Exploring the potential of Air-sourced Heat Pumps in rural West-Central Minnesota

A Field-Based Assessment of Performance, Contractor Engagement, and Utility Rate Structures

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Introduction

Minnesota is a state with limited natural resources that can be used for energy production. It has no coal, no natural gas, and no oil reserves. One of the few abundant natural resources available, however, is wind. The University of Minnesota Morris campus, for instance, generates its electricity primarily through wind turbines located nearby. In addition to wind, Minnesota also benefits from solar energy, which has increasingly become part of the state's renewable energy portfolio. Notable examples include the 400 kW solar array installed at the University of Minnesota Morris, the Hoot Lake Solar Facility near Fergus Falls operated by a local utility with a capacity of 49 MW, and the agrivoltaics research site at Rauenhorst Farm that combines agricultural production with solar power generation.

While electricity generation through renewables is progressing, heating remains a major challenge in Minnesota's path toward carbon neutrality. The state's cold climate and reliance on imported fossil fuels such as oil, gas, and propane make home heating both costly and carbon intensive. To address this, alternative technologies such as air source heat pumps (ASHPs) are being explored. These systems extract heat from the outside air, compress it through a refrigerant cycle, and deliver it indoors for space heating. However, this technology depends on a stable electricity supply and must operate under Minnesota's extreme climate conditions, where summer temperatures can exceed 100 degrees Fahrenheit and winter temperatures can fall well below zero. The question therefore arises whether modern heat pump systems can maintain efficiency and reliability under such challenging conditions, particularly in rural areas with older housing stock.

In alignment with Minnesota's 2050 climate goals, the University of Minnesota Morris Office of Sustainability has partnered with the University of Applied Sciences Münster in Germany through the Climate Smart Municipalities (CSM) program to investigate the potential of ASHPs in rural West-Central Minnesota. Over the past two years, engineering students from both universities have worked collaboratively to evaluate technical feasibility, economic performance, and local acceptance of these systems. The initiative aims not only to identify opportunities for decarbonizing residential heating but also to foster dialogue between Minnesota and Germany on energy transition strategies at the community level.

Within this project, specific focus areas include the analysis of residential and contractor engagement, the documentation of a real-life heat pump installation, and the examination of utility rate structures that influence economic viability. One key objective was to determine the break-even point between the residential electricity rate and the dual fuel rate (DFR) offered by the local utility, as well as to assess the cost-effectiveness of connecting additional devices such as electric water heaters under different rate structures. Together, these analyses contribute to a broader understanding of how heat pump systems can play a role in achieving thermal decarbonization and energy resilience in Minnesota's rural regions.

Program Framework

In 2016 several partners including CERTs, CEE, CUB, SWRSDP, the MN ASHP Collaborative, and the University of Minnesota Morris joined forces to pursue a shared mission of promoting carbon neutral energy production and the thermal decarbonization of heating systems in West Central Minnesota.

With the increasing popularity of heat pumps in the United States and in Scandinavian countries where similar climate conditions prevail, and with the technological progress achieved in recent years, the coalition decided to investigate the potential of air sourced heat pumps as a carbon neutral alternative to conventional heating systems such as gas, propane, and oil furnaces in rural Minnesota.

The Office of Sustainability at the University of Minnesota Morris, in cooperation with the mentioned partners, developed a multi-phase program for Climate Smart Municipalities interns from Germany. The goal was to analyze the potential of air sourced heat pumps in the Morris area as an exemplary case within West Central Minnesota and to foster an open dialogue between the United States and Germany about renewable energy and sustainable heating solutions. This was considered particularly valuable since Germany is undergoing its own major energy transition.

The multi-phase program began in 2024 when an intern from FH Muenster initiated Phase One of the project. This phase focused primarily on residential engagement by evaluating the existing heat pump landscape in Morris and collecting data from residents using air sourced heat pumps in rural parts of West Central Minnesota.

In addition, first contacts with local contractors and utility companies were established to gain insights into how heating, ventilation, and air conditioning experts perceive heat pump technologies. More detailed information about this phase can be found in the report *Exploration of Air Sourced Heat Pumps in West Central Minnesota* by Manuel Reinert, available on the morrismodel.org website.

Phase One created the foundation for Phase Two and serves as a baseline for further developments within the ongoing project.

Framework of Phase 2:

Phase Two continues the exploration of air sourced heat pump potential, shifting the focus from residential engagement toward contractor and installer collaboration. The main objective of this phase is to gain a deeper understanding of the challenges faced by professionals who install and service air sourced heat pumps, and to identify strategies to make the installation process more accessible for residents, contractors, and utility providers.

Alongside the engagement with contractors, follow up interviews with residents were conducted to evaluate the performance of installed systems between September 2024 and April 2025. Moreover, the installation of a residential heat pump system was observed and analyzed to assess each step of the process, the coordination among involved contractors, and the overall project execution.

Building on these activities, a task group also analyzed the local utility company's electricity rate structures. The goal was to provide residents with a clear overview of the available rate options and to determine under which conditions each option becomes financially advantageous depending on household electricity consumption.

Technical Background

In Germany, thermal performance of heating systems is typically expressed in kilowatts (kW) for power and kilowatt-hours (kWh) for energy. In the United States, however, thermal energy and heating capacity are often described using British Thermal Units (BTU) and BTU per hour (BTU/h).

A BTU is the amount of heat required to raise the temperature of one pound of water by one degree Fahrenheit. One BTU/h equals approximately 0.293 watts, or conversely, 1 kW equals about 3,412 BTU/h. To compare U.S. and European heating systems directly, these conversion factors are essential.

In residential HVAC applications, the term “Ton” is also commonly used in the U.S. to describe the cooling or heating capacity of an air-source heat pump or air conditioner. One Ton equals 12,000 BTU/h, which corresponds to roughly 3.52 kW. For example, a 2-Ton unit has a heating or cooling capacity of approximately 24,000 BTU/h, while a 3-Ton unit delivers around 36,000 BTU/h . The Ton terminology originated from the amount of heat absorbed by melting one ton of ice over 24 hours.

The Coefficient of Performance (COP) is a dimensionless indicator used internationally to describe the efficiency of heat pumps. It expresses the ratio of useful heating output to electrical energy input. A COP of 3.0 means that for every kilowatt-hour of electricity consumed, the heat pump delivers three kilowatt-hours of thermal energy. In practice, COP values depend on outdoor temperature, building characteristics, and system design.

The Northeast Energy Efficiency Partnerships (NEEP) maintains a publicly accessible database of air-source heat pumps that meet standardized efficiency and performance criteria for cold climate applications. The *Cold Climate Air Source Heat Pump List* includes verified test results provided by manufacturers and certified through the AHRI (Air-Conditioning, Heating, and Refrigeration Institute). This resource is widely used by engineers, contractors, and policymakers to evaluate system suitability under different operating conditions.

Each entry in the NEEP database consists of two sections: Information Tables and Performance Specifications. The Information Tables summarize technical details such as the brand, model number, system type (ducted or non-ducted), AHRI certificate number, and efficiency ratings including EER, SEER, HSPF, and COP. They also list compliance with ENERGY STAR standards, cold-climate qualification, tax credit eligibility, refrigerant type, and other operational parameters.

Efficiency ratings are standardized metrics used to describe how effectively an air source heat pump converts electrical energy into useful heating or cooling. These ratings are defined by the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) and are listed on certification labels as well as on the NEEP website. They help consumers, contractors, and policymakers compare the energy performance of different heat pump models under typical operating conditions (Neep.org, 2025).

Energy Efficiency Ratio (EER):

The EER measures how efficiently a heat pump or air conditioner provides cooling under fixed indoor and outdoor conditions. It is calculated as the ratio of cooling output in BTU per hour (BTU/h) to the electrical input in watts. The higher the EER, the more efficient the unit. EER is typically determined at an outdoor temperature of 95°F, making it useful for evaluating performance in hot weather or at peak load.

Seasonal Energy Efficiency Ratio (SEER):
While EER represents a single test point, SEER reflects the average cooling efficiency of a system over an entire cooling season. It takes into account variations in outdoor temperature and system load. A higher SEER indicates lower seasonal energy consumption and operating costs. SEER is therefore a more realistic indicator of long-term performance in climates with fluctuating temperatures.

