Solving the Cooling Conundrum: Promoting affordable access to clean cooling through building decarbonization policy

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ABSTRACT

Rising temperatures and extended heat waves related to climate change contribute to a cooling conundrum: keeping ourselves cool is making our world warmer, driving both the demand for cooling and the climate crisis even further. Yet increased access to cooling is a growing public health and equity priority to protect vulnerable communities from heat-related illness. In the northwestern U.S. alone, the summer of 2021 saw approximately 600 heat-related deaths during an extended heat wave (Popovich and Choi-Schagrin 2021). Many vulnerable communities live in cool and temperate parts of the U.S. unaccustomed to dealing with extreme heat.[1] In these regions, accounting for increases in cooling demand and expanding access to affordable, clean cooling are key complements to decarbonizing heating in the clean energy transition.

Decarbonizing space heating through the deployment of electric heat pumps is simultaneously an opportunity to expand access to efficient cooling systems. In this paper, organizations active on both cooling efficiency and building decarbonization explore decarbonization policies that reduce both heating and cooling emissions and embrace expanding access to cooling as a concomitant policy goal. The paper discusses methods of supporting heat pump deployment in ways that prioritize vulnerable populations and promote racial justice, integrating increased cooling demand into energy affordability programs, and managing grid impacts from rising demand for cooling. The authors draw on original research, input from leaders in climate equity and building decarbonization, and lessons from community-led initiatives to identify pathways to zero emission cooling for all.

Introduction

As global temperatures increase, many parts of the world have seen a rise in heat wave occurrence, intensity, and length since the mid-20th century, while extreme cold events have been on the decline (IPCC 2021). Deaths from heat are higher than for any other weather-related incidents in the U.S., and only rising, and the attribution to extreme heat is often under-reported due to the array of severe illnesses caused by heat stress (Gerrard 2018). Today's mean annual temperatures in the U.S. are 1.8 degrees F higher than during the period of 1895-2016, and expected to rise by 2.5 degrees F by 2050 (Gerrard 2018). Climate change is accelerating cooling

[1] The cooling conundrum presented here is a global phenomenon. The research presented here is rooted in the U.S. context based on the authors' policy expertise and program implementation experience but has implications for other countries grappling with increased need for cooling as well.

demand, even in regions that have historically had minimal or no exposure to extreme heat, and globally, cooling degree days are estimated to increase by 50% by 2050 (IEA 2020).

During heat waves, heat-related deaths spike, and hospitalizations for heat-sensitive health conditions rise relative to baseline conditions (Ebi et al. 2021). Consistently warmer summers can also worsen health and well-being over the longer term. Heat is especially dangerous for children, older adults, pregnant individuals, and outdoor workers. Urban areas that are densely developed with more hardscapes and fewer trees are more likely to become "urban heat islands" that trap heat and cool off much more minimally during the evening than do surrounding greener areas. Urban areas can also be up to 22 degrees warmer than surrounding suburbs at night (Donegan 2016). Extreme heat disproportionately impacts low-income communities and communities of color, as these communities have encountered a long history of disinvestment that has resulted in less access to green space, street trees, and adequate housing (Benz and Burney 2021).

Cooling equipment is responsible for more than 7% of the world's greenhouse gas (GHG) emissions (Carbon Trust 2018), and the number of air conditioners in buildings is projected to increase from 1.6 billion today to 5.6 billion by 2050 (IEA 2018). According to IEA, space cooling will be a top driver of global electricity demand and the single fastest growing end use of energy in buildings. Globally, between 2010 and 2018, demand for space cooling rose by 33% (GABC 2019). Additionally, on the hottest days in some regions of the world, 70% of peak residential electricity load is attributed to space cooling (IEA 2018). Cooling's contribution to peak demand creates many potential consequences, such as increasing the use of polluting fossil fuels for electricity generation, raising the risk of brownouts and blackouts, increasing energy costs to ratepayers and utilities, and shifting investments toward heavily polluting peaker plants.

