Energy Modeling and Analysis of Dual Fuel Heating Systems in Single Family Homes

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ABSTRACT

Although dual fuel heating systems are already commercially available, they are still considered an emerging technology. Dual fuel heating systems help customers to avoid using electric systems when they are inefficient or costly to operate. The study investigated the energy and utility cost savings potential of a dual fuel heating system (a split system with electric heat pump, natural gas-fired furnace, and smart thermostat) for single family residential homes in California, the barriers to adoption, and the prospects for the technology to align with statewide goals and incentive programs.

First, the study included subject matter expert (SME) interviews, which identified several aspects of dual fuel heating systems and control methodologies. Several factors which play a central role in determining switchover temperature, emissions reduction and energy savings were also identified. The study uses California's Database of Energy Efficiency Resource (DEER) single family building energy models, typical meteorological year weather, marginal utility rates, and marginal emissions factors to isolate heating end-use operating costs and associated emissions and analyze different dual fuel heating scenarios. The modeling of different scenarios allowed comparison of the annual emissions and operating costs outcomes across control strategies (switchover temperature and optimal). The results from the model focus on two (2) Title 24 climate zones where installing a dual fuel heating system would be the most advantageous in California.

This research will guide utilities, end users and manufacturers to determine how the dual fuel heating system can maximize both energy savings and carbon emissions reductions in the near term.

Introduction

Previous research highlights the fact there are many different pathways for reducing greenhouse gas (GHG) emissions in existing residential buildings (Liss and Rowley 2020). There are different emerging technology pathways which are feasible in the near term and more cost effective than whole building electrification. These include use of high efficiency natural gas equipment, dual fuel heating systems, and building envelope improvements.

Dual fuel heating systems contain an electric heat pump paired with a natural gas furnace, along with controls that select the optimal heat source. These systems offer flexibility to run the heating component (heat pump or a furnace) that is the most cost and emissions effective under the weather and/or grid conditions at a given time. In a dual fuel system, the electric heat pump

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or natural gas furnace is used as a primary source of heat depending upon the fuel prices and weather conditions. By reducing the number of hours that the furnace operates when conditions permit, a heat pump can run most efficiently and take advantage of grid electricity from clean sources. Thereby, the dual fuel heating system reduces the annual GHG emissions. Conversely, by operating the gas furnace at the coldest hours of the year and/or during the peak electric demand periods (thereby avoiding grid electricity from generation sources with greater emissions), the dual fuel heating system reduces operating costs and may reduce annual GHG emissions and/or electric peak demand. The dual fuel heating system provides a unique opportunity to use either the natural gas or the electric heat pump system when one of them is best suited to heat the space in terms of lowest operating cost and/or GHG emissions.

In a home with an existing gas furnace and central air conditioner, the conversion to a dual fuel heating system leaves the natural gas furnace connected to the natural gas supply grid. Figure 1 illustrates a schematic of central AC replacement by a heat pump. The heat pump uses the same ducts as the AC and provides cooling in summer and heating in winter. The gas furnace uses the same duct work when the heat pump is shut off.

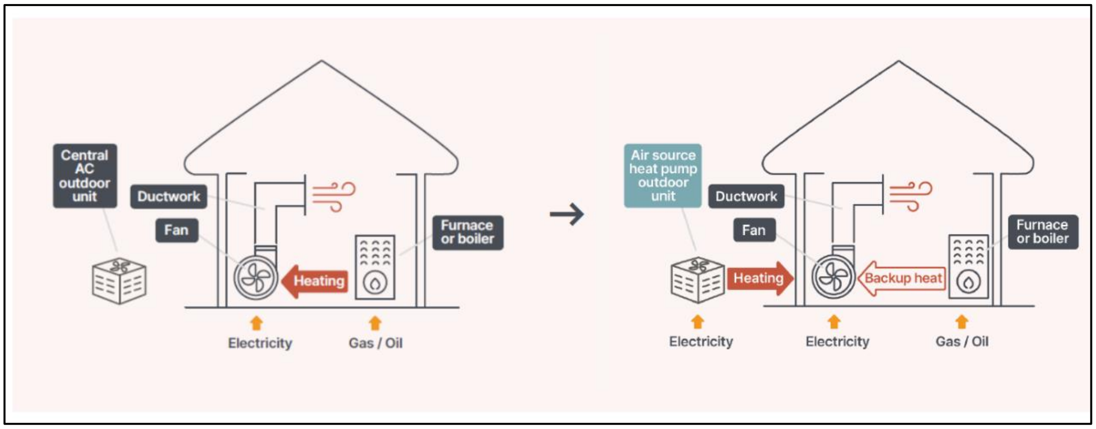

Figure 1: Illustration of central air conditioner replacement by a heat pump. Source: CLASP and RAP 2022.

Dual fuel heating systems can be implemented in a variety of configurations.

- Replacement of air conditioner with an electric heat pump and a controller to work with an existing central furnace.
- Central split system with replacement of existing central furnace with a more efficient one and the installation of new heat pump and a controller.
- Installation of a single or integrated split system.

