National Laboratory of the Rockies

All Systems Go: Regional Collaborations for Scaling AEC Innovation

Preprint

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All Systems Go: Regional Collaborations for Scaling AEC Innovation

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ABSTRACT

The high and rising cost of preserving and delivering housing in the U.S. requires changes to existing practices of finance, design, and construction. Innovative methods such as industrialized construction could offer the means to address housing undersupply while reducing delivery costs, operational costs and material waste in the building industry, but they face challenges to success and to scale. Simultaneously, construction and cleantech innovators themselves face skepticism from the traditional entrepreneurial ecosystem such as incubators and accelerators while attempting to navigate systems level challenges. To respond to this need, various public and private sector stakeholders have launched initiatives to support innovative companies. These include nonprofits such as Terner Labs and Ivory Innovations offering curated programming to architecture, engineering, and construction (AEC) startups; housing developers in Minnesota and California "bundling" multiple projects together to reach economies of scale with a consistent project team; public and private sector entities developing "catalogues" of pre-approved home designs in the U.S. and Canada. This exploratory paper documents several of these emerging ecosystem-development efforts to support innovative housing approaches, characterizing them by leading stakeholder and intervention strategy based on publicly available information. The paper finds that these initiatives share similar high level goals but vary in implementation, reflecting different stakeholder priorities, regional market and policy dynamics, and housing typologies. The early stage of these efforts offer limited data for comparing actual outcomes, but the paper highlights common qualitative themes and identifies opportunities for further research and potential coordination among these efforts.

Introduction

Across the U.S., housing demand outpaces supply, and households of all sizes and incomes grapple with affordability challenges (Kingsella & MacArthur 2022). The high and rising cost of construction, due in part to a shortage of skilled construction workers and rising material costs in recent decades, limits supply by making housing development less feasible (Holt & Ray 2025; Raetz et al. 2020). Stagnant productivity in the building industry relative to other sectors such as manufacturing and agriculture has failed to compensate for the shrinking workforce (Mischke et al. 2024), and rising shortages of labor and construction workers will continue to depress the new construction activity and increase construction costs, further increasing the shortage of affordable housing supply (Howard et al. 2024).

Simultaneously, the ongoing energy crisis increases demand for lower life cycle environmental impacts from new and existing construction. States like California have passed legislation to begin benchmarking and setting quantitative targets on embodied energy reduction for new construction, in addition to the state's stringent energy efficient design standards. However, due to the sensitivity of housing development feasibility to rising costs, energy efficient building improvements face increased pressure to minimize cost impacts (Podder et al.

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2022). For existing buildings, retrofits can reduce energy grid load while also improving housing affordability for low-income households because they often occupy older, inefficient units, and experience disproportionate burden from high utility costs (McKenna et al. 2024; Asensio et al. 2024; Chen et al. 2022).

In recognition of the parallel housing affordability and environmental challenges, many public and private sector actors have turned to building industry innovation in the hopes of addressing both crises. In particular, industrialized construction methods—including methods and terms such as prefabrication, off-site construction, and factory-built housing—have garnered recent attention as a potential synergistic approach to building industry improvement. Industrialized construction (IC) refers broadly to the adaptation of concepts and technologies from the manufacturing industry to the design and assembly of buildings (Smith et al. 2023). This can encompass the production of building elements like enclosed walls and floor cassettes, as well as the prefabrication of entire housing units into volumetric modules. For certain housing typologies and with enabling conditions such as streamlined permitting and aligned financing, off-site methods can reduce the time and cost required for housing development by 20-30% while increasing quality compared to conventional, fully on-site construction (Murdoch et al. 2023; Pullen 2022; Decker 2021). This can lead to cost effective integration of energy efficient building features and ensure consistent installation to maintain the as-designed performance (Grosskopf 2023; Metzger et al. 2023; Nahmens et al. 2023).