So, what will it take to create a more sustainable, resilient, and just future as we face the realities of extreme heat in our lives? Cooling will be needed, but we must swiftly transition away from the conventional cooling appliances of the 20th century, blending effective passive cooling techniques of the past with today's promising innovations and practices. For comprehensive action, key opportunities include:

- **Thermally-conscious design and construction**: design, construct and retrofit buildings that leverage passive cooling practices such as improved building envelope, proper solar orientation, better air flow, use of reflective and more stable materials, etc.
- **Efficient appliance use**: install only right-sized super-efficient electric fans, air conditioners where there is only cooling load and super-efficient dual-function heat pumps where both heating and cooling demand exists.
- **Refrigerant management**: use natural zero or ultra-low global warming potential refrigerants in new appliances and institute pro-active refrigerant leakage prevention.
- **Accessible and affordable solutions**: make next-generation cooling and heating solutions affordable to all at point of purchase and when in operation.
- **Smart and flexible cooling appliances**: ensure all thermostats and space conditioning equipment are grid-connected and capable of load shifting, so that the thermal load's contribution to peak electricity demand is curbed and risk of grid blackouts and brownouts is minimized.
- **Clean energy powered electricity**: ensure space conditioning appliances are powered by carbon-free renewable energy sources, augmented by sufficient storage capacity.
- **Urban heat island mitigation**: redesign and retrofit urban environments with the use of nature-based solutions at neighborhood scale.

- **Emergency heat resilience programs**: as electrification retrofits scale, governments will still need to provide relief to vulnerable people during extreme heat events.

Access to affordable, efficient, climate-friendly space heating and cooling will create more resilience in conditions of extreme weather—such as heat waves—enabling people to be safe from the threats of extreme heat. Additionally, in a future with full building electrification (including the use of heat pumps powered by clean energy), we will improve air quality and health by removing toxic indoor fossil fuel combustion and fossil fuel power plant pollution. Air source heat pumps are an integral component of making this vision a reality. Energy and climate regulations/policies at all levels of government can build the heat pump market, address barriers for low- and moderate-income households, and integrate with complementary climate and cooling solutions (e.g., grid decarbonization and heat wave response).

Building-Scale Decarbonization and Cooling Access through Heat Pumps

The Heat Pump Market

Air source heat pumps, which have dual capabilities of heating and cooling efficiently, can serve as an entry point to broader electrification retrofits in buildings. For example, heat pumps can not only replace inefficient air conditioning (AC) but can simultaneously eliminate the need for electric resistance- and fossil fuel-based heating systems in many climates, further reducing GHG emissions and improving indoor air quality. Conversely, a heat pump installed to replace a fossil fuel-based heating system can offer four-times higher efficiency than conventional heating technology (Pantano et al. 2021) and introduces cooling capabilities (and added resilience benefits) where they were absent before. Higher efficiency, variable speed heat pump models have even greater ability to drive down energy use and emissions, also ameliorating grid impacts of electrifying heating.

Heat pumps are growing in use, and yet are unevenly deployed for efficient heating and cooling. In the U.S., heat pump sales grew by 15% from 2020 to 2021 (Rosenow and Gibb 2022). Heat pumps prevalence is even greater in new construction, with heat pumps installed in 40% of new single family and 50% of new multifamily homes (Census 2021). Most new heat pump purchases are made in the southern U.S., where heat pumps are highly utilized for cooling purposes and gas connections are less prevalent than in other regions. For new construction, the east south central region has the highest share of heat pump installations, representing 77% of the market; the lowest share is in New England, with 5% of new homes being heated with a heat pump (Kuo 2021). Northeastern and northwestern states are, however. beginning to drive sales as the technology has increasingly demonstrated strong performance in cold climates. State governments, like Massachusetts with its three-year Energy Efficiency Plan, adopt policies and create new incentives for heat pumps (Pantano et al. 2021). The western and northeastern parts of the U.S. have the most emissions reduction potential from heat pumps because of the ability for heat pumps to displace fossil fuel combustion-based heating (Pistochini et al. 2022). Advancements in cold climate air source heat pump technology are on display in places like Maine and Canada, demonstrating heat pumps' practicality not only for heating but also for improving resilience to increasingly common extreme heat events.

Increasing heat pump deployment is a strategy to improve energy efficiency and reduce GHG emissions. A California study found that electrification in single-family homes could reduce GHG emissions by 30-60% in 2020, with savings growing to 80-90% by 2050 (taking into account both fugitive methane leaks from natural gas infrastructure and appliance refrigerant leaks) (E3 2019). Another study found that replacing a residential gas furnace with a heat pump only could result in CO_2 emissions reductions of 38-53% (Pistochini et al. 2022). Pairing heat pumps with building efficiency improvements and demand response capabilities can help to further optimize the emissions reduction opportunity and cost savings. The use of high-performance building envelopes (which includes roofs, foundation, windows, and external walls and doors) is also important, cutting mechanical cooling demand by 30-50% (PEEB 2020).

