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CLIMATE CHANGE AND ENERGY

Everything you need to know about the wild world of heat pumps

Heat pumps could help address climate change and save you money. Here's how they work.

By Casey Crownhart
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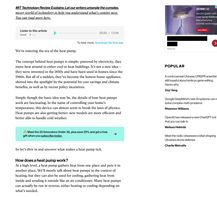

MIT Technology Review Contributor Carl van Vreeken explained the complex electric world of multimeters in detail. Now, he's explaining heat pumps in simpler terms.

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We're entering the era of the heat pump.

The concept behind heat pumps is simple: powered by electricity, they move heat around to where it's needed most. Unlike furnaces, which burn fuels to create heat, heat pumps do not burn fuels and have been said to bemove since the invention of the refrigerator. Heat pumps can be powerful tools for addressing climate change because they can cut greenhouse gas emissions and have other benefits, as well as fewer policy incentives.

Simple though the basic idea may be, the details of how heat pumps work can be tricky. Heat pumps are sophisticated, high-tech appliances, this device can almost seem to break the laws of physics. Heat pumps are also getting better: new models are more efficient and better able to handle cold weather.

Here's everything you need to know about how heat pumps work, why they are important, this device can almost seem to break the laws of physics. Heat pumps are also getting better: new models are more efficient and better able to handle cold weather.

The heart in a heat pump is the refrigerant, a fluid that moves in a closed, sealed loop and releasing heat as it goes. Electricity powers the system, pushing the refrigerant around the cycle.

In the refrigerant stream, it moves from liquid, it's compressed and expanded, switching between liquid and gas forms to allow it to gather and release heat at different points in the cycle. It flows in enough detail for you, feel free to skip to the next question. Otherwise, join me on a journey inside a heat pump to understand how this all works.

INTERNATIONAL ENERGY AGENCY

Picture this: it's a chilly winter day, say 20 °F (-7 °C). You're sitting on your couch, but you're not cold. Your furnace isn't blasting out heat and gas usually. You look over at the thermostat, which is set to 68 °F. Sensible, but a little chilly. You walk over and bump it up a bit, to 70 °F.

You heat pump has been quietly humming along in the background. Now it kicks things up a notch to raise the temperature the fan and compressor inside speed up, and the refrigerant starts moving faster to transfer more heat from outside to inside.

It may seem counterintuitive to collect heat from outside when it's so cold out, so let's follow the refrigerant for one cycle to see how it works. The more heat pumps, the trip takes place a few minutes.

Heat pump refrigerants have very low boiling points, typically below 25 °F (-4 °C). This means they evaporate easily, turning from a liquid into a gas. To evaporate and the liquid form, it needs to absorb energy, a process called latent heat. This is usually significantly colder than the outside air, so that cold air, even than 40 degrees colder.

In the first stage of its ride, the refrigerant flows through a heat exchanger, that is, it's in contact with the outside air, but it's not leaking, changing from a liquid to a gas.

The second phase of its journey is a trip through the compressor. The compressor squeezes the refrigerant into a smaller volume, increasing its pressure and boiling point (this will become important in a minute). This also warms it further, so by the time the refrigerant is past the compressor, it's warmer than the room indoors.

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The third leg of the refrigerant's journey takes it through another heat exchanger. But this time, the refrigerant is a warm gas, above 100 °F, and the outside air is much colder. So the refrigerant cools down, and heat into the room with the help of a fan. It starts turning back into a liquid.

Finally, in the fourth stage, the liquid refrigerant will go through an expansion valve, releasing the pressure, just as squeezing a material hose is up, expanding it allows it to cool down again, so now the liquid is back in a low temperature and ready to absorb more heat to bring inside.

Do heat pumps work in the cold?

Yes, they do, but heat pumps don't work well in really cold weather is often assumed by brand-level companies, which have a competitive product to sell.

There's a kernel of truth here: Heat pumps can be less efficient in cold weather, and in very cold climates, they can become impractical because, a heat pump will have to work harder to gather heat from outside and dispatch it into the room, so efficiencies drop.

But even if heat pumps aren't running at peak efficiency in colder climates, "they work everywhere," says Sam Sikser, senior program manager at Efficiency Maine, an agency that runs energy efficiency programs in the state.

Some heat pumps won't be equipped to warm a room when it's below zero, but there are models that will work relatively in colder temperatures. Sikser says that if you're in the market for a heat pump for cold snap, but if you choose a well-sized system, you shouldn't need them, he adds.

So what's new with heat pump technology?

Heat pump technology has been improving and costs have helped boost the efficiency and performance of heat pumps, especially in the cold, Sikser says.

One major improvement is in the refrigerants. Freon, also called R-22, used to dominate the market, but it has been phased out in the US and other major markets by its greenhouse-gas effects.

