Finding the Sweet Spot: Balancing Cost and Carbon in Hybrid Heating

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ABSTRACT

Vermont Gas Systems (VGS), in partnership with Resilient Edge, has developed an interactive web tool that helps homeowners understand how to operate centrally ducted heat pumps (CDHPs) within hybrid heating systems for both cost and carbon optimization. For existing homes served by natural gas, adding a CDHP to an existing furnace offers the single largest opportunity to decarbonize space heating. Yet, homeowners and contractors often face uncertainty about how to size equipment, set switchover temperatures, and balance comfort, operating cost, and emissions reduction.

The Cost vs. Carbon Estimator allows customers and their HVAC contractors to input basic information—such as their home's size and weatherization level—and receive a recommended switchover temperature aligned with budget and decarbonization goals. By visualizing tradeoffs between cost and carbon, the tool educates users and encourages data-driven operation of their hybrid systems.

VGS has been utilizing this tool with homes where they have installed a centrally ducted heat pump for two years. VGS customers receive customized consultations using the calculator, and their energy usage is tracked to evaluate behavioral and natural gas reduction outcomes. This presentation will share whether the tool influences customer actions and aligns predictive models with real-world data. Findings will inform future enhancements, energy efficiency program design, and customer engagement strategies to advance the utilization of cold climate heat pumps to achieve fossil fuel displacement in cold climates.

Introduction

Vermont Climate Context

Vermont established itself as a national leader in policy-driven climate action through the adoption of the Global Warming Solutions Act (GWSA, or Act 153) in 2020 (Vermont General Assembly 2020). The Act created binding greenhouse gas reduction requirements for the state, mandating a 40 percent reduction below 1990 emissions levels by 2030 and an 80 percent reduction by 2050. To guide implementation, the legislation established the Vermont Climate Council and tasked it with developing a comprehensive Vermont Climate Action Plan. The Plan identifies multiple pathways to meet these targets, with particular emphasis on the thermal sector through large-scale weatherization, electrification of heating loads, and reductions in fossil fuel use. The GWSA also emphasizes a just transition, requiring that climate action reduce energy burden and minimize adverse impacts on rural and historically marginalized communities, while establishing mechanisms for public accountability.

VGS Climate Strategy and Company Background

In anticipation of statewide climate goals, VGS developed its own Climate Plan to address the environmental impact of its core products and the evolving needs of its customers. In 2019, VGS committed to reducing customer greenhouse gas emissions by 30 percent by 2030 and achieving net-zero emissions by 2050 (Vermont Gas Systems, 2019), later increasing its interim target to 40 percent to align with state goals. The Climate Plan rests on three operational pillars: expanding energy efficiency, decarbonizing the thermal energy delivered through its infrastructure, and providing in-home services that support affordability and customer participation in decarbonization.

VGS employs approximately 75 customer-facing staff and 35 additional service employees, out of a total workforce of 150. Since its founding in the 1960s, the company has installed, serviced, leased, and sold natural gas equipment. In 2022, in alignment with its Climate Plan, VGS began offering heat pump water heaters, followed in 2023 by centrally-ducted heat pumps ("CDHPs"). As a regulated utility, VGS provides these services under a model in which profits must demonstrably benefit ratepayers.

The Challenge of Electrification

VGS recognizes that durable fossil fuel reduction in the thermal sector must be achieved without compromising household affordability or comfort. In much of the United States, including Vermont, electricity remains more expensive than natural gas on a per-unit energy basis, and during the coldest winter conditions, operating a heat pump alone is often costlier than relying on a high-efficiency natural gas furnace. These challenges are compounded by Vermont's aging housing stock, where limited insulation and air sealing can constrain a heat pump's ability to maintain consistent indoor temperatures during extreme cold. In this context, HVAC contractors frequently set conservative switchover temperatures, largely to avoid customer discomfort and after-hours service calls driven by uncertainty about system performance or thermostat operation. As a result, hybrid systems may revert to fossil fuel heating earlier than technically necessary, reducing their potential to deliver meaningful emissions reductions.

