# Decarbonization Planning for Affordable Multifamily Housing: Frameworks, Compliance Pathways, and Implementation Barriers

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## ABSTRACT

Decarbonizing affordable multifamily housing is essential to meeting climate goals while preserving affordability, improving resident comfort, and supporting healthier, more resilient homes. Owners of affordable housing face significant barriers, including limited capital, aging buildings, rising operating costs, constrained refinancing cycles, and the need to avoid tenant displacement or rent increases. Strategic decarbonization planning frameworks, including Zero Over Time (ZOT), Strategic Decarbonization Planning (SDP), and building performance standard alternative compliance pathways, offer practical approaches for aligning energy and emissions reductions with real estate decision points.

This paper examines how these planning approaches are being applied through affordable housing case studies, green certification criteria, public-sector technical assistance programs, and regulatory compliance pathways. It compares voluntary planning frameworks with emerging building performance standard requirements and highlights the role of phased implementation, business-as-usual comparisons, capital planning, and post-retrofit verification.

Findings show that long-term planning can help owners move beyond isolated energy audit measures toward coordinated retrofit strategies that reduce stranded asset risk, support funding alignment, and create more realistic pathways to emissions reductions. Regulatory alignment can also support standardization and impact what actions are cost-effective. Once owners have clear direction on next steps, securing capital and procurement strategies remains a barrier. The paper concludes that future research and program design should focus on implementation, including financing structures, incentive timing, standardized compliance documentation, resident protections, and verification methods that can help turn decarbonization plans into completed affordable housing retrofits.

## Introduction

Decarbonizing affordable multifamily housing is essential to achieving climate goals while promoting equity, comfort, health, and resilience. Many affordable housing owners are facing financial challenges that make it difficult for them to prioritize decarbonization. In many places, both operating and capital costs have risen rapidly, driven in part by rising insurance premiums and utility costs, while construction costs have been highly volatile for the last several years. Revenues are not keeping pace, with many affordable housing owners still seeing lower rents collected than before COVID.

Recent studies of affordable housing portfolios in New York and Illinois describe these challenges in more detail. In a portfolio of properties across New York, according to a report from LISC, National Equity Fund, and Enterprise, operating expenses have risen more than 40% since 2017, with insurance costs more than doubling (LISC 2025). Meanwhile, economic occupancy (the share of units from which rent is collected) has fallen to 90%, from a historic expectation of 95%. In Illinois, according to the Illinois Housing Council, affordable housing owners face similar problems with similar causes, and as many as 20% of the analyzed properties face financial weakness. In both geographies, historically high numbers of properties (over 50% in New York and over 25% in Illinois) face negative cash flow (IHC 2026).

Energy efficiency and clean energy can reduce operating costs and provide important co-benefits, but access to up-front capital remains a key challenge. Financially constrained owners may be unable to make investments that require significant initial spending even when they offer long-term benefits. Value-engineering of efficiency features has become common for affordable housing owners undertaking rehab projects in order to reduce capital costs, or to include only the minimum number of green features required by funders. Often, this value engineering is not a choice: there are simply not enough capital resources available. At the same time, there is increasing regulatory pressure for decarbonization through building performance standards, which often necessitate or promote long-term planning. For decarbonization to be a practical opportunity for affordable housing owners, it must be financially feasible and positioned as a strategic, lower-risk investment.

The future planning need is becoming more urgent as state and local building performance standards establish increasingly stringent energy and emissions limits for existing buildings. For affordable housing owners, these policies can create compliance pressure without automatically creating the capital, timing, or technical pathway needed to act. Zero Over Time and related decarbonization planning frameworks can help bridge that gap by translating long-term emissions targets into phased scopes of work that align with refinancing, equipment replacement, major renovations, and other decision points. This paper examines how these planning approaches are being used through certification programs, public-sector technical assistance, regulatory compliance pathways, and affordable housing case studies, and identifies future research needs related to financing, implementation support, and verification of decarbonization plans.

## Decarbonization Planning Approaches

### PARADIGM SHIFT FROM ENERGY AUDITS TO DECARBONIZATION PLANNING

Historically, energy planning in multifamily affordable housing has relied on conventional, point-in-time energy audits focused on identifying near-term operational improvements and discrete efficiency measures. Since these audits are usually evaluated through simple payback, they orient decision-making around how the building can perform better today rather than how it should evolve over time. This approach is useful for uncovering immediate savings opportunities, but it remains largely confined to modest efficiency gains and measures that can be justified within short payback windows. As a result, it misses the opportunity to provide the forward-looking, capital-cycle-aligned insights needed to achieve deep energy and carbon reductions in affordable housing.

