

Building a Better America through Advanced Building Construction: Federal Actions to Scale Industrialized, Energy Efficient, and Affordable Housing

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ABSTRACT

Modernizing the U.S. building construction and renovation sector can help deliver three key goals of President Biden’s agenda: climate mitigation, affordable housing, and good jobs. This paper proposes a pathway to scale Advanced Building Construction (or “ABC”) practices for the affordable housing sector by utilizing existing federal policy tools and potential new investments from the Infrastructure Investment and Jobs Act, the CHIPS and Science Act, and the Inflation Reduction Act. This proposal to scale ABC approaches will require a “whole of government” strategy, with coordination at the federal, state, and local levels across multiple agencies and programs. If successful, this proposal could produce and preserve thousands of high-performance affordable homes constructed or retrofitted with industrialized methods while supporting economic development and good jobs for both manufacturing and onsite construction.

The U.S. Department of Energy’s Building Technologies Office (or “BTO”) is already supporting efforts to modernize the residential buildings sector through the Advanced Building Construction Initiative. This paper proposes a new partnership between DOE, HUD, and other federal agencies to apply ABC approaches to affordable housing construction and renovation. Through demand aggregation using new incentives and technology and market scaling efforts supported by recent legislation, such an interagency partnership could enable ABC approaches to construct and renovate thousands of affordable housing units in the next five years.

Introduction: ABC Can Help Address Housing, Climate, and Jobs Challenges

Today’s practices to build or renovate high-performance and low-carbon housing are generally slow, disruptive, and costly, limiting the supply of high-quality affordable housing. New industrialized¹ approaches for building construction and renovation could help to increase the rate of construction and renovation of affordable housing units. Recent work by DOE’s Advanced Building Construction Initiative has shown that industrialized approaches can achieve superior energy and carbon performance for little to no cost premium above traditional construction practices (DOE 2020). However, most ABC approaches in the U.S. are still in early demonstration stages. This paper proposes a new partnership between DOE, HUD, and other federal agencies to help scale ABC approaches for constructing and renovating affordable housing with superior energy performance. Such a joint effort could also help to modernize the U.S. construction industry to become more globally competitive, help to reduce the costs of low-carbon buildings, and create new pathways to good jobs in construction and renovation.

¹ Industrialization of an industry is an umbrella term that means to streamline it in a way that is reproducible at scale. In this case, industrialization of building construction and renovation could refer to streamlining product manufacturing, system manufacturing, business models, sales, and workforce, as well as onsite installation.

The Current U.S. Construction Industry: Inefficient Construction and Inefficient Housing

In the last several decades, many U.S. economic sectors including automotive, biotech, and aeronautics have grown through investments in digitization and process improvements, leading to soaring levels of productivity. However, U.S. construction labor productivity has remained largely stagnant since the end of World War II. Plagued by labor shortages as well as market fragmentation and an underinvestment in innovation, subpar productivity translates into higher costs, extended construction times, and inconsistent performance (Barbosa, et al. 2017).

While many factors such as land use policy and economic inequality have contributed to the current U.S. housing crisis, low construction productivity limits the available housing supply by pushing up the hard construction costs for new homes. Given these factors, the supply of affordable housing has struggled to keep up with growing demand. There are only 37 affordable homes available for every 100 low-income families, which has resulted in a shortage of around seven million affordable homes in the U.S. for extremely low-income renters, with further shortages of attainable housing among other cost-burdened households (NLIHC 2022).

At the same time, the vast majority of existing homes use energy inefficiently, and many were not built to deal with modern resilience challenges such as wildfires, floods, and electricity disruptions. About half of the nation's 118 million existing homes were built before 1980, prior to modern energy codes. Most affordable housing units are also not wired to enable all-electric space conditioning with flexible demand or other smart energy systems. Only a tiny percentage of the existing stock of affordable housing has undergone low-carbon retrofits because doing so typically requires costly, highly individualized, complex, and disruptive upgrades.

Advanced Building Construction Delivers Benefits of Carbon, Cost, Speed, and Comfort

To address these challenges, the U.S. needs new approaches to housing construction and renovation. One such attempt to foster these new approaches is Advanced Building Construction (ABC), which the Department of Energy describes as “innovative low-carbon new construction and retrofit solutions that are faster to deploy than existing solutions, high quality, affordable, and appealing to owners and users” (DOE 2021). ABC approaches often involve a high degree of industrialized construction, which can streamline and integrate existing methods of design, manufacturing, installation, business models, and other elements of the construction value chain.