These operational and economic constraints highlight the need for targeted guidance to ensure hybrid systems are used effectively. Centrally ducted heat pumps, when properly sized and integrated into hybrid configurations, can help address these challenges by controlling both the heat pump and "backup" fossil fuel heating system with the same thermostat(s).

Approach

Centrally Ducted Heat Pumps as a Solution

The "in-home services" pillar of the VGS Climate Plan reflects the understanding that meaningful emissions reductions depend not only on energy supply but also on how energy is used within the home. CDHPs align with this objective by enabling electrification of whole-home space heating and cooling while leveraging existing ducted distribution systems common in Vermont housing. When properly sized and integrated into hybrid configurations, these systems allow customers to reduce fossil fuel consumption without sacrificing comfort or affordability, translating system-level climate goals into practical, household-scale action.

Analysis of heat pump adoption in Vermont indicates that, absent targeted guidance and system-level optimization, heat pumps are not consistently operated to displace fossil fuel heating as intended. The Vermont Heat Pump AMI Analysis (Ridgeline Energy Analytics, 2025) finds that heat pump installations—particularly in higher-income households—are frequently used for cooling or partial heating rather than as primary space-heating systems, resulting in limited reductions in fossil fuel consumption. The report further suggests that equipment sizing, control strategies, and customer understanding of system operation play a significant role in whether installed heat pumps deliver meaningful carbon and fuel displacement benefits.

The VGS Cost vs. Carbon Estimator

In response to these challenges, VGS enlisted Resilient Edge to develop the Cost vs. Carbon Estimator[1], an online tool for homeowners who have—or are considering pairing—a CDHP with their existing furnace. The tool helps users compare energy costs and carbon emissions between the heat pump and natural gas furnace, taking into account home size, insulation and weatherization, Vermont weather, and other relevant factors. It selects the appropriately sized heat pump and models performance at different outdoor temperatures, calculating costs and carbon emissions when the heat pump serves as the primary heating source and when the gas furnace operates as a backup in colder conditions. Users can set the "switchover temperature" at which the backup system engages to see an estimate of the cost and carbon impacts relative to the baseline case of only heating with gas.

While the Estimator provides guidance for common home sizes and insulation levels, results may vary for homes that differ significantly or for heat pumps that perform differently from the high-quality, cold-climate units used in calculations. The tool incorporates historical NOAA ISD weather data for Burlington and local electricity and renewable natural gas data to estimate potential greenhouse gas reductions in metric tons of CO_2. By visualizing tradeoffs between cost and carbon, the Cost vs. Carbon Estimator supports data-driven decisions that optimize energy use, emissions reductions, and household comfort.

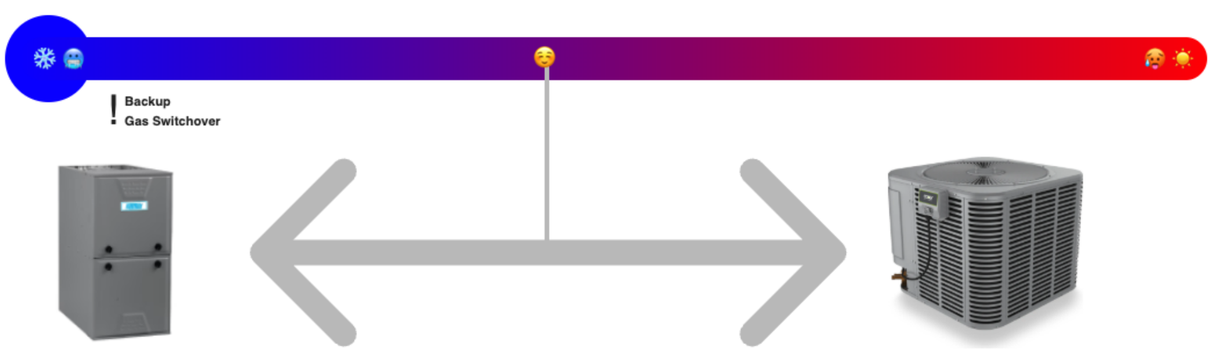

Figure 1: Conceptual diagram of a hybrid heating system and switchover logic

The gas and electricity costs are confined to volumetric charges such as supply, distribution, taxes, efficiency surcharges, etc., but excludes any fixed costs. All VGS customers receive electric service from either Green Mountain Power (GMP) or Burlington Electric Department (BED); the latter has a residential tariff with an inclining block rate after the first