Heat Pump Market Development

Despite their many advantages, heat pumps face a number of deployment barriers today, particularly in retrofit applications. However, these can be addressed through programs and policy, across the technology adoption curve: 1) emerging technology programs, 2) market development programs, and 3) codes and standards. Moreover, coordinated planning and implementation across the curve is essential for advancing the rapid adoption of efficient, climate-friendly thermal technologies, making them cost-competitive and the go-to appliance to meet cooling and heating needs. Each of these approaches can be strengthened by recognizing and institutionalizing the multiple value streams created through building electrification.

Barriers. For each technology, it is helpful to identify any remaining market barriers and non-technical solutions to address them. In addition to cost factors, discussed in greater detail below, other high-level barriers for heat pump adoption in existing buildings include:

- **Lack of awareness:** Installers and customers are unfamiliar with air source heat pumps and how to assess or communicate their applicability when replacing an existing system.
- **Lack of training:** Even when installers are aware of heat pump options, they may not be sufficiently trained to design and install an electrification retrofit, and the size of the trained workforce may be insufficient to meet the growing demand for heat pumps.
- **Lack of time:** Particularly when systems are being replaced at burnout (as is the case in approximately 85-90% of replacements) (VEIC and Energy Solutions 2020), time considerations can discourage electrification. Time considerations include finding a contractor or equipment, updating electrical systems, and permitting processes.
- **Lack of product availability:** This includes cases when commercially-viable products are not readily available on the market, as well as the need for more "plug and play" heat pumps that minimize the need for panel upgrades and/or overcome space constraints.
- **Challenging customer economics:** Based on current heat pump installation costs and comparative natural gas and electric rates in many markets, the costs customers bear for efficient heat pumps can present challenging customer economics.

Enacting policies and developing programs to address these barriers faces the additional challenge of incumbent utility power, making it difficult to disrupt a business-as-usual approach to heating and energy efficiency programs designed to support fossil fuel heating.

Market transformation approaches. Certain states are adopting market transformation strategies that address key barriers and provide equipment incentives. One example is the $120 Million TECH Clean California[2] Initiative which launched in late 2021 to spur heat pump

[2] https://energy-solution.com/tech/

deployment for HVAC and water heating. In addition to activating the supply chain through incentives and trainings, the Initiative is implementing regional pilots that address known barriers to heat pump adoption. TECH Clean California pilots include:

- Streamlined permitting
- Customer targeting
- Accessible finance
- Low-Income fuel switching
- Multifamily portfolio projects
- Load shifting readiness
- Quick Start Grants

The Quick Start Grants program aims to spur innovation and test market solutions. One example of a solution being launched through the TECH Clean California Quick Start Grants for heat pump water heaters that potentially could be applied to HVAC is that installers are equipped to provide temporary replacements while the newer clean cooling technology deployment (i.e., product ordering, permitting and installation) is underway. This model could be adapted to HVAC through an upstream / midstream program where contractors and distributors stock not only the clean cooling technologies, but also the temporary replacement technologies that can alleviate the immediate, urgent need of building occupants when their HVAC system fails, while the longer-term technology solution is implemented (e.g., putting in portable AC units for the duration of HVAC work).

Building codes and standards. Building codes and appliance standards enable rapid adoption because they require all products sold or installed to meet specifications. These requirements are typically adopted through rigorous market analysis evaluated against key criteria and can be applied to other strategies such as incentive program design and implementation. For example, in California, building, appliance and air quality standards are set based on cost-effectiveness, feasibility, and savings potential. With the significant difference in operational costs for customers between electrical heat pumps and gas furnaces (even with programs that will eventually bring down the upfront costs), cost-effectiveness is not yet within reach. Programs and policies are needed to address the operational costs. Some may be exogenous to codes and standards rulemakings, including rate design. Moreover, cost-effectiveness criteria, which are typically based on the “average consumer,” should include multi-customer analysis (e.g., market rate vs. non-market rate) to help illuminate the economic impacts to low-income customers and design programs and policies that address affordability concerns.

