# Heat Pumps

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## Issue

Provide information on heat pumps, including an overview of the types of heat pumps, how they work, the number of Connecticut residents who have them, and their potential benefits and drawbacks.

## Summary

Heat pumps can provide both heating and cooling to a building. They are powered by electricity and can fully or partially replace a building's natural gas, oil, or electric resistance heating equipment. Heat pumps essentially move heat from one place to another, rather than generating it. Because of this, they generally use less energy to warm buildings than conventional heating systems. When cooling buildings, heat pumps work in a manner similar to traditional air conditioning systems. However, newer heat pumps are often more energy efficient than older traditional air conditioning systems.

According to Energize CT data, at least 71,691 Eversource and United Illuminating customers have installed heat pumps using state incentives since 2017. (Additionally, over 17,000 customers installed heat pump water heaters, which are water-heating systems that use heat pumps.) Incentives are largely funded through the state's Conservation and Load Management (C&LM) program, administered by utilities. The most recently submitted C&LM plan describes heat pump technologies as a staple component of the companies' decarbonization strategies (p. 40). Connecticut has also partnered with Massachusetts, Rhode Island, Maine, and New Hampshire to form the New England Heat Pump Accelerator Coalition, a multi-state effort to accelerate the adoption of heat pumps in the region, funded by a $450 million federal grant awarded in 2024.

Heat pumps may have several advantages when compared to other heating and cooling technologies. In addition to generally being more energy efficient than other heating options, as discussed below, heat pumps can lower emissions associated with heating and cooling, depending on various factors. Installing heat pumps may lower customers' energy bills. They may also be more convenient for customers, providing both heating and cooling, and working without requiring fuel deliveries.

On the other hand, heat pump technologies may come with certain challenges. As discussed below widespread adoption of fuel pumps could impact the electric grid. Another drawback of heat pumps is that pumps that are most effective in the coldest climates tend to be more expensive. Additional concerns cited include potential manufacturing and supply constraints, and the global warming potential of refrigerants commonly used in heat pumps.

## Types of Heat Pumps and Their Operations

Heat pumps exploit the fact that heat naturally flows from a region of higher temperature to a region of lower temperature. They have five main components:

1. a refrigerant (a substance that absorbs and releases heat as it changes state between liquid and gas);
2. an evaporator (the refrigerant evaporates and absorbs heat from the surrounding source (e.g., the air or ground, as applicable);
3. a compressor (to increase the pressure of the heated refrigerant, further raising its temperature);
4. a condenser (where the refrigerant releases its heat, either indoors to heat the building or outside to cool it, condensing the refrigerant back into a liquid); and
5. an expansion valve (to lower the liquid refrigerant's pressure and return it to the evaporator, restarting the cycle).

As discussed below, there are two main types of heat pumps: air-source (ASHP) and ground-source heat pumps, which function similarly, using the same main components. There are variations on these two main types that use different technologies (e.g., air-to-water heat pumps and variable refrigerant flow heat pumps), as well as different configurations within a building (e.g., ducted and ductless). Depending on the size, design, and location of the building or buildings the system is intended to heat and cool, some technologies and variations may be more well suited than others.