Figure 1. Advanced Building Construction approaches include innovations across the entire supply chain and streamlined delivery for onsite assembly. *Source:* DOE 2021

The DOE's Building Technologies Office launched the ABC Initiative in 2019 to increase the speed and scale of more efficient and industrialized construction and renovation approaches to deliver more low carbon, high-performing, and high-quality buildings. Thus far, the DOE has invested \$58 million in research, development, and demonstration (or "RD&D") projects focused on advanced building construction for both new and existing buildings (DOE 2020, DOE 2022). HUD is also interested in investing in ABC approaches for affordable housing, as described in its Offsite Construction Research Roadmap (HUD 2022).

While its RD&D projects are still ongoing, the DOE has started to see evidence of key benefits of ABC approaches: high energy efficiency and low-carbon performance, same or lower costs, faster construction timelines, and improved comfort for residents. We highlight these benefits below by describing existing DOE RD&D projects related to affordable housing.

New Construction: VEIC's Zero-Energy Modular (ZEM) factory blueprint system. DOE set a goal that its ABC RD&D projects focused on new construction should achieve 50% less energy usage than the 2018 IECC code level at no additional first cost (DOE 2019). Several ABC projects for single family homes are on track to achieve this goal, including an integrated building system for light wood panels, an additive-manufacturing approach that integrates reinforced concrete with insulation, and a modular system that uses vacuum-insulated panels. The DOE project that best shows the potential for new ABC affordable housing is by VEIC and is named "A New State-of-the-Art: Zero-Energy Modular Multifamily Construction System."

Launched in 2020, the VEIC project aims to develop an open-source factory blueprint that can produce modular multifamily units that use 50% less energy than IECC 2018 at no additional cost (VEIC 2021). The project specifically focuses on low-rise multifamily buildings for the affordable rental market in cold climates, including the Northeast, the Midwest, and the Mountain-West regions. VEIC is partnering with two existing modular companies with factories in the Northeast will provide baseline data, provide feedback on the project approach, and later beta test the construction system for energy reduction, cost reduction, and quality assurance.

VEIC's partner Solar Home Factory of Geneva NY specializes in high-performance buildings for the affordable rental market in New York State. It provided the prototype multifamily building for analysis, a 24-unit low-rise building with an exterior corridor (ibid). VEIC conducted parametric energy modeling of various energy efficiency measure packages using OpenStudio tools for each housing unit's unique location within the building, then summed the results to estimate whole-building energy consumption. From this modeling, VEIC found that the easiest way to achieve the required 50% reduction in site energy was by upgrading from minimum-standard compliant gas heating equipment to high-performance all electrical mechanical systems coupled with an IECC 2018 code-compliant envelope.

VEIC's other factory partner, KBS Homes of South Paris ME, provided the project team with cost data from a completed 24-unit modular multifamily property. This was used to create a baseline cost scenario for a code-compliant modular project (ibid). VEIC then estimated the incremental additional costs of the efficiency measures used in the energy modelling step and added these to the baseline cost scenario. This showed that the total costs of construction with the EE measures needed to achieve 50% lower site energy consumption is expected to be only 2% above the baseline costs. Finally, VEIC showed that a reduction in material waste and a reduction in the cost of quality management could fully cover the 2% cost premium. While not yet confirmed by factory production, this modeling work provides a pathway for modular builders to produce high-performance low-rise multifamily buildings without any cost premium.

Renovation: Affordable housing retrofit projects by ORNL, NREL, and Syracuse U. DOE set a goal that its ABC RD&D retrofit projects should achieve a 75% reduction in thermal loads, or the energy used for heating, cooling, water heating, or ventilation (DOE 2019). These thermal loads account for 46% of all residential energy use and almost all the direct carbon emissions from U.S. homes (EIA 2018). DOE also specifically requested project proposals that would be faster to implement, less disruptive, more affordable, and more desirable to building residents compared to existing approaches for deep energy retrofits. In March 2022, DOE awarded \$31.8 million to seven project teams to demonstrate ABC retrofit approaches that meet these goals (DOE 2022). These projects span a range of geographies and building types, including single family homes, manufactured housing, small commercial, and multifamily buildings. Three projects focused on retrofitting affordable multifamily buildings are highlighted below.