Values streams. An important consideration in developing equitable cooling policies and programs is how we pay for the rapid market transformation. For electrification, several new value streams pose new funding opportunities. While not applicable in every region of the country, some places currently monetize societal benefits, capturing the value of externalities and funding their reduction. A few societal benefits from shifting to heat pumps from air conditioners and gas furnaces and other higher energy intensity heating technologies are:

- Direct and indirect emissions reductions from building energy use and from the use of lower global warming potential refrigerants, which can be monetized through mechanisms such as cap and trade or the Regional Greenhouse Gas Initiative.

- NOx or other outdoor pollutant reductions which deliver benefits to air quality districts.
- Load shifting benefits from grid capable equipment which are being addressed in programs such as PG&E's "Watter Saver"[3] load shifting Pilot.
- Public health benefits from avoiding indoor pollutants from combustion appliances or emergency outages.

The existence and authority of regulatory agencies determines whether these value streams are captured. Policymakers can move to fund equitable cooling by unlocking this value through expansion of authority of agencies or creation of new ones.

Heat Pump Accessibility and Affordability

While decarbonizing buildings and driving toward efficient cooling systems are core strategies for climate mitigation, it is also crucial that the clean energy transition be implemented in a way that encompasses and benefits people of limited economic means, who are disproportionately people of color (Creamer 2020). Improving access to efficient, clean cooling technology is especially critical given that neighborhoods with larger shares of Black, Hispanic, and Asian populations are known to have higher heat exposure than more heavily White and non-Hispanic counties (Benz and Burney 2021). Additionally, lessons from decades of energy efficiency experience demonstrate that low- and moderate-income (LMI) households and historically-disadvantaged communities face distinct barriers that also apply in decarbonization efforts. These include:

- Increased salience of economic factors such as upfront and ongoing operating costs
- Challenges of upgrading rental properties including split incentives[4] and residents' lack of agency around upgrade decisions in their homes
- Neighborhood-level characteristics and historic disinvestment
- Population characteristics including work and health factors

Upfront costs. Achieving the vision that everyone has a comfortable, healthy, and resilient low-carbon home means deploying policy strategies that overcome barriers to comprehensive retrofits of housing occupied by LMI households, including the upfront cost of implementing the range of measures needed to achieve this vision. Measures to be addressed in comprehensive retrofits include:

- Weatherization and passive cooling measures that contribute to building resilience, health, and efficiency and drive down the cost of HVAC equipment
- Efficient, all-electric equipment and appliances that deliver emissions reductions and utility bill savings
- Solar plus storage solutions that reduce energy costs and improve resilience.

A key consideration for how upfront cost impacts play out in LMI-occupied housing has to do with the dynamics of energy upgrades in rental housing. These are particularly relevant because larger shares of LMI households as well as Black and Hispanic Households rent rather

[3] https://www.watter-saver.com/

[4] For further information on split incentives, see https://www.environment.gov.au/system/files/energy/files/hvac-factsheet-split-incentives.pdf

than own their homes (Desilver 2021). In rental housing, residents do not have direct control over upgrade decisions, and owners face a different set of considerations than owner-occupied housing. For one, they face the split incentive problem where if the resident pays the utility bills directly, it diminishes the owner's economic incentive to invest in cost saving measures. Additionally, concerns about existing health and safety needs or wariness of attracting the attention of regulators may discourage owners from engaging in state- or utility-sponsored efficiency programs that could lead to compliance inspections. Incentive programs that cover a higher share of the upfront cost to overcome the split incentive and co-deliver energy upgrades with programs that address other property needs/health and safety concerns are ways to help overcome these electrification barriers in rental housing.

Across the residential building stock (whether rented or owned, single- or multifamily housing) at capital events and when equipment is being replaced are opportune times for investment in sustainability measures including efficient, electric heating and cooling. This dynamic is even more pronounced for LMI-occupied housing, where high upfront costs and capital constraints[5] are an even greater barrier to adopting sustainability measures. Additionally, while heat pumps are in many cases a cost-effective solution for replacing both a heating and a cooling system (E3 2019), this scenario is less likely to play out in LMI-occupied housing, where there is a lower prevalence of cooling systems in the first place. Policy approaches that support access to sufficient, low-cost capital at critical points such as when buildings are first constructed or at time of sale/refinance are important opportunities to address the upfront costs for capital constrained housing. By helping homeowners and affordable housing developers manage upgrade costs, these policy approaches also alleviate concerns about the impact of policy "sticks" such as electrification mandates on housing affordability.