The switchover temperature is the outdoor air temperature at which the operation of system switches to heat pump mode or to furnace mode. This switchover temperature can be based on outdoor air temperature, capacity constraints, pricing, and emission signals. Figure 2 illustrates how a heat pump with the same rated capacity performs differently as temperature decreases. Thus, dual fuel heat pumps can avoid electric heating demand during winter peaks (Margolies and Thayer, 2020).

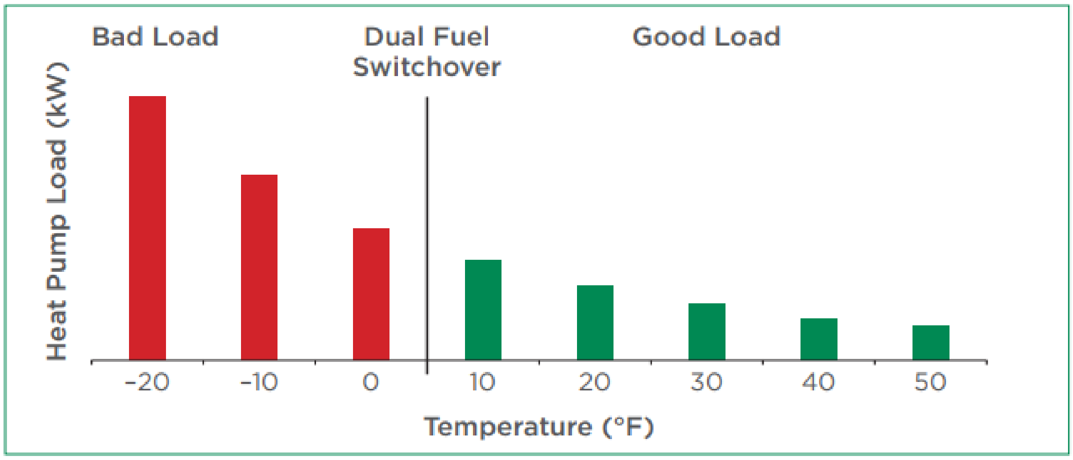

Figure 2: Switchover temperature in dual fuel heating scenarios (Source: Margolies and Thayer, 2020).

Research Objectives

- The primary objective of this research is to determine the technical feasibility of dual fuel heating technology for single family homes using EnergyPlus and spreadsheet analysis.
- The second objective is to gather more information about pre-qualifications for installing dual fuel heating systems, barriers and lessons learned from previous research projects or pilot programs via SME interviews.
- The current ratepayer cost effectiveness of such dual fuel heating systems is unknown. This research aims to determine the cost effectiveness of installing a dual fuel heating system in California, based on the Total Resource Costs (TRC) and Total System Benefit (TSB).
- The modeling of different scenarios and the spreadsheet analysis will analyze the impact of switchover temperature on total energy consumption and operating costs. Additionally, this will involve optimization of the switchover temperature for minimum annual site fuel usage, total operating costs, and source GHG emissions respectively.

Lessons Learned from Previous Studies

Several organizations have undertaken dual fuel heating research projects and below is a summary of the findings from those previous studies.

NEEA Study - Dual Fuel Heat Pump Market Research

The Northwest Energy Efficiency Alliance (NEEA) and its Natural Gas Team published a market research study on dual fuel heating and gas heat pump heating in residential and commercial markets in June 2023 (Lieberman Research Group 2023). The study highlighted that market demand exists for dual fuel heat pump technology. Some of the barriers to adoption of dual fuel heating technologies in residential applications from this study include lack of awareness about technology, residential buyer assumptions that this new HVAC technology will incur higher upfront costs, concerns over the reliability of dual fuel heating systems and HVAC contractors that are unfamiliar with installing these systems.

GTI Study- Assessment of Natural Gas Decarbonization Pathways in Colorado Residential Sector

Gas Technology Institute (GTI) published a report on available and emerging technology pathways for reduction of greenhouse gas emissions in Colorado's residential sector (Liss and Rowley 2020). The report discusses dual fuel heating technology as one of the emerging technology pathways. Complementing electric heat pumps with natural gas furnaces is a cost-effective peak shaving approach that helps avoid electric grid sizing impacts during very cold periods. The results of modeling a 1,660 sq. ft. Colorado home demonstrated that a dual fuel heating system results in lower peak electricity usage. The report also notes the reasons behind national consumer preferences for space heating with natural gas compared to electric. Beyond the cost effectiveness, consumers prefer natural gas heating because of its performance advantages. Homes heated with natural gas offer better indoor comfort because they deliver higher air temperatures and space heating set points are met more quickly as compared to electric heat pumps.

Dual Fuel Air-Source Heat Pump Monitoring Report, Michigan

The Michigan Electric Cooperative Association (MECA) Energy Optimization (EO) Program's heat pump pilot monitored the performance of eight (8) residential, centrally ducted, dual fuel air source heat pumps (Slipstream 2019). The study selected sites with a variety of heat pumps—single speed, variable speed and multi-speed systems backed up with propane furnaces. This study calculated the average COP and emissions savings over the study period for the installed dual fuel heating system vs. the standard gas furnace and AC unit. Emissions savings varied from 5% to 16%. The performance of dual fuel heat pumps in the study varies based on many factors including switchover temperature, system sizing, efficiency levels of equipment and type of rate structure (tiered or time-of-use based). The energy savings will be maximized with a high efficiency, variable speed heat pump that is sized and configured to operate at low temperatures.

