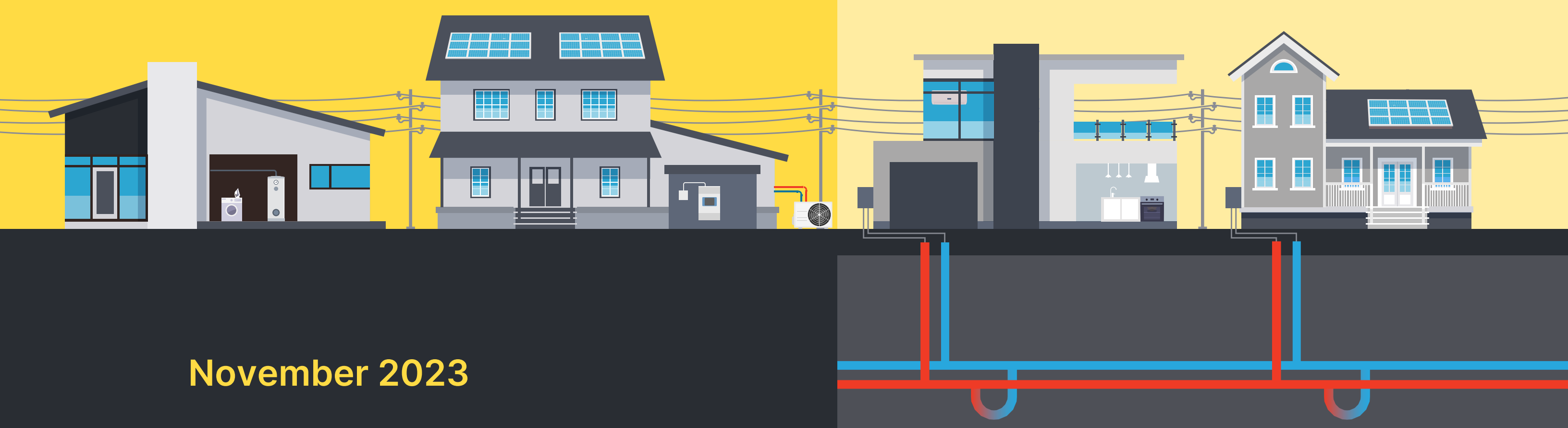
Neighborhood Scale

The Future of Building Decarbonization



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BDC

GRIDWORKS

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Project Partners

BUILDING
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COALITION

The **Building Decarbonization Coalition (BDC)** unites critical stakeholders on a path to transform the nation's buildings through clean energy, using policy, research, market development and public engagement. The BDC and its members are charting the course to eliminate fossil fuels in buildings to improve people's health, cut climate and air pollution, prioritize high-road jobs, and ensure that our communities are more resilient to the impacts of climate change. www.buildingdecarb.org

GRIDWORKS

Gridworks brings stakeholders from across the Western United States together to achieve their decarbonization goals. We facilitate and foster connections between decarbonization advocates, energy providers and utility operators, enabling them to collectively determine the best approach to achieving decarbonization. Together with these stakeholders, we work to advance policy and help states undertake a just transition toward sustainability. We also provide expert advice and guidance to policymakers as they make this important shift. www.gridworks.org

Primary Authors

Building Decarbonization Coalition
Kristin George Bagdanov, PhD; Amy Rider

Gridworks
Claire Halbrook with project management support from Sarina Soor

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Advisory Group Members and Interviewees

Alliance for a Green Economy
Jessica Azulay

BlueGreen Alliance
Jose Tengco

Building Decarbonization Coalition
Nicole Abene, Ania Camargo, Carlos Garcia, Beckie Menten, Ted Tiffany, Tiffany Vu

Center for Popular Democracy
Elizabeth Alex

College of DuPage
Bob Clark

Colorado Energy Office
Adam Berry

Con Edison
Greg Koumoullos

Emergent Urban Concepts
Jared Rodriguez

Eversource Energy
Nikki Bruno

GeoExchange
Ryan Dougherty

Green & Healthy Homes Initiative
RuthAnn Norton

Greenlining Institute
Monica Palmeira

Eco Infinity Nation (Healthy Communities, Healthy Homes, Healthy Kitchens)
Ali Lee

Heinz Foundation
Matt Barron

HEET
Audrey Schulman, Zeyneb Magavi

Independent Consultant
Jim Lazar

KHIMSTONIK
Ione Jones

Pacific Gas & Electric
Rachel Kuykendall, David Sawaya

Physicians for Social Responsibility
Barbara Gottlieb, Zach Williams

Puget Sound Energy
Mark Lenssen, Megan Lacy

RMI
Sherri Billimoria, Mike Henchen

Shenker, Russo & Clark
Ed Draves

Table of Contents

Executive Summary

Fossil fuel combustion in the residential and commercial building sectors currently accounts for nearly 30% of total U.S. greenhouse gas (GHG) emissions.[1] To meet our federal goal of achieving net-zero emissions by 2050,[2] we need to scale our deployment of clean energy solutions in the built environment. Building decarbonization—the rapidly growing movement seeking to reduce greenhouse gas emissions, improve air quality, address inequitable energy cost burdens, and transition to clean energy infrastructure by electrifying homes and businesses—is a central component of the nation's strategy for meeting that target. However, the existing "appliance-by-appliance" or "house-by-house" approach to building decarbonization primarily relies on a mosaic of individual consumers, incentives, technologies, codes, contractors, utilities, and uneven access to capital. By coordinating these actors and resources, we can reduce the total cost of the transition, create savings for ratepayers, ensure continued energy reliability and safety, and encourage an equitable distribution of clean energy benefits. Decarbonizing the built environment block by block, neighborhood by neighborhood, and town by town makes possible a more comprehensive and equitable strategy for meeting our climate goals. We call this strategy neighborhood-scale building decarbonization.

Neighborhood-scale building decarbonization focuses on transitioning street segments, developments, or even entire neighborhoods to decarbonized energy sources and electric appliances with the end goal of managing the transition off of the gas system. It is intended to complement, not replace, the existing appliance-by-appliance approach to building decarbonization. The novelty, scale, and ambition of neighborhood-scale building decarbonization requires that we define terms, clarify objectives, collaborate on solutions, and educate strategic partners. The framework developed in this whitepaper is intended to serve as a springboard for conversations about how to accelerate decarbonization to improve the habitability and sustainability of the buildings in which we spend the majority of our lives. To that end, we offer pathways and recommendations as well as questions for future study, knowing that additional thought partners and research will be required to continue advancing this work.

Technology Pathways for Implementation

Implementation of neighborhood-scale building decarbonization can occur via two primary pathways: the Electric Network and the Thermal Energy Network. These pathways can apply to both new construction and existing buildings and should be paired with weatherization and energy efficiency measures to reduce energy use and costs. The Electric Network pairs the existing electric grid with four primary electric appliances: heat pump water heater, air- or ground-source heat pump, induction or electric resistance range, and a heat pump or electric resistance clothes dryer. The Thermal Energy Network shares and redistributes thermal energy across linked buildings via pipes filled with water or other liquid solution. It utilizes a ground-source heat pump for space heating and cooling, water heating, and clothes drying while an induction or electric resistance range is needed for cooking. Within these two primary pathways, there are many variations on how energy is stored, distributed, and used.

[1] Jessica Leung, "Decarbonizing U.S. buildings," Center for Climate and Energy Solutions," July 2018, https://www.c2es.org/wp-content/uploads/2018/06/innovation-buildings-background-brief-07-18.pdf.

[2] "The Long-term Strategy of the United States: Pathways to Net-Zero Greenhouse Gas Emissions by 2050," November 2021, https://www.whitehouse.gov/wp-content/uploads/2021/10/US-Long-Term-Strategy.pdf.

Advantages of Neighborhood Decarbonization

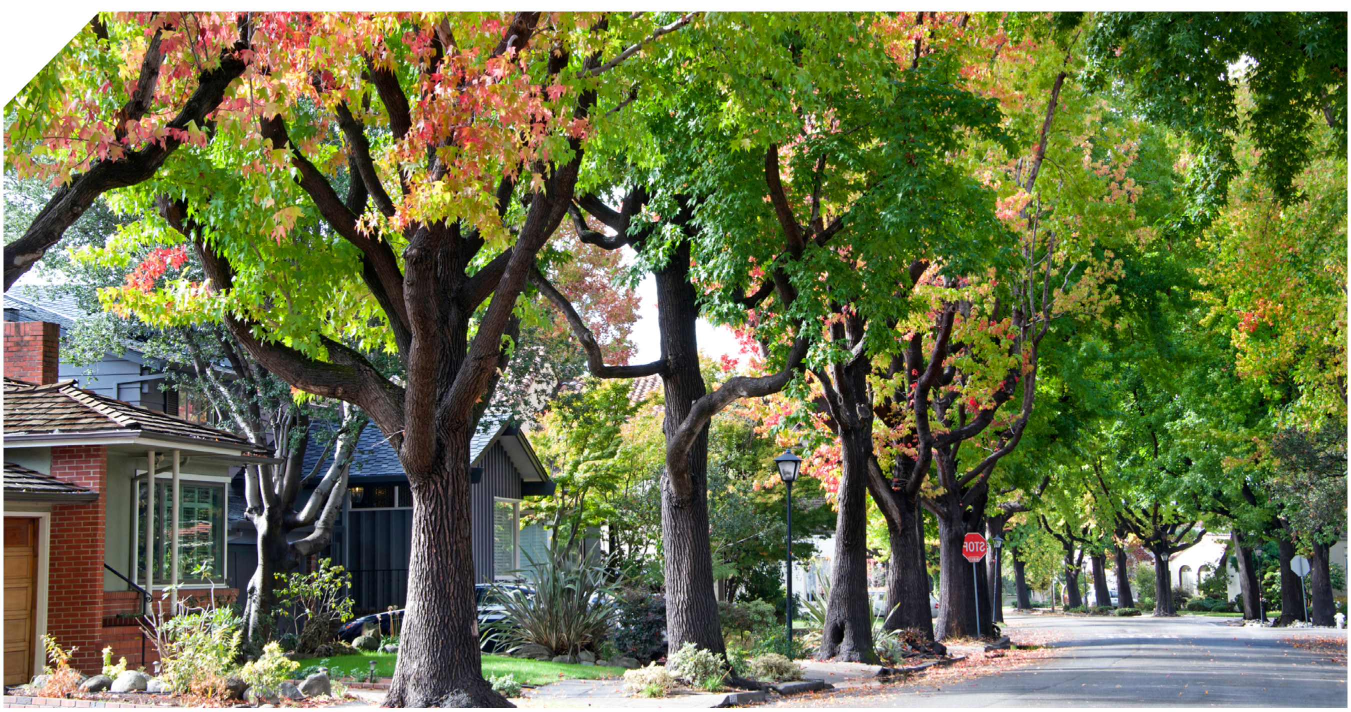
Neighborhood-scale building decarbonization offers a variety of advantages:

1. Accelerates Climate and Health Benefits of Decarbonization
2. Enables a Managed Transition Off of the Gas System
3. Centers Communities
4. Structurally Integrates Equity
5. Provides Demand and Job Security for Organized Labor
6. Supports Alternatives to Major Capital Investments in Fossil Fuel Infrastructure
7. Creates Business Opportunities for Gas Utilities in the Clean Energy Transition
8. Offers Opportunities for Local Ownership
9. Improves Project Economics

Recommendations to Advance Neighborhood Decarbonization

Regulatory, legislative, social, and economic changes are needed to advance neighborhood-scale building decarbonization to meet our GHG reduction goals while also improving air quality, increasing comfort, and managing energy affordability. What follows are steps that stakeholders can take today to scale building decarbonization:

1. Align Utility Infrastructure Investments with Climate Goals
2. Integrate Resource Planning
3. Develop Equitable Rate Models
4. Reform the Obligation to Serve
5. Allow Utilities and Municipalities to Operate Thermal Energy Networks
6. Prioritize High-Road Jobs
7. Engage Communities in Decision Making
8. Designate Funding for Neighborhood Decarbonization
9. Analyze Projects and Conduct Additional Research
10. Encourage Knowledge Sharing



Introduction

Fossil fuel combustion in the residential and commercial building sectors currently accounts for nearly 30% of total U.S. greenhouse gas (GHG) emissions.[3] To meet our federal goal of achieving net-zero emissions by 2050,[4] we need to scale up our deployment of clean energy solutions in the built environment. Building decarbonization—the rapidly growing movement seeking to reduce greenhouse gas emissions, improve air quality, address inequitable energy cost burdens, and transition to clean energy infrastructure by electrifying homes and businesses—is a central component of the nation's strategy for meeting that target. However, the existing approach to building decarbonization primarily relies on a mosaic of individual consumers, incentives, technologies, codes, contractors, utilities, and uneven access to capital. This "appliance-by-appliance" or "house-by-house" strategy has been, and remains, essential to driving market transformation, building awareness, phasing-in early adopters, and socializing lessons learned. However, to create systems-level change at the pace that is necessary to meet climate goals[5] and remediate environmentally burdened communities, we need to standardize and aggregate these discrete pieces. Transitioning to clean energy infrastructure at the neighborhood scale is building decarbonization's best strategy for realizing this future.

The novelty, breadth, and ambition of neighborhood-scale building decarbonization requires that we define terms, clarify objectives, collaborate on solutions, and educate strategic partners. In addition to establishing shared vocabulary, this whitepaper provides an overview of the opportunities associated with neighborhood-scale building decarbonization. This framework is intended to serve as a jumping off point for conversations about how to accelerate decarbonization to improve the habitability and sustainability of the buildings in which we spend the majority of our lives. To that end, we offer pathways and recommendations as well as questions for future study, knowing that additional thought partners and research will be required to continue advancing this work.

[3] Leung, "Decarbonizing U.S. buildings," July 2018.

[4] "The Long-term Strategy of the United States: Pathways to Net-Zero Greenhouse Gas Emissions by 2050," November 2021.

[5] Currently, 23 states and the District of Columbia have established economy-wide greenhouse gas emissions targets. Three states have published recommended targets. "U.S. State Greenhouse Gas Emissions Targets," Center for Climate and Energy Solutions, September 13, 2023, https://www.c2es.org/document/greenhouse-gas-emissions-targets/.

What is Neighborhood-scale Building Decarbonization?

Neighborhood-scale building decarbonization (hereafter referred to as "neighborhood decarbonization") is an emerging strategy that focuses on transitioning street segments, developments, or even entire neighborhoods to decarbonized energy sources and electric appliances with the end goal of enabling a transition off of the gas system. It is intended to complement, not replace, the existing appliance-by-appliance approach to building decarbonization. A neighborhood-scale strategy requires distinct technological solutions, coordinated practices among multiple actors, and supportive policies to maximize cost savings, reduce disruption, and align infrastructure upgrades. It is this systematic approach to systemic problems that ultimately distinguishes neighborhood decarbonization from the status quo of singular, discrete electrification projects.

Neighborhood decarbonization offers several benefits for organizing and aligning the stakeholders and entities involved in building decarbonization. It both requires and enables long-term electric and gas system planning, which in turn benefits communities, workers, and utilities. The criteria for siting neighborhood-scale projects can prioritize communities who have suffered the most from environmental pollution and energy burdens (hereafter referred to as "environmental justice communities") and therefore have the most to gain from a transition to clean and healthy all-electric homes. Neighborhood decarbonization, as a strategy for both new construction and existing buildings, can also enable the retirement of gas system segments that would otherwise need to be replaced, reducing the total cost of the clean energy transition and minimizing fossil fuel infrastructure investments that are misaligned with climate goals.[6]

The broader scope of neighborhood decarbonization can offer a pathway to high-road jobs in the decarbonization movement. Scaling building decarbonization requires engagement from labor unions, who are particularly suited to long-term infrastructure projects and who can ensure that work is of the highest quality due to intensive training requirements, oversight, and depth of experience. In turn, organized labor stands to benefit from the stability of work generated by neighborhood decarbonization projects if these projects are paired with complementary policies that support workers.[7] Utility-directed neighborhood decarbonization makes possible a clean energy pathway for gas-only and dual fuel utilities to operate as "thermal utilities." Workers can apply similar skill sets and training to the installation and maintenance of thermal energy networks, which will be discussed further in the technology pathways section of this report.

> **"There seems to be a real 'roll up your sleeves' moment right now where people really want to put things into motion."**
>
> **Jose Tengco**
> BlueGreen Alliance

[6] Early research in California and New York indicates that gas replacement costs can amount to ~$3-5 million/mile. Michael J. Walsh and Michael E. Bloomberg, "The Future of Gas in New York State" (Building Decarbonization Coalition, 2023). https://buildingdecarb.org/wp-content/uploads/BDC-The-Future-of-Gas-in-NYS.pdf; Claire Halbrook and Ari Gold-Parker, "Strategic Pathways and Analytics for Tactical Decommissioning of Portions of Gas Infrastructure in Northern California: Interim Report" (Energy and Environmental Economics, Inc., June 2023). https://gridworks.org/wp-content/uploads/2023/06/Evaluation-Framework-for-Strategic-Gas-Decommissioning-in-Northern-California-Interim-Report-for-CEC-PIR-20-009.pdf.

[7] Ed Draves, Public Affairs Director at Shenker, Russo, & Clark, who works extensively with the Pipe Trades in New York, emphasized that labor unions want to work at scale as it offers security and stability for the workforce and that he sees neighborhood decarbonization as a pathway toward long-term union jobs in the clean energy space. Zoom interview with Gridworks and BDC, September 25, 2023.

Finally, neighborhood decarbonization represents a chance to scale the benefits of building decarbonization and excise the inequities that often accompany an "early adopter" approach to new technology. The Greenlining Institute offers a five-step approach to equitable building decarbonization, which includes: understanding a community's needs and desires; respecting a community's autonomy in decision making; assessing whether policies have their intended effect following implementation; ensuring that funding reaches low-income communities; and continuing to improve upon policies and practices based on data from ongoing assessment.[8] Neighborhood decarbonization has the opportunity to incorporate all of these provisions into its framework, particularly given the community-centered nature and coordinated approach of this strategy. Constant assessment and revision of our collective approach to neighborhood decarbonization is essential for ensuring equitable strategies, policies, implementation, and outcomes and for ensuring that inequity is not scaled along with decarbonization.[9]

Terminology

"Neighborhood-scale" indicates the figurative scope of this broad approach to building decarbonization. While the precise configuration of a neighborhood may vary, the emphasis is on a group of buildings that is transitioned through a coordinated process. Scale may fluctuate based upon the density and mix of building types in a given area, as well as other shared conditions (e.g., concentration of buildings around a waste heat source). A project for a single city block in New York City could be of equivalent "scale" to multiple streets in a suburban community of residential homes. Furthermore, it is important to acknowledge that "neighborhoods" have uneven access to resources and differing levels of autonomy when it comes to transitioning to clean energy. While this report does not delve into the specific characteristics of affordable housing and tenant-occupied buildings, exploring the distinct opportunities

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[8] Miller, C., Chen, S., Hu, L., & Sevier, I. (2019). "Equitable Building Electrification: A Framework for Powering Resilient Communities." The Greenlining Institute. Oakland, CA: The Greenlining Institute . Retrieved from https://greenlining.org/wp-content/uploads/2019/10/Greenlining_EquitableElectrification_Report_2019_ WEB.pdf

[9] For additional resources on designing and implementing equitable building decarbonization, see the "Equity Appendix" in BDC and GHHI's 2022 paper, "Leveraging the IRA: Transforming the Market for Equitable Building Decarbonization." BDC and GHHI 2023, https://buildingdecarb.org/resource/leveraging-the-ira: 31-34.

and challenges for occupants of these buildings will be important for more detailed studies of neighborhood-scale projects.[10] Additionally, further study will be needed to understand the unique needs and costs associated with rural decarbonization.

"Neighborhood decarbonization" is an umbrella term that encompasses the terms "targeted electrification" and "zonal electrification," which utilities have used to describe a strategic, scaled approach to electrification.[11] We use the term "neighborhood" as opposed to "zonal" to emphasize a more familiar, people-centered approach to decarbonization. This approach includes addressing residential, commercial, and industrial buildings. For the purposes of this report, we primarily focus on residential and commercial buildings, as approaches to decarbonizing industrial buildings can vary significantly by use case. However, this paper does explore the potential to leverage waste heat from sources like data centers and large industrial manufacturing to benefit nearby buildings.

The term "decarbonization" is used rather than "electrification" to clearly communicate a key goal of this movement: reducing greenhouse gas emissions associated with the extraction, transportation, and combustion of methane gas. Decarbonization can be achieved through multiple strategies, which can be pursued independently or in combination with one another, depending on the neighborhood. These strategies involve pairing decarbonized energy sources with electric appliances and systems. Decarbonized energy sources in this instance can include options like the increasingly clean electric grid, rooftop solar, microgrids, and thermal energy networks.

Renewable natural gas (RNG) and hydrogen are not included in this framing of neighborhood decarbonization as those fuels are assumed to be limited in supply and cost-prohibitive, making them a better fit for decarbonizing other energy-intensive end uses like industrial processes.

In addition, relying on these fuels will not contribute to the systematic pruning of the gas system or the investment in renewable energy infrastructure. Furthermore, there is concern that the siting of facilities to manufacture these fuels and the corridors through which they may be transported may further add to the burden placed on environmental justice communities.[12] We do however agree that there may be instances in which temporary reliance on propane[13] may be necessary or where cultural tradition and/or resiliency planning may require the use of pellet or wood burning stoves.[14] The use of these energy sources is not in conflict with neighborhood decarbonization's goal of reducing reliance upon the gas system.

