

Contech to Accelerate Cleantech: Seeding Emerging Innovation Programs for Construction Productivity and Energy Efficiency Integration

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ABSTRACT

Investments in U.S.-based start-ups that focus on advanced building construction technologies to increase construction productivity (“contech”) surged to approximately \$3.1 billion in 2018 (per Crunchbase data). More recently, emerging programs by government funding agencies, philanthropic foundations, and venture capitalists have been instrumental in supporting contech start-ups for innovations that increase productivity of energy efficiency integration and accelerate clean energy technologies (“cleantech”) for the buildings sector. These programs include R&D support and funding mechanisms for contech and cleantech. Traditionally, contech and cleantech are considered to be two different innovation ecosystems. To enhance and scale up energy efficiency in buildings, creative programs that bring together contech and cleantech are critical. This paper provides a landscape assessment of the “contech-for-cleantech” innovation ecosystem in the U.S. and its impact in accelerating technology readiness and the development pipeline of “contech-for-cleantech.” Technologies highlighted are robotics for retrofits, prefabrication of energy-efficient products, and advanced manufacturing of low-carbon net-zero buildings construction. Programs discussed include those led by (1) government-funded agencies, such as the American-Made Challenges with prizes like E-ROBOT for retrofits with robotics; (2) philanthropic foundations, such as the Wells Fargo Innovation Incubator (IN2) that focuses on energy efficiency and prefabrication; and (3) venture capitalists, such as the Shadow Ventures Green Building Accelerator program that provides funding support to start-ups with ambitious plans for decarbonizing the built environment. This paper will also expand upon robust processes and criteria involved in judging and down-selection of start-ups through vetting and feedback from national lab researchers and industry experts in both cleantech and contech.

Introduction

The concept of an “innovation ecosystem” was introduced into mainstream use by a Harvard Business Review article, which also offered its most widely used definition. The article defines an innovation ecosystem as “the collaborative arrangements through which firms combine their individual offerings into a coherent, customer-facing solution” (Adner 2006). A more comprehensive and holistic definition from a recent paper is that the innovation ecosystem is an evolving set of actors, activities, and artifacts, as well as the institutions and relations, including complementary and substitute relations, that are important for the innovative performance of an actor or a population of actors (Granstrand and Holgersson 2020). While certain sectors such as smartphones and personal computers have demonstrated mature innovation ecosystems, with multiple actors involving the government, philanthropic organizations, and venture capitalists to support the creation of successful start-ups, other industries such as construction and clean energy are emerging as important focus areas where

there is a growing need to nurture the culture of innovation ecosystems. In the context of nurturing the culture of innovation ecosystems, as highlighted by a seminal report published by the National Science Foundation (NSF), successful enterprises are those that are self-sustaining. Given that standard, recent statistics on venture capitalist success rates suggests that at least 50% of venture capital investments in the technology arena become viable enough to contribute to the ecosystem's culture by helping to create jobs, helping to shape the competitive environment, and through participation in the ecosystem's ideation and innovation dialogues (Jackson 2011). The NSF report also emphasizes that finding ways to quickly identify and root out failing ventures while simultaneously accelerating the passage of winning ventures through the “Valley of Death” facilitates the efficiency and sustainability of the innovation economy. The phase between research and successful innovation is known as the “Valley of Death” (Hudson and Khazragui 2013).

The NSF report concludes that putting in place rapid prototyping infrastructure is beneficial to the innovation ecosystem because it (i) lowers the entry costs for start-ups to engage in innovation and (ii) raises the success rate by increasing the number of attempts at translating across the Valley of Death to achieve adoption. Government entities may be more willing to invest in an innovation ecosystem because it spreads their risk among a larger number of ventures, thereby increasing the chances that they will have invested in an enterprise that generates more revenue and creates jobs (Jackson 2011). This concept is important because of its potential applications such as in U.S. start-ups and enterprises focused on advanced building construction technologies (contech) and clean energy technologies (cleantech), which continue to face hurdles in moving through the Valley of Death (as shown in Figure 1).

