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Building decarbonization: How electric heat pumps could help reduce emissions today and going forward

The electrification of heating systems could play a significant role in the transition to net zero—and heat pumps are emerging as a solution.

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Buildings are a significant contributor of carbon emissions. As the broader economy transitions to net zero, various stakeholders are pushing for building decarbonization—whether it's real-estate investors who have made net-zero commitments, policy makers setting emissions limits, or tenants looking for greener spaces. Electrifying space and water heating systems is one way to reduce building emissions—and electric heat-pump technology, which has improved and become cost-competitive in certain markets, has emerged as an increasingly viable solution.

Heating and cooking in commercial and residential buildings account for 6 percent of global CO_2 emissions, according to our recent report on the net-zero transition.[1] (By factoring in emissions from total electric power consumed, energy use by buildings contributes approximately 27 percent of global CO_2 emissions.[2]) These emissions are largely due to the on-site use of fossil fuels such as oil and natural gas.

Building heat has typically been a challenge to electrify at scale because of the high cost and complexity of converting a wide variety of current heating systems (steam, hot water, forced air, to name a few), as well as the relative cost-effectiveness of fossil-fuel energy sources in most cold weather population centers. However, electric heat pumps have become an increasingly effective way for buildings to decarbonize due to operating, equipment, and installation costs becoming more competitive in certain markets, as well as developments in heat-pump technology. (A heat pump uses refrigerant and electricity to transfer heat from outdoor air or the ground to the inside of a building, even in colder temperatures). Today's models are 2.2 to 4.5 times more efficient than gas furnaces. If implemented worldwide, using heat pumps instead of traditional boilers and furnaces could cut global CO_2 emissions by 3 gigatons per year. According to McKinsey analysis, heat pumps could constitute approximately 90 percent of new heating unit sales by 2050, compared with 35 percent today.

Our research suggests that shifting demand, an evolving policy landscape, falling costs in certain markets, and technological improvements have all given heat pumps momentum as a decarbonization lever. However, heat pumps are not a one-size-fits-all solution (see sidebar, "Are heat pumps a fit?"). There are additional options to decarbonize a building's energy use, including "greening" power generation with renewables (whether utility scale or on-site), electrification of cooking appliances, energy-efficiency improvements to a building's envelope, and installation of smart building controls (such as thermostats).

In this article, we'll focus on the potential for heat pumps to help reduce building emissions and decarbonize real-estate assets, as well as possible actions stakeholders can consider. These actions are based on homeowner surveys and more than 50 interviews that we conducted with utility leaders, contractors, manufacturers, real-estate developers, and property managers.

Why the electrification of building heat is trending up

Momentum to electrify building heat is accelerating, as investors, tenants, and regulators in many markets press for decarbonization. In response, building owners are increasingly exploring heat pumps as an energy-efficient, cost-effective solution. The interest in heat pumps is driven by four trends.

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[1] *The net-zero transition: What it would cost, and what it could bring*, McKinsey, January 1, 2022.
[2] Thibaut Abergel et al., *Tracking buildings 2021*, International Energy Agency, November 2021.

Are heat pumps a fit?

Heat pumps are an optimal decarbonization solution for only certain building types. When assessing for viability, building owners and other stakeholders will often need to start by looking at a building's current heat distribution system (exhibit).

Buildings with forced air or low-temperature hot water distribution, for example, tend to be good candidates for heat-pump retrofits, as they don't require high operating temperatures. However, distribution systems that require high operating temperatures, such as steam, might make less sense for a retrofit. For some buildings and markets, heat-pump conversion could be significantly expensive compared with other low-emissions options, including hybrid boiler systems in which a fossil-fuel backup turns on when electricity prices spike (in certain cases, the gas distribution system could continue to provide reliability and resiliency in the case of power outages[1]). Regions that rely on district heating are markets in which decarbonizing central facilities could be more cost-effective than installing individual heat pumps.

