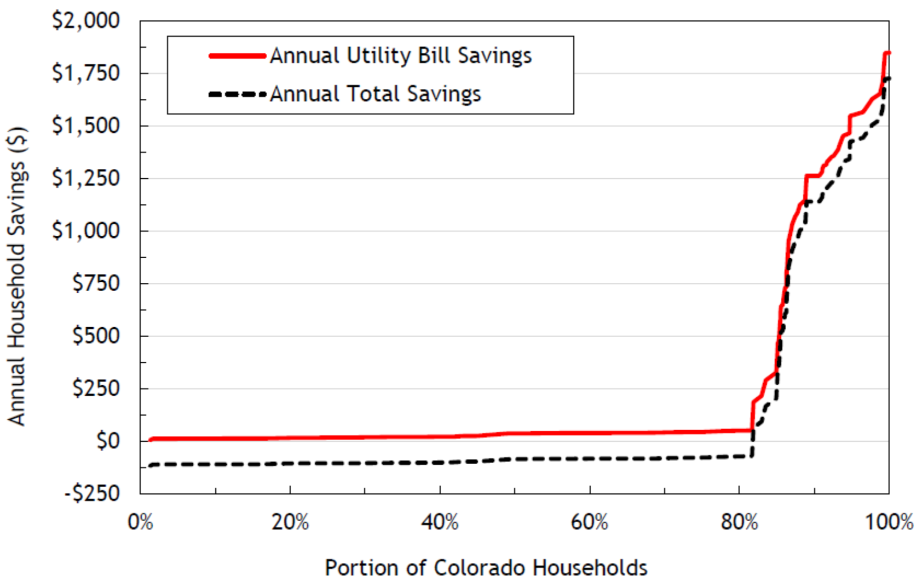

Figure 2. Distribution of annual heating and cooling utility bill savings and annual total savings for Colorado households that install a meHP instead of a meCAC

The key driver behind this uneven distribution of savings is the fuel used by the existing heating systems in each household. Figure 3 breaks down the economic impacts of the Residential CAC Standard by the number of households with each heating fuel type (either natural gas, propane, or electricity). The household economic impacts of the Residential CAC Standard depend strongly on the household's existing heating fuel. Most Colorado households use natural gas furnaces for space heating, and these households see a modest increase in annual total costs ($0 to $100) after installing a meHP instead of a meCAC. Households with existing propane furnace heating systems realize significant annual total savings ($375 to $1,500) after installing a meHP, and the incremental cost of the heat pump is paid back within only a few years. The economic value of installing a meHP is even stronger for households with existing electric resistance space heating systems. These households see annual total savings of $750 to $2,000 and would have their investments in a meHP recovered within 1 or 2 years.

