Cold Climate Heat Pumps Gaining Momentum

Exploring the technological advancements and benefits of cold climate heat pumps, and strategies for optimizing their performance in extreme temperatures

The Rise of Heat Pumps in the United States

The United States heat pump market has seen tremendous growth in the last 10 years. In 2012, around 1.7 million heat pumps were shipped in the United States. In 2022, that number had grown to 4.3 million, which equates to a more than 150% increase in the popularity of the product. **And in 2022, for the first time, more heat pumps were shipped than gas furnaces.**[1]

Globally, the cold climate air-source heat pump market was valued at $529.9 million in 2022 and is expected to grow at a compound annual growth rate of 11.55%.[2]

Why the dramatic increase? The main driver for this impressive growth is the trend of converting the country's energy source from fossil fuels to electricity. This is due in large part to government legislation and regulation that is happening on the federal, state, and local level. The best example of this is the Inflation Reduction Act (IRA), which was passed in the summer of 2022.

The IRA set aside $4.3 billion for state-administered consumer rebate programs designed to promote electrification. This includes the High Efficiency Electric Home Rebates (HEEHR) program that offers consumers up to $8,000 for qualified homeowners who replace their current gas HVAC system with high-efficiency heat pump systems. The rebates occur at the state level.

In addition to action by the federal government, legislation is also occurring on the state and local levels. This includes the California Air Resources Board (CARB) unanimously voting to approve a proposal that would eliminate the sale of gas-powered furnaces and water heating appliances by 2030 and the City of Berkeley, California enacting a ban on all new natural gas infrastructure.

Additionally, in Illinois, Chicago's ComEd offered up to $2,000 in rebates for air-source heat pumps and up to $1,350 for mini-split heat pumps. Maine has awarded more than 116,000 rebates for heat pumps, **surpassing its goal of 100,000** new heat pumps installed by 2025. So, as you can see, this is a trend from coast to coast.

1. The Air-Conditioning, Heating, and Refrigeration Institute. (n.d.). Central Air Conditioners (except window and wall types). https://www.ahrinet.org/analytics/statistics/historical-data/central-air-conditioners-and-air-source-heat-pumps

2. Grand View Research (n.d.). Cold Climate Air Source Heat Pump Market Size, Share & Trends Analysis Report. https://www.grandviewresearch.com/industry-analysis/cold-climate-air-source-heat-pump-market-report

Revolutionizing Cold Climate Heating with Technological Innovations

While legislation is the main driver in the growth of heat pumps, it certainly is not the only reason. **Recent advancements in heat pump technology have made them a much better solution in cold climate temperatures** than they have been in the past.

In late 2021, the Biden administration announced **the Cold Climate Heat Pump Technology Challenge.** The challenge aims to reduce the carbon footprint of cold climate heating solutions by improving the efficiency and affordability of new heat pumps in the field. Currently, 10 manufacturers, including LG, have signed up for the challenge.

Through continued advancements, cold climate, electric heat pumps have the potential to save an average U.S. family as much as $500 annually on their utility bills, reducing their exposure to volatile fossil fuel prices. Currently, space conditioning and water heating account for over 40% of primary energy consumption in buildings in the United States and are a major source of carbon emission. Heat pumps, which heat and cool buildings by extracting heat from the air, use electricity as their only fuel source, creating significant opportunities for on-site carbon emission reductions compared to traditional gas heating appliances.[3]

As more and more consider making the switch, it will be important for HVACR contractors to educate them about technology that might seem “new”.

