

Creating Regional Ecosystems for Scalable, Low-Carbon Whole-Building Retrofits

Patty Kappaz, Allegheny Science & Technology

Adam Hasz, U.S. Department of Energy

Heather Clark, RMI

James Geppner, New York State Energy Research & Development Authority

Maddie Koewler, National Association of State Energy Officials

Meghan Duff, Association for Energy Affordability

ABSTRACT

Advanced building construction (ABC) has the potential to fundamentally transform the building construction and renovation industry by integrating superior energy efficiency and low-carbon solutions into industrialized construction approaches that enable rapid deployment. By modernizing supply and streamlining delivery, ABC can make it easier and more affordable to achieve high-quality retrofits and new construction while re-energizing the U.S. manufacturing industry and workforce. This paper provides a framework for states to develop regional ecosystems that can aggressively stimulate demand and accelerate the production and deployment of ABC low-carbon whole-building retrofits.

This paper particularly showcases RMI's REALIZE regional programs, the New York State Energy Research and Development Authority's (NYSERDA) RetrofitNY program, and the ABC Collaborative. REALIZE and RetrofitNY's state-based efforts use ABC approaches to make scalable, low-carbon whole-building retrofit solutions broadly accessible to building owners, while the ABC Collaborative supports decarbonization efforts of retrofits and new construction nationally. REALIZE is working with local stakeholders and suppliers in California and Massachusetts to establish regional project delivery platforms for building decarbonization retrofit packages. RetrofitNY is building a pool of building owners, component manufacturers, and solution providers for upcoming net-zero-energy demonstration pilots. The ABC Collaborative is producing supporting analysis, coordinating a broad set of stakeholders, and providing market facilitation that will guide and promote the efforts of REALIZE and RetrofitNY. This paper documents the progress made to date to develop scalable retrofit solutions for multifamily buildings in California, Massachusetts, and New York, and will explore opportunities to build off of this momentum to create robust regional ecosystems for ABC retrofit solutions in the Northeast, West Coast, and beyond.

Introduction

Buildings in the United States account for 40 percent of the nation's energy consumption, 75 percent of its electricity use, and more than a third of its carbon emissions, with 75 percent of today's buildings expected to still be standing in 2050 (EIA 2021a, 2021b). Today's energy efficiency retrofit rates—which rarely surpass 30 percent energy savings and are performed on only one percent of buildings each year (IEA, RAP 2011)—fall far short of the levels required to decarbonize the nation's 130 million homes and commercial buildings. Relying on business-as-

usual building construction and renovation practices to address the climate crisis is simply untenable.

While other industries like communications and manufacturing have experienced productivity gains as they've incorporated digitization and process improvements, the labor productivity of the U.S. construction industry has been on a steady decline since 1968, as shown in Figure 1 (McKinsey Global Institute 2017). This declining productivity has resulted from a myriad of factors (e.g., industry fragmentation, underinvestment in R&D, inconsistent building codes across jurisdictions), which together have increased costs and lowered the ability of industry to deliver low-cost, high-performance construction.

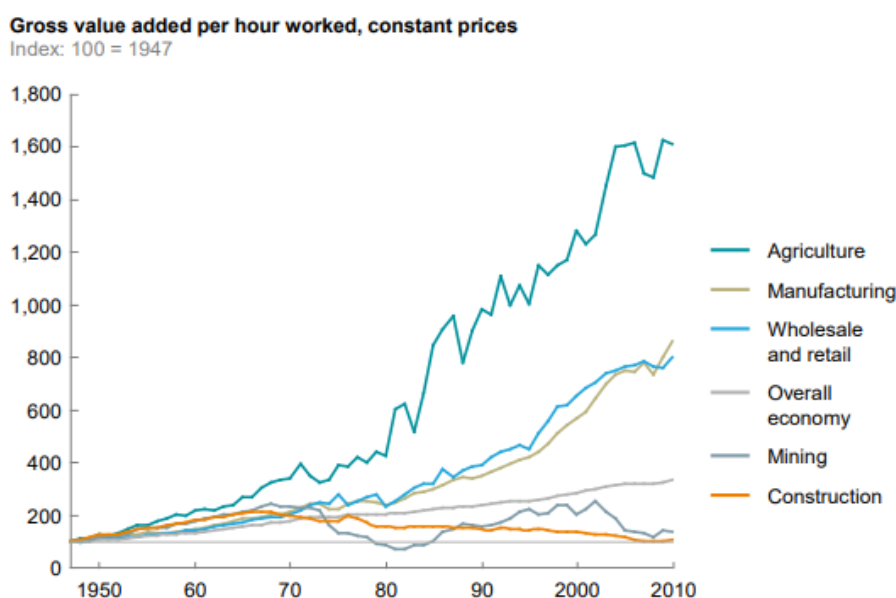


Figure 1. While labor productivity has significantly increased in other sectors, productivity in the U.S. construction industry has mostly declined since 1968.
Source: McKinsey Global Institute 2017.