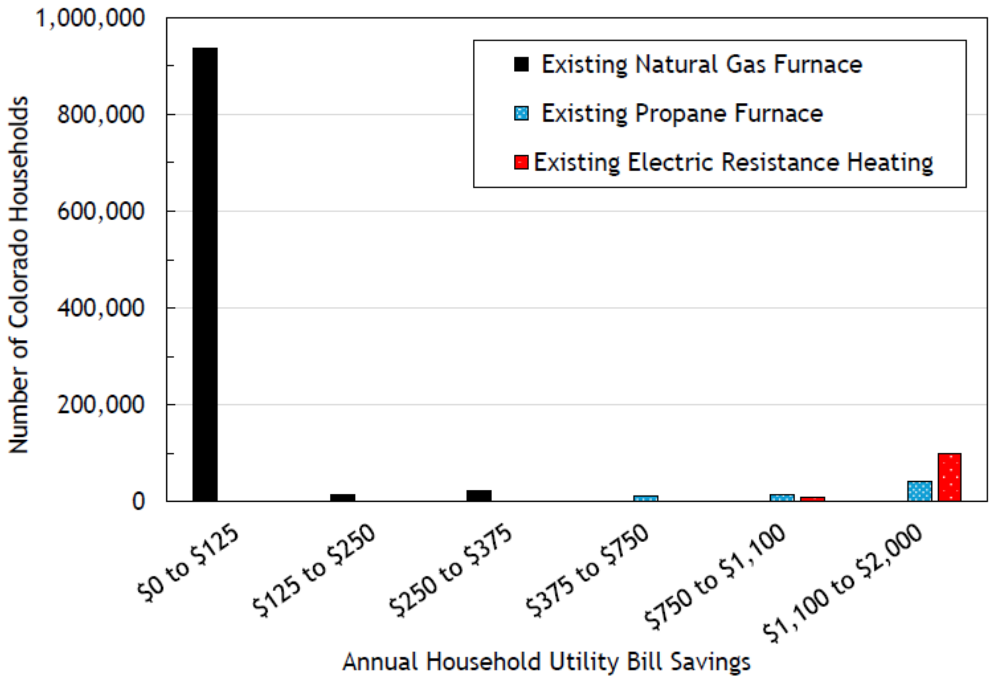

Figure 3. Number of Colorado households, organized by existing heating fuel, as a function of annual utility bill savings after a meHP is installed instead of a meCAC

How frequently a heat pump is utilized for heating plays a primary role in determining how large the energy saving and GHG emission reduction impacts will be. Annual electricity usage from space heating increases in households with natural gas heating systems in all regions, but the increases are generally modest, between 500 and 1,500 kWh, depending on furnace efficiency for meHP scenarios (5% to 30% increase in electricity usage). In households that have propane furnace heating systems, the annual electricity usage increases more significantly after installation of a heat pump, by roughly 4,000 kWh or a 50% increase in overall usage. Because propane is more expensive than natural gas, dual fuel systems that use propane have a lower economically optimal switchover temperature and use the heat pump to cover a greater portion of the building's annual heating needs. For households with existing electric resistance heating, utilizing a heat pump for space heating drives very significant electricity savings, around 11,000 kWh per year (roughly 50% decrease in usage).

On average, households with 80% AFUE and 96% AFUE natural gas furnaces see fossil fuel use reductions of 16% and 5%, respectively, after installing a meHP. When ccHPs are installed, these fuel usage reductions increase to 27% and 13% for 80% AFUE and 96% AFUE furnaces, respectively. Households with propane furnaces see average propane usage reductions of 36% and 40% after meHP installation for 80% AFUE and 96% AFUE furnace scenarios, respectively, and average reductions in propane usage of 58% and 48% after ccHP installation for 80% AFUE and 96% AFUE furnace scenarios, respectively. In general, the fossil fuel savings are correlated to electricity usage impacts because the electricity used by the heat pump for space heating is directly displacing fossil fuels that would have otherwise been used by the existing furnace. ccHPs provide larger reductions in fossil fuel usage for all regions when compared to meHPs, because ccHPs have lower economically optimal switchover temperatures.

As expected, GHG emissions reductions are higher for regions and equipment scenarios with stronger heat pump economic situations (lower electricity-to-fuel price ratios and, thus, lower economically optimal switchover temperatures). Households that use propane for heating see significant GHG emission reductions of 40-60%, depending on region and furnace efficiency. Households that use electric resistance for heating see slightly lower, but still significant, reductions between 35-55%. For households with natural gas heating systems, GHG emission reductions are quite variable across the Geographic Analysis Regions examined. Regions with very low natural gas prices see almost no reduction in GHG emissions, regardless of furnace AFUE, because the dual fuel switchover temperature is high, and the heat pump is seldom used for heating. Regions with favorable heat economics see reductions of 30-40% for both 80% and 96% AFUE furnaces. The regions with more intermediate natural gas prices only realize GHG reductions of between 4% and 22% in households with 80% AFUE furnaces and 2% and 10% in households with 96% AFUE furnaces.

Statewide-Level Impacts

When the estimated impacts of the Residential CAC Standard are aggregated across all affected Colorado households, the electricity and GHG emission savings are substantial. Each year, the Residential CAC Standard would reduce electricity consumption by 7 GWh and GHG emissions by 96,000 MT CO2e. Furthermore, households across the state would reduce their combined natural gas and propane usage by 14 million therms and would save $9 million per year on heating and cooling costs. As previously discussed, these benefits are not evenly distributed to all households in Colorado. Most households with natural gas furnaces see a modest added annual cost after installing a heat pump, but households with propane furnaces or electric resistance heating systems see large annual savings after installing a heat pump. The savings for these households are so large in aggregate that they overcome the added cost realized by all the natural gas households.