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[10] For discussion of the challenges and opportunities associated with decarbonizing affordable and multi-family housing, see York, Dan, Charlotte Cohn, Diana Morales, and Carolin Tolentino. "Building Decarbonization Solutions for the Affordable Housing Sector." ACEEE, April 2022.

[11] PG&E defines targeted electrification as a "cost-based approach to electrification"; typically these are smaller scale projects driven by the fact that electrification costs less than repairing or replacing the existing gas infrastructure. They define zonal electrification as "an equity-based approach to electrification," the scope of which is on par with neighborhood decarbonization. In both cases, the scale of the projects "is dependent on changes to 'obligation to serve,' [significant] external funding, and ability to capitalize behind-the-meter electrification costs." Rachel Kuykendall, "BDC Lunch 'N Learn: PG&E Zonal Electrification," Nov. 9, 2022. https://buildingdecarb.org/resource/lunch-and-learn-webinars

[12] Communities for a Better Environment. "Equity Principles for Hydrogen: Environmental Justice Position on Green Hydrogen in California," October 10, 2023. https://www.cbecal.org/wp-content/uploads/2023/10/Equity-Hydrogen-Initiative-Shared-Hydrogen-Position-1.pdf.

[13] For example, PG&E's Alternative Energy Program has used propane for customers unwilling to electrify in targeted electrification projects.

[14] Ione IronHorse Martel Jones (President of KHIMSTONIK; enrolled member of the Confederated Tribes and Bands of Yakama Nation and lineal descendent of the Fishhook Bend Snake River Renegade Palouse) comments that her community prefers wood burning stoves for heating and cooking instead of new energy efficient appliances. Balancing cultural and historical practices with state-wide decarbonization goals will be essential to ensure an equitable energy transition. Zoom interview with Gridworks and BDC, October 2, 2023.

Technology Pathways for Implementation

Neighborhood decarbonization utilizes many of the same technologies as appliance-by-appliance electrification. As with single-building projects, it is essential that neighborhood-scale projects address environmental concerns and opportunities for efficiency prior to or in tandem with decarbonization. These include: environmental air quality stressors (including and beyond the pollution caused by gas appliances); environmental hazards such as mold and radon; weatherization and efficiency measures, such as insulation and air sealing; and additional remediation and efficiency measures to ensure that electrification efforts lead to the lowest possible use of energy as well as the highest possible habitability for the occupants. The installation of greywater recycling systems can also increase a building's drought resiliency while creating additional pipefitting opportunities for plumbers. While many of the technologies and complementary measures remain the same, what distinguishes neighborhood decarbonization from the appliance-by-appliance strategy is the presence of an organizing entity and a coordinated approach to implementing these scaled-up solutions.

Neighborhood-scale projects can achieve decarbonization via two primary pathways. These pathways entail pairing specific appliances with one or more decarbonized energy sources. Pathway One, the "Electric Network," utilizes the increasingly renewable electric grid and electric appliances. Pathway Two, the "Thermal Energy Network," uses a form of clean energy infrastructure that shares and redistributes thermal energy across linked buildings, pairs with electric appliances, and operates in partnership with the electric grid. Within these two approaches, there are many variations on how energy is stored, distributed, and used that we designate as "Networked Innovations." Below we illustrate and describe these technological pathways to achieving neighborhood decarbonization.

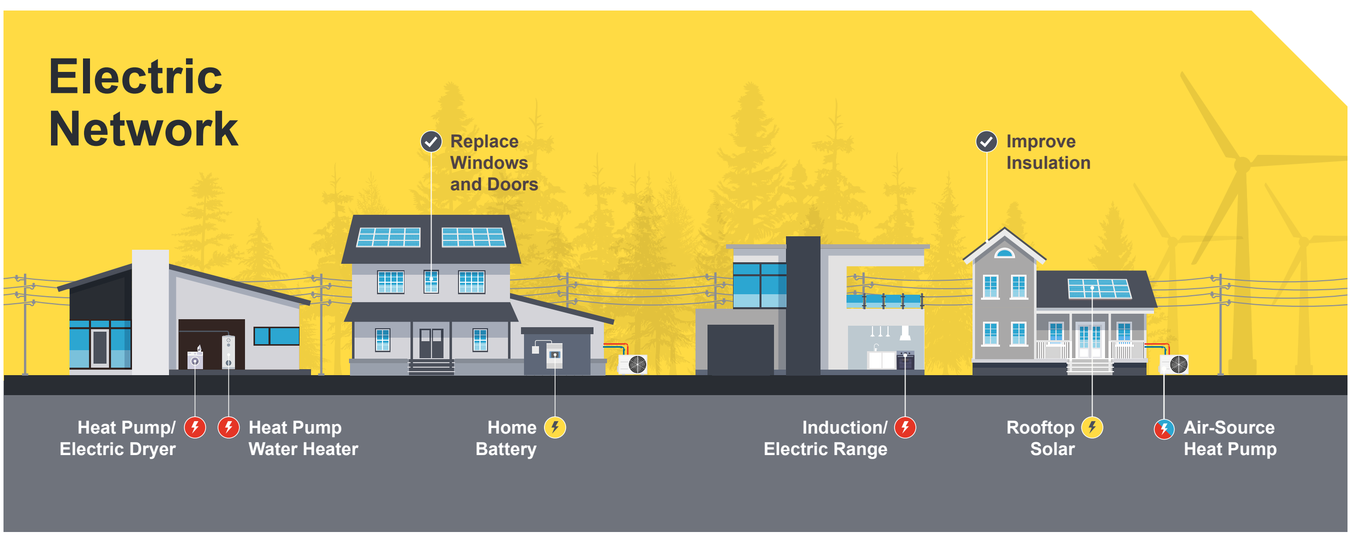
Pathway 1

Electric Network

The Electric Network pathway entails pairing electric appliances with the electric grid. As states achieve increasingly ambitious renewable energy targets, electricity becomes less carbon-intensive and more renewable. In fact, recent research indicates that replacing a gas furnace with a heat pump reduces climate pollution in all 48 continental states.[15]

The Electric Network pathway utilizes four major appliances: heat pumps (air-, water-, and/or ground-source) for water and space heating; an induction or electric resistance range; and a heat pump or electric clothes dryer. Heat pumps operate by moving heat from one source to another (i.e., from the ground, air, or water into or out of a building), providing both heating and cooling by introducing or removing heat. This principle of heat exchange not only reduces the number of appliances needed in a home, but it also makes heat pumps more efficient than their conventional counterparts—thus requiring less energy to operate. This electric, efficient heat pump accounts for reducing the majority of building emissions.

Pacific Gas and Electric (PG&E) has been exploring implementation of the electric network pathway through several targeted demonstration projects. They are now working to pursue larger, neighborhood-scale opportunities. PG&E recently filed an application to electrify 391 buildings containing 620 residential units on the campus of California State University, Monterey Bay.[16] If approved, PG&E would return $2.45 million to gas ratepayers for the avoided gas pipeline replacement costs, helping to keep the costs of the gas system affordable for those who have not yet electrified. PG&E's climate strategy report commits the company to expand this approach to "electrify three to five communities, with a specific focus on the decarbonization of vulnerable communities."[17]



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[15] Lacey Tan and Jack Teener, "Now Is the Time to Go All in on Heat Pumps," RMI, July 7, 2023, https://rmi.org/now-is-the-time-to-go-all-in-on-heat-pumps/.

[16] Pacific Gas and Electric Company. "Application of Pacific Gas and Electric Company (U 39 G) For Approval of Zonal Electrification Pilot Project and Request For Expedited Schedule." CPUC, August 10, 2022. https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M496/K451/496451495.PDF.

[17] "PG&E Climate Strategy Report." Pacific Gas and Electric Company, June 2022. https://www.pge.com/pge_global/common/pdfs/about-pge/environment/what-we-are-doing/pge-climate-goals/PGE-Climate-Strategy-Report.pdf.

Thermal Energy Network

Thermal Energy Networks (TENs) are a neighborhood-scale climate solution that allows entire communities to efficiently access heating and cooling. These networks typically consist of a system of underground, water-filled pipes that share thermal energy across connected buildings. Within this category of TENs, two configurations discussed here are networked geothermal and district energy systems. We use the term "TENs" broadly throughout this paper to refer to these and additional configurations. TENs are a significant climate solution because they replace the existing combustible and emissions-producing gas system that typically heats buildings with non-emitting, clean energy infrastructure. Instead of a gas furnace or boiler, each building connected to a TEN uses ground-source heat pumps to transfer energy in and out of the building.

There are many configurations for networking a ground-source heat pump (GSHP), but the primary formula for these TENs is a heat pump linked to a thermal loop to provide heating and cooling in a building.[18] During summer, the geothermal system draws heat from the air in the building and transfers it to the ground. During winter, it draws heat from the ground and transfers it to the building. Because ground temperature below the frost line is consistent (unlike the air), GSHPs are approximately twice as efficient as air-source heat pumps (ASHPs) and see fewer peaks and valleys in their electric demand.[19] Homes connected to these loops are still connected to the increasingly clean electric grid, which provides the electricity needed to run the heat exchange process occurring in a GSHP. TENs can be designed to interconnect, allowing them to expand over time to serve entire neighborhoods and municipalities. In fact, these systems become easier to balance as they grow by adding more buildings that use heating and cooling in different ways. For example, even in the depth of winter, office buildings and data centers need to remove heat generated by their computer systems. This unwanted heat can be transferred to homes in need of heat, which are connected via the shared network of pipes. Networked together, these systems become more efficient by sharing thermal energy and utilizing thermal storage. A recent case study by Xcel Energy on Colorado Mesa University's networked geothermal system found that it averages a coefficient of performance (COP) of 5.7—three times more than the conventional COP of 1.9.[20]