Incentive programs are a widespread and effective mechanism for addressing upfront costs. They can support heat pump adoption and can complement low-cost capital as a strategy for addressing heat pumps' upfront costs. Well designed, whole building programs also have the potential to spur electrification retrofits outside of capital events or lifecycle replacement opportunities. Factors that contribute to incentive programs being particularly well designed for LMI households include offering comprehensive, whole building retrofits that deliver multiple benefits, providing incentives up front so that low-income households do not have to go out of pocket and wait to be reimbursed, and utilizing an engineered baseline that incorporates adequate levels of heating and cooling when calculating performance-based incentives. Offering low-cost financing and incentive programs that are scaled to meet a comprehensive set of retrofits not only delivers on the multiple climate, health, and resilience benefits of sustainability measures, it has the benefit of reducing the cost of heating and cooling equipment, since weatherization and passive cooling strategies can reduce the system size needed to provide heating and cooling.

While whole-building approaches are core to delivering benefits to residents of LMI-occupied housing, in many cases comprehensive approaches will require a funding source to address deferred maintenance and electrification readiness. Experience from the Weatherization Assistance Program[6] shows that many LMI households need to address health and safety and

[5] Capital constraints do not apply evenly across all LMI-occupied housing but affect a range of owners and property types. LMI homeowners face capital constraints related to limited savings and access to financing. Owners of subsidized multifamily rental properties also face capital constraints related to the limited income streams created by restricted rents, complicated capital stacks and existing lender approvals for taking on new debt, and existing subsidy programs' restrictions on capital upgrades and/or new debt.

[6] https://www.energy.gov/eere/wap/weatherization-assistance-program

building durability measures—such as roof repair/replacement, mold and moisture remediation, and/or unsafe wiring—before being able to undertake weatherization measures (Benshoff 2022). Building electrification programs serving LMI customers face these same barriers as well as electrical system upgrades needed to accommodate fuel switching (e.g., wiring, circuit panel upgrades, service lines, transformers). States are using a variety of funding sources to overcome pre-weatherization barriers (Bourguet and Faesy 2020), but the approaches are piecemeal and at times insufficient to prepare homes for electrification. For example, in California, a pilot program under TECH Clean California is supplementing existing health and safety funds for homes participating in the San Joaquin Valley Pilot Program that have greater remediation needs. A streamlined funding source that addresses both traditional health and safety concerns and electrical system upgrades will be key to increasing heat pump adoption in LMI communities.

Operating costs. For LMI households, policies that deliver on equitable electrification must address both sides of the cost coin—upfront costs and ongoing operating costs. Its potential to drive down long-term operating costs is one of the main drivers of adoption for energy efficiency improvements in LMI-occupied housing. While heat pumps can deliver significant energy savings, in some markets the level of energy savings is not sufficient to overcome the current cost differential between natural gas and electricity,[7] and electrifying heating can lead to near-term bill increases. These dynamics play out in complex ways in multifamily rental housing, where split incentives and the potential for costs to shift between owners and residents reinforce the importance of comprehensive retrofits and calls for consumer protections against utility bill or rent increases.

Similar to how owners face a specific set of considerations when addressing upfront costs, the varying meter configurations of multifamily housing present a complex landscape for how electrification might affect operating costs. While the split incentive may discourage owners from undertaking retrofits that generate cost savings, it may also mean they are less averse to the potential for energy cost increases from fuel switching. In markets with high electric to gas cost ratios where electrification takes place without sufficient additional measures to drive down utility costs, incentives that cover upfront costs may have the perverse effect of motivating owners to undertake retrofits that increase residents' costs.

A second way that multifamily meter configurations can affect the operating cost implications of electrification is that fuel switching has the potential to shift who pays for heating and cooling services. This is a concern particularly in properties switching from in-unit gas to electric systems or from central to in-unit systems. Based on common metering configurations in multifamily affordable housing, the most likely scenario is going from owner-paid to resident-paid heating services. However, efforts to protect residents from taking on heating costs, such as requiring that heat pumps be wired to owner-paid meters, could result in cooling costs shifting to owners. Although owners face a different set of payment capacity constraints than residents, increasing costs to owners has the potential to adversely affect housing affordability in the affordable housing stock. Electrification programs should include efforts to mitigate costs to both parties and to equitably share responsibility for energy services.