Enbridge Gas, Canada

This study modeled a cloud based smart dual fuel switching system (SDFSS) of a residential dual fuel system with an electric heat pump and a natural gas furnace (MaRS Cleantech and Enbridge Gas Canada 2018). The fuel switching algorithm (i.e., the algorithm deciding whether natural gas furnace or electric heat pump will operate at a specific time), accounts for the following factors: Time-of-use (TOU) based electricity pricing, natural gas pricing, outdoor air temperature, capacity and COP of electric heat pump derived from the manufacturer’s data, efficiency of natural gas furnace and GHG emissions factors for electricity and natural gas.

The heating capacity of a heat pump drops as outdoor air temperatures drop. The ‘capacity balance point’ represents the outdoor air temperature when the rate of heat loss from the home equals the maximum rate of heat the heat pump can provide. Like heating capacity, the energy efficiency of a heat pump drops as outdoor air temperature decreases. The ‘economic balance point’ describes the outdoor air temperature at which the operation of natural gas furnace would yield the same operating cost as the heat pump.

Findings from SME Interviews

This study included SME interviews to gain insights on several aspects of dual fuel heating systems, pre-qualification characteristics, control methodologies, range of incremental costs and comfort characteristics. Nine stakeholders from different organizations (including manufacturing companies, utilities, non-profits, and research organizations) were interviewed during May-June 2023. A response rate of 82% and participation rate of 100% was recorded.

The following different types of dual fuel heating systems are identified with increasing system efficiency and incremental costs: single stage heat pump, multi-stage heat pump, variable speed heat pump and variable speed heat pump with cold climate capability. The following are some of the pre-qualifications required for the installation of dual fuel heating systems: visual inspection of ductwork, system configuration changes for thermostat wiring changes, sufficient space, and capacity for adding electrical load to the breaker box, and an identified location for an outdoor condenser.

The following parameters have significant impact on switchover temperature: outside air temperature, performance specifications of the natural gas furnace and electric heat pump, local utility rates for natural gas and electricity, grid emissions data and heating or cooling setpoint conditions. These factors play a central role in determining the energy savings and annual performance of a dual fuel heating system.

System Simulation Model and Methodology

Given the centrality of time-varying factors and controls in the annual performance of a dual fuel heating system, the current work adopts a time series modeling framework to inform the analysis of cost effectiveness of dual fuel heating technology. The purpose of the model is to evaluate the tradeoffs between emissions and operating costs for a given residence. The model was applied to investigate sensitivity to factors such as location (climate), emissions data source, rate tariffs, and control algorithm. The components of the modeling framework are a Building Energy Model (BEM), weather data, rate tariff and operating cost calculation method, GHG emissions factors, and control algorithm.

Assumptions

Table 1 shows the typical properties of the building energy model instances and data sources used in the analysis. The following subsections explain the choices.

Table 1: Properties of Building Energy Model (BEM)

Model assumption	Value
Building energy model	DEER EnergyPlus Single Family (Database of Energy Efficiency Resource Updates, California Public Utilities Commission)
Vintage	Median existing (circa 1975/1985 building energy code)
Size	Small (1-story / 1400 ft^2)
Gas furnace efficiency	95% AFUE
Heat pump efficiency	7.7 HSPF2 / 9.0 HSPF
Heating capacity	Auto-sized with 1.8 sizing factor
End-use load disaggregation	Heating and heating mode fan
Simulation time step	10 minutes
Cost and emissions calculation granularity	Hourly
Location/climate region	CEC Climate Zones 1-16, focus on CZ11 and CZ16
Weather data	CZ2022 ten-year (typical meteorological year)
Emissions source	2022 California Avoided Cost Calculator (ACC 2022) (Energy+Environmental Economics, 2022)

Building Energy Model and HVAC Efficiency

The current work uses a set of off-the shelf building energy models that represent variations on a detached single-family home, called the DEER residential prototypes which were modeled with EnergyPlus. The DEER residential prototypes are calibrated to annual end-use load data for each of the 16 CEC climate zones based on the results of the Residential Appliance Saturation Survey (California Energy Commission, 2020). This set of models includes variations for HVAC system type by climate zone, with instances served by gas furnace and air conditioning, and other instances with heat pump. There are also variations for single-story (small footprint) and two-story homes (large), east-west and north-south orientation, and HVAC efficiency levels.

The dual fuel heating system was not modeled directly in a building energy model. Rather, electric and gas fuel usage for dual fuel heating were synthesized in MS Excel after simulation by combining the time series outputs from two separate model instances, one with gas furnace and another with heat pump heating. Figure 4 illustrates the synthetic model structure. For consistency, all building features aside from the HVAC system are held constant between the two models. Furthermore, fuel usage for heating end-use and fan energy during heating operation were disaggregated from other building loads.

