Decarbonization at the Neighborhood Scale:
Challenges, Learnings and Opportunities in an Emerging Model

by

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ABSTRACT

Decarbonizing residential buildings in the United States is critical for reaching climate goals and has significant public health and energy justice benefits if accessible to all. To date, building electrification has been individual-level and market-driven, with some financial incentives at the state and federal level. This model is generally inaccessible to low-income homeowners and renters who are unable to afford the upfront costs of building improvements and new electric appliances. Neighborhood-scale building decarbonization has been proposed as an alternative in which new developments would be built all-electric or existing buildings would be electrified at the block or neighborhood scale. In the latter use case, neighborhood-scale building decarbonization is often tied explicitly to decommissioning gas lines. Specifically, proponents posit that these projects could be funded through avoided gas line repair and replacement costs. Investor-owned utilities are seen by some experts in the space as key to the success of neighborhood-scale building decarbonization because of their financing capabilities and existing role in providing heating and/or electric service to customers. In recent years, a number of state policymakers have passed legislation approving utility-funded neighborhood-scale building decarbonization and state utility commissions have promulgated regulations approving cost recovery for these projects. Utilizing desk research and informant interviews, this paper analyzes what has enabled and hindered existing utility-funded neighborhood-scale building decarbonization pilot projects in California, Massachusetts, and New York. I diagnose strong and specific climate goals, the passage of enabling legislation, an engaged state utility commission, and strong advocacy ecosystems as key factors for initiating neighborhood-scale pilot projects. Through informant interviews, I identify costs, financing, community buy-in and planning as central determinants for the success of pilot projects and the future of the model. I close by offering recommendations and outstanding research areas for planners interested in pursuing future neighborhood-scale building decarbonization projects.

Thesis supervisor: Mariana Arcaya
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1. Introduction

Decarbonizing residential buildings in the United States is critical for reaching climate goals and has significant public health and energy justice benefits if accessible to all. To date, building electrification has been individual-level and market-driven, with some financial incentives at the state and federal level. This model is generally inaccessible to low-income homeowners and renters who are unable to afford the upfront costs of building improvements and new electric appliances.[1] Neighborhood-scale building decarbonization has been proposed as an alternative with significant theorized benefits.[2] In this model, new developments would be built all-electric or existing buildings would be electrified at the block or neighborhood scale. In the latter use case, neighborhood-scale building decarbonization is often tied explicitly to decommissioning gas lines. Proponents specifically posit that these projects could be funded through avoided gas line repair and replacement costs. Investor-owned utilities are seen by some experts in the space as key to the success of neighborhood-scale building decarbonization because of their financing capabilities and existing role in providing heating and/or electric service to customers. In recent years, several state legislatures have passed legislation approving utility-funded neighborhood-scale building decarbonization pilot projects and state utility commissions have promulgated regulations approving cost recovery for these projects.[3] However, there is limited research on the status of and learnings from these pilot projects.

This thesis analyzes what has enabled and hindered existing utility-funded neighborhood-scale building decarbonization pilot projects and explores the implications of these findings for the future of this model. To complete this analysis, I examined the legislative and regulatory factors that enabled utility-funded neighborhood-scale pilot programs in three states: California, Massachusetts, and New York. I then interviewed a selection of individuals involved in advocacy, design, and implementation of projects in these states to understand their perceptions of the opportunities and challenges surrounding these projects, and their opinions about the model as a whole. In my results section, I synthesize challenges and opportunities surrounding neighborhood-scale building decarbonization as identified by informants. I close with a discussion of key interventions – and outstanding research questions – for planners and policymakers interested in pursuing future neighborhood-scale building decarbonization projects.

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[1] Walker, Iain et al. *Challenges and Opportunities for Home Decarbonization.* Berkeley California: Lawrence Berkeley National Laboratory, 2023. Accessed April 1, 2025. https://escholarship.org/uc/item/60x7310p.

[2] Building Decarbonization Coalition and Gridworks. "Neighborhood Scale: The Future of Building Decarbonization," November 2023.

[3] BDC. "Thermal Energy Networks (State Legislation)." Accessed April 9, 2025. https://buildingdecarb.org/resource-library/tens-state-leg.

2. Background

2.1 Significance of residential building decarbonization

Residential and commercial buildings are responsible for nearly a third of carbon emissions in the United States, a significant portion of which come from combusting fossil fuels to heat building, water, and food.[4] Across the United States about 47% of households use utility gas to heat their homes, and about 9% use propane, kerosene, fuel oil, or coal (59.6 and 9.5 million households, respectively)[5].

This makes electrifying residential buildings both a massive undertaking and a key to reaching climate goals. It is also significant from a public health standpoint: studies have found that burning fossil fuels in homes for cooking is associated with significant negative health impacts, including increased rates of childhood asthma and similar respiratory symptoms in adults.[6][7] Moreover, millions of homes across the country are in moderately or severely inadequate condition, with issues relating to plumbing, heating, electricity and wiring, and general upkeep.[8] This disproportionately impacts Black and Latino households, and is correlated with a wide range of negative health impacts.[9] Deferred maintenance like outdated wiring, mold, and lead paint can also pose health, safety, and technical limitations for building decarbonization.[10] Connectedly, many buildings were constructed prior to the advent of energy codes in the 1980s, making them less energy efficient than newer housing and therefore more expensive to heat and cool.[11] Together, these factors contribute to high energy bills for millions across the United States – for a quarter of households across the country and two-thirds of low income ones, paying for energy

[4] US Environmental Protection Agency. "Sources of Greenhouse Gas Emissions." Sources of Greenhouse Gas Emissions, 2022. https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions.

[5] U.S. Census Bureau, U.S. Department of Commerce, "House Heating Fuel," 2023. *American Community Survey, ACS 5-Year Estimates Detailed Tables, Table B25040*, 2023, accessed on April 14, 2025, https://data.census.gov/table/ACSDT5Y2023.B25040?q=house+heating+fuel.

[6] Weiwei Lin, Bert Brunekreef, Ulrike Gehring, Meta-analysis of the effects of indoor nitrogen dioxide and gas cooking on asthma and wheeze in children, *International Journal of Epidemiology*, Volume 42, Issue 6, December 2013, Pages 1724–1737, https://doi.org/10.1093/ije/dyt150

[7] Jarvis D, Chinn S, Luczynska C, Burney P. Association of respiratory symptoms and lung function in young adults with use of domestic gas appliances. Lancet. 1996 Feb 17;347(8999):426-31. doi: 10.1016/s0140-6736(96)90009-4. PMID: 8618483.

[8] "American Housing Survey (AHS) - AHS Table Creator." Accessed April 6, 2025. https://www.census.gov/programs-surveys/ahs/data/interactive/ahstablecreator.html?s_areas=00000&s_year=2023&s_tablename=TABLE5&s_bygroup1=1&s_bygroup2=1&s_filtergroup1=1&s_filtergroup2=1.

[9] Jacobs, David E. "Environmental Health Disparities in Housing." American Journal of Public Health 101, no. Suppl 1 (December 2011): S115–22. https://doi.org/10.2105/AJPH.2010.300058.

[10] Walker et al. *Challenges and Opportunities.*

[11] "American Housing Survey (AHS) - AHS Table Creator." Accessed April 6, 2025. https://www.census.gov/programs-surveys/ahs/data/interactive/ahstablecreator.html?s_areas=00000&s_year=2021&s_tablename=TABLE1&s_bygroup1=1&s_bygroup2=1&s_filtergroup1=1&s_filtergroup2=1.

constitutes an "energy burden", defined as spending more than 6% of your income on energy utility bills.[12]

Building electrification presents the opportunity to improve indoor air quality and decrease utility bills if coupled with weatherization and addressing deferred maintenance. Individuals report improved health after building retrofits because of improved thermal comfort, decreases in mold and dampness, and fewer respiratory illness symptoms.[13] A recent study found that, when including low and moderate income (LMI) households, electrifying 75% of U.S. residential energy usage would generate $96 billion in utility bill savings and $2 trillion in benefits from improved outdoor air equality and decreased carbon emissions.[14] While there has been national momentum toward residential building decarbonization, significant barriers remain.

2.2 Existing approaches

There are a variety of existing building typologies – and approaches to decarbonizing them – in the United States. Some states and localities have adopted building performance standards, which require large commercial and residential buildings to reduce energy use and/or greenhouse gas emissions.[15] New York City's Local Law 97 and the City of Boston's Building Emissions Reduction and Disclosure (BERDO) are two prominent examples of this approach.[16][17] There has also been significant discussion and some headway in electrifying district heating systems, which often serve dense downtown districts, medical complexes, and academic institutions.[18] In California, the Bay Area Air Quality Management District adopted regulations phasing out the sale of gas furnaces and water heaters on the basis of their nitrogen oxide emissions, and the South Coast Air Quality Management District is pursuing similar

[12] Drehobl, A., L. Ross, and R. Ayala. How High Are Household Energy Burdens? Washington, DC: American Council for an Energy-Efficient Economy. 2020.

[13] William J. Fisk, Brett C. Singer, Wanyu R. Chan, Association of residential energy efficiency retrofits with indoor environmental quality, comfort, and health: A review of empirical data, Building and Environment, Volume 180, 2020,107067, ISSN 0360-1323, https://doi.org/10.1016/j.buildenv.2020.107067.

[14] Fadali, Lyla, Michael Waite, and Paul Mooney. 2024. The Value of Decarbonizing Equitable, Efficient Building Electrification. Washington, DC: ACEEE. www.aceee.org/researchreport/b2405.

[15] "Building Performance Standards - IMT," March 6, 2020. https://imt.org/public-policy/building-performance-standards/.

[16] "LL97 Greenhouse Gas Emissions Reduction - Buildings." Accessed March 10, 2025. https://www.nyc.gov/site/buildings/codes/ll97-greenhouse-gas-emissions-reductions.page.

[17] "Building Emissions Reduction And Disclosure | Boston.Gov," October 4, 2021. https://www.boston.gov/departments/environment/berdo.

[18] Juliet G. Simpson, Nicholas Long, Guangdong Zhu, Decarbonized district energy systems: Past review and future projections, Energy Conversion and Management: X, Volume 24, 2024.

rules.[19][20] At the state level, the California Air Resources Board and the Maryland Department of the Environment are promulgating zero-emission appliance standards.[21] A handful of states are also in the process of developing clean heat standards, which would require fossil fuel heating suppliers to provide increasing amounts of low-emission heating services.[22]

However, the majority of building decarbonization in the United States is voluntary, not required. In this case, building upgrades and appliance switches are primarily paid for and coordinated by individual building owners. The Inflation Reduction Act (IRA) of 2022 provided financial incentives – largely in the form of tax credits, rebates, and grants — to support electrification, but the future of these incentives are in doubt under the Trump Administration.[23] At the federal level, programs like the Department of Housing and Urban Development's Community Development Block Grant, HOME Investment Partnerships Program, and the Department of Energy's Weatherization Assistance Program can also support low-income homeowners to complete home improvements that are necessary prerequisites for electrification.[24][25] Some states have funding streams to improve building habitability and safety, with many pointing to Pennsylvania's Whole-Homes Repair Program as a notable example.[26] However, the overall scale of needed home repairs extends far beyond these programs: the Federal Reserve estimates

[19]"Air District Strengthens Building Appliance Rules to Reduce Harmful NOx Emissions, Protect Air Quality and Public Health." Accessed April 15, 2025. https://www.baaqmd.gov/news-and-events/page-resources/2023-news/031523-ba-rules.

[20]"Residential and Commercial Building Appliances." Accessed April 15, 2025. https://www.aqmd.gov/home/rules-compliance/residential-and-commercial-building-appliances/.

[21] Levin, Emily et al. Zero-Emission Heating Equipment Standards: A New Tool in the Policy Toolbox. Pacific Grove, California: ACEEE Summer Study on Energy Efficiency in Buildings, 2024. Accessed April 20, 2025. https://www.aceee.org/sites/default/files/proceedings/ssb24/assets/attachments/20240722160833812_8b50cd06-0a80-4fa9-beb9-212e36728528.pdf

[22] Stebbins, Gabrielle and Neme, Neme. *A Comparison of Clean Heat Standards: Current Progress and Key Elements*. Hinesburg, VT: Energy Futures Group, 2024. Accessed April 20, 2025. https://www.edf.org/sites/default/files/2024-03/Clean%20Heat%20Standards%20Report_FINAL%2002-2024.pdf

[23]"Home Electrification and Appliance Rebates: A Guide for Homeowners." Accessed April 20, 2025. https://homes.rewiringamerica.org/federal-incentives/home-electrification-appliance-rebates.

[24]Energy.gov. "Weatherization Assistance Program," December 20, 2024. https://www.energy.gov/scep/wap/weatherization-assistance-program.

[25] Martín, Carlos et al. *Catalyzing a Movement to Produce Greater Public, Private, and Civil Resources to Improve Housing Conditions Through Home Repair Programs.* Cambridge, MA: Joint Center for Housing Studies of Harvard University. Accessed April 21, 2025. https://www.jchs.harvard.edu/sites/default/files/research/files/harvard_jchs_home_repair_programs_martin_etal_2024.pdf

[26]PA Department of Community & Economic Development. "COVID-19 ARPA Whole-Home Repairs Program." Accessed May 6, 2025. https://dced.pa.gov/programs/covid-19-arpa-whole-home-repairs-program/.

that there are $149.3 billion in needed home repairs across the country.[27] In sum, building electrification-readiness and building electrification itself as a whole remains largely individual- and market-driven, especially for smaller residential buildings that lack building performance standards.

2.3 Limitations to market-driven, building-by-building approach

Leaving building electrification up to individual building owners is insufficient, both in terms of ensuring equitable outcomes and in reaching climate goals. Literature and practice have identified the following as key barriers to building electrification at scale:

Cost: despite IRA incentives, the high upfront costs of electrification is prohibitive for many, especially low and moderate-income households. This challenge is particularly acute for individuals living in buildings that require rewiring and electric panel upgrades, and those in buildings with significant deferred maintenance or weatherization needs that must be addressed prior to electrification.[28] Additionally, electricity prices are higher than gas prices in some states, meaning that utility bills may increase after converting to air-source heat pumps, particularly in colder climates.[29][30]

Split incentives: where renters pay utility bills, there are split incentives between renters and owners – renters would benefit from home renovations that improve energy efficiency and thermal comfort but they would not pay for them; building owners would be on the hook for these costs but would not immediately benefit financially.[31] On the flipside, there are concerns that building owners will try to recoup the costs of building decarbonization by increasing rents and evicting lower-income tenants.[32]

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[27] Divringi, Eileen. *Research Brief: Updated Estimates of Home Repair Needs and Costs.* Philadelphia, PA: Federal Reserve of Philadelphia, 2023. Accessed April 21, 2025: https://www.philadelphiafed.org/-/media/frbp/assets/community-development/reports/23-02-home-repairs-update.pdf

[28] Walker et al. "Challenges and Opportunities".

[29] Malinowski, Matt, Reuven Sussman, Paul Mooney and Grace Lewallen. *Electricity Rates That Keep Bills Down after Electrification of Home Heating*. Washington, DC: ACEEE, 2025. Accessed April 15, 2025. www.aceee.org/research-report/b2502.

[30] Mills, Ryan. "Electric Rates Can Help or Hinder Heat Pump Progress." RMI, December 5, 2024. https://rmi.org/electric-rates-can-help-or-hinder-heat-pump-progress/.

[31] Department of Energy. *Decarbonizing the U.S. Economy by 2050: A National Blueprint for the Buildings Sector April 2024.* Washington, D.C.: Office of Scientific and Technical Information, 2024. Accessed April 15, 2025 https://www.osti.gov/servlets/purl/2338089

[32] The Greenlining Institute and Energy Efficiency for All. "Equitable Building Electrification: A Framework for Powering Resilient Communities - The Greenlining Institute." Oakland, CA: The Greenlining Institute, October 1, 2019. https://greenlining.org/publications/equitable-building-electrification-a-framework-for-powering-resilient-communities/.

Slow rate of energy efficiency retrofits: While many buildings are receiving energy efficiency retrofits, at current rates it would take 30 and 90 years to upgrade residential windows and insulation, respectively.[33] Inefficient building electrification will put significant stress on the grid, requiring significant additional build-out of renewable energy to meet electricity demand.[34]

Insufficient focus on deferred maintenance: Deferred maintenance needs have negative public health impacts and impede electrification in low-income communities and communities of color. These maintenance needs – including roof repairs, mold, knob-and-tube wiring and asbestos – must be addressed prior to electrification and drive up project costs.[35]

Administrative complexity: Implementing electrification is often a complicated process that requires multiple contractors, making it difficult to electrify if you have limited time and/or experience interfacing with contractors. At scale, it also involves a large number of uncoordinated actors and decision makers– individual homeowners, municipal employees who have to approve permits, utilities who have to ensure sufficient grid capacity, contractors with a wide scope of work, equipment manufacturers and more.[36]

Competing priorities and misinformation: home electrification is not a priority for many homeowners for a wide variety of reasons, including an undervaluing of the benefits of building decarbonization and a lack of familiarity with the involved technologies.[37,38] Additionally, gas utilities have spent millions in a public relations campaign about the benefits of cooking with gas stoves and in industry-backed research minimizing their negative health impacts,[39] which has shaped customer preferences and regulation.

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[33]Department of Energy. *Decarbonizing the U.S. Economy by 2050*

[34]Buonocore, Jonathan J., Parichehr Salimifard, Zeyneb Magavi, and Joseph G. Allen. "Inefficient Building Electrification Will Require Massive Buildout of Renewable Energy and Seasonal Energy Storage." Scientific Reports 12, no. 1 (July 13, 2022): 11931. https://doi.org/10.1038/s41598-022-15628-2.

[35]Walker et al. *Challenges and Opportunities.*

[36] Gibson, Sachi et al. "Neighborhood Scale Decarbonization ." Ottawa, Canada, April 18, 2024. https://buildingdecarbonization.ca/wp-content/uploads/2024/05/BDA_Forum_4c_Neighbourhood-Scale.pdf.

[37]Walker et al. *Challenges and Opportunities.*

[38]York, Dan et al. "Building Decarbonization Solutions for the Affordable Housing Sector." Washington, DC: American Council for an Energy-Efficient Economy, 2022. www.aceee.org/research-report/u2204.

[39]Brady, Jeff. "How Gas Utilities Used Tobacco Tactics to Avoid Gas Stove Regulations." NPR, October 17, 2023, sec. Climate. https://www.npr.org/2023/10/17/1183551603/gas-stove-utility-tobacco.