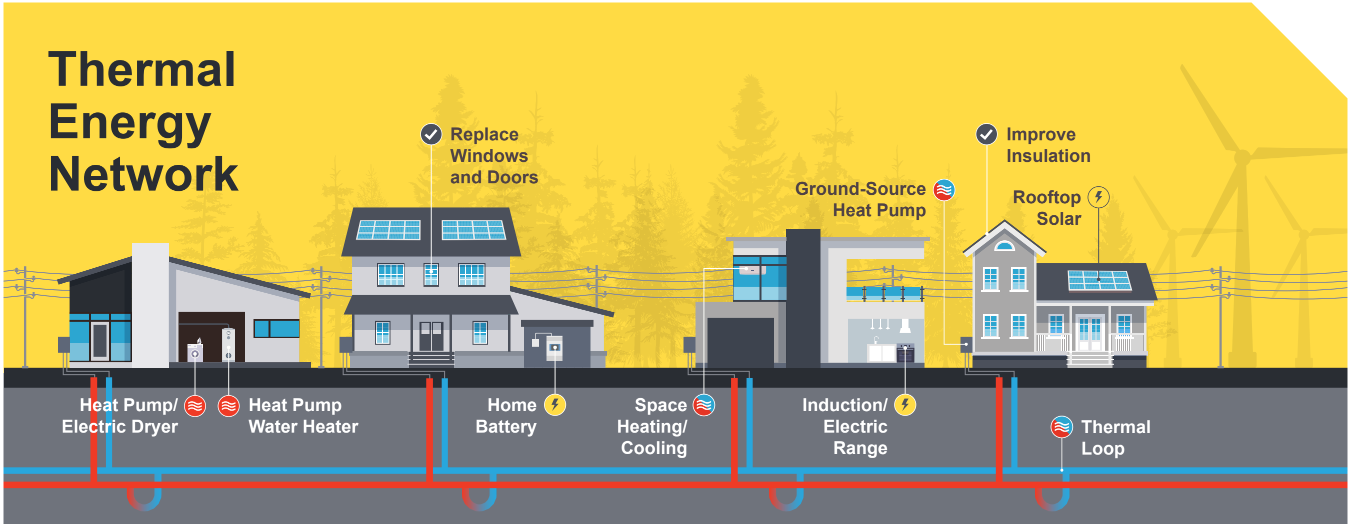
While this technology has been in use for years at college campuses (e.g. Colorado Mesa University), housing developments (e.g., Whisper Valley in Austin, Texas), and other private or single-owner properties, the utility-owned TEN model is a recent configuration that opens up new possibilities for decarbonizing gas utilities.[21] The benefits of the utility-ownership model include allowing gas utilities to divert investments away from fossil fuel infrastructure and towards decarbonized systems like thermal energy, decreasing the tendency toward stranded assets (the costs for which significantly harm low-income ratepayers), as well as avoiding major reductions in work for the gas workforce. The utilities also already have in place financing, customers, and rights-of-way, allowing them to transition communities

[18] Zeyneb Magavi, Zoom Interview with Gridworks and BDC, September 28, 2023.

[19] Some stakeholders claim that heat pumps, particularly ASHPs, are inefficient in cold climates or simply do not work at all because of the significant temperature differential between the air outside and the temperature needed inside the home. Recent research in cold climates around the world finds that heat pump efficiency still exceeds that of natural gas and electric resistance heating at temperatures well below freezing. See: Duncan Gibb et al., "Coming in from the Cold: Heat Pump Efficiency at Low Temperatures," Joule 7, no. 9 (September 11, 2023): 1939–42, https://doi.org/10.1016/j.joule.2023.08.005.

[20] According to the case study, "conventional cooling and heating equipment power and efficiencies were estimated based on ASHRAE 90.1 documentation. Xcel Energy. "Evaluating a Community Ground Source Heat Pump System at Colorado Mesa University." Case study, 2022.

[21] As of the publication of this paper, there were 17 utility-owned TENs pilots in the proposal or planning stages, with two installations under construction by Eversource Energy and National Grid. In addition there are several non-utility feasibility studies being funded at the state and federal level, including from the Department of Energy, New York State Energy Research and Development Authority (NYSERDA) and the Massachusetts Clean Energy Center. See the TENs Appendix for more information on these projects and studies.



safely and efficiently. Furthermore, their rates are controlled by regulatory agencies.

In addition to the utility-owned model, ownership and operation by municipal, non-profit, cooperative, or state actors present equally viable business models with similar and additional benefits for deploying TENs at scale. These benefits include local, democratic control of system investments and customer costs as well as the potential for avoiding the influence of private equity or the need for investor returns. The likelihood of achieving equitable deployment of neighborhood decarbonization may be greater when the influence of private equity is removed from the business model and when systems are owned and managed by local entities.

To build to scale, TENs can be designed in many configurations.

Networked Geothermal is a type of TEN that uses a network of ambient-temperature water connected to shallow boreholes (100 to 700 ft) to harness the temperature of the earth (~55 degrees F) to heat and cool buildings with heat pumps that are connected to the network. These boreholes can store thermal energy, providing daily and seasonal storage for the network by storing heat in the ground, which can be accessed up to several months later.[22] However, TENs do not always need boreholes. A large body of water or other sources of heat—such as energy intensive buildings (e.g. a data center, skating rink, grocery store) or wastewater—can also be used to store energy. A TEN that does not have boreholes does not yet have an agreed upon name in the industry. Networked geothermal also allows the sharing of thermal energy from one building (such as a greenhouse or refrigerated warehouse) to another building for use. Since the boreholes and other sources and sinks are distributed rather than centralized, these systems can grow and interconnect over time without causing "end of the line" issues, which result in a building at the end of the street not being able to access the heating or cooling it needs.

Three utilities in Massachusetts—Eversource, National Grid, and Columbia Gas—have proposed separate demonstration projects that will replace neighborhood gas pipeline networks with pipes that capture and share thermal energy underground. Eversource's Framingham project proposes to convert 37 buildings—32 residential and five commercial—for a total of 140 customers, from gas to geothermal energy.[23]

District Energy Systems, another type of TEN, are characterized by one or more central plants producing hot water, steam, ambient, and/or chilled water, which then flows through a network of insulated pipes to provide hot water, space heating, and/or air conditioning for nearby buildings. District energy systems serve a variety of end-use markets, including downtowns (central business districts), college and

[22] "Borehole Thermal Energy Storage," ScienceDirect, accessed October 16, 2023, https://www.sciencedirect.com/topics/engineering/borehole-thermal-energy-storage.

[23] "Geothermal Pilot Project Updates," Eversource. https://www.eversource.com/content/residential/about/transmission-distribution/projects/massachusetts-projects/geothermal-pilot-project

university campuses, hospitals and healthcare facilities, airports, military bases, and industrial complexes. The central plant has been traditionally powered by fossil fuels but can evolve over time to provide increasingly decarbonized energy without changes to the buildings it serves.

District energy systems, networked geothermal, and other TEN system design typologies are compatible and are able to be integrated. A networked geothermal system may feed a district energy central plant and vice versa. It is important to note that networked geothermal and district energy systems can be flexibly designed to evolve and expand over time. While district energy systems were not originally intended to include this capacity for growth and interconnection due to fixed capacity, the framework of networked geothermal has allowed for the rethinking of this design. Ultimately, local conditions at the neighborhood scale drive the type of system selected, the means by which the system is deployed, and how it grows over time.

Networked Innovations

While electric networks and thermal energy networks are the two primary pathways for achieving building decarbonization at scale, neighborhood decarbonization offers room for innovation with additional clean energy technologies. We call this catch-all space "networked innovations" to indicate how the existing electric grid and/or thermal energy networks can be paired with microgrids, virtual power plants, on-site renewable energy, backup storage, etc. to achieve decarbonization at scale.

These pathways are ideally implemented when buildings are constructed, along with weatherization and energy efficiency measures, but they are suitable for retrofit applications as well.

How to Select the Technology Pathway

When selecting the ideal technology pathway for neighborhood decarbonization, it is important to consider both the upfront costs of installation and construction (e.g., appliances, new infrastructure, labor, etc.), the long-run operational costs, and how state, community, and building-specific criteria may affect the cost and feasibility of implementing a particular pathway.

Criteria that will affect the selection of a technology pathway include:

- Location of the project area on the gas system (e.g., near the end of the line, which can be easily removed from service without impacting pressure and flow rates)
- Types and condition of buildings in the area, including building density
- Condition of the electric grid in the area, including existing peak demand and capacity
- Other planned street infrastructure projects (waste water system upgrades, undergrounding of electrical cables, etc.)
- Age and condition of gas pipeline in the area to re-allocate any avoided costs
- Proximity to a heat source/sink and buildings with a variety of heating and cooling needs
- Presence of anchor customers and/or community champions
- Existence of political will and diverse stakeholders ready to advocate for the approval of particular technology pathway implementation
- Local climate
- Climate change risk or natural hazards such as fire, flood, and earthquake prone areas

Advantages of Neighborhood Decarbonization

Neighborhood decarbonization is intended to complement, not replace, the appliance-by-appliance approach to building decarbonization. While both strategies share the goals of reducing emissions, saving energy, and improving habitability, the systemic nature of neighborhood decarbonization produces several advantages unique to working at a coordinated scale. Further, it helps expand the solution set for decarbonizing buildings to provide options that best fit local communities' needs and may offer unique benefits not afforded by other approaches. Some of the most significant advantages are as follows (not listed in order of priority).

1 Accelerates Climate and Health Benefits of Decarbonization

Scaling up the rate of decarbonization also speeds up the reduction of GHG emissions and the improvement of indoor and outdoor air quality. A recent Harvard study found that twenty-one air pollutants designated by the U.S. Environmental Protection Agency (EPA) as hazardous are released into homes and neighborhoods from combusted and uncombusted methane.[24] Children living in homes with gas stoves are 42% more likely to develop asthma symptoms.[25] Poor air quality disproportionately affects low-income homes, which have poorer ventilation and are often located near major roadways and/or large polluters (e.g., refineries). Ali Lee, who specializes in the intersection of equity and electrification, notes that any approach to neighborhood decarbonization must be "holistic" to achieve "health equity" as well as environmental benefits, addressing "not only appliances, but the whole spectrum" of the energy system feeding into those appliances.[26]

2 Enables a Managed Transition Off of the Gas System

An unmanaged transition off of the gas system will exacerbate existing inequities and energy cost burdens as "those with the most agency and access to resources will be able to reduce their gas use, leaving behind those with less agency and less access to resources."[27] Neighborhood decarbonization both necessitates and enables a managed transition, as it requires the centralization of authority, the coordination of resources, and the alignment of stakeholders. While the appliance-by-appliance approach to decarbonization can continue without much oversight, a neighborhood-scale transition requires the type of management that can ensure low-income communities

[24] Tiffany Chan, "Study Shows Gas Stoves Could Be Leaking Toxic Chemicals," Boston, June 28, 2022, https://www.cbsnews.com/boston/news/harvard-study-gas-stoves-leaking-toxic-chemicals/.

[25] Li Shang et al., "Effects of Prenatal Exposure to NO2 on Children's Neurodevelopment: A Systematic Review and Meta-Analysis," Environmental Science and Pollution Research 27 (April 30, 2020): 24786–98, https://doi.org/https://doi.org/10.1007%2Fs11356-020-08832-y.

[26] Ali Lee (Healthy Communities, Healthy Homes, Healthy Kitchens), Advisory Group Meeting, August 22, 2023.

[27] "The Future of Gas in New York State": 43.

are prioritized. A managed transition can instead maximize cost savings as electric and gas utilities (or dual fuel utilities) work together to transition street segments or whole neighborhoods through an integrated, phased, and segmented plan that incorporates both electric and gas infrastructure upgrades.

3 Centers Communities

Neighborhood decarbonization offers an opportunity to bring entire communities into the clean energy transition in a tangible, long-term, and meaningful way. In discussing the growing excitement around neighborhood-scale solutions, Jessica Azulay, Executive Director of AGREE says: "We like collective things, things that are more of a community solution...[thermal energy networks] feel like a technology we can promote that is community based"—not leaving anyone behind on the gas system but also not forcing anyone to face the transition alone.[28] A community-centered approach can reduce the consumer fatigue of managing discrete home improvement projects and simplify engagement by streamlining education, outreach, and time spent upgrading homes. By performing comprehensive home upgrades and appliance replacement all together at one time, neighborhood decarbonization projects can reduce disruption to residents' lives.