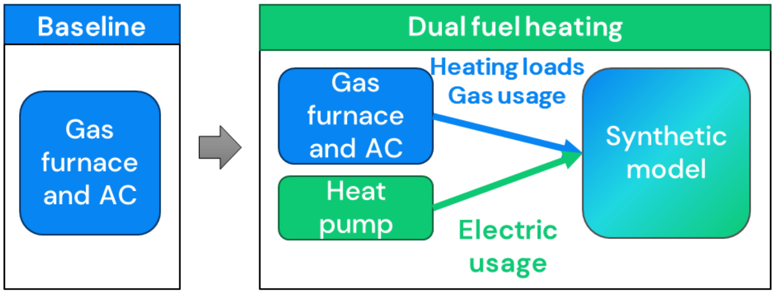

Figure 4: Synthetic building energy model for dual fuel heating.

The gas furnace was modeled at an efficiency of 95% AFUE with a variable speed motor. This efficiency level also would meet federal appliance regulations expected to come into effect in the near term. Although 95% is more efficient than the code minimum efficiency applicable when many existing furnaces were installed (around 80%), this assumption yields conservative estimates of the potential for emissions or operating cost reduction with the replacement of the AC with a heat pump.

The heat pump was modeled at an efficiency of 9.0 HSPF (7.7 HSPF2), which is slightly above the code minimum for split system central heat pumps (7.5 HSPF2) and packaged heat pumps (6.7 HSPF2). In the DEER residential prototypes and in the measure SWHC049-03. Residential HVAC, the 9.0 HSPF heating efficiency level is paired with a 16 SEER (15.2 SEER2) cooling efficiency and a variable speed fan, so it is a good candidate to pair with the modeled gas furnace.

Climate Zones and Weather Data

Simulation was performed using CZ2022 weather files for the weather station associated with each of the 16 CEC Climate Zones. The weather files represent a typical meteorological year, developed using ten years of weather data. This dataset is mandated for use in certain applications for building energy modeling in California, including code compliance and ratepayer funded incentive programs.

Climate Zones and Rate Tariffs

Customer operating costs were modeled as a function of building location (climate zone), having electric and gas utility service from the predominant service provider for the climate zone. For most scenario analyses, the cost of electric service can be calculated using the current default residential rate tariff as a function of electric utility. An alternative rate tariff was highlighted as a potential additional comparison, based on engineering judgment. (For a given climate zone, refer to the subsection **Error! Reference source not found.**.) Table 2 summarizes t he default tariffs by utility, as well as an alternative rate tariff selected for purposes of comparison.

Table 2: Default Electric Rate Tariff by IOU

IOU	Default Electric Rate Tariff	Comparison Electric Rate Tariff
PG&E	E-1: Residential Services	E-TOU-C: Residential Time-of-Use Service
SCE	D: Domestic Service	TOU-D-4-9PM: Time-of-Use Domestic
SDG&E	TOU-DR1: Residential Time-of-Use	DR: Domestic Service

Default residential natural gas tariffs were used from PG&E, SoCalGas, and SDG&E as listed in Table 3. Each month's cost of natural gas, the average cost per therm, and marginal cost per therm can be calculated.

Table 3: Default Gas Rate Tariff by IOU

IOU	Default Electric Rate Tariff
PG&E	G-1: Residential Service
SoCalGas	GR: Residential Service
SDG&E	GR: Domestic Natural Gas Service

Table 4 shows two of the CEC climate zones out of 16, that were selected based on relatively high heating degree days and large differences, in terms of emissions and annual operating costs for heating, between gas furnace and heat pump operation modes.

Table 4: Predominant PA to Use for Statewide Savings Analysis

CA Climate Zone	Electric service attributes		Gas service attributes	
	Utility	Average rate ($/kWh)	Utility	Average rate ($/therm)
CZ 11	PG&E	$0.387	PG&E	$1.750
CZ 16	SCE	$0.331	SCG	$1.539

Operating Cost Calculation Method

Because the default rate tariffs have a tiered structure, utility bill calculation using the exact or full rate tariff definition only applies to models that yield the whole-building hourly loads. In particular, the operating cost for a customer contributed by a single building system in isolation from the rest of the building, such as HVAC, cannot be calculated using the full rate tariff because without the whole building usage there is not enough information to determine the ultimate price tier that the customer pays for each unit of energy.

For the current work, to mitigate the issue of sensitivity to the usage of the single, representative building model for select applications (involving only the heating system load, and/or incremental changes in usage, and/or requiring an hourly price signal), simplified rate calculations were prepared. In the analysis of heating operating costs, where only the heating end-use load is modeled and the remaining building loads are omitted, the simplified rate calculation for marginal hourly costs was used in place of the full rate tariff.

GHG Emissions Factors

To evaluate and optimize source fuel usage or greenhouse gas emissions (GHG emissions), GHG emissions factors from available data sources were reviewed. These factors were a necessary assumption used to convert from site energy usage into CO2e emissions (ENERGY STAR®, n.d.). GHG emissions factors consider not only combustion emissions but also transmission and distribution losses.

