Two Approaches To Buildings Decarbonization

By Klaus Bundgaard, Climate Project Manager, City of Copenhagen, and Jenna Tatum, Director, Building Electrification Initiative

Approaches to decarbonizing heating and cooling systems in buildings depend on whether the city provides an extensive district-scale heating and cooling system (as many European cities do) or uses a market in which individual buildings purchase and operate their own systems (which is the prevailing practice in Asia and North America). In this edition of the Game Changers Deep Dive, we have two guest contributors. Klaus Bundgaard, Climate Project Manager to the City of Copenhagen, invites you to learn more about how Copenhagen has worked to achieve a state-of-the-art district heating system. Jenna Tatum, Director of the Buildings Electrification Initiative (BEI), offers a deep dive into how BEI works to make the switch to heat pump technology in the North American market, as illustrated by two city case studies in Burlington, Vermont and New York City.

Copenhagen's District Heating System

In the start of the twentieth century, Copenhagen was once heated like most other cities. Individual heating supplied every home, which meant the city was heavily polluted from coal, petroleum and coke burned in stoves locally. In 1925, due to rising electricity demand, more power plants were constructed within the city, which led to an increasing amount of excess generated heat. A smart person proposed the idea of utilizing the heat by pumping it out as steam to the nearest households through a network of pipes, and hereby the first district heating network in Copenhagen was established. Now, 90 years later, Copenhagen has built one of the world's most extensive district heating networks, supplying more than 99 percent of the city with sustainable and efficient heating. Between 1925 and now, more than 1,400 kilometers of pipes were installed, providing heat to more than 500,000 Copenhageners. More impressively, the district heating network in the City of Copenhagen is a part of four connected networks covering 17 surrounding municipalities in the Greater Copenhagen Metropolitan, and the assembled network covers a fifth of Denmark's total heat demand.

Establishing a district heating network makes so much more sense in a dense city, since the density of end-users cuts the price of constructing the transmitting network. Of course, the economic business case has been favorable and helped with the expansion of the district heating network, but another important measure was the mandatory connection to the network introduced up through the 80s and 90s. With this regulation, all property owners in Copenhagen had to be connected to the network within a limited time, otherwise they would have to pay an annual fee.

Our road towards a carbon neutral heating will probably be less bumpy than other cities, since we – together with surrounding municipalities – own the utilities. Due to this ownership model, our vision is also shared by the utilities. Today, 65 percent of the heat supply is carbon neutral, and we expect an increase by next year that will allow us to go above 80 percent, due to the opening of the BIO4 power plant. This is a new biomass-based power plant unit that will replace an old unit running on coal, and hereby also highlight the end of coal-based power plants in Copenhagen. This means that our main inputs for heat production will come from waste and biomass with a sustainable certificate. The remaining 20 percent of carbon dioxide will derive from plastic and other fossil fractions in the waste, and further the need for peak-load capacity.

Amager Bakke Energy Plant, a combined heat and power waste-to-energy plant in Copenhagen, Denmark. Photo credit: Amager Resource Center.

To overcome this, we plan to add carbon capture technologies to the waste-to-energy plants, removing the carbon dioxide emitted from the remaining plastic and fossil fractions, which is roughly 165,000 tons. We're collaborating with our waste-to-energy plant, Amager Resource Center, and have recently completed a technological screening of a possible carbon capture facility. It is still undecided whether the carbon dioxide will be stored underground or used for producing new e-fuels. Adding this technology to the list of solutions related to district heating offers a huge potential as a game changer, due to the possibility of producing energy with a 'negative' carbon footprint, if it is coupled with biomass. Through the annual CNCA Innovation Fund, we received funding for a project focusing on Carbon Capture Storage and Usage from a city perspective. It is our hope that together with the cities of Amsterdam, Helsinki, Oslo and Stockholm, we can join forces and share knowledge while pushing each other closer to implementation.

The district heating network is constantly evolving, and it's not only the transition to biomass that makes it more sustainable. Currently the remaining steam-based pipes are being replaced with low temperature water-based pipes, which will reduce the heat loss by 140 GWh, equivalent to 6,000 family homes, and further cut costs for operation and maintenance by 90 percent. Also, with the increasing amount of wind turbines introduced into the energy system, there is a need for new solutions to balance the grid. Here, Copenhagen's district heating network can become an integrated part of the future energy system that will utilize renewable energy. On windy days with lots of excess electricity, large scale heat pumps and electric boilers could raise the temperature of the water in the district heating network and function as a storage capacity. Creating flexibility in the energy system is something that is being tested and demonstrated in the project EnergyLab Nordhavn.