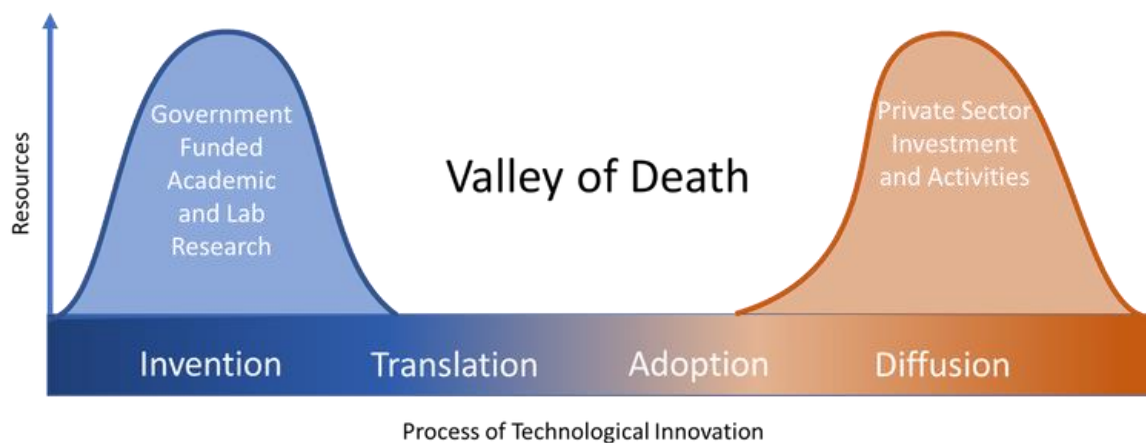


Figure 1. The “Valley of Death” is a metaphor for how long it can take to scale up innovations and inventions.
Source: Jetta Wong/Information Technology & Innovation Foundation.

Our paper provides a landscape review of both contech and cleantech innovation ecosystems and how emerging programs by government funding agencies, philanthropic foundations, and venture capitalists have been instrumental in supporting contech and cleantech start-ups for the built environment survive the Valley of Death and emerge on the other side as successful self-sustaining enterprises. We introduce the unique innovation ecosystem of “contech-for-cleantech” for the built environment, highlight the lack of venture capital funding directed to innovation specific to decarbonization of the built environment, and expand on the

emerging programs that accelerate the advent of affordable, energy-efficient buildings. Our paper also highlights the importance of collaboration between national laboratory researchers and industry experts for the contech-for-cleantech innovation ecosystem.

State of the Contech Innovation Ecosystem

Contech in the building industry includes automation, construction robotics, prefabrication, and industrialized construction that are central to multiple emerging start-ups in the U.S. Other contech such as building information modeling and concrete 3D printing continues to receive investments from venture capitalists. There are a multitude of programs focused purely on supporting the contech innovation ecosystem. Early-stage funding increased by close to 100% from 2020 to 2022, while late-stage funding jumped more than 150% percent during that same span, according to an analysis of data from the investment information platform Crunchbase, by Construction Dive (Obando 2021). Investments in U.S.-based start-ups that focus on contech (to increase construction productivity) surged to approximately \$3.1 billion in 2018 (Azevedo 2019). Marketwatch predicts the construction artificial intelligence market will exceed \$2.11 billion by 2023 (Precision Reports 2022). In the U.S., recent investments in ventures such as the Oracle Industries Innovation Lab, which provides a demonstration site for contech start-ups (Oracle Industries Innovation Lab n.d.), and Kattera¹ (Wikipedia contributors 2022), a Silicon Valley contech start-up that raised around \$2 billion from firms like SoftBank, have set the industry on the path to a promising future.

Outside the U.S., there are recent examples of national governments leading investments in contech. For example, the Australian government has pledged support for the prefabricated building industry with up to \$2 million to be spent developing a new collaborative lab (Built Offsite 2019). The UK government is preparing to launch a £10 billion “Offsite Construction Solutions framework” that will involve the supply, design, delivery, construction, and maintenance of buildings across the UK (Stein 2022). Leading global property technology (proptech) and contech venture capitalists include Pi Labs, MetaProp, RET Ventures, Camber Creek, JLL Spark APAC, Taronga Group, CEMEX Ventures, and BuiltUp Ventures (Donati 2021; CEMEX Ventures 2021).

Contech is still a heavily fragmented, point-solutions-driven market with ample opportunity for integration plays that create either new platforms or attractive component acquisition targets for growing incumbent platforms. The construction and commissioning phase continues to be the most active, with twice the investment activity and more active players than other phases. Preconstruction and “overarching technologies,” which include advanced technological applications such as artificial intelligence, robotics, and advanced visualization, were the next largest investment areas (McKinsey & Company 2020). Venture capitalists such as Hometeam Ventures are focused on investing in start-ups and early-stage founders who are using breakthrough contech strategies to help close the affordable housing gap (Hometeam Ventures n.d.).

As contech adoption continues to ramp up in the building sector, one area receiving a lot of attention is occupational safety (Johansen 2021). Worker safety should be the number one priority on every construction project site, and contech solutions are making it easier to properly

¹ Kattera filed for bankruptcy in June 2021 due to delayed projects, construction costs, pandemic-related impacts, and an inability to convince developers and contractors to move away from their traditional subcontractors. Source: [Modular builder CEO: ‘Kattera’s failure was spectacular’](#).

train and monitor workers to prevent accidents and reduce the rate of serious worker injuries and deaths.