The 2022 ACC provides hourly time-series emissions factors developed through analysis as required by California Public Utilities Commission (CPUC,) like the time-series factors used for simulation-based building energy code compliance software in California (Energy+Environmental Economics, 2022). The ACC is used for evaluating cost-effectiveness of CPUC-regulated energy efficiency and demand response programs (California Public Utilities Commission, 2022). The ACC hourly factors are made available as a lookup table that varies by utility, hour of the year, and year. The year-on-year changes reflect projections regarding the annual grid load, new generation, and fraction of renewable generation in the grid following the state’s renewable portfolio standards requirements.

Control Algorithm

To allow for efficient optimization of heating controls in the energy model for a dual fuel heating system, the current approach is to simultaneously model two different operational modes of the measure case HVAC system: one in which the gas furnace is operating alone, and another in which the heat pump is operating alone. Each operational mode is simulated in its own building energy model. A combined, dual-fuel system was then synthesized from these two models by switching between the two modes of operation at each time step, using a heating mode control signal. The heating mode control signal is either the output of a control algorithm, or for purposes of optimal performance analysis, a free variable subject to optimization. With switching controls, the signal will be a Boolean value representing furnace or heat pump. The control system can be considered to be a function of input signals for outdoor temperature, gas emissions and marginal electric emissions, and fuel prices. A switchover temperature controller was modeled to represent a conventional control algorithm that toggles between modes based only on temperature, with a dead band and/or timeout to avoid short cycling the heat pump.

Analysis

Using the dual fuel heating model, analysis of hourly trends, control strategies, and parametric studies are performed.

Hourly Trends for Heating Load and Electric Emissions Factor

To examine the interplay between hourly profiles of heating loads and emissions factors, the furnace natural gas use from the EnergyPlus model data was used to determine the average daily heating load shape for the winter season. Similarly, the grid electric emissions factor using the ACC data for each hour was calculated to show the seasonal emissions profile. Figure 5 and Figure 6 show the trends of ACC emissions profile and winter heating load shape for each climate zone[2] (11 and 16, respectively). The yellow box highlights the hours for peak heating load. As expected, peak heating loads occur in the morning. Based on thermostat and load schedules within the model, CZ 11 shows a secondary heating peak in late evening. CZ 16 lacks a secondary peak, but its heating load steadily increases starting around 9 PM.

It was observed in control outputs optimized for minimum emissions that during morning peak heating loads, heat pump operation mode is usually preferred for single family heating applications. This is also supported by the observation that when heating load hits a peak, the emissions factor is not at its highest.

Since electric emissions are at a secondary peak during the peak heating, heat pump operation is preferred almost all the time when the controls optimize for emissions reduction. The emission savings for the dual fuel system are between 0-5% indicating that the gas-furnace is almost never preferred to minimize emissions. However, since the cost of natural gas in California is low relative to electricity, gas furnace operation is always preferred when the control optimizes for lowest fuel cost. Although the data shows heat pump operation is preferred to minimize emissions, the data also points to potential future electric grid constraints and changes to the forecasted emissions profile in the winter morning hours as more homes in California electrify. It also shows potential for a strategy to pre-heat a home in the early hours of the morning to reduce this heating load peak much like precooling a building in the early afternoon reduces the late afternoon/early evening cooling load peak. Unlike precooling, which is done before peak temperatures (in the summer), a preheating strategy would typically increase overall heating energy consumption due to shifting load towards more extreme temperatures.

Since the simulation results did not show an ‘economic balance point’ or ‘emissions balance point’ as expected, additional analysis was undertaken to examine at what gas-electric cost ratio would there be an emissions balance point. Additionally, analysis was undertaken to assess the impact of a carbon emissions credit on consumer overall operating costs for a dual fuel system if the consumer chose to run their system in heat pump mode to gain the emissions credit.

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[2] Climate zone 16 is in the mountains in Northern California and has 4403 HDD, Climate zone 11 is in the Sacramento Area and has 2742 HDD.

