ELEPHANT ENERGY

DEFYING THE COLD:

How Heat Pumps Keep Homes 68°F Inside When Its -15°F Outside

May 2023

EXECUTIVE SUMMARY

The myth that heat pump technology is not robust enough for extremely cold climates such as Colorado still exists today even though the Mitsubishi Hyper Heat was released in 2007. Technology improvements have now rendered this belief a myth. This white paper explores the performance of cold climate heat pumps in December 2022, when the Colorado Front Range experienced the coldest temperatures the area has seen in four decades. We at Elephant Energy conducted a study using real world data from our own heat pump installations to assess how our technology performed during these cold temperatures. We found that all of our customers' homes maintained a temperature within their desired set point between 60 to 75 degrees (range represents our customers default thermostat preferences), affirming the ability of heat pumps to withstand even the coldest of temperatures in the Denver metropolitan area.

Elephant Energy was founded in 2021 to radically simplify and accelerate home electrification. We are currently one of the largest deployers of heat pumps and heat pump water heaters in Colorado. With our customers encountering some of the coldest temperatures in the country, the success of our installations has proven that heat pumps do in fact provide the same performance in cold climates as traditional heating systems do. We hope that this study will encourage residents in cold climates to consider heat pumps for their heating and cooling needs, ultimately improving energy efficiency and reducing household carbon emissions.

INTRODUCTION

Heat Pump Basics

A heat pump is a type of HVAC (Heating, Ventilation, and Air Conditioning) system that uses a small amount of energy to transfer existing heat from one source such as the air, ground, or water to another (Heat Pump technology works the same way refrigerators in your kitchen do!). As a result, heat pumps are 3x to 5x more energy-efficient than traditional HVAC systems. Therefore, heat pumps cost less to operate and provide a more comfortable in-home experience.

Cold Climate Heat Pumps

Cold climate heat pumps work exactly the same as normal heat pumps, except cold climate heat pumps are specifically designed to work in extremely cold temperatures . For example, the Mitsubishi Hyper Heat is rated to work at 100% capacity even down to -5°F and is designed to operate down to -22°F or below. Oftentimes, cold climate heat pumps are more energy efficient and can produce more heat at lower temperatures compared to conventional heat pumps that typically lose significant heating capacity when temperatures drop. Today, cold climate heat pumps are used as far north as the Arctic circle and are popular options in very cold countries like Finland and Norway. They are also now available in a broad range of configurations including both ducted and ductless mini split systems to meet the specific needs of one’s home.

