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WHITE PAPER

Dual-fuel technology balances the residential electric HVAC equation

Considering the merits of dual-fuel heat pump and gas furnace technologies as an enabling strategy along the path to HVAC decarbonization and electrification

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Abstract

Reducing greenhouse gas (GHG) emissions in residential HVAC equipment and/or applications is a goal shared by consumers, industry stakeholders, regulators and environmental organizations. According to the U.S. Department of Energy (DOE), the residential sector accounts for 21% of total U.S. energy **consumption** — **52** percent of which is consumed on space heating and cooling.

Historically, electric AC units and fossil fuel-powered heating systems have comprised the bulk of these legacy HVAC technologies. But a transition to lower-emissions alternatives is underway. The adoption of electric heat pumps is widely considered one of the most impactful choices for HVAC equipment in helping to enable the long-term decarbonization of residential HVAC footprints.

Along the path to electrification and decarbonization, dual- fuel heat pump technology is being explored as an enabling, eco-friendly stepping stone, capable of bridging the gap between today's HVAC equipment installed base and the carbon-neutral footprint of the future. Dual-fuel heat pump technology relies on a combination of electric heat pumps and fossil fuel-based furnace technologies, similar to hybrid vehicles prevalent in today's automotive industry.

Within the HVAC community, a debate is brewing about the proposed migration to going all-electric using heat pumps. Evidence suggests that **electrification alone** may not achieve decarbonization targets within expected time frames — and may place significant economic burdens on consumers and unprepared electrical grids. Today, OEMs offer a variety of dual-fuel heat pumps to help consumers balance cost, comfort and environmental considerations..

Recent research conducted at The Helix Innovation Center has examined many variables of the electrification and decarbonization equation in the HVAC sector, including sustainability impacts (GHG emissions), regional effectiveness, and numerous consumer and/or market drivers. This white paper presents data that makes a case for the adoption of dual-fuel heat pump technologies as a necessary intermediate step toward an all-electric, heat pump-only approach.

Objectively planning for the future of HVAC

As countries, companies and consumers set their sights on decarbonization of space and water heating in commercial buildings and residential homes, electrification is often viewed as an essential strategy for achieving these goals. In the residential HVAC sector, electric heat pumps are widely perceived as the best case for phasing out fossil fuels while maintaining — or even enhancing — the desired levels of comfort heating and cooling. As is the case with many technological or market shifts, the path to HVAC electrification may be most effectively achieved via incremental, phased steps leading to the desired long-term objectives.

Within industry organizations and the equipment supply chain, the viability of moving forward with a proposed one- size-fits-all, all-electric heat pump strategy is being closely examined. Balancing decarbonization targets with application effectiveness and consumer needs requires a thoughtful evaluation of a full spectrum of technological considerations and application barriers, including:

- Relative grid cleanliness and/or readiness within specific regions
- Regional climates and their specific heating and cooling load requirements
- Actual GHG emissions (electricity vs. natural gas)
- Emerging availability of renewable natural gas
- Cost considerations (first and lifecycle)
- Consumer comfort

In fact, without objective examination of all possible variables, the migration to an all-electric HVAC approach may result in many unwanted, unintended — even counterproductive — consequences:

- Production of higher GHG emissions where the grid relies on traditional, non-renewable power generation
- Inability to meet comfort and/or load requirements in colder climate zones
- Increased and unintended costs of migration

ASHRAE classifies the continental U.S. into six distinct regional climate zones — with wide ranges of seasonal temperature and relative humidity — which impact cooling and heating loads. From a historical perspective, traditional HVAC technologies and regional solutions have evolved to meet the unique characteristics of each climate zone, including electric AC units and fossil fuel-powered space and water heating systems.

These regional considerations should also play a deciding role in the migration to lower-emissions HVAC and heat pump technologies.

Decarbonizing the residential HVAC carbon footprint

Decarbonization of residential HVAC starts with understanding legacy technologies and their relative contributions to GHG emissions. Based on data from the U.S. Energy Information Administration (EIA) used in our research calculations, from a total energy consumption standpoint, comfort heating, comfort cooling and water heating account for 34%, 11% and 17%, respectively.