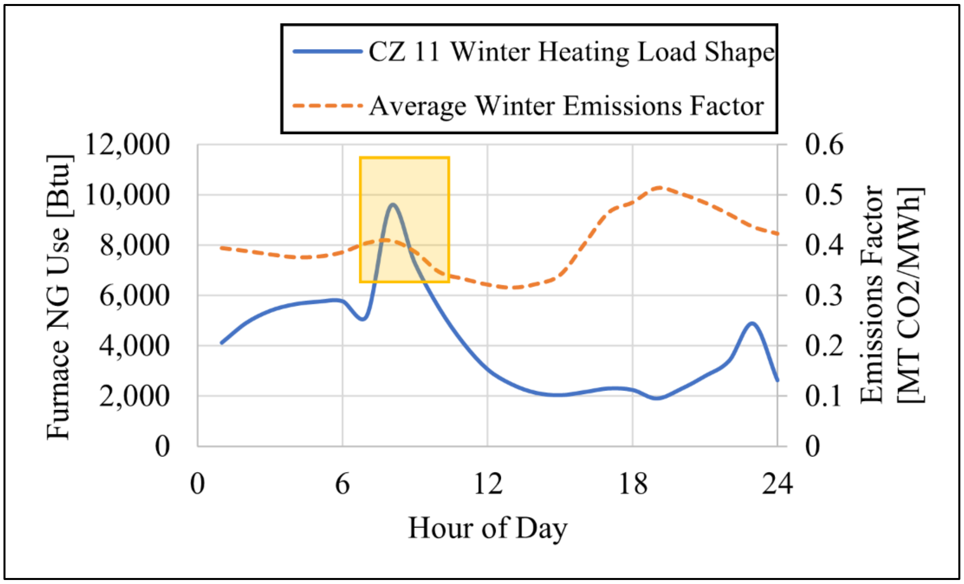

Figure 5: Emissions factor profile and heating load shape, CZ 11

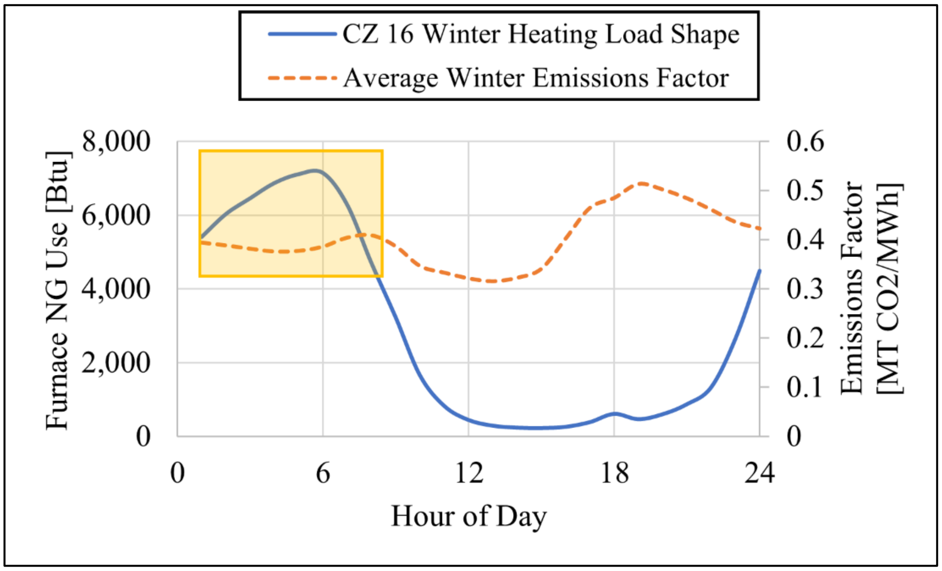

Figure 6: Emissions factor profile and heating load shape, CZ 16

Annual Outcomes from Switchover and Optimal Controls

Figures 7 and 8 show the locus of feasible outcomes for annual operating cost and emissions due to heating in CZ 16 and CZ 11. The figures compare the outcomes that can be achieved via switchover temperature control strategy and by optimal control (Pareto front).

The inflection of the Pareto front between the minimum cost and minimum emissions points, in Figure 7, indicates the potential for savings beyond the straight line connecting solo gas furnace to solo heat pump. For illustration, at the midway point of emissions (along the vertical line), the minimum operating cost on the Pareto front is less than the average operating cost on the straight line. This inflection also indicates that the incremental cost per unit emissions reduction (relative to solo gas furnace) is low for a small amount of emissions reduction, and the incremental cost becomes higher as emissions approaches their minimum value.

Potential outcomes from static switchover temperature controls vary based on the switchover temperature setpoint. As the setpoint increases, the operation transitions from solo heat pump operation approaching solo gas furnace. Note that at 50% relative emissions reduction (about 0.355 metric tonnes/year), the annual operating cost for the Pareto optimal point is substantially lower than that for the switchover temperature controls. Furthermore, the switchover temperature controls may achieve results near the minimum emissions point, but do not achieve 100% feasible emissions reductions. Seeing the potential for reducing operating costs, a later section discusses the design and performance of controls that are informed by the cost and emissions minimization results. Note that in terms of percentage savings, there is less potential for the controls to create variation in emissions (18%) than there is in potential to cause variation in costs (50%) under this scenario shown in Figure 7.