State of the Cleantech Innovation Ecosystem

According to the PricewaterhouseCoopers (PwC) report titled “State of Climate Tech 2020,” climate-tech can be defined as technologies that are explicitly focused on reducing greenhouse gas (GHG) emissions or addressing the impacts of global warming (PwC 2020). Climate-tech applications can be grouped into three broad sector-agnostic groups—those that directly mitigate or remove emissions, or help us adapt to the impacts of climate change, or enhance our understanding of climate. The climate-tech market is a rapidly maturing asset class, offering investors significant financial returns and the opportunity for outsized environmental and social impact (Energy Impact Partners 2021). Venture capital funds poured \$23.2 billion into climate-tech firms in 2021, more than doubling the amount invested in 2020, according to PitchBook data (Chin 2022). Our paper focuses on cleantech, a subset of climate-tech, for the built environment. To accelerate cleantech for the buildings sector, there are several emerging start-ups focused on applications such as advanced retrofits, energy-efficient products such as heat pumps and home batteries, and low-carbon net-zero building construction.

Outside the U.S., cleantech investments in the European Union (EU) reached an aggregated total of €7 billion in the first half of 2021. In the past decade, EU companies seeking to scale-up have often turned toward Asia or North America for larger markets, more abundant funding, and more ambitious public policies that can accelerate the adoption of cleantech (Business Wire 2021). These investments cut across multiple sectors, with most of the funding support going into manufacturing, electric vehicles, and batteries. According to the Shadow Ventures report titled “The State of Green Building Tech,” the built environment has a critical role to play in responding to the climate crisis. Buildings and construction together account for 36% of global final energy use and 39% of energy-related carbon dioxide (CO₂) emissions (Abergel, Dean, and Dulac 2017). Real estate, as an asset class, also happens to be extremely vulnerable to rising sea levels, wildfires, floods, and other forms of extreme weather (Shadow Ventures 2021). Cleantech investments in the building industry, such as the recent investment in BlocPower (PR Newswire 2021), point to a promising resurgence in importance of the built environment to the clean energy transition.

Need for Contech-for-Cleantech Innovation Ecosystem for Market Transformation

Emerging programs established by government funding agencies, philanthropic foundations, and venture capitalists have been instrumental in supporting innovative contech start-ups that increase the productivity of energy efficiency integration and in accelerating cleantech for the buildings sector. Table 1 highlights a few examples of “contech-for-cleantech” applications. More details can be found in a technical guide for the industry titled ‘The Energy in Modular (EMOD) Buildings Method’ that was recently published by the National Renewable Energy Laboratory (NREL). The EMOD guide disseminates key frameworks and research takeaways on how specific contech products such as virtual design and construction tools, integrated building information modeling tools, automation in construction, and digital twins can accelerate relevant cleantech products such as high-performance envelope, residential and

commercial heat pump technologies, and solar plus storage (Pless et al. 2022). The EMOD guide was the result of a 3-year project funded by the U.S. Department of Energy’s (DOE’s) Office of Energy Efficiency and Renewable Energy Building Technologies Office. There also is a growing need for R&D support and funding mechanisms for start-ups focused on creating and delivering products and services for the built environment that are at the intersection of contech and cleantech. These start-ups often find themselves in the Valley of Death, and traditionally, contech and cleantech are considered to be two different innovation ecosystems. Hence, there is critical value in creative programs that bring contech and cleantech together in a joint ecosystem, to successfully translate ventures across the Valley of Death and enhance and scale up energy efficiency in buildings.

Table 1. Emerging applications of “contech-for-cleantech” for decarbonization in the built environment.

	Contech	Cleantech	Contech-for-Cleantech
1	Construction robotics	Advanced retrofits	Construction robotics for advanced retrofits
2	Prefabrication	Energy-efficient products such as heat pumps and home batteries	Prefabricated pods or skids with heat pumps and home batteries
3	Advanced manufacturing	Low-carbon net-zero buildings construction	Industrialized construction of net-zero energy buildings
4	3D printing	High-performance envelope, low-carbon concrete	Integrated high-performance envelope and low-carbon concrete for 3D-printed homes

According to PwC’s report titled “State of Climate Tech 2021,” venture capital can play a critical role in accelerating the uptake of climate technologies by 2030, to achieve net zero by 2050. However, in comparing global GHG emissions by challenge area to the investment capital each has received, it’s clear that some areas are not proportionally funded (as shown in Figure 2). The funding gap is largest in the “Built Environment” challenge area, which receives just 4% of funding in proportion to its contribution to GHG emissions of 21% (PwC 2021). Therefore, there is a need for creative programs that bring together government funding and philanthropic organizations for funding support as well as national laboratory researchers and industry experts for technical support.