Workforce limitations: there are a limited number of contractors with the skillset to weatherize and electrify homes.[40] The small scale of many residential building electrification projects means that most construction work is done by smaller contractors. These contractors often have lower pay and more limited benefit packages than larger commercial contractors, and their workers are often less skilled and less experienced.[41,42]

Inequitable gas utility costs: As more individuals electrify, gas utilities could face a "utility death spiral": while the number of gas customers decreases, the fixed costs of maintaining the gas system will remain or increase, leading to higher per-customer costs, which will lead more customers to defect off of gas.[43,44] For example, a 2019 Gridworks report found that, without a managed transition plan, the cost of gas in California could increase twelvefold in the state's lowest-cost decarbonization pathway.[45] In this scenario, the most economically vulnerable individuals unable to transition to electric heating will be left footing the bill for the entire gas system.

Missing climate targets: Across the United States, states lag behind their targets for building electrification.[46] In 2024, the U.S. Department of Energy suggested that, in order to reach national 2050 residential building decarbonization and efficiency targets, heat pump deployment and retrofits would need to increase 10- and 25-fold by 2030, respectively.[47] This suggests that the existing model currently provides insufficient incentives for customers to improve energy efficiency, get off of gas, and install clean energy appliances.

In summary, high upfront costs and difficulty accessing financing are a central challenge for equitable and rapid building electrification. These costs are exacerbated by existing maintenance and building conversion needs, as well as administrative complexity and a limited workforce. High electricity rates also hinder building decarbonization, as can a lack of understanding and support for building

[40]Walker et al. *Challenges and Opportunities.*
[41]Building Electrification Institute. "Inclusive Workforce Development Strategies for Building Electrification." Building Electrification Institute, September 2024. https://static1.squarespace.com/static/5b6a482db27e39e8fcf65bbf/t/67913fad67dfa823a2cafe0a/1737572269865/BEI_Inclusive+Workforce+Development+Strategies+for+Building+Electrification_Sept+2024.pdf.
[42]Walker et al. Challenges and Opportunities.
[43]Davis, Lucas W., and Catherine Hausman. "Who Will Pay for Legacy Utility Costs?" Journal of the Association of Environmental and Resource Economists 9, no. 6 (November 1, 2022): 1047–85. https://doi.org/10.1086/719793.
[44]Ibid
[45] Gridworks. "California's Gas System in Transition," Oakland, CA: Gridworks, 2019. Accessed April 23, 2025. https://gridworks.org/wp-content/uploads/2019/09/CA_Gas_System_in_Transition.pdf.
[46]Mills, Ryan. "The State of State Climate Action: Updated Scorecards Tracking Progress to 2030." RMI, July 11, 2023. https://rmi.org/state-climate-action-updated-scorecards-tracking-progress-to-2030/
[47]Department of Energy. *Decarbonizing the U.S. Economy by 2050*

decarbonization among politicians and the public. Studies suggest that providing sufficient funding, supporting workforce and technological development, educating stakeholders and designing more favorable electrification rates, can help to scale residential building electrification.[48,49,50]

2.4 Neighborhood-scale building decarbonization

Defining neighborhood-scale building decarbonization

In recent years, neighborhood-scale building decarbonization has been proposed as an alternative approach with the potential to address the limitations outlined above. This model, which people sometimes refer to as zonal decarbonization, changes the unit of building decarbonization from the individual to the block, neighborhood, or development. The advocacy organization Building Decarbonization Coalition (BDC) has been a leading proponent of this approach and this framing. In their 2023 report "Neighborhood Scale: The Future of Building Decarbonization", BDC and Gridworks define neighborhood-scale building decarbonization as follows:

> 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.[51]

As conceptualized by BDC's report, neighborhood-scale building decarbonization is typically approached using one of two technologies: thermal energy networks (TENS) (also known as networked geothermal) or electric networks. Both approaches include energy efficiency retrofits, environmental toxin remediation, replacing gas-powered appliances with electric ones, and rooftop solar. For energy networks, electricity is supplied primarily from the grid whereas for TENs, the energy is supplied via geothermal wells and a thermal loop that transfers energy in the form of heat throughout the neighborhood.[52] Building Decarbonization and Gridworks theorize the following benefits of this model:

1. Accelerates Climate and Health Benefits of Decarbonization
2. Enables a Managed Transition Off of the Gas System

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[48]Ibid

[49] York, Dan et al. "Building Decarbonization Solutions for the Affordable Housing Sector." Washington DC: American Council for an Energy-Efficient Economy, April 2022. https://www.aceee.org/sites/default/files/pdfs/u2204.pdf.

[50] Walker et al. Challenges and Opportunities.

[51] Building Decarbonization Coalition, and Gridworks. "Neighborhood Scale: The Future of Building Decarbonization," November 2023, page 5. https://buildingdecarb.org/wp-content/uploads/BDC_Neighborhood-Scale-Report_WEB.pdf.

[52] Ibid

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[53]

For organizations focused primarily on networked geothermal, notably the Massachusetts-based non-profit organization HEET, a central goal of neighborhood-scale building decarbonization is to transition gas utilities to thermal utilities. HEET calls this the Gas to Geo model.[54] This model has attracted the interest of the building trades and other labor advocates, as it creates an employment pathway for existing gas distribution utility employees and oil and gas workers involved in drilling.[55]

The discourse surrounding neighborhood-scale building decarbonization is closely linked to conversations within public utility commissions and investor-owned utilities about non-pipeline alternatives (NPAs). Non-pipeline alternatives (NPAs) are utility "investments or activities that defer, reduce, or avoid the need to build or upgrade gas delivery system infrastructure", typically in response to greenhouse gas reduction goals. [56] Along with energy efficiency and demand response measures, NPAs can include utilities pursuing targeted electrification – "geographic electrification and/or retirement of gas assets, with the goal to reduce gas rates through the avoidance/reduction of gas utility spending."[57] To some, neighborhood-scale building decarbonization represents an extension of this utility-driven model which extends to urban areas with various building types and building owners. For others, it represents an opportunity to support collective ownership of energy infrastructure and/or to prioritize decarbonization in low-income communities of color.[58]

[53] Ibid, page 6.
[54]"Gas to Geo Hub." Accessed May 8, 2025. https://www.heet.org/gas-to-geo-transition.
[55]Cohen, Reyna et al. "Understanding Thermal Energy Networks." Ithaca, NY : Climate-Jobs Institute at Cornell University , December 2024. https://www.ilr.cornell.edu/sites/default/files-d8/2024-12/understanding-thermal-energy-networks.pdf.
[56]Nelson, Ron et al. "A Framework for Non-Pipeline Alternatives Analysis and Review of Existing Approaches. Lawrence Berkeley National Laboratory". Berkeley, CA: Strategen, December 2024, page 5. https://escholarship.org/uc/item/4km135j0
[57]Henchen, Mike et al. "Non-Pipeline Alternatives." Zoom webinar, June 17, 2024. https://rmi.org/wp-content/uploads/2024/06/24.06.17-NPA-webinar.pdf.
[58]EcoBlock. "EcoBlock." Accessed May 8, 2025. https://ecoblock.berkeley.edu/

Current state of neighborhood-scale building decarbonization

Neighborhood-scale decarbonization, particularly as applied to residential or mixed-used neighborhoods, is quite new in the United States context. BDC has identified 50 operational neighborhood-scale building electrification projects and 12 projects under construction[59]. These projects are largely district heating systems with a central thermal borefield that serve universities and other large institutions. Colorado Mesa University's geothermal network in Grand Junction, Colorado, built in 2007, is often pointed to as the first networked geothermal project in the country while Whisper Valley, a 2017 master-planned development that plans to serve about 450 homes with a geothermal network is pointed to as the largest neighborhood-scale project to date.[60] Eversource's Framingham, Massachusetts project, which became operational in 2024, is the first networked geothermal project serving a mixed-use neighborhood. To date, there are no large-scale electric network projects that have been completed, according to BDC's database. Utilities in New York and California have paid for a small number of customers to electrify in order to avoid expanding or replacing aging gas pipelines as part of NPA programs.[61] In its New York City service area, National Grid identified 27 potential projects that would impact 398 customers. As of spring 2024, they had received responses from 37% of individuals and support from only 5% of customers and were moving toward implementation for three projects serving five customers.[62] Con Edison is also actively pursuing NPA projects in New York.[63,64] California utility Pacific Gas and Electric (PG&E) completed 88 targeted electrification projects that electrified 105 customers and allowed the utility to decommission 22 miles of gas transmission pipelines. All of the planned and implemented projects serve five or fewer customers.[65]

In recent years, a number of state legislatures have passed bills intended to support neighborhood-scale building electrification programs. Since 2021, eight states – Massachusetts, Minnesota, New York, Colorado, Washington, Maryland, and Virginia – have passed legislation allowing utilities to provide geothermal energy and/or creating geothermal pilots. In most cases, the legislation allows gas and electric utilities to own and operate this infrastructure, and in Colorado, New York, and Maryland, it requires

[59]BDC. "Neighborhood-Scale Building Decarbonization Map." Accessed May 8, 2025. https://buildingdecarb.org/neighborhood-scale-projects-map.

[60] Ibid

[61]Henchen, Mike et al. "Non-Pipeline Alternatives: Emerging Opportunities in Planning for U.S. Gas System Decarbonization." RMI and National Grid, May 2024, page 15. https://www.nationalgridus.com/media/pdfs/other/CM9904-RMI_NG-May-2024.pdf.

[62]Henchen, Mike et al. "Non-Pipeline Alternatives", pages 8, 12

[63] James, Ford. "All-New Appliances for Free? How a New Con Ed Program Provides Them." *PIX 11*, July 10, 2024. https://pix11.com/news/local-news/bronx/all-new-appliances-for-free-how-a-new-con-ed-program-provides-them/.

[64] Consolidated Edison Company of New York. "Non-Pipes Alternatives Implementation Plan," November 18, 2024. Non-Pipeline Alternatives Implementation Plan https://documents.dps.ny.gov › public › ViewDoc.

[65]Henchen, Mike et al. "Non-Pipeline Alternatives", 11.

large investor-owned utilities to pilot networked geothermal projects. Guaranteed cost recovery for pilot projects is either included in the legislation or delegated to the public utility commission for consideration.[66] In California, the legislation includes both networked geothermal and electric networks as eligible for pilot projects.[67]

2.5 The role of utilities in neighborhood-scale building decarbonization

Utilities – and specifically investor-owned utilities (IOUs)– are seen by some experts as key to the success of neighborhood-scale building decarbonization. These experts point to at least three major benefits to utility-driven neighborhood-scale building decarbonization: their status as regulated natural monopolies providing heating and/or electricity, their financing capabilities, and their existing technical skillset and workforce.

Natural monopolies and the obligation to serve

Gas and electric distribution utilities are natural monopolies, meaning that the services they provide become cheaper on a per-unit basis as they increase in scale.[68] Since the early 1900s, utilities in the United States have been granted monopoly status in the areas they serve. In some service areas, a single utility provides both gas and electricity services (called a "dual-fuel utility"). In others, there are separate electric and gas utilities, or only electricity service. These utilities can be privately owned, cooperatively owned, or publicly owned. In exchange for being the sole gas and/or electricity provider in their service areas, IOUs are regulated by a state utility public service commission.[69]

The specifics of utility regulation vary at the state level but typically includes the obligation to serve. The obligation to serve – also sometimes called the duty to serve – refers to the requirement that utilities provide a service to all customers in the region they serve. It is made up of two connected obligations: 1) "the duty to interconnect and extend service if requested" and 2) "the duty to continue service once it has commenced."[70]. It often includes other measures intended to protect consumers, including charging just and reasonable rates, not discriminating in access to service, and promoting energy safety and

[66]BDC. "Thermal Energy Networks." Accessed May 13, 2025. https://buildingdecarb.org/resource-library/tens.
[67]Min, Dave. Gas corporations: ceasing service: priority neighborhood decarbonization zones., Pub. L. No. SB 1221 (2024). https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=202320240SB1221.
[68]Lazar, Jim. Electricity Regulation in the US: A Guide. Second Edition. Montpelier, VT: The Regulatory Assistance Project, 2016. Retrieved from http://www.raponline.org/knowledge-center/electricityregulation-in-the-us-a-guide-2
[69]Ibid
[70] Payne, H (2022). Unservice: Reconceptualizing the Utility Duty to Serve in Light of Climate Change. In University of Richmond Law Review (Volume 56, Issue 2), 603.

reliability.[71] In many states, this duty is fuel specific, meaning that gas utilities are legally required to provide natural gas service (not just heating service) to anyone who requests it. Gas utilities use this requirement to justify the maintenance of gas service for existing customers and the expansion of natural gas infrastructure to serve new customers, even in states with ambitious decarbonization goals.[72] In the context of neighborhood-scale decarbonization projects in states with a fuel-specific obligation to serve, this means that projects must receive 100% customer buy-in to electrify in order to decommission gas lines.[73]

On the flip side, the obligation to serve means that a single utility – whether gas, electric or dual fuel — provides energy to all customers connected to the area's electricity grid or gas infrastructure. This provides utilities a unique level of access to customer energy consumption data and a system-wide understanding of infrastructure needs, which has the potential to make them key players in supporting system-wide decarbonization.

Financing capabilities

In return for providing service to all customers in a given service area, utility regulators guarantee IOUs cost recovery and an authorized rate of return (ROR) for capital expenditures that meet state standards. This ROR is theoretically set based on the "just and reasonable" standard for rates established by the 1948 Supreme Court Case *Federal Power Commission v. Hope Natural Gas Company.* In this ruling, the Court allows that "the return to the equity owner should be commensurate with returns on investments in other enterprises having corresponding risks".[74] In other words, the ROR is set at the cost of capital, reflecting interest rates on debt and the cost of equity. In simplified terms, this model – cost-of-service regulation – can be expressed as follows:

Revenue Requirement = Rate Base Investment x ROR + Operating Expenses[75]

Capital expenditures constitute the utility's rate base investment, and utility consumers pay back these expenses – and a return on equity (ROE) – on their energy bills over the course of the infrastructure's lifetime, along with the utility's operating expenses. Critics maintain that IOUs' ROE (an average of

[71] Bagdanov, Kristin George. "Decarbonizing the Obligation to Serve," Lewes, Delaware: BDC, March 2024. https://buildingdecarb.org/wp-content/uploads/FINAL_Decarbonizing-the-Obligation-to-Serve_Oct2024.pdf.
[72] Ibid
[73] Ibid
[74]Supreme Court of the United States. "FPC v. Hope Nat. Gas Co., 320 U.S. 591 (1944)", page 320. Accessed May 13, 2025. https://supreme.justia.com/cases/federal/us/320/591/
[75]Lazar, Jim. Electricity Regulation in the US.

9.6% across the US) exceeds the cost of equity[76] and note that these returns have increased in recent years.[77] [78]A broader critique of this approach to setting utility rates is that it incentivizes over-investment in capital infrastructure, which is often called "gold-plating".[79] In recent years, a number of state utility commissions have shifted toward performance-based ratemaking for electric utilities, which compensates utilities for their performance on metrics like grid resilience and decarbonization, not just their expenditures.[80]

This cost recovery structure also has significant implications for utilities' ability to make clean energy investments. Firstly, their ability to recoup costs from ratepayers, coupled with their large scale and exclusive access to their service area, enables them to secure low-interest financing for large capital projects. Secondly, they recover the upfront costs of capital expenditures over a long period of time through depreciation, typically the useful lifetime of the infrastructure.[81] Thirdly, they are able to spread out costs among all ratepayers. These latter two capabilities make large investments less expensive in the short term for individual rate payers, while the relatively lower cost of capital decreases the overall project expenses.

Proponents also believe that utilities have an opportunity to couple neighborhood-scale building with gas line decommissioning, and in doing so, create a managed transition off gas infrastructure that is less costly and more equitable.[82] Across the country and especially on the East Coast, natural gas infrastructure is aging and leaky, leading policymakers to pass legislation requiring the repair and replacement of existing gas lines and gas utilities to propose major investments in infrastructure upgrades.[83,84] In 2022 alone, gas utilities spent nearly $21 billion on gas distribution infrastructure.[85] Gas

[76]Ellis, Mark. "Rate of Return Equals Cost of Capital." Washington DC: American Economic Liberties Project, January 2025. https://www.economicliberties.us/wp-content/uploads/2025/01/20250102-aelp-ror-v5.pdf.
[77]Lusiani, Nicholas, Power Struggle: How Shareholder Primacy in the Electrical Utility Sector Is Holding Back an Affordable and Just Energy Transition (May 5, 2022). The Roosevelt Institute, 2022, Available at SSRN: https://ssrn.com/abstract=4410886 or http://dx.doi.org/10.2139/ssrn.4410886
[78] Daniel, Joe. "Rebalancing 'Return on Equity' to Accelerate an Affordable Clean Energy Future." Denver, CO: RMI, February 21, 2025. https://rmi.org/rebalancing-return-on-equity-to-accelerate-an-affordable-clean-energy-future/.
[79]Lazar, Jim. Electricity Regulation in the US.
[80]RMI. "The Nuts and Bolts of Performance-Based Regulation:" Denver, CO, July 2024. https://rmi.org/wp-content/uploads/dlm_uploads/2024/07/PBR_Deck_final.pdf.
[81]Lazar, Jim. Electricity Regulation in the US.
[82]Walsh, Michael, and Michael Bloomberg. "The Future of Gas in New York State." Lewes, Delaware : BDC, March 2023. https://buildingdecarb.org/wp-content/uploads/BDC-The-Future-of-Gas-in-NYS.pdf.
[83]Department of Public Utilities. "GSEPs Pursuant to 2014 Gas Leaks Act." Mass.gov, 2025, https://www.mass.gov/info-details/gseps-pursuant-to-2014-gas-leaks-act.
[84]Walsh and Bloomberg. "The Future of Gas in New York State."
[85]American Gas Association. "Gas Construction Expenditure by Type of Facility," 2024. https://www.aga.org/wp-content/uploads/2023/01/Table12-1.pdf.

pipelines have a useful life of 40-50 years, meaning that their costs are likely not to be fully recovered if states reach their building decarbonization goals. Analysts estimate that up to $150-180 billions of gas infrastructure could be under-recovered in the transition off fossil fuels.[86] Many advocates for neighborhood-scale building decarbonization, and some utilities pursuing NPAs, believe that this money should instead be put toward building decarbonization projects that allow gas lines to be decommissioned.[87]

Infrastructure and interests

Utilities distributing electricity and/or gas to customers are well-established service providers with existing infrastructure. Utility structure varies between states, with some utilities providing generation transmission and distribution, and other states having restructured their market to unbundle those functions.[88] In deregulated markets, electric utilities typically own and operate transmission lines, local distribution lines, transformers, utility poles, and meters,[89] and gas utilities operate gas distribution and sometimes transmission lines. Most importantly in the context of building decarbonization, these companies have information regarding this age and condition of infrastructure, as well as data on customer energy usage and planned infrastructure upgrades.