Declining construction productivity, paired with supply chain disruptions, sharply climbing materials costs in recent years, a shortage of affordable housing across the United States, and insufficient climate solutions for existing buildings all point to the need for a new way of constructing and retrofitting buildings (Fisler et al. 2021).

The U.S. Department of Energy's (DOE) Building Technologies Office launched the Advanced Building Construction Initiative in 2019 to help steer us in a new direction as we face the monumental task of decarbonizing the U.S. building stock by 2050. It is achievable, but it will require radically new approaches for delivering deep energy retrofits. Industrialized construction approaches provide the key to delivering high-performance, carbon-neutral solutions at the speed, scale, and cost necessary to meet the challenge of our lifetimes.

Advanced building construction (ABC)—retrofit and new construction approaches that combine energy-efficient decarbonization with scalable, streamlined industrialized construction—will help get us there. The ABC Initiative is working to accelerate the speed and scale of the decarbonization of the U.S. buildings sector through industrialized innovations that

deliver efficient, affordable, and appealing new buildings and retrofits. DOE is supporting the development of new building technologies and innovative fabrication and installation processes that can be deployed quickly with minimal onsite construction time and leverage related efforts to increase the productivity of the construction industry.

The ABC Initiative builds on efforts currently underway, including RetrofitNY, an initiative of the New York State Energy Research and Development Authority (NYSERDA), and REALIZE, a market facilitation platform active in California and Massachusetts led by RMI. Both programs are working to test new retrofit packages and delivery models that can quickly deploy deep energy, carbon-neutral retrofits in affordable low-income multifamily housing. RetrofitNY and REALIZE expect to achieve energy savings that are two to three times greater than standard weatherization, while making buildings more resilient, as well as healthier for residents through better ventilation and the elimination of fossil fuel combustion on site. Their pioneering efforts to develop an ABC marketplace that benefits everyone, particularly the most vulnerable, is inspiring others to join their ranks and turn these nascent ABC markets into thriving regional ecosystems. Finally, the DOE-funded Advanced Building Construction Collaborative (ABC Collaborative), led by RMI—which brings together forward-looking people and organizations to modernize building construction and retrofit technologies and practices—will play a vital role in building and connecting supply chains and demand pipelines in regions around the country to build the ABC market.

Current State of Industrialized Construction in the Buildings Sector

In Europe, the Energiesprong model that began in the Netherlands and has since spread to four neighboring countries has demonstrated success in compressing costs for innovative deep energy retrofits in affordable housing. Using industrial fabrication processes and aggregation of demand, Energiesprong retrofit costs were reduced by 55% over a three-year period while bringing site energy use to net zero (Energiesprong 2015). RetrofitNY, REALIZE, and DOE's efforts were all inspired by the Energiesprong model, as well as by examples of large-scale deep energy retrofits in the U.S.

Industrialized construction processes, such as factory-based offsite fabrication and mechanized installation, enable traditionally disparate building components to be packaged in a single assembly or product. With the types of ABC approaches described in this paper, deep savings can be achieved by utilizing (1) factory-built, super insulated panelized roof and wall systems that can be mass fabricated and delivered to a building site to be hung on the roof or walls to serve as a new façade of an existing building, thus reducing heating and cooling needs, and (2) all-electric, high-performance mechanical systems packaged in a single unit to provide heating, cooling, fresh air ventilation, and water heating. These smaller-footprint mechanical systems have the potential to be installed quickly, leveraging a single electrical circuit, and relying on a single heat pump to serve multiple end-uses. A packaged mechanical system can be embedded into a panelized envelope system, resulting in a comprehensive building retrofit product. This industrialized construction approach creates the ability to rapidly improve a building envelope with one integrated product, often while building occupants remain in place during the renovation. While the examples used in this paper are focused on multifamily

buildings, ABC approaches can be tailored and applied to a variety of commercial and residential building types.

In addition to the fabrication of building components, industrialization can be applied to building and installation processes. Incorporating augmented or virtual reality technology and automation into the installation process can allow for mass customization and reduce install time, errors, injuries, and inefficiencies.

Currently, prefabrication is used for some individual building components—like structurally insulated panels (SIPs) and less commonly for things like residential framing—which are produced in a factory setting and delivered as a product to the site for installation. This same concept can be used for more comprehensive building components, like an entire wall system or mechanical retrofit. However, the industrialized infrastructure and the building components produced by that infrastructure are limited in the U.S. market. Federal, state, and regional entities are currently funding research and development efforts to design, demonstrate, and create markets for these products and processes, and study their market potential.

DOE (through its ABC Initiative), the California Energy Commission (CEC), and NYSERDA are funding research projects that incorporate technology and process demonstrations, resulting in stepping-stone products that are being installed in buildings today. These efforts are being funded to revitalize the growth and modernization of the construction industry, to make buildings and construction practices a solution for addressing the climate crisis, and to deliver better, healthier, more resilient buildings. While the current state of industrialized construction for the buildings sector is in development, the market is still in its infancy, but quickly picking up speed. Building demand, in part by creating regional ecosystems for these building practices, will fuel the growth of the industrialized construction movement.