[1] The Cost vs. Carbon Estimator can be accessed at https://vgsvt.resilientedge.io/

100 kWh/month, and that second block rate is the used by the Estimator. The tool calculates GHG emissions as zero for electricity consumption, based on the state-approved assertion of both electric utilities in their Integrated Resource Plans that their electricity is 100% "carbon free" (after accounting for sales of renewable energy credits). Because the electricity is considered to be carbon free, we did not have to deal with calculating hourly, marginal emissions factors to match the heat pump operation schedules. The GHG impact of natural gas consumption is taken from the EPA GHG equivalencies calculator.

Based on interviews with heat pump customers and energy experts, most hybrid systems' switchover temperatures are not informed by data about the implications of this choice. In most cases, it seems that HVAC system installers set this switchover temperature without much consultation with the customer, and often set this temperature conservatively high, between 40°F and 50°F. While this approach almost certainly reduces the likelihood of comfort callbacks, it results in very little heating load being shifted to the heat pump. Despite the cold-weather performance of the modern generation of heat pumps, many installers still believe that heat pumps don't heat effectively under 40°F.

To the extent that these decisions are informed by some sort of analytical tool, they are likely to focus on minimizing the cost of heating fuel. Many fuel cost calculators are available online, typically following the approach of converting heating load to fuel units and then to cost, factoring in the conversion and distribution efficiency. Some of these tools even offer estimates for heat pumps that take into consideration the fact that their efficiency is dependent on outdoor temperature.

If such tools include an analysis of the switchover temperature, they are typically calculating the economically optimal point where heat pumps become more expensive to operate than gas-fired heating systems. Given the high cost of electricity and the relatively low cost of gas in the Northeast, this will yield a high switchover temperature where the heat pump will hardly ever be used. In fact, with the current prices for both fuels in Vermont, the economically optimal switchover temperature for the heat pumps modeled in the Cost vs. Carbon Estimator, the switchover temperature is 55°F, which is close to the balance point for a moderately well-insulated home.

Design Principles and Objectives

Because VGS observed that many customers were motivated to install heat pumps by their desire to reduce their home's greenhouse gas (GHG) emissions, they started with the hypothesis that some customers might be willing to spend some additional money on heating their homes each year if it resulted in more GHG savings. While this runs counter to the typical "payback calculation" approach to justifying energy upgrades, there is no scenario where the reduction in operating costs will ever match the upfront cost of these systems, at least not at current fuel prices[2]. We also considered converting CO_2 savings to societal costs and even prototyped a version of the tool that calculated the effective cost per ton of CO_2 savings for each switchover point, but based on the user interviews we determined that users did not have enough context to make use of that information. Instead, this framing starts with a homeowner's desire to reduce GHG emissions and attempts to help to answer the questions:

[2] As of April 15, 2026, the volumetric portion of the residential natural gas tariff was $1.48 and the residential electricity volumetric charges were $0.21/kWh for Green Mountain Power and $0.20/kWh for Burlington Electric.

- Are you confident that installing a CDHP will reduce your GHG emissions?
- How much more are you willing to spend annually in order to reduce GHG emissions?
- How do you communicate these goals to your HVAC installer?