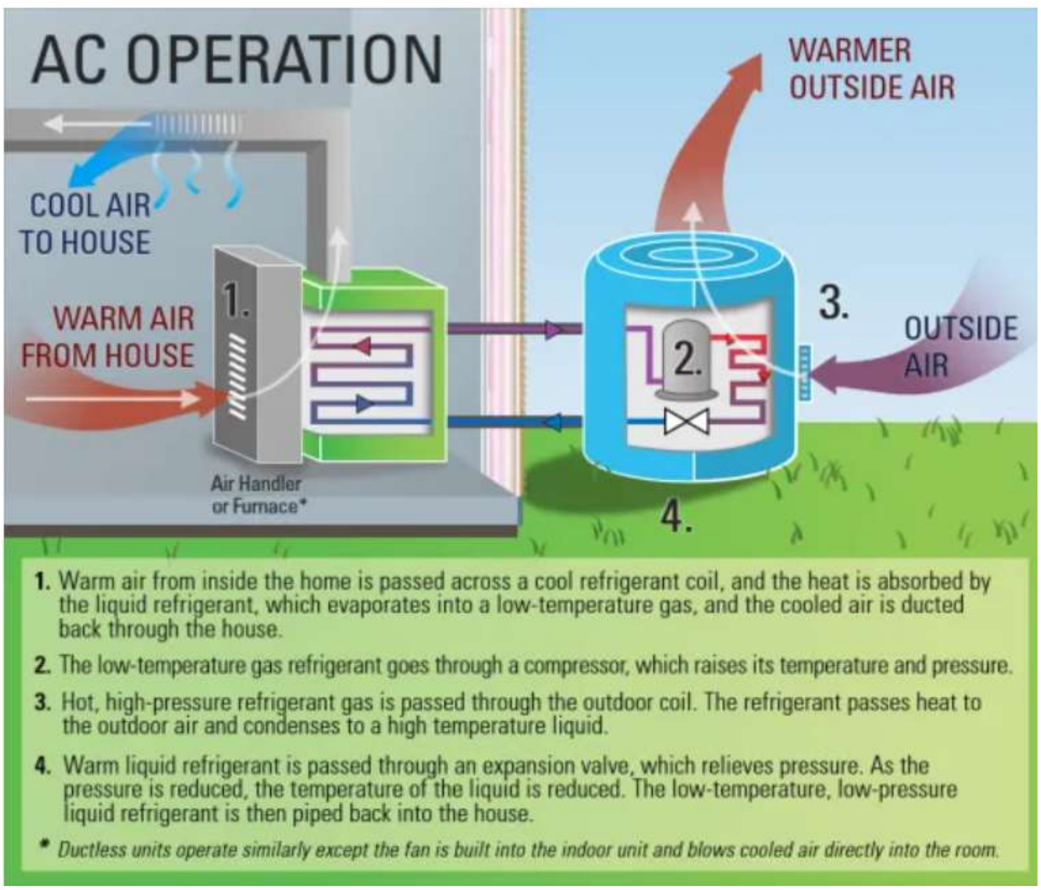
These heat pump systems may be installed with the intent of fully replacing the building's pre-existing heating system (full displacement) or to partially replace the existing system (partial displacement). They may also be used as a supplemental system (e.g., for cooling and for heat during milder periods, while periodically using another heat source).

## *Air Source Heat Pump*

ASHPs are the most common type of heat pump (and the primary focus of this report). The technology is not new; the oil crisis in the 1970s spurred research and investment that improved efficiency and made the ASHPs more viable as a heating and cooling alternative.

When used to cool a building, ASHPs work just like traditional air conditioners, which are also powered by electricity. The system uses a refrigerant to absorb unwanted heat inside a building and transfer it to the air outside by changing the pressure of the refrigerant fluid, as shown in Diagram 1 below.