While some parts of EnergyLab Nordhavn relate to more systematic changes, it also tests solutions within the households of our citizens. The previously mentioned peak-load capacity is a challenge since it relies on backup from oil or gas turbines. On a calm and cold day in January, most people wake up and go to the shower while heating up their household, which creates a peak load. But what if the utility centrally could manage their room temperature and could raise the room temperature a couple of degrees before people wake up, and thereby move forward the

demand a couple of hours? We call this ‘flexible heating customers’, and they should of course be rewarded for this service.

Lastly, why limit yourself by only installing a network for district heating? In the center of Copenhagen, we’ve now installed a new district cooling network utilizing the sea temperature in the harbor through cooling exchangers. As for now, it is voluntary to connect your property, and it is still only in certain central areas. But in the future, we expect the network to expand as it delivers some clear benefits such as substantial reductions in cost and carbon dioxide and further requires less space and produces less noise.

The Buildings Electrification Initiative (BEI) and Switching to Electric Heat Pump Technology

Why Building Electrification?

In cities across North America, fossil fuels used to provide heating, cooling, and hot water in buildings account for a significant portion of greenhouse gas (GHG) emissions—accounting for between 15% and 40% of emissions in a typical U.S. city. This is particularly true in heating-dominated climates like the Northeast. In New York City, for example, on-site fossil fuel use in buildings accounts for 42% of the city’s GHG emissions, which is the largest single source of citywide emissions.**[1]**

In the North American market, where individual building owners generally purchase and operate their own heating, cooling, and hot water systems, the most viable option is to convert these systems to cold climate air source heat pumps (ASHPs) and heat pump water heaters (HPWHs). These are highly efficient electric technologies that use a compressor to pull heat from the outdoor air to provide indoor space heat and hot water—essentially an air conditioner that can run in reverse.

Because these technologies are so energy efficient, heat pumps reduce emissions in nearly all parts of North America today, and they have the potential to dramatically reduce emissions even further over the long run by using electricity increasingly powered by clean and renewable sources. During warmer seasons, ASHPs can also provide high efficiency cooling, which is an increasing need across North America as cities experience increased heat and waves due to climate change. Electrifying building systems also has the potential to dramatically reduce indoor and outdoor air pollution and reduce the risk of fire from gas infrastructure—over the past two decades, there have been over 640 gas distribution accidents, resulting in 221 fatalities across the U.S.**[2]**

In the long term, major utility investments and state regulatory action will be needed to fully transition buildings away from fossil fuels. In the short term though, city action can spark the development of new markets and equitable approaches for transitioning to high efficiency electric building systems. This action will deliver immediate GHG and air pollution reductions, while also providing information on best practices and laying the groundwork for more ambitious efforts that will be needed at all levels of government.

The Building Electrification Initiative

The **Building Electrification Initiative** (BEI) equips cities with the tools, knowledge, and resources they need to implement strategies to accelerate the transition of building heating and cooling systems away from fossil fuels. BEI currently works with six leading cities: New York City; Washington D.C.; Boulder, CO; Burlington, VT; Berkeley, CA; and Salt Lake City, UT.

BEI emerged from the “Thermal Decarbonization Initiative for Cities,” a project launched in 2016 with startup support from the USDN and CNCA Innovation Funds. Under this Initiative, cities conducted market analysis and developed roadmaps for accelerating building electrification in their communities. They also began forming critical partnerships with states, regional organizations, utilities, manufacturers, and others to co-invest in solutions and coordinate regional action.

Building on these activities, BEI has developed a Theory of Change for how it will scale up these initial efforts and deploy city leadership to accelerate the transition away from fossil fuels in buildings.

Theory of Change

When it comes to building electrification, it is important to recognize the scale of the problem. There are over seventy million homes and businesses that burn natural gas, oil, or propane on-site in the U.S. for space heating and hot water production.**[3]** Electrifying all or most of these buildings would be a massive investment. For example, electrifying all the residential homes in Boulder alone—a city of roughly 100,000 people—would require an estimated investment of at least $1 billion. Moreover, there are tens or hundreds of billions of dollars of gas infrastructure assets across the U.S. that will need to be depreciated or phased out.