Oak Ridge National Laboratory (ORNL) plans to demonstrate a modular, exterior panel retrofit solution on 12 single-family attached duplexes that are provided as affordable rental housing by the Knoxville Community Development Corporation. ORNL’s initial energy modeling projects the proposed retrofit design to achieve a 77% reduction in thermal energy loads with minimal air leakage, improving resident comfort. The project also includes a laser scanning system to achieve rapid measurement of the existing home exterior surfaces, an easy-to-install panel design, and state-of-the-art integrations with HVAC equipment and controls—all of which are expected to decrease the time needed to complete an installation. Finally, ORNL expects its exterior envelope solution to achieve an installed cost of \$15 per sq ft, which is dramatically lower than estimated costs of \$70 per sq ft for comparable project proposals.

The National Renewable Energy Laboratory (NREL) plans to demonstrate a prefabricated retrofit package for two 13-unit low-rise affordable multifamily buildings in Arvada, CO. Each apartment’s retrofit engineering design will be customized through machine learning techniques applied to site data collected by laser scanning, with expected thermal load energy savings of at least 75% and significant comfort benefits for residents currently experiencing drafts from air leakage. NREL plans for the fabrication of envelope insulation panels to be done offsite, with augmented reality tools available to assist with onsite installation. This combination of tools is expected to reduce construction time and project costs by 50% compared to a business-as-usual approach for completing a deep energy retrofit.

Syracuse University plans to demonstrate a rapid retrofit approach for student dormitories that can be widely applied to low-rise affordable multifamily housing across cold climates. The Syracuse retrofit package uses a highly insulated, prefabricated envelope panel, an integrated mechanical system pod for heating, cooling, ventilation, and domestic hot water, and 3D information capture to model and configure panel fabrication into an optimized workflow. Initial modeling estimates thermal energy savings of 78%. The Syracuse team also aims to develop a “1-2-3 approach” that will allow a full retrofit to be completed in just six days: 1 day for measurements, 2 days for rough-in and demolition work, and 3 days for construction. The speed of this approach would make deep retrofits for multifamily buildings much more convenient.

By leveraging commercialization resources and pursuing demand aggregation and market matchmaking opportunities, DOE, HUD, and other federal agencies can help the ABC innovative approaches described above to scale. If applied to more buildings, these ABC approaches have the potential to create widespread benefits of superior energy and carbon performance for the same or lower hard costs and faster construction or renovation timelines. However, as the next section shows, cross-agency federal actions are likely needed to help scale up these new ABC approaches to be used in thousands of buildings across the country.

Existing Efforts to Scale Industrialized Housing Construction in the United States

Industrialized housing construction approaches attracted a great deal of attention from private investors in recent years, with offsite construction companies like Katerra and Factory_OS raising billions of dollars from venture capital firms and tech giants like Google and Facebook (Peters 2020). These and other modular start-up companies aim to dramatically cut construction costs of new homes in tight housing markets like the Bay Area, Seattle, or the Northeast. Industrialized approaches also can provide good union jobs in a factory-setting, as demonstrated by “wall-to-wall” contracts for workers in Bay Area modular factories negotiated by the Northern California Regional Carpenters Union (Modular Building Institute 2018).

While industrialized retrofits are still a nascent market in the United States, the EnergieSprong Initiative has already provided prefabricated net-zero energy retrofits for 5,700 units of social housing in the Netherlands (EnergieSprong 2022). The New York State Energy Research and Development Authority and the California Energy Commission have committed \$30 million (NYSERDA 2022) and \$7.2 million (RMI 2019) respectively to launch efforts to replicate the EnergieSprong model in the U.S. Building on these state level commitments, the U.S. DOE invested \$26.3 million in RD&D for ABC approaches in 2020 (DOE 2020) and another \$31.8 million for demonstration projects in 2022 (DOE 2022).

However, efforts to boost U.S. construction productivity, affordability, and energy efficiency performance have been hindered by several factors. These include deep-seated localized practices and fragmented business structures, an extremely diverse set of existing buildings across many different climate zones and codes/permitting regimes, a relatively near-term financial focus, risk aversion and consequent resistance to new technologies, and lengthy adoption processes for novel techniques like industrialized construction.