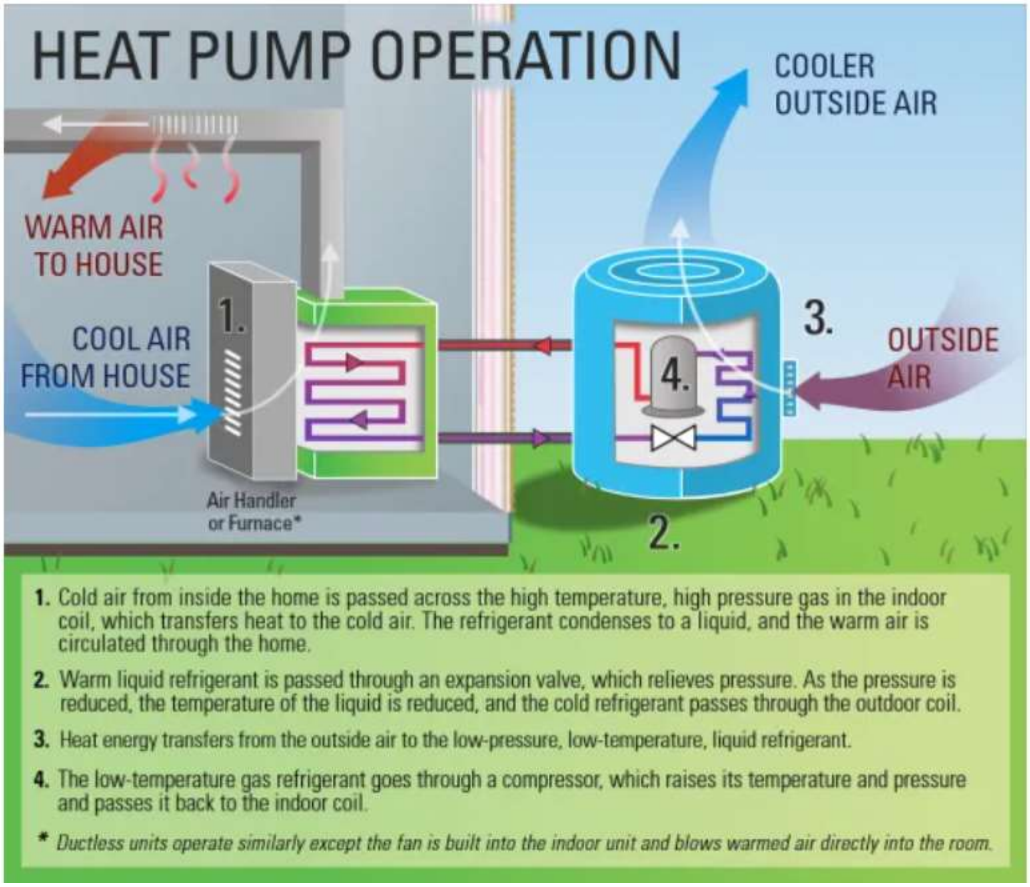
**Diagram 1: ASHP Cooling Mode**




Source: EnergyStar

Unlike traditional air conditioners, heat pumps have a reversing valve that switches the direction of refrigerant flow, allowing the system to also heat the building. As shown in Diagram 2 below, to provide heat, the ASHP essentially works in reverse. It extracts heat from the air outside, which contains a certain amount of heat even when it is cold outside, to warm the air inside.

**Diagram 2: ASHP Heating Mode**




Source: EnergyStar

## *Ground-Source (Geothermal) Heat Pumps*

Like ASHPs, ground-source heat pumps (also referred to as "geothermal heat pumps") provide both heating and cooling and similarly do so by transferring heat into a building during the winter and reversing the process in the summer. But instead of using outdoor air, they use a ground loop. A ground loop is a series of buried pipes filled with a liquid that absorbs or releases heat. The indoor distribution system may consist of ducts, hydronic baseboards, or radiant floors. In addition to heating and cooling, some ground-source heat pumps can also provide domestic hot water.

According to Energize CT's *Your Guide to Ground-Source Heat Pumps*, ground-source heat pumps are the most efficient heating and cooling system available because they take advantage of the stable, underground temperature of the earth (about 50 degrees Fahrenheit in Connecticut). At least 14 municipalities in the state have installed these systems to heat and cool town halls, libraries, schools, and other public facilities, according to data from the Department of Energy and Environmental Protection (DEEP).

***Large Scale and Utility-Owned.*** Although ground-source heat pumps can be more efficient and perform well in colder climates, they are generally more expensive, especially when used for individual residences. Ground-source heat pump proponents promote the technology's commercial and large-scale applications.

A 2024 article from the journal Joule describes utility-owned thermal networks that incorporate ground-source heat pumps (sometimes called "networked geothermal") as a way for gas utilities to pivot into thermal utilities, while eliminating upfront costs for customers by financing them or including them in the rate base. In Massachusetts, Eversource is piloting a utility-scale geothermal program to service an entire neighborhood using a shared network of underground pipes. A 2022 New York law required each utility in the state to submit proposals for thermal energy network pilot projects (see, e.g., Central Hudson's webpage on its pilot project). The state's Large-Scale Thermal Program also provides funding to design these projects for large buildings and groups of buildings using a networked or non-networked approach. Connecticut also recently passed legislation on this topic (PA 25-173, § 32).

## *Variations*

There are multiple subtypes of and variations of heat pumps. For example, air-to-water heat pumps work using the same concept as ASHPs, drawing heat from the outdoor air. But air-to-water pumps deliver the heat to the building through water (rather than hot air). They can be paired with underfloor heating systems, fan coil units, and certain radiators. Variable refrigerant flow systems consist of an outdoor unit connected to multiple indoor units through refrigerant piping to provide cooling and heating to individual zones or rooms in a building. These can be an option for larger commercial or industrial spaces.

Inside the home or building, there are also various configurations. Ducted ASHP systems can work with existing ducting in the building, functioning as a central air system. There are also ductless (or mini-split) systems that typically use indoor units mounted on a wall, floor, or ceiling and blow conditioned air into a space. The U.S. Department of Energy's Heat Pump Systems webpage provides additional information on these and other heat pump configurations and technologies.

# Potential Benefits

As discussed below, some benefits of heat pumps include their efficiency, adaptability to alternative fuel sources, and potential to decrease customers' monthly energy bills. Among other things, they may also be more convenient for customers, providing both heating and cooling, and work without requiring fuel deliveries.