All of U.S. residential dwellings	Comfort heating	Comfort cooling	Water heating	Refrigerators	Other	Total
Electricity	10%	11%	9%	5%	31%	65%
Natural gas	19%		7%		2%	27%
Propane	2%		<1%		<1%	3%
Fuel oil/kerosene	4%		<1%		<1%	4%
Total	34%	11%	17%	5%	33%	100%

Figure 1: GHG emissions by energy source and equipment type

It's essential to consider total GHG emissions from these applications, including the direct emissions from fossil fuel consumption and the indirect emissions from the combustion of fossil fuels needed to generate electrical power at the grid.

- Air conditioning produces indirect emissions (i.e., power consumed from the grid) and is an already electrified technology.
- Comfort heating produces both direct and indirect emissions because it relies on a combination of electricity and fossil fuels (i.e., natural gas, propane and heating oil).

Among the comfort heating technologies used in the U.S. residential home sector, ducted furnaces are installed in 69% of homes, accounting for 72% of total GHG emissions*. Natural gas is used to fuel 47% of these homes, contributing to 45% of GHG emissions. Lesser-used heating technologies include ducted heat pump, boiler, electric baseboard and floor/wall heating. The application of specific technologies varies widely by region (e.g., boilers are prevalent in the Northeast region).

Percentage determined from the data provided at https://resstock.nrel.gov

U.S. Residential single-family home space heating technology, architecture	U.S. totals			Space heating fuel source							
				Electricity		Natural gas		Propane		Heating oil	
	# of homes	% of homes	GHG%	% of homes	GHG%	% of homes	GHG%	% of homes	GHG%	% of homes	GHG%
Ducted furnace	55,320,685	69%	72%	14%	15%	47%	45%	6%	7%	3%	5%
Ducted heat pump	7,919,086	10%	7%	10%	7%						
Boiler (water or steam)	5,549,714	7%	10%	<1%	<1%	3%	4%	<1%	<1%	3%	6%
Baseboard	3,415,086	4%	7%	4%	7%						
Floor/wall	3,015,542	4%	4%			3%	3%	<1%	<1%	<1%	1%
Other fuel	3,119,086	4%									
None	1,236,114	2%									
Total	79,575,313	100%	100%	28%	28%	53%	53%	6%	7%	7%	12%

Figure 2: GHG contribution in residential home space heating by number of homes and fuel source

Variables that impact decarbonization via electric heat pump implementation

Electric heat pumps are widely promoted as the most effective solution for decoupling from the historic reliance on fossil fuels for comfort heating. Although the trend toward electrification is well-intended, current realities present many challenges and barriers to applying a prescriptive, all-electric heat pump approach.

Grid readiness and/or cleanliness

Due to indirect GHG emissions generated by powering electric heat pumps, the local grids used by homeowners first must be sufficiently clean and stable to support decarbonization. In fact, if a local grid is not clean, GHG emissions from all-electric heat pumps may be potentially higher than a traditional fuel- burning furnace. A clean and reliable grid must consist of sufficient renewable resources and an infrastructure capable of supporting widespread electric heat pump adoption. Currently, California, New York and Vermont have updated grids that are cleaner than the national average.

Regional climate zones and consumer comfort requirements

From a regional perspective, annualized temperature profiles greatly impact the efficacy of electric heat pump implementation. Existing homes in cooler regions — such as those in climate Zones 4 and 5 — have higher annual heating loads than standard electric heat pumps can adequately support.

During cold months, homeowners have observed that standard electric heat pumps may be unable to provide sufficient comfort levels. When they can only produce maximum air temperatures that are lower than average body temperatures (98.6 °F), heat from electric heat pumps in these cold conditions does not produce adequate comfort levels. When the heating load exceeds the capacity of the electric heat pump in low temperatures, the heat pump stops running, and auxiliary electric strip heating switches on to meet the increasing heat load. During auxiliary heating mode, the blower fan runs at a high speed, which can increase the airflow rate to a level that is typically higher than the ductwork can support and reduces the overall performance of a heat pump system. This use of electricity for auxiliary heating in regions with lower temperatures results in significantly higher levels of indirect GHG emissions.

First and lifecycle costs

The costs to migrate to an all-electric heat pump footprint may place excessive financial burden on consumers. At a minimum, most older homes will likely need to upgrade their electrical panels, which can cost between $5,000–10,000. In some cases, a new meter and transformer may be required, increasing the total cost of the electrical upgrade alone to as high as $30,000. In addition, poor insulation R-values will remain a barrier to the efficiency of any heating strategy, especially in older homes. As a result, excessive electricity use may increase lifecycle costs from 25–30 percent in Zones 4 and 5, based on some estimates. Although incentives are available to offset first costs, they are unlikely to relieve the burden placed on consumers entirely.