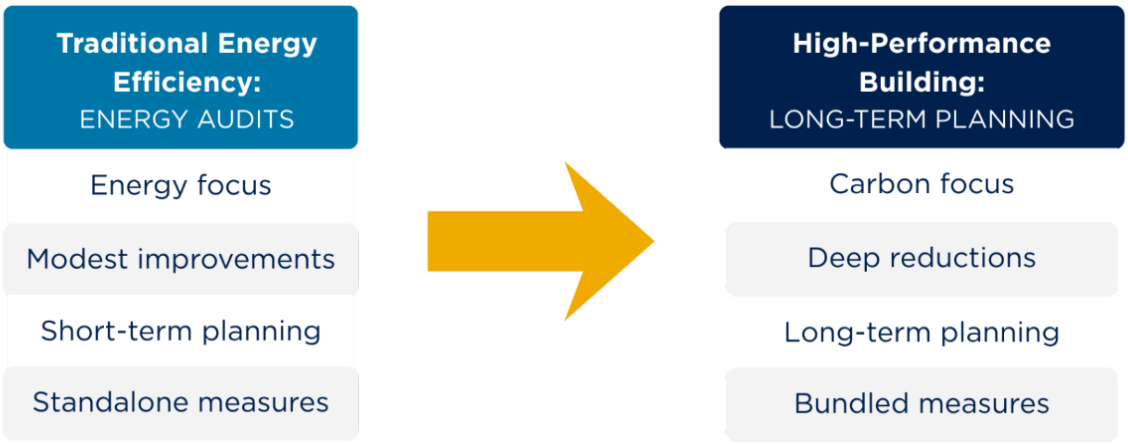


Figure 1. The Paradigm Shift in Planning. Source: IMT 2026a.

By contrast, a series of emerging frameworks for building performance planning shift the focus from incremental improvements to staged performance gains over 10 to 25 years (Figure 1). This longer-term approach allows integration of energy efficiency and decarbonization with financial planning, equipment end-of-life schedules, refinancing windows, and tenant-impact considerations. Rather than optimizing individual measures, plans develop bundled sequences of strategies like envelope improvements to reduce loads and allow heat pump system simplification. They are then evaluated on lifecycle cost compared to business-as-usual expenditures and potential monetary risks from inaction.

A survey of six common frameworks for long-term building performance planning, including Zero Over Time, Strategic Decarbonization Planning (SDP), and the New York Retrofit Playbook, found more commonalities than differences between them, showcasing growing industry consensus for what it takes to affordably and strategically decarbonize buildings (Duer-Balkind, Koolbeck, and Kelley 2025). All the frameworks have a few distinct phases, which can be generalized into the groupings shown in Table 1, though these may be grouped or named differently.

| Phase | Assess | Develop | Implement and Monitor |
|---|---|---|---|
| Goals | • Establish baseline conditions<br>• Build multidisciplinary team<br>• Establish capital planning calendar | • Identify measures to lower energy and carbon emissions<br>• Align action steps with capital planning events<br>• Create different options for a decarbonization trajectory | • Implement items identified in the plan<br>• Track and measure reductions over time<br>• Adjust and iterate |

| | | | |
|---|---|---|---|
| Outputs | ● Building energy use and carbon baseline summary<br>● Equipment list<br>● A capital planning event calendar and impact on potential retrofits<br>● Financial and carbon BAU trajectory | ● List of energy efficiency, electrification, renewable energy, and enabling measures<br>● Timeline for measure implementation<br>● Financial analysis<br>● Expected savings<br>● Short-term capital plan | ● Summary report and selected option<br>● Procurement of any immediate actions<br>● Follow-up engineering studies and plan adjustments<br>● Measurement of savings over time |

Table 1. Generalized stages of decarbonization planning

Most fundamentally, these planning approaches tackle the reality that major mechanical systems are only replaced once or twice before 2050 by identifying necessary interventions to ready the building for the shift from combustion-based systems to efficient electrified alternatives. Without advanced planning of infrastructure enabling activities, such as electrical and thermal distribution upgrades, most buildings will default to like-for-like replacements upon equipment failure.

This shift is particularly consequential in the affordable multifamily sector, where properties often face unique constraints such as restricted cash flow, set refinancing windows, and equipment replacement cycles out of tune with many financing opportunities. A simple energy audit may recommend cost-effective measures that fail to address these structural constraints, inadvertently locking buildings into stranded assets.

Strategic over-time planning enables owners to time major decarbonization investments with scheduled refinancing, capital needs assessments, or tax credit compliance cycles. This helps preserve affordability by reducing long-term costs, minimizing tenant disruption, and ensuring residents benefit from healthier, low-carbon homes. This need not be seen as a radical departure, as strategic planning is already part of traditional asset management in various ways, like annual budgets, capital plans, reserve studies, and property condition assessments.