State Delivery Models for ABC Whole Building Retrofits

RetrofitNY and REALIZE have emerged as leading models for state-based industrialized low-carbon retrofit programs. RetrofitNY is a state-funded and state-led effort with NYSERDA at the helm. REALIZE is funded through various sources including philanthropic, state, and federal funding and led by RMI. Alternate program delivery models may also be feasible for other states considering developing their own ABC-type programs. Both RetrofitNY and REALIZE are working to (1) develop retrofit packages that are standardized and easy to deploy in occupied buildings, reduce tenant disruption, and achieve near zero-carbon operations, (2) streamline and standardize financing so that it can be done similarly each time, and (3) build a robust supply chain and aggregate building owner interest to ensure a pipeline of demand in the future. Together, these are ultimately what will enable scale.

RetrofitNY

Launched by NYSERDA in 2018, the RetrofitNY initiative is developing new solutions to renovate multifamily buildings to achieve carbon neutrality, and creating standardized and scalable processes to improve resident comfort and building energy performance. New York’s relatively uniform building stock will enable the initiative to rapidly activate a large market and compress costs by using solutions that can be replicated across many similar buildings (NYSERDA 2022d).

The RetrofitNY strategy focuses on lowering value chain costs by supporting companies with business models conducive to a scalable solution; accelerating the development of whole-building solution use cases as a pathway to scale; increasing the capital available to finance projects and reducing reliance on gap funding by developing a long term net-zero energy warranty; using existing pipelines and funding resources (e.g. housing finance agencies) to create a demand pipeline; and supporting the development of integrated technologies with R&D funding.

In 2018, as one of its first steps, NYSERDA awarded six design-build teams to design high performance, low-carbon retrofit solutions for affordable multifamily buildings. The project teams created retrofit designs for low- and mid-rise buildings in New York City and upstate New York, several of which are either expected to go to construction or have already begun. One of those buildings, “Casa Pasiva,” a 1931 four-story, 46-unit building in the Bushwick neighborhood of Brooklyn, was RetrofitNY’s first retrofit pilot and was completed in summer 2022. Another pilot, 439 West 125th, a 21-unit, six-story building in the West Harlem neighborhood of Manhattan, is expected to begin construction in early 2023.

The first phase of RetrofitNY’s efforts to test new retrofit designs provided promising results and drew sharper focus on some of the challenges that need to be addressed moving forward. The incremental costs of these solutions, unsurprisingly, are a major challenge and will remain a central focus of RetrofitNY’s efforts as it strives to achieve the cost compression necessary to enable ABC retrofits to be a viable solution for building owners. Other challenges that were brought to light included the lack of available technologies in the supply chain (specifically high performance retrofit wall systems and combination mechanical systems)—which NYSERDA, DOE, and others are working to address through R&D investments—and the market segmentation of the retrofit industry that prevents a streamlined delivery process.

To address some of these issues, in 2021, NYSERDA released three requests for qualifications (RFQLs) targeted respectively at affordable housing multifamily building owners; component manufacturers to develop new, higher performance building retrofit components; and solution providers (multidisciplinary companies capable of delivering and scaling low-cost, replicable whole-building retrofit solutions via a direct delivery to customer model). NYSERDA is using this approach to build a pool of candidates for upcoming ABC-style demonstration pilots. Candidates qualified through the RFQL will be able to apply for gap funding to implement the retrofits as part of a project team with other qualified candidates. In this model, manufacturers will be able to lower sales costs by working directly with solution providers and avoiding the intermediaries typical of traditional sales channels. Solution providers will work directly with manufacturers and building owners to deliver whole-building retrofits using a business model with efficiencies currently not available to competitors (NYSERDA 2022a). As of August 2022, RetrofitNY had qualified eight building owners, six component manufacturers, and seven solution providers (NYSERDA 2022c). RetrofitNY is working aggressively to retrofit a large number of affordable housing units that approach or achieve carbon neutrality by 2025. This effort will help move RetrofitNY closer to its goal of developing “retrofits as a product” that can be applied to buildings with similar typologies and improving process efficiencies that will ultimately drive down costs.

In late 2021, NYSERDA announced \$5 million in funding for all-electric, deep energy retrofit pilot projects for affordable housing, including \$100,000 for project design and up to

\$40,000 in gap funding per dwelling unit to cover the incremental costs of the retrofits. Applications are being accepted on a continuous basis through 2024. Only qualified building owners from NYSERDA's RFQ process are eligible to apply and those selected will partner with a qualified solution provider (NYSERDA 2022b).

REALIZE

Similar to RetrofitNY's vision of "retrofits as a product," REALIZE views ABC-type approaches as "having the potential to unlock the retrofit market as a function of turning the retrofit process into a product, as opposed to a complex set of activities that increase an already complex capital improvement process" (RMI 2020).