The way that operating cost dynamics play out in multifamily rental properties reinforces the importance of comprehensive retrofits and program designs that include consumer protections. While utility programs are designed to meet cost effectiveness tests from the utility's

[7]Cost differentials between natural gas and electricity are dynamic, with natural gas prices showing greater volatility than electricity (USA Facts 2022).

perspective, it is also important to screen for customer bill savings or pair retrofits with bill assistance when incorporating measures that may lead to cost increases. Consumer protections that address rent increases provide another mechanism for avoiding the potential for owners to pass upfront costs of retrofits on to residents through rent increases.

An additional approach to avoiding potential operating cost increases is to pair electrification retrofits with programs that drive down the cost of electricity. A suite of tools is available today to help manage bill impacts and promote energy affordability, including rate design, demand response, bill assistance programs, and community solar. Projecting operating costs for different heating and cooling systems should take into account not only average natural gas and electricity rates, but also time of use rates and demand response programs that may lower electricity costs based on *when* a household uses energy. Designing rates and programs that take into account the typical usage patterns for LMI customers and support their having the tools to respond to price signals or demand response calls can make electrification a more favorable option but should be implemented based on real-world data and through robust community engagement. As an example, a project led by the University of Michigan partnered with community-based organizations in four Detroit neighborhoods to create energy improvement plans tailored to individual homes and address barriers to participation in efficiency programs (Erickson 2020). One key feature of the project is that it will collect smart meter data on participating households' energy usage patterns and use that data to inform recommendations on rate design that meet low-income households' energy needs.

A more direct approach to addressing operating costs is to update bill assistance programs to consider the increasing need for cooling and the expected cost of electrified heating. At the federal level, updating the Low-Income Home Energy Assistance Program (LIHEAP) would expand states' ability to address heating and cooling. The program's overall funding level should be expanded to cover both heating and cooling needs. In addition, the formulas for how the expanded pot of funds is allocated to states should reflect both heating and cooling needs. States today have the ability set the level of LIHEAP assistance households receive based on both heating and cooling needs, but the limited pot of funds allocated based on heating needs alone is insufficient to address the growing demand for cooling.

Bill assistance programs regulated by public utility commissions (PUCs) provide another mechanism for directly addressing cost impacts of electrification. One method of ensuring that both PUC-regulated and LIHEAP bill assistance programs respond to cost changes is to set assistance levels according to household-specific factors such as income and energy costs. Using household income levels means that assistance can be more accurately calibrated to alleviate energy burden compared to fixed levels or even ratios of assistance. Using household-level energy costs means that assistance can increase to cover the cost of electrification if needed and can decrease over time should the customer economics of electrification improve (as expected). Offering LMI households the ability to subscribe to lower cost electricity through a community solar program is a more recent model for addressing energy affordability that has the added benefit of delivering the benefits of clean electricity to LMI communities. Like bill assistance programs, the level of benefit offered could be scaled to the cost of the electrification to provide a direct incentive to move to efficient, clean heating and cooling.

Grid Integration

Cooling solutions are integral to driving down GHG emissions in the built environment, but to be fully effective, grid integration is vital. While cooling demand continues to rise, appliances should be efficient and connected to minimize disruption to grid stability. By pairing efficient heat pump technology with building efficiency and tapping into tools such as smart controls or onsite solar/storage for load-shifting, increased cooling load could work in lockstep with utilities and grid operators to create more grid flexibility. In times of anticipated peak demand, these appliances could reduce pressure on the grid by shifting space cooling to times that are more conducive to maintaining grid stability. When there is an abundance of renewable energy feeding the grid, grid-connected cooling and heating appliances could be leveraged to pre-cool or -heat a space, potentially reducing the need to curtail renewables. Broadly speaking, demand response capabilities should not be limited to just cooling appliances, but must also become more ubiquitous with non-critical load appliances.

The imminent widespread electrification of transportation and space/water heating are expected to require a significant build out of renewable energy sources and grid expansion. However, instead of only increasing power supply and expanding grid capabilities, lower cost non-wire alternatives include tapping into demand flexibility measures. Smart meters, which can show more granularity in customers' electricity use, are increasingly being utilized around the country, but there still are not always the policy drivers, price signals, and/or appliance communications needed to incentivize use during times of lower emissions and cost. Pricing has great influence on electricity use, so utilities can offer more dynamic pricing with time of use rates, peak-time rebates, or critical peak pricing (Baatz 2017). However, it is essential to have pricing for low-income consumers, to make electricity affordable, and incentivize safe load-shifting (e.g., pre-cooling a home at lower-cost times, to minimize use at peak times, but not penalizing use in the event of dangerous heat waves).