**Zero Over Time (ZOT)**

ZOT encourages building owners and portfolio managers to create a multi-decade pathway to zero carbon emissions by aligning efficiency and electrification upgrades with building life-cycle events, such as equipment replacement, major renovations, or tenant turnover (Jungclaus, Peterson, and Carmichael 2018). This strategy minimizes stranded assets and reduces costs by implementing improvements when systems are already scheduled for replacement, other construction is taking place, or tenant spaces are already vacant. ZOT also prioritizes efficiency measures with shorter payback periods early in the process, allowing early energy savings to help finance deeper retrofits later.


Figure 2. ZOT approach as defined by RMI. Source: Jungclaus, Peterson, and Carmichael 2018

Typically, ZOT is a six-step planning process. First, the team should establish clear and actionable sustainability goals and ensure all critical stakeholders are made aware of them to build broad buy-in. Next, an energy baseline must be established to understand current building performance and identify opportunities. Then, efficiency projects can be planned in a sequenced manner by developing a trigger events calendar that maps building life-cycle events that can enable deeper retrofit opportunities. Some combination of on-site and off-site renewables should be incorporated into the project after pursuing all energy efficiency improvements and determining the most cost-effective options. After the implementation of projects is complete, the team should track post-retrofit data against the initial goals to determine success and make adjustments as needed (Jungclaus, Peterson, and Carmichael 2018).

In practice, ZOT planning may be initiated by different actors. Some owners use it as an internal asset-management tool, particularly when they manage portfolios with recurring recapitalization events. In other cases, it is encouraged through green certification, utility or state-funded technical assistance, or emerging BPS compliance pathways. This flexibility is important for affordable housing because the trigger for planning is often not a single policy requirement, but the overlap of financing, equipment condition, incentive availability, and regulatory risk.

**Strategic Decarbonization Planning (SDP)**

Building on earlier ZOT concepts, Strategic Decarbonization Planning (SDP) has emerged as a broader industry framework for organizing long-term retrofit pathways. Although the terminology differs, this approach closely mirrors the ZOT methodology. Under the SDP framework, establishing a building baseline and evaluating existing conditions precedes the design of retrofit packages, and projects are typically organized into phased timelines aligned with capital planning cycles and trigger events. Several industry resources have adapted the SDP concept into practical tools and guidance.

A prominent example is the Retrofit Playbook for Large Buildings knowledge platform, developed by the New York State Energy Research and Development Authority (NYSERDA), RMI, Building Energy Exchange, and Urban Land Institute. The Retrofit Playbook outlines three core steps to its version of SDP: examine current conditions, design resource-efficient solutions, and build the business case for decarbonization, with a precursory initiation step to kickstart planning.

The recently published Guide to Strategic Decarbonization Planning, published by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) in collaboration with the U.S. Green Building Council (USGBC) and with support from NYSERDA, provides a more comprehensive version of SDP (Hinge, Kerr, and Burt 2025). The

ASHRAE-USGBC guide organizes its steps into two distinct phases: pre-planning and a planning phase. The pre-planning phase suggests compiling a baseline for the building with performance data and conditions assessment, as well as creating a trigger events calendar. However, this pre-planning phase goes further to recommend compiling other exemplary SDP case studies of similar buildings, developing multiple decarbonization plan options, and creating a five-year capital plan for the energy conservation measures to be implemented in that time span (Hinge, Kerr, and Burt 2025).

Both the Retrofit Playbook and the ASHRAE-USGBC guide place a more distinct emphasis on finding the most financially advantageous path to decarbonization through financial analysis and constructing a sound business case that aligns the engineering plan to the business-as-usual capital plan for the building. While not an explicit step in itself, ZOT similarly focuses on sequencing investments in ways that maximize lifecycle financial performance rather than evaluating measures independently.

The SDP process is also the basis of the LEED v5 O+M credit for 'Decarbonization and Efficiency Plans', and USGBC has developed a guidebook for reporting SDP plans to jurisdictions (USGBC 2025). These industry guides signal that strategic over-time planning is becoming a more widely accepted best practice for building performance and decarbonization. Additionally, a growing number of building performance standards are utilizing models similar to ZOT and SDP in their compliance pathways, demonstrating that these approaches are gaining traction in the regulatory landscape.