SEER2:
In 2023, the U.S. Department of Energy introduced SEER2 as an updated version of SEER, based on revised testing standards (DOE Appendix M1). SEER2 uses higher external static pressures, which better reflect real-world duct losses and installation conditions. As a result, SEER2 values are typically about 4 to 5 percent lower than the older SEER numbers, even though the actual efficiency of the system has not changed.

Heating Seasonal Performance Factor (HSPF):
HSPF is the heating equivalent of SEER and represents the seasonal efficiency of a heat pump in heating mode. It is calculated as the total heating output (in BTU) divided by the total electrical energy consumed (in watt-hours) over an entire heating season. A higher HSPF means that the unit delivers more heat for the same amount of electricity.

HSPF2:
Similar to SEER2, the HSPF2 rating was introduced to align testing procedures with more realistic field conditions, using the updated DOE M1 standard. Because of these changes, HSPF2 values are generally slightly lower than HSPF, even though they represent the same overall efficiency. The new scale ensures better comparability across different manufacturers and system types.

The Performance Specifications section provides measured heating and cooling capacities and corresponding Coefficient of Performance (COP) values at different outdoor air temperatures, typically 95°F, 82°F, 47°F, 17°F, 5°F, and -13°F. These data points illustrate how a heat pump’s efficiency and output vary with changing ambient conditions—an essential factor in cold climates such as Minnesota.

Understanding “Min,” “Rated,” and “Max” Performance Values

For each temperature condition, the NEEP data show three performance levels: Minimum (Min), Rated, and Maximum (Max).

- Minimum (Min) capacity represents the lowest output at which the unit can operate stably under normal control settings. This value corresponds to reduced compressor speed or part-load operation, typical for mild weather or low heating demand. It indicates how effectively the unit can modulate without cycling on and off, which directly influences comfort and efficiency.
- Rated capacity denotes the nominal or reference output of the heat pump under standard test conditions, as defined by AHRI procedures (for example, 47°F outdoor dry bulb for heating or 95°F for cooling). This value serves as the benchmark for model comparison, certification, and marketing. The rated COP and capacity are often used for system design calculations and energy modeling.

- Maximum (Max) capacity describes the upper performance limit of the system under full compressor speed or boost mode. This value is relevant for peak load conditions, such as very low outdoor temperatures or rapid indoor temperature recovery after a setback period. Although the Max capacity can provide additional heating output, it usually comes with reduced COP, reflecting lower efficiency under high compressor stress (Tosot direct, 2024).

Additional Metrics

The NEEP listing also provides capacity maintenance ratios, indicating how well a heat pump maintains its output at low temperatures compared to standard conditions. For example, a capacity maintenance of 75% at 5°F relative to 47°F means that the system retains three-quarters of its nominal heating power even in near-subzero conditions.

Overall, the NEEP database provides a transparent and standardized foundation for comparing air-source heat pump performance under realistic environmental conditions. It supports data-driven decision-making in equipment selection, system sizing, and economic evaluation for cold-climate regions such as Minnesota (Neep.org, 2025)

Load-Controlled Operation and Dual Fuel Rate Analysis

In the context of system operation, many utilities in the U.S. offer load-controlled rates, also known as dual fuel rates, to balance grid demand and encourage off-peak heating. Under these programs, electric heat pumps are automatically cycled off by the utility during high-demand periods. When this occurs, a secondary heating source (usually natural gas or propane) temporarily provides heat. For example, the local utility company in Morris, Minnesota, operates such a dual fuel rate program. Customers receive a discounted electricity rate for allowing temporary interruptions of their electric heating load, while maintaining comfort through backup systems. Technically, this load control is managed through a signal sent to the customer's meter or control relay, which disables the heat pump during peak demand hours, typically for a few hours per day.

For economic evaluations, it is useful to determine the break-even point between two electricity rates, such as the standard residential rate and the dual fuel rate. The break-even point represents the energy consumption level or operating time at which the total cost of one rate equals that of the other. In this project, comparing the residential rate with Otter Tail's dual fuel rate helps identify under which operating conditions the load-controlled option becomes financially advantageous for heat pump users (Representative, 2025).

Residential Engagement

Follow-up Interviews

Building on the foundation established in 2024, the follow up interviews focused on the performance of the heat pumps over time between September 2024 and April 2025. In addition, participants were asked about their experiences with the local utility company's rate structures and about how well prepared they felt their contractors were.

A total of 36 questions were asked regarding the heat pump systems, their performance, the preparation by the contractors, and the electricity rate structure of the local utility company. The questions were divided into three categories: summer performance, winter performance, and shoulder season performance, followed by a general section.

The main focus questions included:

1. Did you use your Heat pump for cooling/ heating last Winter/ last Summer?
2. How often did you run it for cooling- / for heating purposes?
3. What was the coldest/ hottest temperature your heat pump was heating/ cooling at?
4. Did your Heat pump perform well under those temperatures?
5. Would you say that the heat pump contractor provided you with detailed information about the system's heating performance and capabilities?
6. What electricity rate are you on?
7. Do you know if your Utility company offers other rates?

These questions were chosen to determine whether residents were actively using their heat pumps and to gain an overview of their general settings and heating or cooling behavior. Furthermore, the interviews provided insight into the residents' experiences with their installers, their level of engagement with their utility company, and their knowledge of available rate options. This information allows conclusions to be drawn about the overall interaction between residents, contractors, and utilities.
The full list of questions can be found in the annex.

Results:

Of the fourteen residents interviewed in 2024, five participated in follow up interviews. Among these five, three had non ducted air sourced heat pumps, one had a ducted air sourced heat pump, and one had a geothermal system with two wells combined with an additional floor heating system. The three non ducted systems were installed by the same contractor.

All residents reported using their heat pumps during summer for cooling and during the shoulder seasons for both heating and cooling. However, their general usage patterns differed. The geothermal and ducted systems served as the main heating and cooling source and were running continuously. The three residents with air sourced heat pumps used their systems primarily during the day, between twelve and seventeen hours daily. Four residents observed sufficient cooling at outdoor temperatures between ninety and ninety-two degrees Fahrenheit, while one resident reported effective cooling even above one hundred degrees Fahrenheit.

During winter, the residents with non-ducted air sourced heat pumps switched to their gas furnace. The switching points and reasons varied between the three households. In two cases, the switch was based on comfort and personal preference, while one resident cited a personal condition that made heating with the heat pump impractical. Two residents typically switched at outdoor temperatures between thirty- and forty-degrees Fahrenheit, whereas the third resident had programmed their boiler to activate when the indoor temperature dropped below sixty eight degrees Fahrenheit.

A recurring topic among the three residents with air sourced systems was the lack of information provided by their installers. Two out of three stated that they did not feel well informed about the cooling capabilities, and all three said they had received insufficient information about heating performance.

The resident with the ducted system also reported limited information, since the HVAC work was managed by a general contractor who oversaw a full home renovation. The resident with the geothermal system felt well informed after replacing the first system, which had failed after ten years. The second installation came with improved documentation and well prepared informational materials.

Only one of the five residents was aware of alternative electricity rates offered by the local utility company. Another resident reported having asked the company directly but was told that no alternatives existed. As a result, four of the five participants were on the general residential rate and not on a load controlled rate, even though all were aware of an off peak rate for electric water heaters.

In addition to the follow up interviews, two new interviews were conducted with residents who had not participated in the initial 2024 survey.

Interview Resident X

Contact with Resident X was established through a local utility sales representative. Unlike the follow up interviews, this conversation focused on the specific heat pump system installed in Resident X's house and its potential for collecting real time data on electricity consumption in rural West Central Minnesota.

Resident X operates a five to six ton ducted residential heat pump system that serves as the only heating and cooling source. The system is capable of tracking its own electricity consumption in kilowatt hours and displays the corresponding cost savings in dollars. This comparison is based on electricity rates entered into the system versus the equivalent cost of using propane.

A digital display is mounted on the south wall of Resident X's hallway, showing energy consumption and cost savings either for the current month or for the last three months.