When calculating decarbonization, installing an all-electric heat pump may not always result in the most favorable GHG reductions. In some cases — where grid-supplied power has a high CO_2 equivalent, the price of natural gas is low, and annual temperatures are on the lower range — a fossil fuel-powered furnace will not only be the more affordable option, but it could also result in producing fewer GHG emissions (*see Figure 5*).

In addition, in regions where electricity rates are higher than the cost of natural gas, an all-electric heat pump strategy could result in higher first and operating costs. Conversely, if consumers use fuel oil or propane, an all-electric heat pump may be less expensive to operate. Regardless, technological advancements are enabling heat pumps to maintain comfort in in lower ambient temperatures (i.e., zones 4 and 5), but these cold climate-capable systems cost more than standard heat pumps.

Dual-fuel heat pump configurations

A dual-fuel comfort heating solution offers an incremental approach for addressing the near-term challenges to all-electric heat pump adoption. As the electrical grid and market conditions continue to improve over the coming decades, dual- fuel heat pumps can overcome cold climate comfort limitations while delivering lower-GHG emissions in nearly all regions and current grid conditions.

This solution relies on the combination of an electric heat pump supplemented by a traditional fossil fuel-powered furnace. As Figure 3 illustrates, the two primary dual-fuel heat pump configurations include:

- **Independent operation** — The heat pump provides 100 percent heating until the outdoor ambient temperature drops and exceeds heat pump capacity. When the heat pump turns off, the gas furnace turns on (i.e., heat pump and gas furnace never operate at same time).
- **Concurrent operation** — The heat pump operates 100% of the time until the outdoor ambient temperature drops and exceeds the heat pump's capacity to meet the heating load. The heat pump continues to operate while the gas furnace supplements the heating load of the home (i.e., both technologies always operate concurrently when the heating load exceeds the heat pump's capacity).

Based on the ambient temperature, these dual-fuel heat pump configurations rely on each fuel source to varying degrees to manage associated home heating load demands (*see Figure 4*).

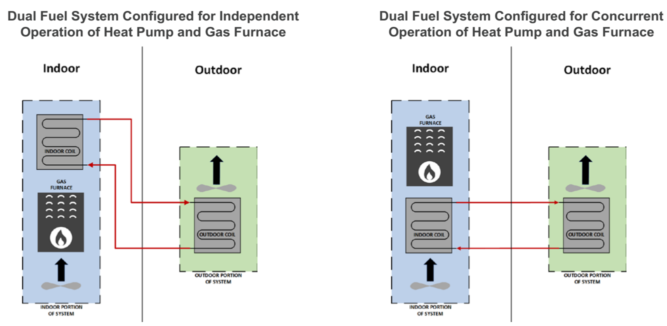

Figure 3: Independent versus concurrent dual-fuel heatpump system configurations

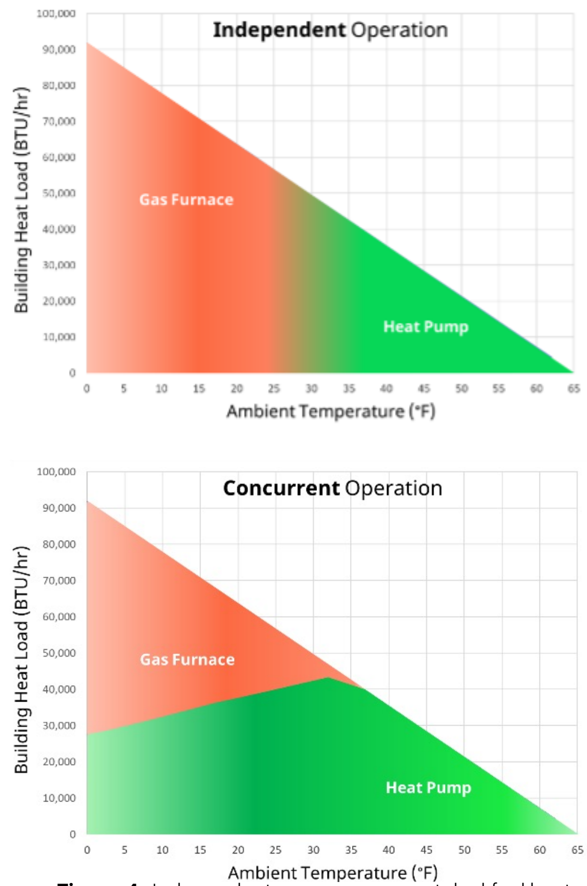

Figure 4: Independent versus concurrent dual-fuel heat pump, home heating load management strategies