**Planning as an Emergent Property of Building Performance Standards**

The planning frameworks described above are increasingly appearing in regulation through building performance standards (BPS), which require large existing buildings to meet energy or carbon performance targets by specified deadlines. BPS policies have been adopted in 17 jurisdictions across North America, including New York City and Boston, the two examples discussed below (IMT 2026b). Many BPS policies set long-term decarbonization targets extending toward 2050, yet many buildings will only replace major equipment once between now and the final deadline. This means that strategic capital planning is an essential emergent property of a BPS regulatory regime, and also an important flexibility mechanism to provide (Duer-Balkind, Koolbeck, and Kelley 2025).

For affordable housing, this connection between planning and regulation is especially important because compliance requirements can arrive before owners have access to the capital, resident relocation capacity, procurement pathways, or equipment replacement opportunities needed to complete major work. Each affordable housing property faces a different combination of physical constraints, resident needs, subsidy requirements, reserve limitations, and recapitalization timing. Alternative compliance pathways (ACPs) and custom plans are therefore not simply flexibility mechanisms; they are often the structure that makes equitable implementation possible. A building performance action plan (BPAP) allows owners to document how a building will reach and maintain compliance over time; the concept is included in the Institute for Market Transformation's model BPS law and similar pathways have been adopted in New York City, Boston, Denver, and Montgomery County, Maryland (Hart, Majersik, and Eagles 2022; Duer-Balkind et al. 2024).

For affordable housing owners, a custom plan pathway can align compliance with preservation financing, LIHTC recapitalization, utility incentives, equipment end-of-life, and tenant protection requirements. A well-designed ACP can use the same core elements as a ZOT

or SDP plan: a baseline, a business-as-usual trajectory, phased measures, financing assumptions, interim milestones, and post-implementation tracking.

**Boston BERDO and Building Emissions Performance**

Boston's Building Emissions Reduction and Disclosure Ordinance (BERDO) illustrates how performance-based climate policy is driving more structured decarbonization planning. BERDO sets progressively tighter emissions limits for covered buildings, including multifamily housing, with all covered buildings expected to reach net-zero emissions by 2050 (City of Boston 2026a). Although BERDO is a performance standard rather than a formal planning framework, it requires forward-looking analysis of future capital work, electrification, efficiency measures, renewable energy procurement, and alternative compliance payments.

For affordable housing portfolios in Boston, these analyses often produce differentiated pathways. Properties with central gas systems and limited electrical infrastructure may pursue interim hybrid solutions paired with envelope improvements, while projects undergoing substantial rehabilitation may be able to fully electrify within a single recapitalization event. Framed through a ZOT lens, BERDO compliance becomes less a one-year regulatory obligation and more a structured capital planning exercise. Boston also offers a “hardship compliance plan” alternative compliance pathway under BERDO that allows compliance obligations to be stretched over time to address financial and technical hardships identified through planning (Duer-Balkind, Koolbeck, and Kelley 2025).

BERDO does not require owners to use ZOT by name. However, it creates conditions where ZOT-style planning becomes useful. A BERDO compliance analysis often requires the same ingredients as a ZOT plan: a current energy and emissions baseline, a business-as-usual trajectory, a sequence of future measures, cost and timing assumptions, and a method for tracking progress. BERDO creates demand for long-term planning, while ZOT can provide a practical structure for turning that demand into an implementable retrofit pathway.

**New York City Local Law 97**

In New York City, Local Law 97 (LL97) sets carbon emission limits on most buildings larger than 25,000 square feet and creates a glide path toward carbon neutrality by 2050. Rent-regulated and income-restricted residential buildings are eligible for delayed compliance, and buildings that exceed their emissions limits but demonstrate good faith efforts may be offered a mediated resolution and avoid financial penalties (NYC DOB 2025).

The good-faith effort pathway can include evidence of emissions reduction projects, electrification readiness projects, previous compliance, financial hardship tied to critical services, or a decarbonization plan. NYC DOB defines a decarbonization plan as an actionable roadmap to reduce net carbon emissions, including phased energy efficiency improvements, emissions reduction strategies, eventual electrification, implementation timelines, funding strategies, equipment inventories, and operations and maintenance changes (NYC DOB 2025). By creating this option, LL97 provides a regulatory incentive for ZOT-like capital planning rather than relying only on annual penalty exposure.

## Decarbonization Planning Programs in Practice

After the BPS examples above, the following programs show how long-term decarbonization planning is being translated into practice through voluntary and technical assistance channels. Some programs, such as Enterprise Green Communities, use certification criteria and technical resources to encourage owners to prepare ZOT plans voluntarily. Others, such as the Empire Building Challenge and MassCEC BETA, use public funding and technical assistance to help owners create and evaluate phased retrofit pathways before implementation. Together, these examples show that ZOT and SDP are not limited to a single program model. They can operate as owner asset-management tools, certification requirements, technical assistance frameworks, or supporting documentation for future regulatory compliance.