4 Structurally Integrates Equity

The appliance-by-appliance approach to building decarbonization primarily relies upon market forces to encourage financially equipped customers to purchase electric appliances. This approach can limit who is able to transition to electric appliances and benefit from the associated improvements to indoor air quality and comfort. Because neighborhood decarbonization requires a central organizing entity to design and implement projects, there is an opportunity to build equity into the very structure of this process by including the prioritization of environmental justice communities in the criteria for project selection. For example, PG&E's selection criteria for its Zonal Equity Electrification Pilot Solicitation seeks to optimize equity by incorporating California's map of Disadvantaged Communities (DAC).[29]

> **"We like collective things, things that are more of a community solution."**
>
> **Jessica Azulay**
> AGREE

[28] Jessica Azulay (Executive Director, AGREE), Zoom Interview by Gridworks and BDC, September 22, 2023.
[29] Rachel Kuykendall, "BDC Lunch 'N Learn: PG&E Zonal Electrification," Nov. 9, 2022. https://buildingdecarb.org/resource/lunch-and-learn-webinars.

5 Provides Demand and Job Security for Organized Labor

Short-term solutions are not sufficient for ensuring the long-term security of the energy workforce. As Jose Tengco from BlueGreen Alliance explains, conversations must move beyond "transition" to "what [workers] are transitioning to" specifically.[30] Scaled-up, long-term infrastructure projects, such as those offered by neighborhood decarbonization, can establish a clearer picture of the industry into which workers are transitioning and the types of jobs that will be available. Ed Draves, who represents the New York State Pipe Trades, realized the promise and value of thermal energy networks as a long-term solution for pipefitters immediately after learning about the technology. He reports: "They obviously were our work. We had the folks to build them and the skill sets to build them; they were industrial in scale and could replace the fossil work."[31] While fossil fuel workers should be prioritized for neighborhood-scale projects, if the demand for skilled workers exceeds the number of available workers, municipal water and sewer workers are also well-prepared to construct and maintain this infrastructure. Finally, Tengco notes that it is important to pair any workforce training with standards that create demand for a highly trained workforce (such as apprenticeships, labor standards, and training requirements) to ensure the longevity and sustainability of jobs. These guarantees, paired with the long-term, wide-scale, staged projects required by neighborhood decarbonization, can ensure that a growing workforce meets a growing need.

6 Supports Alternatives to Major Capital Investments in Fossil Fuel Infrastructure

Neighborhood decarbonization offers the opportunity to avoid major gas system replacement projects, and minor ongoing maintenance costs, by converting particular neighborhoods to alternative energy sources. Avoiding major capital investments reduces the total cost of the clean energy transition and ensures that we are investing in energy infrastructure that will be fully used and useful as we pursue our climate goals. It can also allow for "derating" of gas transmission pipes to distribution pipes by reducing the amount of pressure under which they operate. Derating can reduce operational costs for segments of the gas system that must remain in place.[32] Finally, an unmanaged transition off of the gas system could create a self-reinforcing negative feedback loop, resulting in higher bills for customers left on the gas system the longest.[33] Managing this transition through the reinvestment in clean energy infrastructure can help avoid this cost shift.

7 Creates Business Opportunities for Gas Utilities in the Clean Energy Transition

Neighborhood-scale solutions like thermal energy networks help to ensure that gas utilities and their workers play an important role in our country's decarbonized future. Legislation and regulation that allows for gas-only and dual fuel utilities to operate as "thermal utilities" establishes a clean energy pathway for these otherwise existentially threatened companies. Their expertise and resources can be applied to financing, constructing, and maintaining networks of water pipes instead of gas pipes to heat and cool buildings, thereby allowing workers to maintain their wages and benefits through the application of their skills to clean energy infrastructure.

8 Offers Opportunities for Local Ownership

Decarbonized energy sources like thermal energy networks and/or DERs (e.g., solar, batteries, wind, microgrids, etc.) could be municipally financed and/or owned. In the case of municipally-owned clean energy systems, local stakeholders

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[30] Jose Tengco (Vice President, State Affairs, BlueGreen Alliance), Zoom Interview by Gridworks and BDC, September 26, 2023.

[31] Ed Draves (Public Affairs Director at Shenker, Russo, & Clark), Zoom Interview by Gridworks and BDC, September 25, 2023.

[32] The California Public Utilities Commission (CPUC) is currently exploring this possibility in its Long-term Gas System Planning Proceeding. Cathleen A Fogel, Rulemaking 20-01-007: Decision On Phase 2 Issues Regarding Transmission Pipelines And Storage § (2023), https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M520/K496/520496934.PDF.

[33] BDC's 2023 report, "The Future of Gas in New York State" discusses the nature of this feedback loop with regard to declining throughput and customers: "fewer ratepayers and lower consumption would lead to less revenue for gas utilities. However, gas utilities must continue recovering the costs of their capital assets and operations, and so they would have little choice but to charge their remaining ratepayers more for the same service. This would drive more ratepayers to avoid the cost of consuming gas, initially by reducing their consumption and eventually by exiting. Because gas utilities do not have many options for alleviating costs to their ratepayers, the effect would worsen, leaving many ratepayers unable to afford the cost of gas service and leaving gas utilities unable to continue providing safe and reliable service to their remaining ratepayers. Together, these outcomes combine to create a self-reinforcing feedback mechanism" (pg. 26), https://buildingdecarb.org/resource/the-future-of-gas-in-nys.

would own part or all of a renewable energy project and share in the profits of providing power and other ancillary services to the wider grid. Community ownership models include: cooperatives, partnerships among individuals, non-profit organizations formed through investments from their members, community trusts, and housing associations.[34] However, ensuring that these models include adequate standards for the quality of installation and maintenance of neighborhood-scale systems will be critical. Communities in some areas are now also able to own microgrids, which can provide a source of localized power when the larger grid is down. For example, PG&E's Community Microgrid Enablement Tariff (CMET) and associated Community Microgrid Enablement Program (CMEP) creates a regulatory pathway and offers financial incentives for communities to own and operate microgrids (or have a third party do so on the community's behalf) connected to PG&E's distribution system.[35]

9 Improves Project Economics

When the costs and benefits of projects can be shared across more buildings and when investments in fossil fuel infrastructure can be avoided, benefit-cost calculations are more likely to look favorable. Buildings that previously appeared "uneconomic" on an individual basis can now be part of the transition. Utilities, program implementers, and/or communities could potentially buy appliances and pay for installation in bulk to bring down costs for demonstration pilots. However, utilities would socialize these up-front costs to all customers, making this an unlikely long-term solution for a utility-owned project. In addition, overhead costs can be minimized by conducting all of the home upgrades and appliance changes at once. Project economics are optimal when neighborhood decarbonization is paired with decommissioning the gas system in that area.

> **"We don't care what goes through the pipe. We just want it to be in a pipe because when it's in a pipe our guys are working."**
>
> **Ed Draves**
> NYS Pipe Trades Representative

[34] Alessandra Salgado, Arina Anisie, and Francisco Boshell, "Innovation Landscape Brief: Community-Ownership Models" (International Renewable Energy Agency, 2020), https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jul/IRENA_Community_ownership_2020.

[35] Electric schedule E-CMET community microgrid enablement tariff - PG&E, October 7, 2022, https://www.pge.com/tariffs/assets/pdf/tariffbook/ELEC_SCHEDS_E-CMET.pdf; "Community Microgrids," Community microgrid programs at PG&E, accessed October 16, 2023, https://www.pge.com/en_US/safety/emergency-preparedness/natural-disaster/wildfires/community-microgrid-enablement-progam.page.

Recommendations for Advancing Neighborhood Decarbonization

Regulatory, legislative, social, and economic changes are needed to advance neighborhood decarbonization. Below we outline (ordered by topic, not priority) the most pressing changes as well as the stakeholders and decision makers most responsible for initiating and implementing these changes. These recommendations are for near-term actions that stakeholders can begin implementing today. The subsequent section details a series of outstanding questions, the answers to which could inform longer term planning and actions.

1 Align Utility Infrastructure Investments with Climate Goals

State Energy Offices, Utilities, Utility Regulators

States and public utilities commissions should proactively address issues like capitalization of retired gas system assets and treatment of investments in appliances and energy sources to support decarbonized neighborhoods. For example, if a state has a 2050 net-zero economy-wide goal, then gas infrastructure depreciation schedules should align with this timeline.[36] Addressing these issues and aligning schedules is particularly important because many utilities around the country earn a return on capital investments (e.g., infrastructure), not on expense spending (e.g., selling fuel, buying appliances, etc.). Moreover, capital investments are allocated over longer periods of time while expense dollars impact customer rates immediately the year the cost is incurred. Changes to this financing approach can help dual fuel utilities overcome concerns about avoiding capital investments (e.g., gas system infrastructure) in favor of expense outlays (e.g., purchasing electric appliances for customers). Clearly established processes by which utilities can submit project proposals are also needed. Filing one-off applications for projects will not suffice given the scale and speed at which we need to decarbonize buildings.

2 Integrate Resource Planning

Utility Regulators and Utilities

By combining all energy (and potentially water) system planning into a long-term, coordinated process, the full scope of energy demands and the existing and emerging ways to meet those needs can be assessed as they evolve

[36] For example, the New York Public Service Commission directed the study of depreciation schedules that would align with the state's Climate Leadership and Community Protection Act, asking for utilities to "provide an alternative bill impact analysis that assumes the full value of any new gas assets is depreciated by 2050 as part of the long- term plan filing." New York Public Service Commission. "Proceeding on Motion of the Commission in Regard to Gas Planning Procedures" (20-00652/20-G-0131), Filing No. 99 (May 12, 2022): 61, https://documents.dps.ny.gov/public/MatterManagement/MatterFilingItem.aspx?FilingSeq=286895&MatterSeq=62227

over time. This electric, gas, and thermal energy system planning enables utilities and other energy providers to better plan for their respective roles in our decarbonized future and the associated investments required. Nikki Bruno of Eversource Energy, the first utility to break ground on a thermal network pilot, noted that the nature of thermal energy networks demonstrated how "the lines [are] blurring between gas and electric" and that they are in fact "inextricably linked," especially in areas like New England where gas still generates a large portion of the region's electricity. Furthermore, she notes that utilities "owe it to customers to think about [gas and electric planning] in a holistic, integrated way" to get to a decarbonized future.[37] Consideration of thermal energy production and distribution as electric capacity in a high-building-electrification scenario is needed to adequately and optimally invest in local electric distribution, transmission, and capacity generating resources. For example, TENs and distribution or transmission upgrades must be compared on a total cost and total system benefits basis. An effective, managed, phased transition will require coordinated engagement by state actors and the rethinking of the dominant role that gas utilities have played in charting our climate future.