In each configuration, the dual-fuel heat pump system offers the best of both current technologies to create an optimal solution — typically without requiring an electrical upgrade by the homeowner. However, it is important to understand that a dual-fuel heat pump solution should not be designed as two separate entities, but as one integrated system that seamlessly leverages two technologies. OEM system designs must leverage controls capable of managing loads and coordinating the operation of one fully integrated system.

Dual-fuel advantages: Decarbonization, cost and comfort

When compared to an all-electric heat pump or an all-gas furnace system, a dual-fuel heat pump solution can offer improvements in GHG emissions, lifecycle costs and comfort. GHG emissions in all climate zones are significantly reduced, with independent operation offering an attractive combination of affordability, availability and decarbonization potential, particularly in areas with a clean grid. Concurrent operation could further advance the decarbonization of dual-fuel heat pumps; however, technology challenges make it less likely to be commercially available than independent systems.

Migration to a clean grid composed of sufficient renewable resources will take time and change the GHG emissions potential over the lifespan of a dual-fuel heat pump. Thus, the scope of our research captured the current state of grid emissions, as well as a projected 12-year, long-term view across the most populated regions and ASHRAE climate zones.

State comparison: Short-run grid emissions

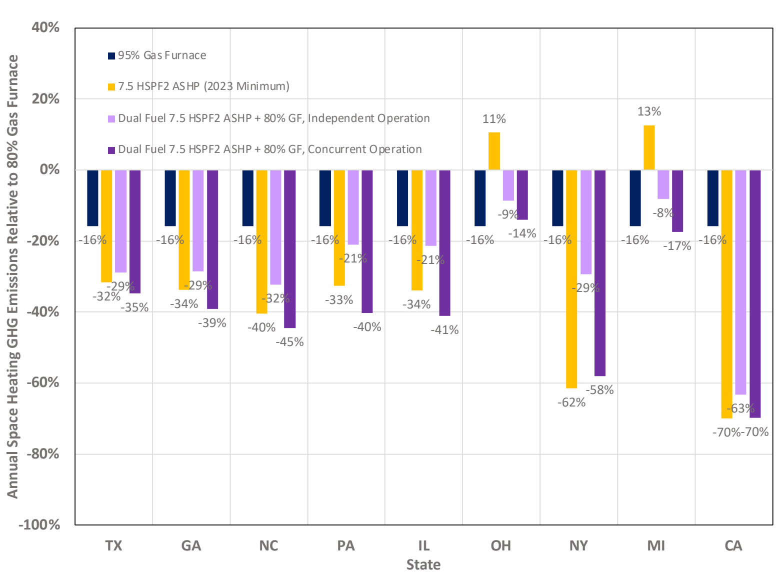

Figure 5: Short-run GHG emissions per residential home heating in states with the highest single-family homes, relative to an 80 percent gas furnace.

State comparison: Long-run grid emissions (12 years)

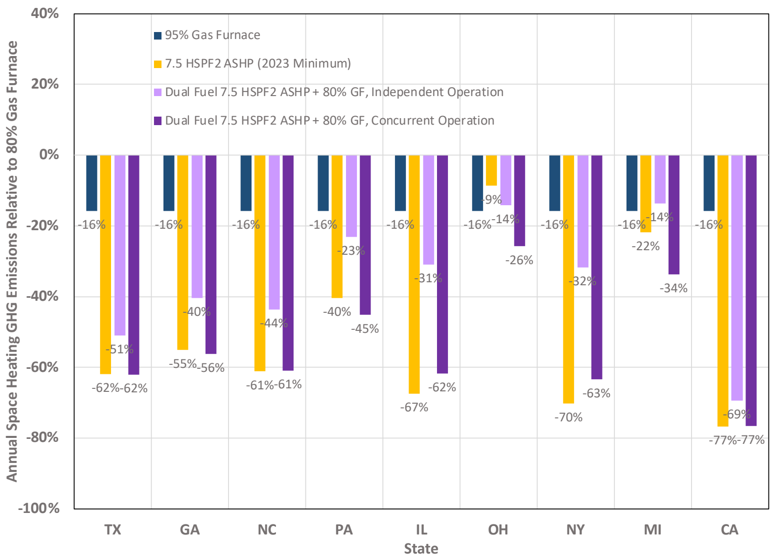

Figure 6: Long-run GHG emissions per residential home heating in states with the highest single-family homes, relative to an 80 percent gas furnace.