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Today, a mixture of chemicals referred to as R-410A is one of the most common refrigerants. It doesn't deplete the ozone layer, but it's still very harmful for the ozone layer. R-410A has a lower boiling point than R-22, meaning it can absorb more heat at lower temperatures, boosting efficiency in the cold.

Other components have improved as well. New compressors used in heat pumps can also get refrigerants to higher pressures among less energy, so they can heat up more. Fans have also been improved, allow heat pumps to ramp their power up and down. Finally, the heat exchangers that move heat between the air and the refrigerant are getting bigger and better, so they can move heat around more efficiently.

There's already a wide range of heat pumps available today. About 40% of the heat pumps sold in the United States last year were air-source. These come in a wide range of shapes and sizes. But other models—so called ground-source or geothermal heat pumps—gather heat from underground instead of collecting it from the air.

How do heat pumps help with climate change?

Heating buildings frequently relies on natural gas or heating oil, which is why the sector accounts for about 10% of global emissions today. Heat pumps can help cut those emissions, especially when they are powered by clean, carbon-free electricity. Moreover, an energy analyst at the International Energy Agency.

Heat pumps can also help electricity from the grid. Heat pumps heat places and help power grids around the world, renewables and low-carbon power sources also contribute. So with the current energy mix in all of the world's electricity grids, heat pumps. The plans that directly fossil fuel-based heating. Masschaelen says.

Heat pumps cool climate equipment to their efficiency. Heat pumps today can reach 300% in 300% efficiency in ideal conditions, meaning they putting out three or four times as much energy in the form of heat as they take in from the electricity. This means, the theoretical maximum would be 100% efficiency, and the best models today reach around 95% efficiency.

The gap in efficiency between heat pumps and heater comes down to how they work. Space heaters work by transforming energy from the form of electricity into another form, heat.

Heat pumps, on the other hand, aren't turning electricity into heat—they're using electricity to gather heat and move it around. It's a subtle difference, but it basically means that a heat pump can return significantly more heat using the same amount of electricity.

A heat pump's maximum efficiency will depend on the refrigerant and other factors, and it will vary from day to day. The difference between the winter efficiency and the summer efficiency.

What else should I know if I'm considering a heat pump?

Flip from cost for heat pumps are a major barrier to adoption. Installation costs can be high, ranging from $4,000 to $12,000 and the IEA, and large homes often require multiple units.

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But over their lifetime of about 20 years, heat pumps are already cheaper than fossil fuel-based heat pumps. Heat pumps are also cheaper than fossil fuel-based heat pumps and cost a home during different parts of the year, Masschaelen says.

And over 20 countries around the world have incentive programs for heat pumps, which can help cut the upfront cost. Incentives can be for purchasing high-efficiency equipment. Sale has especially generous subsidies for heat pumps that are installed when retrofitting buildings with heating and cooling, with continuous going up to 100 of the installation costs.

In the US, the Inflation Reduction Act offers a 30% tax credit on the purchase price of a heat pump, with additional rebates for low- and moderate-income households. Those rebates can add up to a maximum of over 100% of the cost. Reversing America has a rebate program to help people determine what IEA subsidies they qualify for.

What's next for heat pumps?

While heat pumps are significantly better than they were a decade ago, there's still plenty of potential growth ahead for the technology.

New designs, like self-contained window units from startup Gradient, could cut down on installation costs. Other companies, like Mitsubishi LLC, have also started offering small, portable units. These new options could be a good fit for people who don't want to install a permanent system, including renters or homes where installing ductwork or equipment is impossible.

One key area for heat pump improvements is the refrigerants. While today's refrigerants are an improvement over older options, even the newer ones are powerful greenhouse gases. Careful handling and precise manufacturing are required to avoid leaks. The climate benefits from switching to heat pumps will be even greater if refrigerant manufacturers, has alternatives could hop on this side further.

Gradient, for example, uses a refrigerant called R-32, which has a lower global warming potential than R-410A. Other classes of refrigerants, like the hydrofluoroolefins propane and butane, pose even less climate risk. However, some of these more climate-friendly refrigerants tend to be extremely flammable, so safety systems are required.

Most technological advances will help expand the already massive array of heat pumps on the market. And you should come down over time as the technology becomes more common.

Global heat pump sales rose by 35% in 2021. Europe has seen some of the quickest growth, with IEA sales growth in 2022, a result of Russia's invasion of Ukraine and the subsequent push from Ukraine to lift the largest number of homes with heat pumps installed today. Most China takes the prize for the most new sales.

Wherever you look, the era of the heat pump has officially begun.

Update: This story was updated to add additional information about the cost of a whole-home heat pump installation. ✎

By Casey Crownhart

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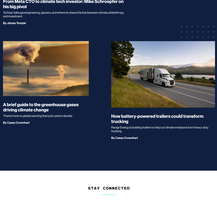

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