VGS engaged Resilient Edge to test a prototype of the Cost vs. Carbon Estimator with six current and potential CDHP owners. Similar interviews were conducted with eight expert users who could provide feedback on the tool's accuracy and relevance. This population was not intended to provide statistically meaningful feedback, but rather focused on qualitative responses to the tool. These sessions were conducted by a usability researcher and were structured as hour-long sessions with one participant at a time. The sessions started with questions probing into perspectives around carbon reduction strategies, personal beliefs around how they prioritize carbon reduction vs. energy costs, investments they have made in home energy systems and the process they used to decide which investments to make and when to make them. See Appendix A for a list of the survey questions.

In the second portion of the interview, participants were given access to a copy of the tool that was configured with parameters such as their home's balance point and the BTU/degree-hour that were derived from a fuel bill analysis. They were asked to talk aloud about their thought process as they used the tool. After they finished using the tool, researchers asked them questions around the perceived intent and value of the calculator, their understanding of the data points provided by the calculator and whether/why they were meaningful, and decisions that they might make using the calculator.

Participants found the tool to be engaging, easy to use, and informative. Most said that they felt more confident in the ability of CDHPs to reduce their GHG emissions, and in VGS' commitment to help them reach their household's climate goals. The vast majority said they found the tool helpful and would use it to make decisions about operating their heat pump; only one responded "probably not." All the participants expressed awareness that outdoor switchover temperature has an impact on the GHG-saving performance of heat pumps. This is a strong finding, but we acknowledge that the study population is likely skewed towards more customers who are more knowledgeable about heat pumps.

Other findings highlighted customer skepticism that heat pumps can adequately keep a house warm on colder days, with some participants citing the cooler supply air temperature of heat pumps relative to fossil-fired furnaces. They also seemed to lack context about the meaning of saving a ton of CO_2 and whether that represented a significant improvement in their personal carbon footprint or not. Expert users requested an "advanced" mode that exposed more detailed data about the inputs and allowed users to adjust more parameters. On the other hand, non-expert users did not immediately realize that the tool had been customized using their home's own fuel consumption data.

Based on this feedback, the final version of the tool that is being offered on VGS' web site has some changes from the prototype. It currently does not require a custom bill analysis but rather asks customers to answer two simple questions about their home's general size, as shown in Figure 1, and weatherization status, according to the following description: "Weatherization is the practice of protecting a building and its interior from the elements, particularly from sunlight, precipitation, and wind, and of modifying a building to reduce energy consumption and optimize energy efficiency." It does allow the ability to override the tool's selection of the heat pump size, and it offers a detailed PDF report with a full accounting of all the inputs, outputs, assumptions, and methods, as well as charts and text descriptions that are intended to help a homeowner convey their desired switchover temperature to their HVAC installer.

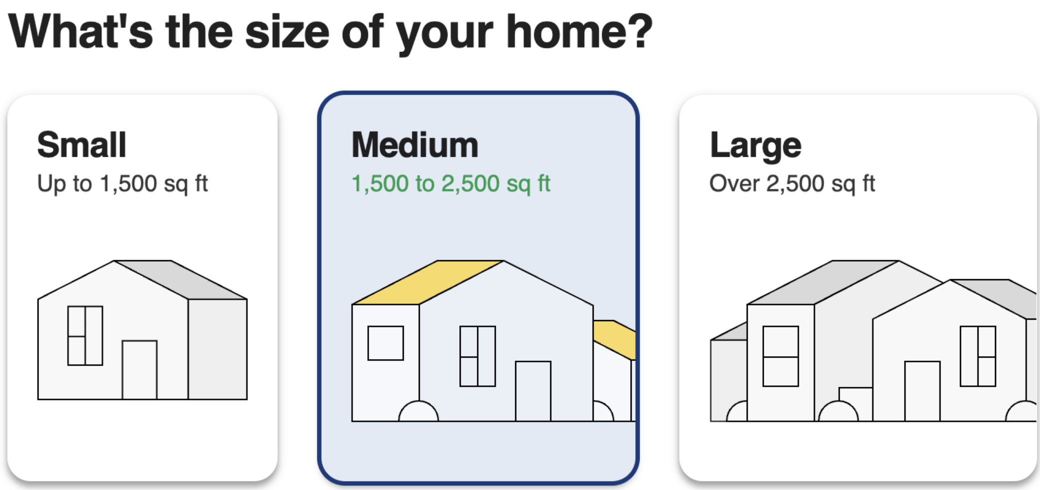

Figure 2. Screenshot of the home size selector from the Cost vs. Carbon Estimator