Public Investments Can Support Advanced Building Construction Housing Solutions

Historically, there has been no coordinated national effort in the United States to create a qualified base of ABC supply and technical expertise, nor any national efforts to use federal incentives for higher-performance, lower-carbon buildings with streamlined delivery. Without a coordinated “whole of government” approach focused on advanced building construction, the U.S. is likely to lag behind other nations like China, Japan, Canada, Scandinavia, Continental Europe, and the U.K., which have made significant public-sector investments in modernizing construction through RD&D, government procurement, and subsidies for industrialized approaches. While industrialized construction has attracted more attention in recent years, the U.S. still currently builds only 3% of its housing with offsite methods (Bertam, et al. 2019).

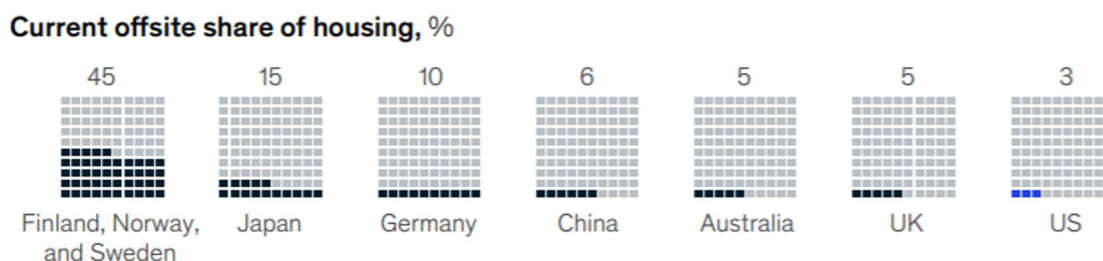


Figure 2. Industrialized offsite construction has a much larger market share in other countries compared to the U.S. *Source:* Bertam, et al. 2019

While there are many differences between the U.S. and Scandinavian housing systems, one specific difference stands out in the context of supporting offsite ABC approaches: Sweden's consistent public support for affordable housing. In the 1960s Sweden embarked on the "Million Dwellings Program" to ease its housing shortage by building 1 million new prefabricated and publicly financed homes over ten years (Turner Center 2017). This was quite an achievement, given that Sweden's population was only 8 million. While new housing construction now happens at a slower rate, the Swedish housing system still gives direct authority over most housing construction to public Municipal Housing Corporations, which provide a stable source of demand for new high-quality multifamily housing. Investors are confident that Swedish prefabricated homebuilders will continuously be able to produce new housing units for the public sector, increasing the amount of capital invested in housing factories.

The consistent Swedish public support for affordable housing stands in stark contrast to the U.S. housing model, where the majority of housing is built and financed by the private market. The U.S. approach ties the rate of new housing construction to the state of the general economy. Good economic times with tight labor markets have triggered a surge of U.S. start-ups focused on prefabricated homebuilding, as happened during the mid-2000s. But after the 2008 economic collapse, many of these new firms went out of business (Drueding 2012). Unfortunately, the Covid19 downturn appears to have triggered a similar pattern of closures for prefabricated construction start-ups, as evidenced by the closure of the multifamily prefabricated builder Skender Manufacturing in the fall of 2020 (Bousquin 2020) and Kattera's bankruptcy in the summer of 2021 (Barzso 2021).

U.S. industrialized construction approaches do not need to fail every time there is an economic downturn. According to McKinsey & Company, a prefabricated construction company can achieve a ~40% boost in productivity by reaching production levels of 1000 units per year (Bertam, et al. 2019). These "units" can vary in size and function, ranging from a single apartment unit in a multifamily building to a classroom in a school. What is most important from a productivity perspective is replicability and consistency. These are characteristics that government intervention can help achieve by aggregating demand and incentivizing multi-year commitments from developers and owners to utilize high-performance ABC approaches—helping to ensure purchases regardless of underlying economic conditions.

Federal Actions can help Standardize, Streamline, and Scale ABC approaches

As shown in the example of expanded Swedish housing production using offsite methods, ABC approaches generally require consistent demand over time and certain design standards that enable replicability as a large scale. This demand is easier to sustain through economic downturns with consistent public investment. Recently passed and agreed-upon legislation will provide billions of dollars in rebates and tax credits for high-efficiency new housing and retrofits, with substantial funding reserved for low-to-moderate income households. With the help of these new subsidies, the DOE, HUD, and other federal agencies can organize developers and owners to spur consistent and standardized construction and retrofitting of affordable housing that utilizes ABC approaches with proven carbon and energy benefits.