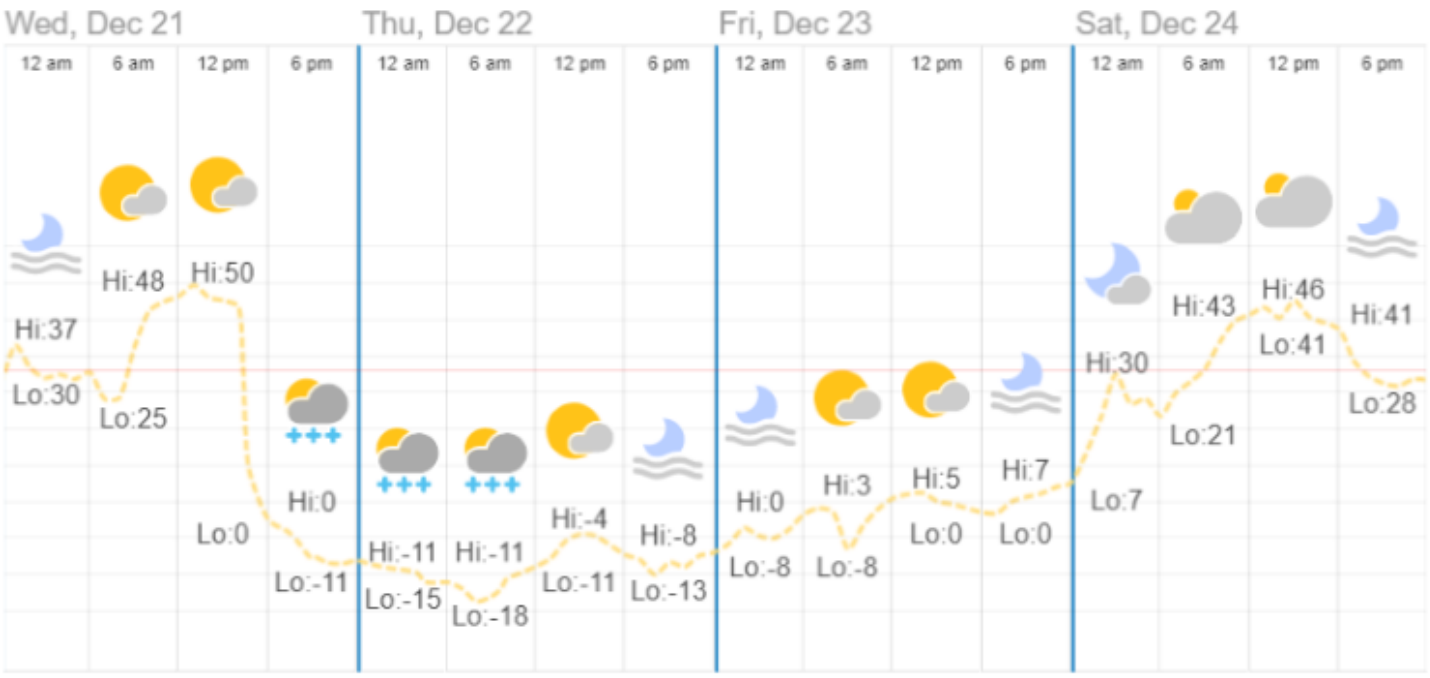
STUDY OVERVIEW AND BACKGROUND

Research Motivation

Prospective customers interested in installing heat pumps often ask us how the technology performs in very cold climates. Some HVAC contractors have had poor experiences with non cold-climate rated heat pumps in the distant past and have recommended residents opt for traditional heating sources or at a minimum maintain a backup gas heat source for Colorado winters.

Which begs the question - what is the origin of this myth? In the 1980s, Toshiba created the first inverter-driven compressor that reduced the start/stop inefficiencies of traditional systems, increasing energy efficiency and improving home comfort. As the technology continued to improve, heat pumps became more efficient at adjusting to variable temperatures including extremely cold climates. Heat pump technology has improved dramatically rendering it capable of standing up to bitter, negative temperatures.

With consumer concerns around cold climate heat pumps still lingering, we wanted to conduct a quantitative assessment using real-world data from our customers to assess how their heat pumps performed in extreme cold. In December 2022, Colorado experienced some of the coldest temperatures it had seen in the past four decades. For ~36 hours, overnight lows hit -16°F while daytime highs remained at 0°F (see chart below) – the perfect opportunity to test and collect this data from our fleet of heat pumps. Elephant Energy has completed hundreds of installations of heat pumps in Colorado and has collected performance data from SmartAC systems from a dozen of these installations' during Colorado's coldest period of the 2022/23 winter. We conducted a quantitative assessment using real-world data from our customers for a few days in December 2022, when Colorado experienced the coldest temperatures it had seen in the past four decades. For ~36 hours, overnight lows hit -18°F while daytime highs remained at 0°F (see chart below) – the perfect opportunity to test and collect this data from our fleet of heat pumps. Some of our customers systems even recorded temperatures as low as -24°F due to localized weather patterns.



METHODOLOGY

Data Collection

SmartAC: What is it and how did it make this study possible?

SmartAC units are custom sensors designed to collect HVAC performance data through monitoring three key data points:

1. The air temperature coming from one's vents
2. The pressure in the return duct which indicates filter condition
3. The water in the overflow pan to avoid costly water damage

By collecting over 50,000 daily readings from one's home, SmartAC units are able to provide a clear and comprehensive view of a home's HVAC performance. For each heat pump we install at Elephant Energy, we also include a SmartAC unit to track and monitor that heat pump's performance.

Delta T: Why is it important?

The temperature of the air produced by the heat pump is defined as the supply temperature. Meanwhile, the return temperature is the temperature of the air in the room being returned to the heating system. The difference between the return and supply temperature is known as Delta T, one of the most commonly used measurements in the HVAC industry. When heating or cooling a room, the industry standard for Delta T is between 15°F to 30°F in order to achieve and maintain the desired room temperature. (Delta T is specified by the manufacturer and can vary by equipment). Monitoring Delta T is important because a delta beyond the accepted 15°F to 30°F temperature range can signify a wide range of issues such as suboptimal system performance, unnecessary energy usage or impending equipment failure.

How we used and interpreted SmartAC data

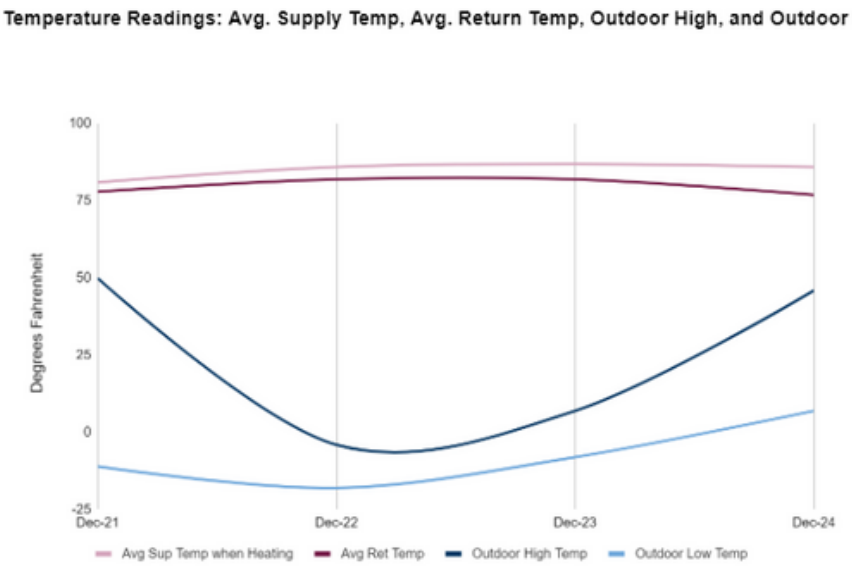
We pulled the SmartAC data for 12 of our randomly selected clients' homes between December 21st and December 24th where we had installed heat pumps as the home's primary heating and cooling source. We focused on supply temperature readings above 70°F as an indicator for when the heat cycle was turned "on" in a household. To assess the performance of the heat pump, we compared the supply temperature to the return temperature to ensure the delta was within the 15 to 30 degree standard. By comparing the two, we could understand if the heat pump was efficiently producing enough heat to maintain the required temperature.