Table 4 shows the statewide impacts broken down by household existing heating system fuel for the meHP scenario. Impacted Colorado households with existing natural gas heating systems see aggregated heating and cooling utility bill savings of roughly $2.6 million per year, but these bill savings are outweighed by the incremental cost of installing a meHP instead of a meCAC. After accounting for heat pump incremental cost, these households see an annual total cost increase of $5.9 million. Households with propane heating systems realize large utility bill and total annual savings after installing meHPs and very significant GHG emission reductions. Households that use electric resistance for heating see over $10 million in annual total savings and see a 91 GWh reduction in annual electricity usage.

Table 4. Statewide Annual Impacts of the Residential CAC Standard, meHP Scenario

Fuel Type	Annual Utility Bill	Annual	Annual GHG Emission Reduction	Annual Change in Electricity	Annual Change in Fossil Fuel	Cost of GHG Emission Reductions

	Savings (M$)	Total Savings (M$)[3]	(MT CO2e)	Consumption (GWh)	Consumption (therms)	($ per MT CO2e)
Natural Gas	$2.6	-$5.9	59,600	66.6	-11,900,000	99
Electricity	$11.0	$10.1	20,680	-91.2	0	-488
Propane	$5.3	$4.7	15,880	17.5	-2,460,000	-296
Total:	$18.9	$8.9	96,168	-7.0	-14,360,000	-93

Table 5 shows the statewide impacts for the ccHP scenario. In this scenario, the annual total economic impact across all households in the state is negative $3.7 million, indicating an added cost to households. This change from total savings ($8.9 million in the meHP scenario) to a total cost (negative $3.7 in the ccHP scenario) is driven by the higher incremental cost of ccHPs compared to meHPs. ccHPs drive roughly 70% higher fossil fuel usage reductions and GHG emission reductions when compared to the meHP scenario, but the utility bill savings are not large enough to make up for the higher incremental cost (absent incentives that may apply to reduce the ccHP cost).

Table 5. Statewide Annual Impacts of the Residential CAC Standard, ccHP Scenario

Fuel Type	Annual Utility Bill Savings (M$)	Annual Total Savings (M$)[4]	Annual GHG Emission Reduction (MT CO2e)	Annual Change in Electricity Consumption (GWh)	Annual Change in Fossil Fuel Consumption (therms)	Cost of GHG Emission Reductions ($ per MT CO2e)
Natural Gas	$9.3	-$16.2	120,572	86.7	-21,460,000	135
Electricity	$12.0	$9.2	22,033	-98.4	0	-417
Propane	$5.0	$3.4	20,819	22.3	-3,290,000	-162
Total:	$26.3	-$3.7	163,420	10.6	-24,750,000	23

The estimated average cost of GHG emission reduction is roughly $100 per MT CO2e for households with existing natural gas heating systems and a meHP and $135 per MT CO2e for ccHPs. Thus, installing meHPs instead of meCACs in these households can produce GHG emission reductions at a cost that is lower or comparable to the social cost of carbon of $190 (EPA 2023). Households with propane or electric resistance heating systems have a negative cost of GHG emission reduction, which means these households both save money on an annual basis and reduce their carbon footprint.

Conclusions

If implemented in Colorado, a Residential CAC Standard would have a profound effect on the residential HVAC market, resulting in an estimated 80,000 additional heat pump

[3] Including incremental cost of heat pumps.
[4] Including incremental cost of heat pumps.

installations each year. This large acceleration in heat pump adoption would lead to significant reductions in GHG emissions for the residential building sector. Such significant growth of the heat pump market in Colorado could potentially lead to a transformation of the residential HVAC market, with more competition between heat pump installers and reduced project costs for households that install heat pumps.

The household economic impacts that would result from a Residential CAC Standard present a more nuanced picture. Roughly 20% of Colorado households, those with existing propane furnaces or electric resistance heating systems, would see a clear economic benefit if they install a heat pump instead of a CAC. These households could save upwards of $1,000 per year by using a heat pump for heating and cooling and should be encouraged to adopt heat pump technology regardless of whether a Residential CAC Standard is in place or not.