For new construction, all-electric buildings typically have lower construction costs because they avoid the cost of extending gas infrastructure. A study by RMI found that across five states, extending gas service to single-family homes had costs ranging from $1,000 to $24,000 (with many variables in play such as proximity to gas main) (Billimoria et al. 2018), and wide-ranging costs tend to apply to multifamily developments as well. In many cases, retrofits from natural gas-served buildings to full electrification have capital cost premiums today, which is why policy and financial levers need to be deployed to shift the market and reap the many long-term cost, air quality, health, and resilience benefits of electrification.

In already developed areas, phased-in, geographically targeted electrification focused first on neighborhoods with high pollution exposure, low-income communities, and locations above natural gas distribution line outer branches can help to ensure gas decommissioning can happen neighborhood by neighborhood (Hens, Lamon, and Weissman 2021).

Community-Level Heat Wave Response

Developing the heat pump market in a manner that enables accessibility and affordability helps communities prepare for and respond to heat waves and can complement community-level nature-based and hard-infrastructure solutions. Even in temperate and cool climates, the last few years have brought a string of extreme heat events or heat waves that have made governments and residents confront the new threats of a changing climate. For the contiguous U.S., 2021 was the hottest summer on record (NOAA 2021), and cities are needing to cope with extreme heat in the face of insufficient access to cooling. In Seattle, Washington, where two-thirds of homes do not have air conditioning (AC) (Gerrard 2018), temperatures in 2021 peaked at 108 degrees Fahrenheit on a summer day (Tan and Fathollahzadeh 2021). In Denver, Colorado, one-third of homes do not have AC, but the city is increasingly experiencing heat waves, compounded by bad air quality due to increasing wildfires (Plumer 2021).

Heat waves have also affected New England, where household use of space cooling appliances rose by 7% between 2009 and 2015 (Shankman 2021). For Boston and Providence, 2021 was the year with the hottest average minimum temperature (UMass 2022), and scientists predict that by the 2030s, climate change could lead to more than 40 days a year with temperatures over 90 degrees (Boston 2016). There also are deep disparities in access to cooling, with lack of access disproportionately affecting low- and moderate-income residents and communities of color. For example, in New York City, which experiences both hot and cold seasons, 90% (NYCDOH 2007) of the city's residents report having some form of space cooling in their homes, but as recently as 2016 less than half (Gonzalez 2016) of those in the city's public housing have access.

To make progress on mitigating these challenges, cities like Boston as well as municipalities, communities, and individuals around the country can proactively prepare for rising temperatures by increasing access to cooling resources, implementing policies and projects to reduce urban heat islands, improving healthy housing, and making substantial investments to cut GHG emissions, particularly through energy efficiency and clean heating and cooling in our buildings. To be most effective, these strategies will be deployed collectively, as near-term interventions such as portable cooling equipment must be integrated with longer-term more sustainable deployments of green infrastructure and clean cooling technologies.

Nature-based solutions are one such tool in the toolbox that can both reduce the inequities and heightened risks of urban heat islands and generate benefits for the community, especially when implemented in conjunction with complementary cooling strategies. Benefits range from increased comfort and resilience to extreme temperatures and stormwater runoff to improved air quality and public health benefits, access to recreation and exercise, and economic and cultural development. Nature-based solutions can include green infrastructure, such as engineered parks, pocket parks, or parklets, bioswales, rain gardens, green roofs, and pervious pavement, as well as the preservation or expansion of the natural landscape in the form of street trees, old- and new-growth forests, living shorelines, grasses, healthy soils, and wetlands.

Hard infrastructure can play an important role in complementing or amplifying our natural landscapes to enhance cooling. Splash pads, hydration stations, shade panels, and temporary structures such as movable shade and misting equipment, for instance, can provide relief from extreme heat in public spaces, benefiting public health and expanding recreational opportunities in addition to reducing urban heat island impacts and cooling demand. Cooling centers as an indoor resource were severely limited during the COVID-19 pandemic, and were previously used more in some localities than in others. Co-use of spaces such as public libraries, senior centers, and school facilities can offer communal cooling sites during heat waves. In the face of pandemic constraints, several municipalities and community-based organizations in Eastern Massachusetts shifted to individual emergency interventions, from cooling kits and wearable cooling equipment to bulk purchases of box fans and air conditioners for those in need.