REALIZE has gained traction by focusing on retrofit technology R&D to be applied and demonstrated as integrated packages in specific regions. To date, they have received funding to do so in California and Massachusetts. Before selecting demonstration sites, the most common building typologies and their existing systems were identified in a region, with retrofit packages designed for repeatability and to fit those typologies. Packages have included prefabricated exterior wall panels and other exterior insulation solutions; high performance roofs with solar PV; all-electric mechanical systems, including integrated mechanical pods with domestic hot water, heating, cooling, and ventilation; and all-electric appliances. When electrifying buildings in regions with high electricity rates, packages often include grid-interactive features to reduce operating costs. REALIZE also strives to use low embodied carbon materials and has been engaging with panelized wall manufacturers to encourage them to replace foam-based insulation with alternatives like wood-based insulation, cellulose, and hemp. Retrofit packages are often assembled offsite to ensure high quality and performance using precision tools available in factory settings.

What would become REALIZE-MA began in 2017 with secured funding from DOE for an Energiesprong-style pilot. Through a competitive selection process, following a cold and very cold climate typology study, the Eva White apartment complex owned by Winn Companies was selected as a model demonstration of a very common typology in the Northeast. The pilot is expected to break ground in the fall of 2022. Leveraging learnings from the Eva White design process, REALIZE-MA has now more fully launched its demand aggregation activities, specifically the 1,000 Apartment Challenge (The Challenge), which is targeting 1,000 apartments to begin deep energy retrofits by 2023. The Challenge is being implemented in partnership with the Massachusetts Clean Energy Center (MassCEC), Local Initiatives Support Corporation (LISC), Massachusetts Association of Community Development Corporations (MACDC), and Citizens' Housing and Planning Association.

REALIZE-CA was launched in 2018 with \$7.2 million in funding from the California Energy Commission. Supported by this funding, REALIZE-CA is tasked with carrying out 300,000 square feet of retrofits for apartments in disadvantaged communities across the state, as well as establishing an ongoing model for scaling and delivering decarbonization retrofits to multifamily housing in California. The program must attempt to hit levels of roughly 50,000 units of zero-carbon retrofits per year by 2030.

Demonstrations. REALIZE’s first concluded retrofit pilot was completed in April 2022 on the Vera Cruz Village, a townhouse-style apartment complex in Richgrove, California. The demonstration included insulated metal roof panels to replace the aging roof, double pane windows, a heat pump in each unit for HVAC and domestic hot water, and improved ventilation systems, resulting in an all-electric property. Four additional REALIZE pilots are expected to be completed in California by the end of 2023.

The Eva White pilot, a building in Boston’s South End neighborhood, is a Rental Assistance Demonstration (RAD)¹ conversion that presented an opportunity to add a deep energy retrofit scope of work to an already planned rehab. REALIZE is collaborating with Castle Square Tenants Organization, WinnCompanies, Open Market ESCO, and a team of technical experts to deliver this project. Originally built in 1967, the seven-story, low-income multifamily building will receive highly insulated exterior wall panels with integrated high-performance windows and doors that will be attached to the building’s existing façade; all-electric heating, cooling, hot water, heat recovery ventilation, and cookstoves; LED lighting and ENERGY STAR appliances; grid interactivity capabilities to manage demand; and solar PV. The package is expected to deliver 67% energy savings to the building, with construction expected to start in the fall of 2022.

A second pilot in Boston, the Allston Brighton Community Development Corporation’s Hano Homes—a two-story, wood-framed building built in the 1800s—is slated to begin renovation in the first quarter of 2023. It is targeting zero energy and Passive House certification by using a super-insulated, low embodied carbon exterior insulation panel with hemp insulation in some locations and a built in-place mineral wool exterior insulation system in other locations. It will be all electric with heat recovery ventilation and powered with solar PV.

Additionally, in March 2022, REALIZE, in ongoing collaboration with WinnCompanies—the largest owner/manager of affordable housing in the U.S.—was selected by DOE through a competitive funding opportunity to demonstrate an integrated retrofit package that includes prefabricated insulated envelope panels, a heat pump mechanical pod, and innovative financing in a mid-rise, 120-unit low-income multifamily building in Cambridge, Massachusetts. This will build off the deep knowledge and experience gained from the first REALIZE/Winn partnership on Eva White.