### Enterprise Green Communities – Energy Planning Criteria and Zero Over Time Standards

Enterprise Green Communities is a national green building certification program designed for affordable housing. The 2026 version includes optional Criterion 5.1, Energy Planning, which incentivizes applicants to complete a ZOT plan that considers short- and long-term design, asset management, equipment replacement, benchmarking, and cost-effective decarbonization (Enterprise Green Communities 2026). The plan sets goals and milestones from existing conditions through a planning period of up to 20 years.

In addition, Enterprise also provides a Zero-Over-Time Standard outside of formal certification for projects interested in reducing energy use and costs as part of asset management. Its resources include a ZOT audit protocol, sample report template, implementation road map, and qualifications guide. Together, the certification criterion and standard show how ZOT can operate as both a green building requirement and an owner-facing planning tool.

### The New York State Empire Building Challenge (EBC)

The New York State Empire Building Challenge (EBC) demonstration program is a public-private partnership between NYSERDA and leading commercial and multifamily real estate owners that showcases the SDP approach to low-carbon retrofits in tall buildings (NYSERDA n.d.). In its three cohorts to date, NYSERDA has partnered with real estate owners committed to decarbonizing their properties through innovative technical solutions in a cost-effective manner. The third and newest cohort included 22 showcase buildings, 123 million square feet of real estate, 123,000 residential units, 13,000 affordable housing units, and 17 buildings located in disadvantaged communities (Retrofit Playbook 2026). The projects are currently featured on the Retrofit Playbook website as case studies.

### MassCEC BETA

The Massachusetts Clean Energy Center launched the Building Electrification Transformation Accelerator (BETA) Project Planning pilot to scale decarbonization of commercial and large multifamily buildings. The program develops and pilots decarbonization assessment processes for commercial buildings and multifamily residential buildings with 15 or more units, providing custom plans that help owners evaluate cost-effective, phased pathways toward electrification and net-zero emissions by 2050 (MassCEC 2026).

Massachusetts' transition toward net-zero buildings by 2050 is increasingly shaped by state and local building performance policies, including Boston's BERDO and Cambridge's Building Energy Use Disclosure Ordinance (BUEDO), which require large buildings, including multifamily properties with 15 or more units, to report energy use and emissions annually and meet increasingly stringent greenhouse-gas limits. A statewide Large Building Energy Reporting regulation further expands disclosure requirements across the Commonwealth.

BETA's assessment process combines engineering analysis with capital-planning considerations to produce replicable strategies, case studies, and market resources that support building-sector transformation. The program's emphasis on custom plans is especially relevant to affordable housing because nearly half of the application pool has been affordable housing, underscoring demand for no-cost planning support and financing analysis (MassCEC 2026).