[1] This will require gas-powered heating units to be able to function without electricity, but that should not pose a significant barrier technologically.

Exhibit

A building's low-carbon heating solution depends on its current heat distribution system.

Feasibility of lower-carbon heating solutions, by heat distribution system

● Less desirable option ● More desirable option ● Best option if district heating system nearby ● Best option (in most cases)

Current distribution system	Typical setting	Heat pump	District heating	Hybrid system[1]
Steam	High-rise buildings, dense urban environment	Less desirable option	Best option if district heating system nearby	Best option (in most cases)
High-temperature hot water	Low-rise buildings with on-site gas- or oil-fired boilers	More desirable option	Best option if district heating system nearby	Best option (in most cases)
Low-temperature hot water	Buildings previously converted from fossil fuel, newer buildings	Best option (in most cases)	Less desirable option	Less desirable option
Forced air	More common in US, especially in newer buildings	Best option (in most cases)	Less desirable option	Less desirable option
Electric resistance	Older and rural buildings, especially commercial or industrial	Best option (in most cases)	Less desirable option	Less desirable option
District heating	Northern Europe, major urban centers	Less desirable option	Best option (in most cases)	Less desirable option

[1]Commonly an electric boiler paired with a natural gas boiler; electric boiler runs until electricity prices are too high, at which point the natural gas boiler switches on. This requires real-time communication with the grid, which may not currently be possible in some places.
Source: McKinsey analysis

Shifting demand

Major real-estate investors, lenders, property managers, and tenants have made decarbonization commitments that now need to be met by reducing operating emissions of buildings. Given that space and water heating are the primary contributors of building emissions, electrification represents a meaningful step toward realizing decarbonization goals. Assuming the electricity were to come from clean sources, electrifying space and water heating in residential and commercial buildings where it is feasible could reduce those buildings' 2016 heating emissions by 20 percent.

Evolving regulation

Policy makers, particularly in Europe and the United States, are beginning to introduce legislation supporting building decarbonization, including changes to building code requirements, bans on gas connections to new buildings, emissions limits (with financial penalties for noncompliance), and incentives. Examples of recent regulatory shifts include the following:

— In Germany, the country's coalition agreement states that by 2025, all newly installed heating systems must operate with at least 65 percent renewable energy.[3]

— A number of US cities, including Denver and Boston, and several municipalities in the Bay Area of California, have introduced building code changes that stipulate more stringent requirements for energy efficiency and emissions.[4]

— Bans on gas connections to new buildings are being implemented in several areas. The Netherlands passed a law in 2018 providing that new homes would not be connected to the gas grid, by default.[5] Several US cities have banned gas connections to new buildings as well, including Berkeley, California, in 2019 and New York City in 2021. Recently, New York Governor Kathy Hochul voiced support for a statewide gas ban on new buildings.[6]

— Additionally, in New York City, Local Law 97 requires an 80 percent reduction in emissions intensity over the next 30 years for large multifamily and commercial buildings, with annual fines beginning in 2024 and increasing in 2030 for exceeding emissions caps.[7]

— In several US states, including Massachusetts and New York, incentives for replacing fossil-fuel heating systems with heat pumps are becoming available, whether from local utilities or government-sponsored programs. For example, Massachusetts' Mass Save program, sponsored by local electric and gas utilities, provides residential building owners with rebates that help offset the cost to install heat pumps.[8]

Improving economics

Heat pumps are approaching cost parity compared with fossil-fuel sources of heat in multiple markets. Rising natural gas prices in certain regions, particularly in Europe, as well as continuing improvements in energy efficiency have given heat pumps an operating-cost advantage in some cases.