The need is acute and the potential benefits of IC methods are significant, but adoption has been slow to scale (Smith et al. 2023). Existing pathways for supporting innovation such as construction technology ("contech") incubators and venture capital investments often prioritize software companies or small products and technologies with relatively fast returns, and so fail to accommodate the needs of many new IC companies. In the effort to stabilize and accelerate successful IC execution, numerous programs and initiatives have spawned to provide more holistic and integrative support to facilitate innovative building methods.

The following sections highlight the gaps in existing pathways of support for building industry innovations and spotlight a number of initiatives meant to nurture an ecosystem of building industry innovation. This serves as a non-exhaustive, preliminary exploration of new and emerging programs attempting to align affordability and energy goals in the housing sector.

Existing State of Play for Building Industry Innovation in Housing

Industrialized construction currently supplies a modest proportion of annual housing starts in the U.S., estimated around 5% (2024 Permanent Modular Construction Report 2024), though the market share is closer to 15% when including manufactured (HUD Code) homes (Rumbach et al. 2025). Significant, multibillion-dollar levels of investment into new IC companies has been met with several high profile firms shuttering their doors: Katerra, Entekra, Skender Modular, and others (Podder et al. 2022). Some developers faced cost and schedule overruns due to factories shutting down operations mid-project, while other logistical and financing challenges (partially related to a lack of familiarity with IC methods among project teams) erode potential cost, time, and quality improvements. These real and perceived risks make many developers and financing partners hesitant to commit to IC methods at scale. And without consistent pipeline to support production, even many of the innovative companies still operating have not delivered the benefits and scale often promised by the entrepreneurs and needed by developers and housing markets (Pullen 2022).

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In the context of the typical timeline of technology innovation and adoption, IC companies often encounter the "valley of death" in the deployment stage, characterized by technologies able to complete their first sale but facing challenges establishing a full pipeline of customers. Figure 1 below highlights the typical dynamics across "technology readiness levels" commonly used in the Department of Energy's materials to define relative advancement for new technologies and innovations (Technology-to-Market 2025). These are guidelines rather than rules, but the deployment phase includes the overlap between technology scaling and the market scaling needed to sustain substantial output and impact. It also reflects the layered (potential) roles of government, investors, industry adopters, and banks to accomplish this transition, which offers a useful lens for understanding the current state of entrepreneurial support for IC firms.