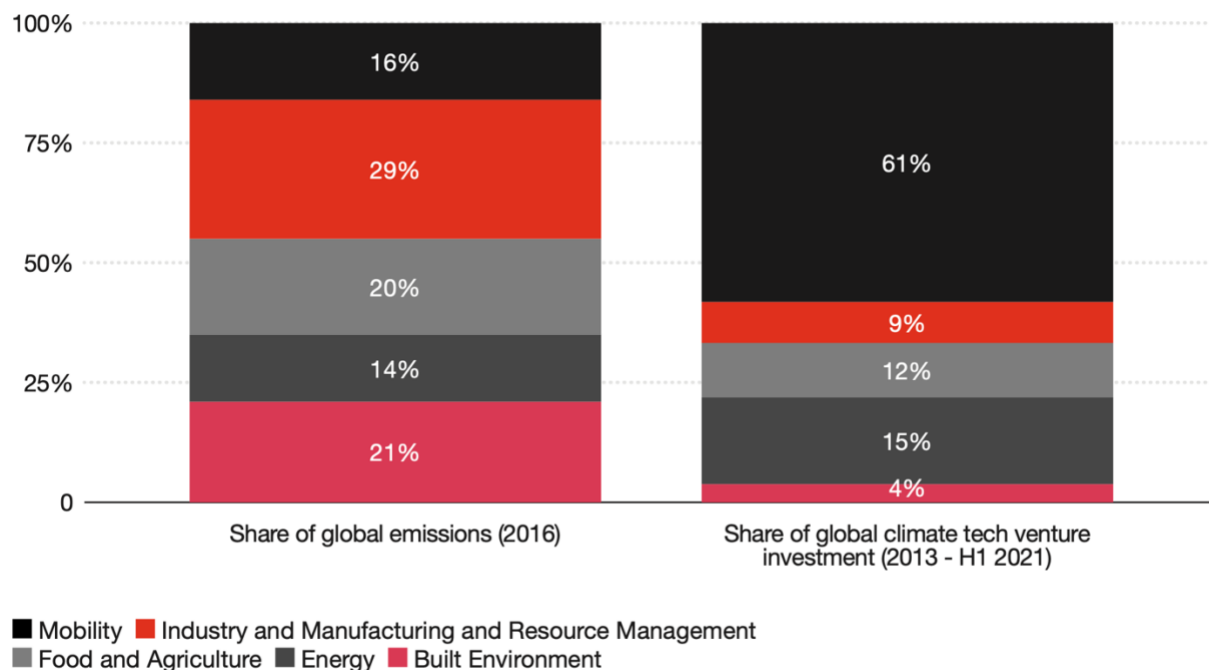


Figure 2. Share of global emissions and climate tech venture investment by challenge area. *Source:* PwC State of Climate Tech 2021, analysis of Dealroom data.

According to Shadow Ventures (2021), there are several barriers to innovation in using the “contech-for-cleantech” innovation ecosystem, such as:

1. Regulation stifling innovation: The built environment is risk averse. Things are done the way they have been for generations, with most innovation being incremental at best. This is largely due to the rules and regulations that have evolved into the standards, codes, and laws governing buildings.
2. An incredibly fragmented sector: The built environment is deeply fragmented with a wide range of stakeholders and players at every stage of the building life cycle. It is also highly localized making it more difficult for start-ups to scale-up quickly.
3. The uncertainty of new technology: Early-stage start-ups in this space face an uphill battle with uncertain R&D timelines and a difficult journey toward product/market fit. These challenges can present significant roadblocks to securing the capital that start-ups need to scale-up operations.
4. Financing: The typical methods of project financing do not always cover the soft costs associated with green building projects. Also, uncertainties about efficacy and future project values make financing green building technologies seem riskier.

Table 2 shows multiple start-ups working on a wide range of green building technologies (Shadow Ventures 2021). They have been categorized by technology focus areas. Note that while these start-ups primarily fall under cleantech, a select few actively leverage contech strategies to scale their cleantech product offerings. For example, INOVUES (listed under energy efficiency focus area) retrofits existing building facades and windows with the latest energy-saving and smart glass technologies without removal or replacement (INOVUES n.d.).

INOVUES leverages contech strategies such as nonintrusive and nondestructive nature of the installation method. INOVUES recently signed a memorandum of understanding with RMI-led Advanced Building Construction (ABC) Collaborative, a market transformation effort supporting innovative retrofit and new construction solutions that combine energy-efficient building decarbonization and streamlined industrialized construction (INOVUES 2022). Similarly, Boston Metal (listed under new materials focus area) is decarbonizing steel (cleantech) by innovating steelmaking process through advanced manufacturing (contech) (Boston Metal 2022).

Table 2. Green Building Tech Start-up Landscape.

Green Building Tech	Start-ups
Building Management Systems	Point Guard
	Embue
WaterTech	Epic Cleantec
	Kairos
Energy Efficiency	Inovues
	Bloc Power
Indoor Air Quality	Arbnco
	Awair
New Materials	Carbon Cure
	AeroShield
Design & Life Cycle Assessment	One Click LCA
	Ecobot
Corporate Carbon Management	EC3
	Engie Impact

Source: The State of Green Building Tech by Shadow Ventures (2021).