Gas, electric, and dual fuel utilities have different interests in the clean energy transition. Most of the 30 largest investor-owned electric utilities in the country have established net zero greenhouse gas (GHG) targets[90] and will experience increased demand for their services as customers electrify appliances and switch to electric vehicles. With utility commission supervision, they are responsible for planning to ensure that the electric grid has sufficient capacity through integrated resource plans.[91] The future of retail gas-only distribution utilities is less certain, especially in states with strong climate goals. The natural gas industry emphasizes increases in efficiency through new equipment and weatherization, and its efforts to replace leaky pipes and invest in renewable natural gas as cornerstones of its climate

[86]Brattle. "The Future of Gas Utilities Series." August 2021. https://www.brattle.com/wp-content/uploads/2021/08/The-Future-of-Gas-Utilities-Series_Part-1.pdf

[87] Building Decarbonization Coalition. "Neighborhood Scale."

[88]US EPA, OAR. "Understanding Electricity Market Frameworks & Policies." Overviews and Factsheets, August 29, 2021. https://www.epa.gov/greenpower/understanding-electricity-market-frameworks-policies.

[89]Canary Media. "Electric Utilities 101: A Breakdown of the Basics on US Power...," October 12, 2022. https://www.canarymedia.com/articles/guides-and-how-tos/power-by-people-glossary-bundle.

[90] National Public Utilities Council. "Annual Utility Decarbonization Report 2024." National Public Utilities Council, December 2024. https://decarbonization.visualcapitalist.com/wp-content/uploads/2024/12/2024_Annual_Decarbonization_Report_Updated.pdf

[91]Slanger, Dan. "What's the State of Utility Planning Halfway through 2024?" RMI, July 12, 2024. https://rmi.org/whats-the-state-of-utility-planning-halfway-through-2024/.

strategy.[92] However, gas utilities and their regulators continue to project flat – or even increased – demand for natural gas, even in states with ambitious GHG reduction targets.[93] In nine states and the District of Columbia, state utility commissions have initiated future of gas proceedings that consider the long-term planning for the gas system.[94] In some states, these proceedings have included a discussion of the role of TENs in a transition away from natural gas.

Role of other utilities

While much of the existing conversation surrounding the utility role in neighborhood-scale building decarbonization centers around IOUs, there is also a potential for publicly-owned and cooperative electric utilities to participate in neighborhood-scale decarbonization. Across the country, there are 830 cooperative electric utilities[95] and over 2,000 publicly owned utilities.[96] These entities are typically much smaller than IOUs – serving about 13 and 16 percent of total customers, respectively[97] – but nonetheless serve millions of customers and have many of the same capabilities as the IOUs. There are also about 1,000 publicly- and community-owned natural gas systems across the United States.[98]

Alternatives to utility-led model

Utility-led neighborhood-scale building electrification is not the only approach to this model.

At the federal level under the Biden administration, the Green and Resilient Retrofit Program supported energy efficiency retrofits in public housing buildings.[99] In New York, the state committed to investing $70 million to develop and produce heat pumps for public housing buildings[100] and in

[92]American Gas Association. "Natural Gas Industry Climate Change Commitments," 2021. https://www.aga.org/wp-content/uploads/2022/02/aga-climate-change-progress.pdf

[93]Karas, Natalie et al. "Aligning Gas Regulation and Climate Goals." Environmental Defense Fund (blog), January 2021. https://blogs.edf.org/energyexchange/wp-content/blogs.dir/38/files/2021/01/Aligning-Gas-Regulation-and-Climate-Goals.pdf.

[94] "Natural Gas Utility Decarbonization - Energy Industry Update V23 I2 - The Waiting (Is the Hardest Part)." Accessed May 5, 2025. https://publications.scottmadden.com/energy-industry-update-v23-i2/natural-gas-utility-decarbonization.

[95]NRECA. "America's Cooperative Electric Utilities Fact Sheet," February 2025. https://www.cooperative.com/programs-services/bts/Documents/Data/Electric-Co-op-Fact-Sheet.pdf.

[96]"Where Is Public Power?" American Public Power Association, n.d. https://www.publicpower.org/system/files/documents/MAP-%20Where%20is%20Public%20Power.pdf .

[97]"Investor-Owned Utilities Served 72% of U.S. Electricity Customers in 2017 - U.S. Energy Information Administration (EIA)." Accessed May 5, 2025. https://www.eia.gov/todayinenergy/detail.php?id=40913.

[98]"Natural Gas Facts - American Public Gas Association." Accessed May 5, 2025. https://www.apga.org/aboutus/facts.

[99]U.S. Department of Housing and Urban Development Office of Recapitalization. "Green and Resilient Retrofit Program (GRRP) Owner Guide for Comprehensive Cohort Awards." Washington D.C. : U.S. Department of Housing and Urban Development, 2023. https://www.hud.gov/sites/dfiles/Housing/documents/Comprehensive_Cohort_Owner_Guide.pdf.

[100]Ibid

Massachusetts, the state energy agency has committed over $50 million to funding affordable housing decarbonization. While some of these projects support single buildings, many support multi-building complexes and demonstrate a public-sector driven approach to larger-scale building decarbonization projects. All of the financing tools available to the public sector – including bonds, revolving-loan funds, and tax credits – could also theoretically be used to facilitate neighborhood-scale building decarbonization projects. Some advocates also propose locally owned and operated neighborhood-scale systems. For example, Vermont Community Thermal Networks is advocating for TENs owned by residents, businesses, and municipalities.[101] Alternatively, this model could be implemented by the private sector for new developments, as was the case for the aforementioned Whisper Valley development in Texas. In Colorado, a home builder recently announced plans to install ground-source heat pumps in 1,500 buildings but opted for individual-level systems.[102] On-bill lending – in which users pay back upfront clean energy investments on utility bills or property taxes[103] – is another mechanism that could be utilized to support neighborhood-scale building decarbonization.

2.6 Plan for analysis

The literature on the importance of building retrofits and decarbonization for climate goals and public health – coupled with the equity, cost and implementation limitations of a building-by-building decarbonization – suggests that another approach is needed. Considered in conjunction with the role of the utility, a utility-financed neighborhood-scale building decarbonization appears to be a promising alternative model. As theorized, this model would support equitable access to the benefits of building decarbonization while decreasing system costs and supporting a just transition. However, only a handful of papers have been written on neighborhood-scale building decarbonization and non-pipeline alternatives. These papers are largely written by advocates invested in scaling this approach and primarily consider it in theoretical or policy terms.

In response, my thesis examines ongoing utility-financed pilot projects to understand what enables and hinders utility-funded neighborhood-scale building decarbonization pilot projects– and the implications of these findings for the future of this model. In other words, it is interested in what makes these neighborhood-scale projects fail or succeed. Most of these projects are not yet under construction, with some still undergoing public utility proceedings for regulatory approval. In some cases, utilities are

[101]Vermont Community Thermal Networks. "The Basics: Thermal Energy Networks." Accessed May 1, 2025. https://www.vctn.org/the-basics.
[102]Canary Media. "Lennar Will Build 1,500 New Colorado Homes with Geothermal Heat Pumps," April 2, 2025. https://www.canarymedia.com/articles/geothermal/heat-pumps-dandelion-lennar.
[103]"On-Bill Energy Efficiency | ACEEE." Accessed May 2, 2025. https://www.aceee.org/toolkit/2017/02/bill-energy-efficiency.

still in the process of completing feasibility studies to select project sites.[104] It is therefore difficult to ascertain project success or failure – with the exception of projects that are already operational or have been abandoned prior to completion – and little written on the subject. I therefore ground my research in what the literature says about the factors that enable or hinder the success of building-scale decarbonization retrofit projects.

Based on the limitations, barriers, and opportunities for building-scale decarbonization and the structural context described above, I hypothesize that the following political and regulatory conditions as necessary prerequisites for neighborhood-scale building decarbonization projects:

- **Strong and specific climate goals:** projects will be unlikely to move forward in the absence of binding net-zero GHG targets that include building sector decarbonization.
- **Passage of enabling legislation**: if state code regarding IOUs is fuel specific, geothermal must be added as a technology that utilities can own and operate; encouraging or requiring utilities to pilot neighborhood-scale projects will also support their development, as will guaranteeing utility cost recovery or otherwise funding these projects.
- **Engaged public utility commission**: given the fact that IOUs are regulated by these commissions, they will need to be actively involved in reviewing and approving neighborhood-scale building decarbonization projects; existing future of gas proceedings will also likely incentivize gas and dual-fuel utilities to pursue TENs or electric network projects.

Once pilot projects are approved, I anticipate that the following factors their outcomes:

- **Cost and funding availability:** projects will be impacted by the extent of costs and project leads' confidence in their ability to recover these costs.
- **Community buy-in**: residential building decarbonization involves a significant scope of work inside of people's homes along with some behavior changes related to electrification. Gaining buy-in from residents will be key to project success.
- **Number of building owners:** residential building decarbonization projects often include a large number of actors and decision makers, which can slow timelines and hinder buy-in. Projects will be easier to implement when there is an anchor tenant and/or a small number of building owners, and fewer renters.
- **Workforce availability:** having skilled workers with experience with the electrification technology being utilized will be key to the project's success.

[104]BDC. "Neighborhood-Scale Building Decarbonization Map."

I also anticipate that the following changes will be necessary for neighborhood-scale building decarbonization to expand:

- **Modification to obligation to serve:** fuel-specific obligation to serve means that projects can only include decommissioning gas lines if 100% of customers agree to participate. Shifting the obligation to serve to define it in terms of thermal service (not fuel) or lowering the threshold at which utilities can require customers to switch from gas to electric will likely be important to the scaling of this model.
- **Continued financial support** given the current economics of building decarbonization, it is unlikely that neighborhood-scale building decarbonization will expand without significant additional financial incentives.
- **Policy incentives for utilities:** IOUs are only likely to pursue this model if they receive a directive – or large economic incentive – to do so. While synergies exist, it represents a significant departure from their existing business model, particularly for gas-only utilities.

The remainder of this paper will be dedicated to an exploration of policies and neighborhood-scale building decarbonization projects in three states: California, Massachusetts, and New York. I begin by providing an overview of relevant policy and regulatory developments in each state to understand the context in which neighborhood-scale building decarbonization projects are currently under development. This will include state-level climate statute and how this statute relates to building decarbonization and related utility proceedings. I will also describe the legislation and regulations that precipitated utility-funded neighborhood-scale building decarbonization projects. Lastly, I will provide a brief overview of the status of utility-financed pilot projects in each state, including the structure of involved utilities and other key actors. After completing this desk research, I interviewed 19 individuals involved in advocacy, design, and implementation for a selection of projects and policies to understand their perceptions of project successes and/or failures, and their opinions about the model as a whole. I synthesize key themes – largely framed in terms of opportunities and challenges for neighborhood-scale building decarbonization – identified by informants in the second portion of my results section. I close with a discussion of recommended interventions for planners and policymakers to support the success and expansion of neighborhood-scale projects, based on findings from interviews and research.

3. Methods

Desk research on state political context: in order to complete research on state policy and regulatory context, I reviewed state code, statute, and proposed legislation, along with white papers by advocates and news articles. I complemented this research with insights from informants relating to state context. Where advocates, interviewees, and advocates made statements regarding policy and regulation, I checked these claims with the relevant policy text and typically cited the original text

Interviews: recruitment and response

In order to complement existing literature focused on the theorized benefits and policy interventions of neighborhood-scale, I focused my outreach primarily on the universe of individuals who have been directly involved with pilot design and implementation in California, Massachusetts and New York. In order to get these perspectives, I reached out to people already in my network. I also identified other people via new articles and used snowball sampling to connect with additional individuals. In total, I reached out to 23 individuals and conducted 19 interviews over the course of March and April 2025.

The sectoral representation of the individuals I spoke with is shown below. All 19 individuals consented to being quoted directly in this thesis, with four requesting to be identified only by their role type and location, and three speaking as individuals, not organizational representatives. The remaining 12 agreed to be quoted with their name, title, and organization included. All interviewees were given the opportunity to review quotes prior to finalizing the thesis. In this review process, some of the 12 named individuals requested that specific quotes be anonymized.

Informant interview sectors	**Number**
Energy service providers	5
Policy experts and consultants	4
Public sector	3
Advocates	3
Community-based and environmental justice groups	2
Academia	1
Geothermal drilling	1
TOTAL	**19**

This sample draws from some of the most prominent neighborhood-scale projects in the three states under consideration but is not representative of all individuals involved in projects. It over-represents policy experts and underrepresents contractors and community-based organizations.

Interviews occurred via zoom and lasted between 45 minutes and 1.5 hours, including an introduction to the thesis topic and obtaining informed consent. A list of interview questions is included in the appendix. After completing interviews, I utilized Otter.AI or Zoom to obtain a transcript and reviewed the transcript. From there, I compiled quotes from key informant interviews in Google Sheets using a set list of categories, also described in the appendix.

Across interviews, I identified a cluster of four key themes: costs, financing, community buy-in, and planning and coordination. In my results section, I complete an analysis of informant responses across these themes. I also explore the implications of a utility-led approach, along with introducing other key actors and broader informant perspectives on the model.

My discussion draws from my literature review, desk research and thematic analysis of informant interviews to offer recommendations to planners and policymakers to enable the expansion of utility-financed neighborhood-scale building decarbonization. I close with broader reflections on the model and areas for future research.

4. Results: State-Level Context

Before speaking with people involved with neighborhood-scale pilot projects in California, Massachusetts, and New York, I considered the political and regulatory factors that enabled these pilots. I considered the hypothesized prerequisites across states – strong and specific climate goals, the passage of enabling legislation, and an engaged state utility commission – and found that these all bore out. Through interviews, I also identified the importance of advocacy organizations as a key factor supporting the creation of neighborhood-scale pilots. I also briefly introduce pilot projects and programs that exist in each state.

4.1 Strong and specific climate goals

Each state on which I focus has passed binding GHG-reduction goals that include targets for building energy decarbonization or directs agencies to consider sector-specific decarbonization strategies.

California: In California, the 2006 Global Warming Solution Act required the state to reduce GHG emissions to 1990 levels by 2020.[105] It gave the California Air Resources Board jurisdiction to create a program to reach this target and establish further targets beyond 2020.[106] In 2018, the California Legislature passed SB100, the 100 Percent Clean Energy Act of 2018, which established a renewable portfolio standard for energy providers to procure 60% of electricity from renewable sources by 2030 and 100% zero-carbon sources by 2045.[107] California Governor Brown simultaneously established an economy-wide 2045 carbon neutrality target.[108] A subsequent statutorily-mandated agency report noted that "construction of and conversion to zero-emission buildings has rapidly emerged as a key decarbonization strategy"[109]. In 2022, California Governor Newsom set a "goal of 3 million climate-ready and climate-friendly homes by 2030 and 7 million homes by 2035, which shall be supplemented through the deployment of 6 million heat pumps statewide by 2030," with 50 percent of funding going to disadvantaged communities.[110]

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[105] Nunez, Fabian . California Global Warming Solutions Act of 2006, Assembly Bill No. 32 (2006). https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=200520060AB32.

[106] Ibid

[107] De León, Kevin. California Renewables Portfolio Standard Program, Senate Bill 100 (2018). https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180SB100

[108]"Executive Order B-55-18 of September 10, 2018, to Achieve Carbon Neutrality" (2018): https://archive.gov.ca.gov/archive/gov39/wp-content/uploads/2018/09/9.10.18-Executive-Order.pdf

[109]California Energy Commission. "SB 100 Joint Agency Report: Charting a path to a 100% Clean Energy Future", accessed April 25, 2025. https://www.energy.ca.gov/sb100.

[110] Newsom, Gavin. "Governor's Letter to CARB," July 22, 2022. https://www.gov.ca.gov/wp-content/uploads/2022/07/07.22.2022-Governors-Letter-to-CARB.pdf?emrc=1054d6.

Massachusetts: The Commonwealth of Massachusetts also passed a Global Warming Solutions Act in 2008 that limited GHG emissions to 80% below 1990 levels by 2050, with interim targets. As part of this legislation, the Massachusetts Executive Office of Energy and Environmental Affairs (EEA) commissioned a roadmap to "identify cost-effective and equitable strategies to ensure Massachusetts achieves net-zero greenhouse gas emissions by 2050" across six priority sectors, including residential and commercial building electrification and efficiency.[111] In 2022, legislators passed "An Act Creating a Next-Generation Roadmap for Massachusetts Climate Policy", which codifies a 2050 net-zero target, directs the EEA to create sector sub-limits every five years, increases the Commonwealth's renewable portfolio standard and more. The legislation also directed the Department of Energy Resources (DOER) to create "a municipal opt-in specialized stretch energy code" that includes net-zero building performance standards.[112] The Massachusetts Department of Environmental Protection is also completing a rulemaking process to create a Clean Heat Standard regulation, pursuant to the Commonwealth's Clean Energy and Climate Plan for 2025 and 2030.[113]

New York: In 2019, the New York State Legislature passed the Climate Leadership and Community Protection Act (CLCPA), which set a goal of reducing GHG emissions by 85 percent by 2050 relative to 1995 levels, with an interim target of a 40 percent reduction by 2030.[114] As mandated by statute, the New York Department of Environmental Conservation (DEC) adopted these targets as legally binding in 2020 and calculated a social cost of carbon.[115] The legislation also created a Climate Action Council tasked with creating a scoping plan with recommendations to reach these goals.[116] The Scoping Plan sets a goal of electrifying one to two million residential buildings and 10-20 percent of commercial spaces by 2030, with an overall goal of electrifying 85% of homes and commercial buildings across the state by 2050.[117] The Scoping Plan also states that implementing CLCPA will require "a substantial reduction

[111]Massachusetts Executive Office of Energy and Environmental Affairs . "Massachusetts 2050 Decarbonization Roadmap Abridged." Commonwealth of Massachusetts , 2021. https://www.mass.gov/doc/ma-decarbonization-roadmap-abridged-english/download, pages 1, 26.

[112]M.J. Bradley & Associates. "MJB&A Summary: Act Creating a Next-Generation Roadmap for Massachusetts Climate Policy," April 2021. https://www.erm.com/globalassets/documents/mjba-archive/insights/mjba-summary-of-massachusetts-climate-legislation_april-2021.pdf.

[113] Massachusetts Department of Environmental Protection. "Background on the Clean Heat Standard." Mass.gov, 2025. https://www.mass.gov/info-details/background-on-the-clean-heat-standard.