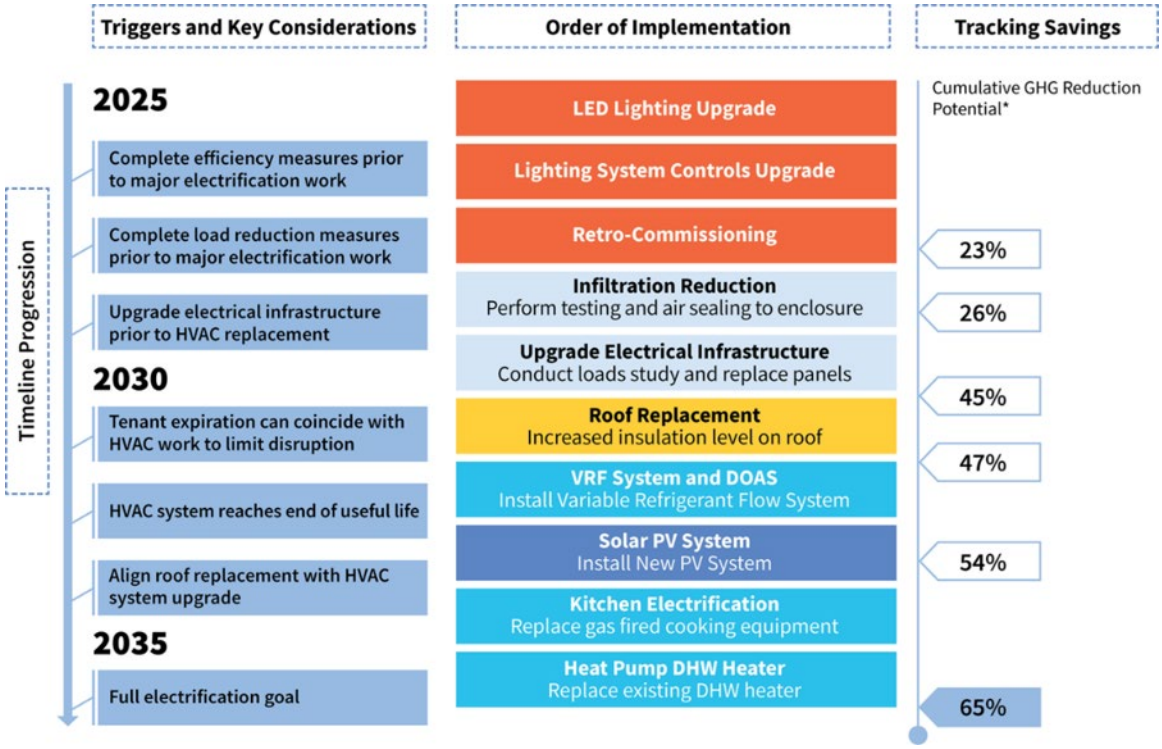


Figure 3. Example decarbonization implementation timeline. Source: Building Energy Hub 2025.

Core components of these plans include:

- Assessing existing building conditions, including utility benchmarking, emissions performance, and equipment readiness for electrification.
- Establishing a business-as-usual (BAU) financial baseline projecting utilities, maintenance, and like-for-like equipment costs through 2050.
- Developing an optimized decarbonization pathway that identifies the lowest-cost, highest-benefit set of efficiency measures, load-reduction strategies, equipment electrification, and renewable energy or battery storage integration.
- Comparing lifetime costs and emissions between the BAU and optimized pathway often shows higher upfront investment but comparable or lower long-term costs.

- Sequencing implementation actions, identifying financing strategies, and aligning upgrades with key triggers such as recapitalization cycles, equipment replacement timelines, and future building-performance standards.

BETA is actively working to expand statewide planning capacity and translate technical insights into accessible resources and case studies. Pilot results will be shared through the Building Performance Exchange, a statewide decarbonization hub for building owners and stakeholders.

## Case Studies

The following case studies illustrate two distinct entry points into long-term decarbonization planning. Carol Avenue shows how a recapitalization event, performance-based incentives, and BPS exposure can converge to support a deep retrofit at a single affordable housing property. Enterprise Community Development demonstrates how a portfolio owner can begin with renewable-energy deployment and financing outside the conventional LIHTC cycle, then use that platform to support later efficiency, electrification, and compliance planning.

### Case Study 1: Capital-Timed Electrification Within a ZOT Framework: Carol Avenue Apartments

To understand how a ZOT framework changes real-world capital decisions, consider Carol Avenue Apartments, a 33-unit affordable housing rehabilitation project in Boston, Massachusetts (City of Boston 2026b; Allston Brighton CDC 2024). The property is subject to Boston's Building Emissions Reduction and Disclosure Ordinance (BERDO), which applies to residential buildings with 15 or more units and establishes progressively tighter emissions limits for covered buildings (City of Boston 2026a). Although the project was not initiated under a named ZOT process, it demonstrates a ZOT-aligned pathway: a recapitalization event, performance-based incentives, BERDO compliance risk, whole-building modeling, and coordinated scope decisions combined to move the property toward full electrification rather than conventional fossil-fuel replacement.

Carol Avenue consists of three early-twentieth-century masonry buildings. Prior to renovation, two were heated by gas-fired steam systems and one by oil-fired steam. Domestic hot water was produced through indirect tanks connected to the boilers. The building envelope reflected its age: minimally insulated masonry walls with effective performance around R-4 to R-5, roofs near R-20, aluminum double-pane windows with U-values around 0.50, and exhaust-only ventilation (New Ecology 2019; RMI 2023).

A 2019 ASHRAE Level II audit established a weather-normalized baseline of roughly 2,789 MMBtu per year, equivalent to a site EUI of about 80 kBtu per square foot. Space heating and domestic hot water dominated consumption, and the oil-heated building carried a disproportionate share of emissions (New Ecology 2019; RMI 2023).

Under a conventional capital planning approach, the likely business-as-usual path considered in project planning would have been straightforward: replace aging steam boilers with high-efficiency gas units, perform limited air sealing, upgrade lighting, and continue operating within the existing fuel structure. Energy use would have declined modestly, but fossil infrastructure would have been reset for another 20 to 30 years. That pattern - incremental

efficiency layered onto fossil replacement - is exactly what the ZOT framework is designed to interrupt (New Ecology 2019; New Ecology 2024).

In 2024, Carol Avenue advanced through Massachusetts' Income-Eligible Deep Energy Retrofit pathway. Unlike traditional rebate programs that reward individual measures, this program required whole-building interactive modeling and a minimum 40 percent reduction in site EUI to qualify for incentives (LEAN Multifamily 2025). The minimum energy reduction requirement changed the conversation. Instead of asking which upgrades produced the best standalone savings-to-investment ratios, the team asked what coordinated package of improvements could meet a defined performance target within a scheduled recapitalization event. The focus shifted from optimizing isolated measures to designing a complete decarbonization pathway.