According to a report assessing the Wells Fargo Innovation Incubator (IN2), titled “Perspectives from the IN2 Network: State of the Cleantech Landscape,” the lack of entrepreneurial training and business acumen also presents a significant barrier for start-ups. Many start-ups are created by scientists or engineers, who may struggle with the dynamics of running a successful company, including understanding the market or customer, building a team, writing a business plan, and more. This largely impacts companies as they seek funding and could be addressed by increasing entrepreneurs’ awareness of incubator or accelerator services (Ott et al. 2021).

Programs Led by Government-Funded Agencies

In the U.S., government agencies such as the U.S. DOE are driving American-Made Buildings Prizes like Envelope Retrofit Opportunities for Building Optimization Technologies (E-ROBOT) to support start-ups delivering minimally invasive, low-cost, and holistic building envelope retrofit solutions using robotics and automation such as drones (DOE n.d.). IMPEL+ is another DOE tech-to-market program focused on building technologies, funded by the Building Technologies Office and implemented by Lawrence Berkeley National Laboratory. IMPEL+ supports early-stage individuals from business, academia, and DOE’s national labs translate the premise and promise of their technology into the language of business, boosting their chances of bringing it to market. The program acts as an engine that accelerates climate tech in buildings

and energy by recruiting and fostering a dynamic innovator community, mentoring them to develop strong entrepreneurial skill sets, and enabling access to powerful public and private tech-to-market pipelines (IMPEL+ n.d.). For instance, in June 2022, IMPEL+'s Innovators took to Boston, MA to participate in the IMPEL+ Greentown Labs Building Tech Pitch Day (Lawrence Berkeley National Laboratory n.d.). DOE is also instrumental in the emergence of the ABC Collaborative that brings together forward-looking people and organizations to modernize the construction industry and advance the buildings sector. The ABC Collaborative is paving the way for high-performance, low-carbon new construction and building retrofits (ABC Collaborative 2022). Several U.S. states are providing regional support to start-ups innovating in contech-for-cleantech. A total of \$30 million has been made available for seven rounds of innovation challenges to encourage private investment and advance the next generation of HVAC systems for buildings by NYSERDA's Advanced Buildings Program. NYSERDA's support is helping scale-up innovations such as panelized systems for deep-energy retrofits and an integrated HVAC solution for midrise buildings (NYSERDA n.d.).

Programs Led by Philanthropic Foundations

Philanthropic foundations such as the Wells Fargo Foundation have created unique programs to support start-ups with ambitious plans for decarbonizing the built environment. The Wells Fargo IN2 was launched in 2014 by the Wells Fargo Foundation and NREL with the goal of de-risking innovations and speeding clean technologies to commercial markets. Recently, the Wells Fargo IN2 program has increased its focus on affordable housing, construction innovation, and buildings energy efficiency by supporting U.S.-based start-ups such as Pre-Framing Corp. and Blokable Inc (Wells Fargo Foundation 2022).

Affordable, zero carbon emissions represent an important climate-performance target for the future of multifamily housing, and the multifamily construction industry plays an essential role in achieving this goal in the United States. Building construction and operation account for 37% of global energy-related carbon emissions (UN Environment Programme 2021). Meanwhile, an additional 3.8 million housing units are needed to address the shortage in the United States (Khater et al. 2021). Recent reports by NREL and Blokable Inc., funded by the Wells Fargo IN2 program, details actionable pathways for the industry to leverage advanced building construction, reduce net-zero energy incremental costs, and achieve significant GHG emissions reduction by 2030 (Klammer 2021).

Programs Led by Venture Capitalists

As suggested in the 2021 PwC report, sectors such as the buildings sector that have the greatest capacity to make progress on decarbonization tend to receive the smaller share of venture capital (PwC 2021). However, some venture capitalists such as Shadow Ventures have special programmatic pathways for start-ups focused on contech-for-cleantech. The Green Building Accelerator program by Shadow Ventures drives investment in contech and cleantech to address operational carbon (such as intelligent building management systems, renewable energy, energy efficiency upgrades, more modern HVAC, lighting systems, curtain walls) and embodied carbon (identification and sourcing of low-carbon alternatives to traditional building materials that offer opportunities to sequester carbon, like aggregate made from hard-to-recycle plastics or treated timber) (Shadow Ventures 2021). More recently, Fifth Wall, a Los Angeles-based venture capital firm focused on real estate technology, raised \$500 million for a climate

fund to help decarbonize the industry. The fund, which brings together some of the largest owners and operators of real estate globally, will invest in software, hardware, renewable energy, energy storage, smart buildings, and carbon sequestration technologies (Lash 2022). Breakthrough Energy Ventures also recently backed a contech-for-cleantech start-up called CarbonCure, focused on injecting CO₂ into ready-mix concrete (Cornell University 2021).