The Tool

The home size and weatherization status are used to look up the heating demand in BTU per heating degree-day for a typical home with those attributes, based on an aggregate analysis of homes from VGS' weatherization program. That analysis involved roughly clustering homes by conditioned area into the groups shown in Figure 2 and then averaging the therms per degree-day metrics that VGS had calculated for each home in the group as part of the program participation. That metric is combined with local hourly typical weather data to calculate hourly energy demand and the coefficient of performance (COP) for the heat pump model that is matched to that prototype home. The tool calculates the gas needed to heat the home if the temperature is below the switchover temperature or if the selected heat pump lacks the capacity to meet the load at that temperature, or the electricity used if the heat pump will instead be operating.

The interface, an example of which is shown in Figure 2, allows the user to drag a slider to try different switchover temperatures and see the cost and carbon emissions updated on the charts, and the changes relative to an all-gas system are also displayed in absolute and percentage terms. There is another slider that allows you to see the cost and carbon impacts of purchasing a portion of their gas supply from renewable sources. The gas and electricity rates are updated one to four times per year to keep the results up to date.

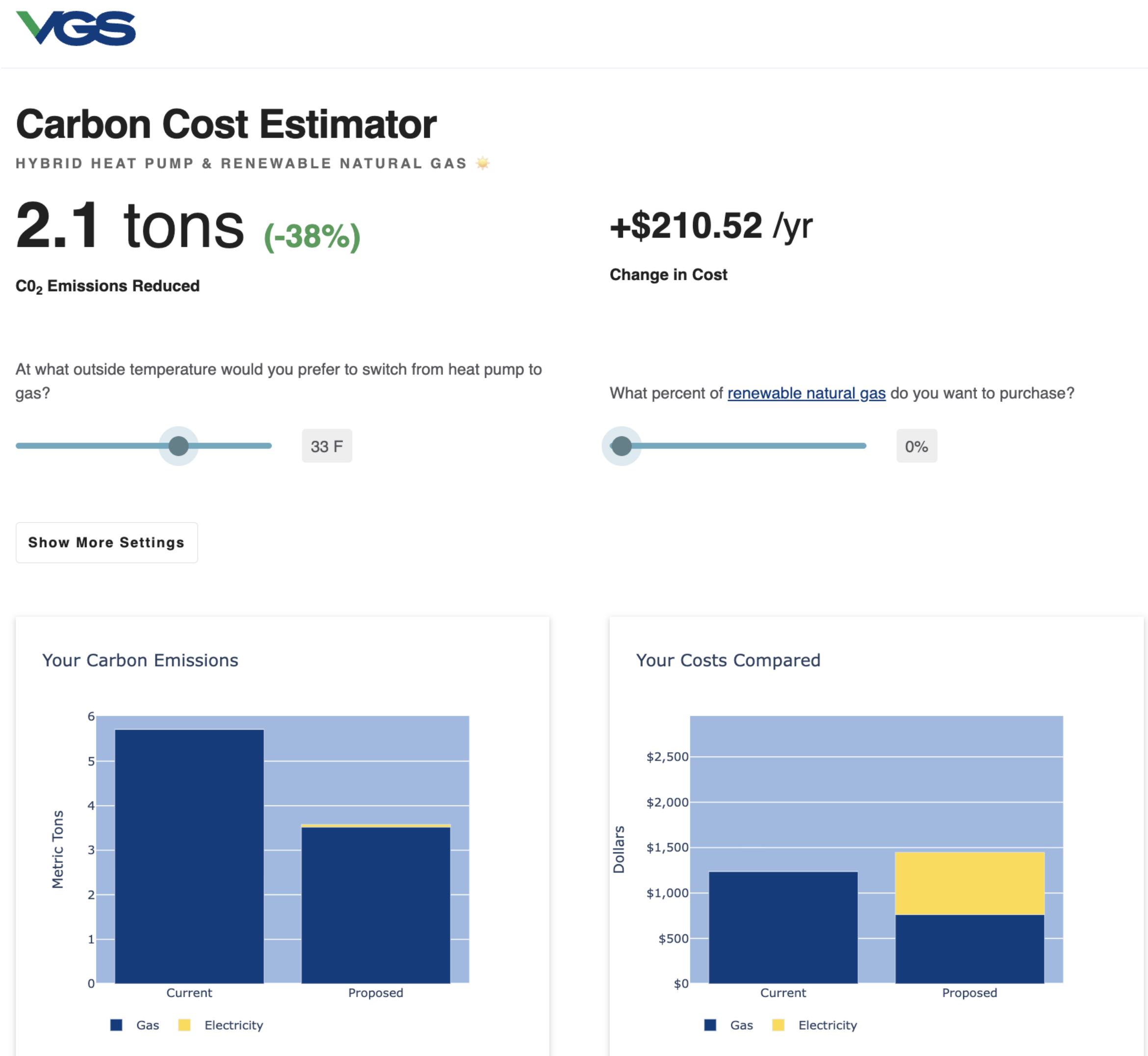

Figure 2: Screenshot of the Cost vs. Carbon Estimator

Once the user has found the inputs that meet their personal goals for cost and carbon, they can click through to the report generator. This form allows them to enter a name and address to customize the report. It also offers them the option to request a follow-up contact from VGS customer service to help them with their heat pump installation. The report documents the selected switchover temperature, the estimated cost and carbon impacts, and all the inputs and assumptions used to calculate those results. It also includes frequently asked questions and a glossary of terms used by the calculator so that they can be better informed when interpreting and sharing the results.

Implementation with Vermont Gas Systems Customers