The three coordinated phases were: first, reduce heating and domestic hot-water loads; second, electrify space conditioning and eliminate on-site combustion; and third, restructure domestic hot water and ventilation around the new electrified platform.

First phase, the project reduced structural heating demand. Interior mineral wool insulation improved wall performance from roughly R-5 to approximately R-12. Roof insulation increased to R-50 or greater. Windows were replaced with assemblies rated near U-0.25, and air leakage was reduced through coordinated envelope work. Lowering thermal loads before electrification was essential to avoid oversizing heat pump systems and to preserve long-term efficiency (RMI 2023; New Ecology 2024).

Second phase, all on-site combustion equipment was removed. The steam boilers were decommissioned and replaced with cold-climate VRV systems providing both heating and cooling, with a weighted annualized heating COP of approximately 2.1. Limited electric resistance heaters were added in select common areas. Gas and oil services were eliminated entirely. Modeling projected a reduction of roughly 2,272 MMBtu per year in combustion fuels, offset by about 877 MMBtu of additional electric consumption, resulting in a net site energy reduction of approximately 1,395 MMBtu annually. From a ZOT perspective, this marked the completion of the fuel-elimination milestone (New Ecology 2024; RMI 2023).

Third phase, domestic hot water and ventilation systems were restructured to align with the electrified platform. Boiler-fed indirect tanks were replaced with electric resistance storage systems configured to allow future heat pump water heater integration. Low-flow fixtures, drain water heat recovery, and demand-controlled recirculation reduced hot water loads prior to electrification. Central energy recovery ventilators replaced the previous exhaust-only approach, providing balanced ventilation and improved indoor air quality. Interactive modeling ensured that load reductions preceded fuel switching in the calculations, maintaining internal consistency and avoiding double-counting of savings (New Ecology 2024; RMI 2023).

Post-retrofit modeling showed site energy declining from roughly 2,789 MMBtu per year to approximately 1,394 MMBtu per year for a 50 percent reduction. Site EUI fell from about 80 to 36 kBtu per square foot. With rooftop solar photovoltaics included, the modeled site EUI approached 29 kBtu per square foot, representing a 64 percent reduction from baseline (New Ecology 2024; RMI 2023).

More significant than the efficiency gains, however, was the complete elimination of on-site fossil fuel combustion. This result should be understood as ZOT-aligned rather than as proof that a formal ZOT process alone caused the outcome. The structural shift occurred because the project combined a capital trigger, performance-based incentives, whole-building modeling, and a coordinated scope of work that avoided like-for-like fossil system replacement.

Total retrofit costs were approximately $5.16 million, or about $148 per square foot and $156,000 per unit, with envelope upgrades representing a substantial share of the investment. Financing relied on layered funding sources, including performance-based deep energy retrofit incentives, municipal housing capital, state decarbonization programs, tax-exempt bond financing, and federal low-income housing tax credit equity (New Ecology 2024; New England Real Estate Journal 2023; Allston Brighton CDC 2023).

Although modeling projected a 50 percent reduction in site energy use, annual utility-cost savings were not presented as a single comparable value because the project shifted major heating and domestic-hot-water loads from gas and oil to electricity. Actual cost impacts will depend on electric rates, demand charges, equipment operation, and future fuel prices. The post-construction verification study will compare actual utility use and costs with the modeled baseline.

The Deep Energy Retrofit pathway helped close the cost gap by tying incentive eligibility to whole-building modeled savings rather than individual measures. LEAN's pathway requires at least a 40 percent reduction in site EUI and provides incentives based on modeled MMBtu savings, which allowed envelope, electrification, and ventilation measures to be evaluated as an integrated package (LEAN Multifamily 2025). Without the minimum performance requirement and associated incentive structure, gas boiler replacement would likely have remained the lower-cost conventional option, even though it would have extended fossil fuel dependence and increased long-term BERDO compliance risk (New Ecology 2024).

Twelve months of post-construction utility data are currently being collected to compare measured performance with modeled savings and refine future ZOT pathway assumptions.

**Case Study 2: Portfolio-Scale Clean Energy Planning at Enterprise Community Development**

The Carol Avenue case study shows how a single recapitalization event can enable a ZOT-aligned retrofit. Enterprise Community Development (ECD) provides a different model: portfolio-scale decarbonization that begins outside the traditional LIHTC redevelopment cycle. In this case, solar development and clean energy financing became the first step, creating a platform for later energy efficiency, electrification, and compliance risk management.