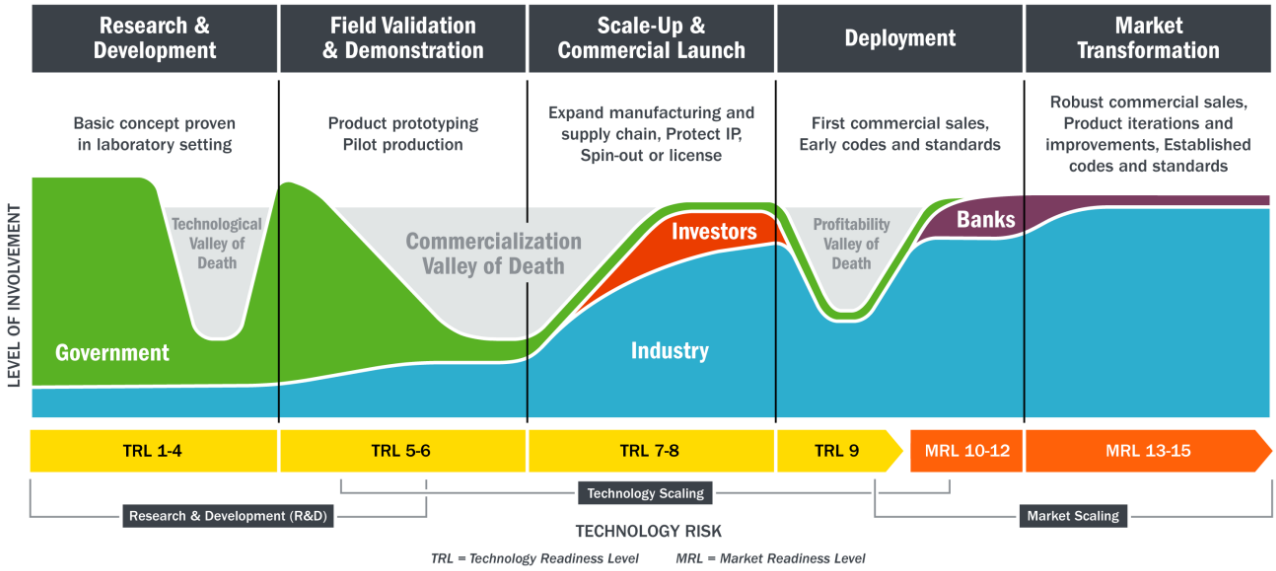

Figure 1. Technology-to-market process across technology- and market readiness levels. *Source*: U.S. Department of Energy 2025.

We identified three primary dimensions along which existing entrepreneurship ecosystems tend to provide support:

1. **For earlier stage firms**: Many programs focus on the first and second valleys of death: technological and commercialization. This is often true for those focused primarily on green building technology like high-performing windows, insulation, and materials innovations. For example, the IMPEL+ program anchored by Lawrence Berkeley National Labs and the Los Angeles Cleantech Incubator both specialize in earlier stage startups and technologies. Autodesk's Technology Centers host innovators and technologies outside of the green building sphere but similarly prioritize early stage companies.
2. **For software or hardware-lite companies**: The conventional startup and entrepreneurial ecosystem often curates support—and expected growth rates—to companies with software products. This may be because there is a lower barrier to entry for tech startups (developing a new software tool can be done in a matter of days and with minimal capital) and because they can quickly iterate and grow through asset-light and service-focused business models. Y Combinator may represent the largest and most tenured of

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these software-focused ecosystem builders, but efforts targeting the building industry in particular often anchor to tech companies as well. Both Formwork Labs, launched by Brick & Mortar Ventures, and Suffolk Technologies, from the general contractor Suffolk Construction, have company portfolios reflecting this dynamic.

3. **For low-risk, smaller-scale interventions**: Programs that do center on building industry innovations *and* allow space for later stage and hardware-focused companies still often spotlight lower-risk, lower-impact firms. This can be on-site sensor technology to streamline quality or progress tracking, or digital tools to streamline communication within and across project teams. Though easier to prototype and pilot, this can lead to cohorts or portfolios of companies pursuing interstitial innovations targeting niche pain points within the status quo that do not meaningfully reduce the cost of construction (especially in ways that pass through to housing affordability). Programs like Turner Ventures and Shadow Ventures offer support for companies in this general category.

These existing pathways play an important role for seeding and growing building industry innovations and entrepreneurs writ large, but they leave a relative gap in support for later stage and larger scale businesses hoping to meaningfully address the housing crisis. Critically, IC companies pursuing factory-based production and with multiple completed projects cannot utilize these existing resources and programs to overcome the final "valley of death" portrayed in the deployment scaling phase of Figure 1. These include ambitious manufacturers capable of producing hundreds or thousands of housing units annually in each factory to complement the capacity of the existing construction workforce (Pullen 2022). The gap in support for these firms is not a critique of existing entrepreneurial resources and programs, but rather an identification of a need for follow-on support for companies attempting to directly address much-needed sustainability and affordability goals in housing.

Programmatic Ecosystem for Building Industry Innovation in Housing

In an attempt to stabilize and grow building industry innovation towards affordable and sustainable housing outcomes, the last decade has seen a variety of new initiatives and programs launched by a variety of different stakeholder groups. They demonstrate different approaches to systems change and slightly different goals and priorities, but each program in turn helps address the gap in existing entrepreneurial ecosystems described above.

The following is a series of vignettes of these different programs, categorized by the stakeholder leading each effort (though many engage both public and private sector actors). The list is not all-inclusive, but rather spotlights a select variety of initiatives in order to calibrate a theory of change being put into practice in real time. The selection prioritizes programs along two criteria: 1) those with an explicit focus on housing affordability, and 2) those with ongoing or regular programming (for example, excluding one-time grants from a philanthropic foundation).