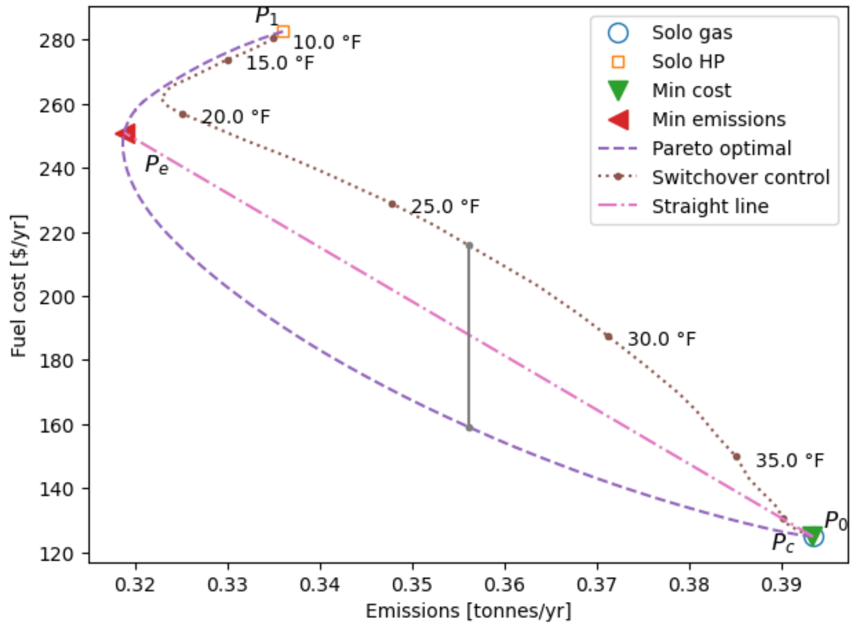

Figure 7: Pareto optimal front, CZ 16, flat rate electric tariff (Note: gray bar is 50% emissions reduction point.)

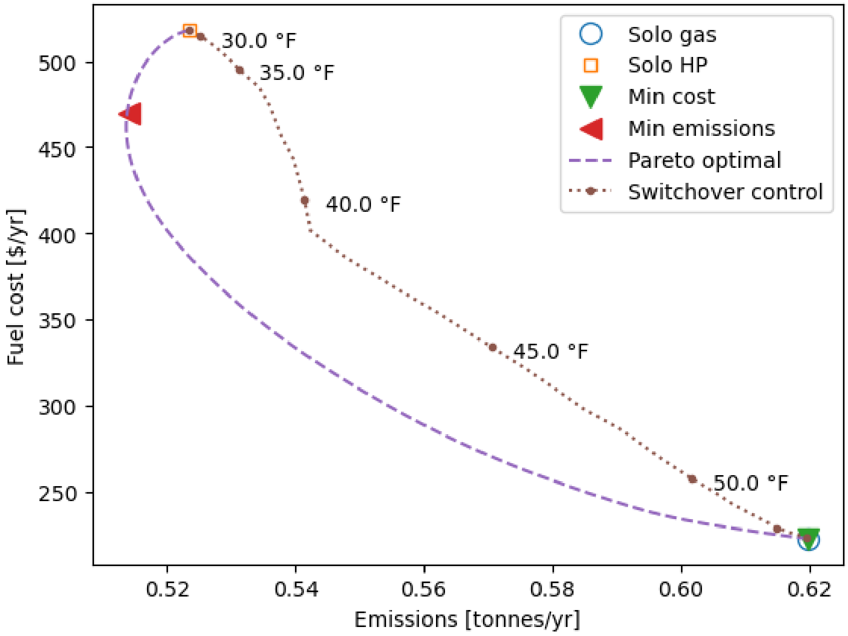

Figure 8: Pareto optimal front, CZ 11, flat rate electric tariff

For TOU electric tariffs (not shown here), the cost-emissions trends are similar to those for flat rate electric tariffs. This suggests that the weather and GHG emissions factors are more significant in determining the inflection characteristics of the tradeoff, while rate tariffs determine the slope between solo gas and solo HP points.

Parametric Analyses

While the previous section assumed the present rate structures for electric and gas residential service, this section treats customer economics as a parametric variable and considers the impact on the results as the costs are varied for Climate Zone 16. Figure 9 shows how the Pareto front evolves as the electric operating costs are scaled by a multiplier relative to current electric rates, uniformly across all hours of the year. Figure 10 shows how the Pareto front evolves as a hypothetical emissions cost credit varies. In other words, assume the customer is granted a credit per unit emissions reduction ($/Metric tonne (MT) of CO_2 reduced) relative to a gas furnace baseline. The amount of credit is varied to study the impact on the customer economics.

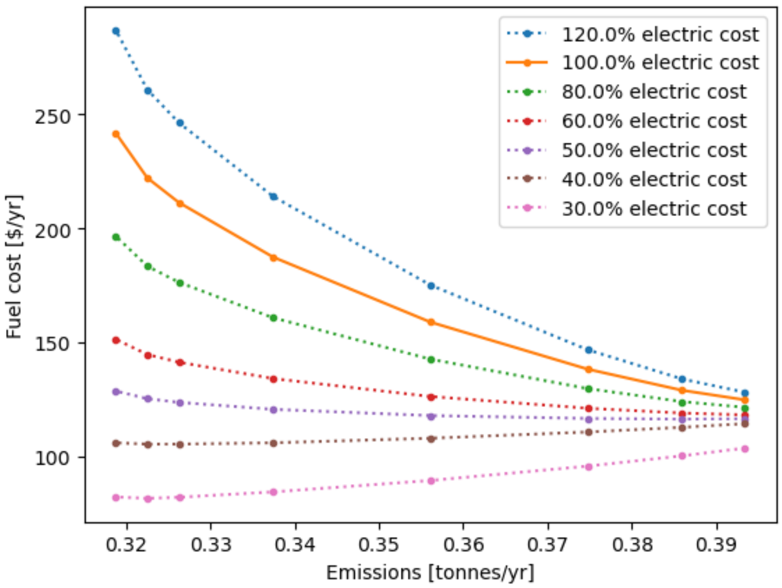

Figure 9: Parametric variation of electric costs, CZ 16, flat rate electric tariff

If electric costs are reduced relative to current gas costs, the annual operating cost flattens out. At 80% of present electric-to-gas cost ratio, there is a modest cost premium (~ 17%) to achieve 50% of emissions reduction potential. At 60% of present electric rate- to gas cost ratio, there is a smaller cost premium (~ 7%) to achieve 50% of emissions reduction potential. The current electric-gas ratio would need to be reduced by 55% to achieve a 100% emissions reduction with no increase in operating costs.