Upon assessment, it became clear that the data is not permanently stored but only visible on the display. This makes the system unsuitable for long term data collection, as it lacks an internal memory or cloud storage function. To make it suitable for analysis, the system would need to be equipped with a data storage function that allows continuous tracking over time. Additionally, the data would need to be combined with meteorological parameters such as temperature, weather conditions, and cycle settings to determine the active running time by comparing inverter operation with total run time. Ideally, the tracking would include hourly data points for a more precise analysis.

Interview Resident Y:

Contact with Resident Y was established through the sustainability director Mr. T. Goodnough. Resident Y is planning to integrate an air sourced heat pump system into a new property currently under construction. According to Resident Y, the plan is to install one outdoor unit and one indoor head that will distribute the full capacity throughout the house.

The new house consists of two floors. The upper floor contains two rooms and one bathroom, while the main floor includes an open entry area combined with a living and dining space, an open kitchen, and two additional rooms. Using ceiling fans, Resident Y intends to distribute the heat evenly across the house.

Due to self-installed insulation and calculations of the building's heating and cooling load, Resident Y is confident that the system will perform effectively.

Unlike most systems, which typically include several indoor units, this design is unique. The aim is to collaborate with Resident Y to monitor the installation process, the contractor's involvement, and the system's functionality once in operation. The findings and data collected from this project could later serve as guidance for future residential consultations in the area of self-built heating and cooling systems.

Project Guinea Pig

Project Guinea Pig, named after the expression "being the guinea pig," which refers to serving as the subject of an experiment or test, was initiated by Sustainability Coordinator Mr. T. Goodnough. The project involved the observation and documentation of the installation process of a residential air sourced heat pump system. The opportunity arose when the resident's existing air conditioning system required replacement, and the decision was made to install an air sourced heat pump instead.

Although not part of the original research plan, this case provided valuable practical insights into the steps required for a residential heat pump installation, starting from the initial idea and system research to the final installation and first operational testing.

The process began with an initial consultation and data collection on the defective air conditioning system, including its cooling capacity, performance characteristics, and the homeowner's expectations for the new system. Before the failure, the existing air conditioning setup had a combined cooling output of approximately twenty thousand BTU per hour across two indoor units. The main goals for the replacement system were to achieve better indoor temperature distribution and comfort while lowering the cost per unit of cooling capacity.

The residence is a two-story building with a basement. The main living spaces and kitchen are located on the first floor, while the upper floor contains additional rooms. To ensure effective cooling throughout the home, the residents preferred a multi zone configuration with at least two indoor units, one serving the primary living area and another covering the upper floor rooms.

This real-life installation provided a detailed perspective on the entire implementation process, including system sizing considerations, contractor decision making, and coordination between installers and suppliers. Observing this project offered valuable insight into both the technical and organizational aspects of residential heat pump integration.

Contractor Engagement and Heat Load Assessment

As part of the project, a local contractor from Morris with previous experience in heat pump installations was approached to gain insight into common sizing and installation practices. After presenting the general project objectives, the contractor agreed to perform a site visit.

During the visit, the contractor inspected the proposed installation area and took measurements of the indoor unit locations. The heating and cooling capacity was first estimated based on the room volume.

To do so, the contractor measured the cubic feet of each room and multiplied that value by a factor of two to approximate the required cooling or heating load.

Following the visit, the contractor provided a more detailed explanation of the sizing process and demonstrated a digital calculation tool originally developed by a heat pump manufacturer. Although the contractor no longer sells or installs systems from that manufacturer, the tool remains in use because it allows installers to, as the contractor explained, “find the sweet spot for the cooling and heating load.” The calculation process, however, focuses primarily on cooling performance rather than on precise heating demand.

The software uses satellite imagery to outline the building footprint and dimensions. For the residence in question, the contractor entered measurements of approximately 26 by 16 by 8 feet for the first floor and 11 by 14 by 8 feet for the upper floor. Additional parameters included insulation levels (R11 for the basement, R0 and R13 for the upper floor and roof), the number of occupants, estimated heat loss through windows and doors (ten percent), ceiling height (eight feet), and air infiltration level (classified as “loose”).

For the basement area, the software calculated a load of approximately 1.2 tons, equivalent to 12,000 BTU per hour multiplied by 1.2. The program automatically rounded this value up to the next available unit size, resulting in a final recommendation of 18,000 BTU per hour.

For the upper floor, the software produced an estimated cooling capacity of one ton. Based on experience, however, the contractor decided to reduce this to 9,000 BTU per hour, reasoning that the calculated value was likely oversized for the actual space.

When asked whether this software could also be used to calculate the primary heating demand, the contractor attempted to perform the calculation. The process took significantly longer, and several input parameters had to be repeatedly adjusted by the operator. The resulting value of approximately 55,000 BTU per hour was ultimately considered unreliable by the contractor.

The approach demonstrated during this process does not fully align with the requirements of an official Manual J calculation. A Manual J load calculation typically includes more detailed inputs such as wall and roof construction type, insulation values for each component, orientation of the building, local design temperatures, internal heat gains, window specifications by direction, and precise infiltration rates. These factors are essential to produce an accurate and standardized estimate of the heating and cooling load. In this case, several of these parameters were simplified or omitted, which limits the precision of the calculation and makes it more of a practical estimation than a standardized design analysis.

Quotes

After the load calculations were completed, both contractors presented their quotes. Each proposed a two-ton ductless system with one outdoor and two indoor units.

Contractor A recommended a Mitsubishi system consisting of one outdoor unit and two indoor heads with capacities of 18,000 BTU for the main living space and 9,000 BTU for the upper floor. The system uses the R410A refrigerant. The total cost for equipment and installation was estimated at 10,985 dollars, without considering any available rebates.

Contractor B proposed a Bosch system with a total capacity of 28,000 BTU, also using the R410A refrigerant and a similar configuration of one outdoor and two indoor units (18,000 BTU and 9,000 BTU). Contractor B quoted 6,900 dollars for equipment and installation.

While no rebates were deducted in the quote, the contractor noted that the system qualifies for a rebate program of approximately 1,800 dollars from the local utility company. The quote also included an AHRI certificate verifying the official performance ratings.

To verify the accuracy and efficiency of both systems, additional research was conducted using the heat pump database provided by the Northeast Energy Efficiency Partnerships (NEEP).

Contractor	Contractor A	Contractor B
Offered Heat pump brand	Mitsubishi	Bosch
Outside Unit model no.	MXZ-3C24NAHZ4-	BMS500-AAM027-1CSXRC
Inside Unit model no.		BMS500-AAU018-1AHWXC BMS500-AAU009-1AHWXC
Operating Temperature range	(-13)°F - 95°F	(-13)°F - 95°F
Rated Cooling capacity at 95°F	22,000 BTU/h	28,000 BTU/h
Rated Cooling input power at 95°F	1.63 kW	2.24 kW
Rated COP at 95°F	3.96	3.66
Heating capacity at 47°F	25,000 BTU/h	28,000 BTU/h
Heating input power at 47°F	1.73 kW	2.2 kW
Rated COP at 47°F	4.24	3.73
Heating capacity at 5°F	25,000 BTU/h	19,000 BTU/h
Heating input power at 5°F	3.76 kW	2.79
Rated COP at 5°F	1,95	2
Max. Heating capacity at -13°F	22,500 BTU/h	11,000 BTU/h
Max. Heating input power at -13°F	4.05 kW	2.3
COP at max. Heating input at -13°F	1.63	1.4
Capacity maintenance (Rated 17°F / Rated 47°F)	56%	75%
Capacity maintenance (Rated 5°F / Rated 47°F)	100%	67%
Capacity maintenance (Max 5°F / Rated 47°F)	100%	55%
SEER 2	19	24.6
HSPF2 (IV / V)	10 / 8.2	9.5 / 7.1
Refrigerant	R-410A	R-410A
Cost without rebates	$10,985.00	$6,900.00
Possible Rebate	$1800	$1800
Cost with rebates	$9,185.00	$5,100.00

Expert Review

After reviewing the two quotes, additional input was requested from installer Nick Bender, an experienced professional from the Minneapolis region with over 18 years of field experience in air sourced heat pump systems. According to a publication by *Fresh Energy Magazine*, he is considered one of Minnesota's leading installers for new generation heat pump technologies.

