Heating buildings leaves a huge carbon footprint, but there's a fix for it

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Credit: Stephen Downes

As winter weather sets in, the heat kicks on in New York City's

approximately one million buildings. Most of these buildings' furnaces or boilers run on fossil fuels such as natural gas and oil; as a result, heating and hot water account for about 42 percent of the city's total greenhouse gas emissions.

Vijay Modi, a professor in the Department of Mechanical Engineering at Columbia University and an Earth Institute faculty member, and his research group are studying how to decarbonize heating. His solution? Heat pumps that run on electricity—because as more and more electricity is sourced from renewable energy, "it is much easier and affordable to make electricity green than to make a green fuel."

"Policy makers have recognized the value of heat pumps," he said, "And they are part of the New York State governor's energy efficiency goals—that by 2030, we should have 25 percent of the heating from heat pumps."

Electrified heating is important for the rest of the nation, too. To avert the catastrophic impacts of climate change, we must reduce our carbon emissions to zero as soon as possible. According to a 2018 report by the Rocky Mountain Institute, reaching "deep decarbonization" goals of reducing greenhouse gas emissions 75 percent or more will entail, among other measures, eliminating most of the emissions produced by the burning of natural gas, oil or propane in American homes and businesses for heating and hot water.

What is a heat pump?

Modi describes heat pumps, which have been in use since the 1940s, as air conditioners with internal hardware and controls that enable them to operate in reverse.

A popular type of heat pump has an outdoor unit containing a

compressor and condenser that works with an indoor unit (although heat pumps can also be contained in one unit). In hot weather, a heat pump operates like an air conditioner, pulling heat from air inside the home and transferring it outside, cooling the home.

In cool months, it pulls heat from the outside air and transfers it inside; counterintuitively, even when the weather is cold, the outside air contains enough heat to warm your home. While most heat pumps transfer heat from the air, there are geothermal and water source pumps that transfer heat from the ground or a nearby water source; others act as water heaters.

Heat pumps are more energy efficient than furnaces and boilers since instead of generating heat, they simply move heat from one place to another, and they can both heat and cool the home. They provide the most efficient heating and cooling available, producing two to four units of heat for each unit of energy used—a gas furnace produces a little less than one unit of heat per unit of energy.

Compared to furnaces and baseboard heating, heat pumps can reduce energy use by 50 percent. And according to a Natural Resources Defense Council (NRDC) study, over its lifetime, a new air-source heat pump can reduce greenhouse gas emissions by 46 to 54 percent compared to natural gas alternatives.

How to transition to heat pumps

Decarbonizing heating in New York City is challenging because of the city's density, huge demand for energy, aging infrastructure, variety of building types, and space constraints. Modi's Quadracci Sustainable Engineering Lab is researching how it might be done, studying the benefits of electrifying heating, and addressing potential issues that could arise.

When natural gas became cheaper than oil, many buildings in New York City converted from oil to gas. But since upfront costs to replace an existing natural gas system with an all heat pump solution are high, Modi doubts most people would opt to do this. Instead, to be cost-effective, retrofits could install heat pumps to be used the majority of the time, alongside existing heating systems.

He explained that buildings with a furnace that heats up air and distributes it could also incorporate a heat pump into its loop to heat the air. Little retrofitting would be required. A big high-rise building would present more of a challenge because it would require an industrial size heat pump, which would be difficult to retrofit.

Heat pumps might also more easily be adopted when buildings need to add or replace air conditioning or natural gas systems, upgrade their electrical systems, or do gut renovations. And new construction could easily rely entirely on electric heat pumps.

Concerns about heat pumps

There are concerns about what might happen if more and more electricity is needed for heating in the winter. System-wide electricity demand currently peaks in the summer with the use of air conditioning; Modi maintains we have the capacity to grow heat pump use until we reach a comparable winter peak. Getting there and beyond, wind resources could provide a solution. "We have very good off-shore wind resources right here in New York City," said Modi. "It is a very good match for the heating, as we get stronger winds in the winter that would allow an increasing amount of heat to come from wind power."

Another issue is that the electrical wiring of many buildings may not be able to accommodate the extra electricity needed by heat pumps, which run on 220/240 volts. Modi suggested that window unit air conditioners

that run on 220/240 volts could be replaced by heat pumps (which also cool). "For most of your heating, when it's above freezing, you may be fine," he said. And in New York City, at least, "that may be what 60 percent of the heating need is. In addition you would be reducing emissions too."

The outlook for the future

According to Forbes, "The global economy of the future is going to be driven by electricity and heated/cooled by electricity—not just powered by it."

The Rocky Mountain Institute cited several factors that could help speed this transition and make heat pumps more cost-effective. As heat pumps catch on and manufacturers achieve economies of scale, prices will fall. Smart technology that can help shift the time of energy consumption could, for example, enable heat pumps to preheat a home in the early afternoon when electric rates might be lower and help integrate more renewable energy into the grid. Carbon pricing could entice more people to install heat pumps.

Even with our current electric grid in New York State, however, the electrification of heating reduces greenhouse gas emissions. And with a grid increasingly run on renewables, heating emissions could foreseeably be eliminated altogether.

"It may very well be that in the next 20 years, we will figure out how to make all electricity green and cheap all the time. Then we'd use heat pumps all the time," said Modi. "But the pathway to doing that is tricky—as we make this transition, it has to be cost-effective."

For new home construction, the NRDC study determined that in California, installing electric heat pumps instead of natural gas systems

could save homeowners $1,500 upfront, and hundreds of dollars each year in operating costs. But since the initial costs to install or retrofit heat pumps may discourage some people from making the switch, utilities, governments, and manufacturers need to promote heat pump technology and make it more affordable. Financial incentives are key. "We are giving very big incentives to buy an electric car," said Modi. "But dollar for dollar, it would be much better to do it for heating…because the emissions reduction would be very significant for the same amount of money."

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