Because most of the selected initiatives are too recent to offer data and measurable outcomes for comparison, the purpose is descriptive rather than conclusive. Nonetheless, identifying emerging trends in this exploratory paper can inform iterative improvements to the initiatives themselves while highlighting clear opportunities for future research.

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Multi-Sector Collaborations

UC Berkeley Terner Center and Terner Labs.

The two Terners, based in the Bay Area, represent a triple helix model of ecosystem innovation for housing: they connect university, industry, and government knowledge and resources to facilitate innovation in both the public and private sector (Leydesdorff 2000).

The Terner Center for Housing Innovation at UC Berkeley, founded in 2015 and hosted within the College of Environmental Design, connects university and academic neutrality and research rigor to timely industry and policy reform with the goal of more affordable, equitable, and sustainable housing. Supported primarily through philanthropic sources and research grants, the Terner Center outputs research that is made freely and publicly available and written to a general audience with the explicit aim of making the evidence legible to relevant decision makers. This includes detailed qualitative and quantitative analyses on the potential impacts of policy reforms, often collecting feedback from key practitioners such as lenders, developers, and general contractors.

Terner Labs was founded in 2020 as an independent nonprofit organization to allow for more proactive and nimble programming with housing industry entrepreneurs. While driven by the same mission and values, the Labs operationalizes much of the knowledge generated by the Center's research to find and showcase scalable innovations through its accelerator program, the Housing Venture Lab (HVL). This program operates annual cohorts of 5-6 innovative building industry firms in the deployment phase of their scaling. Cohort companies are chosen with advisement from an interdisciplinary selection committee comprised of experts from academia and industry. Direct insights from individuals with on-the-ground knowledge of emerging trends in implementation also helps refine the aperture of technologies and business models sought by the program each year.

The HVL serves two key functions:

1. Supporting innovative companies and founders through several program features:
    - Coaching and networking for companies on their individual challenges and goals
    - Peer-to-peer learning within the cohort to support deeper, long-term learning in the fragmented industry and innovation landscape
    - International study tour to learn from companies, governments, and other key stakeholders that support more stable IC ecosystems in other countries
2. Parsing the signal from the noise for the incumbent industry: Terner's research-informed diligence spotlights more trustworthy technologies and business models and offers an important market signal for hesitant industry actors and policy makers looking to support practical innovations

Some of these functions are similar to other, existing incubators and accelerators for entrepreneurs in and outside the housing industry. However, Terner's network and reputation within the housing sector sphere reflects the reality that, for the building industry in general and the housing industry in particular, individual relationships and word of mouth are often critical for entrepreneurs to earn clients and build trust. Terner's expertise also help companies navigate uniquely complex housing market dynamics, including disjointed policy, regulatory, and financing environments. The comparative complexity of housing leads many innovators—and the entrepreneurship ecosystem that supports them—to focus on commercial and industrial market segments despite the eminent need for housing progress.

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Across seven cohorts, Terner Labs has supported 34 ventures (out of nearly 1,000 total applicants) that have gone on to fundraise $580M additional capital since their participation in HVL. Based on that success, recent philanthropic funding and additional outside fundraising will allow them to expand their program with follow-on investment opportunities for innovators. More specifically, these additional offerings intend to address the gap between risk-forward venture capital and traditional investments. The former often have rapid, high-growth expectations that misalign with the long timelines of housing projects and can put young companies under undue financial pressure. The latter sources have limited appetite and diligence capabilities for innovative approaches. Altogether, the continuous learning and improvement of the program builds on insights from each cohort and ongoing research to identify and fill gaps in the innovation ecosystem.

Ivory Innovations.

Since 2018 and in parallel to Terner's intersectional approach, the nonprofit Ivory Innovations hosts an annual competition called the Ivory Prize to collect and spotlight promising innovations. Identifying similar gaps to Terner, Ivory's finalists and winners receive the market signal and publicity from Ivory's nationwide audience and network. They also provide curated consulting and operational support and the potential for grant funding with the similar goal to help new and emerging companies navigate complex housing market dynamics. Their partnership with the University of Utah's David Eccles School of Business also facilitates applied and market research in and outside the Ivory Prize portfolio.