During the review, Nick Bender highlighted several key aspects that homeowners and contractors should consider before installation. He emphasized the importance of working with contractors who conduct a complete Manual J load calculation to accurately determine the building's insulation quality and heat loss characteristics. He also recommended using variable speed inverter driven heat pumps, which are standard in most cold climate systems.

Variable speed systems adjust their power output according to actual heating and cooling needs, resulting in lower electricity consumption and reduced mechanical stress on the equipment. This enhances both energy efficiency and system longevity.

Bender also discussed the ongoing refrigerant transition within the United States HVAC industry.

Refrigerant Transition in the United States

R410A has long been one of the most widely used refrigerants in residential and light commercial HVAC systems, particularly after the phase out of older refrigerants such as R22. It became popular due to its stable performance and zero ozone depletion potential. However, R410A has a global warming potential (GWP) of approximately 2,088.

In response to international climate agreements and U.S. environmental regulations, the HVAC industry is shifting toward refrigerants with significantly lower GWP values. One of the most prominent alternatives is R454B, a next generation HFC-HFO blend with a GWP of about 466 - a reduction of more than 75 percent compared to R410A.

The transition is primarily driven by the American Innovation and Manufacturing (AIM) Act, which requires a gradual reduction in the use of high GWP hydrofluorocarbons (HFCs). Starting January 1, 2025, the U.S. Environmental Protection Agency (EPA) will prohibit the manufacture and import of new HVAC systems using R410A. The continued use and servicing of existing systems will still be permitted until January 1, 2026.

R454B, classified as ASHRAE A2L, is characterized by low toxicity and mild flammability. Because it operates at different pressures and has a slight temperature glide, it is not a direct replacement for R410A. Systems designed for R454B require specific compressors, heat exchangers, expansion valves, and safety mechanisms in accordance with the UL 60335-2-40 (4th Edition) standard. Retrofitting existing R410A systems for R454B is therefore technically and economically impractical (Endless Energy, 2025), (Bosch , 2025), (TRANE, 2025), (Federal Register, 2024).

Updated Quotes with R454B

Following these insights, both contractors were asked to provide updated quotes featuring heat pump systems that use the new A2L refrigerant. Only Contractor B submitted a revised proposal at the time of evaluation.

Contractor	Contractor B
Offered Heat pump brand	Bosch
Outside Unit model no.	BMS500-AAM036-1CSXRD
Inside Unit model no.	BMS500-AAU018-1AHWXD BMS500-AAU009-1AHWXD
Operating Temperature range	(-13)°F - 95°F
Rated Cooling capacity at 95°F	36,000 BTU/h
Rated Cooling input power at 95°F	3.00 kW
Rated COP at 95°F	3.52
Heating capacity at 47°F	37,000 BTU/h
Heating input power at 47°F	3.10 kW
Rated COP at 47°F	3.50
Heating capacity at 5°F	26,000 BTU/h
Heating input power at 5°F	3.81
Rated COP at 5°F	2
Max. Heating capacity at -13°F	14,600 BTU/h
Max. Heating input power at -13°F	3.20
COP at max. Heating input at -13°F	1.34
Capacity maintenance (Rated 17°F / Rated 47°F)	71%
Capacity maintenance (Rated 5°F / Rated 47°F)	70%
Capacity maintenance (Max 5°F / Rated 47°F)	70%
SEER 2	24
HSPF2 (IV / V)	9.5 / 7
Refrigerant	R-454B
Cost without rebates	$9,100.00
Possible Rebate	$1800
Cost with rebates	$7,300.00

The revised Bosch system uses the R454B refrigerant and features an upgraded three-ton outdoor unit. According to Contractor B, this change was made to improve both heating and cooling capacity and to provide an additional safety margin for performance under extreme weather conditions. The system also qualified for a local utility rebate of up to $1,800, offered through the regional incentive program for high-efficiency electric heating systems. In addition, the equipment met the ENERGY STAR® criteria required for the Federal Tax Credit under the Inflation Reduction Act (IRA), which provides up to $2,000 per household for the installation of qualified air source heat pumps. Together, these incentives significantly improved the economic feasibility of the project and contributed to the final decision to select the Bosch R-454B model (IRS, 2025).

Nick Bender emphasized that the minimum output capacity is equally important as the maximum output. The new Bosch system is capable of lowering its output to approximately 7,000 BTU per hour at -5°F and 9,000 BTU per hour at 95°F. This flexibility allows the outdoor unit to match the capacity of the smallest indoor unit and prevents short cycling, a process where the system repeatedly turns on and off in short intervals. Short cycling often occurs when an indoor unit is installed in a location with poor air circulation or when the outdoor unit is oversized, causing rapid temperature changes. This behavior can reduce efficiency and shorten system lifespan. The new Bosch system with R454B offers more stable capacity maintenance across temperature ranges, ensuring smoother and more efficient operation.

Final Selection

After evaluating all offers and expert opinions, the decision was made to install the Bosch system with the R454B refrigerant offered by Contractor B. Although the Mitsubishi system proposed by Contractor A achieved slightly higher efficiency values (COP) and better low temperature performance, the Bosch system represented the more future proof and regulation compliant option.

In addition, the Bosch system's higher overall capacity, the eligibility for a federal tax credit, and the cost advantage of approximately 1,885 dollars after rebates made it the most suitable choice for the project in cooperation with the Office of Sustainability and installer Nick Bender.

Utility Engagement

To determine the most cost-efficient electricity rate for Resident T and the new electric household that includes a heat pump, the project team contacted the local utility. The sales representative explained the rate options that can be applied to a heat pump.

Residential Rate:

The residential general service rate is the default connection. All devices that are not on a special rate are billed through this meter. Electricity use is measured by the house meter that is connected to the local grid.

Dual Fuel Rate (DFR):

The DFR is an off-peak load-controlled rate that can be assigned to electric heating and cooling equipment.

To use this rate, a backup heating system is required because the utility can interrupt power to the connected device during peak conditions, maintenance, or system emergencies in winter. For equipment that also cools, the unit can be cycled on and off in fifteen-minute intervals in summer. A separate meter is required, typically rated at one hundred amps.

To control a non-ducted air sourced heat pump in this case, the sales representative described two setups.

In the Setup shown in Graphic 1, the utility sends a wireless control signal to a radio receiver installed near the heat pump or electric meter. The receiver outputs a 24-volt control signal that operates a relay. When the signal is active, the relay remains closed, and electricity flows normally to the heat pump. When the utility sends a load control event, the 24-volt signal is interrupted, which opens the relay and disconnects the heat pump from power.
This method is low-voltage and signal-based, meaning that the high-voltage circuit remains physically separated from the control logic. It is the most common and safe configuration for modern load control programs because it is compatible with smart thermostats and other control equipment.

In some older or simpler installations, the radio receiver is wired directly into the 240-volt power circuit supplying the heat pump as shown in Graphic 2. Instead of using a low-voltage relay, the receiver directly controls a high-voltage disconnect switch. When the receiver is energized, the switch stays closed and allows power to flow. When a control signal is sent, the switch opens and physically cuts the 240-volt supply to the heat pump.
This approach achieves the same result — temporary disconnection — but without a separate low-voltage control circuit. It is technically straightforward but less flexible, since it interrupts the full power circuit and offers limited compatibility with modern smart controls.

In both cases, the purpose of the load control system is the same: to reduce peak demand on the electrical grid by temporarily disabling electric heating systems, while a backup heating source such as natural gas or propane maintains comfort in the building.

Other rates:

Some utilities also offer deferred load or residential demand control options for high consumption devices such as washing machines. According to the sales representative, these options are generally not recommended for heat pumps.

Resident T’s Electrical Household

Resident T has two electrical meters connected to the property: a thirty amp off peak meter for the built in electric water heater, and a general service meter for all other electrical devices. At the time of decision making and communication with the utility, the water heater was connected to an off-peak rate.

In addition, Resident T participates in a green energy initiative that supports the expansion of renewable electricity generation for the utility. This tariff is more expensive than the standard residential rate and can be purchased in blocks of one hundred kilowatt hours, which are generated from renewable sources and contribute to further expansion of clean energy.

Between July 2024 and June 2025, before the heat pump installation, Resident T’s total energy consumption was 9,689 kilowatt hours.