## *Energy Efficiency*

According to the U.S. Department of Energy, an ASHP can deliver up to two to four times more heat energy to a building than the electrical energy it consumes because it transfers heat from one place to another rather than creating it.

A 2022 New York Independent System Operator study found that the energy used by a heat pump, including supplemental electric resistance heat, was about 65% less than furnaces fueled by natural gas and 59% less than electric resistance heating. During the entire heating season, the calculated coefficient of performance (COP) of the heat pump was 2.44; including supplemental heat, the COP was 2.3. But ASHP performance decreases with decreasing outdoor air temperatures and, in winter conditions of -3 Fahrenheit, the COP was 1.43.

*The **COP** is a ratio between the rate at which the heat pump transfers thermal energy in kilowatts (kW), and the amount of electrical power required to do so (in kW). A COP of 3 means that for every 1 kW of electrical energy used, the heat pump transferred 3 kW of heat. A higher number indicates greater efficiency (Natural Resources Canada).*

## *Emissions*

Heat pumps run off electricity. Generally, that electricity is supplied by the electric grid, which may use natural gas, coal, oil, or other carbon-emitting fuels or lower emissions sources (e.g., nuclear, hydroelectric, solar, or wind). The degree to which heat pumps lower emissions depends on (1) whether they are partially or fully displacing higher emissions heating sources (e.g., natural gas or fuel oil) and which source they are displacing; (2) the emissions produced by the electricity the heat pumps use, whether from the electric grid or elsewhere; and (3) other factors, including the heat pump's efficiency. Because the emissions profile of the electric grid varies by region, season, and time of day, the emissions associated with heat pumps will vary. Heat pump proponents often emphasize future benefits under the assumption that the electric grid will get cleaner over time.

Studies have explored various scenarios and documented trade-offs. For example, a 2021 study found that heat pump adoption in the U.S. almost always reduces $CO_2$ emissions, but may increase other emissions (e.g., $SO_x$, $NO_x$, and particulate matter) that have negative effects on public health. According to the authors, this is because residential furnaces and boilers operate at lower combustion temperatures and under stricter air quality regulations compared to power plants. The authors argue that the health damages of heat pump adoption are often outweighed by the climate benefits and note that public benefits of heat pump adoption could be improved by reducing the power sector's emissions through greater regulation (p. 10).

In their 2024 approval of the previous C&LM plan, DEEP describes heat pumps as "one of the most effective measures to reduce emissions from the building sector while also promoting affordability and equity," also noting that the majority of residential sector emissions originate from oil, propane, and natural gas used for heating.

## *Energy Bill Impacts*

Customers installing heat pumps may save money on their monthly energy bills. Whether, or how much, a customer would save depends on a variety of factors, such as (1) the heat pump type and its efficiency; (2) the type of fuel being fully or partially displaced; (3) the comparative rate for the displaced fuel type and electricity at a given time; (4) if the building already had air conditioning; and (5) whether the switch is coupled with "building envelope upgrades" (thermal efficiency improvements, like adding insulation and attic floor air sealing).

Estimates vary, but studies typically indicate that customers switching from electric resistance heating, propane, or fuel oil are most likely to save money when switching to heat pumps, whereas natural gas customers are less likely to save money.

For example, a 2024 study by the National Renewable Energy Laboratory, *Heat pumps for all? Distributions of the costs and benefits of residential air-source heat pumps in the United* States, estimates the impact of installing ASHPs across the country and under different scenarios. The study estimates that 74% of homes in the Northeast currently using fuel oil or propane and 75% of homes currently using electric induction would experience a positive net present value if they adopted a high-efficiency cold-climate heat pump (meaning their energy bill savings over the pump's lifetime, about 16 years, would be greater than the heat pump's price), even without incentives or subsidies (Figure S8). When a $13,500 incentive is provided, these estimates increase to 99% and 100% respectively (Figure S10). Not all classes of customers are estimated to equally benefit, though. The study estimates only 5% of homes using natural gas would see a net positive value unless a financial incentive were provided (Figure S8).

Similarly, the New York Times recently published an article using National Renewable Energy Laboratory and U.S. Energy Information Administration data to estimate, for each state, the percent of homeowners whose energy bills would decrease by switching to a heat pump and the median annual decrease, based on 2023-state level fuel prices. As shown in Table 1 below, the type of fuel being replaced impacts the expected savings.