Equipment and installation costs, which have historically posed the biggest economic barrier to heat-pump adoption, are beginning to decline.[9] Increased competition among OEMs—including Asian manufacturers of air-conditioning systems, which now produce air-to-air heat pumps at scale—

[3] *Dare more progress: Alliance for freedom, justice and sustainability*, Coalition agreement 2021-2025 between the Social Democratic Party of Germany, Alliance 90/The Greens, and the Free Democrats.
[4] Ordinance 20211310, City and County of Denver, November 29, 2021; Ordinance amending City of Boston municipal code, Ordinances, Chapter VII, Sections 7-2.1 and 7-2.2, Building Energy Reporting and Disclosure (BERDO), City of Boston; Mike Jaske et al., *California building decarbonization assessment*, California Energy Commission, August 13, 2021.
[5] Climate Act, May 28, 2019, Government of the Netherlands.
[6] Ordinance No. 7,672-N.S., City of Berkeley, CA, July 16, 2019; "Mayor de Blasio signs landmark bill to ban combustion of fossil fuels in new buildings," City of New York press release, December 22, 2021; "Governor Hochul delivers 2022 State of the State," New York State press release, January 5, 2022.
[7] Local Law 97, City of New York, 2019.
[8] Air Source Heat Pump Rebates, Mass Save.
[9] "Ditching costly gas and oil is cheaper thanks to heat pump scheme," United Kingdom press release, May 23, 2022; "Fact sheet: President Biden takes bold executive action to spur domestic clean energy manufacturing," White House press release, June 6, 2022.

is leading to lower equipment prices. In markets where adoption is more prevalent, the labor costs of installation have gone down, due to improving technical expertise. In a few Nordic countries, for example, installation of a typical air-to-air heat pump requires an average of two person-days, compared with four to eight person-days in the rest of Europe, according to our analysis.

Advancing technology

Developments in technology, including refrigerant composition and better compressor speeds, have improved heat pumps' effectiveness.[10] On average, the efficiency of heat pumps increases by about 2 percent annually, our research found. Rising cold temperature coefficient of performance values, a measure of energy efficiency, have made heat pumps effective in some Nordic climates.[11] According to a 2014 study, approximately one-fourth of Norwegian households were already heated by heat pumps, for example.[12]

One size does not fit all

While heat pumps offer a potential decarbonization solution, they don't currently meet every building and building owner's needs. Operational viability and installation costs vary widely across different types of buildings, due to factors such as age, size, and the current heat distribution. It's key for building owners and other relevant stakeholders to have flexibility in considering different decarbonization paths, even if timelines are tight (to meet new emissions-reduction targets, for example).

How building owners and other leaders could prepare for an electrified future

Heat-pump adoption at scale could benefit from actions taken by multiple stakeholders, both collectively and individually. Aside from policy makers—many of whom are already taking steps—building owners, heat-pump manufacturers, electric utilities, and investors are among the potential stakeholders that could help accelerate building-heat decarbonization in the near and medium term.

Building owners

Building owners may face new regulatory guidelines or shifting tenant demands when it comes to heating. In some markets, a heat-pump system could potentially be cost-competitive. Building owners could be proactive in understanding their options and planning for upgrades by considering a few potential actions:

— *Replacing heating systems before failure or end of equipment life.* Some building owners may choose to wait until their heating system fails or falters. This approach could result in a rushed replacement decision without full consideration of heat-pump viability. Instead, building owners could proactively investigate and evaluate heat-pump alternatives.

— *Exploring the potential for retrofits during building turnover.* Particularly for large multifamily or commercial buildings, retrofits to enable heat-pump installation (for example, ductwork or wiring) or improved energy efficiency (building envelope) could lay the groundwork for future heating, ventilation, and air-conditioning (HVAC) upgrades. Vacant buildings or buildings undergoing major renovations could be an option to consider.

— *Combining heat-pump-system installation (or preparation) with other measures.* During a building retrofit, envelope upgrades, electric-vehicle (EV) charging equipment installation, and other energy-efficiency measures could also be considered to support the decarbonization impact of a single project.