Of this total, 7,747 kilowatt hours were billed under the residential rate, corresponding to an average of 645.58 kilowatt hours per month, and 1,942 kilowatt hours were billed under the off-peak rate for the water heater, corresponding to an average of 161.83 kilowatt hours per month.

At first, Resident T tried to learn about the available electricity rates through the information materials provided on the utility's website, brochures, and direct contact. However, it turned out to be more challenging than expected to determine which rate would be most suitable for the soon to be installed heat pump, how the new meter implementation would work, and how the overall billing and rate structure would change as a result.

Rate Structure Discussion

During the installation of the heat pump at Resident T's house, several uncertainties arose regarding the applicable electricity rates. These challenges reflected a broader pattern found in the follow up interviews with other residents, many of whom stated that they were unaware of the different rate options offered by their utility.

To address this issue, a task force was formed consisting of the Sustainability Director of the University of Minnesota Morris, Troy Goodnough, CERTs Coordinator Imani Mosher, Citizens Utility Board representative Carmen Carruthers, CEE Project Coordinator Rachel Mitchell and a utility representative. The goal of this group was to find ways to make information about available rate structures more transparent and accessible for residents.

Comparison of the Main Rates

As clarified during Project Guinea Pig by the utility representative, the most relevant electricity rates for residents who install a heat pump are the Dual Fuel Rate (DFR) and the Residential Rate. The following section therefore compares these two rates. Additionally, the Residential Rate will be compared with the load-controlled Water Heater Rate (WHR) to determine under which conditions each option would make sense for Resident T.

Only comparisons between the Residential Rate and individual off-peak load-controlled rates are considered here. A combined scenario including all three rate types is not analyzed.

When connecting a device to a load-controlled rate, an additional meter must be installed. The installation cost of this meter varies depending on the model and is not performed by the utility company itself but by an independent electrical contractor. Because of this variation, installation costs are not included in the cost comparison below.

To decide which of these rates is the most cost efficient, several questions must first be addressed and a number of factors considered.

Crucial Background Information

Before choosing to enroll in an off peak load controlled rate, a resident must evaluate both personal and technical aspects.

On a personal level, one must be comfortable with the idea of giving up a certain amount of control over heating or cooling, since the utility can temporarily interrupt the power supply during peak conditions. These interruptions occur without prior notice or warning. Residents therefore need to accept that short-term outages can happen and that comfort levels may vary during these times.

From a technical and financial perspective, it is important to understand that the Residential Rate serves as the electrical baseline. It covers all devices that are not connected to an off-peak rate. A load-controlled rate such as the DFR or WHR does not replace the Residential Rate but rather operates in parallel with it.

To enable this setup, an additional meter must be installed for each load-controlled rate. These meters are dedicated to specific devices. For example, the heat pump in the case of the DFR or the electric water heater in the case of the WHR. All other electrical consumers in the household continue to operate under the Residential Rate.

In the case of the DFR, it is also essential to have a reliable backup heating system that can maintain the desired indoor temperature during control periods or outages, especially in the winter or shoulder seasons.

Overview of Cost Components

With the assistance of the sales representative and the internal rate calculation sheet provided by the utility, the different rate structures and their associated charges were reviewed in more detail. These elements ultimately determine the price per kilowatt hour and therefore the overall cost difference that decides whether a specific rate leads to financial savings.

In general, the total cost of electricity can be divided into fixed charges and variable charges.

Fixed Charges

Fixed charges are the settled monthly fees that appear on every electricity bill in the same amount, regardless of consumption. These costs can vary slightly between different rate types.

- Customer Charge: This represents the basic fee for being connected to the electrical grid.
- Facility Charge: This applies when an additional meter is installed that is not part of the general residential service. The amount depends on the type of meter and can differ between installations for the Dual Fuel Rate (DFR) and the Water Heater Rate (WHR).
- Energy Use Infrastructure Charge (EUIC): This charge supports shared investments in energy infrastructure.
- Uplift Charge: This covers costs related to grid support and wholesale market operations managed by the utility company.

Together, these components form the monthly fixed portion of the bill, which remains constant regardless of energy use.

Variable Charges

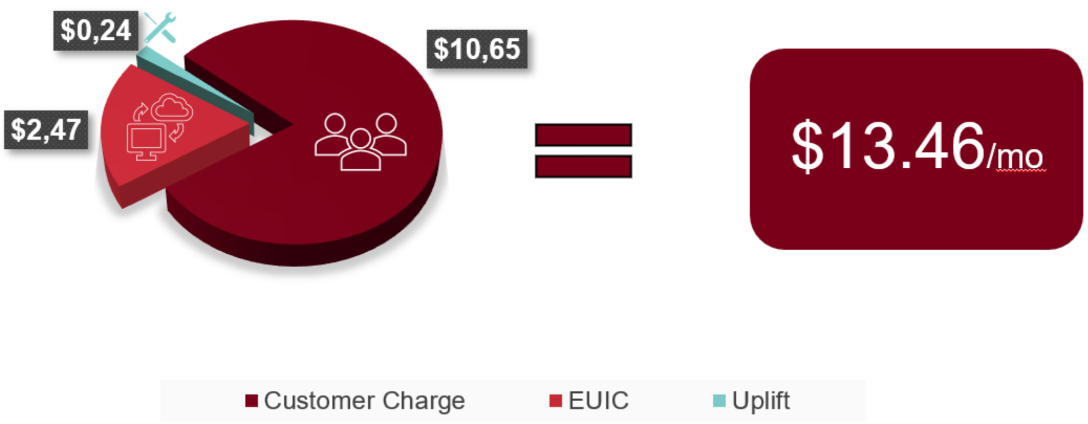
Variable charges are based on actual electricity consumption and can differ from month to month and between rate types.

- Energy Charge: The basic price per kilowatt hour charged by the utility.
- Energy Adjustment Charge: A short-term adjustment that reflects fluctuations in fuel or power purchase costs and serves as part of the utility's risk management.
- Energy Cost Outlook (ECO): A long-term adjustment reflecting broader market forecasts and anticipated cost trends.
- Transmission Cost Recovery: This fee helps recover the cost of delivering power through high voltage lines and compensates for transmission losses.
- Environmental Cost Recovery: A charge that supports investments in environmental compliance and sustainable energy measures.
- Revenue Decoupling Adjustment: An adjustment used to balance differences between forecasted and actual revenues due to variations in consumption patterns.
- Energy Intensive Trade Exposed Credit (EITE): A state mandated credit that offsets costs related to the competitiveness of energy intensive industries.

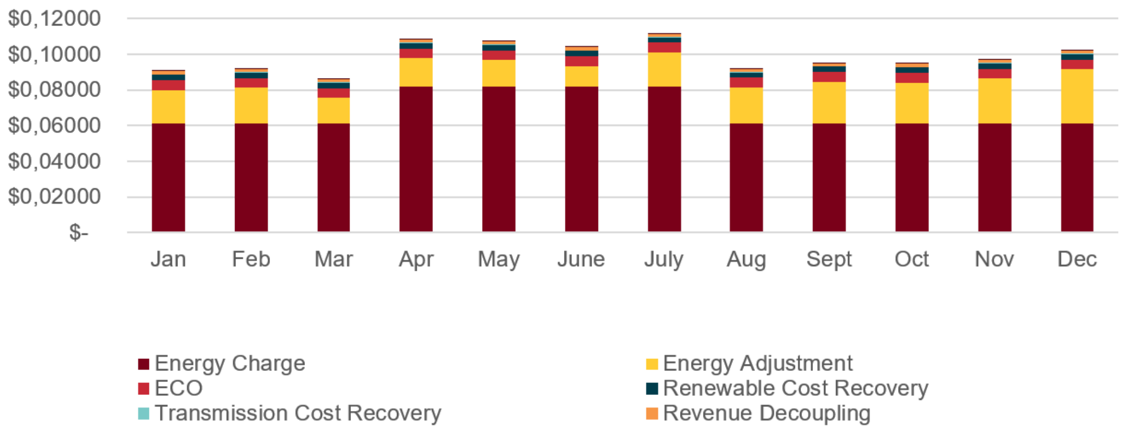
Together, these fixed and variable elements define the total electricity cost per month for each rate structure. Understanding their composition is essential for identifying which rate provides the best economic outcome for residents considering a heat pump installation.