In addition, recent legislation authorizes billions of dollars for new clean energy RD&D, commercialization support, regional innovation hubs, support for updated energy codes, financing programs, and efficiency workforce training programs. This section summarizes the new legislation, proposes strategies to utilize new legislative programs in ways that help to scale ABC approaches, and highlights potential models for effective interagency collaboration.

Summary of New ABC-Related Legislative Programs: IIJA, CHIPS+, and the IRA

Three pieces of recently signed and agreed-upon legislation will invest hundreds of billions of dollars into research, development, and infrastructure upgrades, including tens of billions designated for programs related to improving the energy efficiency of America's housing that can potentially support efforts to scale up ABC approaches. First, the Infrastructure Investment and Jobs Act (or "IIJA") signed into law by President Biden in November 2021 will invest over \$5 billion in grants to states and local governments that fund programs for building efficiency upgrades. The title of this paper comes from the White House guidance document for implementing the IIJA (The White House 2022). Second, the CHIPS and Science Act (or "CHIPS+") that was approved by Congress in July 2022 authorizes the Economic Development Administration (or "EDA") to invest over \$10 billion in regional innovation hubs. CHIPS+ also authorizes an additional \$695 million for the DOE to invest in regional clean energy innovation and commercialization activities (U.S. Senate Commerce Committee 2022). Given strong bipartisan support, these programs are likely to be funded in future appropriation bills.

Finally, in July 2022 Senate Majority Leader Schumer and Senator Manchin reached agreement on \$369 billion in climate investments packaged into legislation entitled the Inflation Reduction Act (or "IRA"). As of this writing in late July 2022, the legislation has not yet passed. However, many clean energy advocates believe that the legislation is likely to become law. The legislation contains nearly \$9 billion in direct rebates for residential energy efficiency retrofits and additional tax credits for heat pumps and other home efficiency products (Senate Democrats 2022). In addition, the legislation contains substantial funding for programs that would provide support for adopting new building codes, innovative financing, and workforce development.

A summary table of the key programs within the IIJA, CHIPS+, and IRA legislation that are most relevant to scaling ABC approaches for affordable housing is included below.

Legislation	Agency	Category	Program Relevant to ABC for Affordable Housing	\$ (millions)	Status of Funding
Tax Code	IRS	NewCon \$	Low-Income Housing Tax Credits	Varies	Existing Law
IRA	IRS	NewCon \$	45L New Energy Efficient Home Tax Credit	TBD	Senate agreement
IRA	DOE	Retrofit \$	Performance-based, whole house EE rebate program	\$ 4,300	Senate agreement
IRA	DOE	Retrofit \$	High-efficiency electric home rebate program	\$ 4,500	Senate agreement
IRA	HUD	Retrofit \$	Affordable Housing Resilience and Efficiency Investments	\$ 1,000	Senate agreement
IRA	IRS	Retrofit \$	Residential Energy Efficiency Tax Credit	TBD	Senate agreement
IIJA	DOE	Retrofit \$	Weatherization Assistance Program Funding	\$ 3,500	Appropriated
IIJA	DOE	Retrofit \$	Energy efficiency revolving loan fund capitalization grants	\$ 250	Appropriated
CHIPS+	DOE	RD&D \$	DOE Clean Energy Applied RD&D Activities	\$ 11,200	Authorized
CHIPS+	DOE	T2M \$	DOE Commercialization Activities for New Technologies	\$ 695	Authorized
CHIPS+	EDA	Regional Hubs	Regional Technology and Innovation Hubs	\$ 10,000	Authorized
IIJA	DOE	Codes \$	Cost-effective codes implementation for EE and resilience	\$ 225	Appropriated
IRA	DOE	Codes \$	Efficient Building Code Adoption Grants	\$ 1,000	Senate agreement
IRA	EPA	Financing	GHG Reduction Fund (National Green Bank)	\$ 27,000	Senate agreement
IRA	DOE	Financing	Clean Energy Loan Guarantees	\$ 40,000	Senate agreement
IRA	DOE	Workforce \$	State-based home EE contractor training grants	\$ 200	Senate agreement
IIJA	DOE	Workforce \$	State-based energy auditor training grant program	\$ 40	Appropriated

Figure 3. Summary of legislative programs relevant to ABC efforts for building or retrofitting affordable housing. *Source:* Authors' analysis of legislative text for the IIJA, CHIPS+, and IRA legislation.