The Path Forward: Creating Regional Ecosystems for ABC Retrofits

Much is being learned from observing the RetrofitNY and REALIZE programs. States in the surrounding regions stand to benefit from these visionary efforts. By joining forces across state boundaries, funding streams can be leveraged, a coordinated supply chain can emerge along key travel corridors, and regional demand can be aggregated to ramp up economies of scale. RetrofitNY is already working beyond its own state boundaries with national partners, including RMI’s REALIZE team and the ABC Collaborative, to mobilize a larger regional market to more rapidly compress costs and demonstrate viability. REALIZE intends to use strategies developed in New York, Massachusetts, and California to expand to other states. The RetrofitNY and REALIZE teams coordinate regularly to update each other on progress and discuss opportunities

¹ RAD is a U.S. Housing and Urban Development (HUD) program that allows HUD-assisted public housing to “convert” their assistance to long-term, project-based Section 8 contracts.

for collaboration. Their strong presence in New York and Massachusetts points to a clear opportunity to establish a robust regional ABC market in the Northeast. In the West, REALIZE-CA can serve as an anchor for a broader regional effort. Figure 2 shows a map of the United States featuring the 20 cities with the highest density of multifamily housing, with potential regional ABC markets grouped within Building America’s climate zones.



Figure 2. Map showing the 20 U.S. cities with the highest density of multifamily housing arranged into potential regional markets for ABC retrofits. Dot size indicates relative number of housing units. *Source: Hasz, A. 2021.*

This section lays out the beginnings of a framework that states and other stakeholders can use to establish regional ecosystems capable of supporting a viable ABC industry. This includes four key components for ABC market development as described below, as well as engagement with and convening of state actors, and identification of viable funding options.

Key Components for ABC Market Development

Learnings from the RetrofitNY and REALIZE models and the work being led by DOE and the ABC Collaborative bring to light four key components for ABC ecosystem development within individual states, and ultimately within connected regions. These include (1) identifying target markets, (2) coordinating the supply chain, (3) building the demand pipeline, and (4) streamlining and standardizing financing.

Identifying target markets. Any good building decarbonization strategy should begin with analysis to identify and prioritize which buildings to target. The first step is identifying the most common building typologies for which retrofit packages can be designed and replicated throughout the region.

REALIZE’s use of characterization studies provides a solid example of how upfront analysis can guide the selection of buildings and retrofit package designs. In California, REALIZE’s analysis found that townhouse, garden style, and loaded corridor are the three most common typologies in the multifamily building stock, collectively representing over 2 million units across California. REALIZE-CA used these typologies to guide the selection of

demonstration sites to ensure that the technologies and approaches developed would be able to scale across the typologies. After completion of the market characterization study, a robust parametric energy modeling analysis, and analysis of key product and structural characteristics, the REALIZE-CA team synthesized its findings into a set of preliminary envelope retrofit guidelines. These guidelines are intended to be standardized and approachable, providing a starting point for building owners and designers as they begin retrofit project scoping (Egerter 2020). RetrofitNY similarly conducted a market characterization study that included a building inventory assessment and architectural profiles for the major multifamily building typologies in New York.

The National Renewable Energy Laboratory (NREL) has since published the first comprehensive building stock characterization study for the United States. It sorts residential and commercial buildings by vintage, fuel uses, envelope quality and energy consumption and can help identify and prioritize the buildings that need the heaviest envelope upgrades or fuel switching for HVAC, as an example. This foundational tool empowers decision makers to identify technology requirements and engineering solutions for moving the existing U.S. building stock toward a zero-carbon future (Reyna et al. 2022).

Coordinating the supply chain. “Successful modernization of the U.S. construction industry requires a supply chain that can meet the increasing demand for high performance buildings” (Advanced Building Collaborative 2022). In order for ABC retrofits to achieve cost compression and be viable in the market, there must be a process for creating integrated teams throughout the supply chain that can seamlessly deliver to building owners’ specifications (Fisler et al. 2021). One way to do so is through requests for qualifications and requests for proposals, which can be used effectively to both engage and shape the supply chain around ABC goals.

RetrofitNY uses a “Zero Carbon Solution Provider” model where integrated multi-functional teams work together using new business models to deliver building retrofits. By optimizing and integrating the value chain and leveraging digital technologies and processes, the Zero Carbon Solution Provider can deliver turnkey services to building owners. RetrofitNY expects advantages of this model will include significant cost compression and a pathway to a self-sustaining retrofit industry; investment in the design of a replicable retrofit solution; scale by using known products with known outcomes and using purchase agreements with component manufacturers for those products; ability to attract investment capital; investment in new technologies (e.g. digital processes); reduced risk for building owners; and it changes incentives so that the seller’s fate is tied to the building’s performance (Geppner 2021).

Efforts should also be made to regionalize the supply chain, for example, building local manufacturing capacity in the region where the products will be used, and locating them within close proximity to materials suppliers when possible. Not only does a regionalized supply model support efficiencies in product delivery—including potentially reduced costs, time, and carbon emissions associated with shorter travel distances—but can provide enormous economic development benefits for the region, including supporting a robust, inclusive workforce. For REALIZE-MA and RetrofitNY, focusing on developing the supply chain from Massachusetts to New York can effectively meet demand for the entire Northeast region. The two state programs have also proposed a regional supply chain that would include a carbon-storing, bio-based

material (such as wood pulp) producer in Maine that could supply panelized wall fabricators with low embodied carbon materials for insulation.