3 Develop Equitable Rate Models

Utility Regulators and Utilities

Utility rate models should be adjusted to ensure that they do not disincentivize individual customers or entire communities trying to transition away from fossil fuels. Where possible, they should instead incentivize customers of all types to make the switch to decarbonized energy systems. Options like all-electric rates act as an incentive for making the transition to electric appliances and can also support electric vehicle adoption, which helps to accelerate GHG emissions reductions and air quality improvements for more sustainable communities. Technologies like thermal energy networks require rethinking rate structures more broadly. Audrey Schulman of HEET suggests beginning with a merged gas and thermal rate base, which can help address the issues of a declining gas rate base (as previously discussed). This structure would maintain the number of customers across which fixed costs for both systems are spread, helping mitigate escalating energy burdens and stabilize costs. Schulman also offers suggestions for how to charge for thermal network use, since a commodity is not being consumed. The operator of a TEN could charge according to 1) Gallons of water used 2) BTUs via a meter 3) A flat rate based on building size and/or 4) Develop a "thermal marketplace" where buildings providing large amounts of waste heat to the system are compensated and thereby incentivized to join.[38] Finally, measurements that include BTU/Therm and their equivalents in kilowatt/kilowatt hours may help thermal customers and the industry at large better understand the merger between electric and thermal energy systems. With all of these possibilities in mind, neighborhood decarbonization presents a rare opportunity to rethink rates through an equitable, decarbonized lens.

4 Reform the Obligation to Serve

Legislators and Utility Regulators

Legal scholar Heather Payne writes: the obligation to serve is "a bedrock principle of state utility regulation" that "demands that utilities provide nondiscriminatory service to all those within their geographic territory for the specific service for which they have been granted a monopoly."[39] As several utilities noted in our conversations about neighborhood-scale projects, the obligation to serve can cause a single "holdout" to stall or sink an entire gas decommissioning project. While a neighborhood decarbonization project can technically move forward if a building owner elects to opt out, this lack of participation could prevent the end goal of decommissioning the gas system in that area and therefore remove the possibility of avoiding the costs associated with repair or replacement and maintenance of gas assets.[40] Reforming this duty to allow gas and dual fuel utilities to provide thermal energy, while maintaining the commitment to provide nondiscriminatory service to consumers, can enable and streamline neighborhood-scale projects. Similar changes are needed to allow dual fuel utilities to serve electricity rather than gas to customers for the purposes of neighborhood decarbonization projects.

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[37] Nikki Bruno (Vice President of Clean Technologies, Eversource Energy), Zoom Interview with Gridworks and BDC, September 28, 2023.

[38] Audrey Schulman (HEET Co-Founder and Co-Executive Director), Zoom Interview with Gridworks and BDC, September 28, 2023.

[39] Payne, Heather. "Unservice: Reconceptualizing the Utility Duty to Serve in Light of Climate Change." *University of Richmond Law Review* 56, no. 2 (2022 2021): 603.

[40] Eversource's Framingham pilot demonstrates that 100% participation is not needed for a project to work. According to Nikki Bruno, due to a combination of opt-outs and difficult to reach customers, the thermal energy network demonstration project includes >80% of customers in the targeted area. (Zoom Interview by Gridworks and BDC, September 28, 2023). More information on that and other TENs pilots by Eversource can be found on their website: https://www.eversource.com/content/residential/save-money-energy/clean-energy-options/geothermal-energy

5 Allow Utilities and Municipalities to Operate as Thermal Energy Utilities

Legislators and Utility Regulators

Allow utilities and municipalities to become "thermal energy utilities" by developing thermal energy systems and permitting electric utilities to serve former gas customers.[41] New York's Utility Thermal Energy Network and Jobs Act (UTENJA) enables both gas and electric utilities to build, own, and operate thermal energy systems and provide thermal energy. The law also includes support for transitioning utility workers and promoting union jobs for local residents in the expanding decarbonization sector.[42] This legislation is one model of many in a rapidly evolving area. In states where the authority of municipalities is limited, create legislation that allows and/or affirms municipalities' right to provide thermal energy services as a public good. Such affirmation will allow municipalities (if they aren't already authorized) to finance, construct, and operate thermal energy utilities in their jurisdiction.

6 Prioritize High-Road Jobs

Labor Leaders, Independent Contractors, Legislators, Utility Regulators, Utilities

A workforce consisting of organized labor and independent contractors is critical to this infrastructural transition. Plans for neighborhood-scale projects must include policies that protect workers, especially fossil fuel workers who could be adversely affected by a shrinking gas system. As discussed in the advantages section, certain technologies like thermal energy networks and water recycling systems require the skilled labor of plumbers and pipefitters and offer a clearer pathway toward a clean energy career. However it is still unclear how many jobs in each trade will be recuperated on the electric or thermal energy side of the energy sector, and so a holistic accounting of what happens to specific jobs when the gas system is replaced with clean energy infrastructure is needed to ensure that workers are not left behind. At the same time, a focus on "net" growth of the clean energy workforce can overlook the individual jobs lost or eliminated, each of which represents a person and a livelihood. Similarly, not all workers will want to, or be able to, transition into new careers in the clean energy sector. For these workers, early retirement buy-outs or similar policies can provide protective measures. While there are still many unknowns in how jobs and skills will transition in the clean energy sector, the outcome should not be left to the market or to the fate of an unmanaged transition. Policies promoting neighborhood-scale solutions must be developed in collaboration with labor leaders and workforce representatives to include high labor standards and worker protections to ensure that individual workers are not overlooked in this wide-scale transition.

7 Engage Communities in Decision Making

Utilities, Advocates, Community-Based Organizations

Meaningful community engagement takes time and "moves at the speed of trust," as Monica Palmeira of Greenling Institute reminded us when discussing how to engage communities in neighborhood decarbonization. She recommends pairing larger-scale entities like utilities with local, community-based organizations to earn the trust of people who literally have to open up their doors to these projects.[43] It is essential to build trust with these communities to ensure that equity is centered throughout the process. Ideally, this trust is built before a project is proposed. Stakeholders interested in implementing neighborhood decarbonization projects should begin building these relationships now. Municipal or cooperative-led decarbonization projects are another opportunity to build local equity and trust. An approach that can encourage sustained community engagement may include:

1. Ensuring community autonomy is retained through community-led decision making.
2. Allocating sufficient time in the beginning stages of a project to allow for education, outreach, and co-design.
3. Holding listening sessions to uncover community needs before sharing materials.
4. Focusing on localized benefits like affordability and improved health and indoor air quality.
5. Ensuring that early stage messaging includes free, near-term action individuals can take, such as turning on their vent and opening windows

[41] There is variance across states regarding the authority of municipalities to operate a thermal energy utility. Some states may need to enable or clarify municipal authority to include the ability to operate a thermal utility while in other states municipalities may already have the authority to do so.

[42] Senate Bill S9422, Kevin S. Parker. New York State Legislative Session (2022), https://www.nysenate.gov/legislation/bills/2021/S9422

[43] Monica Palmeira (Climate Finance Strategist, Greenlining Institute), Zoom Interview with Gridworks and BDC, Sept. 25, 2023.

while cooking.

6. Translating messaging into multiple languages while using accessible terminology.
7. Scheduling any community engagement outside of working hours and including childcare services.
8. Partnering with trusted local organizations such as environmental justice and housing justice groups to advocate for avoiding displacement, rent increases, and other potentially harmful impacts.[44]

8 Designate Funding for Neighborhood Decarbonization

Legislators, Utility Regulators, Local Governments, and Utilities

Funding and financing resources that encourage larger-scale building decarbonization should be promoted and may include: grants, rebates, loans, tax credits,[45] subsidies re-directed from fossil fuel system expansion, and other innovative financing mechanisms. These financing options should prioritize a holistic, whole-home approach and would ideally allow layering between different funding sources. Furthermore, to ensure that funding is reaching the communities who need it most, specific provisions, such as those indicated in the federal Justice 40 initiative,[46] or as mandated by a state's specific environmental justice goals, should be included in funding commitments.[47] To promote an increase in neighborhood-scale demonstration projects, legislators can designate funding for neighborhood-scale pilots, as exemplified by Colorado's 2022 law, "Colorado Energy Office Geothermal Energy Grant Program," which includes the "community district heating grant, which is awarded to support ground-source, water-source, or multi source thermal systems that serve more than one building."[48] For thermal energy networks, identify financing mechanisms such as existing pipe replacement funds, securitization, fee in gas or electric utility bill, or the creation of a thermal energy fund.[49] While it may seem logical to leverage avoided gas capital spending to finance neighborhood decarbonization projects, it is important that the majority of this money be used to keep gas bills affordable for customers during the transition. Electric rates and non-ratepayer sources of funding should instead be considered. Electric rates could help fund these projects in instances where greater utilization of the electric grid helps generate incremental revenue and thus downward pressure on rates.

9 Analyze Projects and Conduct Additional Research

Utilities, State Energy Offices, Researchers

Analyzing current and future neighborhood-scale projects will be essential to socializing this approach while improving its design and implementation. For example, HEET has formed a funded, multi-stakeholder research team, "Learning From the Ground Up" (LeGUp), to collect data from the first utility-led installations of networked geothermal in Massachusetts in order to develop reports that will help these projects scale.[50] State energy offices

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[44] According to Nikki Bruno, Eversource Energy utilized many of these strategies in the planning of the Framingham thermal energy project and reported that this approach was successful in engaging the community and providing multiple opportunities and venues for stakeholders to participate in the process. As a result, the project was well received and understood by the community.

[45] It should be noted that tax credits are not an effective financing mechanism for many low-income households and should not be relied upon to make a lasting impact in these communities.

[46] The J40 Initiative "directs 40% of the overall benefits of certain Federal investments – including investments in clean energy and energy efficiency; clean transit; affordable and sustainable housing; training and workforce development; the remediation and reduction of legacy pollution; and the development of clean water infrastructure – to flow to disadvantaged communities (DACs)." https://www.energy.gov/diversity/justice40-initiative.

[47] With regard to Native American tribes, who maintain a unique government-to-government relationship with the United States, unique provisions beyond those listed here may be required to match the needs, policies, and governance structures of each tribal nation. For an assessment of how federal funding in general has failed to meet the needs of Indigenous communities, see the 2016 report "Broken Promises: Continuing Federal Funding Shortfall for Native Americans" by the U.S. Commission on Civil Rights: https://www.usccr.gov/files/pubs/2018/12-20-Broken-Promises.pdf.