ABC New Construction: DOE and HUD Can Work with HFAs, Developers, and Builders

Any federal effort focused on spurring the construction of new subsidized affordable housing that uses ABC approaches will need to work with three key stakeholders: state-level housing finance agencies (or “HFAs”), affordable housing developers, and builders or fabricators that utilize advanced building construction approaches. These stakeholders are critical because of the specific tax credits that are available to support energy efficient and affordable housing.

The agreed-upon IRA legislation text contains a revised 45L tax credit for new homes that reach the DOE’s Zero Energy Ready Home (or “ZERH”) standard, which is 40-50% more efficient than a typical home (DOE 2022). The tax credit would award \$5,000 for new ZERH single-family homes and \$1,000 for each unit in a new ZERH multifamily building. Since these tax credits can provide substantial funding for energy efficient new construction, affordable housing developers need to be engaged to understand both the financial and performance benefits of the ZERH standard. In addition, builders and/or fabricators need to understand how to produce prefabricated homes that can meet the ZERH standard. DOE can help to reach these critical stakeholders through targeted educational outreach and technical assistance.

In addition to 45L, the low-income housing tax credit (or “LIHTC”) will be a vital source of funding for ABC new construction projects. The LIHTC is part of the current U.S. tax code and funds most new subsidized affordable housing, supporting 80,509 new affordable housing units in 2019 (NMHC 2021). The Internal Revenue Service (or “IRS”) issues LIHTC allocation to state HFAs, which then award them through a competitive process to affordable housing developers. HUD also has a limited role of tracking LIHTC projects for its database (HUD n.d.).

HFAs often incentivize developers to build to more efficient standards by awarding higher evaluations for projects that build to ZERH or other green labeling programs. For example, Pennsylvania’s HFA incentivizes Passive House construction standards (Serlin 2016). Some state HFAs, including Pennsylvania, Idaho, Minnesota, and Virginia, also incentivize building project proposals that can reduce cost and construction time (Chaudhuri 2022).

The DOE and HUD can encourage more HFAs to incentivize ABC approaches by talking with them about how the goals of energy efficiency, lower cost, and reduced construction time will yield benefits for residents living in affordable housing. If multiple HFAs within a region included identical incentives for ABC approaches through their LIHTC qualified allocation plans, then many affordable housing developers within a region would likely consider utilizing similar approaches. However, affordable housing developers will still have discretion in choosing their architects, general contractors, financing partners, and other construction-sector entities involved in each of their LIHTC projects. Thus, a potential intervention for DOE and HUD to accelerate ABC methods could be to coordinate leading affordable housing developers to develop shared procurement standards for ZERH industrialized construction methods.

If these shared ZERH industrialized construction procurement standards also matched incentives within HFA qualified allocation plans, then leading developers could potentially make a purchase commitment with ABC builders for multiple years. This would give prefabricated builders confidence to invest in the manufacturing capacities needed to meet the ZERH high-performance specifications needed for ABC approaches. Collaboration between affordable developers working across different states within the same regional climate zone could also yield enough volume to place larger orders for high efficiency prefabricated housing, such as VEIC’s Zero Energy Modular design (VEIC 2021). This could help translate the productivity gains of ABC approaches into better energy performance at a lower price per unit, allowing LIHTCs to support the production of greater numbers of affordable housing units.

ABC Retrofits: DOE and HUD Can Work with SEOs, PHAs, and Retrofit Implementers

Federal efforts focused on scaling retrofits of affordable housing that use ABC approaches will need to work with three key stakeholders: state energy offices (or “SEOs”), public housing authorities (or “PHAs”), and retrofit implementers, including community action agencies (or “CAAs”) that implement local weatherization programs as well as utility EE program implementers and qualified energy retrofit contractors. These stakeholders are critical because of the design of the low-income retrofit funding available within the IRA legislative text, which distributes DOE energy efficiency rebate funding through SEOs and provides HUD with energy efficiency improvement funding for properties mostly managed by local PHAs.

There are two rebate programs included within the IRA legislative text designed to support home energy efficiency upgrades. The \$4.3 billion program called “HOMES” would offer up to \$2,000 for a whole-home efficiency upgrade that reduces energy use 20-35% and up to \$4,000 for energy reductions of greater than 35%. These rebate amounts are doubled for efficiency upgrades for low-income households, defined as below 80% of area median income. The rebates would be distributed through SEOs, which gain approval to administer a HOMES rebate program after submitting an acceptable program plan to the DOE.