Electricity Rate Structure and Cost Breakdown

Residential Rate:

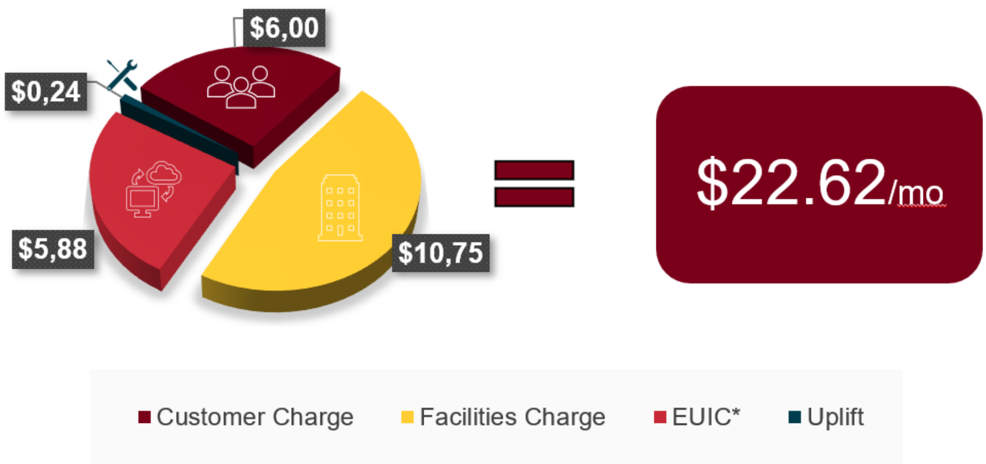


As illustrated in Graphic 3, the fixed monthly charges for the local utility in Morris, Minnesota, consist of a customer charge of 10.65 dollars, an Energy Use Infrastructure Charge (EUIC) of 2.47 dollars, and an uplift charge of 0.24 dollars, resulting in a total fixed charge of 13.46 dollars per month.



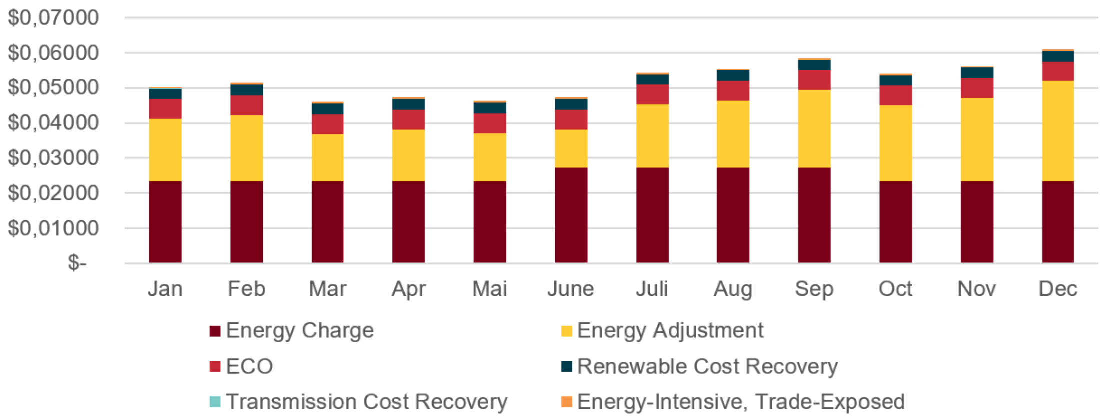
In addition to the fixed charges, the variable energy costs fluctuate throughout the year, ranging from 0.086 dollars per kilowatt hour in March (lowest) to 0.116 dollars per kilowatt hour in September (highest). These variations reflect seasonal demand and market adjustments applied by the utility.

Dual Fuel Rate (DFR)



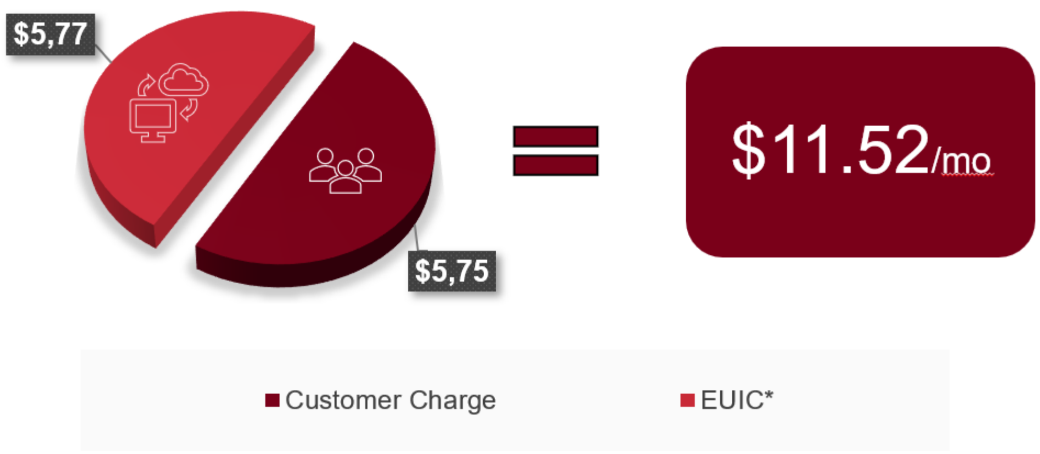
As shown in Graphic 5, the Dual Fuel Rate offered by the local utility in Morris results in a monthly fixed charge of 22.62 dollars. This total includes a facility charge of 10.75 dollars for the additional meter, a customer charge of 6.00 dollars, an EUIC charge of 5.88 dollars, and an uplift charge of 0.24 dollars.

Compared to the Residential Rate, this represents an increase of 9.16 dollars per month in fixed costs. Since the DFR requires an additional meter and operates alongside the Residential Rate, both fixed charges apply simultaneously, leading to a combined total of 36.08 dollars per month for customers who choose this setup.



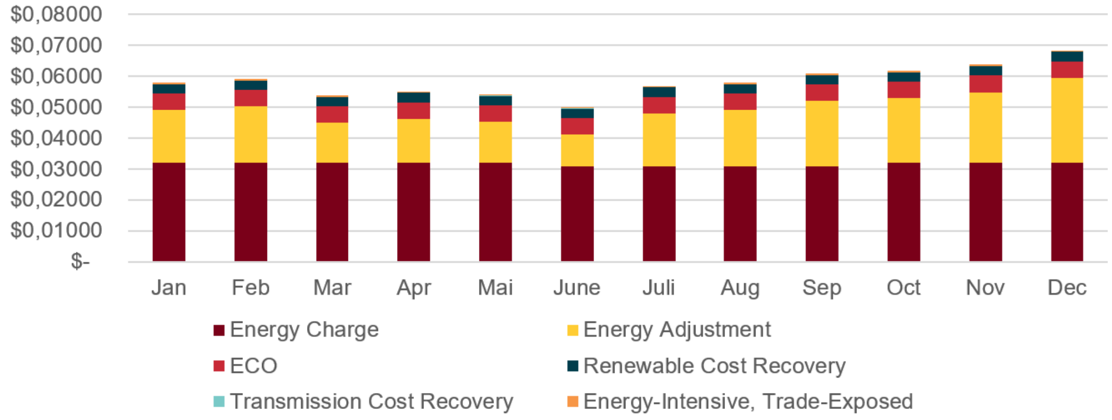
The variable energy price under the DFR also changes by season, ranging from 0.0459 dollars per kilowatt hour in March to 0.061 dollars per kilowatt hour in December (see Graphic 6). On average, the DFR energy price of 0.052 dollars per kilowatt hour is 0.047 dollars lower than the Residential Rate average of 0.099 dollars per kilowatt hour.

Water heater rate (WHR)



As shown in Graphic 7, the Water Heater Rate includes a customer charge of 5.75 dollars and an EUIC charge of 5.77 dollars, resulting in a total fixed charge of 11.52 dollars per month.

When combined with the Residential Rate, this results in a total monthly fixed charge of 24.98 dollars for households that also participate in the WHR program.



The variable charges under the WHR fluctuate throughout the year, ranging from 0.05 dollars per kilowatt hour in June to 0.068 dollars per kilowatt hour in December (see Graphic 8).