Communities can consider cooling equipment deployment and nature-based solutions such as street tree planting as complementary strategies for improving heat resilience. One recent example of this win-win approach comes from Lawrence, Massachusetts where municipal officials partnered with local environmental justice organization, Groundwork Lawrence, and All In Energy, a nonprofit clean energy outreach organization, during the summer of 2021 to provide free street trees to residents in combination with free energy assessments and energy efficiency measures. Similarly, Chelsea, Massachusetts has simultaneously worked on building out hard infrastructure, like public water fountains, in conjunction with short-term cooling solutions, like distributing box fans and air conditioners, while also conducting in-depth outreach campaigns to promote the adoption of heat pumps and weatherization. While communities may be hesitant to deploy longer-term infrastructure due to concerns with maintenance and operations, the above use cases have been successful to date and may signal a new municipal perspective.

However, in order for these types of solutions to be successful, they need both to scale up significantly and to evolve fully away from emergency band-aid solutions to those embracing resilient electrification. Communities are starting to think about how to transition to cleaner heating and cooling solutions that pair weatherization with heat pumps for the most vulnerable communities. Cooling centers, or other public spaces doubling as shelters, need greater funding and technical support to more thoroughly consider and install centralized or district systems, like variable refrigerant flow (VRF) systems and networked ground-source heat pumps, as well as battery storage for back-up. Likewise, as COVID has resulted in increased air filtration requirements in these centers, schools, and other public buildings, the opportunity for enhanced energy recovery systems should be maximized.

Conclusions

Solving the cooling conundrum means meeting the growing need for cooling without increasing the GHG emissions that are driving increased cooling needs. A vision of the future where cooling needs are met as part of a holistic path to addressing decarbonization, resilience, health, and energy equity is possible, but requires policy solutions that both leverage the benefits and reframe the costs to fully account for climate and equity externalities. Air source heat pumps, as a core strategy for decarbonizing heating, have the benefit of addressing both heating and cooling and will play a central role in assuring efficient, equitable cooling. Developing the overall market for heat pumps will facilitate more people having access to efficient cooling and will reduce the costs and barriers to heat pump adoption. Market transformation approaches can scale heat pump deployment and enable policy strategies appropriate to different points along the technology adoption curve. Yet to achieve full market transformation, including LMI households and historically-disadvantaged communities, policies and programs tailored to those populations' particular barriers will be necessary.

On its own, building electrification is a compelling strategy for its impacts on emissions and access to cooling, and it can be combined with grid modernization efforts and local heat wave response in mutually reinforcing ways. Grid interactive heat pumps enable electricity sector decarbonization by helping to manage a higher share of intermittent renewable electricity sources, and programs that compensate customers for flexible loads provide an additional value stream that encourages heat pump adoption. Similarly, heat pumps are both a partial solution to heat wave response and are served by other municipal heat wave response strategies. Expanding access to efficient cooling reduces the need for emergency cooling programs during heat waves. Reducing urban heat islands reduces cooling loads and supports heat pump affordability.

The recommendations laid out in this paper build toward a vision of low-emissions, resilient, healthy, and equitable access to cooling, creating opportunity out of conundrum.

Table 1. Summary of policy recommendations

Category	Recommendations
Overarching	Integrate decarbonization, resilience, health, and equity considerations
Market development	Align policy approaches with technology adoption curve
	Utilize integrated market transformation strategies
	Prepare for and develop codes and standards
	Recognize multiple value streams
Accessibility and affordability	Provide sufficient, low-cost capital
	Fund electrification readiness
	Design incentives to address LMI-specific barriers, including split incentives in rental housing
	Expand and reform energy subsidy programs to address bill impacts of electrification
Grid integration	Incentivize efficient, connected appliances
	Develop non-wires alternatives to grid expansion
	End natural gas system expansion and geographically-target its decommissioning
Heat wave response	Increase access to cooling
	Mitigate urban heat island effects
	Improve healthy housing
	Cut greenhouse gas emissions

Addressing the full suite of solutions needed for this transformation takes coordinated effort, but solutions are underway on each of these fronts to solve the cooling conundrum.

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