Collaborative Efforts Between National Laboratory Researchers and Industry Experts For Market Transformation

Because contech and cleantech are considered to be two different innovation ecosystems, there is a growing need to establish collaborative efforts between researchers and industry experts from both contech and cleantech. Programs such as E-ROBOT, Wells Fargo IN2, and the Shadow Ventures Green Building Accelerator have demonstrated how such a collaboration can impact the overall success of both contech and cleantech start-ups that are addressing both operational and embodied carbon challenges in the built environment. For example, NREL researchers, with expertise in buildings energy efficiency, industrialized construction innovation, and clean energy technologies, help assess and vet start-up applicants in the Wells Fargo IN2 program, and follow up by providing technical assistance and validation to the accepted start-ups, under the thematic areas of affordable housing, commercial buildings, and sustainable agriculture (as shown in Figure 3). The Wells Fargo IN2 Channel Partner network includes more than 60 incubators, accelerators, and universities that refer companies to the program and provide mentorship and connection.

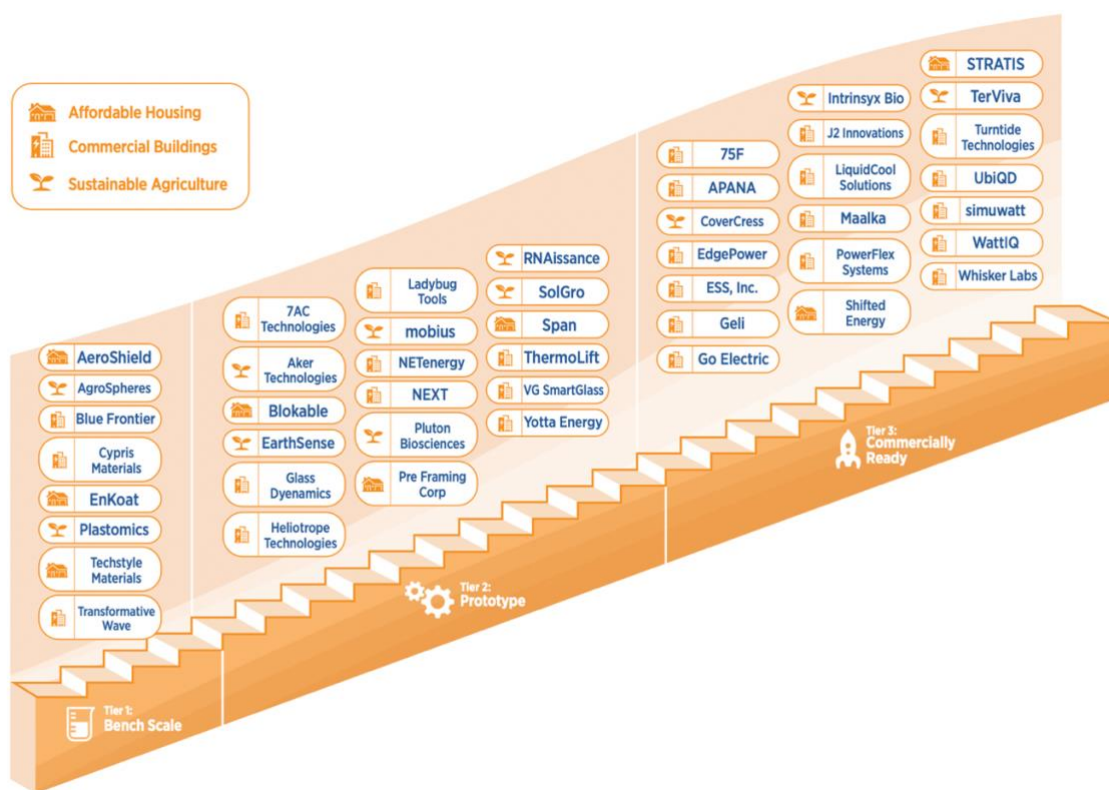


Figure 3. Most of the start-ups that enter the Wells Fargo IN2 program are at the bench scale or prototype stage, and more than 55% exit the program commercially ready. *Source:* IN2 Annual Report from 2020.

According to the IN2 Annual Report from 2020, this unique collaborative effort led to a significant impact on the innovation ecosystem with 46 portfolio companies and \$410 million in external funding received after joining IN2. These portfolio companies went on to raise more than \$33 for every \$1 invested by IN2, demonstrated 73% employment growth for the IN2 portfolio of companies, and completed a total of nine mergers and acquisitions (Wells Fargo IN2 2021). Traditionally, 90% of start-ups fail but Wells Fargo IN2 portfolio companies have turned out to have a much higher success rate.

Conclusions

Emerging national-scale funding and technical support programs from DOE are filling the void created by the smaller share of venture capital going into cleantech innovation for the built environment. Philanthropic organizations such as the Wells Fargo Foundation and venture capitalists such as Shadow Ventures are creating new programs and focus areas that bring together the siloed innovation ecosystems of contech and cleantech. NREL researchers, with expertise in buildings energy efficiency, industrialized construction innovation, and clean energy technologies, continue to help such programs by assessing and validating the start-ups' technologies.