3. U.S. Department of Energy. (n.d.). Heat Pump Systems. https://www.energy.gov/energysaver/heat-pump-systems

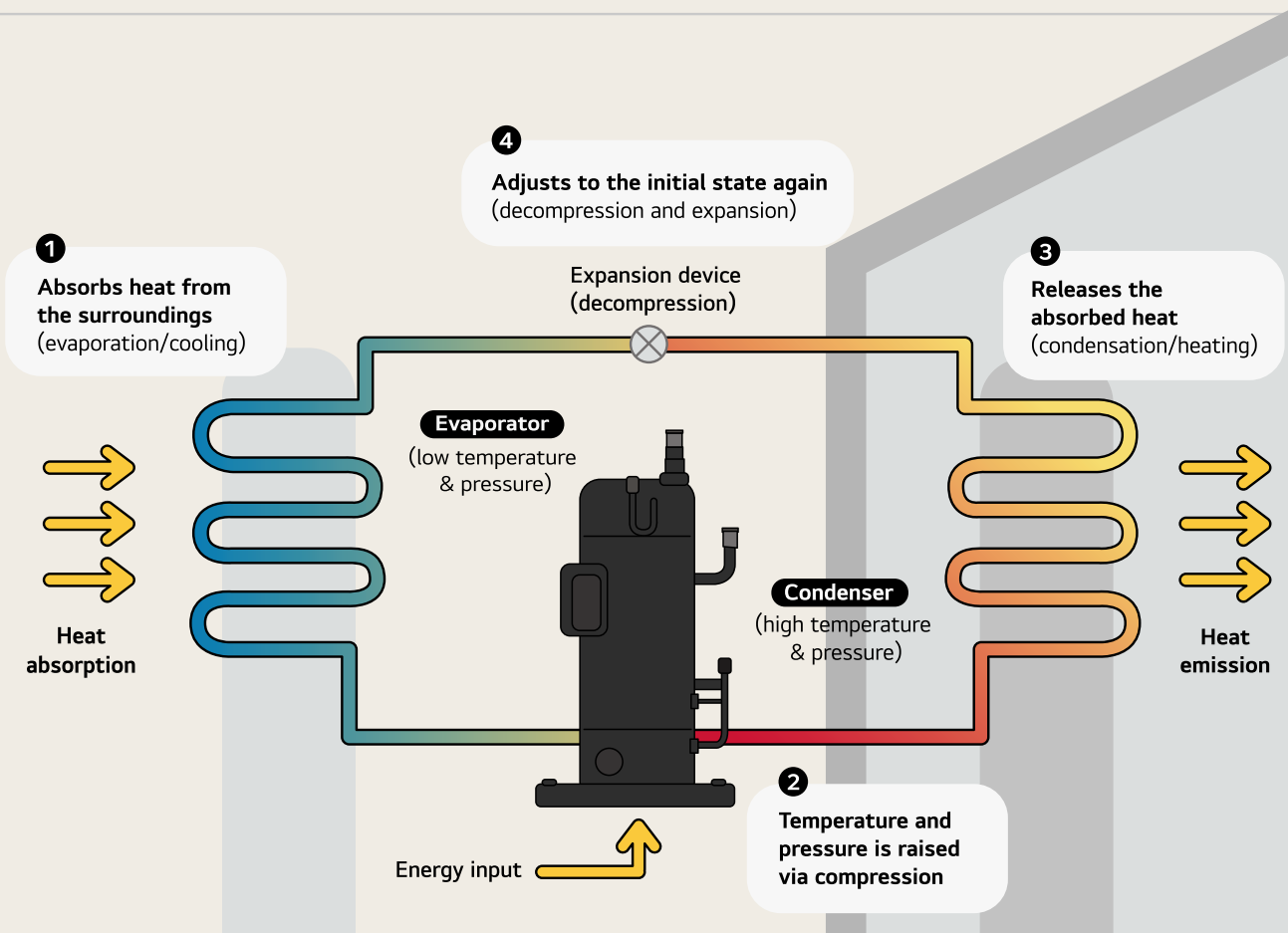
How the Cold Climate Heat Pump Works

In reality, a cold climate heat pump works in a fairly similar fashion to a traditional, ducted air-source heat pump that many HVACR contractors are familiar with and have installed frequently. However, it has specifically been designed for improved operation in lower outdoor ambient temperatures than where heat pumps have typically been applied. To make this happen, two major specification improvements are needed — **additional capacity as the outdoor ambient drops and a lower ambient temperatures condition where the compressor/refrigerant circuit is disabled.**

It is important to remember that **the cold climate heat pump is still a heat pump, so it is affected by the outdoor conditions as far as what heating capacity and efficiency it can provide.** While better than a traditional heat pump, there are limitations, and they still require some backup heat sources for extreme conditions and defrost operation.