Findings

From December 21st to December 24th, our heat pumps averaged a supply temperature of ~86°F and a return temperature of ~67°F. All of our customers were able to maintain a desired temperature above 65 degrees with little variation in the average return temperature, although it is important to note exact temperatures are dictated by personal preference. Many thermostats were set to temperatures above 70 degrees and the heat pumps had no issues maintaining that temperature. The delta between the return and supply temperature was stable between 15 to 21 degrees, showcasing the ability of heat pumps to not only achieve a desired heating temperature in the Winter, but also the ability to maintain warm temperatures without drastic fluctuations, leading to a more comfortable in-home experience. The data table below displays the average supply and average return temperatures from our SmartAC readings over the four days:

Date	Average Supply Temperature (°F)	Average Return Temperature (°F)	Delta T °F (Supply - Return)
12/21/2022	83	68	**15**
12/22/2022	88	67	**21**
12/23/2022	89	67	**21**
12/24/2022	84	67	**17**

Even when temperatures dropped to a low of -18°F between the hours of 12am and 6am on December 22nd, our heat pumps produced an average supply temperature of 90.1°F. For example, the line chart below shows the daily supply and return temperature for one of our clients as well as the daily high and low outdoor temperature. Even as outside temperatures drastically changed, the average supply temperature and the average return temperature for their home remained relatively consistent.



CONCLUSION

DOES IT WORK?

Yes, heat pumps do work in the coldest climates! As we have seen from our results, our heat pumps in the Denver-Boulder Front Range generated supply temperatures over 90°F even when temperatures dropped down to -18°F. Even in Denver where the high altitude requires heat pumps to generate additional heat, customers were kept warm and comfortable throughout even the coldest days.

TAKING ACTION

Choosing a heat pump for cold climate

Energy Star recently launched a standard for air-source heat pumps that includes a certification mark for cold-climate heat pumps. The standard signifies a suitable level of low-temperature performance and efficiency. As mentioned above, the key feature in a cold-climate heat pump is a variable speed compressor, powered by an inverter that enables a single heat pump to work efficiently and effectively in various extreme temperatures. Like traditional heat pumps, cold-climate heat pumps are available in ducted or ductless designs. In 2021, the U.S. Department of Energy launched the Residential Cold Climate Heat Pump Technology Challenge to accelerate deployment of cold climate heat pump technologies. A few U.S. manufacturers have announced through the challenge they have designed heat pumps for -20°F to -25°F.

Sizing a heat pump for cold climate

Getting the sizing right for a cold climate heat pump is vital because an oversized sized heat pump – as is common practice with furnaces – will be extremely expensive. In our experience in improving home comfort, gas furnaces are often oversized for the homes in which they are installed. This leads to lots of downstream comfort issues including very hot dry air blasting on and off, uneven heating and cooling throughout the home, and excessively high energy bills. In order to ensure the heat pump is accurately sized, a heating and loading calculation must be performed. The goal of this analysis is identifying the smallest possible-sized heat pump that meets the home's heating demands year-round. At Elephant, we've created a proprietary heat pump sizing methodology that incorporates the industry standard Manual J approach, as well as applied building science and real world historic data. For every house we install a heat pump in, we also conduct a careful analysis of the last 12 month heating bills, which helps us to develop a comprehensive view of the home's demand.

Recommended Resources

Interested in learning more about cold-climate heat pumps or installing one in your home? Check out the following resources:

- Your Electrification Roadmap
- Cold Climate Heat Pump Guide
- The Best Cold Climate Heat Pumps
- Air Source Heat Pumps Overview

About Elephant Energy

Elephant Energy provides home electrification as a service. We make it easy for homeowners to confidently upgrade their home appliances to modern electric technologies. Our platform incorporates building science and proprietary technology to generate a unique Electrification Roadmap for each homeowner - enabling them to electrify all at once, or over time. Beyond significantly lowering carbon emissions, home electrification increases comfort, decreases monthly utility bills, and improves indoor air quality. We currently operate in the Denver and Boston metro areas and will be expanding to additional markets in 2023.