While a large number of start-ups are focused on addressing the challenges in the built environment, many energy innovators and entrepreneurs never get enough funding to cross the Valley of Death. Historically, the Valley of Death is less challenging for software innovations in consumer electronics like smartphone apps. However, the valley is much wider and deeper for both software and hardware innovations that focus on decarbonization of the built environment. Creative programs such as E-ROBOT that bring together national laboratory researchers and industry experts to assess, support and guide start-ups could prove to be important for the sustenance and long-term success of the contech-for-cleantech innovation ecosystem.

Disclaimer

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References

ABC Collaborative. (2022, March 10). *ABC Collaborative*. Retrieved May 18, 2022, from <https://advancedbuildingconstruction.org>

Abergel, T., Dean, B., & Dulac, J. (2017). Towards a zero-emission, efficient, and resilient buildings and construction sector: Global Status Report 2017. *UN Environment and International Energy Agency: Paris, France*, 22.

- Adner, R. (2006). Match your innovation strategy to your innovation ecosystem. *Harvard business review*, 84(4), 98.
- Azevedo, M. A. (2019, February 16). *Investor momentum builds for construction tech*. TechCrunch. Retrieved May 18, 2022, from <https://techcrunch.com/2019/02/16/investor-momentum-builds-for-construction-tech/?guccounter=1>
- Boston Metal. (2022, May 4). *Decarbonizing Steel Production*. Retrieved May 18, 2022, from <https://www.bostonmetal.com>
- Built Offsite. (2019, July 18). *Government Backing For Australia Prefab*. <https://builtoffsite.com.au/emag/issue-16/government-backing-australia-prefab/>
- Business Wire. (2021, July 8). *New Investment Tracker: EU Cleantech Investments Shatter Records*. Retrieved May 18, 2022, from <https://www.businesswire.com/news/home/20210708005349/en/New-Investment-Tracker-EU-Cleantech-Investments-Shatter-Records-%E2%82%AC7-Billion-Invested-in-First-Half-of-This-Year>
- CEMEX Ventures. (2021, December 3). *CEMEX Ventures Names Top 50 ConTech Startups and Startup Competition Winners*. For Construction Pros. Retrieved May 18, 2022, from <https://www.forconstructionpros.com/construction-technology/news/21928309/cemex-ventures-names-top-50-contech-startups-and-startup-competition-winners>
- Chin, K. (2022, March 16). *Corporate Venture Investors Boost Climate-Tech Spending*. WSJ. Retrieved May 18, 2022, from <https://www.wsj.com/articles/corporate-venture-investors-boost-climate-tech-spending-11647432001>
- Cornell University. (2021, February 17). *Bill Gates shines spotlight on carbon-emitting cement and need for something new*. Retrieved May 18, 2022, from <https://www.newswise.com/articles/bill-gates-shines-spotlight-on-carbon-emitting-cement-and-need-for-something-new>
- Donati, A. K. (2021, January 10). *Proptech And Contech VCs Predict What Is In Store For 2021*. Forbes. Retrieved May 18, 2022, from <https://www.forbes.com/sites/angelicakrystledonati/2021/01/10/proptech-and-contech-vcs-predict-what-is-in-store-for-2021/?sh=18e88b907073>
- Energy Impact Partners (EIP), EIP Climate Tech Index, accessed Dec 9 2021, <https://eipclimateindex.com/>
- Granstrand, O., & Holgersson, M. (2020). Innovation ecosystems: A conceptual review and a new definition. *Technovation*, 90, 102098.
- Hometeam Ventures. (n.d.). *Hometeam Ventures*. Retrieved May 18, 2022, from <https://www.hometeam.vc>

- Hudson, J., & Khazragui, H. F. (2013). Into the valley of death: research to innovation. *Drug discovery today*, 18(13-14), 610-613.
- IMPEL+. (n.d.). *IMPEL+*. Retrieved July 25, 2022, from <https://impel.lbl.gov/impel>
- INOVUES. (n.d.). *INOVUES – Facade and Window Upgrades Without Replacement*. Retrieved May 18, 2022, from <https://www.inovues.com>
- INOVUES. (2022, April 29). *INOVUES Signs MOU With DOE’s Market Transformer ABC Collaborative*. Retrieved May 18, 2022, from <https://www.inovues.com/advanced-building-construction-collaborative-mou>
- Jackson, D. J. (2011). What is an innovation ecosystem. *National Science Foundation*, 1(2), 1-13.
- Johansen, A. (2021, July 22). *Increasing Construction Site Safety With Artificial Intelligence*. National Center for Construction Education & Research. Retrieved May 18, 2022, from <https://www.nccer.org/news-research/newsroom/BlogPost/breaking-ground-the-nccer-blog/2021/07/22/increasing-construction-site-safety-with-artificial-intelligence>
- Khater, S., L. Kiefer, and V. Yanamandra. 2021. “Housing Supply: A Growing Deficit.” *Economic & Housing Research Note*.
- Klammer, N., Kaufman, Z., Podder, A., Pless, S., Celano, D., & Rothgeb, S. (2021). *Decarbonization During Predevelopment of Modular Building Solutions* (No. NREL/TP-5500-81037). National Renewable Energy Lab.(NREL), Golden, CO (United States).
- Lash, H. (2022, July 21). *Fifth Wall climate fund aims to decarbonize property industry*. Reuters. Retrieved July 25, 2022, from <https://www.reuters.com/business/finance/exclusive-fifth-wall-climate-fund-aims-decarbonize-property-industry-2022-07-21/>
- Lawrence Berkeley National Laboratory. (n.d.). *Jun 2022 GTL Recap*. *IMPEL+*. <https://impel.lbl.gov/media/jun-2022-gtl-recap>
- McKinsey & Company. (2020, November 11). *Rise of the platform era: The next chapter in construction technology*. Retrieved May 18, 2022, from <https://www.mckinsey.com/industries/private-equity-and-principal-investors/our-insights/rise-of-the-platform-era-the-next-chapter-in-construction-technology>
- NYSERDA. (n.d.). *Advanced Buildings Program*. Retrieved May 18, 2022, from <https://www.nyserda.ny.gov/All-Programs/Advanced-Buildings>
- Obando, S., & S. (2021, October 6). *Construction technology funding skyrockets to record levels*. Construction Dive. Retrieved May 18, 2022, from