[114] Kaminsky. Todd. Climate Leadership and Community Protection Act (CLCPA), S6599, Chapter 1 (2). https://www.nysenate.gov/legislation/bills/2019/S6599

[115] New York State Department of Environmental Conservation, New York Codes, Chapter 6 (496). Statewide Greenhouse Gas Emission Limits, 2020. https://dec.ny.gov/sites/default/files/2023-12/6nycrrpart496adopted2020.pdf

[116]Kaminsky. CLCPA.

[117] New York State. New York State Scoping Plan, 2019 https://climate.ny.gov/resources/scoping-plan/, page 11.

of fossil natural gas use and a strategic downsizing of the gas system" and specifically mentions the need to identify opportunities for gas line decommissioning and pursue neighborhood-scale electrification.[118] As of April 2025, the DEC has not yet submitted draft regulations for a cap-invest-trade program to reach these goals and is being sued by environmental groups for the delay.[119] Specifically relating to building decarbonization, the state legislature modified the state building code as part of the 2023-2024 budget package to "prohibit the installation of fossil-fuel equipment and building systems" for new buildings, starting in 2026 for smaller buildings and 2029 for all buildings.[120]

4.2 Passage of enabling legislation

If state code regarding investor-owned utilities is fuel specific, geothermal must be added as a technology that utilities can own and operate– whether in pilot projects or generally – in order for utilities to pursue neighborhood-scale projects. Language encouraging pilot projects and providing for cost recovery will also support the development of pilot projects. The three states under consideration have all passed legislation to this effect in recent years.

New York The 2022 Utility Thermal Energy Network and Jobs Act allows both gas and utilities to own, operate and sell thermal energy, and requires the state's seven largest utilities to propose pilot projects for the Public Service Commission's approval.[121] The legislation also includes provisions prioritizing pilots in disadvantaged communities and employment for gas system workers and local residents. It also requires prevailing wages and pre-apprenticeship programs.[122]

Massachusetts: In addition to the provisions outlined above, the "An Act Creating a Next-Generation Roadmap for Massachusetts Climate Policy" allows gas utilities to apply for "1 or more pilot projects for the development of utility-scale renewable thermal energy" and authorizes the Department of Public Utilities (DPU) to approve these projects, and cost recovery based on the balance of costs and benefits, including "the social value of greenhouse gas emissions reductions."[123] In November 2024, state

[118] Ibid, 20.

[119]"Environmental Groups Sue DEC over Failure to Launch Cap-and-Invest." Accessed May 15, 2025. https://spectrumlocalnews.com/nys/central-ny/news/2025/04/01/environmental-groups-sue-dec-over-failure-to-launch-cap-and-invest.

[120] New York State Budget, Chapter 3 (19). 2023. https://www.budget.ny.gov/pubs/archive/fy23/ex/index.html

[121]Parker, Kevin. Utility Thermal Energy Network and Jobs Act, S9422 (2022). https://docs.google.com/document/d/1FpKGFGEDkAlPN6wLtzyYijb29Vr6islonYgSRdwGkwU/edit?tab=t.0.

[122] Ibid

[123]Barrett, Michael. An Act creating a next-generation roadmap for Massachusetts climate policy, S.9, Section 16. (2021). https://malegislature.gov/bills/192/S9

policymakers passed legislation allowing gas utilities to provide heating and cooling to homes through networked geothermal energy. [124] It also requires the DPU to assess new gas line connection requests with climate impacts, stranded asset costs, and alternative energy sources in mind.[125]

California: In 2024, the California legislature passed SB 1221, which "authorize(s) gas corporations to deploy a limited and targeted number of pilot projects to decommission portions of the natural gas corporation distribution system."[126] The legislation authorizes up to 30 pilot projects and lowers the threshold for buy-in to 67% of property owners. It also requires that gas corporations recover pilot project costs related "that are deemed just and reasonable", including undepreciated gas infrastructure, and prohibits them from "from recovering behind-the-meter costs associated with the pilot projects as capital costs that are afforded a rate of return."[127] As originally written, the legislation would have reformed the obligation to serve more broadly.[128]

Obligation to serve: With the exemption of the 67% threshold for California pilot projects, all states have maintained some form of the obligation to serve, with California code stating it as "every public utility shall furnish and maintain such adequate, efficient, just, and reasonable service"[129] Massachusetts code defining in terms of the "right of user to gas or electricity"[130] and New York code framing it as "every gas corporation, every electric corporation and every municipality shall furnish and provide such service, instrumentalities and facilities as shall be safe and adequate and in all respects just and reasonable."[131] In each state, the obligation to serve has enabled the expansion of gas service to new customers as well. In the New York context, the code includes a specific provision requiring utilities to provide new gas hook-ups for buildings located less than 100 feet from an existing line.[132] In recent legislative sessions advocates have put forward the New York Clean Heat Act to reform this rule and

[124]Bill promoting a clean energy grid, advancing equity and protecting ratepayers. S.2967 (2024). https://malegislature.gov/Bills/193/S2967
[125] Ibid
[126]Min. SB 1221, Section 8B.
[127] Ibid
[128] Interview with Katie Valenzuela on March 25, 2025
[129]"Rights and Obligations of Public Utilities." California State Code, Chapter 3 (1951): 451, https://leginfo.legislature.ca.gov/faces/codes_displaySection.xhtml?lawCode=PUC&sectionNum=451
[130]"Manufacture and Sale of Gas and Electricity" Massachusetts General Law, Chapter 164: 92, https://leginfo.legislature.ca.gov/faces/codes_displaySection.xhtml?lawCode=PUC&sectionNum=451
[131]"Safe and adequate service" New York Consolidated Laws, Chapter 58, Article 4 (2024): 65, https://www.nysenate.gov/legislation/laws/PBS/65
[132]"Applications for Service." New York Consolidated Laws, Public Service Law - Public Service Law (2024), 31. https://codes.findlaw.com/ny/public-service-law/pbs-sect-31/

define the obligation to serve in terms of service not fuel.[133] Similar legislation has been introduced in Massachusetts.[134]

4.3 Engaged public utility commission

Public utility commissions in California, New York, and Massachusetts all have open regulatory proceedings relating to the future of gas distribution utilities in the context of the states' climate goals. As mentioned above, the commissions are also actively involved in promulgating regulations relating to neighborhood-scale building decarbonization pilots.

California: The California Public Utility Commission (CPUC) opened a proceeding to "Establish Policies, Processes, and Rules to Ensure Safe and Reliable Gas Systems in California and perform Long-Term Gas System Planning" in January 2020.[135] In 2022, the CPUC voted to eliminate ratepayer subsidies for extending gas lines to new customers.[136] In September 2024, the Commission said that "numerous broad and complex issues remain unresolved"[137] and opened a new rulemaking process "aimed at further reducing the state's reliance on natural gas".[138] Multiple California-based informants noted that the rulemaking process has been moving slowly and/or expressed a desire for greater leadership from the CPUC on gas transition planning.

Massachusetts: In Massachusetts, the Department of Public Utilities (DPU) opened a Future of Gas Proceeding in 2020. The DPU issued Order 20-80 in late 2023, which requires utilities to prove that they considered non-gas alternatives before recovering costs for new natural gas infrastructure[139]. In early 2024, the DPU announced a draft policy that would "require a customer seeking an extension for

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[133] "Senator Liz Krueger Announces Reintroduction of NY HEAT Act | NYSenate.Gov." Accessed May 1, 2025. https://www.nysenate.gov/newsroom/press-releases/2025/liz-krueger/senator-liz-krueger-announces-reintroduction-ny-heat-act.

[134]Owens, Steven. "Act Relative to a Tactical Transition to Affordable, Clean Thermal Energy, H.3539 (2025), Accessed May 15, 2025. https://malegislature.gov/Bills/194/H3539.

[135] https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M539/K683/539683149.PDF

[136] "California Becomes First State to Eliminate Subsidies for Gas Line Extensions amid Electrification Push | Utility Dive." Accessed May 15, 2025. https://www.utilitydive.com/news/california-puc-gas-subsidies-electrification/632006/.

[137] California Public Utilities Commission, "Order Instituting Rulemaking to Establish Policies, Processes, and Rules to Ensure Safe and Reliable Gas Systems in California and Perform Long-Term Gas System Planning," Agenda ID #22887. January 27, 2020. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M539/K683/539683149.PDF.

[138] "CPUC Launches New Rulemaking to Advance Long-Term Natural Gas Planning." September 26, 2024. https://www.cpuc.ca.gov/news-and-updates/all-news/cpuc-launches-new-rulemaking-to-advance-long-term-natural-gas-planning.

[139]Commonwealth of Massachusetts Department of Public Utilities. "Department of Public Utilities Issues Order 20-80." December 6, 2023, https://www.mass.gov/news/department-of-public-utilities-issues-order-20-80

new gas service to pay for the entire cost of connecting to the distribution system"[140] in most cases, which would represent a significant shift in the commonwealth's obligation to serve.

New York: In May 2020, the New York Public Service Commission (NYPSC) opened a proceeding in response to utilities instituting moratoria on new service connections and to align gas planning with CLCPA. Thus far, the proceeding has required gas utilities to submit long-term plans that comply with the state's GHG reduction goals, including ones in which they make no new traditional gas infrastructure investments, and to consider accelerated depreciation schedules for natural gas infrastructure.[141]

4.4 Strong advocacy ecosystems

All of the climate and TENs legislation described above is the result of advocacy by a specific set of actors, some of whom I spoke with over the course of my research. While describing the specifics of the interest groups involved in each state is outside the scope of this paper, it is clear that the large and active ecosystem of climate and environmental justice has been integral to enabling utility-financed neighborhood-scale pilots in each state. To give one example, a leader in the Framingham networked geothermal project said that "the entire genesis of the project was probably that outreach from HEET approaching the utilities and pitching the idea of doing geothermal networks as an alternative to traditional gas service". This in turn has had ripple effects, with a representative from a New York-based utility saying that his utility would not be pursuing pilot projects were it not for the work in Massachusetts.

4.5 Key projects

Each of the states I examine is at a different phase in the development of neighborhood-scale pilot projects, with some states in the early stages of site selection and regulatory approval and others actively implementing projects.

Massachusetts: Massachusetts regulators have approved three TENs pilot projects in the Commonwealth. The aforementioned networked geothermal project in Framingham – fully funded by

[140]Commonwealth of Massachusetts Department of Public Utilities. "Procedural Notice and Request for Comments Regarding Policies and Practices for Proposed Line Extension Allowances and Contributions in Aid of Construction for Gas Local Distribution Companies". February 5, 2025, https://fileservice.eea.comacloud.net/FileService.Api/file/fileroom/19883930

[141]Tung, Robin. "DecarbNation, Issue 2: The Future of Gas." BDC, December 15, 2022. https://buildingdecarb.org/decarbnation-issue-2.

Eversource – is already operational and has become the poster child for the TENs model.[142] In Boston, the Boston Housing Authority (BHA) and utility National Grid are partnering to convert 129 public housing buildings at Franklin Field to a networked geothermal system.[143] In this project, BHA will be responsible for all building conversion work, with support from the rate-payer-funded Mass Save energy efficiency program, and National Grid will be responsible for the borefield, pumphouse and geothermal network.[144] The project is currently in the design phase for interior work and borefield, and is out for bidding for electrical upgrades.[145] National Grid canceled a planned TENs pilot project in Lowell due to higher than anticipated per customer costs, which a spokesperson for the utility attributed to inflation, rising supply costs, geologic conditions and a lack of competition for geothermal construction.[146] In 2023, the Massachusetts Clean Energy Center provided the non-profit organization HEET with $450,000 to award to municipalities and community members to complete networked geothermal feasibility studies across the state.[147]

California: As mentioned in the literature review, the utility PG&E has completed smaller non-pipeline alternative projects that have electrified fewer than five customers through its Alternative Energy Program. Prior to the passage of SB1221, the utility established a Zonal Electrification Equity Pilot with the goal of electrifying 72 Bay Area homes in low-income areas.[148] This pilot will be paid for utilizing gas decommissioning funds along with federal and state incentives. In 2022, PG&E proposed a project to electrify about 400 apartments at California State Monterey Bay campus but pulled the plug on the project in February 2025 due to disagreements about how costs would be treated.[149] Other utilities do not have materials readily available online about neighborhood-scale pilots or planning. However, they will be required to identify potential sites for gas line decommissioning, and have the option to put

[142] "Geothermal System Is a US First | Smart Cities Dive." Accessed May 15, 2025. https://www.smartcitiesdive.com/news/first-networked-geothermal-utility-eversource-framingham-building-decarbonization/718015/.

[143]Daniel, Seth. "Franklin Field Complex Will Be Outfitted with Geothermal Heating, Cooling Technology | Dorchester Reporter". January 26, 2024. https://www.dotnews.com/2024/franklin-field-complex-will-be-outfitted-geothermal-heating-cooling.

[144] Ibid

[145] Interview with Joel Wood, March 31, 2025

[146] Borkhetaria, Bhaamati. "National Grid Pulls Plug on a Geothermal Pilot Program in Lowell." CommonWealth Beacon, February 4, 2025. http://commonwealthbeacon.org/energy/national-grid-pulls-plug-on-a-geothermal-pilot-program-in-lowell/.

[147]"Kickstart Massachusetts." Accessed May 15, 2025. https://www.heet.org/Kickstart-Massachusetts.

[148] Kuykendall, Rachel. "SB 1221 Implementation– PG&E's Role, Goals, and Needs." n.d. https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/meeting-documents/workshops/senate-bill-1221-workshop/pgne-sb-1221-presentation.pdf.

[149] Klivans, Laura. "PG&E Wants to Pull the Plug on Electrification Project at CSU Monterey Bay | KQED," February 3, 2025. https://www.kqed.org/science/1995529/this-project-is-a-win-for-the-climate-and-ratepayers-why-is-pge-pulling-the-plug.

forward pilot proposals, in the coming year as part of SB1221 implementation. Lastly, a team of researchers in the Bay Area received a grant from the California Energy Commission to develop a "prototype EcoBlock" that includes energy efficiency upgrades, electrification, and rooftop solar.[150] This project is currently in its implementation phase.

New York: There are currently nine proposed pilot projects in the engineering phase of the Utility Thermal Energy Network Act implementation process. Con Edison and National Grid have each proposed three projects that have been approved by the NYPSC to this point, and three other utilities have been approved for one each.[151] The projects are located across the state but are most concentrated in and around New York City.

[150]EcoBlock. "About," April 7, 2016. https://ecoblock.berkeley.edu/about/.

[151]Upgrade NY. "Nine Utility Thermal Energy Network Pilot Projects Advance, Moving New York Closer To Neighborhood-Scale Clean Heat And Cooling." Accessed April 15, 2025. https://www.upgradeny.org/nine-utility-thermal-energy-network-pilot-projects-advance.

5. Results: Thematic analysis of interviews

The 19 individuals I interviewed raised many of the same themes; while the challenges and barriers they identified were similar, the solutions and ideas they offered varied greatly. I came into my interviews hypothesizing two central barriers to neighborhood-scale building decarbonization: financing and community buy-in. While these barriers bore out in my interviews, I realized that challenges around financing were closely linked to questions of who pays for and owns the system and that high costs are a challenge independent of financing. I also identified a bucket of themes relating to planning and coordination within the model. I report results for challenges and opportunities for neighborhood-scale building decarbonization across the following themes: costs, financing, community buy-in, planning and coordination, and a utility-led approach. I also briefly discuss the possibility of a state-led approach, along with sharing background on key players and informant perceptions of neighborhood-scale building decarbonization.

5.1 Key players and informant perceptions

I began each conversation by asking the interviewee to introduce themselves and their involvement with neighborhood-scale building decarbonization. They uniformly saw a role for themselves and their organization in a neighborhood-scale building decarbonization model and viewed it as complementary to building-by-building decarbonization. Some viewed the model (i.e. neighborhood-scale building decarbonization) as a difficult-to-implement and thought that it should be used in a targeted, limited way, while others viewed it as a scalable approach that, in the case of TENS, could displace natural gas utilities. In the section below, I introduce the informants and how they responded to these introductory questions.

Public sector employees: I interviewed two municipal staff involved in neighborhood-scale building decarbonization. The **Massachusetts municipal employee** described the City's role as a touch point for residents and a convener while the **California municipal employee** largely described its role in terms of code compliance and financial administration. For **Joel Wool, the Deputy Administrator for Sustainability and Capital Transformation at the Boston Housing Authority (BHA)**, neighborhood-scale building decarbonization represents part of his team's broader efforts to electrify and improve the housing authority's building stock.

Community-based and environmental justice groups: For organizations focused on ensuring an equitable clean energy transition, the promise of the model focused largely on its impact on community members. Alliance of Californians for Community Action (ACCE) is a state-wide member-based racial and economic organization whose Contra Costa chapter is campaigning to win a neighborhood-scale

building decarbonization project in Richmond. **David Sharples, the Contra Costa Director of ACCE** said that "Neighborhood-scale decarbonization makes a lot of sense for us, because it's something that improves people's housing, improves their lives and also improves the environment." He described his team's role as being "to build organization around this campaign" and spoke to ACCE's efforts to sign up and develop member leaders, organize educational community events and put pressure on elected officials and the utility to fund and implement the project. **Katie Valenzuela, the facilitator of California's Building Energy, Equity, & Power (BEEP) Coalition**, said that it is "quasi-absurd how much money and time and advocacy has gone into [building decarbonization] and still hasn't solved basic access questions." She described BEEP Coalition's role as "local work to support pilots to share best practices with each other" and to "help that experience drive state policies and funding decisions" that reflect on-the-ground learnings. She says that neighborhood-scale decarbonization "makes sense from organizing, buy-in, cost, program-effectiveness [perspective]" and pointed to BEEP member organizations' involvement in ongoing pilot projects and a San Joaquin Valley Pilot Program that installed electric appliances in low-income households using wood or propane.