The other 80% of Colorado households, those with natural gas furnaces, would not realize a clear economic benefit if they install a heat pump instead of a CAC, unless they have access to incentives to reduce the upfront cost of the heat pump (assuming current natural gas and electricity prices persist)[5].

This analysis found that there are likely no significant technical or workforce barriers that would prevent the existing residential HVAC workforce from adapting to installing heat pumps instead of CACs. That said, the heat pump market in Colorado is currently small and is primarily concentrated in the Front Range region of the state. More heat pump-specific training opportunities for the residential HVAC workforce in the rest of the state would be important to keep heat pump installation quality high and bolster consumer confidence in the capabilities of heat pump technology.

Finally, the authors have several strategic considerations that may help with the success of a standard like this considered in other jurisdictions. While the proposed legislation ultimately was not passed in Colorado, the team believes that a standard like this could be a reasonable choice depending on the goals and political climate where it is being considered.

1) **Identify opportunities to create incentives for meHPs.**
   The most affordable heat pumps (meHPs) are not currently eligible for rebates or tax credits in most states or at federal level and determining which heat pump equipment is eligible for rebates is time consuming and confusing for both homeowners and HVAC contractors. Providing a $2,000 incentive to each household that installs a heat pump would ensure that almost all households benefit economically from the heat pump and making meHPs eligible for incentives would reduce prices for consumers and make it easier for homeowners and HVAC contractors to utilize incentive programs. Even with the meHPs being required by a standard, this would bridge the gap between their cost and the cost of CACs and provide cost efficient GHG reduction opportunities.

2) **Set an effective date for the standard that allows the market to prepare.**
   The HVAC contractors that were interviewed during this research effort primarily installed high performance heat pumps or ccHPs. Colorado utility rebate program usage data and market share data from Heating Air-Conditioning Refrigeration

[5] The authors considered the economic benefit of carbon reduction as a societal benefit, rather than an economic benefit accruing to individual participants. The authors did not report on the economic benefits of improved air quality or other non-energy benefits.

Distributors International (HARDI) support that most of the existing heat pump customer base in Colorado are choosing to install heat pumps with high or moderately high performance (i.e. not meHPs). If a Residential CAC Standard goes into effect, the residential heat pump market would likely expand significantly beyond this current customer base. Data from HARDI shows that approximately 70% of residential CACs sold in Colorado are low efficiency units, so most equipment that would be affected by the Residential CAC Standard would be low cost meCACs. To reduce upfront costs, households may prefer to install meHPs after CAC failures. An ample planning period would allow distributors to ensure meHPs and other low-cost heat pump options are in stock prior to any Residential CAC Standard implementation.

3) **EPCA preemption may pose legal hurdles for a Residential CAC Standard.** Multiple stakeholders indicated that a Residential CAC Standard is likely to receive legal challenges based on existing federal air conditioner efficiency standards. Such legal challenges could potentially prevent implementation of the standard or could delay implementation and create market confusion during protracted legal proceedings. Developing a legal strategy to prevent EPCA challenges could be important in case the state sees a legal challenge related to a Residential CAC Standard.

4) **Structure the Residential CAC Standard to apply to all residential CACs.** The Residential CAC Standard examined in this analysis would only apply to CACs utilized in one- and two-family dwelling units and townhouses. Thus, it would still be legal to sell CACs for use in residential building types that are not covered by the standard, potentially creating confusion for HVAC equipment distributors and retailers. It may be more effective to design a Residential CAC Standard to apply to all residential CACs below a nominal cooling output threshold. For example, the standard could apply to all CACs with rated capacity below 65,000 Btu per hour, regardless of the building type or size that the CAC will be installed in.

5) **Develop low-cost financing options for households that install heat pumps.** The incremental cost estimated for a meHP installation is $2,200, which can be a significant added financial burden for many households after they experience a CAC failure. Low-cost financing options would reduce this burden and would allow households to better manage the financial impacts of a Residential CAC Standard.

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