Electricity Cost Comparison and Break-Even Analysis

To compare the different electricity rates, the method of determining the breakeven point between two rates was used. This approach identifies the electricity consumption level at which one rate becomes more cost efficient than the other.

To make the comparison realistic, a baseline electricity usage for a typical household in Minnesota was established, along with the estimated consumption of the newly installed heat pump. The baseline represents the average household electricity cost without heating or cooling demand.

Resident T's monthly average electricity consumption was 645.58 kilowatt hours (kWh). When multiplied by the average price of 0.098 dollars per kWh and added to the fixed monthly charge of 13.46 dollars, the result is:

$$645.58\left[\frac{kWh}{mo.}\right] \times 0.098[\$] + 13.46\left[\frac{\$}{mo}\right] = 76.72\left[\frac{\$}{mo}\right] \qquad (1)$$

This corresponds to 76.72 dollars per month or approximately 920.72 dollars per year for general household electricity, independent of any heat pump operation.

Comparison: Dual Fuel Rate (DFR) vs. Residential Rate

As described earlier, the DFR adds an additional meter and thus an extra fixed monthly cost of 22.62 dollars. However, its variable energy cost of 0.052 dollars per kWh is significantly lower than the Residential Rate average of 0.099 dollars per kWh.

To determine when the DFR becomes cost effective, the additional fixed cost is divided by the difference in variable rates:

$$\frac{22.62[\$]}{0.099\left[\frac{\$}{kWh}\right]-0.052\left[\frac{\$}{kWh}\right]}=481\ [kWh] \qquad (2)$$

This means that a heat pump connected to the DFR must consume more than 481 kWh per month on average throughout the year to save money compared to keeping it on the Residential Rate.

Based on the performance data published in the NEEP (neep.org) database for the Bosch R-454B outdoor unit, the expected electricity consumption for the heat pump is approximately 720 kWh per month for the period March through October. This estimate is derived from the unit's certified SEER2 and HSPF2 efficiencies in combination with the heating and cooling degree-day distribution of Morris, Minnesota, which together allow calculation of the seasonal electrical energy required to meet the building's thermal load.

For the case of Resident T, the Bosch air-sourced heat pump from Contractor B's R454B system quote was used as the reference unit for an example scenario. By comparing the total monthly cost of the household electricity on the Residential Rate with the heat pump consumption billed under the DFR, it can be determined whether this setup leads to savings.

$$720\ \left[\frac{kWh}{mo.}\right]\times 0.098[\$]+13.46\left[\frac{\$}{mo}\right]=84.02\ \left[\frac{\$}{mo}\right] \qquad (3)$$

$$(645.58+720)\ \left[\frac{kWh}{mo.}\right]\times 0.098[\$]+13.46\left[\frac{\$}{mo}\right]=147.3\ \left[\frac{\$}{mo}\right] \qquad (4)$$

The heat pump consumption, if billed under the DFR, would follow the formula:

$$720\ \left[\frac{kWh}{mo.}\right]\times 0.052[\$]+22.61\left[\frac{\$}{mo}\right]=60.05\ \left[\frac{\$}{mo}\right] \qquad (5)$$

The sum of both amounts represents the combined Residential and DFR setup:

$$76.72 \left[\frac{\$}{mo.}\right] + 60.05 \left[\frac{\$}{mo.}\right] = 136.77 \left[\frac{\$}{mo}\right] \quad (6)$$

By comparing this configuration to a scenario in which all household electricity-, including the heat pump, is billed under the standard Residential Rate, the potential cost savings can be assessed. It should be noted that the installation of the additional meter and control equipment should ideally occur simultaneously with the heat pump installation in order to avoid extra service charges. The utility representative also emphasized that Dual Fuel Rate (DFR) contracts apply on a yearly basis and cannot be activated seasonally. Consequently, residents should evaluate their expected annual heat pump usage before enrolling, as households that primarily rely on their heat pump during the summer may not benefit from an off-peak, load-controlled rate.

In the case of Resident T, the estimated savings would amount to approximately $10.53 per month, or $126.36 per year, if the heat pump were placed on the Dual Fuel Rate.

Comparison: Water Heater Rate (WHR) vs. Residential Rate

For the electric water heater, a similar break even analysis was conducted. The WHR carries an additional fixed monthly cost of 11.52 dollars but offers a lower average energy price of 0.058 dollars per kWh compared to the Residential Rate’s 0.099 dollars per kWh.

Dividing the fixed charge by the difference in variable prices yields:

$$\frac{11.52[\$]}{0.099 \left[\frac{\$}{kWh}\right] - 0.058 \left[\frac{\$}{kWh}\right]} = 280\ [kWh] \quad (7)$$

Thus, the WHR becomes cost effective only when the water heater consumes more than 280 kWh per month. Resident T’s water heater, however, uses only 161.83 kWh per month, which is well below this threshold.

To quantify the impact, two billing scenarios were compared:

1. Water heater on Residential Rate:

$$(645.58 + 161.83)\ \left[\frac{kWh}{mo.}\right] \times 0.098[\$] + 13.46 \left[\frac{\$}{mo}\right] = 92.59\ \left[\frac{\$}{mo}\right] \quad (8)$$

2. Water heater on WHR:

$$161.83\ \left[\frac{kWh}{mo.}\right] \times 0.058[\$] + 11.52 \left[\frac{\$}{mo}\right] = 20.91\ \left[\frac{\$}{mo}\right] \quad (9)$$

$$76.72\ \left[\frac{\$}{mo.}\right] + 20.91 \left[\frac{\$}{mo.}\right] = 97.63\ \left[\frac{\$}{mo}\right] \quad (10)$$

When comparing both billing scenarios, the total monthly cost under the Residential Rate amounts to 92.59 dollars, whereas the combined cost under the Water Heater Rate setup reaches 97.63 dollars per month. This results in a cost difference of approximately 5 dollars per month in favor of the Residential Rate, corresponding to an annual saving of around 60 dollars.

By switching the water heater from the WHR to the Residential Rate, Resident T would therefore achieve a modest but measurable cost reduction. In addition, removing the water heater from the off-peak control program ensures continuous access to hot water throughout the day, without being affected by temporary power interruptions initiated by the utility during high demand periods.

Results and Discussion

The results of the cost comparison show two key break-even thresholds that determine the most economical setup for residents in Morris, Minnesota.

- For the Dual Fuel Rate (DFR), the break-even point is reached at a monthly consumption of approximately 481 kWh. Above this threshold, the DFR becomes more cost efficient due to its lower variable energy rate of 0.052 $/kWh compared to 0.099 $/kWh under the Residential Rate.
- For the Water Heater Rate (WHR), the break-even point is reached at around 280 kWh per month. Below this consumption, the Residential Rate remains the cheaper option.

For Resident T, these findings indicate the following optimal configuration:

- Connect the heat pump to the Dual Fuel Rate (DFR) to take advantage of the lower variable rate and annual cost savings
- Connect the electric water heater to the Residential Rate to avoid unnecessary fixed charges and off-peak interruptions.

With this configuration, Resident T would save approximately $5.04 per month (or $60.48 per year) on the water heater alone, while also benefiting from the lower DFR energy price for the heat pump, which yields an additional $126.36 in annual savings.

Beyond the financial advantages, this setup also improves overall comfort: hot water availability is no longer affected by load control, and heating operation remains cost-optimized through the Dual Fuel Rate.

Overall, the analysis demonstrates that careful evaluation of utility rate structures and their consumption thresholds can lead to measurable long-term savings for residents transitioning to electrified heating systems in rural Minnesota.

Contractor Engagement

Framework and Purpose

As part of the broader exploration of heat pump adoption in rural West-Central Minnesota, it was important to complement the residential engagement with direct discussions with contractors and installation experts. Contractors possess practical experience and a broader perspective on equipment distribution, installation challenges, and customer behavior. Their feedback helps explain not only the current number of heat pumps installed in the region but also the barriers preventing wider adoption.

To approach contractors in a structured way, a questionnaire consisting of 26 questions was developed, focusing primarily on five key questions. These questions aimed to identify the most relevant challenges, information sources, and needs of local contractors.