The second rebate program included within the IRA legislative text is \$4.5 billion for high-efficiency electric home upgrades. Rather than basing rebate amounts on the energy savings achieved through a whole-home package of measures, this program designates rebates for individual measures, including \$1,750 for a heat pump water heater and \$8,000 for a heat pump system for space conditioning. Program rebates would cover half of project costs for moderate income households and 100% of project costs for low-income households. This funding would also be distributed through SEOs after DOE approves an acceptable rebate program plan.

In addition to the \$8.8 billion available in DOE rebate programs, the IRA legislative text also would provide HUD with \$1 billion for energy efficiency and climate resilience retrofits. This funding applies to subsidized affordable housing for the elderly, the disabled, and project-based rental assistance, most of which are managed by local PHAs. However, public housing units owned directly by PHAs do not appear to be eligible for funding under this program.

Beyond the above IRA programs, the IIJA law also provides \$3.5 billion in new Weatherization Assistance Program (or “WAP”) funding. This funding is more restrictive than the IRA programs, as only designated CAAs can implement WAP-funded retrofits, upgrades are capped at \$6500, and only households with less income than 200% of the federal poverty line are eligible. However, WAP measures could possibly be combined with other IRA rebate programs.

To effectively utilize a portion of the \$13.5 billion available for low-income energy efficiency upgrades for ABC approaches, DOE and HUD will need to work closely with SEOs to design state-level programs that include retrofits with deep energy savings and more efficient envelope measures. These ABC measures can be especially beneficial to low-income residents because they improve indoor air quality, thermal comfort, and resilience in extreme temperatures. With these benefits in mind, DOE and HUD can help connect SEOs to PHAs to identify affordable housing buildings that would be good candidates for ABC retrofits.

Finally, the DOE and HUD will need to work with retrofit implementers to scale up ABC retrofit approaches. These implementers include several stakeholders, such as local program administrators of WAP and utility EE programs, innovative retrofit delivery companies, and qualified equipment and component installers. These implementers should aim to translate the productivity gains of ABC approaches into a lower price per retrofit as greater volumes of retrofits are delivered, using the subsidies provided by the IRA and IIJA to help to reduce costs.

Tech/Market Scaling for ABC: RD&D, T2M, Hubs, Codes, Financing, and Workforce

The IIJA, CHIPS+, and IRA legislation also have substantial potential funding to help ABC approaches achieve technology scaling and market scaling. While this funding is not yet appropriated, DOE, HUD, and other federal agencies should begin planning now for how this likely future funding could be utilized to develop, commercialize, and scale ABC technologies in a way that supports the construction and renovation of high-efficiency affordable housing.

The CHIPS+ legislation contains \$11.2 billion in authorizations for continued research, development, and demonstration (or “RD&D”) investments across DOE’s applied energy offices. This includes continued investments from DOE’s Building Technologies Office as well as other offices that could invest in RD&D projects related to ABC, such as the Advanced Manufacturing Office. BTO’s forthcoming ABC Roadmap will contain recommendations on future RD&D investments for both new construction and retrofits. HUD’s new Offsite Construction Research Roadmap also contains recommendations for future RD&D (HUD 2022).

The CHIPS+ legislation authorizes \$695 million in new technology to market (or “T2M”) activities to help commercialize new technologies. This includes \$250 million for a new regional clean energy innovation program, \$125 million for small businesses to utilize expertise from DOE’s national labs, and \$100 million for commercialization support from the Office of Technology Transitions. ABC technologies developed by DOE and other ABC partners could greatly benefit from commercialization support, including the newest ABC retrofit approaches.

In addition to the above programs, CHIPS+ also authorizes the EDA to make substantial investments in innovation-oriented economic development, including \$10 billion for regional technology and innovation hubs in places that are not currently leading technology centers. While this program does not yet exist, it would likely be similar to the EDA’s ongoing Build Back Better Regional Challenge, which features two ABC-inspired finalists focused on industrialized construction and mass-timber construction. If funding for these innovation hubs is appropriated, DOE and HUD should encourage industry partners to consider applying for funding for an ABC hub that could accelerate new industrialized construction innovations.