Utilities and energy providers: I interviewed five individuals involved in providing energy services, four of whom work at investor-owned utilities and one who works at a community choice aggregator. I interviewed **Rachel Wittman**, who works at a California-based investor-owned utility implementing zonal pilots but spoke in her individual capacity. Speaking to the utility's net zero GHG emissions target, she said that "Every integrated assessment model says that building decarbonization where feasible is the most affordable lever that you can pull." I also spoke with a **representative from a California Community Choice Aggregator** (CCA). The representative from the CCA described her organization's role in the context of neighborhood-scale as being to "educate, assist and provide services for our customers that get them where they want to be." In addition, I interviewed **Eric Bosworth**, who managed Eversource's development and implementation of the Framingham TENs project but spoke in his individual capacity. I also spoke with a **representative from a New York State-based utility** who requested not to be named in connection to this research. He emphasized the high costs of TENs, describing it as "a tool in the toolbox, not a replacement of the gas system." Lastly, I interviewed **Morgan Hood**, who works as the Manager of Innovative Products and Services at Vermont Gas and spoke in her capacity as the **Co-Founder and Co-Leader of the Utility Networked Geothermal Collaborative**, which together 29 North American utilities with the goal of breaking down silos and sharing learnings. Morgan Hood said that she is "optimistic about the case for thermal energy networks, the case for geothermal, it's just going to take a lot of patience. [...] We're looking out into the future, like really long term here, to get to the state that we want it to be, but we're making some really important steps."

Policy experts and consultants: I spoke with representatives from three organizations, Building Power Resource Center (BPRC), Gridworks, and Hua Nani Partners that provide technical assistance, policy analysis, and other support to entities working on the clean energy transition. **Yong Jung Cho, the Executive Director of BPRC** described BPRC's role as "campaign strategy, technical assistance on project development, support and facilitation of stakeholders who might not regularly work with one another on an implementation project" along with policy analysis, research into financing mechanisms, and grant writing. **Neha Bazaj, the California and Hawaii Director of Gridworks** described her involvement in neighborhood-scale as being a "supportive research role." I also spoke with **Claire Halbrook**, a Principal at Hua Nani Partners, a climate consulting firm. Claire Halbrook previously worked at both Gridworks and PG&E and spoke to her involvement with neighborhood-scale building decarbonization at those institutions. Lastly, I spoke with **Sonal Jessel**, who previously served as the Policy Director of WE ACT for Environmental Justice and currently works as a Senior Program Director at BPRC, in her individual capacity.

Advocates: I also interviewed representatives of HEET and BDC, two of the leading proponents of thermal energy networks and, in the case of BDC, neighborhood-scale building decarbonization more broadly. **Andrew Iliff, the Policy Director of HEET** described his team's mission as being "to scale the technology", referring to TENs. **Beckie Menten, the California Director of BDC**, described her role as leading legislative and regulatory engagement and serving as a "liaison to interested communities" for the implementation of SB 1221, the zonal pilot program. **Allison Considine, the Senior Campaign and Communications Manager for BDC** in New York, described her role in terms of strategy development and coalition building to "win an equitable transition to neighborhood-scale building decarb[onization] through a lot of different venues: legislative, regulatory, public service commission proceedings, and shifting the market and the narrative."

I also spoke with **Therese Peffer, the Principal Investigator of EcoBlock** and the Associate Director of the California Institute for Energy & Environment (CIEE) at the University of California-Berkeley, and **Johnny Fry, the U.S. Country Manager for Celsius Energy**, which completed the borefields for the Framingham networked geothermal project.

5.2 Costs

Nearly every informant identified upfront high costs as a central challenge to expanding neighborhood-scale building decarbonization. Some of the trends they shared were common to other models of residential building decarbonization while others were specific to projects at the neighborhood scale. They echoed existing literature on building decarbonization in expressing the health benefits of

addressing deferred maintenance regardless of electrification, the economic benefits of weatherization, and the long-term costs of inaction on climate change. For both neighborhood-scale technologies, pilot expenses are driven by higher per-home costs because all homes on the block are electrifying (not just the least expensive) and the limited number of contractors able to take on the complex project scope. For TENs, additional drivers of high upfront costs are drilling and pipe laying expenses, the lack of a competitive geothermal drilling market, and contractors' lack of experience with ground-source heat pumps. Even as informants articulated high costs as central barriers, they also emphasized that neighborhood-scale projects were necessary, cost-effective when defined in broader terms, and likely to decrease in cost going forward. These dynamics can be summarized as follows:

Neighborhood-scale costs: key challenges and opportunities	
Challenges	**Opportunities**
Electric networks and TENs: ● Many building typologies with different scopes of work in one project ● A small number of homes with the largest maintenance needs drive up overall costs ● Limited number of contractors ● Community outreach expenses	*Electric networks and TENs:* ● Costs likely to decrease with experience and market development ● Potential for bulk purchasing and aggregation to drive down costs at scale ● Expanding heat pump options
Specific to TENs: ● Drilling boreholes and laying pipe is expensive, especially because of the limited number of drillers ● More expensive than air-source systems	*Specific to TENs:* ● Long-term cost savings by decreasing stress on the grid ● Per-building costs decrease as systems expand in size

Cost-related challenges

Costs common to all residential building decarbonization projects: Many of the drivers of high costs voiced by informants mirror the broader literature on existing building decarbonization project costs. Informants shared that many buildings are old and not up-to-code, with outdated heating and electrical systems and poor insulation and ventilation. They noted that they have often underestimated the costs of weatherization, health and safety upgrades, and building conversions at the outset. Various informants also reported that levels of deferred maintenance were highest in low-income communities.

Costs specific to neighborhood-scale projects: Respondents emphasized that retrofitting multiple building typologies in various states of repair drives up costs for neighborhood-scale projects. "We're not talking cookie cutter homes from the 90s that were all laid down with ducting and forced air furnaces. That would be a dream," said Eric Bosworth. "I found asbestos, mold, knob and tube wiring, steam systems, hydronic systems, electric systems. You name it and it existed in this neighborhood." Others also reported that aiming to electrify every building in a given area also drives up costs because a small number of homes typically require the most extensive, expensive repairs and conversions, and would not be prioritized outside of neighborhood-scale approach. Informants also noted that there are a limited number of firms equipped to coordinate neighborhood-scale projects from beginning to end. While some expressed optimism that the building trades could help to fill this gap, others opined that utilizing the building trades can lead to larger crew sizes and higher costs. Looking toward larger-scale projects, Beckie Menten from BDC also raised concerns about the expense of community engagement for larger projects, saying that "the cost of running the necessary marketing education and outreach campaigns to educate everybody, to get them to yes, can really impact the cost effectiveness of this model overall."

Costs specific to TENs: The upfront costs of TENs, driven largely by the costs of drilling boreholes and laying pipes, currently outstrips the costs of air-source systems. Morgan Hood of UNGC shared that Vermont Gas has completed multiple feasibility studies and has not yet identified a cost-effective business model for TENs compared to air-source heat pump electrification, emphasizing that these feasibility studies include the lower energy and maintenance costs of geothermal compared to air-source systems over the course of the project's lifetime. In the Northeast, informants report that the limited number of geothermal drillers also increase costs.

Cost-related opportunities

Cost savings by decreasing stress on the grid: Practitioners emphasized the long-term benefits to the grid of investing in neighborhood-scale building decarbonization projects that distributed energy resources. In the words of Morgan Hood of UNGC, "when we look at the growth that needs to happen to the electric grid in order to electrify the way we want to, there are so many obstacles in their way – crossing state lines, the permitting [...] to getting [the generation] where it needs to go, and the costs associated with that, thermal energy networks and district energy systems in general become more attractive."

Costs likely to decrease with experience and market development: Individuals working on both electric networks and TENs emphasized that costs are likely to decrease as they gain experience with

neighborhood-scale projects, the industry workforce expands, and heat pump technologies evolve. TENs proponents specifically highlighted the potential of dual air- and ground-source heat pumps, which could allow customers to initially use an air-source heating system and convert to a ground-source heating system if a geothermal loop comes to their neighborhood. Individuals working on TENs also emphasized the cost saving potential of drilling innovations and utilizing heat sinks. To the latter point, all utility representatives involved in TENs pilots also spoke about the opportunity to use waste heat from sources like waste treatment facilities and data centers to decrease drilling costs and supplement energy storage. More broadly, they mentioned attempting to ensure a balanced heating and cooling load as a way to improve efficiency and decrease costs. Lastly, some including Johnny Fry from Celsius Energy suggested that workforce development will significantly decrease drilling costs, saying "As there is larger workforce development and you are not limited by number of providers, naturally there is going to be increases in competition and further necessary focus on efficiency and delivery to make this work."

Economies of scale: While the model remains too new to collect evidence to this effect, a number of respondents mentioned economies of scale for larger TENs systems and for bulk purchasing of heat pumps and other equipment. For thermal networks, a number of informants noted that projects are more affordable at a larger scale, both in terms of servicing a larger amount of load and in terms of expanding existing projects. The Framingham project is planning a second loop, which respondents said will make the existing system more efficient and resilient. More specifically, the expansion will not require another central pipehouse and will require relatively fewer boreholes. In the words of one informant, "There's always a need for central infrastructure but that need decreases [...] In addition to the benefits of learning that help decrease costs, [...] the actual infrastructure needed to keep building onto this system is going to be less."

5.3 Financing

Informants articulated that fully funded utility projects, while hugely beneficial in the pilot stage, would be unlikely to continue as the model expands. In the face of the high upfront costs described above, interviewees identified robust funding streams as critical for ensuring that the projects are accessible to all residents, including LMI households unable to cover upfront electrification costs. Informants identified the administrative burdens of accessing and braided funding and the lack of federal support for climate action as major challenges. They pointed to gas line decommissioning, state-level programs, and low-interest loans as key opportunities. These dynamics can be summarized as follows:

Neighborhood-scale financing: key challenges and opportunities	
Challenges	**Opportunities**
● Existing incentives are insufficient to cover all costs ● Incentives are difficult to access for both residents and contractors ● Funding is spread out across many agencies and programs, creating a large administrative burden ● Lack of federal support is a major impediment to future projects	● Repurposing utility resources intended for gas line repair and replacement to neighborhood-scale decarbonization and gas line decommissioning ● State programs and ratepayer funded programs that create single pots of money and/or coordinate other funding streams ● Low-interest loans and private financing for middle- and upper-class communities

Financing challenges

Incentives are insufficient and difficult to access: Informants complained that specific funding resources to support habitability repairs and pre-electrification conversions are often limited, despite being critical for health and safety, and necessary in order to access electrification incentives. Katie Valenzuela of BEEP Coalition emphasized that "[Electrification] rebates are hard for low-income people to access. They can't afford to wait, they are inadequate to cover costs, there is no program to cover additional repairs; and some of the appliances don't work that well if the building isn't sealed." The municipal employee from California also emphasized that accessing electrification incentives is a significant burden for contractors: "[Contractors] need to be well versed in the paperwork necessary to be able to leverage that rebate or that incentive. With a state program, it is so freaking hard to fill out that paperwork. Good God. How the hell are people supposed to figure this out?" While these challenges are not distinct to neighborhood-scale projects, their difficulty mounts for larger projects.

Braiding funds is difficult: Many informants also spoke to the challenge of combining many different funding sources as a specific challenge for neighborhood-scale projects. "Unless someone is willing to put down millions–one entity–you have to braid or create a financial stack, versus a single home [where] it's feasible you could find one funding source and move on to the next home" said Sonal Jessel, noting that different building typologies further increases the difficulty of finding a single funding source. The California CCA representative described blending and braiding funds as "a very disjointed way to do this type of project, especially for the first time. [...]Program administrators or program managers can take on a lot of that coordination behind the scenes, but I myself would not want to be the program manager that is taking on that work for these projects, because it seems extensive." Katie Valenzuela of

BEEP echoed this sentiment, saying "The biggest obstacle is that the money is too spread out between bureaucratic and legislative programs – that's a fixable problem because we created it."

Lack of federal support: Lastly, many interviewees shared the sentiment that the current federal political context represents a significant impediment to expanding neighborhood-scale building decarbonization, both in terms of rollbacks to IRA incentives and the current near impossibility of passing federal legislation that would incentivize large-scale clean energy projects.

Financing opportunities

State and federal incentives: Informants are currently utilizing federal and state-level incentives to support neighborhood-scale projects, including IRA rebates, grant funding, and state level programs. In California, multiple interviewees spoke positively about their experience with the Equitable Building Decarbonization (EBD) Program, including Katie Valenzuela who said, "what we like is how EBD is structured: one fund, a pot of money that's easy to track and easy to access with built-in expectations regarding community engagement and tenant protection." She expressed support for its continued funding and raised the prospect of moving resources from net metering to support its expansion. She described net metering as "largely subsidizing solar for people who don't need [subsidies]" leveling a common critique that rooftop solar has primarily benefited wealthy homeowners, while shifting costs to low-income communities.[152] In Massachusetts, a number of informants pointed to Mass Save, a ratepayer-funded energy efficiency program, as another possible funding pathway.[153] The Massachusetts municipal employee noted that "Mass Save is starting to go down the pathway of decarbonization, so I think it's aligning in that sense" and mentioned ongoing work to create some type of decarbonization clearinghouse for the Commonwealth.[154] For middle- and upper-class neighborhoods, Sonal Jessel raised the low-interest Greenhouse Gas Reduction Fund loans – which are frozen as of April 2025 [155]– as a promising financing avenue in the case that they start to flow.

Additional state funding: A number of interviewees advocated for increased state-level funding for building decarbonization, particularly for home repairs and energy efficiency upgrades. "As a state, we have a lot of spending on efficiency and we should be spending a lot more," said Joel Wool of BHA,

[152]National Academies of Sciences, Engineering, and Medicine. 2023. The Role of Net Metering in the Evolving Electricity System, Chapter 5. Washington, DC: The National Academies Press. https://doi.org/10.17226/26704.
[153]Informants note that this funding pathway was not available for the Framingham project because the project was utility-led and Mass Save is rate payer funded and administered.
[154]VEIC. "Options for a Building Decarbonization Clearinghouse." November 2024. https://www.mass.gov/doc/ma-building-decarbonization-clearinghouse-english/download.
[155]"EPA Granted Appellate Stay after Judge Rules to End GGRF Funding Freeze | ESG Dive." Accessed May 15, 2025. https://www.utilitydive.com/news/epa-dc-appeals-court-stay-greenhouse-ggrf-funding-freeze/745677/.

adding that he wanted to see some of this funding come from taxpayers. Many others also expressed a desire for additional state-level non-rate-payer-funded programs to fund neighborhood-scale building decarbonization projects. In the words of Beckie Menten from BDC "Significant investment from state budgets in home remediation work is going to be one of the most important if we're centering frontline communities [and] we don't want to drive up costs for ratepayers. It's time for the states to start putting their money behind their policies in my mind."

Local funding: While most individuals focused on state- and federal- actions, some also mentioned efforts to secure municipal funding for projects. David Sharples of ACCE said that his team is organizing to get the City of Richmond to "fund the work that's hard to fund, like weatherization and getting rid of mold, lead paint and asbestos." EcoBlock's Therese Peffer said of the City of Oakland "it's great that you have this climate action plan. How are you going to fund [taking] out all the natural gas from the City of Oakland in 15 years?" and suggested that the City work with a local green bank. Advocates also expressed a sense that local governments could be doing more to support neighborhood-scale building decarbonization, including Sonal Jessel who said that "local governments need to be more aggressive in getting funding to do the projects and ideologically understand and economically understand the benefits of the work."

Loans and private financing: While much of the rationale for and discourse around neighborhood-scale focused on low-income communities, interviewees mentioned different financing pathways for middle- and upper-income households. "Some [communities] can afford to do it on their own and just need the guidance" said Therese Peffer of EcoBlock. "You could start with the wealthier communities, get them going, and then through that lesson learned of not having to come up with that upfront capital costs, you could help develop those lessons learned for other communities." Some respondents also mentioned the opportunity to utilize low-interest financing and on-bill financing as a promising avenue to recoup energy efficiency and electrification costs while limiting upfront expenditures. Other informants also mentioned microgrids and virtual power plants as revenue streams that could potentially be utilized to recoup upfront costs. Lastly, multiple informants raised the possibility of utilizing an energy-as-a-service model in which customers would pay for energy services (e.g. space and/or water heating) and the service company would own and operate equipment. In this model, customers would not cover the upfront costs of purchasing and installing the equipment, which proponents argue could accelerate neighborhood-scale electrification.

Key opportunity – Gas line decommissioning: Decommissioning aging gas pipelines and repurposing utility resources intended for their repair to neighborhood-scale building decarbonization was by far the most commonly discussed opportunity to finance the high upfront costs of neighborhood-scale building decarbonization.

Echoing the literature, interviewees noted that continuing to maintain the existing natural gas infrastructure as customers electrify will drive up prices for the remaining customers. "It's a market signal, why can't we let [gas] prices go up?" Rachel Wittman asked rhetorically, answering that "The folks left paying the prices are the people who can't electrify proactively like low-income households or renters [...] It is fundamentally an equity issue." She went on to describe appliance-by-appliance building electrification as "Hole punching leaves off the plant when you still have the entire tree to sustain, still need to make the same nutrients: the same cost to maintain the system." Various other informants also described neighborhood-scale building decarbonization as creating the opportunity to cut off a branch of the tree. Informants echoed the literature in describing zonal decarbonization as the best opportunity to shrink the gas system. In Claire Halbrook's words, "neighborhood electrification or decarbonization can happen without gas system decommissioning, but not really the other way around."

To many informants, the opportunity to decommission gas lines is also one of the core opportunities of neighborhood-scale building decarbonization. Proponents of coupling neighborhood-scale building decarbonization with gas line decommissioning, who included some utility representatives and advocates, see it as the way to decrease gas spending while enabling affordable electrification. Beckie Menten at BDC, which has helped orient the conversation around neighborhood-scale building decarbonization around gas line decommissioning, summarizes the economic argument as follows "it is a better investment for utility ratepayers overall to shrink the gas system and invest in these buildings [to electrify them] than it is to continue expanding the gas system." BDC and utility representatives proposed prioritizing "cost-effective" projects where the costs of electrification are less than the costs of the planned gas system work. Some interviewees, including Neha Bazaj of Gridworks, expressed pessimism that pruning the gas line would be sufficient to address rising gas costs, saying "Costs of gas system, even with decommissioning will be spread across smaller and smaller number of customers and put upward pressure on the amount that people need to spend on gas service."

In order to decommission gas lines – and access the associated utility resources – 100% customers in the project area must electrify or otherwise convert all gas-powered appliances. As will be discussed further below, informants report that reaching this threshold is very difficult.