In 2025 alone, the Ivory Prize received over 1,200 company nominations across three innovation categories: construction and design, finance, and policy and regulation. Nominees—which can include individual companies but also public sector-led efforts such as innovative policy reforms—are scored based on their level of innovation, scalability, and their expected impact on housing affordability. Though energy efficiency is not an explicit focus of this scoring, past winners include many firms and initiatives aligned with explicit and implicit energy and sustainability outcomes like biomass uptake in construction materials, and transit-oriented infill housing development.

Local Government Efforts

Several initiatives to explicitly support IC methods have involved or been led by local government directly.

Minneapolis.

In Minneapolis, Minnesota, this began with a broad-sector coalition-building effort called Construction Revolution around 2019. The group was comprised of a number of individuals and organizations with public and private sector experience, and coalesced around the ambitious housing supply targets set by the state government while wanting to build sustainably (Tingerthal 2020). The group prioritized early convening, knowledge sharing, and consensus-building around potential solutions appropriate to both industry practitioners and local government actors. They ultimately identified innovative and industrialized construction as a key part of the solution to meet the production and affordability targets. Another strategic overlay was the desire to take advantage of the recent upzoning effort that allowed small multifamily developments in parcels previously reserved for one detached single family home per lot. The effort converged on a

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dispersed site approach, in which 84 units would be "bundled" together as one project despite being built across 16 sites.

This allowed the IC factory partner, Rise Modular, to economize the design across the 84 standardized units, while also allowing the local public housing authority to finance the deal as if it were one affordable housing project. At the same time the Minneapolis construction market faced challenges related to inflation and supply chain disruption during the pandemic, the pilot project benefitted from the early design lock-in and material purchasing. This allowed the project to avoid cost overruns relative to site-built methods, though it is unclear if this project has had follow-on momentum. Nonetheless, the initiative offers a notable precedent for the potential synergies between land use reform (through upzoning, in this case), innovative construction methods, and local housing finance tools to spur the development of "missing middle" housing typologies in demand across the U.S. (Smithson 2025; Wilson 2023).

Boston.

Facing similar needs of affordable homes built sustainably, the city and regional government in Boston arrived at different methods for procuring homes delivered using IC methods. Through its Housing Innovation Lab, the city hosted a design competition explicitly calling for innovative construction methods to supply missing middle housing typologies fitting the historic architectural aesthetic (Co-Creating the Future-Decker 2024). The "carrot" incentive for participation included an inventory of more than 1,000 city-owned sites identified to potentially provide a stable pipeline of demand and the cost reduction that might come with economies of scale. The Housing Innovation Lab anchors other, complimentary initiatives on an ongoing basis, many of which seek to tie housing needs to industry capabilities and innovation (Housing Innovation Lab 2026). The regional government, meanwhile, won $3M through the federal PRO Housing grant program with the intent to incentivize new, centrally-located IC producers to supply regional housing needs. Though the exact mechanics were not determined by the time of application, this program also intended to aggregate housing demand to provide a stable pipeline of projects needed for IC producers (Leonard & Herrmann 2025; PRO Housing Grant Application 2023). Both initiatives reflect the Boston region's strategy to support industry-side innovation through parallel policy and procurement innovation within the government.

State Government Efforts

State governments, too, have recognized the potential and need for larger scale interventions to support larger scale innovations not sufficiently supported by the existing ecosystem.

Both Colorado and Oregon offered direct grants and low-cost loans to IC producers looking to start or expand affordable, sustainable housing production. Colorado's program, launched in 2022, reserved $40M in state funding to support up to $1.5M per awardee in grants or up to $10M per awardee in loans accepted on a rolling basis. The stated goal is to support manufacturers that can produce at least 3,000 units per year once fully operational. Awardees can earn additional per unit incentives for delivering units with measurable affordability and sustainability outcomes with several certification pathways (such as tiers of LEED, HERS, or passive house standards). Building for density earns additional incentives in recognition of the inherent synergy across affordability and sustainability outcomes for small and infill housing types (Innovative Housing Incentive Program 2026).