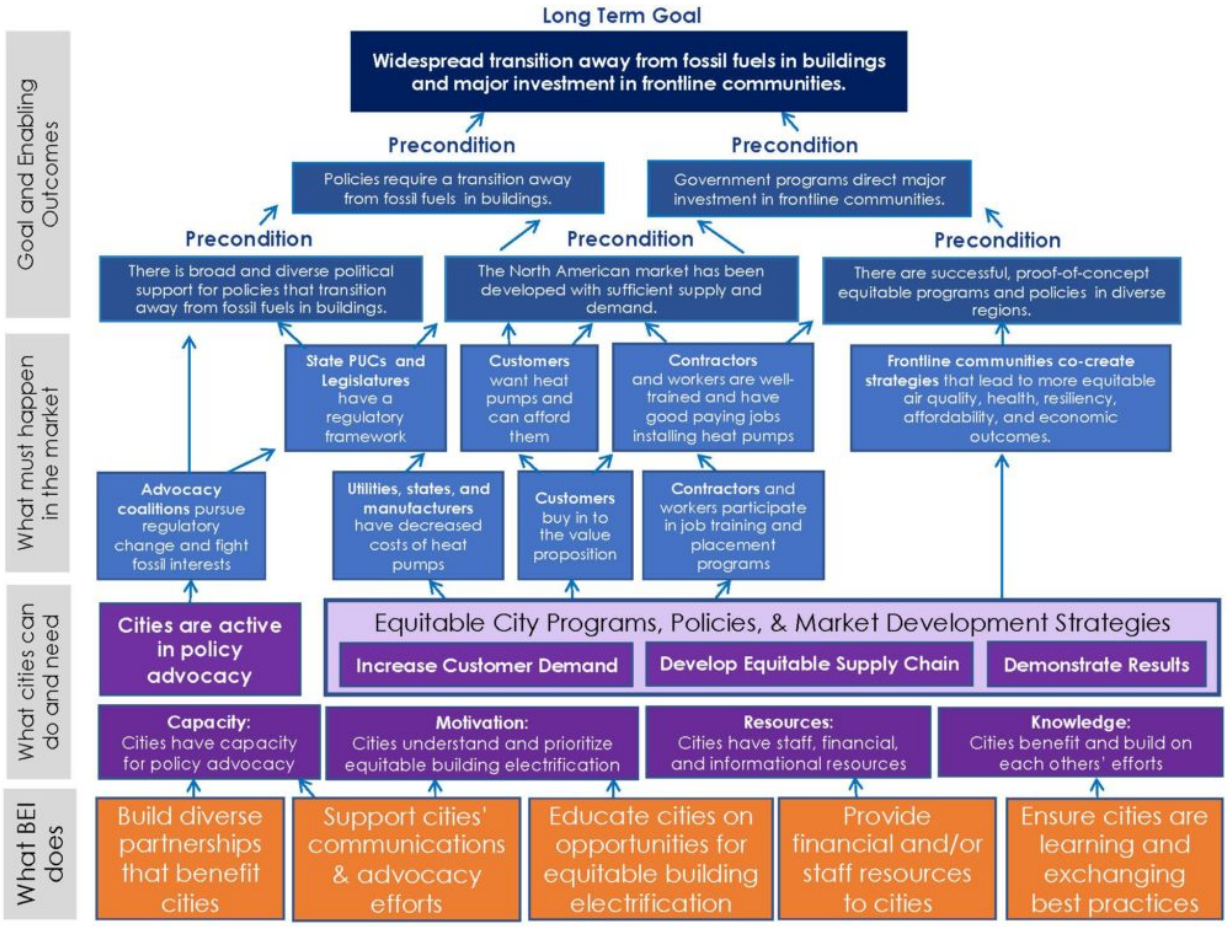
In general—but particularly in regions with colder climates—heat pump technologies have not moved beyond the “innovators” or “early adopters” and into the mainstream market. However, because heating systems have 15-20 year replacement cycles, it is critical to begin installing high efficiency electric heat pump systems today in order to minimize the cost of the large-scale transition and reach broad market scale by 2050.

Given the scale, voluntary market development alone will probably not be sufficient to achieve these goals; it will require robust local, state, regional, and federal policy regimes to transition away from fossil fuel-based building systems. Supporting market development activities will also be necessary to improve existing heat pump products, train and qualify contractors who can install them, and ensure there are customers who want heat pumps and understand their value.