<https://www.constructiondive.com/news/construction-technology-funding-skyrockets-to-record-levels/607769/>

Oracle Industries Innovation Lab. (n.d.). Oracle. Retrieved May 18, 2022, from <https://www.oracle.com/industries/construction-engineering/innovation-lab.html>

Ott, K., Wadsack, K., Ihly, R., & Cozart, T. (2021). Perspectives from the IN2 network: state of the cleantech landscape. *Innovation Incubator*.

Pless, S., Podder, A., Kaufman, Z., Klammer, N., Dennehy, C., Muthumanickam, N.K., Rothgeb, S., Louis, J., Swanson, C., Wallace, H. & Blazek, C., 2022. *The Energy in Modular (EMOD) Buildings Method: A Guide to Energy-Efficient Design for Industrialized Construction of Modular Buildings* (No. NREL/TP-5500-82447). National Renewable Energy Lab.(NREL), Golden, CO (United States).

PR Newswire. (2021, February 22). *BlocPower Raises \$63 Million Series A to Green Urban Buildings and Creates Innovative Financing Solution Alongside the Goldman Sachs Urban Investment Group*. Retrieved May 18, 2022, from <https://www.prnewswire.com/news-releases/blocpower-raises-63-million-series-a-to-green-urban-buildings-and-creates-innovative-financing-solution-alongside-the-goldman-sachs-urban-investment-group-301232145.html>

Precision Reports. (2022, March 10). *Artificial Intelligence in Construction Market Size 2022*. MarketWatch. Retrieved May 18, 2022, from <https://www.marketwatch.com/press-release/artificial-intelligence-in-construction-market-size-2022-industry-share-global-trend-in-depth-manufacturers-analysis-revenue-supply-development-growth-demand-regional-outlook-till-2028-2022-03-10>

PricewaterhouseCoopers (PwC). (2020, September 9). *The State of Climate Tech 2020*. Retrieved May 18, 2022, from <https://www.pwc.com/gx/en/services/sustainability/publications/state-of-climate-tech-2020.html>

PwC. (2021). *State of Climate Tech: Scaling breakthroughs for net zero*, accessed Mar 25 2021, <https://www.pwc.com/gx/en/sustainability/publications/assets/pwc-state-of-climate-tech-report.pdf>

Shadow Ventures. (2021) *The State of Green Building Technology*, <https://shadow.vc/insights/the-state-of-green-building-tech-research/>

Stein, J. (2022, January 4). *Contractors readied for £10bn offsite framework*. Construction News. Retrieved May 18, 2022, from <https://www.constructionnews.co.uk/buildings/contractors-readied-for-10bn-offsite-framework-04-01-2022/>

UN Environment Programme, 2021. *2021 Global Status Report for Buildings and Construction*. <https://globalabc.org/resources/publications/2021-global-status-report-buildings-and-construction>

U.S. Department of Energy. (n.d.). *American-Made Challenges*. Retrieved May 18, 2022, from <https://americanmadechallenges.org/challenges/EROBOT/index.html>

Wells Fargo Foundation. (2022, April 27). *IN2 Ecosystem*. Innovation Incubator (IN2). Retrieved May 18, 2022, from <https://in2ecosystem.com/about/>

Wells Fargo Innovation Incubator. (2021, February). *IN2: Catalyst to Success (Annual Report 2020)*. https://in2ecosystem.com/wp-content/uploads/2021/02/IN2_2020_Annual_Report.pdf

Wikipedia contributors. (2022, May 5). *Katerra*. Wikipedia. Retrieved May 18, 2022, from <https://en.wikipedia.org/wiki/Katerra>