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Oregon's program started in 2023 with $20M in grants to factories and followed similar guidelines to award expansive production of more affordable housing (McLean 2023). A specific aim of the fund was also to accelerate home rebuilding efforts after wildfires and other disasters. The state expanded their IC-forward support in 2025 with an additional $25M, this time oriented at housing more generally (not just disaster rebuilding) and at projects rather than factories themselves. The more recent program is accompanied by an advisory committee and resources to grow awareness, share best practices, and provide technical assistance to public and private sector actors. The intent is to take advantage of the streamlining of permit and inspection made possible through IC methods, which requires greater awareness and cooperation from local officials unfamiliar with these innovative methods (Hawke et al. 2026; Factory-Produced Housing Initiative 2025). These efforts explicitly encourage the use of locally-sourced and sustainable materials, though it is unclear what metrics or incentives exist to support that goal.

California already hosts the greatest number of IC projects relative to other states, likely a partial result of the high housing demand and high construction costs that increase the appeal of cost-saving innovations (2024 Permanent Modular Construction Report 2024). Simultaneously, California has also been host to a number of the highest profile factory failures and negative project outcomes and remains a tenuous market for many innovative builders (Hawke et al. 2026; Pullen 2022). In recognition of this, the state's Strategic Growth Council—an interagency group housed under the Governor's office to coordinate housing and sustainability efforts—launched a regional pilot program to spur IC methods in early 2026. The $12M allotment intends to fund regionally-anchored initiatives with a broad range of eligible uses. Applicants must propose activities that help create an enabling environment for IC, potentially including new financing tools, demand aggregation, or technical assistance to harmonize local building and zoning codes in service of standardization (Zhang 2026). In tandem, state legislatures recently formed a special advisory committee to develop a bill package focused on unlocking and accelerating building innovation to encourage more cost effective housing production. These and other efforts within the state reflect the need for intersectional and systems-level changes to evolve the ecosystem behind building industry innovation. As such, they benefit directly from the convening and network-building facilitated through Terner Center and Terner Labs throughout the state over the last five years (Hawke et al. 2026).

Federal Government Efforts

The federal government plays an important role in many industry ecosystems, from directly funding research and development into innovative methods, to convening, to policy and regulatory reform. These and other avenues for support are relevant and potentially impactful for building industry innovation towards housing affordability and sustainability. Of particular notes the Innovative Housing Showcase which began in 2019 and runs annually. This offers innovative building technologies, from on-site robotics to entire modular and manufactured housing units, the chance to showcase their work to a public audience on the National Mall in Washington, D.C. Alongside the demonstrations, the event offers educational programming, including speakers and panel sessions highlighting various industry topics. Although the ultimate impact of an annual convening is limited, the event facilitates critical cross-exposure across innovators and federal policy makers and officials at HUD, the Department of Energy, and other agencies.

More recently, HUD provided seed funding for a research center at UT Austin focused explicitly on building industry ecosystem development for more affordable, sustainable housing innovations. To date, the effort has hosted a cross-sector convening with representatives from the

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public and private sector, paired with facility and site tours local to Austin (UT Austin 2025). Compared to conventional industry conferences, these free or low-cost events offer a more neutral clearinghouse for education and knowledge sharing that more openly welcomes public sector officials and decision makers. These feedback loops are another aspect of ecosystem development that is difficult to imitate or replicate within the existing support structure for building industry innovators.

The US Department of Energy Building's Technology Program continues to support industry focused research and demonstration needs through long-running industry partnerships such as the Advanced Building Construction program, the Building America residential program, and the Better Buildings and Plants program. Each of these programs have engaged the construction and real estate industry to understand technical and affordability barriers, evaluate innovation opportunities, and demonstrate novel technology approaches across the US construction industry. While not historically focused on startups or small-scale pilots, these programs have supported broader industry adoption in both new construction and retrofit innovations.

International Examples

Several other countries have also turned to building industry innovation as a potential solution. Though several countries such as Sweden and Japan have more mature ecosystems for IC methods in their housing industries, Scotland, Australia, and Canada are closer to the adoption curve and ecosystem development stage of the U.S.