When operating in "heat pump" mode, the outdoor coil is functioning as the evaporator while the indoor coil is functioning as the condenser. The evaporator must absorb heat from the outdoor environment, so the coil saturation temperature is lower than the outdoor ambient temperature. The condenser must release heat into the indoor environment; thus, the coil saturation temperature is above the indoor ambient temperature.

Working Mechanism of a Heat Pump



Elevating Cold Climate Heat Pumps Performance and Optimizing Compressor Operations

As the outdoor temperature drops, the evaporator condition moves lower. From the viewpoint of capacity delivery, this is unfavorable for the refrigerant system. The compressor is receiving lower-temperature refrigerant and must still compress it to a high condensing value — which means the compressor is operating at higher compression ratios. For a fixed-speed compressor, the speed and displacement is fundamentally constant. Without any other adjustment, the compressor's delivered capacity will continue to go down as the evaporator goes down and compression ratio goes up. This is the nature of the hardware when operating at higher compression ratios.

In a standard heat pump, the delivered capacity eventually drops to a point where the heat pump is no longer producing enough capacity to be more valuable than electric strip heat. That occurs at an outdoor ambient temperature that is generally too high for proper operating in cold climates. This fundamental limitation of the hardware must be addressed in order to create a cold climate heat pump. **A cold climate heat pump will bring in additional capacity when the outdoor temperature drops to a level where a single-stage compressor would no longer meet the building demand.**

A differentiation should be made between heat pumps with booted heating, and cold climate heat pumps. The cold climate heat pumps have specific minimum requirements for capacity and COP. A boosted heat pump may supply higher-than-normal BTUs, but may not reach the same levels of performance as set forth by the cold climate heat pump.

To get additional capacity, the first approach is to apply a multistage or variable-speed compressor, where lower stages and speeds are matched for the cooling requirements. This allows higher stages and speeds to provide boosted capacity for the heating requirement.

If even more capacity is required, a form of refrigerant injection can be used. A compressor that functions with vapor and liquid injection must be coupled with a secondary heat exchanger — to accomplish the dynamic necessary to boost capacity. As a final step, very large capacity boosts can be achieved by including additional compressors in tandem or multi-circuit configurations.

There are obviously pros and cons on the different compressor types currently being used in heat pumps. The two-stage compressors have the lowest applied cost, but provide the least flexibility in output. The second stage is not enough to meet the Cold Climate Heat Pump Challenge.

Variable-speed rotary compressors are the lowest cost variable-speed option. The full speed range helps dial in the capacities necessary across the system operating range. Any variable-speed option requires the additional cost to cover the variable frequency drive (VFD). The VFD is the electronic component necessary to vary the compressor speed.

Variable-speed scroll compressor with injection technology provides the input port necessary to facilitate the injection function. This boosts system capacity at low outdoor ambient temperature. The compressor added cost is relatively small, but the addition of the system-level components that enable the boosted heating function adds significant cost to the overall system. The variable-speed scroll compressor is more expensive, but also more efficient across the higher tonnages.

Tandem (multi-compressor/single circuit) or multi-circuit solutions add the cost of additional compressors and some system components. This avoids the addition of a VFD, but adds the full cost of additional compressors and additional heat exchangers.

Regardless of the type of system configuration chosen, there is no denying that the cold climate heat pump is going to become more integrated into colder regions as regulations continue to boost efficiency standards and reduce fossil fuel emissions. It will be crucial for HVACR manufacturers to adopt the right strategies and components into their product lines moving forward to stay competitive.

LG Compressors and Motors are based on advanced technology, revolutionizing the HVACR business across residential, commercial, and refrigeration systems.

LG provides a variety of different models that adhere to current specifications and provide improvements for OEM integration and in-field replacement. Our line-up includes fixed scroll, rotary, 2-stage, and variable speed compressors along with electronically commutated and fan BLDC motors for HVACR industry applications.

Additionally, LG is focused on new refrigerant compatibility with all of our components to meet more stringent D.O.E. specifications in the US market, as well as continuously improving efficiency and reliability to meet future demand.

For more information, please contact us.