The IIJA and IRA contain \$1.225 billion for the DOE to support states and municipalities in adopting the latest building energy codes. These codes can sometimes be difficult for ABC approaches, as code compliance for offsite construction approaches often involves inspection within a factory—a different process than field inspection typical for site-built construction. For this reason, the International Codes Council and the Modular Building Institute recently created new offsite construction standards for planning and regulatory compliance (Colker, et al. 2022). DOE could potentially use part of its codes funding to support jurisdictions in adopting the latest energy codes in conjunction with the new offsite construction standards.

The IRA legislative text also contains substantial resources for innovative financing approaches for clean energy. In particular, the IRA would give \$27 billion to the Environmental Protection Agency (or “EPA”) to capitalize the nation’s first national green bank. In addition, the IRA would give DOE’s Loan Programs Office (or “LPO”) an additional \$40 billion in loan guarantee authority to support deployment of new clean energy technologies. Both programs could potentially be utilized as financing to help scale new ABC technologies.

Finally, the IIJA and IRA both provide resources for workforce development training programs. The IIJA contains \$40 million for training home energy auditors, while the IRA contains \$200 million for training programs for contractors involved in home efficiency improvements. These programs could be utilized to train auditors and contractors to evaluate and install ABC technologies within home retrofits, helping them to achieve greater adoption.

Federal Coordination: Potential Cross-Agency Structures for an Expanded ABC Initiative

As described above, DOE, HUD, EDA, EPA, IRS, and other federal agencies could all utilize programs under the IIJA, CHIPS+, and IRA to help to scale ABC approaches for the construction and renovation of affordable housing. Thus, an expanded ABC Initiative could ideally be structured as a coordinated effort across several agencies. Forty housing organizations recently suggested a similar idea, proposing that President Biden form an interagency “Council of Housing Affordability” (National Housing Council 2022). Below, we provide two potential models of “whole of government” structures based on the previously successful cross-agency initiatives Operation Warp Speed and the Advanced Manufacturing Partnership.

Operation Warp Speed (or “OWS”) was a public-private partnership that dramatically accelerated the development of vaccines for the Covid-19 coronavirus. According to an overview of OWS in the *American Affairs Journal*, “organizationally, OWS resembled a pharmaceutical company, with Slaoui and Perna,” [the leaders of OWS, a pharma executive and a General], “reporting to a board, here composed of the secretaries of Defense and HHS, and officials from the White House Coronavirus Task Force” (Adler 2021). The ABC Initiative could have a similar structure: those leading the initiative would be a private sector leader from the housing sector and a public sector executive from DOE, HUD, or another agency. The board would consist of the secretaries of the agencies involved as well as members of the Council of Environmental Quality and/or National Economic Council. Industry experts such as affordable housing developers, builders, and retrofit implementers, as well as state and local governments, could provide input for on how the new federal programs funded by the IIJA, CHIPS+, and the IRA could best be implemented to accelerate affordable housing construction and renovation.

Another model for coordination is the Advanced Manufacturing Partnership (or “AMP”), an effective interagency partnership during the Obama Administration. Bill Bonvillian, an expert on American manufacturing policy, credited the AMP’s success to its leadership structure within the federal government. In the AMP, the “Chair of the National Economic Council and the Acting Commerce Secretary co-led a cross-agency effort. Within the White House, NEC and OSTP staff provided leadership” (Bonvillian 2018). The ABC Initiative could follow this structure, with the Council of Environmental Quality and/or National Economic Council leading the coordination of ABC-related initiatives across DOE, HUD, and other relevant agencies. State and local governments, including state housing finance agencies, state energy offices, and public housing authorities, could also be included within this public-sector coordination structure.

Conclusion

Advanced Building Construction approaches have the potential to reduce construction and retrofit timelines, reduce hard construction costs, and achieve superior energy performance. Through the focused use of new programs included in recent legislation and effective coordination across federal, state, and local governments and the private sector, the federal government could utilize ABC approaches to build and renovate thousands of affordable housing units in the next five years. These new and renovated affordable housing units would provide immediate efficiency and comfort benefits to thousands of low-income households. Scaling ABC approaches with affordable housing would also help to modernize the U.S. construction industry and support the creation of good jobs in both manufacturing and onsite construction.

Advanced Building Construction creates an opportunity to advance President Biden’s housing, climate, and jobs goals. We hope the federal government seizes the opportunity.

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