[48] Colorado General Assembly. "Colorado Energy Office Geothermal Energy Grant Program," Pub. L. No. HB22-1381 (2022). https://leg.colorado.gov/bills/hb22-1381

[49] For example, in 2014, Massachusetts created the Gas System Enhancement Plan (GSEP) "as a way for its six investor-owned natural gas distribution companies to accelerate the replacement of this leaking infrastructure by 2039." ("Visualizing the Gas System Enhancement Program (GSEP)," Home Energy Efficiency Team (HEET), June 13, 2023, https://heet.org/gsep/.) And in 2022, the Clean Energy and Offshore Wind bill added provisions specifying that TEN pilots can be paid for with funds from GSEP, ensuring that instead of locking in upwards of 50 years of emissions with new gas infrastructure, this cost recovery mechanism could be used for "non-emitting renewable energy infrastructure." https://www.centennialplastics.com/assets/site/files/MiscDocuments/geoexchange-update-tax-credits-july-2022.pdf

[50] Information on this research collaborative can be found on HEET's website: https://heet.org/legup/

can also lead by funding relevant studies. For example, the California Energy Commission funded a study on the targeted electrification of buildings and the tactical decommissioning of the gas system for particular neighborhoods in the East Bay to create site-specific modeling of costs and benefits.[51] Additional research priorities for neighborhood decarbonization include:

1. Developing a replicable analytical framework for identifying ideal locations for neighborhood decarbonization. This may vary from utility to utility based on the unique attributes of their system and customers. One tool recently developed for Northern California could serve as a model for others.[52]
2. Studying the electric system impacts of thermal energy resource heat recovery and the implications for reducing waste heat and improving efficiency.
3. Analyzing utility bill impacts and identifying strategies to ensure that low-income customers will not experience an increase in their total utility bill.
4. Creating utility planning tools that bring multiple utility infrastructure maps together. Tools that visually align electric, gas, water, sewer, and thermal utilities on the same planning tool will allow for coordinated transition strategies where cost optimization can occur.
5. Comparing the costs of appliance-by-appliance electrification and neighborhood decarbonization (electric nework vs. thermal energy network) by region to understand which building decarbonization strategy is best suited for distinct environments.

10 Encourage Knowledge Sharing

Utilities, Advocates, Manufacturers

Many of the utilities that are engaging in neighborhood decarbonization are already sharing best practices about new technologies like thermal energy networks. Utilities are also retraining their workforce by observing existing thermal network projects and then ensuring that these skills are shared and integrated. Greg Koumoullos of Con Edison described how the utility has a workforce development committee that is a conglomeration of company representation from a variety of departments, including: thermal networks, gas, electric, human resources, and Utility Workers Union of America (UWUA) Local 1-2, which is the local union which represents the company's electric, gas and steam workforce.[53] The skills required go beyond those of the workers who are installing the infrastructure and include ancillary services such as customer service. In addition, Con Ed has a three-step plan for workforce knowledge sharing for thermal energy networks: engage workforce in the development of the pilots; during operation of pilots, train Con Ed employees on the systems; and determine how to integrate TENs into the company structure.[54] Informal and formal knowledge sharing structures such as these are essential to developing economies of scale and amplifying the growth of neighborhood decarbonization.

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[51] The final report has not yet been released, though the interim report shows favorable results for a neighborhood-scale approach to decarbonization: E3, EBCE, Gridworks. "Strategic Pathways and Analytics for Tactical Decommissioning of Portions of Gas Infrastructure in Northern California: Interim Report." (report), June 2023. https://gridworks.org/wp-content/uploads/2023/06/Evaluation-Framework-for-Strategic-Gas-Decommissioning-in-Northern-California-Interim-Report-for-CEC-PIR-20-009.pdf

[52] Halbrook and Gold-Parker, 8.

[53] Information on Con Edison's proposed neighborhood-scale projects in New York that utilize TENs can be found on their website: https://www.coned.com/en/our-energy-future/our-energy-vision/where-we-are-going/thermal-energy-networks

[54] Greg Koumoullos (Project Manager–Thermal Energy Networks, Con Edison), Zoom Interview with Gridworks and BDC, September 13, 2023.

Outstanding Questions for Neighborhood Decarbonization

Several outstanding questions remain that interested stakeholders must work together to address. These questions can be explored concurrently with implementation of the recommendations listed in the previous section.

1 How much funding is needed?

Building electrification has been proven to be cost-effective in many settings, especially new construction.[55] While retrofitting existing buildings presents more challenges and uncertainties with regard to costs, the decarbonization of existing buildings remains an essential part of achieving the economy-wide net-zero goals set by many states and the federal government. Recent modeling demonstrates how a cross-sector decarbonization strategy can be comparable to current energy infrastructure spending, provided that there are supportive policies in place.[56] However, comparative cost studies between "business-as-usual" fossil fuel infrastructure, appliance-by-appliance electrification, and neighborhood-scale decarbonization are needed to make this cost-based argument more robust. Furthermore, broad interpretations of cost—including the social cost of carbon, the cost of inaction, and who bears the environmental costs of fossil fuel pollution—should be incorporated into discussions of cost-effectiveness.

2 Who pays for what when we decarbonize neighborhoods?

While neighborhood decarbonization appears to be cost-effective at the societal level, particularly when gas system investments can be avoided, addressing who pays for what introduces additional complexities. For example, at its Framingham pilot, Eversource Energy is paying for the full cost of installing the geothermal network, including the customer-side equipment needed to interact with this system (such as ground-source heat pumps and ducting). Nikki Bruno, Vice President of Clean Technologies at Eversource notes, however, that while covering these costs is necessary to facilitate community buy-in for early demonstration projects, this strategy would not be a cost-effective approach for the utility for all future TEN projects.[57] With the electric network pathway to decarbonization, utilities would similarly need to decide which technologies (i.e. air-source heat pumps) will be recovered through the rate base and which will be paid

[55] A 2022 study by RMI demonstrates that "all-electric single-family new construction is more economical to build and operate than a home with gas appliances and has lower lifetime emissions in all nine cities studied." Tan, Lacey, Mohammad Hassan Fathollahzadeh, and Edie Taylor. "The Economics of Electrifying Buildings: Residential New Construction." RMI, December 2022. https://rmi.org/insight/the-economics-of-electrifying-buildings-residential-new-construction/.

[56] Princeton University's 2021 study on how to achieve a net-zero economy in the U.S. examines several decarbonization pathways and concludes that "a successful net-zero transition could be accomplished with annual spending on energy that is comparable or lower as a percentage of GDP to what the nation spends annually on energy today. However, foresight and proactive policy and action are needed to achieve the lowest-cost outcomes." E. Larson, C. Greig, J. Jenkins, E. Mayfield, A. Pascale, C. Zhang, J. Drossman, R. Williams, S. Pacala, R. Socolow, EJ Baik, R. Birdsey, R. Duke, R. Jones, B. Haley, E. Leslie, K. Paustian, and A. Swan, Net-Zero America: Potential Pathways, Infrastructure, and Impacts, Final Report Summary, Princeton University, Princeton, NJ, 29 October 2021.

[57] Nikki Bruno, Zoom Interview, September 28, 2023.

for by individual customers. Standardizing who pays for what at which stage of a neighborhood-scale project while also creating protections for low-income residents will be essential for achieving equity and scale.

3 How do we phase the transition to ensure equity and manage complexity?

A neighborhood-scale transition will not happen all at once. There are many questions regarding the timing and equity of this transition at the micro- and macro-scale, including: who will be transitioned off of the gas system first and how to protect low-income ratepayers from rising gas bills; which segments of the gas system should be prioritized for retirement; how to manage the "mid-transition," during which fossil energy systems and decarbonized energy systems co-exist;[58] and the granular street- and building-level logistics of switching from one energy source to another. With regard to the threat of a negative feedback loop of fewer gas customers and higher bills, a recent report estimates that bills could increase significantly in both low- and high-electrification scenarios: as much as 21% by 2040 with a 25% electrification scenario and as much as 129% in a 75% electrification scenario.[59] Ensuring low-income ratepayers are not left on the gas system the longest is therefore imperative. Furthermore, implementing neighborhood decarbonization does not necessarily mean choosing between the electric network pathway and the thermal energy pathway, but incorporating or phasing-in aspects of both. Determining which phased, managed approach is ideal for a given area will vary according to the characteristics of a particular neighborhood. A phased approach to address near-term needs while preparing a street segment for a long-term transition to clean energy infrastructure might look like weatherizing the whole street and adding air-source heat pumps to buildings where boilers or furnaces are nearing burnout to prepare the area for a future network. Once a thermal energy network comes to the area, a water- or ground-source heat pump can be added to take the primary load from the air-source heat pump. If the air-source heat pump still has useful life, it can be used elsewhere if needed or left in place for backup. A similarly gradual transition to electricity can be pursued in areas located at the end of gas lines. These "terminal branches" of the gas system, sites that lie at the end of radial portions of the distribution system and have no downstream customers, can be more easily decommissioned without affecting pressure and flow rates elsewhere.

4 How can we streamline coordination and address lack of consensus for neighborhood-scale projects?

Converting entire neighborhoods rather than one appliance at a time requires coordination from regulators, government officials, utilities, labor, and communities to make key decisions. Under existing regulatory paradigms, most utilities around the country believe that 100% customer opt-in is required before the gas system in a neighborhood can be decommissioned in favor of decarbonized energy sources. Mark Lenssen of Puget Sound Energy cites the obligation to serve as one of the main obstacles preventing utility-owned neighborhood-scale projects, as a single customer requiring the maintenance of an entire portion of energy infrastructure would be untenable.[60] While advocates are currently working on legislation to reform this provision to make neighborhood decarbonization more effective and equitable, Eversource's Framingham project, described previously, demonstrates that 100% participation is not needed for a project to work.

5 What type of workforce and training is needed to build at scale?

Neighborhood decarbonization requires skilled workers to ensure that systems are correctly sized and installed and will require growth in several fields, including: contractors and engineers to design and oversee projects; electricians and plumbers to install and maintain appliances; drilling experts to develop boreholes for geothermal systems or thermal energy networks; linemen and pipefitters to construct new and upgrade existing energy distribution systems to serve new demand; and project management

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[58] Grubert and Hastings-Simon use the term "mid-transition" to designate the period when "the conventional, fossil-based energy system coexists with a new, zero-carbon energy system" and the constraints that the current fossil system will impose upon the development of a decarbonized system. Grubert, Emily, and Sara Hastings-Simon. "Designing the Mid-Transition: A Review of Medium-Term Challenges for Coordinated Decarbonization in the United States." *WIREs Climate Change* 13, no. 3 (2022): e768. https://doi.org/10.1002/wcc.768.

[59] Nadel, Steve. "Impact of Electrification and Decarbonization on Gas Distribution Cost." ACEEE, June 2023. https://www.aceee.org/research-report/u2302.

[60] Mark Lenssen (Manager, Strategic Planning, Evaluation, & Research, Puget Sound Energy), Zoom interview with Gridworks and BDC, Sept. 21, 2023.

teams that understand all facets of the project, including customer engagement, construction, and equipment installation. While many of our stakeholders agree that thermal energy infrastructure is parallel to gas infrastructure in terms of the skills needed to install and maintain these networks, Greg Koumoullos of Con Edison hesitates to say that it's as easy as a one-to-one replacement. He comments: "when people hear that we want to transition the workforce, that's true. The infrastructure is very similar, but it's not a direct transition."[61] Strategic, coordinated, and phased investments in the workforce, paired with policies that encourage demand for this workforce, are necessary to scale up building decarbonization, transition gas utility workers, and provide long-term stability for independent contractors and organized labor will be required.