A robust workforce is critical to supporting the supply chain. Workforce development presents opportunities for municipalities, states, and regions in terms of economic development and high-quality jobs, including small business contractors to deliver the retrofit solutions as well as new jobs in offsite construction or the construction manufacturing industry that will be needed to support and supply the volume of retrofits necessary to address the climate and affordable housing crises. The ABC Collaborative is helping to assess and define the workforce landscape and better understand what construction jobs will look like under an ABC paradigm. That analysis will be used to help launch workforce training programs with local, state and regional workforce development actors to help meet the needs of the growing ABC retrofit market (Campbell et al. 2021).

Building the demand pipeline. Cultivating demand early on is critical to ensuring the success of a new product. A first step to building a demand pipeline for ABC retrofits is to obtain “soft” or aspirational commitments from building owners using a pledge. Pledges can be a good tool for initiating engagement with building owners, raising awareness about the retrofit solution as a product with defined outcomes, including a multitude of benefits for both owners and tenants, and fostering support from policy makers for a regional ABC market. A pledge gives owners the opportunity to commit to using ABC technologies and approaches if and when they become available and are cost effective. It can be the first step in the customer acquisition process for the manufacturer and solution provider, giving them visibility into the market and allowing them to model various demand levels to determine if market entry is feasible. A pledge sends a signal to industry and policy makers that building owners care about carbon-neutral building solutions, and can reduce concerns of risk by manufacturers, ideally aided through greater state and local support, motivating them to develop the desired solutions. Pledges also provide building owners with the opportunity to be seen as a leader among peers.

Both RetrofitNY and REALIZE have pledges which, as of July 2022, have respectively secured soft commitments to retrofit approximately 400,000 and 60,000 housing units, respectively, using ABC-type approaches (NYSERDA 2022e; RMI 2022b). While pledges alone don’t guarantee a pipeline of projects, they can play an important role by beginning a process that will ultimately lead to matchmaking between solution providers and building owners.

The next step for demand aggregation is getting hard commitments from building owners and developers, as REALIZE-MA is demonstrating with its 1,000 Apartment Challenge targeted at affordable multifamily housing already scheduled for major rehab work. The building owners that have signed on to The Challenge are committing to going beyond their initial rehab plans to include ABC-style, whole-building deep energy retrofits, with construction beginning by the end of 2023. While direct capital support is not provided, REALIZE-MA is providing owners with financing options—such as funding available through energy efficiency programs such as Mass Save and other sources—to cover the incremental cost above a standard rehab, and connecting owners with manufacturers, designers, and contractors for project execution. Low-Income Housing Tax Credit (LIHTC) projects or RAD conversions where window, roof, mechanical, and/or siding replacements are already scheduled are ideal candidates for The Challenge. Results

from The Challenge will provide insights and lessons to other states and regions looking for ways to aggregate demand (RMI 2022a).

Creating a robust regional ecosystem comprised of both supply and demand actors with supporting market enablers (e.g., from finance, regulatory, permitting, and workforce training) is the ultimate goal to ensure a thriving ABC market. Figure 3 shows one such ABC concept proposed by a coalition of partners in the Northeast.

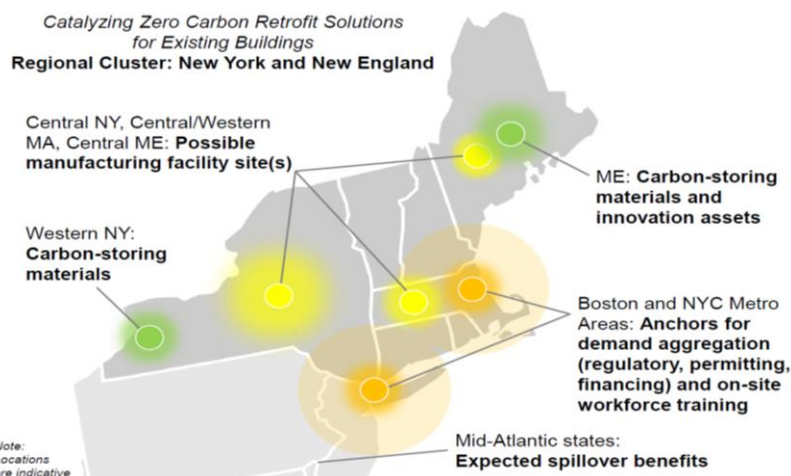


Figure 3. Holistic regional ABC ecosystem approach that includes low-carbon materials producers, manufacturing facilities, anchors for demand aggregation, and workforce training sites. *Source:* RMI 2021.

Streamlining and standardizing financing. For ABC retrofits to achieve scale in the market, both willingness to pay and the incremental cost of retrofits must come down to be competitive with traditional business models and technologies.