VGS staff began installing centrally-ducted heat pumps in the spring of 2023 as part of a regulated CO_2 reduction program and introduced the Cost Carbon Estimator later that fall. Heat pump installers received training not only on integrating a centrally-ducted heat pump with an existing natural gas furnace but also on the installation and programming of smart thermostats to ensure optimal system performance. The program typically installs Honeywell RedLink thermostats with hybrid CDHPs so that the switchover temperature can be set from the thermostat. Following the launch of the Cost vs. Carbon Estimator, installers were educated on its purpose and use, encouraged to incorporate the tool both as part of the sales process and in customer interactions when programming thermostats and explaining system operation. The CDHP installation program was designed to ensure that customers understood the ideal operation of their dual-fuel systems and had realistic expectations regarding performance and operating costs. The Cost vs. Carbon Estimator was also made publicly available on the VGS website, allowing customers to interact with the tool directly. Users could generate a report to share with any contractor, specifying desired switchover temperatures, or request a callback from VGS if they were interested in having a centrally-ducted heat pump installed by the company.

So far, there is limited feedback on the Estimator from customers who have participated in the CDHP installation program. Of the 97 projects completed since the program launched, about half have been completed since the Estimator was launched. VGS sent a survey to everyone who submitted an email address in the contact request form in the Estimator. That email contact field is optional and is part of the final “download your report” step in the Estimator, so only a subset of users would have provided their email. Since the form is publicly available on the VGS website, some of those email addresses could be from users who did not participate in the CDHP installation program. VGS received only one survey response, which stated that the tool was valuable, that they did not previously understand the relationship between cost, carbon, and switchover temp and that they have not yet installed a heat pump. They did say it made them more comfortable about potentially installing a heat pump.

Once there is adequate post-installation fuel use data from the CDHP program participants, it would be possible to perform a weather-normalized pre-post comparison to see if customers who installed their CDHPs after the Estimator was launched are reducing their gas consumption more than prior program participants, but that evaluation analysis has not yet been performed.