[10] Thibaut Abergel, *Heat pumps*, International Energy Agency, November 2021.
[11] While heat-pump technology for colder climates has become more efficient, air-to-air heat-pump systems in these areas still typically require backup heating (geothermal systems do not). Additionally, when outdoor temperatures reach the 0–5°F range during winter, heat pumps can lead to spikes in electrical load, which can challenge buildings' electrical panels and grid infrastructure. For customers with concerns over the efficacy of cold climate heat pumps, hybrid systems (for example, electric heating solutions combined with backup fossil-fuel heating) can be deployed.
[12] "Large increase in the use of heat pumps," Statistics Norway, July 14, 2014.

— *Designing new buildings with electrical infrastructure for the future.* Building owners could coordinate with architects and designers early in the process to ensure that building design is optimized for heat pumps. Owners and engineers could also plan for potential increased electrical capacity needs for other uses, such as cooking appliances, clothes dryers, and EV charging.

— *Preparing for increased demand on the electrical grid.* As energy systems transition toward electrification, demand on electricity grids is likely to increase. According to McKinsey research, electricity demand could triple by 2050. In some regions, electricity demand could outstrip capacity if an electrical grid's infrastructure hasn't been updated to accommodate higher demand peaks. Building owners considering heat-pump installation in colder climates—where electricity demand could increase during winter months—might consider having an on-site hybrid heating system where a fossil-fuel backup turns on when electricity prices spike, for example.

Manufacturers

There are potential ways heat-pump manufacturers could play a role in market activation and widespread adoption, including the following:

— *Educating both customers and HVAC professionals.* Some early adopters of heat pumps have experienced poor system performance, often from improperly installed equipment. Consequently, some potential buyers are wary of their effectiveness. Manufacturers and installation professionals could work together to overcome this perception. For example, some manufacturers are setting up online and in-person training sessions on heat-pump installation and maintenance.[13] They are also connecting contractors with interested customers through online lead-generation platforms.

— *Innovating heat-pump design for improved performance, reduced equipment cost, and easier installation.* Manufacturers could help address key barriers to adoption through improved design, with more modular or compact solutions, for example, or systems designed to mitigate electric-panel or grid constraints. More streamlined, efficient equipment could also make installation easier—potentially leading to lower installation costs.

— *Providing a variety of offerings—particularly for different building types and colder climates.* More equipment options would create more pathways for buildings to electrify. For some very cold climates, manufacturers could further develop hybrid options that combine heat-pump technology with a backup fossil-fuel heater.

— *Bundling heat-pump installation with advanced building controls.* Technologies such as smart thermostats could enhance customer cost savings and energy efficiency. Manufacturers may offer customers such technologies along with heat-pump purchases.

— *Considering partnerships with capital providers.* Manufacturers could make installation costs more attractive for building owners by partnering with capital providers on retrofit services.

[13] "Mitsubishi Electric Trane HVAC US launches new website," Mitsubishi Electric Trane HVAC US press release, July 14, 2021.

Electric utilities

Electric utilities are at the intersection of multiple stakeholders that would be involved in heat-pump adoption at scale and have the potential to play a convening or coordinating role. And greener electricity is key to optimizing heat pumps' potential as a decarbonization strategy. Traditional electric utility actions could include:

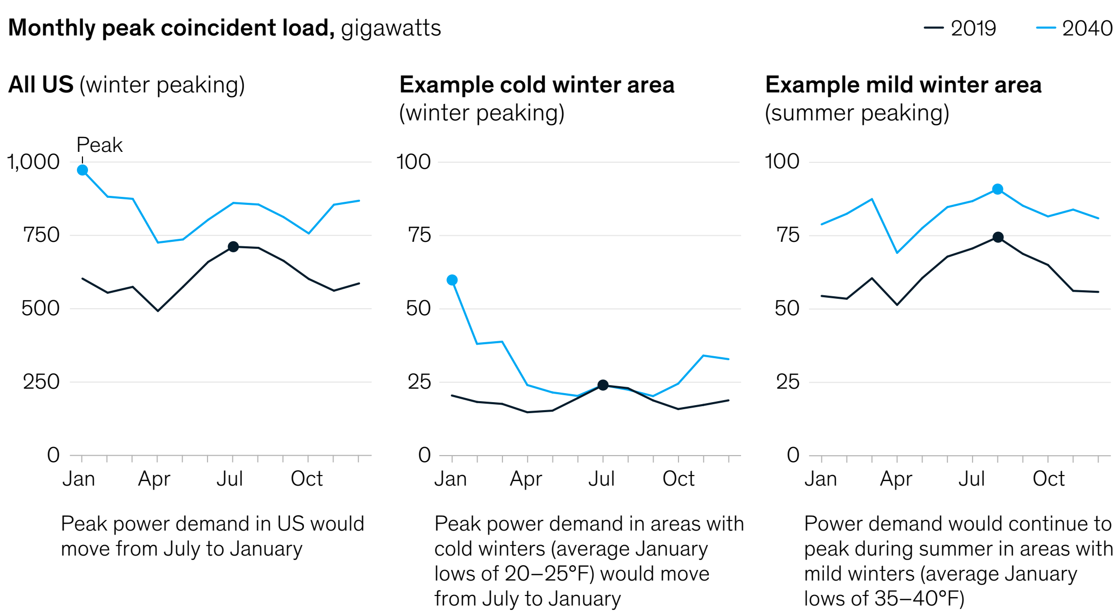
— *Advancing mitigation measures for shifts in demand peaks.* As heating electrifies, electric peak loads could shift from summer to winter in colder regions (Exhibit 1) as well as to different times of the day. Utilities could begin to identify and mitigate grid constraints. For example, electric utilities could rethink their system maintenance schedules: an eight- to nine-month maintenance window during non-summer months could eventually shift to two- to three-month windows during the more temperate (and potentially less peak-load-inducing) spring and autumn. Utilities could also consider load-control mechanisms, such as smart thermostats.

— *Coordinating between gas and electric planning.* A combination of gas and electric infrastructure will likely be needed to supply many customers through the broader energy transition. As more customers electrify, infrastructure decisions may benefit from coordination to help ensure that both networks continue to operate safely and reliably. For example, some markets could maintain the gas network as a "hybrid backup" to the electric network for the coldest days.

— *Pivoting energy-efficiency programs toward electrification.* Working with local and state policy makers, utilities could consider offering incentives for building owners to make upgrades. This process is already beginning in some places. Colorado, for example, recently passed a union-backed law requiring utilities to offer financial

Exhibit 1

As heating electrifies, electric peak loads could shift from summer to winter in colder regions.