Reaching scale will also require major investments in frontline communities to ensure these communities are not negatively impacted by the transition and that benefits are equitably distributed. Cities have long been on the frontlines of historical societal inequities, and are now facing a growing affordability crisis that threatens to displace many of their existing communities. Climate change will only exacerbate this rising inequality. Moreover, enacting transformative policies will require building new and broad coalitions of support. Communities who are most likely to be impacted will need to help create these policies, and can also become key allies for policy implementation. If implemented well, these policies can also help address cities’ equity and affordability needs by creating better quality and more affordable housing, providing new economic and job opportunities for those who need them, and mitigating against climate, health, and safety risks.

Cities can take the lead on developing strategies that pave the way for an equitable transition. Cities play an outsize role in their regional markets due to their size and population density. They can develop “proof of concept” programs and policies that can pave the way for future state, regional, and federal policy action on building electrification. They can also participate as strong voices within coalitions advocating for the necessary policy changes at other levels of government, and help ensure that these efforts equitably distribute benefits to frontline communities.

By equipping cities with the tools, knowledge, and resources they need to implement these strategies today, BEI aims to achieve a widespread transition away from fossil fuels in buildings by 2050 while delivering major investments that prioritize benefits for frontline communities.



The Building Electrification Initiative's Theory of Change

City Highlights: Burlington, VT

Burlington is Vermont's largest city, with a population of approximately 42,000. In 2014, Burlington became the first city in the country to source 100% of its electricity from renewables, and today is poised to make the transition to net zero energy in the building and transportation sectors.

Achieving Burlington's goals will be no easy feat, given its cold climate, older housing stock, and the fact that more than 90% of housing units use natural gas for heating, which is relatively low cost compared to electricity. Fortunately, Burlington has a municipal electric utility, the Burlington Electric Department (BED), which is committed to supporting Burlington's climate goals and has delivered innovative energy efficiency programs for nearly 30 years.

In 2018, BED launched a **cold-climate heat pump rebate program** that includes a combination of weatherization services and installations of high-efficiency electric heat pumps for customers using oil and propane for heating, which are more expensive than natural gas. In this program, BED prioritized low- and middle-income customers so they can be first to benefit from energy savings and gain access to cooling. To date, BED has provided incentives to over 300 customers to convert to cold climate heat pumps. Additionally, the City has found that cold-climate heat pumps are becoming a popular option for new multifamily buildings, due in part to the cost-savings that come from avoiding the installation of gas infrastructure to the development.

Building on its progress, going forward, Burlington will explore the potential to create new policy options for installing heat pump retrofits in new and existing multifamily buildings. To ensure their focus on equitable building electrification, these efforts will include an emphasis on building new partnerships between the City and representatives of low-income communities and communities of color to ensure these policies are implemented as successfully and equitably as possible.

City Highlights: New York, NY
New York City is the largest city in the U.S., with more than 8.5 million residents and over one million buildings. To achieve New York City's commitment to 80×50, the City estimates that over half of these buildings must convert to high-efficiency electric heating and more than 90% will need to electrify their domestic hot water.

Through a detailed market segmentation analysis, the city identified over 175,000 small residential buildings that are the best candidates for heating electrification in the near-term based on a combination of technical, market, and socio-demographic characteristics. This includes more than 75,000 buildings located in the borough of Staten Island. Based on the market opportunity, the City is collaborating with its electric and gas utility, Consolidated Edison, the New York State Energy Research and Development Authority (NYSERDA), and Mitsubishi Electric, one of the world's largest manufacturers of heat pumps, to propose a coordinated outreach and assistance program to scale up heat pump installations in Staten Island. To ensure that the program delivers equitable benefits, New York City plans to develop a strong workforce development and job access component to connect un- and under-employed New Yorkers in frontline communities to new HVAC contracting jobs.

New York City is also piloting heat pump installations in larger multi-family and commercial buildings through its **NYC Retrofit Accelerator** program. As part of this initiative, the City is publishing **case studies** and **technology primers** that will help accelerate future action across other real estate owners and developers. The City has also compiled a list of technology needs to improve existing heat pumps for the NYC market and has begun working directly with manufacturers to identify opportunities to develop these new systems. As a result of these efforts, New York City will begin to unlock its huge market and help drive the long-term transformation away fossil fuel use in buildings.

[1] New York City Mayor's Office of Sustainability, *New York City's Roadmap to 80×50.* **www.nyc.gov/80×50**

[2] Reuters, based on data from the U.S. Pipeline and Hazardous Materials Safety Administration

[3] Rocky Mountain Institute, *The Economics of Electrifying Buildings*, based on data from the U.S. Environmental Protection Agency. **https://rmi.org/insight/the-economics-of-electrifying-buildings/**