ECD is a nonprofit affordable housing owner and operator affiliated with Enterprise Community Partners. Its portfolio includes approximately 115 communities and 13,000 homes serving more than 24,000 residents across the Mid-Atlantic region (Enterprise Community Partners 2026). ECD's ZOT approach grew from the overlap of market opportunity, local policy, and operating cost pressure. Beginning in 2016, ECD began exploring clean energy investments that could move outside the typical new-construction or year-15 LIHTC recapitalization cycle. It later joined the DOE Better Climate Challenge and committed to reducing portfolio-wide greenhouse gas emissions by more than 50 percent within 10 years, with a goal of nearly 50 MW of solar generating capacity over seven to 10 years (Enterprise Community Partners 2023).

ECD used portfolio analysis to identify early solar opportunities based on roof condition, renovation status, utility costs, SREC value, and resident benefits. Phase 1 included 1.1 MW of solar across 12 Washington, D.C. properties, while Phase 2 added 2.2 MW at four properties and incorporated community solar, solar carports, EV charging, battery storage, and workforce training. Public Enterprise sources confirm the broader program direction, including resident electricity discounts of 20 to 50 percent and more than 3 MW of solar deployed across Washington, D.C. and Maryland; the more detailed phase-level values are based on ECD internal

project data (Enterprise Residential 2024; Enterprise Community Partners 2026; Enterprise Community Development 2026).

Phase 3 is now focused on scaling the strategies tested in earlier phases across 25 Maryland sites, including onsite and offsite solar, EV charging, battery storage, and $1.8 million of energy efficiency upgrades. The key lesson is that a ZOT pathway does not always start with a deep retrofit scope. For some affordable housing portfolios, the first feasible step may be taking control of energy costs through renewable energy ownership, using tax credits and financing structures to create value, and then reinvesting that value into efficiency, electrification, and compliance planning.

## Standardizing BPS Action Plans to Support Affordable Housing

The policy examples and case studies above point to a common implementation challenge: long-term decarbonization plans are becoming more important. However, the format, review process, and enforceability of those plans vary widely across jurisdictions. At present, BPS alternative compliance pathways differ in terminology, eligibility, documentation, and regulatory consequences, creating confusion for owners and service providers and limiting replicability (Duer-Balkind, Koolbeck, and Kelley 2025).

Standardization is especially important for affordable housing owners because they often operate across multiple jurisdictions, rely on layered public and private financing, and must align building work with tenant protection, relocation, reserve, and affordability requirements. In 2025-2026, IMT, Slipstream, Building Energy Exchange, and New Ecology worked with stakeholders to develop a unified framework for BPS ACPs, including short-term extensions, percent reduction over baseline, trajectory approach, a revised BPAP, and payments in lieu of performance (Duer-Balkind, Koolbeck, and Kelley 2025; IMT 2026a).

The revised BPAP is the most direct regulatory analogue to ZOT and SDP because it can document baseline performance, business-as-usual emissions, trigger events, phased scopes of work, financing assumptions, interim milestones, and measurement and verification (IMT 2026a). Future implementation work should focus on shared templates, standardized financial assumptions, clearer guidance on acceptable financing gaps, methods for valuing avoided penalties and fossil replacements, and measurement protocols that allow owners and regulators to track progress over time.

## Conclusion and Future Research

ZOT and related decarbonization planning frameworks are helping affordable housing owners move beyond point-in-time audits toward practical long-term implementation pathways. The case studies and programs discussed in this paper show that these pathways can begin at different points: a recapitalization event, a BPS compliance obligation, a certification requirement, a public technical assistance program, or a portfolio-level clean energy financing opportunity. The common thread is that decarbonization becomes more achievable when technical measures are sequenced around real capital events, funding sources, equipment replacement needs, and resident impacts.

The next stage of work should focus less on whether decarbonization plans are useful and more on how they can be implemented consistently. Future research should evaluate which financing structures most effectively move projects from planning to construction, including performance-based incentives, tax-exempt bond financing, LIHTC recapitalization, green banks,

credit enhancements, renewable energy ownership, and blended public-private funding. Research should also examine how plan-based compliance pathways can recognize financing gaps without allowing indefinite delay.

Additional research should track completed projects against modeled assumptions, including measured energy use, emissions, operating costs, resident utility impacts, equipment performance, and maintenance outcomes. This feedback loop is particularly important for affordable housing because a pathway that reduces emissions but increases operating risk, resident costs, or maintenance complexity will be difficult to scale. Shared templates, open-source planning tools, and common review standards can help owners identify feasible pathways, secure financing, protect residents, and move from plans to completed projects.

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