Source: McKinsey Power Model

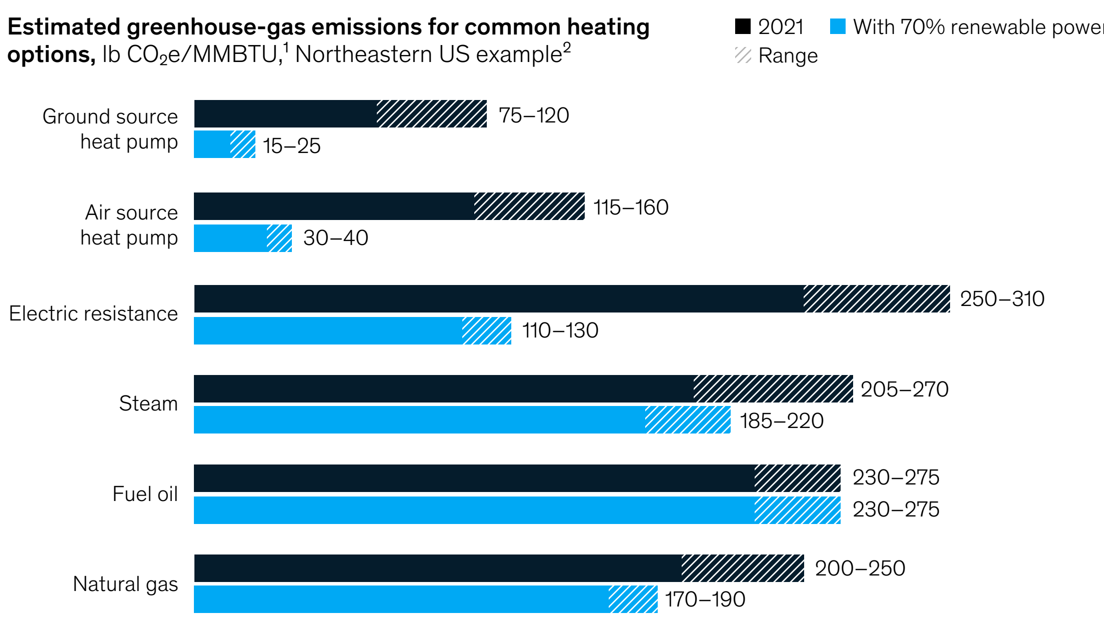
support for building owners looking to electrify their heating systems.[14] In New York, Con Edison plans to invest billions of dollars to reduce emissions from buildings through energy-efficiency upgrades and electrification of space and water heating, with a goal of electrifying more than 150,000 buildings by 2030.[15]

— *Investing in renewables and energy storage methods.* Reducing power sector emissions is key to most decarbonization pathways. On a grid that's primarily powered by fossil fuels, carbon emissions can be at their highest during peak load times, when fossil-fuel-powered auxiliary stations (also known as peaker plants) come online to meet sharp increases in demand. Our analysis shows that, for a typical North American grid, heat pumps powered by renewables could produce significantly lower emissions than those from other common heating methods (Exhibit 2). Long-duration energy storage technologies, while still nascent, could also help to reduce emissions generated by heat pumps. By maintaining stores of renewable electricity via hydrogen or batteries, utilities could limit exposure to high-emissions energy sources, even on the coldest days.

Exhibit 2

Heat pumps powered by renewable energy could produce significantly lower emissions than other common heating methods.

Estimated greenhouse-gas emissions for common heating options, lb CO_2e/MMBTU,[1] Northeastern US example[2]



[1]Pounds of carbon-dioxide equivalent per million British thermal units.
[2]Averages across different building types.
Source: US Environmental Protection Agency; McKinsey analysis

[14] State Bill 21-246, Colorado 73rd General Assembly, June 2021.
[15] "Our clean energy commitment," Consolidated Edison Company of New York.

Investors

There is potential for private-equity and real-estate investors to consider building decarbonization as an investment priority. As we explored in a recent article,[16] real-estate leaders are looking to decarbonize their assets, future-proof portfolios, and create new sources of value. McKinsey research on the net-zero transition estimates that decarbonizing the buildings sector would require increased capital spending at an average of $1.7 trillion per year between 2020 and 2050.

Investors could help to set and track decarbonization targets, and could work with relevant stakeholders (for example, operators and tenants) to explore how heat pumps might help meet those goals. Investors may also explore different financing models for electrification (energy-as-a-service leases, for example) and related energy-efficiency measures.

Additionally, innovation is still needed to advance building decarbonization in areas such as electrical infrastructure and energy management. These could be areas for start-ups to consider, for example, with backing from venture capitalists.

Electrifying building heat is a key and challenging step in achieving global and local net-zero goals, as well as in decarbonizing real-estate assets. It will likely require a significant investment of time, money, and planning. A one-size-fits-all solution doesn't yet exist, as full electrification might not be suitable for a subset of building types or energy delivery systems. However, electric heat pumps have emerged as a viable decarbonization technology for many building types and could provide a path to energy efficiency and emissions reductions.

[16] Brodie Boland, Cindy Levy, Rob Palter, and Daniel Stephens, "Climate risk and the opportunity for real estate," McKinsey, February 4, 2022.

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