In California and New York, where the grid is cleaner than the national average, dual-fuel heat pumps still deliver significant short- and long-run GHG reductions among available options — with their decarbonization increasing as the grid becomes cleaner over the long term (*see Figures 5 and 6*). In colder regions (Zone 5), an all-electric heat pump currently results in higher GHG emissions than an 80 percent and 95 percent gas furnace. *Note: Heating requirement assumptions are based on the AHRI 210/240 heat pump rating standard. In addition, a dual-fuel heat pump approach delivers comparable GHG emissions reductions in every climate zone in the U.S. (see Figures 7 and 8).*

In all zones, an independent or concurrent dual-fuel approach better balances the needs of consumer first costs, environmental regulations and decarbonization goals, delivering optimal improvements in all categories for all stakeholders. Although concurrent systems aren't readily available today, OEMs are working to overcome their application challenges. In doing so, concurrent dual-fuel systems will provide the equivalent decarbonization potential as an all-electric heat pump approach across the long term.

When combined with incentives and/ or rebates in participating regions and the abatement of $50/metric-ton GHG (the estimated social cost of carbon), consumers can potentially achieve a return on investment in less than five years (depending on state, region or climate).

By converting a fossil-fuel burning furnace to a dual-fuel heat pump configuration, fossil-fuel usage decreases significantly (*see Figure 9*).

Regional comparison: Short-run grid emissions

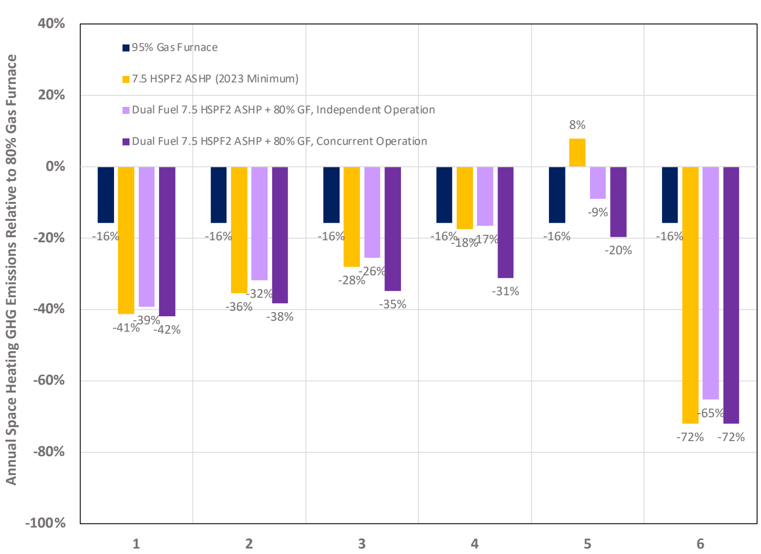

Figure 7: Short-run GHG emissions per residential home heating among U.S. climate zones, relative to an 80 percent gas furnace.

Regional comparison: Long-run grid emissions (12 years)

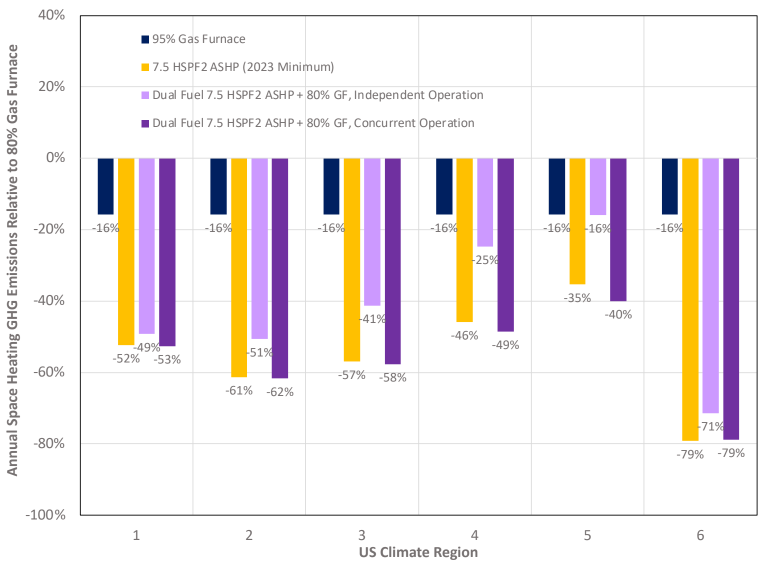

Figure 8: Long-run GHG emissions per residential home heating among U.S. climate zones, relative to an 80 percent gas furnace.