5.4 Community buy-in

All informants agreed that getting customer buy-in for neighborhood-scale building decarbonization is a major barrier. The communities who this model is intended to benefit have experienced structural discrimination in accessing housing and have been subject to predatory lending practices.[156] They are likely to be skeptical of these projects but their buy-in will be necessary project success, particularly because of the obligation to serve. In Sonal Jessel's words "At the end of the day, if you have the funding, and residents say no, you still don't get to do the project." Some interviewees focused their comments on the importance of customer organizing and education while others put a greater emphasis on regulatory reform as a pathway to scale. Despite its challenges, many participants expressed the opportunity for meaningful community engagement and organizing as one of the core benefits of a neighborhood-scale approach to building decarbonization. These dynamics can be summarized as follows:

Neighborhood-scale community buy-in: key challenges and opportunities	
Challenges	**Opportunities**
● The obligation to serve requires 100% buy-in before decommissioning gas lines ● Getting 100% buy-in is very difficult ● A large number of building owners in a project area creates a large number of separate decision makers ● Neighborhood-scale work can be more invasive because it occurs over a longer time period and, in the case of TENs, involves drilling ● Low levels of trust and concerns about resilience with a single fuel source	● Reforming the obligation to serve ● Identifying trusted messengers to serve as liaisons at the hyper-local level and resourcing community organizers to lead community outreach ● Re-training utility gas marketing staff to market TENs ● Setting expectations clearly and communicating proactively ● Engaging and educating community members who would otherwise not be aware of – or able to access – building electrification

[156]Quillian, Lincoln, John J. Lee, and Brandon Honoré. "Racial discrimination in the US housing and mortgage lending markets: a quantitative review of trends, 1976–2016." *Race and Social Problems* 12 (2020): 13-28.

Community buy-in challenges

Obligation to serve: In cases where there is a fuel-specific obligation to serve – or states where regulatory commissions have interpreted state code as such – projects require buy-in from 100% of affected customers to move forward with decommissioning a gas line. Respondents uniformly cited this as a challenge for implementing neighborhood-scale projects but split on the extent to which reforming it was the first-order problem. Representatives from the advocacy organizations BDC and HEET stressed obligation to serve reform as a necessary pre-requisite for the model. "It all hinges on not having to go door to door, organizing people one by one, which is just not a way to do an energy transition," said Allison Considine of BDC. Speaking to SB1221's 67% threshold for zonal pilots, Beckie Menten of BDC said "Ideally, we would love to see something closer to simple majority for a pilot like this, but the comfort of the legislature was not there. It makes sense in my mind to pilot this approach and to understand how customers respond to basically being told that they can no longer be served with natural gas. It's that tension between personal choice and our climate mandate."

Others, especially utilities and environmental justice groups, expressed hesitancy about an approach that took away customer choice. In the words of one informant, "I don't think the dictator approach is the right way to go," adding that "If you force people to electrify, you will get huge public backlash and legislation that won't allow you to do the projects anymore." Eric Bosworth echoed this concern and emphasized that "Geothermal at this point needs market development, it needs momentum. We need to go from a one-off demonstration pilot to multiple systems in and running, and if we shoot it in the foot before it gets there by forcing customers to choose or forcing them over onto the system, we may not build the momentum that we need." The representative for the California CCA also voiced concern about this approach, saying "I personally don't want to be the one to go into a home that does not want XYZ services and say, now you're getting XYZ services and here's what you got to do. I don't want to be that person. I don't want to be that entity."

100% buy-in is difficult: Informants report that no existing neighborhood-scale building decarbonization projects with multiple building owners have 100% customer buy-in and emphasized that reaching this threshold is extremely difficult. Rachel Wittman noted that "even for single building projects where the costs are fully covered [...] uptake is less than half, most people are still saying no. With zonal, that compounds." David Sharples of ACCE, whose organization has been running a canvass operation in support of neighborhood-scale building decarbonization echoed this sentiment. Sonal Jessel underscored this point saying "100% yes on a block feels impossible. It's not just 'are people interested in clean energy or not?' It's a question of where people are in their lives more generally," mentioning long-term hospitalization and house fires as examples of barriers to participation.

Navigating many decision makers: For neighborhood-scale building decarbonization projects where there are many renters and/or privately-owned single-family homes, informants emphasize the large number of people who have to get to "yes" as a barrier. "Each and every home and building needs a touch point, it needs a decisionmaker," emphasized Claire Halbrook. "There's also people who live out of state or that are going to be hard to reach," said David Sharples of ACCE, referencing renter-occupied homes with absentee landlords. Various informants also noted the broader difficulty of community engagement in tenant-occupied buildings and the question of the extent to which renters should have decision making authority in this context. Allison Considine noted that even the first step of getting residents to consent to a home energy audit for New York utility TENs pilots is "a big organizing effort. Utilities are not organizers, right? They haven't had to be."

Buy-in is often required before the project is finalized: Informants noted that projects often have to start getting buy-in before the project is a done deal and shared that it is difficult not to be able to promise benefits while also gaining buy-in. For example, the Massachusetts municipal employee shared that "At step zero in a utility selection process where it is unclear whether the community would be picked as the host, directly engaging residents too early to advocate for the pilot could cause confusion and risk eroding trust if it doesn't come together."

Disruptive scope of work: Individuals involved with project implementation emphasized that building electrification can be an intensive, invasive process, especially when done at the neighborhood scale because project timelines are longer. "They can't just say yes to the good stuff," emphasized the representative of California CCA. "They have to say yes with a full understanding and expectations of what the project is: you're going to get all this great stuff, but we're going to be in and out of your house for the next three months." She also expressed concern that combining different funding streams to enable projects to move forward can negatively impact customer service by creating more complex processes. In addition to inside-the-home renovations, individuals working on TENs projects also mentioned the specific disruption of drilling boreholes, which is loud and generates waste products.

Concerns about equity implications: echoing the literature on barriers to building decarbonization, respondents raised customer concerns about utility bills and housing security. "I don't think there is quite price parity [for electricity]" said Neha Bazaj of Gridworks. "Price is always going to be customers' biggest concern." Informants focused on environmental justice highlighted concerns that increased utility bills or rent payments after electrification could lead to displacement. For example, in response to the talking points about the negative health impacts of gas, Katie Valenzuela of BEEP Coalition said: "You know what also kills people? Losing their housing!"

Education, resilience, and gas stoves: Informants also echoed existing literature regarding the importance of customer education, speaking to the need to build familiarity with new technologies and address concerns about giving up gas stoves in order to create buy-in. "Nobody is going to move forward with a new system if they don't understand it and they don't feel comfortable that it is going to keep them warm in the winter, cool in the summer," said Eric Bosworth. Beckie Menten of BDC also noted that "this zonal conversation goes nowhere the first time a customer is retrofitted to all electric and the power goes out for five days. And they have no heat and no form of cooking technology." Others noted that many gas appliances may not be usable during power outages either, but still mentioned attachment to gas stoves as a major barrier to getting 100% community buy-in.

Community buy-in opportunities

Utility marketing: Some individuals spoke positively about the role of utilities in community engagement. Allison Considine of BDC said "[Con Edison] is doing a really good job of explaining this marketing, making it really accessible, making it easy for people to participate in the home energy audits and learn about utility TEN pilots" and another informant mentioned the levels of customer interest in the Framingham project, noting that Eversource got 40 sign-ups from residents during its first weekend of canvassing. Eric Bosworth shared that "[Eversource] retrained a number of our gas sales and marketing team members to, for lack of a better term, sell geothermal. So they helped with fact sheets and talking points and one pagers and door hangers, and they got out there in the community and started walking around and knocking doors and talking to people." Others felt that utilities would not have sufficient trust or local understanding to get community buy-in and advocated for a stronger role for community-based organizations.

Trusted messengers: multiple individuals spoke to the importance of identifying trusted individuals and organizations in the places where projects take place. Interviewees mentioned everyone from churches, Boys and Girls Clubs, and social service agencies to elected officials, utilities and advocacy organizations as important actors because of the hyperlocal scale of projects. Individuals involved in the San Joaquin Pilot and EcoBlock referenced their "community intermediaries" and "community liaison", respectively, as critical to getting out the word and ensuring equitable access. Program participants "need someone they can trust who they can call – it's not the role of contractors," said Katie Valenzuela of BEEP Coalition.

Community organizing: Advocates and environmental justice organizations emphasized the role of community-based organizations in building support. "You're going to have so much more success when you start from that very community organizing based perspective than when you start from a top-down

perspective," said Beckie Menten of BDC. Beckie and other California respondents cited ACCE's efforts in Richmond as a model for this work and emphasized the importance of resourcing community-based organizations (CBOs) to do this work. The ACCE team has organized leadership development trainings, town halls about the health impacts of gas stoves and induction stove demonstrations, as well as turning out members to City Council meetings in support of the project. Therese Peffer of EcoBlock also emphasized the role of the community itself saying that "One of the biggest lessons learned is [to] bring in the community as a decision maker, so they have skin in the game right away." Regarding the challenge of getting 100% buy-in, Sonal Jessel said "CBOs and organizers have been organizing against much harder issues for a very long time."

Customer education: Much of informants' comments on the role of organizing tied to the role of customer education. For example, Claire Halbrook said that "someone, if not many someones, need to be educating customers about indoor air quality and comfort improvements from electric appliances, and just making sure that they're aware of electric appliances and all the evolutions in those technologies." Multiple respondents pointed to the importance of educating customers about induction stoves as a particularly high priority. Eric Bosworth from Eversource also underscored the importance of providing informational materials to customers, saying that he was surprised by detailed and technical questions he received from residents. "Being prepared to provide that material, to get into the community, to talk to them, to answer their questions, is absolutely critical to the acceptance of the technology in general." Individuals involved with the Framingham project and the California CCA representative also highlighted the importance of maintaining strong lines of communication for the duration of the project, so residents know what to expect throughout. "If there's already a trust barrier, there's already a lack of awareness, it's extremely important to educate the customer and provide true expectations of what is going to happen," she said. Informants also noted that this model had the potential to reach and engage people who would otherwise be unaware of – and unable to access building decarbonization.

Concrete resident benefits: Respondents report that once projects are implemented, people typically offer positive feedback and adapt to new technologies. Individuals involved in the Framingham project said that people generally adapted quickly to heat pump systems or even reported not noticing the difference. For that project, and other projects underway, many participants received central air conditioning and retrofits that made their homes more energy efficient and comfortable. "If I was a homeowner and somebody came and offered me a lot of money to upgrade my house, I would go for it," David Sharples from ACCE said with regards to electric network projects. "I don't think it's going to be hard to show people that want this," said Morgan Hood of UNGC. "I have yet to meet someone to whom the idea of affordable accessible thermal energy networks is like 'I think that's bad.'"

Informants in California and New England also noted that many homes lack central air conditioning systems and experience significant improvements in thermal comfort as a result of switching to heat pump systems. Another interviewee noted that many systems have air handling units that filter air in rooms that were previously never filtered. More broadly, informants spoke to the opportunity to build a greater sense of connection and empowerment through approaching decarbonization at the block scale, especially when projects have a sense of community ownership. Therese Peffer described people as "lighting up" when she recounts her experience with the EcoBlock project. "You're tapping into something here that is really very integral to the human experience", she said.

Regulatory changes: Individuals who support modifying the obligation to serve point to the New York HEAT Act[157] and recently passed legislation in Washington State[158] as promising avenues to expand neighborhood-scale decarbonization. In the California context, some informants also voiced support for the 67% threshold for the state's zonal pilots and forthcoming clean appliance standards as supporting the goals of neighborhood-scale building decarbonization. More broadly, a number of individuals cited the importance of creating beneficial electrification rates as key to securing customer buy in.

5.5 Planning and coordination

While informants were primarily involved with pilot programs, they offered a variety of insights regarding the structural challenges and potential of neighborhood-scale, including aligning planning timelines with gas line and appliance timelines, how to balance equity and customer choice considerations, and coordinating across stakeholders. In the words of one informant, "all of this work ends up having so many more intricacies than you realize when you're just dreaming up the possibilities." These dynamics can be summarized as follows:

[157]"Senator Liz Krueger Announces Reintroduction of NY HEAT Act | NYSenate.Gov." Accessed May 15, 2025. https://www.nysenate.gov/newsroom/press-releases/2025/liz-krueger/senator-liz-krueger-announces-reintroduction-ny-heat-act.

[158] Doglio, Fitzgibbon. "Supporting Washington's clean energy economy and transitioning to a clean, affordable, and reliable energy future." HB 1589 (2024). https://app.leg.wa.gov/billsummary?BillNumber=1589&Year=2023&Initiative=false

Neighborhood-scale planning and coordination: key challenges and opportunities	
Challenges	**Opportunities**
● In order to decommission gas lines, projects must be planned significantly before repairs are needed but not so far before as to create stranded assets ● Tension between focusing on the most difficult projects and decarbonizing the largest number of buildings ● Lack of coordination between and within utilities and government agencies	● Pursuing projects in places where the timeline aligns for capital improvements and gas line decommissioning ● Choosing projects with a smaller number of decision makers who have existing relationships ● Strategically siting projects to maximize the cost-effectiveness of each technology ● TENs and electric network new builds

Planning and Coordination Challenges

Gas line and appliance replacement timelines: Informants noted that the timelines for gas line replacements can make gas decommissioning difficult. In the words of Neha Bazaj of Gridworks. "[Obligation to serve] is a huge challenge and is irrelevant if you're not planning projects on a reasonable timeline." Claire Halbrook said that "It makes sense to be looking at areas where the gas system is due for repair replacement, where the gas system is fully depreciated, and that those are areas where there is a terminal branch that could be decommissioned without affecting much of the other system." On the flipside, Beckie Menten of BDC noted that "you can't have a project that has too near of a timeline [for replacement]. If there is a piece of pipeline that has a potential safety risk, it can take some time to develop these zonal decarbonization projects, and you don't want to create a safety risk situation by identifying that as a potential site." Informants also noted that the planning horizon for gas system repair and replacement– three to five years – often does not give enough runway for neighborhood-scale projects. On a smaller scale, individuals and institutions need to immediately replace appliances like gas boilers when they break – not on the much longer timeline of a neighborhood-scale project. Therese from EcoBlock spoke to the importance of educating customers about switching to electric and emphasized that this "has to happen before the point of failure". On the other hand, customers are hesitant to replace appliances before the end of their useful life, especially if they are relatively new.

Balancing equity considerations with establishing the model: Many advocates and community organizers voiced support for piloting neighborhood-scale projects in low-income communities. For

example, David Sharples of ACCE said "if you prioritize working class, black and brown neighborhoods, and you prove it's possible to do it there, then I think it helps everyone in the long run, because you've proven it can be done in a lower income neighborhood – then it can be done elsewhere." The representative from the California CCA questioned this approach, saying "Why aren't we going to a market rate neighborhood where folks are buying in, they're saying that they want to do this project, and it's at least providing some proof of concept?" The representative of the New York utility similarly critiqued the decision to focus TENs pilots in low-income communities, saying "it probably makes sense to test out where people can handle it not going well." As mentioned previously, various informants also acknowledged that the scope of work would likely be greater in low-income neighborhoods because of deferred maintenance.

Balancing in-depth requirements with costs for TENs: Informants noted a tension between the desire to create specific requirements and tracking metrics to ensure equity and support learning from pilot projects and the impact of these measures on project costs. Specifically, some informants raised concerns regarding the anticipated high costs of the New York pilots while others critiqued the Framingham project as being too bare bones.

How much to focus on 100% buy-in: While many informants cite gas line decommissioning as the most promising funding avenue for neighborhood-scale decarbonization, they also questioned whether it is possible with the obligation to serve in place. Sonal Jessel raised this tension directly, saying "I would consider it a win at the stage that we're at with neighborhood scale, if we can decarbonize and electrify 70% of the homes on a block, and then eventually we'll get the other 30. Do we spend years trying to get to 100% or do we do 70% move on to the next block? Do 70 percent move on to the next block, and then eventually we'll get back to that 30? I don't know. Maybe that's faster."

Coordination challenges: Interviewees cited coordination challenges within utilities, between state agencies, and more as barriers to neighborhood-scale building decarbonization. For example, Joel Wool of BHA noted that because capital planning is done by individual institutions, not holistically, it can be difficult to identify and map opportunities for zonal projects. Sonal Jessel also noted that many structural decisions are made before funding comes out, making it difficult for communities who are not already involved to access funding. More broadly, informants mentioned a desire for more opportunities to share learnings across projects and jurisdictions. In addition, both utility representatives and advocates referenced significant siloing between gas and electric utilities —as well as within dual-fuel utilities — and cited this as a barrier to accurately quantifying the benefits of a neighborhood-scale building decarbonization strategy. Allison Considine of BDC also spoke to a desire for an industry table, saying "There's the district energy industry, there's the geothermal industry, but

not that industry table that's not technology specific, but is looking at neighborhood scale, non-combusting, heating and cooling technologies, and being an industry actor there, and saying 'this is the market certainty we need. These are the benefits we can provide." I think having that stakeholder at the table is going to be an important part of allowing this to scale up."

Planning and Coordination Opportunities

Right timeline for repair: While informants recognized the challenges of timing the development of neighborhood-scale projects to line up with gas line decommissioning, they also believed that it was possible and promising. "Can we look at where there's either leak prone pipe or other items where, if we go and target resources here, then we can avoid a different investment, and we can do that years ahead? I think that makes a ton of sense," said Joel Wool of BHA. "Maybe there are neighborhoods nearby [the Framingham project] that are getting to that point where they're going to need gas pipes replaced – this could be a really interesting way [of] tying in other resources to help replace people's appliances and help them connect to this geothermal network," said another informant.

Small number of decision makers with existing relationships: Respondents shared that this model is a lot easier to implement where there are a smaller number of decision makers and building owners, especially if those actors have pre-existing relationships. "If we had a couple of key stakeholders we knew would want to participate, you can build from there," said the Massachusetts municipal employee. Joel Wool of BHA highlighted that the Franklin Field project benefits from having "a single building owner, so one consent process" and highlighted "there are areas where you have a discrete number of owners who could improve a lot of households' lives, if you brought the different funding streams together" for targeted decarbonization projects.

Supporting marginalized communities: While informants differed on their opinions about whether it made sense to pilot projects in low-income communities of color, nearly all mentioned significant justice and equity benefits of approaching building decarbonization at the neighborhood scale. In David Sharples' words: "We know that wealthier people [...] are going to electrify and our folks who are lower income and black and brown will be stranded on the gas lines and see their bills go up. The idea of doing this at scale is really important. We feel like if we can prove it's possible, then we could be a leader for other cities in the country." Others highlighted the importance of continuing to prioritize siting neighborhood-scale projects in locations with high energy burden and exposure to environmental pollution as pathways to ensure that marginalized communities benefit from this model.