6 How can we ensure community representation with a centralized approach to decarbonization?

While the centralized approach required by neighborhood decarbonization can help accelerate building decarbonization and emissions reductions, it could generate pushback from customers who may distrust utilities, state agencies, and local governments. Balancing community and consumer choice with the system-wide changes needed is often a challenge for major infrastructure projects and it's important not to repeat the mistakes of the past by disregarding the social underpinnings of neighborhood decarbonization. Opportunities to offset the potential consolidation of utility ownership include municipal and cooperative owned infrastructure systems, which provide decentralized governance and ownership mechanisms that can create local support and build equity into the clean energy transition at the community level.

7 How do we reform relevant regulatory structures to enable neighborhood-scale projects?

Public utility commissions and local governments across the country currently do not have the internal structures in place to review and approve neighborhood-scale building decarbonization projects. Public utility commissions need to provide clear guidance to their regulated utilities about what information and analytics must be included in an application to implement a neighborhood decarbonization project. Staff to review these applications are also needed. In some instances, it is also unclear who can own and operate thermal energy networks. Rate structures to support decarbonized buildings are also largely absent.

8 What types of investments in the electric grid are required and where?

In certain areas, the electric grid may not have the capacity to meet additional demand for electricity from decarbonized neighborhoods. Utilities use peak load estimates to design their electric distribution grids and make investment decisions. If an all-electric neighborhood is projected to exceed prior estimates for peak demand in the area, alternative peak-reducing systems like TENs will need to be explored or costly distribution system upgrades may be needed. Many customers may also have questions about the resiliency and reliability of solutions that depend upon electric infrastructure. However, TENs actually help the existing electric grid by providing efficient energy 24/7, regardless of outdoor conditions, and by flattening the demand for electricity on the hottest and coldest days when the system reaches peak demand.[62] As such, TENs and the thermal energy resources connected to them provide electric grid capacity at the level of local distribution, transmission, and peaking generation. Given this, TENs are able to provide a great deal of value to state-wide decarbonization efforts across multiple sectors.

9 What aspects of neighborhood decarbonization are portable across climates and locales and what aspects are necessarily unique?

While a benefit of scaling-up decarbonization is creating economies of scale through which increasing experience and knowledge can reduce costs the more this approach is duplicated, the portability of implementation can be challenged by the unique features of distinct

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[61] Greg Koumoullos (Project Manager–Thermal Energy Networks), Zoom Interview with Gridworks and BDC, September 13, 2023.

[62] Buonocore, J.J., Salimifard, P., Magavi, Z. *et al.* Inefficient Building Electrification Will Require Massive Buildout of Renewable Energy and Seasonal Energy Storage. Sci Rep 12, 11931 (2022). https://doi.org/10.1038/s41598-022-15628-2

communities.[63] As Audrey Schulman of HEET attests, this will need to be "a phased, granular, street-based transition."[64] As much as this approach promises to streamline many aspects of building decarbonization, the extensive variation in neighborhood typologies will introduce challenges for executing projects with the speed needed to meet our climate goals.

> "We need a phased, granular, street-based transition."
>
> **Audrey Schulman**
> HEET

10 How do we coordinate with ground-source and air-source heat pump manufacturers to ensure they are scaling up production at a pace that matches deployment?

Ground-source heat pumps occupy a smaller portion of the heat pump market share in the U.S. as compared to air-source heat pumps. Working alongside manufacturers on the equipment needed for electric and thermal energy networks will be essential to making sure the technology is available for bulk purchasing and mass deployment as we scale up decarbonization.

[63] A common concern in particularly cold climates is where there is a need for gas-powered appliances as a backup for air-source heat pumps. However, recent research in cold climates around the world finds that heat pump efficiency still exceeds that of natural gas and electric resistance heating at temperatures well below freezing. For more information: Duncan Gibb et al., "Coming in from the Cold: Heat Pump Efficiency at Low Temperatures," Joule 7, no. 9 (September 11, 2023): 1939–42, https://doi.org/10.1016/j.joule.2023.08.005.

[64] Audrey Schulman, Zoom Interview.

Conclusion

Neighborhood decarbonization is a promising strategy for reducing GHG emissions in the building sector while offering a holistic, community-oriented approach to clean energy solutions. It not only reduces continued investments in fossil fuel infrastructure but also fosters integrated energy system planning and paves the way for a broader solution set, including networked systems like TENs.

While some outstanding questions need to be addressed in the longer term, stakeholders can begin taking action on neighborhood decarbonization today. Regulators, legislators, local governments, utilities, communities, non-profit organizations, appliance manufacturers, and workers all have a role to play in this neighborhood-scale transition and will need to collaborate and coordinate with one another for this strategy to succeed. Several technology pathways for implementing neighborhood decarbonization are already available and ready for demonstration projects. Pursuing these demonstration projects, alongside other analytical efforts, will provide the foundation of experience and knowledge needed to ensure equitable implementation of these decarbonized systems. Scaling up building decarbonization in this manner offers a rare opportunity to align actors and resources across industries and regions to build an equitable, decarbonized future together.

Appendix A

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Appendix B

Thermal Energy Network Overview

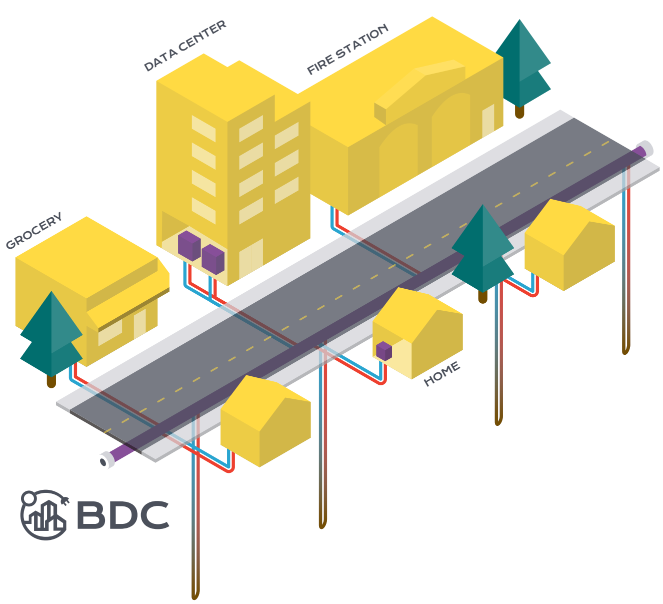
Thermal Energy Networks

Thermal energy networks (TENs) provide an opportunity to reimagine how we heat and cool our homes, free from fossil fuels.

TENs are an elegant solution to a complex problem faced by communities across the country: how to eliminate the use of fossil fuels in our buildings, at scale. With TENs, the existing gas pipe system that currently heats buildings is replaced by an underground water loop system to provide highly efficient heating and cooling to connected buildings.

TENs can be designed at any scale and in many configurations that can be connected to each other over time. Networked Geothermal is a type of TEN that uses shallow boreholes (100 to 700 ft) to harness the temperature of the earth (50-70 degrees F) to heat and cool buildings that are connected to the network. TENs do not always need boreholes, as temperature from a large body of water or from other sources of heat—such as energy intensive buildings (e.g. a data center, skating rink, grocery store) or wastewater—can also be used.

Currently, only four states have legislation that mandates or allows utilities to develop thermal energy network pilots. What follows is a summary of that existing legislation as well as considerations for advocates who are currently crafting TEN legislation for their states.



Example of a Thermal Energy Network with Boreholes.

10 Considerations for TEN Legislation

1. Permit gas and electric utilities to sell thermal energy.
2. Permit communities, co-ops, developers, and water utilities to also sell thermal energy.
3. Reform the "obligation to serve" by revoking its fuel specificity, such that gas utilities are obligated to serve thermal energy but not gas in particular.
4. Include labor transition, training, and recruiting plans in the pilots.
5. Prioritize pilots in existing disadvantaged communities and areas with leak-prone pipe.
6. Identify financing mechanisms: existing pipe replacement funds, securitization, fee in gas or electric utility bill, or the creation of a thermal energy fund.
7. Create a plan for building retrofits that specifies who pays for appliances, electrical upgrades, weatherization, and upkeep.
8. Eliminate subsidies for gas service expansion (i.e. line extension allowances).
9. Where applicable, align timeline with state climate commitments.
10. Direct PUC / PSC to study rates such that heat pumps customers are not penalized.

TEN Pilot Projects

Several states are pursuing novel approaches for using this technology at neighborhood scale.

Utility-Owned Model

17 pilots are in the proposal or planning stages.

- Eleven proposed pilot projects and 3 feasibility studies in New York are being considered by the NY PSC. There are more pilot projects being developed.
- Five pilots (Eversource: 1; National Grid: 4) have been approved in Massachusetts since 2021.
- In 2023, Centerpoint Energy in Minnesota proposed a networked geothermal district energy system as part of their 5-year innovation plan.

Two installations are under construction.

- In 2022, Eversource Energy in Massachusetts broke ground on the first gas utility-installed networked geothermal system in the nation. The system will provide heating and cooling to 140 customers in homes and businesses.
- In April of 2023, National Grid broke ground on its first networked geothermal system in Lowell, MA.

Existing Systems

While the utility-owned model for TENs is new, the technology has been successfully operating in other settings for years.

Community and Single-Owner Models

Colleges and universities have been installing TENs for years to decrease emissions, save on energy costs, and reduce water use.

- Examples: Colorado Mesa University, Weber State University, Skidmore College, Carleton College, and Smith College.

Communities and developers are seeing the value of installing these networks.

- Examples: Whisper Valley in Texas, Springwater Mattamy Homes in Canada, and West Union, Iowa.

Non-Utility Feasibility Studies

State and federal research and support for exploring TENs is growing.

- This year the Department of Energy is awarding $13 million in federal grants to 11 communities across 10 states to explore geothermal systems.
- New York State Energy Research and Development Authority (NYSERDA) has awarded over 35 grants for thermal energy network feasibility studies in the state.
- The Massachusetts Clean Energy Center in collaboration with HEET will be funding up to 10 projects to explore how networked geothermal systems could be installed in communities across the Commonwealth.

Next Steps & Resources

What is most exciting about TENs is perhaps not even the technology itself. Rather, it is the ability of TENs to draw together stakeholders from environmental justice communities, organized labor, gas utilities, environmental organizations, legislators, regulators, industry, and many others that makes this approach such an exciting prospect for equitably decarbonizing entire communities.

If you are interested in advocating for TENs, you can learn more at: BDC's TEN Resource Module or by contacting Ania Camargo, Thermal Energy Networks, Sr. Mgr: acamargo@buildingdecarb.org

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