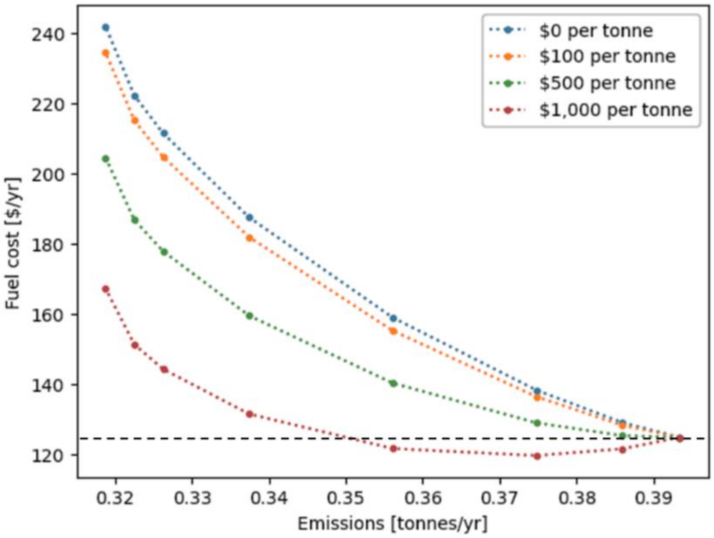

Figure 10: Parametric variation of emissions reduction credit, CZ16, flat rate electric tariff

At a credit of $100/tonne, the customer faces an operating cost premium equal to 24% in order to achieve 50% of emissions reduction potential, compared to 27% premium without the credit. At a credit of $500/tonne, the operating cost premium for the same goal is only 12%. For comparison, within the California Cap and Trade program (which would not be applicable to this customer class), cap and trade credit is approximately $38.73/tonne as of 2023Q4.

Cost Effectiveness Analysis

The Cost Effectiveness Tool (CET) is used to determine the Total System Benefit (TSB) and Total Resource Cost (TRC) for dual fuel heating technology in selected climate zones in California (CPUC, 2021). The replacement of an existing air conditioner with an electric heat pump and addition of a controller to work in parallel with an existing natural gas furnace is considered as a proposed measure for this analysis. Table 5 indicates average TRC and TSB values for both the selected climate zones in California. It is commonly understood that often emerging technologies have lower TRCs and TSBs when they are first adopted into programs since they do not have the benefit of economies of scale. The average TRC and TSB values of CZ 11 are higher than CZ 16. This can be attributed to the difference in operating hours of the natural gas furnace. Note that this comparison is done for Normal Replacement measure application type.

Table 5: Average TRC and TSB values- Climate Zone Comparison

CA Climate Zone	Average TRC	Average TSB
CZ 11	0.6	$208.48
CZ 16	0.5	$107.37

Conclusions

The SME interviews indicate that major barriers in implementing dual fuel heating systems are lack of sophisticated control methodology or innovative thermostats, lack of availability of skilled contractors, and supply chain barriers. In California, the lowest operating cost is always met with the gas furnace and the lowest emissions are usually met with the electric heat pump. In other words, there is not an ‘economic balance point’ or an ‘emissions balance point’ so a dual fuel system operating in a mild climate with a high electric to gas price ratio and a ‘greener’ electric grid yields limited value in terms of optimizing emissions and operating costs. The operating cost of a dual fuel system is between 69%-144% more than a solo gas furnace system. The emissions savings of a dual fuel system are between 0%-5% of the emissions from a solo heat pump system. However, the hourly heating load and emission factor trends indicate potential future electric grid constraints and changes to the forecasted emissions profile in the winter morning hours as more homes in California electrify. The impact of rate ratios and hypothetical emission reduction credits on energy and emissions savings of dual fuel heating systems is analyzed. The current electric-gas ratio would need to be reduced by 55% to achieve a 100% emissions reduction for CZ 11 with no increase in operating costs. At a carbon credit of $100/tonne, (which is three times the California Cap & Trade Credit) the customer faces a 24% cost premium to achieve 50% of the emissions reduction potential. The Cost Effectiveness Tool (CET) is used to determine the TSB and TRC for dual fuel heating technology in selected climate zones of California. The average values of TRC and TSB of CZ 11 are higher than CZ 16. The average values of TRC are 0.6 and 0.5 for CZ 11 and CZ 16 respectively. Also, the average values of TSB are $208.48 and $107.37 for CZ 11 and CZ 16 respectively.

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