Strategically siting projects based on technology: Various interviewees shared a belief that it is more economic to pursue TENs in dense areas and easier to pursue electric networks in more spread out areas. "If 100 people are served by a segment of pipeline, you have to get 100 to agree versus if only 10 people are served by the same length –fewer people need to buy-in and it's less expensive to electrify everyone, leading to greater savings. There is an idea that in decommissioning the gas system you could prioritize doing so in places that are less dense and that would give you the biggest bang for your buck in terms of relieving upward pressure [on rates]," said Neha Bazaj of Gridworks. The representative from the New York State-based utility said that TENs make most economic sense where there is "tremendous loads, only a handful of buildings" and smaller homes make less sense because it is "a lot of money to connect a small amount of load." Various informants involved with TENs projects mentioned to utilize waste heat, whether from data centers, wastewater treatment centers, or other sources to make projects more efficient and affordable. For both electric network and geothermal projects, location is key: choosing locations at the end of gas lines enables gas line decommissioning. Another informant suggested that choosing locations at the end of the electric line also minimizes grid impacts.

Geothermal and electric new developments: While not the focus of this thesis, a number of informants mentioned the benefits of utilizing electric networks or geothermal for new developments. "If a road is being built and the infrastructure is being laid, it's the easiest time to just go in there with geothermal," said Morgan Hood of UNGC. The New York State-based utility representative similarly said that "For new construction, the building owners would have already been installing new HVAC systems, so the overall project costs would be less, since there is no building conversion costs." Another informant described the "spaghetti of infrastructure" in New York City as a challenge for geothermal retrofits there. Eric Bosworth also spoke about "seed[ing…] a loop with a new development" and then expanding it as a way to decrease upfront costs.

Coordinating actors: Various actors described improving coordination between different actors as a key opportunity. In the words of Joel Wool of BHA, "People are like 'it's too hard' whereas I think it's actually somewhat silly not to be coordinating some of the different public/utility/ratepayer funds planning." Andrew Iliff of HEET similarly advocated for system-scale planning as a key intervention to support neighborhood-scale building decarbonization, stating simply that "Geothermal requires systems planning."

5.6 Utility-led neighborhood-scale building decarbonization

A neighborhood-scale building model that hinges on decommissioning gas pipelines involves significant involvement from investor-owned utilities (IOUs). Proponents of utility-led neighborhood-scale

building decarbonization argue that utilities have the financing mechanisms and workforce necessary to rapidly scale this model, while detractors argue that utilities' profit motive will increase utility bills and harm low-income rate payers. These dynamics can be summarized as follows:

Utility-led neighborhood-scale: key challenges and opportunities	
Challenges	**Opportunities**
● Utilities are profit-motivated actors ● Many individuals and communities distrust IOUs ● Concern that this model could drive up overall ratepayer costs and individuals' utility bills, with disproportionate impacts on poorer households	● IOUs can repurpose gas system costs to electrify buildings ● IOUs can spread out costs among all ratepayers, minimizing bill impacts on individuals ● IOUs can recover costs over the lifetime of the project, making electrification more affordable in the short term ● IOUs have experience managing large capital projects and a workforce equipped to do this type of work ● Expanding TENs could create a just transition for some fossil fuel workers

Utility-led neighborhood-scale building decarbonization challenges

Profit motivated: A number of individuals expressed hesitancy about the fact that IOUs would profit from neighborhood-scale building decarbonization. "The most likely pathway that we're seeing now is utilities paying for it, and then they recoup their costs from their ROI," said one informant. "I don't love that pathway because of the reasons that IOUs are difficult." Others raised their belief that IOUs would oppose gas line decommissioning in the first place as "undermining their profit model." Andrew Iliff of HEET opined, " I really don't want [return on equity] to apply to TENS, I want TENS to come at the lowest possible cost".

Lack of trust: Both utility representatives and advocates also pointed to the existing lack of trust in IOUs. "If you knock on a random stranger's door and say, 'Hi, I'm here with the utility, skepticism is putting it lightly," said Eric Bosworth. "Door-to-door sales folks have done us no favors." Advocates mentioned that, even if residents believe that it is legitimately the utility is at their door, they may have concerns if their utility bills are already high or they are behind on payments– which is more likely to be the case in environmental justice communities. On informant noted that residents and local elected

officials may be hesitant to work with utilities in the first place because they are seen as "not trusted people or trusted entities."

Impact on utility bills: A number of individuals worry that utility-financed building decarbonization will drive up utility bills for customers. Therese Peffer of EcoBlock said "I can imagine a utility would be like 'great, you're giving us an excuse to upgrade all these things, and we don't have to pay for it.' The ratepayers are paying for it." Beckie Menten at BDC says she has been asked "What assurance do we have that [the utility] PG&E is not going to continue to increase electricity rates if we go to a solely electric space? And that's a great question that I don't have a great answer to." Already, informants note that both gas and electric utilities are receiving blowback for increasing their rates. Various advocates also articulated that utility bills are typically regressive, meaning that the costs of neighborhood-scale building decarbonization will fall more heavily on low-income individuals. While this concern is not necessarily specific to neighborhood-scale decarbonization, it remains a central critique of any approach that includes utilities as central players and financiers.

Utility-led neighborhood-scale building decarbonization opportunities

Long cost-recovery period for capital projects: Respondent highlighted that IOUs structure enables them to make large capital investments and recover the costs over a long period of time. In the words of Beckie Menton from BDC, "[In California, utilities] are able to treat their investments in infrastructure as capital expenses, that unique cost treatment allows them to pursue financing to cover the costs of these large-scale investments, that allows the utilities both to spread those costs over an amortization schedule, so that they don't have to bill customers in one year for the full expense of the project". Andrew Iliff of HEET similarly noted that "[Utilities'] whole business model is built around building equity serving, energy serving infrastructure with cost recovery [...we] need to build infrastructure really really quickly; need to be able to amortize capital infrastructure over long time frames."

Ability to spread out costs across customers: Morgan Hood of UNGC shared that "the benefit of the utility model is that some projects are going to be crazy expensive. Some are going to be far less expensive. You spread it out among the masses, and it kind of evens out in the wash but unless we have the authority to do that there's not much future right now." Some also pointed to utility regulation as providing assurance of reasonable rates and emphasized that affordability – more than fuel source – is a top priority for gas utilities.

Existing workforce: A number of informants also spoke to the benefits of utilizing the existing gas distribution workforce, as well as current oil and gas workers, to expand thermal energy networks. In

the words of Morgan Hood from UNGC, "Instead of taking pleasure in the death of the gas industry, let's repurpose the gas industry to do something that they're really well equipped to do." Some individuals also expressed excitement about the opportunity for unionized distribution gas workers to transition into the geothermal sector. Utility representatives differed in their understanding of the scale of the Gas to Geo workforce opportunity, with some believing that there are many of the same skills and that it is broadly transferable and others saying that the only thing that is similar is the pipes.

5.8 Outstanding questions: utility-led neighborhood-scale building decarbonization

If a utility-financed approach moves forward, it will raise questions about whether gas or electric utilities should cover costs and the extent to which utilities should make a profit from these projects. More broadly, it begs the question of whether existing economic and political regulations are sufficient to compel utilities to take a leading role in neighborhood-scale building decarbonization. These threads can be summarized as follows:

Outstanding questions: utility-led neighborhood-scale building decarbonization
Do gas or electric utilities pay? ● Respondents were split on this question, with gas utility representatives advocating for electric utilities to contribute and advocates proposing that gas utilities should cover costs **Can utilities treat behind-the-meter expenses as capital costs?** ● Utilities profit off capital expenditures like laying gas lines but not on the costs of retrofitting homes ● Utility representatives advocated for capital asset treatment, saying that treating behind-the-meter costs as expenses would lead to a rate spike **Who is responsible for behind-the-meter work for TENs?** ● Respondents raised doubt about financially feasibility of include behind-the-meter work in TENs projects at scale ● Utility representatives also raised concerns about owning behind-the-meter equipment **Are existing incentives sufficient to motivate IOUs to implement neighborhood-scale?** ● Gas distribution utilities typically oppose building decarbonization while electric and dual-fuel utilities may be more supportive; TENs could shift dynamics for gas utilities ● Utility commissions will need to play a central role in defining the regulatory terms of neighborhood-scale and requiring utilities to pursue projects ● Additional legislative action will likely be required to scale this approach

Do gas or electric utilities pay?

Informants commented – and sometimes disagreed – on whether gas or electric utilities (and ultimately their ratepayers) should be responsible for the costs of neighborhood-scale decarbonization in a utility-financed model.

Gas utilities should pay: in cases where a single utility provides both gas and electricity service, some argued that it made sense for the funding to come entirely from the gas side of the business, utilizing resources intended for gas line repairs to instead electrify buildings and prune gas lines. In the words Beckie Menten from BDC, "If you are following the cost effectiveness metric [...] ideally it's only going to improve outcomes for gas customers, because [...] you're shrinking the rate base, which helps to avoid future gas rate increases, because there's a smaller fixed system that you have to deal with." Others argued that paying for neighborhood-scale electric network building decarbonization projects out of the gas-replacement fund would still increase rates for remaining gas customers because of the decreasing gas customer base. In cases where there are different gas and electricity energy providers, Beckie Menten raised the tension of "having gas companies basically pay for shrinking their own system. And so there may be some justification for some portion of the cost to be shared by the electric utility, who will be the off taker of those energy services." Others couched their support for gas rate payers covering costs in terms of the imperative of disincentivizing fossil fuel use in the face of climate change or in terms of the economic opportunity for gas utilities to become thermal utilities through TENs.

Electric utility should pay: Gas utility representatives and individuals on the gas side of dual-fuel utilities unsurprisingly advocated for electric utilities to cover the cost of neighborhood-scale building decarbonization. The representative from the New York state utility suggested that gas customers should pay for the system at scale. Morgan Hood of UNGC expressed a similar opinion, saying "If the electric utilities are forced to look at long term cost effectiveness of different approaches to electrification, I hope they will be encouraged to put more money into thermal energy networks, and then the gas utilities will be there to own and operate these systems, owning and operating thermal infrastructure is something we've always done."

Who is responsible for behind-the-meter work?

When individual building owners electrify their own homes, the utility is typically not involved in the retrofit itself – the utility's primary involvement is to ensure grid reliability. For utility-led neighborhood-scale projects on the other hand, utilities become key players in completing building conversions. The role of the utility in doing work on the consumer's side of the utility meter (called "behind-the-meter"), like installing heat pumps and addressing deferred maintenance was a central

question raised by informants across sectors. This discussion centered around the cost treatment of behind-the-meter costs – and its implication for ratepayers –along with the core competencies of utilities.

Behind-the-meter costs treated as expenses: Behind-the-meter costs and community outreach are typically treated as expenses, not capital expenditures. This means that IOUs recoup these costs the year that they occur and they do not profit off of these expenditures. Behind-the-meter work constitutes the majority of the scope of work for electric network projects while TENs' behind-the-meter work is a smaller percentage of the overall scope of work because of the high costs of drilling and laying thermal distribution infrastructure.

Utilities support capital asset treatment: Utility representatives unsurprisingly voiced support for recovering behind-the-meter costs as capital costs. Rachel Wittman noted that there is "not a mechanism in place in the California regulated market that allows a utility to earn a return on capital for appliances in someone's home – it's not a model that we have needed." She said that an IOU could pursue working with a third-party who would own and operate appliances – an "energy as a service" model – but argued that a "regulatory fix is much more straightforward to implement and more efficient from a cost perspective." Advocates raised the possibility of utilities being allowed to treat behind-the-meter costs as capital expenses but not receiving a full ROE as a potential pathway forward. We talk about should [utilities] be able to capitalize and it's like, well, at what rate At 12%? Oh, I don't know. At 1%? Sure," said Claire Halbrook. "I think it's a question that needs follow up details, and we don't often ask those follow ups."

Pass-through expenses increase short-term costs: Rachel Wittman expressed concern that treating behind-the-meter expenses as expenses will lead to a spike in utility bills because utility customers pay for expenses the year that they occur. Referencing this concern, Beckie Menten of BDC said that "that does raise questions of how fast utilities can scale if you're going to be expensing a ton of zonal decarbonization projects in one year, that may cause a rate spike." She also noted that, even with cost recovery, the depreciation schedule for neighborhood-scale building decarbonization will likely be shorter than that of gas pipelines because of the shorter useful life of electric appliances (15-20 years vs. 50 years). "If you're in a voluntary environment where you're asking gas utilities to proactively identify these potential alternative approaches, then it's hard to imagine that many utilities are going to be super ambitious if they're essentially going to be losing funding."

Utilities hesitant to own and operate: Some informants expressed doubt that it was financially feasible or structurally desirable to include behind-the-meter conversions in TENs projects. "If we really

want these systems to fly, just having the utility own the loop initially is likely the least complicated path with the lowest costs," said Morgan from UNGC. She also highlighted that utilities owning and operating in-home equipment is not "a model that customers are used to from a utility" and would likely incur significant costs for maintenance. In the case of electric networks, Rachel Wittman echoed this, saying "the IOU is not an appliance supplier. They generally don't want to be going into customer homes. It's not their business model." She said that the model for behind-the-meter work was still under development for California zonal pilots, with some doing direct installations, and others working with contractors or providing checks to customers. In the Framingham project, the utility currently owns all project infrastructure. However, various utility representatives mentioned liability concerns in the scenario that utilities own behind-the-meter equipment going forward, raising questions about maintenance responsibilities, natural disaster impacts, and where utility ownership begins and ends. As summarized by Eric Bosworth: "At scale, it could be quite challenging for a utility to be responsible for tens of thousands of systems within homes."

Are existing incentives sufficient to motivate IOUs to implement neighborhood-scale building decarbonization?

Some informants viewed IOUs as conservative institutions that profit off the status quo. One informant said "IOUs have become a money-printing mechanism. They are trained to be incredibly conservative and do what they do to get guaranteed returns and privileged access to capital markets." Katie Valenzuela of BEEP Coalition spoke to the bigger structural issues surrounding the energy transition, saying that the "barriers we are experiencing are a direct result of redlining and segregation that [utilities] have profited from [...] there is some collective responsibility for them to be part of solution because they are responsible for making things worse." A neighborhood-scale building decarbonization model represents a departure from the status quo of building decarbonization and a number of interviewees questioned whether current incentives and regulations are sufficient to compel IOUs to play a leading role in the model.

IOU incentives differ based on structure: Respondents noted that incentives are significantly different depending on whether a single utility provides both gas and electric service to customers in a given area, or whether there are separate gas and electricity providers. Various respondents noted that gas distribution utilities are typically strongly opposed to building electrification because it threatens their business model. Informants note and the literature reflects that gas utilities are lobbying heavily against legislation that would ban gas connections in new buildings or reform the obligation to serve.[159]

[159] InfluenceMap. "New Report: Fossil Fuel Lobbying Against the Electrification of Buildings Threatens Planet and Public Health." Accessed May 12, 2025. https://influencemap.org/pressrelease/Building-Electrification-US-press-release-31785.

In the words of Yong Jung Cho from BPRC, "There is absolutely no incentive for a gas only utility to engage in [neighborhood-scale building decarbonization], because there's just no incentive for a fossil utility to decarbonize." Others pointed to thermal energy networks as a potential avenue through which to engage gas-only utilities in building decarbonization, arguing that gas utilities could maintain customers in a decarbonized energy system as thermal utilities. Interviewees noted that dual-fuel and electric utilities are likely to be more supportive of electric networks, with electric-only utilities standing to profit from a growing customer base and increased electric load.

Utility commissions need to play a central role: a number of policy experts interviewed believe that public utility commissions will need to play a leading role in order for utility-led neighborhood-scale projects to expand. Respondents noted that these regulators are well situated to answer outstanding technical questions about rate structure, cost recovery, and the obligation to serve. Informants believe that they also have the power to require neighborhood-scale to be a central pillar of utilities' decarbonization plans and to direct existing funds to these projects. Some also shared a desire for utility commissions to be better-educated and more proactive in advancing neighborhood-scale building decarbonization.

Broader policy changes will likely be necessary to enable this model to scale: Every utility representative I spoke with referenced state climate policies as shaping their calculus surrounding neighborhood-scale building decarbonization. For example, Eric Bosworth said that they "approached [initial conversations about TENs] with a 'we're happy to talk any and all solution here' especially since the state, again, is setting these goals, they are mandating that we need to come up with solutions." Other utility representatives voiced a belief that TENs would be unlikely to expand significantly without significant regulatory changes to support them, including requiring electric utilities to contribute to the costs of TENs. As mentioned previously, advocates spoke to the need to reform the obligation to serve as a necessary prerequisite for more extensive gas line decommissioning. More broadly, some shared their belief that utilities would pursue and/or expand their efforts to move forward neighborhood-scale projects primarily when required by state law to do so.

5.7 State-led neighborhood-scale building decarbonization

While most respondents believed a utility-led approach to neighborhood-scale building decarbonization tied to gas line decommissioning was most feasible in the short term, many also voiced a desire for a public-sector-driven approach. This ranged from "having people plan in the same direction" at the state and local level to select neighborhood-scale projects targeting affordable housing complexes and other low-income housing to developing central procurement agencies that could finance these projects.

Multiple informants also mentioned existing municipality-owned utilities as key actors. They specifically noted that these utilities' incentives could better align with the climate goals and that they could lead to lower ratepayer costs because they are not profit motivated. Some believed that the state would ideally be responsible for funding neighborhood-scale building decarbonization projects – potentially with support from gas decommissioning dollars – and that public policies like cap-and-invest, a carbon tax or "polluters pay" could equitably fund such an approach.

6. Discussion

Neighborhood-scale building decarbonization represents a fundamental shift from the dominant approach to electrifying buildings in the United States and is at an early stage of development. Across interviews, informants spoke to the challenges of trying to do something new in different ways. In the case of TENs, gas marketing teams are learning how to talk about a new technology and gas distribution companies are learning how to manage a project that includes drilling and building conversion. In the case of electric networks, implementers are learning just how difficult it is to convince an entire neighborhood to change how they cook their food and heat their homes.

Across the two technologies, informants identified high costs, insufficient financial resources, community buy-in, and planning and coordination as major implementation challenges. Even so, they expressed optimism that a neighborhood-scale decarbonization model could be beneficial for decreasing rate payer costs, supporting disadvantaged communities, addressing climate change, and creating a just transition for oil and gas workers. Even the most measured respondents seemed to believe that there is a role for the model, at least in certain contexts. From a climate planning and policy perspective, this alone suggests that there is value in supporting and expanding neighborhood-scale pilot projects. This position may also reflect my personal bias – I had the opportunity to work on two projects in early phases of development in Summer 2025. I believe that doing work at the neighborhood-scale brings the broader structural challenges of creating a just energy transition into stark relief and addressing these challenges will help accelerate building decarbonization more broadly.

Drawing from my literature review and thematic analysis – and implicitly my personal experience – I offer the following recommendations to planners to support a potential next round of pilot projects to succeed. I also build off existing literature and interview insights to offer a broader set of policy recommendations to facilitate neighborhood-scale building decarbonization and other beneficial electrification projects.