Scotland.

Scotland's emerging building industry innovation sector is hosted in part by a university-anchored, government-seeded, and industry-sustained program and facility called Built Environment, Smarter Transformation (BE-ST) started in 2014. Here, discrete research projects pulling in engineering, construction management, architecture, and materials science fields are seeded by industry partnerships to ensure relevant applications while balancing the need for open knowledge sharing and the desire for proprietary products. Specific projects center around new materials to reduce embodied energy of the building industry, as well as IC methods that can improve material efficiency while reducing the cost of new construction and retrofit projects for housing. The facility also anchors a variety of workforce training programs for industry practitioners to learn about green building science and the implications of better design and construction quality on building performance (Edinburgh Napier University 2026).

Australia.

Australia's federal government seeded a similar effort called Building 4.0 as part of their Cooperative Research Centres Program (CRC) in 2020, though its physical space focuses more on showcasing than on R&D like Scotland's BE-ST facility. It focuses on similar themes of housing affordability and sustainability and addresses similar gaps in the existing innovation ecosystem by centralizing cross-sectional research efforts from multiple departments. The CRC also coordinates the education and respective pilot efforts for regional policy and regulatory audiences, including events for convenings and assistance on reporting outcomes to build the evidence base of innovative projects. Currently, they are working with a broad industry coalition to develop a standardized design catalogue for "kit of parts" building systems to encourage more

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uptake and interoperability of IC producers (Australian Government: Department of Industry, Science and Resources 2026).

Canada.

Most recently, Canada established a new federal agency in 2025 called Build Canada Homes, intending to anchor new financing and procurement tools to support the IC sector from one centralized place. The efforts are early, but public-facing materials suggest they may use government-owned lands and other tools to aggregate housing demand like in other initiatives. Other related efforts include a product design catalogue of code-compliant, pre-approved designs at the regional level intending to standardize and streamline demand, but uptake is unclear. The effort is primarily focused on expanding and improving affordable housing production, but online materials suggest a focus on sustainable building practices and local materials uptake as well (Government of Canada 2026). Notably, the effort has been informed by and builds off of the momentum of work at several universities, including the University of New Brunswick's Off-site Construction Research Centre which facilitates convenings and research across North America (University of New Brunswick 2026).

Key Takeaways

The programs and initiatives described offer some key early insights despite the limitations of direct comparison.

1. The intersectional interest across various institutions reflects the acute and cross-cutting nature of the housing and environmental challenges, as well as the potential cross-cutting benefits offered by IC and other innovative building methods.

Even this non-exhaustive shortlist demonstrates different efforts led and joined variously by universities, philanthropic foundations, nonprofits and for-profits, and local, regional, state, and federal governments. And there are illuminating differences between these examples even beyond these high-level stakeholder categories. University involvement often anchors to different departments, including engineering and construction management, real estate development, and the business school. Beyond IC producers themselves, industry actors involved can include developers, general contractors, and labor groups. And the government entities include more than housing agencies like HUD or state-level equivalents, but also offices of the governor, regional planning organizations, and agencies focused on economic development; the Department of Energy and National Labs like NLR and ORNL also support many of these efforts directly and indirectly (Podder et al. 2022). Even the recent effort from California alone depended on close collaboration between a university research center and a nonprofit convening numerous industry practitioners and multiple state legislatures and government agencies.

Cost savings are a primary motivation for most of the examples provided, but several of the leading stakeholders—including Terner Labs, the states of Colorado, Oregon, and California, as well as the Scottish, Australian, and Canadian governments—also prioritize sustainability and workforce development. Though it was not a central focus in this exploratory paper, some agencies even centralize job creation and safer career pathways in construction and advanced manufacturing through IC methods.