A number of strategies and factors can facilitate cost compression. Subsidies present one opportunity to defray costs initially while stimulating the demand needed to create economies of scale that lead to cost compression. Buildings historically have received a far lower level of subsidies than clean energy technologies in other sectors like electric vehicles and solar PV, whose value, unlike homes and buildings, depreciate over time. The greatest potential for cost compression lies in accelerating industry advancement up the learning curve on ABC retrofit approaches, industrialized construction practices, and innovative business models. From there, as technologies mature and retrofit delivery options become more widely available, costs will further decline (Campbell et al. 2021).

Willingness to pay could increase if additional value streams (e.g., decreased insurance premiums or lower transaction costs) could be monetized by owners (Geppner 2021). Carbon credits could also present an interim opportunity as the market develops to defray some of the incremental costs. Additionally, there's an opportunity for lenders to underwrite deeper energy savings. Today, at best, only about 50% of projected energy cost savings can be underwritten, but programs like REALIZE are looking to increase that to 75-100%.

There is a need to develop financing programs designed specifically for deep energy retrofits. These programs would take into account the many financial benefits of a deep energy

retrofit to the building owner and would weave together financing products that account for these benefits. For example, capital providers may use contracts similar to energy service agreements to lower upfront costs to building owners while reducing building owner technology risk and better sizing the value of the building's performance. These can include lower rent nonpayment and delinquency rates, higher occupancy rates and lower turnover costs, lower insurance costs, lower maintenance costs, and increased longevity of the building.

Engaging State Actors and Relevant Stakeholders

State Energy Offices. State and territory energy policies and programs are vital to increasing energy efficiency, expanding clean, domestic energy resources, and spurring economic development. State Energy Offices can play an influential role in creating a supportive policy and project transaction environment to enable state-based ABC retrofits. This can include advocating for a more streamlined regulatory and permitting landscape for ABC retrofits, supporting the development of ABC-enabling finance programs, engaging building owners and technology manufacturers and suppliers to support demand aggregation and supply chain integration efforts, supporting workforce and economic development, and championing ABC demonstrations through direct funding, technical assistance, or other support.

State and Territory Energy Offices may be interested in designing and implementing new programs that holistically addresses ABC similar to NYSERDA's RetrofitNY program. The holistic approach requires significant market development along the lines of demand aggregation, financing program design, and workforce development, as well as direct subsidies to owners. An alternative to initiating a new program is to integrate ABC technologies and practices into existing building energy efficiency programs. The opportunities associated with offsite construction, low-carbon materials, and new technologies have the potential to streamline and scale building efficiency programs. As ABC technologies and program models are validated, best practices and lessons learned can be applied to energy efficiency programs. Finally, State and Territory Energy Offices can collaborate with other agencies and stakeholders to develop a market for ABC projects. State Energy Offices can lend energy and policy expertise to partnerships with Housing Finance Agencies, workforce development organizations, and manufacturers interested in deploying ABC.

Housing Finance Agencies. State Housing Finance Agencies (HFAs) can play an important role in enabling the financing of ABC retrofits for affordable housing. HFAs "play a central role in the nation's affordable housing system, delivering financing to make possible the purchase, development, and rehabilitation of affordable homes and rental apartments for low- and middle-income households" (NCSHA 2022b). HFAs have financed approximately 4.6 million low- and moderate-income rental homes, 3.6 million of which utilize LIHTC (NCSHA 2022a). HFAs can include criteria in qualified allocation plans (QAPs) that require or incentivize LIHTC projects to use ABC approaches for major rehabs, with specific energy and carbon reduction targets for existing buildings. HFAs can also use their Housing Bond authority to provide low-cost mortgages to low-income borrowers for purchasing a home that was retrofitted—or built new—using ABC approaches, or to pay for ABC retrofits on affordable rental units.

The ABC Collaborative. The ABC Collaborative’s mission is to “bring together and catalyze constructive relationships among incumbent and emergent buildings sector actors to accelerate the uptake, scaling, and mainstream adoption of ABC solutions, while supporting—and leveraging—modernization of the construction industry” (Advanced Building Construction Collaborative 2022).

The ABC Collaborative brings together major buildings sector stakeholders, from supply, demand, and R&D, as well as market enablers from across the public sector and from the finance, workforce, regulatory, and insurance sectors. In addition to engaging and coordinating this broad set of stakeholders, the Collaborative is producing supporting analysis and providing market facilitation that will guide and promote the efforts of REALIZE and RetrofitNY as well as other ABC activity across the country. The Collaborative performs several core activities, including foundational activities (e.g., programming like topical working groups, thought leadership), market mobilization activities (e.g., place-based scaling, technology innovation scaling, workforce development), and transacting activities (directly organizing and connecting demand to supply).

The Collaborative’s place-based scaling activities are focused on developing and testing transferable models for scaling ABC implementation—particularly relevant to municipalities, states, and regions. This will involve creating ABC scaling “recipes” that can be replicated, as well as ABC “playbooks”—building upon lessons learned from the REALIZE and RetrofitNY efforts—outlining guidance for socializing the concept of ABC, obtaining buy-in from public agencies, engaging owners and manufacturers, and accessing state and federal resources.