**Table 1: Estimated Impact of Switching to Heat Pump — Connecticut**

| Heat Source Replaced | Percent of Homes Est. to Save on Energy Bills | Median Annual Bill Decrease |
|---|---|---|
| **Electric (baseboards or furnace)** | more than 95% | more than $1,000 |
| **Natural gas boiler or furnace** | 40% | $0 (no significant change to median bill) |
| **Propane or fuel oil** | more than 95% | more than $1,000 |

The Energize CT website similarly notes that significant savings may not be realized when switching from natural gas (although the cost advantage of natural gas may change over time). A 2022 market analysis of heat pumps in Connecticut identified cost and electric and utility bill savings not meeting expectations as a barrier to heat pump adoption in the state (p. 38). Additionally, customers adding a heat pump where there was no cooling source before may consume more energy and incur more costs.

# Challenges and Other Impacts

As discussed below, concerns about heat pumps often include their effectiveness in colder climates and their impact on the electric grid. Other considerations include (1) their upfront costs (the most efficient types often cost more); (2) manufacturing and supply constraints; and (3) the global warming potential of refrigerants commonly used in heat pumps (hydrofluorocarbons) and air conditioners, meaning installers must take care to ensure refrigerants do not leak and are disposed of properly.

## *Effectiveness in Colder Climates*

The ability of standard air source heat pumps to function in severe cold conditions is often cited as a concern. But cold climate ASHPs (also referred to as ccASHPs) are designed to perform in cold climates even when outdoor temperatures drop below freezing (only ccASHPs that meet certain cold climate standards are eligible for rebates under the Energize CT program). According to Efficiency Maine, heat pumps are now more common than oil heat in new homes built in the state but it suggests residents consider a secondary backup heating system if their areas experience prolonged periods below their heat pumps' listed minimum operating temperatures.

A 2024 study done on behalf of the Connecticut Energy Efficiency Board found that 75% of Connecticut residents surveyed that had full displacement heat pumps as well as backup heating systems (e.g., furnaces, pellet stoves, fireplaces) reported using their backup systems during the coldest periods. They reported doing so for comfort concerns, heating costs, and for ambiance (p. 89).

ASHPs designed to work in colder climates also tend to have higher upfront costs.

### *Impact on the Electric Grid*

ISO New England's 2025-2034 Forecast Report of Capacity, Energy, Loads, and Transmission (CELT Report) projects demand on the region's power grid will increase by about 11% (from 117,262 gigawatt hour (GWh) to 130,665 GWh) over the next decade, with more than half of the increase attributable to accelerating electrification of heating (see also *Final 2025 Heat Pump Forecast* for projections on adoption rates). Electrification is also expected to alter the times during which New Englanders use the most electricity.

By the mid-2030s, the ISO projects that peak demand will occur during the winter rather than the summer, which has seen higher peaks since the 1990s (primarily due to air conditioning use), according to an ISO Newswire article. Switching to winter peaking could mean, among other things, that less peak demand coincides with peak solar generation, which could put more pressure on system operators to maintain existing firm capacity or build more. It is worth noting, though, that heat pumps are not the sole driver of these projections. Transportation electrification (electric vehicles), expected changes in climate, and other factors also play a role.

Ultimately, the actual impact heating electrification (heat pumps) could have on the grid is difficult to predict. Studies suggest the impact can be substantially lessened, though, through envelope improvements and using the most efficient heat pumps — specifically geothermal heat pumps. The following studies provide additional information:

- Rahman Korramfar et al, *Cost-effective planning of decarbonized power-gas infrastructure to meet the challenges of heating electrification* (2025).
- Oak Ridge National Laboratory (U.S. Department of Energy), *Grid Cost and Total Emissions Reductions Through Mass Deployment of Geothermal Heat Pumps for Building Heating and Cooling Electrification in the United States* (2023)).
- AECOM (on behalf of the State of Maryland), *Electrical Grid Impact of Ground Source Heat Pump Technologies* (2023).

## Additional Resources

DEEP, 2022 Comprehensive Energy Strategy Technical Sessions, Building Thermal Decarbonization – Heat Pump Barriers and Market Strategies, Session 2A and Session 2B, September 2022.

DEEP, EPA Climate Pollution Reduction Grant Planning First Deliverable: A Priority Climate Action Plan (Draft), March 1, 2024.

ISO-New England, Final 2025 Heat Pump Forecast, May 1, 2025.

Northeast Energy Efficiency Partnerships, *Northeastern Regional Assessment of Strategic Electrification* (2017).

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