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2. Many of the programs identify similar gaps in the existing ecosystem for building industry innovation, and offer different and often complimentary elements

One way to interpret the diversity of approaches is that many of the homegrown efforts meet the contextually-specific needs of each market and region. In each scenario, the programs and initiatives attempt to address many of the same housing market failures by supporting building industry innovation, but they identify different areas and strategies for innovation. These differences likely stem from different constellations of stakeholders with varying degrees of urgency, resources, and vested interests, as well as strategic roles to play in the ecosystem. For example, where Terner Labs prioritizes depth of engagement and rigorous diligence, Ivory Innovations excels in breadth and accessibility. Their intake and selection requires less time and resources than Terner's despite collecting nearly an order of magnitude more applicants, and thus the two programs serve complimentary roles in bringing a degree of focus to the housing innovation space.

Simultaneously, this partially reflects the reality that these efforts are still relatively new, and there is not a well-defined playbook of success for supporting truly innovative, systems-level change and ecosystem development for so large and fragmented an industry as the building sector (and housing sector within that).

Nonetheless, the following elements and programmatic features could offer value across many of these initiatives:

- Engaging a broad set of subject matter experts can improve key decisions. Proactively incorporating or considering the perspective of housing developers, policy makers and regulatory officials, real estate financers, architects, engineers, construction managers and on-site workers, and entrepreneurs themselves can maximize the relevance and effectiveness of different reforms or program design changes.
- Stakeholder access is a critical value for businesses trying to scale. Entrepreneurs may have functional technology and evidence of successful execution, but connections to key stakeholders such as housing developers or scaling partners like general contractors can be invaluable. Programs like Terner's and Ivory's may benefit from stronger industry partners to support scaling beyond their program.
- Data is invaluable, but undersourced and underutilized. Both public and private sector entities driving these programs could place a higher priority on tracking (and sharing) core metrics such as construction costs and timelines, quality and building performance, and business outcomes for innovators they support.
- Direct funding to entrepreneurs can be helpful, but may not be necessary for success. Some of the state-led interventions offer funding for IC producers themselves, and some are pursuing building code harmonization and other reforms to make innovation easier (and Colorado is pursuing both). Most of the other examples center on non-monetary benefits to innovative companies, such as coaching and networking.
- Demand aggregation can secure a predictable pipeline for IC producers. Among the examples in this paper, only Boston and Minneapolis tried to operationalize demand aggregation. The mechanics of their initiatives, such as targeting "missing middle" infill housing typologies, may translate well to other demand aggregation efforts.
- Broader market education on IC and other innovative methods is still needed. The international examples in Scotland and Australia may offer useful precedent for how to

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involve and improve exposure to innovations among the incumbent industry proactively and at a scale that matters.

Further Research and Conclusion

The broad palette of initiatives offers a rich research landscape for incisive, interdisciplinary work across architecture, engineering, construction, housing development and finance, and policy and regulation.

Many of the efforts may be too early to determine true "success," so efforts to benchmark and document outcomes would offer useful insights to refine and improve decision making within and across programs. There may be benefits to maintaining many regionally-distinct approaches, but establishing and strengthening pathways for continuous knowledge sharing can ensure best practices. The crises are nationwide, and a more interconnected ecosystem can ensure effective solutions achieve impact and scale more quickly.

In the meantime, the many, currently-fragmented efforts can lead to redundancy, duplicative efforts, and inefficient expenditure of limited public and private resources. In the wake of cautionary tales about less-than-successful programs, companies, and projects pursuing IC and other innovative methods, the stigma may worsen without more tangible industry progress. The fragmented building industry may be especially vulnerable to this due to the lack of a "single source of truth" in terms of industry-wide pathways for education, and reliable, publicly-available data around cost, schedule, and quality outcomes (and building performance data has a long lag time). This increases the value of applied and interdisciplinary research itself, but also the networking and knowledge sharing in formal and informal settings. Increasing exposure and access to information across different audiences is vital in this regard.

The nature and the depth of the housing and environmental crises are complex. Innovative and industrialized construction methods may play a key role, but the solution space will likely depend on numerous interventions across the public and private sector. The brief insights into the wide variety of attempts in and outside the US reflect this. The exciting and uncertain environment of ecosystem development highlights the need to connect, coordinate, and collaborate across disciplines, sectors, and geographies.

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