One of the key roles the ABC Collaborative will ultimately play is as a market scaling engine to help accelerate ABC retrofits on the ground and support the vision of a vibrant ABC industry. A central component of that role will be to provide matchmaking services between building owners and ABC supply teams. The Collaborative intends to also provide other demand-side and supply-side services including technical assistance and connecting performance-focused developers or ABC manufacturers to growth capital providers. States and regional stakeholders can look to the Collaborative for support in initiating ABC market development plans.

Potential Funding Opportunities to Leverage

Large federal investments are vital to kickstarting a nascent market like ABC and providing the critical resources needed to improve the quality of affordable housing while adequately addressing the role buildings play in our climate crisis. Significant investments by the federal government have the ability to ignite innovations and initiatives to decarbonize our buildings at the speed and scale needed to meet our nation’s climate goals.

States can utilize their own appropriations, federal funding streams, or a combination of the two, to support ABC retrofits. Through the Infrastructure Investment and Jobs Act (IIJA), DOE’s State Energy Program (SEP) will provide \$500 million to State Energy Offices via formula grants in addition to formula funding through annual appropriations. IIJA also includes \$250 million for an SEP Revolving Loan Fund for residential and commercial building energy audits and retrofits, \$550 million in Energy Efficiency Conservation Block Grants (EECBG), \$3.5 billion through the Weatherization Assistance Program, as well as funding to support

workforce development (NASEO 2022a). States may also be able to allocate a percentage of their American Rescue Plan Act (ARPA) funds to rapidly decarbonize existing buildings, such as is being proposed in Massachusetts with the Zero Carbon Renovation Fund, where some of the state's ARPA funding would go to the fund to support the rapid decarbonization of existing buildings in Massachusetts with a focus on low-income housing, municipal buildings, minority- and women-owned businesses, and buildings located in environmental justice communities (MCAN 2022).

States and municipalities can support the ABC retrofit market—and reap economic development benefits—by making smart investments that enable a vibrant ABC industry. For deep energy retrofits, states should consider allocating the majority of funds to qualified providers with turnkey, replicable solutions, such as those being developed by RetrofitNY and REALIZE. States can help build a pipeline of ABC projects by providing gap funding to cover the incremental cost of the retrofits. States can also develop a capital reserve fund that supports a warranty for ABC whole-building, deep energy retrofit solutions.

States, municipalities, and regional coalitions can get creative in weaving together—or “braiding”—funds across various funding streams to maximize impact. In addition to federal, state, or local funding, there may also be opportunities to fund ABC efforts using philanthropic investments. Several states and municipalities have successfully stacked funds to expand existing retrofit services. Philadelphia's “Built to Last” program, which seeks to restore the safety, health, affordability, comfort—and ensure the long-term quality—of existing affordable housing, can serve as a model of a well-coordinated, cross-agency approach to program funding and deployment. Inter-agency coordination and layered service delivery has enabled collaboration across Philadelphia's siloed government agencies. The program was able to stack funding from more than 20 sources—including utility programs, legal services, repair programs, and health and housing counseling—to provide free retrofits to 40-50 low-income households at no cost (Philadelphia Energy Authority 2020). In New York, the City of Ithaca—as part of its innovative and ambitious initiative to decarbonize all of the city's buildings by 2030—raised \$100 million in private equity funds to finance comprehensive building retrofits (Rosenbaum 2021). Even in the absence of massive federal investments, states and local governments are finding creative ways to make significant investments by stacking funds from across various programs or from non-traditional funding streams.

Conclusion

A burgeoning market for ABC retrofits is beginning from New York to Massachusetts and across California thanks to the efforts of RetrofitNY, REALIZE, DOE, CEC and other partners. With additional stakeholder interest and action, the existing efforts in New York and Massachusetts can be expanded into a broader regional ecosystem across the Northeast and adjoining Midwest, and work underway in California can anchor a broader network throughout the West. As innovative delivery models for ABC retrofits are refined and shared across regions, new champions will emerge to help tenants, building owners, and the construction industry across the United States reap the benefits of high performing, carbon-neutral buildings. But this won't be possible without new players rolling up their sleeves and stepping up to the plate. RetrofitNY Program Manager, Christopher Mahase, captured that sentiment well, noting “No

one state has all the resources to fully support this developing market, but together we stand a very good chance of really accelerating and being successful with the industrialized retrofit market” (Campbell et al. 2021).

As we face the converging crises of climate change and a massive shortage of affordable housing, and are left daunted by the challenge of decarbonizing our building stock in less than 30 years, we are presented with an opportunity. We have an opportunity to improve the quality, comfort, resilience, health and appeal of the buildings in which we live, work, and play. ABC has the potential to deliver all of these things while decarbonizing our buildings, and it can do this because of the scale that is made possible by industrialized solutions that can deliver a desirable product quickly, conveniently, and (eventually) affordably.

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