The outreach was conducted mainly by phone. When no valid phone number was available or when repeated attempts to reach a contractor were unsuccessful, an email was sent if an address could be found. The five core questions were asked first; if contractors were willing to continue, additional questions from the extended list were discussed.

The five main questions were:

1. How many air source heat pumps (ASHPs) have you installed, and what are the main challenges when installing them in existing homes in this area?
2. Are there specific types of homes for which you do or do not recommend ASHPs? Do you usually install them as primary systems or as supplementary systems?
3. What kinds of resources or support would help you install more ASHPs, and where do you currently obtain your technical information?
4. Do you discuss utility rebates or financial incentives with your customers?
5. Have you received any training specifically focused on ASHPs? If so, from whom? Do you also provide training or information to your customers after installation?

All responses were recorded in an Excel database to quantify trends and identify recurring issues for later analysis.

Outreach Process

A total of 53 contractors within a 56-mile radius around Morris were contacted. Their contact information was collected using the Certified Contractor Directory of the *Minnesota ASHP Collaborative* and an online utility platform that lists local contractors by region.

The results were measured according to the number of contractors contacted by phone, the number who answered, the number who agreed to participate, and the number who declined.
Declined interviews were defined as any instance in which the contractor either expressed no interest, refused participation, or terminated the call prematurely.

After each interview, participants were asked for an email address to maintain potential future contact.

The outreach process was conducted in two rounds of calls.

Round 1:

Of the 53 contractors, 7 were contacted by email, resulting in no completed interviews.
The remaining 46 were contacted by phone, with 25 answering the call and 7 agreeing to and completing an interview.

Contractors Contacted via E-Mail	7
Contractors Contacted via Call	46
Answered Calls:	25
Interviews deducted:	7
Unanswered Calls:	21
Declined Interviews:	5

Round 2:

Conducted approximately 19 days later, this round consisted solely of phone calls. Out of 31 calls, 18 contractors answered, and 3 agreed to and completed an interview.

Contractors Contacted via E-Mail	0
Contractors Contacted via Call	31
Answered Calls:	18
Interviews deducted:	3
Unanswered Calls:	13
Declined Interviews:	4

In total, 10 interviews were successfully completed.

Results

The interviews revealed several consistent patterns and valuable insights into the regional heat pump market in West-Central Minnesota. Many contractors reported that they are currently installing or have recently installed air source heat pumps (ASHPs) and that customer interest in this technology has noticeably increased over the past few years. However, in most cases, heat pumps are not used as the primary heating system but rather as a supplementary source of heating and cooling during the shoulder seasons, particularly in spring and fall.

Contractors generally agreed that ASHPs are suitable for most homes, with the main exceptions being manufactured homes and houses with poor insulation. Regarding professional development, most contractors indicated that their training was provided by wholesalers or equipment suppliers, while a smaller number received training through local cooperatives.

When asked what would help them install more ASHPs, contractors emphasized three main points. First, they highlighted the need for clear, up-to-date, and easily understandable information about available rebates and incentives, as the cost of installation remains one of the main barriers for customers. Second, they expressed a desire for educational materials that can be shared with homeowners to improve their understanding of ASHP technology and performance. Third, several contractors mentioned the need for better support in managing the growing customer demand, particularly in relation to clarifying utility rate structures and electricity pricing options.

Overall, the interviews indicate a steadily growing acceptance of air source heat pumps among contractors in rural Minnesota. At the same time, the findings demonstrate a strong need for improved access to information, greater financial accessibility, and enhanced customer education to support wider adoption of the technology in the coming years.

Observed Challenges During Contact

While many contractors were open and cooperative, several expressed hesitation toward participating in interviews, particularly after learning that the project was associated with the University of Minnesota Morris.

Some contractors voiced skepticism about the university's reputation as a liberal institution with a strong environmental and social focus. One contractor explicitly stated that better results might have been achieved "if the university's name had not been mentioned," arguing that the institution is known for its progressive stance on environmental and gender issues. Another contractor repeatedly asked whether interview results would be published anonymously, emphasizing, *"I don't want to be published by name."*

These reactions suggest a degree of distrust or discomfort among some rural contractors toward being publicly associated with a politically or socially active institution. The underlying reasons, whether fear of reputation damage, loss of customers, or general political skepticism, would require further sociological research to understand in depth.

In summary, the hesitation to participate appears partly linked to the local political and cultural context, reflecting broader tensions between rural business communities and academic or environmental institutions.

Conclusion

The exploration of air source heat pumps (ASHPs) in West-Central Minnesota has shown that the transition toward more sustainable heating systems is both technologically feasible and socially complex. The research, conducted in collaboration with local residents, contractors, and the regional utility, provided valuable insights into the practical, financial, and informational challenges that continue to shape the adoption of ASHPs in rural communities.

The residential engagement revealed that most households use their heat pumps primarily for cooling in summer and for supplemental heating during the shoulder seasons, while relying on conventional systems such as gas or propane furnaces during the coldest months. This pattern highlights that, although ASHPs are gaining acceptance, they are not yet perceived as a complete replacement for traditional systems. Limited understanding of system capabilities and the lack of clear guidance from contractors and utilities continue to slow full-scale adoption.

The observation of a real-life installation through Project Guinea Pig demonstrated how practical implementation challenges, ranging from system sizing and contractor coordination to refrigerant transitions, can influence overall project outcomes. The comparison of contractor quotes further revealed significant cost differences between models and manufacturers, with efficiency ratings and refrigerant types playing an increasingly important role in long-term decision making. The shift from R410A to R454B refrigerants under the upcoming 2025 standards underscores the importance of anticipating regulatory changes and aligning local installations with future-ready technologies.

The contractor engagement provided a clearer understanding of the professional environment that shapes heat pump distribution in the region. Interviews with local HVAC professionals indicated a growing market interest but also identified persistent barriers such as limited training access, complex rebate programs, and uncertainty about utility rate structures. Many contractors expressed that clearer communication, consistent rebate information, and educational materials for customers would help expand the market further. Cultural and institutional skepticism in parts of rural Minnesota was also observed as a subtle but noteworthy factor influencing collaboration and participation in sustainability-related projects.

From the financial and technical perspective, the rate structure analysis provided important insights into how electricity tariffs influence the cost efficiency of heat pump systems. The evaluation of the Dual Fuel Rate (DFR) and Water Heater Rate (WHR) showed that smart rate selection can significantly affect the economic viability of electric heating. The study found that heat pumps become more cost effective under the DFR once their monthly electricity consumption exceeds approximately 481 kWh, while water heaters are more economical under the standard residential rate when their consumption remains below 280 kWh. For Resident T, the optimal configuration proved to be connecting the heat pump to the DFR and billing the electric water heater under the residential rate, resulting in measurable annual savings and improved comfort.

In summary, the results of this study demonstrate that the successful adoption of air source heat pumps (ASHPs) in West-Central Minnesota relies on the interaction of several key factors: technological readiness, contractor engagement, financial feasibility, and effective information exchange among all stakeholders. Incentive programs such as rebates and optimized rate structures are essential to make ASHP systems affordable and appealing to residents. However, the findings also show that information flow and communication between utilities, contractors, and homeowners are equally important.

Only when each group understands both the technical capabilities and the limitations of ASHPs can widespread and confident adoption occur.

Beyond the analytical results, this project and its partners have already contributed significantly to the development of stronger local networks. The close collaboration between the University of Minnesota Morris Office of Sustainability, CERTs, the Citizens Utility Board, and regional contractors has helped build bridges between academic research, practical field experience, and local energy policy. By directly engaging residents, installers, and utility representatives, the project created a shared platform for dialogue and mutual learning. These exchanges not only increased local understanding of heat pump technology and rate structures but also strengthened the professional ecosystem needed to support Minnesota’s broader decarbonization goals.

Looking ahead, continuing this form of collaboration will be essential. Future initiatives should build upon the established relationships and use them to improve technical training, promote transparent communication about upcoming refrigerant standards, and simplify access to rebate and rate information. By reinforcing these local partnerships, rural regions such as West-Central Minnesota can position themselves as living laboratories for sustainable heating transitions. The ongoing cooperation between educational institutions, utilities, and contractors represents a powerful foundation for long-term market transformation and provides a replicable model for other communities aiming to reduce carbon emissions while maintaining affordability and reliability.

Acknowledgements

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