The Future of the Tool

There are several options for future improvements that would make the tool more accurate and useful. VGS customers could opt to connect their gas billing data to allow the tool to model their specific home heating demand profile to customize the cost and carbon calculations. This data connection could be used to continuously monitor their actual changes in weather-normalized fuel consumption to confirm that they are achieving the expected carbon emissions reductions, or to alert them if their heat pump is not displacing as much gas-fired heating as expected. If the customer also connected their electricity billing data to the tool, it would be even more accurate when estimating how much heating load had been shifted to that energy source.

Numerous evaluations (Ridgeline Energy Analytics and Guidehouse, Inc 2024 and DNV 2022), including several of Vermont’s heat pump programs (Ridgeline Energy Analytics, Demand Side Analytics, and West Hill Energy and Computing 2024), have found far less fossil fuel savings than expected when customers add a heat pump but retain their fossil fuel backup system. These low realization rates are currently being applied to new projects that are supported by VGS, which reduced the cost-effectiveness of those programs. If VGS was able to demonstrate that users of this tool (and their HVAC contractors) were better educated about how to configure and operate a CDHP, it might be possible to justify higher unit savings for heat pumps purchases that were informed by this tool.

The transition to lower-carbon heating and cooling will require more than widespread adoption of new technologies. It will also depend on ensuring that homeowners and contractors understand how to operate these systems to achieve their intended cost and carbon benefits. This suggests that educational resources and tools translating technical information into practical operating guidance should be viewed as a key component of heat pump deployment, alongside heat pump incentive programs.

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Appendix A: Survey questions

- When were you born?
- How interested are you in reducing your carbon footprint even if it means you'll pay more on your home heating bill?
- Are you interested in working with a one stop shop to handle all your home energy needs from planning and finance to installation and quality assurance?
- How much more would you be willing to pay per year to upgrade your home's heating and cooling systems, and household appliances, so they were more energy efficient and contributed to lowering greenhouse gas emissions?

- How much have you seen, read, or heard about Vermont Gas' Renewable Natural Gas program that uses organic matter such as cow manure, food scraps and sewage to create renewable methane gas that is low carbon and can be used instead of traditional natural gas to heat homes?
- On a scale of one to 10, with 10 meaning VERY WILLING and one being NOT AT ALL WILLING, please tell me how willing you are to purchase Renewable Natural Gas for your home or business?
- How much more would you be willing to pay per year for 20% of your energy to come from renewable natural gas?
- What is your level of education?
- What is your annual income?
- How interested are you in reducing your carbon footprint even if it means you'll pay more on your home heating bill?
- Are you interested in working with a one stop shop to handle all your home energy needs from planning and finance to installation and quality assurance.
- How much more would you be willing to pay per year to upgrade your home's heating and cooling systems, and household appliances, so they were more energy efficient and contributed to lowering greenhouse gas emissions?
- On a scale of one to 10, with 10 meaning VERY WILLING and one being NOT AT ALL WILLING, please tell me how willing you are to purchase Renewable Natural Gas for your home or business?
- How much more would you be willing to pay per year for 20% of your energy to come from renewable natural gas?
- How interested would you be in installing a hybrid heat pump to augment your furnace?
- Do you think that a hybrid heat pump would be an effective way to cut your CO_2 emissions?
- Do you think a hybrid heat pump would be an affordable way to heat your home?
- Did using the calculator make you feel more or less confident about using a hybrid heat pump to cut CO_2 emissions?
- Would you use the calculator to help you make decisions about operating your heat pump (if you had one)?
- What did you learn from the calculator that made you feel more inclined to use a hybrid heat pump?
- What did you learn from the calculator that made you feel less inclined to use a hybrid heat pump?
- Do you still have questions you would want to be answered before you make a decision about purchasing a hybrid heat pump?
- Do you think that there are any aspects of operating a hybrid heat pump that can affect cost and/or CO_2 emissions?

AI Disclosure

AI-assisted tools used: ChatGPT
Used for: Developing an outline. Light editing.
Extent: Light editing
Human review: The authors reviewed and verified all content, calculations, and citations.