		% Reduction in Fossil Fuel Required for Space Heating by US Climate Region					
Current Space Heating Technology	**New Space Heating Technology**	**I**	**II**	**III**	**IV**	**V**	**VI**
Fossil Fuel Furnace (Natural Gas, Propane, Heating Oil, Kerosene)	Dual Fuel 7.5 HSPF2 ASHP + Fossil Fuel Furnace, Concurrent Operation	99%	96%	92%	82%	71%	99%
Fossil Fuel Furnace (Natural Gas, Propane, Heating Oil, Kerosene)	Dual Fuel 7.5 HSPF2 ASHP + Fossil Fuel Furnace, Independent Operation	93%	79%	65%	40%	26%	90%

Figure 9: Dual-fuel heat pump adoption delivers significant reductions in fossil-fuel consumption in all climate zones.

Lower-carbon gases increase dual-fuel decarbonization potential

Today, efforts are underway to capture and harness renewable natural gas (RNG), which offers lower GHG emissions compared to legacy natural gas options. Where renewable natural gas is available, some states are already leveraging this cleaner form of fossil fuels to reduce carbon footprints. As the energy market continues to evolve, there simply is no predicting the emergence of new lower-GHG gases or technologies that could deliver even greater emissions reductions. When used responsibly, lower-emissions gases can only strengthen the case for dual-fuel heat pump adoption.

Conclusion: Dual-fuel provides a stepping stone to the future of HVAC

Considering the evolving state of the nation's existing electrical infrastructure and the range of regional differences in heat load requirements, HVAC industry stakeholders should consider dual-fuel heat pumps as a viable, regionally tailored path to achieving substantial decarbonization and partial electrification. Research conducted at The Helix Innovation Center has established that an integrated dual-fuel heat pump and gas furnace with concurrent operation controls represents a significant potential for immediate and long-term GHG reductions, while providing the cost savings and comfort levels needed to appeal to consumer preferences.

In time, as regional grids become cleaner and more reliable — and as heat pump technologies continue to improve — the implementation of an all-electric heat pump strategy may offer the most beneficial reductions in GHG emissions and costs. But in the meantime, HVAC industry stakeholders should evaluate and consider adopting dual-fuel heat pump solutions for their vast short- and long-term potential and numerous advantages *(see Figure 10)*.

Copeland is focused on taking a holistic approach to HVAC industry challenges, balancing GHG reductions, technological challenges and stakeholder perspectives to develop the next generation of heat pump solutions. To learn more about the research taking place at The Helix Innovation Center, please contact our lead of innovation technologies, Brian Butler.

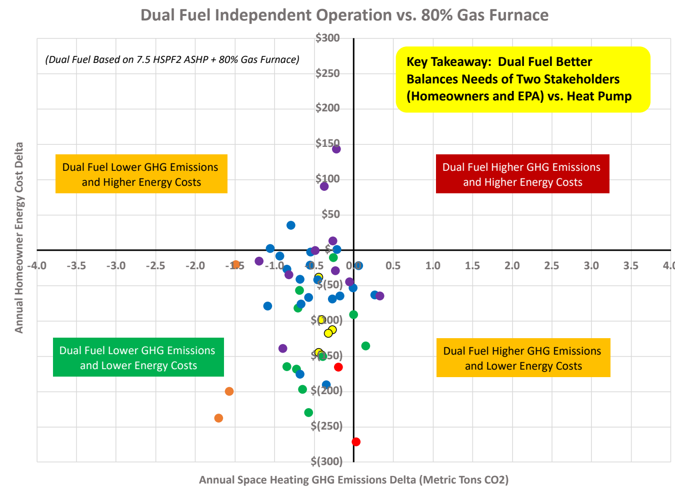

Figure 10: In the near term, dual-fuel heat pumps can provide the best balance of homeowner and environmental benefits.

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