6.1 Planning recommendations

Planning practitioners can play an important role in expanding neighborhood-scale decarbonization. While many of these recommendations are specific to public sector actors, planners working at non-profits, utilities, and private firms will all play key roles in designing and facilitating successful projects.

Gaining community buy-in

Regardless of whether the obligation to serve continues to exist in its current form, it will be critical to gain support from the individuals whose homes or businesses will be electrified. The recommendations

below reflect perspectives shared by informants and existing literature like Greenlining's 2019 Equitable Building Electrification report and BDC's 2023 Neighborhood Scale report. These recommendations are intended for local government staffers, community-based organizations, and utilities, all of whom will need to play a role in building community support.

1. **Prioritize sites where there is pre-existing support:** multiple informants – and common sense – suggest that projects are more likely to succeed in places where there is pre-existing support. This can look like prioritizing sites with a supportive anchor tenant or blocks where there is a strong level of initial interest and/or a neighborhood champion ready to organize their neighbors to support the project. It can also look like allowing blocks to self-nominate to demonstrate that there is a baseline level of organization and enthusiasm in the area.
2. **Leverage and build relationships with key stakeholders:** Because of the large scope of work of neighborhood-scale projects, they will involve large amounts of coordination. Respondents emphasized the importance of developing existing relationships with key actors in project implementation, whether that is utilities, building owners, community-based organizations or municipal governments. Where those relationships don't exist, prioritize building them during the early phases of the project, and where they do, prioritize deepening them.
3. **Consider starting with projects with a smaller number of building owners:** as discussed by Joel Wool of BHA and others, certain locations lend themselves more easily to successful outcomes. It is easier to get buy-in when there is a single anchor tenant and/or small number of building owners – like an affordable housing complex or other publicly-owned facilities.
4. **Center community engagement in project design:** A strong outreach and education plan must be a central pillar of neighborhood-scale projects. Where outreach is being led by a utility, it is important to include additional messengers who may have a greater level of trust. Where possible, including – and resourcing – a grassroots community-based organization to lead resident outreach will deepen neighborhood involvement with the project and help it to succeed.
5. **Set realistic expectations:** The long time horizon and technical complexity of neighborhood-scale projects – especially TENs – creates inevitable uncertainty. Being clear about this uncertainty is important for maintaining community trust. This means communicating with community members that their building may or may not ultimately be part of a project during the site selection process and not sugar coating the noise and construction impacts they will experience if the project moves forward.
6. **Create safeguards for vulnerable communities:** While building decarbonization can improve indoor air quality and decrease utility bills, it can also lead to increased costs and displacement if done poorly. Vulnerable community members are all too aware of this reality.

Creating safeguards to protect tenant rights and prevent rates increase will go a long way towards building community trust and ensuring equitable outcomes.

Creating cost-effective projects

While informants make strong arguments about the long-term cost-effectiveness and societal benefits of neighborhood-scale building decarbonization, this model exists in the context of a market-driven system with limited resources. As many informants noted, this constraint is particularly pronounced given the Trump Administration's lack of support for climate action. Given this, it generally makes sense to prioritize pilot projects that are comparatively affordable while still centering equity and community needs. The following steps can support this:

1. **Align project siting with utility planning:** Municipalities and other actors considering neighborhood-scale building decarbonization should prioritize projects that create the possibility for gas line decommissioning and/or minimize stress on the grid. As Beckie Menten and Neha Bazaj suggest, this means choosing projects in places where gas lines need to be replaced soon but not immediately (perhaps five to 10 years). For electric network projects, choosing sites where a neighborhood-scale electrification project will not trigger a major electric upgrade —or where such an upgrade is already planned — will also minimize project costs and delays. For TENs, choosing sites that would require a grid upgrade if utilizing air-source heat pumps will make the project more appealing to electric utilities. To support planners to consider these factors, utilities should proactively make information about gas line replacements and grid upgrades available to municipalities and other relevant actors. They should provide this information with sufficient lead time to allow for it to inform planning and siting decisions.
2. **Synergize projects with needed capital improvements:** Many public sector buildings have significant deferred maintenance and heating and cooling infrastructure that is nearing the end of its useful lifetime. Municipal planners should reference their city's capital improvement plan – or other relevant documents – to identify potential sites that could serve as anchor tenants for neighborhood-scale projects. As with coordinating with utilities, making this synergy possible will require a longer-term planning horizon than may be typical in capital planning.
3. **Design projects with funding criteria in mind:** Existing funding streams for neighborhood-scale building decarbonization typically come with specific statutory or regulatory requirements. Some require projects be sited in environmental justice communities and use high-road labor, and others require that projects are cost-effective, get 100% buy-in and decommission gas lines. When deciding whether to pursue a neighborhood-scale pilot, it makes

sense to keep these factors front of mind when choosing a site and identifying a general contractor.

4. **Choose technology based on physical characteristics:** As all informants involved with TENs note, finding a site that includes a heat sink and a balanced heating and cooling load can decrease drilling system costs significantly and improve system efficiency. They also note that these projects are more cost-effective when there is a concentrated load in a smaller area – and unlikely to be feasible in more rural areas. For electric networks, the dynamics are reversed. Air-source heat pump projects typically cost less when they serve a smaller number of customers in sprawling areas – these projects have a less significant impact on the electric grid, require fewer building conversions, and allow gas utilities to decommission a longer length of gas pipeline. This is reflected in the fact that, to date, successful non-pipeline alternative projects have involved fewer than five customers.
5. **Leverage existing programs to complete behind-the-meter work:** as raised by both utility representatives and advocates, leaving behind-the-meter building retrofits to utilities is politically and economically complicated. While respondents expressed concerns about the administrative and customer service limitations of braiding funds, it will likely be necessary to stack funding to cover the costs of behind-the-meter building improvements. Programs like California's taxpayer-funded Equitable Building Decarbonization and Massachusetts' ratepayer-funded Mass Save have been utilized for this purpose and will likely continue to be key tools.

Providing financial support

Respondents returned to one fact again and again: neighborhood-scale building electrification is expensive, especially in this early phase of its development. While many voiced support for financing neighborhood-scale building decarbonization by decommissioning utility gas lines, it appears unlikely that this will be sufficient to cover costs for many projects, at least during the early phases of this model. The private sector, including IOUs, are unlikely to fill this gap unless economic incentives shift or they are required to do so. Already, utilities have abandoned pilot projects in California and Massachusetts because of higher-than-anticipated costs and issues relating to cost recovery for behind-the-meter expenses. As raised by informants, there is also already early concern that utility TENs projects in New York will come in at too high of a cost to encourage the expansion of the model. In the short term, this money is unlikely to come from the federal government, meaning that state and local governments will be responsible for filling the gap with project- and model-specific funding streams. Increased investment in pre-electrification retrofits, individual projects and research and development for networked

geothermal technologies, will allow neighborhood-scale building decarbonization to expand and develop as an industry.

1. **Dedicate resources to completing project scoping:** A number of individuals cited an initial lack of institutional and financial capacity as a barrier to taking the first step of determining project feasibility. This limitation can exist within the public sector, with local governments lacking the capacity to coordinate other actors or apply for grant funding, or in the non-profit sector, with grassroots organizations lacking resources to do community outreach. For TENs projects in particular, government staff typically lack the skill set to complete feasibility studies. Providing resources to bolster this capacity – whether it's a grant to a community-based organization, a contract with an engineering firm, or dedicated staff time to coordination – can help get pilot projects off the ground. Making a relatively small initial investment creates an option of sorts: after scoping the project, the project lead can make a decision about whether it makes sense to pursue the project further. The aforementioned Massachusetts Kickstart grant from Mass Clean Energy Center is a promising example of this approach.
2. **Invest in addressing deferred maintenance:** While addressing deferred maintenance is often framed in terms of its impacts on the prospects for building decarbonization, it is a challenge in its own right that rarely attracts private capital. Local and state governments arguably have a stake in ensuring that people have homes that are safe and healthy, and should act accordingly. Planners should assess the maintenance needs in their jurisdiction and build alignment on the role of government in making investments to address these needs. Programs like Pennsylvania's Whole-Home Repairs demonstrate what these investments can look like in practice. Planners could also consider supporting a neighborhood-scale approach to weatherization, as policy makers have proposed in New York,[160] which could help to attract private capital because of its larger scale.
3. **Consider alternative financing mechanisms:** While utilizing loans can raise equity concerns, it also has the potential to increase the number of people able to access the benefits of neighborhood-scale building decarbonization and decrease the model's reliance on utility financing. For example, utilizing on-bill financing to recoup the costs of energy efficiency and solar has the potential to accelerate building decarbonization at both the individual and neighborhood scale. Creating a revolving loan fund and providing low-interest loans could also support middle- and upper-class communities to complete neighborhood-scale projects.

[160]Conrad, William. Home Utility Weatherization Jobs Act. New York State Senate A3655 (2025). https://www.nysenate.gov/legislation/bills/2025/A3655

4. **Support workforce development and coordination:** Workforce development will be critical to expanding neighborhood-scale decarbonization, especially for thermal energy projects. While questions remain about how to best integrate the building trades into this model – particularly for electric projects where the trades have not traditionally been involved – unions will be key actors in workforce development. Planners should advocate for pre-apprenticeship programs for HVAC technicians and support contractors invested in taking a neighborhood-scale approach. Where possible, they should collaborate with union contractors who pay a living wage and could become champions of this approach at scale.
5. **Improve coordination between programs and agencies:** various informants report that a lack of coordination between building decarbonization programs and agencies makes implementation of large-scale projects administratively burdensome. As suggested by various informants, creating a decarbonization clearinghouse and/or earmarked funds for neighborhood-scale decarbonization would make this model accessible to a greater range of communities and institutions. Furthermore, this type of coordination will support actors to share learnings that decrease costs.

6.2 Policy and regulatory recommendations

As identified in the state background section, neighborhood-scale building decarbonization pilots are primarily occurring in places with binding climate targets, enabling legislation for utility pilot projects, open regulatory proceedings regarding the future of natural gas, and a strong ecosystem of building decarbonization advocacy organizations. In states where these enabling factors are not yet in place, those are natural first steps toward implementing neighborhood-scale pilots. Where those factors are in place, reforming the obligation to serve, requiring additional utility pilot projects, ensuring a beneficial electric rate structure, and integrating gas and electric utility planning will be important levers to complement additional public sector funding.

1. **Reform the obligation to serve:** While informants disagreed on the relative importance of reforming the obligation to serve (and its relation to customer choice), the majority understood regulations requiring utilities to supply natural gas to customers as a significant barrier to neighborhood-scale building decarbonization. If policymakers want to support large-scale decarbonization projects and shrink the gas system, re-defining the obligation to serve in terms of service provided – not fuel utilized – will be critical. While some argue that regulators could take this action, it seems more likely that this reform will require legislative action.
2. **Require utilities to pursue additional pilots:** As highlighted in interviews and reflected in the field, new approaches require practice and experimentation. State policymakers should continue to resource existing pilot programs and pass legislation to expand pilot programs.

3. **Ensure progressive and beneficial electricity rate structures:** Existing literature and respondent interviews demonstrate the importance of electric rate design in accelerating building decarbonization and ensuring equitable outcomes. Promising avenues include setting heat-pump rates to be competitive with gas and decreasing the electric utility bills for low-income customers by capping payments at a percentage of total income or a fixed rate.[161]
4. **Move toward integrated gas and electric planning:** de-siloing gas and electric planning will better account for the true costs and benefits of neighborhood-scale building electrification and support a managed transition off methane gas infrastructure.

[161] "Equity and Electrification-Driven Rate Policy Options | ACEEE." Accessed May 15, 2025. https://www.aceee.org/white-paper/2023/09/equity-and-electrification-driven-rate-policy-options.

7. Conclusion

One simple comment from my interviews has stayed with me: "there's this barrier of *how we've done things is the only way we can do things*." The model of neighborhood-scale building decarbonization in the United States emerged out of a recognition that appliance-by-appliance, home-by-home electrification is moving far too slowly to reach decarbonization targets and is leaving behind vulnerable communities. It came out of a recognition that it is not financially prudent (or ecologically ethical) to make continued investments in expanding and maintaining natural gas infrastructure in the face of the climate crisis. As multiple informants noted, it is a significant paradigm shift. In practice, it brings together actors who have previously not worked together to complete projects outside of their typical scope of work. Of course it will be expensive. Of course there will be growing pains. We are doing something new.

As I write this in April 2025, most neighborhood-scale pilot projects are in an early phase of community outreach, site selection, and project design. Even individuals involved in completing the Framingham networked geothermal project said that they had not yet reflected on the project as a whole. The biggest critics of this approach think it could have some potential while the biggest cheerleaders have outstanding questions. This thesis does not and cannot answer all of these questions. It does suggest that some of the foundational elements of successful planning are unsurprisingly required for neighborhood-scale building decarbonization as well: meaningful community engagement, thoughtful siting and stakeholder engagement, more money, and values-aligned policies. It also provides a snapshot of this moment in time: state and local actors piloting something new, hoping to find a more equitable and affordable approach to electrification in a time of great uncertainty.

There is still a lot to learn about neighborhood-scale building decarbonization – and a lot that will hopefully become clearer in the coming years. Additional research areas of interest to me include:

- A similar treatment of other states where utility-financed projects are underway, especially Colorado, Minnesota and Washington;
- A deep dive on future of gas regulatory proceedings, including engaging with involved regulators;
- An examination of community engagement in successful projects to identify best practices;
- A review of the existing residential building decarbonization workforce and an assessment of opportunities for the involvement of organized labor in neighborhood-scale projects;
- A mixed-methods assessment of the impacts of allowing utilities to use capital asset treatment for behind the meter costs;

- A quantitative analysis of pilot project costs across technologies and states, and the anticipated ratepayer impacts of utilizing gas decommissioning dollars for neighborhood-scale electrification at scale;
- A synthesis of learnings from pilot projects in two to three years, including required utility reporting, and
- An exploration of alternative financing mechanisms, including community ownership of distributed energy resources.

I hope this list of future research avenues is helpful to students and scholars interested in further exploring what enables and hinders neighborhood-scale building decarbonization pilots. My research has shown that strong climate goals, the passage of enabling legislation, an engaged state utility commission, and strong advocacy ecosystems are key factors for initiating neighborhood-scale pilot projects. Once projects are underway, strategically minimizing costs, accessing utility resources and other financing, securing community buy-in, and ensuring strong planning will be key to project success.

8. Postscript

I became interested in neighborhood-scale building decarbonization in Fall 2023 before I knew that such a term existed. I was taking David Hsu's Urban Energy Systems and Policy class and our coursework had made clear that the existing approach to residential building decarbonization was moving too slowly and leaving behind marginalized communities. I wondered what it would look like if we tackled electrifying buildings more collectively and proposed a city-wide building retrofit strategy for my final paper. David wisely encouraged me to scale it down to a few neighborhood blocks. In Summer 2024, I had the opportunity to work on two neighborhood-scale projects in early phases of development and learned first-hand how complicated this approach can be in practice. The process of writing this thesis has added further nuance to my understanding of what this model entails.

At the same time, a part of me continues to believe that neighborhood-scale building decarbonization is perhaps less complicated than I make it out to be. As with much of addressing the climate crisis, we simply need to build political will to win the policy changes and financial resources required to make neighborhood-scale building decarbonization happen. In Switzerland, two cities have made plans to decommission gas pipelines, with utilities giving residents 10 years advance warning that their gas service will be discontinued and offering compensation to affected customers.[162] In Vermont, the gas utility has committed to never undertake major infrastructure projects and has begun installing heat pumps.[163] While the energy transition strategies in Switzerland and Vermont may not be applicable in other places, they remind me that other pathways are possible. Looking back in history, I marvel at the fact that we laid all of these gas lines in the first place and that the patchwork-built electric grid now extends across the United States, providing (mostly) reliable power. We have been to the moon. We have built large language models that can write code, pass the Bar Exam and provide companionship. We can definitely decarbonize a neighborhood.

I hope that practitioners continue to experiment with neighborhood-scale building decarbonization in the coming years, operating under the assumption that it is a possible and worthwhile endeavor. In a decade, maybe – hopefully – there can be thousands of collectively electrified blocks across the United States and a much smaller gas distribution system. We will only know if we try.

[162]Henchen, Mike. "Non-Pipeline Alternatives."
[163] Interview with Morgan Hood, April 11, 2025

9. Appendix

Interviews utilized the following base questions, with some variation and follow up:

- Could you introduce yourself and your role?
- How would you describe your involvement in neighborhood-scale building decarbonization (and/or thermal energy networks)?
- Could you share more about the neighborhood-scale project(s) you have been involved with?
- Who do you see as the most important actors in this space? What do you see as the ideal role of investor-owned utilities in this model? What about the role of local governments?
- What have you learned from your involvement with neighborhood-scale pilot projects? What are the benefits and drawbacks of taking this approach?
- In your opinion, to what extent is it possible and/or desirable to scale neighborhood-scale building decarbonization?
- What are the political, financial, and social factors that will make this expansion possible? Which do you see as the biggest current barriers?
- If you could wave a magic wand to make one change to facilitate neighborhood-scale building decarbonization, what would you use your wand for?
- What are your biggest outstanding questions about this approach?
- Who else would you recommend that I speak with?

After completing the interviews, I utilized Otter.AI and Zoom recordings to transcribe interviews and code them according to the following categories in a Google spreadsheet:

- Individual / organizational role: how the individual or actor sees their role in neighborhood-scale building decarbonization
- Neighborhood-scale as a model: general comments relating to a neighborhood-scale building decarbonization model
- Role of investor-owned utilities: informant perspectives on the appropriate role for these utilities in neighborhood-scale building decarbonization
- Costs – barriers and opportunities: comments relating the costs of neighborhood-scale building decarbonization.
- Financing –barriers and opportunities: comments relating to the financing of neighborhood-scale building decarbonization.
- Community buy-in – barriers and opportunities: comments relating to securing community buy-in for neighborhood-scale building decarbonization.
- Planning / implementation – barriers and opportunities: comments relating to institutional collaboration and planning for neighborhood-scale building decarbonization.

- Rates, regulators and policy: comments relating to the existing political landscape and the roles of utility commissions and state policymakers
- Actors / coordination: comments relating to key actors involved in project design and implementation
- Biggest barrier: largest challenge identified by informants
- One change: response to question regarding how people would use a magic wand to support neighborhood-scale building decarbonization
- Alternative financing mechanisms: comments regarding alternatives to a utility-financed approach to neighborhood-scale building decarbonization
- Workforce and technology: comments relating to existing neighborhood-scale building decarbonization workforce and technologies